Water Budgets, Water Quality, and Analysis of Nutrient Loading of the Winter Park Chain of Lakes, Central Florida, 1989-92

By G.G. Phelps *and* E.R. German

With a section on Littoral Vegetation

By Brian Beckage *and* W. Scott Gain

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4108

Prepared in cooperation with the

City of Winter Park, Florida, and
St. Johns River Water Management District

Tallahassee, Florida
1995

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Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square foot (ft^2)	0.0929	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meter
cubic foot (ft^3)	0.028317	cubic meter
	Flow	
foot per day (ft/d)	0.3048	meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch per day (in/d)	2.54	centimeter per day
inch per month (in/mo)	2.54	centimeter per month
inch per year (in/yr)	2.54	centimeter per year
	Mass	
pounds (lb)	0.454	kilograms
tons per year (tons/yr)	0.9072	metric ton per year

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Equations for temperature conversion between degrees Celsius (°C) and degrees Fahrenheit (°F):

$$°C = 5/9\ (°F - 32)$$

$$°F = 9/5\ (°C) + 32$$

Altitude, as used in this report, refers to distance above or below sea level.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in sediments are given either in milligrams per kilogram (mg/kg), grams per kilogram (g/kg), or micrograms per kilogram (µg/g).

Mass-to-volume ratios of stormwater debris are given in lb/gal.

Areal loading ratios are given in grams per square meter per year ($g/m^2/yr$)

ADDITIONAL ABBREVIATIONS

ft/ft	feet/foot	min	minute
fw	filtered water	mo	month
D	discharge computed	N	nitrogen
g	gram	NTU	Nephelometric turbidity units
g/kg	grams per killogram	P	phosphorus
kHz	kilohertz	Pt-Co Units	Platinum-Cobalt units
L	liter	QW	bimonthly water-quality samples
μg/g	micrograms per gram	R	rainfall
μg/L	micrograms per liter	rw	raw water
μm	micrometer	S	continuous stage
μS/cm	microsiemens per centimeter at 25 degrees Celsius	SD	discharge for selected storms
		SS	stage for selected storms
mg/g	milligrams per gram	ST	stormwater-inflow samples
mg/kg	milligrams per killogram	SU	Standard Unit
mg/L	milligrams per liter	sw	screened water
mL	milliliter	Wh	whole water
mm	millimeter	yr	year

ACRONYMS

CF	color fathometer
NOAA	National Oceanic and Atmospheric Administration
SIN:SRP	ratios of total-soluble-inorganic-nitrogen to total-soluble-reactive-phosphate
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TSI	tropic-state index
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Water Budgets, Water Quality, and Analysis of Nutrient Loading of the Winter Park Chain of Lakes, Central Florida, 1989-92

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Abstract

The Winter Park chain of lakes (Lakes Maitland, Virginia, Osceola, and Mizell) has a combined area of about 900 acres, an immediate drainage area of about 3,100 acres, and mean depths ranging from 11 to 15 feet. The lakes are an important recreational resource for the surrounding communities, but there is concern about the possible effects of stormwater runoff and seepage of nutrient-enriched ground water on the quality of water in the lakes.

The lakes receive water from several sources: rainfall on lake surfaces, inflow from other surface-water bodies, stormflow that enters the lakes through storm drains or by direct runoff from land adjacent to the lakes, and ground-water seepage. Water leaves the lakes by evaporation, surface outflow, and ground-water outflow. Of the three, only surface outflow can be measured directly. Rainfall, surface inflow and outflow, and lake-stage data were collected from October 1, 1989, to September 30, 1992. Stormflow, evaporation and ground-water inflow and outflow were estimated for the 3 years of the study. Ground-water outflow was calculated by evaluating the rate of lake-stage decline during dry periods. Estimated ground-water outflow was compared to downward leakage rates estimated by ground-water flow models. Lateral ground-water inflow from surficial sediments was calculated as the residual of the flow budget.

Flow budgets were calculated for the 3 years of the study. In water year 1992 (a year with about average rainfall), inflow consisted of rainfall, 48 inches; stormflow, 15 inches; surface inflow, 67 inches; and ground water, 40 inches. The calculated outflows were evaporation, 47 inches; surface outflow, 90 inches; and ground water, 33 inches.

Water-quality data also were used to calculate nutrient budgets for the lakes. Bimonthly water samples were collected from the lakes and at surface inflow and outflow sites, and were analyzed for physical characteristics, dissolved oxygen, pH, specific conductance, major ions, the nutrients nitrogen and phosphorus, and chlorophyll (collected at lake sites only). Specific conductance ranged from about 190 to 230 microsiemens per centimeter at 25 degrees Celsius in Lakes Maitland, Virginia and Osceola and from about 226 to 260 microsiemens per centimeter at 25 degrees Celsius in Lake Mizell. The median concentrations of total ammonia-plus-organic nitrogen in all the lakes ranged from 0.79 to 0.99 milligrams per liter. Median total phosphorus concentrations ranged from less than 0.02 to 0.20 milligrams per liter. Stormwater samples were collected for 17 storms at one storm-drain site and 16 storms at another storm-drain site on Lake Osceola. Median total nitrogen concentrations at the sites were 2.23 and 3.06 milligrams per liter and median total phosphorus concentrations were 0.34 and 0.40 milligrams per liter.

The water quality in the Winter Park lakes generally is fair to good, based on a trophic-state index used by the Florida Department of Environmental Protection for assessing the tropic state of Florida lakes. This index was determined

from median total nitrogen, total phosphorus, and chlorophyll-*a* concentrations, and median Secchi-disk transparency for all lakes for the period September 1989 to June 1992.

Based on a one-time sampling of 20 sites around the lakes, surficial ground-water quality is highly variable. Nutrient concentrations were highly variable and could not be correlated to the proximity of septic tanks. Fertilizer probably is the primary source of nutrients in the surficial ground water.

Nutrient budgets were calculated for the lakes for the 3 years of the study. The most variable source of nutrient loading to the lakes is stormwater. Nutrient-loading modeling indicates that reduction of nutrients in stormflow probably would improve lake-water quality. However, even with complete removal of nitrogen and phosphorus from stormwater, the lakes might still be mesotrophic with respect to both nutrients during periods of below average rainfall because of the input from the other sources of inflow to the lakes.

Littoral vegetation in the lakes was surveyed in March 1992. The length of shoreline containing vegetation was 44 percent in Lake Maitland, 62 percent in Lake Virginia, 46 percent in Lake Osceola, and 76 percent in Lake Mizell. The types of vegetation present generally were similar for all four lakes.

INTRODUCTION

The Winter Park chain of lakes, located in the cities of Winter Park and Maitland, Florida, consists of Lakes Virginia, Mizell, Osceola, and Maitland. The lakes are part of a 21-lake system that begins with Spring Lake in Orlando and ends with the outflow from Lake Maitland to Howell Creek. The system has a total drainage area of about 17 mi^2 (fig. 1). The four lakes of the Winter Park chain are connected by navigable canals.

The area around the lakes is highly urbanized. Much of the land use in the area is residential. Commercial areas of downtown Winter Park and Maitland and the campus of Rollins College occupy part of the drainage area. Orange groves are cultivated in a small area along the north side of Lake Mizell and in the area between Lakes Osceola and Mizell. The 1994 combined population of the cities of Winter Park and Maitland was about 33,500 residents.

The lakes are an important recreational resource that provide fishing, boating, and swimming, as well as a scenic setting for lakeside estates and the surrounding communities. Because of the value of the lakes as an aesthetic and recreational resource, there is concern about the possible impact of development in the basin on lake-water quality. Quality of water in the lakes can be affected by stormwater from the surrounding area and seepage of ground water enriched by nutrients from fertilizer, septic tanks, or leaking sewer lines. Other sources of water entering the lakes include precipitation and surface flow from upstream lakes. Occasional algal blooms and high bacteria counts in Lake Virginia, resulting in long-term closing of the swimming beach, have increased the concerns of water managers and residents about lake-water quality. Knowledge of the relative contribution from various sources of the nutrient load to the lakes is needed so that a management plan for maintaining or improving lake-water quality can be designed. The U.S. Geological Survey (USGS) began a 4-year study of the Winter Park chain of lakes in cooperation with the city of Winter Park and the St. Johns River Water Management District in order to quantify the hydrologic budgets for the lakes, to assess the quality of lake and inflow water, and, ultimately, to determine the principal sources of nutrient (nitrogen and phosphorus) loading to the lakes.

Purpose and Scope

This report summarizes the results of the 4-year study of the Winter Park chains of lakes. It includes the estimated 1990-92 water budgets for the lakes. Elements of the budgets include surface inflow from the basin upstream, rainfall directly onto lake surfaces, stormwater inflow from the immediate drainage area and from storm drains, ground-water inflow, evaporation, surface outflow and ground-water outflow. Water quality and seasonal variation of water quality in the lakes and in surface inflow and outflow are also described. Data presented include concentrations of major ions, nutrients, chlorophyll-*a* and -*b*, pH, dissolved oxygen, and measurements of transparency. Also summarized are nutrient concentrations in stormwater inflow based on sampling 17 storms at 1 site and 16 storms at another site

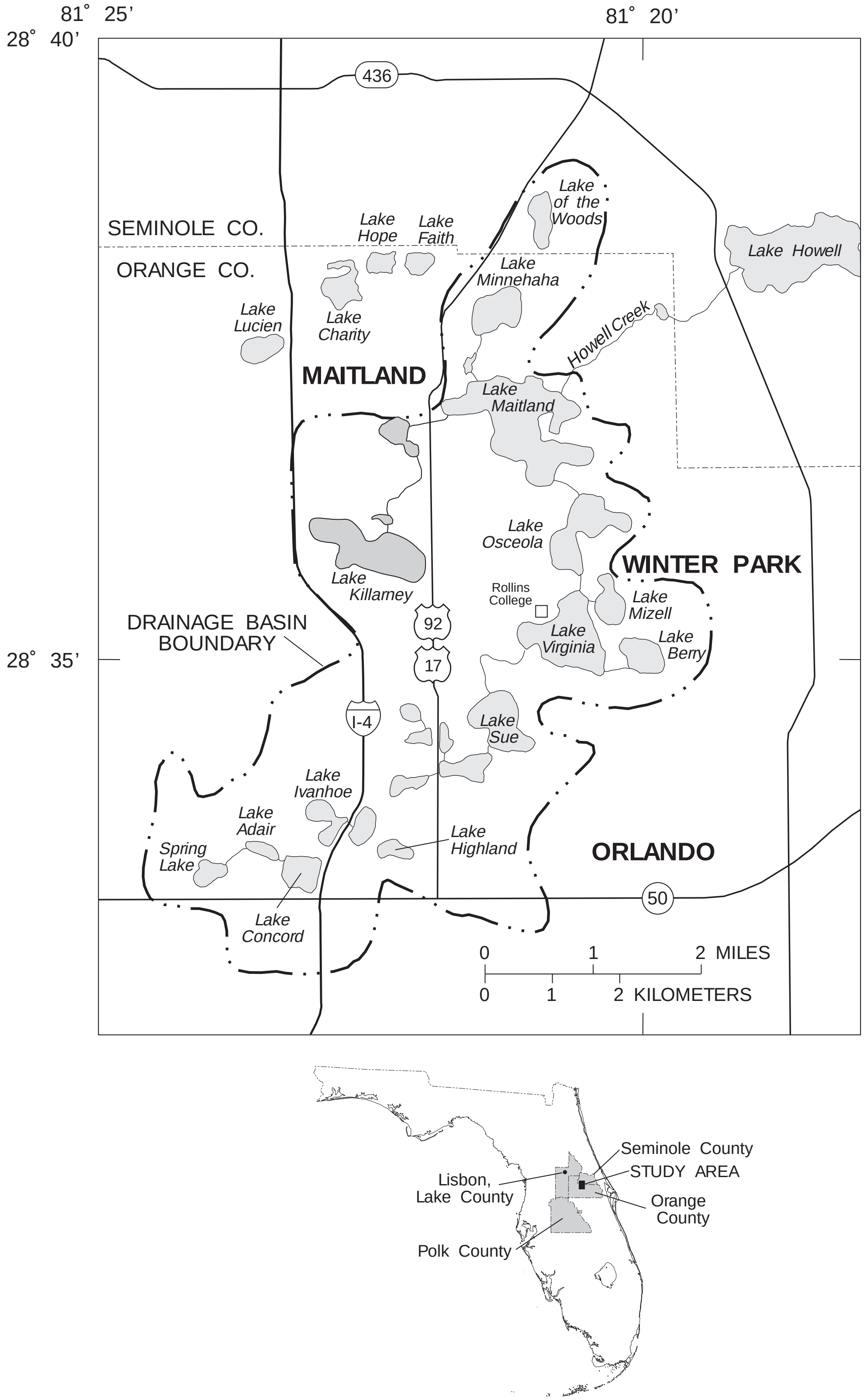

Figure 1. The Winter Park chain of lakes drainage basin.

during 1989-92, and the relative proportions of nutrients in the dissolved, fine-particulate matter, and leaf-sized debris fractions of the total stormwater load. A preliminary appraisal of the quality of the surficial ground water surrounding the lakes, based on one-time samples collected at 20 sites, is also presented. Flow and water-quality data have been combined to provide estimates of a nutrient budget for the chain of lakes and an analysis of nutrient loading using a steady-state input-output model. The report also includes a catalog of emergent littoral vegetation existing in March 1992, a bathymetric survey of the lakes, and a tabulation of chemical and physical characteristics of sediment collected along 1 transect each in Lakes Virginia and Maitland.

Previous Investigations

The general hydrology of the Winter Park chain of lakes area is included in the description of the water resources of Orange County, Florida, by Lichtler, Anderson and Joyner (1968). The water quality of nearby Lakes Faith, Hope, Charity, and Lucien was studied by German (1983). Research by the Biology Department of Rollins College (1979) included studies of plankton, fish, and selected plant species in the Winter Park chain of lakes, as well as analysis of lake-bottom cores and a preliminary model of lake water turnover. Another report prepared at Rollins College (Small, Richard, and Gregory, 1988) summarized water-quality data and biologic information collected in the lakes from 1984-88. The lack of inflow and outflow data for the chain of lakes was noted during those studies. An evaluation of the lakes was prepared for the city of Winter Park by Professional Engineering Consultants (1987). An inventory of septic tanks around the lakes was prepared for the city of Winter Park by Glace and Radcliff, Inc. (1989) and included a study of the fluctuations of surficial ground-water levels and of some chemical constituents in water samples collected downgradient from the septic tanks.

Description of the Study Area

The Winter Park chain of lakes is part of a 21-lake system that begins in Orlando and drains northeastward to Howell Creek (fig. 1). The drainage basin for the total lake system is about 17 mi^2, of which approximately 3 mi^2 is water surface. The four lakes included in this report have a combined water-surface area of about 900 acres (1.4 mi^2). Lake Maitland has a surface area of 470 acres; Lake Virginia, 224 acres; Lake Osceola, 154 acres; and Lake Mizell, 66 acres. The immediate drainage area of the lakes is about 3,100 acres (3.5 mi^2) (Professional Engineering Consultants, Inc., 1987).

The drainage area of the chain of lakes lies across the boundary of two topographic areas delineated by Lichtler, Anderson, and Joyner (1968, fig. 3) and termed the “intermediate” and the “highlands” areas. The north part of the study area is in the intermediate topographic area, where land-surface altitudes generally range from 50 to 85 ft, including swamps in the low-lying areas. To the south is the highlands region, where land-surface altitudes typically are greater than 105 ft. The highlands area is characterized by sinkhole lakes and closed depressions. Land-surface altitude around the Winter Park chain of lakes is about 68 ft and lake-surface altitudes are about 66 ft. Within a mile to the east, south, and west of the lakes, land-surface altitudes rise to about 85 to 100 ft; and to the north, about 75 to 85 ft.

The climate of the Winter Park Lakes area is humid and subtropical. The average annual temperature measured at nearby Orlando is 72.4 °F, and the average annual rainfall is about 48 in. (National Oceanic and Atmospheric Administration, 1990). Total annual rainfall at Orlando for 1990 was 31.68 in. and for 1991, 60.91 in. The annual distribution of rainfall is characterized by two distinct seasons: a summer rainy season (June-September), when about 50 percent of the total annual rainfall usually occurs, and a dry season (October-May). During the rainy season, convection thunderstorms predominate, resulting in a spatially non-uniform distribution of rainfall. During the dry season, rainfall usually is associated with cold fronts and is more uniformly distributed across the area.

The surficial sediments in the area are mostly sands with some organic debris and occasional layers of clay or clayey sand. The thickness of the surficial sediments ranges from about 50 to about 75 ft. Underlying the surficial sands are sediments of Miocene age. Some of the sediments are undifferentiated clayey sands and some are the Hawthorn Formation. Hawthorn sediments include clayey sand, clay, and phosphate-bearing limestone and sandstone. The clayey sediments of the Hawthorn Formation do not form a continuous confining layer, but do retard the downward seepage of water from the water table to the underlying Upper Floridan aquifer. The Miocene sediments range in thickness from about 75 to about 95 ft. Underlying the Miocene sediments is the Eocene Ocala Limestone of the Upper Floridan aquifer. The top of the Ocala Limestone was identified at about 175 ft below land surface in a well approximately 1/2 mi west of Lake Virginia. However, the surface of the limestone has been modified by erosion and the altitude of the top of the formation varies widely. Sinkholes, caused by fluctuations in the potentiometric surface of the Upper Floridan aquifer combined with the gradual subsurface movement of unconsolidated sediments into solution features in the limestone, are actively forming in the Winter Park area.

Methods of Investigation

Because of the complexity of this multidiscipline study, detailed information about data-collection methods is given in respective sections of this report. Data-collection methods can be summarized as follows:

- Surface inflow to the lakes was gaged at three tributaries flowing into the lakes. Outflow from the chain of lakes was computed from lake stage in Lakes Virginia and Maitland using a rating based on a series of field discharge measurements at the outflow weir on Lake Maitland.
- Rainfall was measured using a recording tipping-bucket rain gage.
- Stormflow was estimated by analyzing lake-stage hydrograph rises immediately following storms and evaporation was calculated using nearby pan evaporation data.
- Ground-water outflow was calculated by analyzing lake-stage hydrograph recession during dry periods and ground-water inflow was calculated as the residual of the water-flow budget.
- The quality of inflow and lake water was determined from bimonthly samples collected from October 1989 to May 1992.
- Samples of stormwater inflow from 2 storm drains on Lake Osceola were collected from 17 storms at one site and 16 storms at the other site and analyzed for nutrients, specific conductance, and dissolved solids.
- The nutrient content and rate of nutrient leaching from leaf debris were studied using samples of leaves removed from screens around storm drains.
- Surficial ground water was sampled using a drive-point sampler at 20 sites during February-June 1992.
- Bathymetric contours of the lakes were drawn based on data derived from color fathometer surveys of the lakes made in February and March 1992.
- Grab samples of lake-bottom materials were collected in October 1991 using an Eckman dredge at 7 sites each in Lakes Virginia and Maitland. Samples were analyzed for nutrients, total carbon, lead, and zinc, and a grain-size analysis was made by sieve and hydrometer.
- A field survey of littoral vegetation in the lakes was made in March 1992.

Acknowledgments

The authors gratefully acknowledge T. L. Turner, E. P. Simonds, M. Brizio, and S. Jacobs, all of the U.S. Geological Survey, for their contributions in this study.

LAKE CHARACTERISTICS

The biological, geological, and chemical characteristics of a lake (which affect the trophic state of the lake) are closely related to the age of the lake, climate, local geology, and lake morphology, in addition to such factors as local land use and the quality of inflow water. Eutrophication is the process through which lakes become enriched by nutrients and gradually become filled with sediments, ultimately becoming dry land. As nutrients and sediment deposits accumulate, vegetation growth increases and the depth of the lake decreases. As the lake becomes shallower, the eutrophication process accelerates and the lake eventually becomes a bog or swamp, and, finally, dry land. This is a natural process and is the fate of most lakes. However, the effects of human activity can greatly accelerate the eutrophication process.

Nutrient-poor lakes, termed oligotrophic, are characterized by high concentrations of dissolved oxygen at all depths and low concentrations of dissolved-chemical constituents, particularly nutrients. Mesotrophic lakes are characterized by increased concentrations of dissolved constituents and increased plant growth, but not so excessively that plants become a threat to aquatic animal habitats and a nuisance to human activities. Eutrophic lakes are characterized by high concentrations of dissolved chemicals and nutrients, large numbers of phytoplankton (small plants of which algae are the most commonly known variety), and oxygen depletion with depth (Phelps, 1982).

The lakes of the Winter Park chain are relatively shallow (mean depths calculated during this study range from about 11 to 15 ft), which can affect lake-water quality by providing an environment suitable for rapid algal and submergent plant growth. Some physical characteristics of the lakes are summarized in table 1. The volume for each lake was calculated by digitizing the areas within each depth contour. Volume data are useful for calculating lake budgets and hydraulic-residence time.

Bathymetry

Surveys of the four lakes were made in February-March 1992 using ground-penetrating radar and a color fathometer. Ground-penetrating radar has been used in some lakes to estimate the thickness of bottom sediments or the depth to a hard, reflecting geologic unit, such as the top of limestone. The purpose of using ground-penetrating radar was to locate possible sinkholes in the lakes, but the technique was not effective because the radar signal was attenuated at water depths of about 15 to 20 ft, possibly because of the dissolved solids concentrations in the lake water.

Color fathometer (CF) surveys of all 4 lakes also were made. The CF transmits signals in the 20 to 100 kHz frequency range. The transmitted and reflected signals are shown on a screen similar to a color computer monitor and also are recorded on digital audio tapes for later replay. The replays of data from the surveys were recorded on video tape.

The CF is useful because, in addition to showing the depth of the lake, the signals can penetrate into lake-bottom materials, and provide information about the density of sediments. The best results were obtained using a transmission frequency of 20 kHz. Reflected signals with a small amplitude (weak signals) are blue and generally indicate soft bottom material. As the amplitude of the reflected signals become larger (stronger) the color changes from green to yellow to red. A red signal indicates hard bottom or subbottom materials. CF can be used in water depths greater than about 5 ft.

Bathymetric maps of Lakes Maitland, Virginia, Osceola, and Mizell compiled using the CF data are shown in plates 1-4. The lakes are all relatively shallow, with maximum depths ranging from about 30 ft in Lake Maitland to 21 ft in Lake Mizell.

During most of the CF traverses, the reflected signals indicated good signal penetration into relatively soft sediments. In a few areas, lake-bottom vegetation prevented good signal penetration into the bottom sediments.

Three bottom features that could be sinkholes were noted in Lake Maitland (fig. 2, pl. 1 for site location). Feature 11-M (fig. 2) is about 140 ft across and the bottom depth at the site suddenly drops from about 15 to about 25 ft. Feature 8-M is about 110 ft across with a depth change of about 10 ft. The bottom material at both 8-M and 11-M is soft. Feature 4-M, which is about 85 ft across, is actually two coalescing features. The dark CF signal (red) at the bottom of 4-M was the hardest subsurface material noted in the CF surveys and could be limestone. If limestone is present in the lake bottom, downward leakage through the lake bottom can be a significant component of the flow budget. No sinkhole-like features were noted in the other lakes. However, more detailed CF surveys would be needed to eliminate the possible presence of other sinkholes.

Table 1. Physical characteristics of the Winter Park chain of lakes

[Drainage area data from Professional Engineering Consultants, 1987, table 1. Area and volume calculated at a lake stage of 66.09 ft above sea level in March 1992. Mean depth = volume/surface area. ft^2, square foot; ft^3, cubic foot; ft, foot; --, not applicable]

Lake	Drainage area (acres)	Surface area (acres)	Surface area (ft^2)	Volume (ft^3)	Shoreline length (miles)	Maximum depth (ft)	Mean depth (ft)
Maitland	1,374	470	20.5×10^6	23.3×10^7	6.2	30	11.4
Virginia	944	224	9.8×10^6	14.8×10^7	2.9	23	15.1
Osceola	567	154	6.7×10^6	7.2×10^7	2.8	23	10.7
Mizell	258	66	2.9×10^6	3.1×10^7	1.4	21	10.7
Total	**3,143**	**914**	$\mathbf{39.9 \times 10^6}$	$\mathbf{48.4 \times 10^7}$	**13.3**	--	--

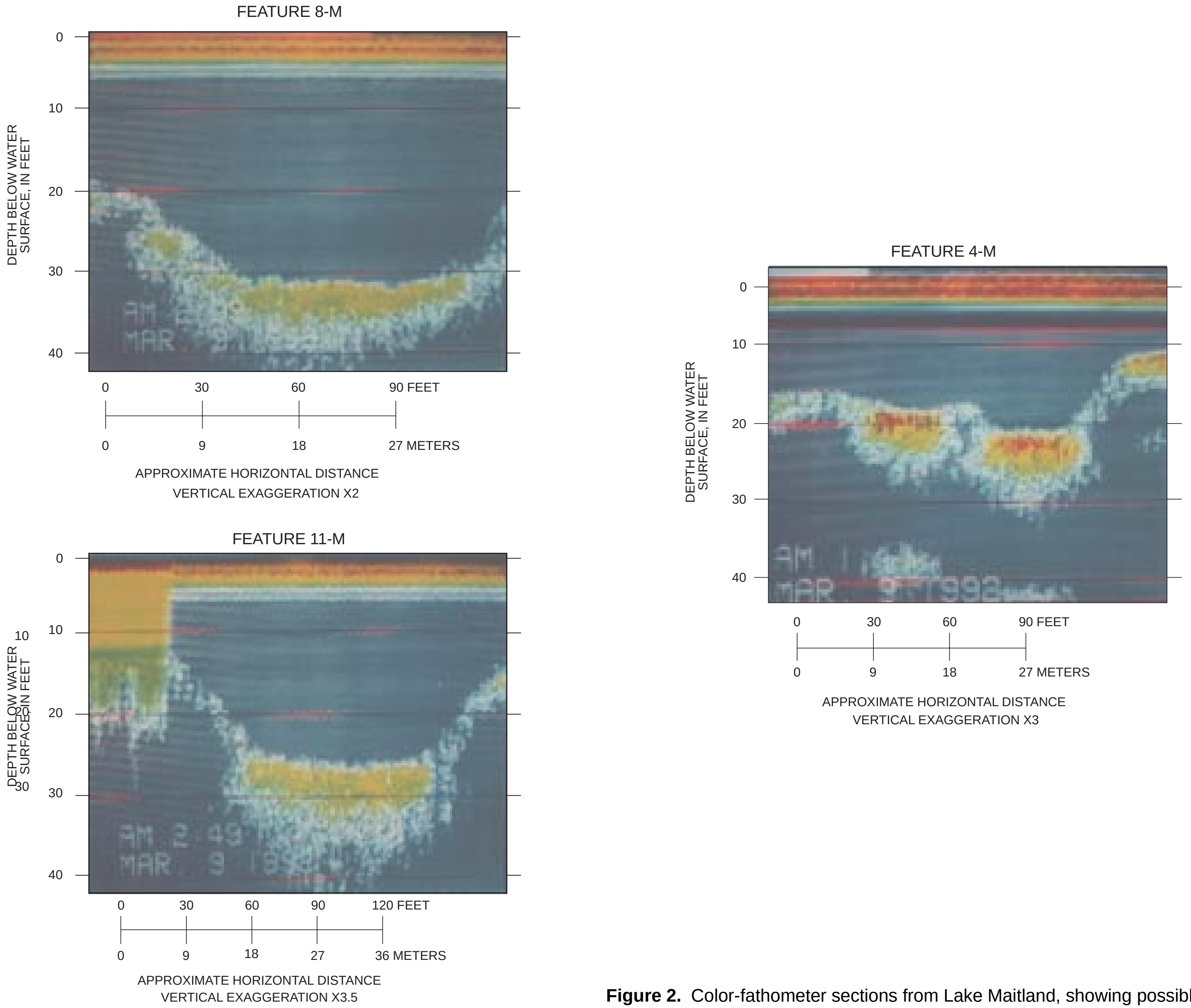

Figure 2. Color-fathometer sections from Lake Maitland, showing possible sinkholes.

Bottom Sediments

Bottom sediment samples were collected using an Eckman dredge along traverses in Lakes Maitland and Virginia and sediment sizes were determined using sieves and a hydrometer. The traverses are shown in figure 3.

Because this sampling was a reconnaissance, grab samples were collected with a dredge, from which small-sized sediments could be washed out during the collection process, thus causing a bias in favor of larger grain sizes. Therefore, no conclusions about sedimentation rates can be made from the data. A series of lake-bottom core samples could provide more information about sedimentation rates.

The distributions of bottom-sediment grain sizes for the two traverses are shown in figures 4-5. Most of the sediments were fine- to medium-grained sand with an average grain-size diameter in the range of about 0.1 to 1.0 mm. At site M-6, the bottom was so hard that the dredge was unable to collect a sample. The samples collected at sites M-2, V-3, and V-4 contained a greater proportion of finer sediments than samples collected at the other sites. The size distribution of sediments in the lakes probably is related to the combined effects of currents, wind and boat traffic.

The lake-bottom sediment samples collected in Lakes Virginia and Maitland on October 2, 1991, were analyzed for nutrients, total carbon, lead and zinc (table 2). The samples containing the greatest percentage of fine sediments, M-2, V-3, and V-4 (figs. 4 and 5), also had the highest concentrations of lead and zinc. This probably is because metals tend to be adsorbed on fine-grained sediment particles (often clay) as opposed to coarser, sandy sediments. The sites from which the samples in Lake Virginia were collected (fig. 3) show the influence of storm drains. The northeast side of the lake is relatively undeveloped and has no storm drains. The sediments on that side of the lake had a lower percentage of fine sediments and lower lead and zinc concentrations than sites V-3 And V-4, which are closer the area where storm drains are present. The fine sediments probably are carried into the lakes in the stormflow.

The samples with the highest percentages of fine sediments also had the highest concentrations of total carbon. This probably is because fine-grained sediments incorporate decaying plant material. The resuspension of fine-grained sediments could contribute to the concentrations of total nitrogen and phosphorus in lake water, especially in relatively shallow lakes and during dry periods, when the lake volume is smaller.

Previous investigators (Rollins College, 1979, p. 1) were concerned that sedimentation rates in the lakes seemed to be high, causing rapid infilling. However, based on the limited bottom-sediment sampling in this study and on comparison of current bathymetry to past data, there are no indications of rapid sediment infilling of the lakes.

Summary of Littoral Vegetation

Vegetation in the littoral (near shore) part of lakes can be important to the lake processes that affect eutrophication. The growth of some plants can be useful because they remove nutrients (nitrogen and phosphorous) from the water. However, the excessive growth of “nuisance” plants, such as hydrilla, can be detrimental because they contribute large amounts of plant detritus to the lake, which can adversely affect water quality and habitats. Many factors, such as disturbance of the shoreline and its overstory, nutrient concentrations in the lake water, and erosion and sedimentation rates, interact with natural conditions to affect the diversity of plant species in a lake. The extent and character of emergent vegetation is also strongly influenced by the means and extremes of water levels in the lake.

A reconnaissance survey of the emergent littoral vegetation in the Winter Park chain of lakes was made by personnel of the U.S. Geological Survey in March 1992. Plants were identified to species, but in some instances only to family. Woody species were inventoried but were excluded from areal coverage estimates because areal coverages for woody and non-woody species cannot be readily compared. The percentages of shoreline containing vegetation were: Lake Maitland, 44 percent; Lake Osceola, 46 percent; Lake Virginia, 62 percent; and Lake Mizell, 76 percent. Generally, the types of vegetation in all four lakes were similar, which is not surprising given the proximity of and connection between the lakes. Lake Maitland was dominated by torpedo grass, followed by cattails, with bald cypress present in more than 50 percent of the lake sections. Lake Virginia was dominated by cattails, followed by torpedo grass, with bald cypress and water primrose present in about 25 percent of the sections. Lake Osceola was not clearly dominated by any species, but torpedo grass and other Panicum species were most prolific, with bald cypress in 33 percent and water primrose in 25 percent of the sections. Nuisance vegetation did not seem to be a problem in the lakes. A detailed description of the vegetation survey is presented at the end of this report.

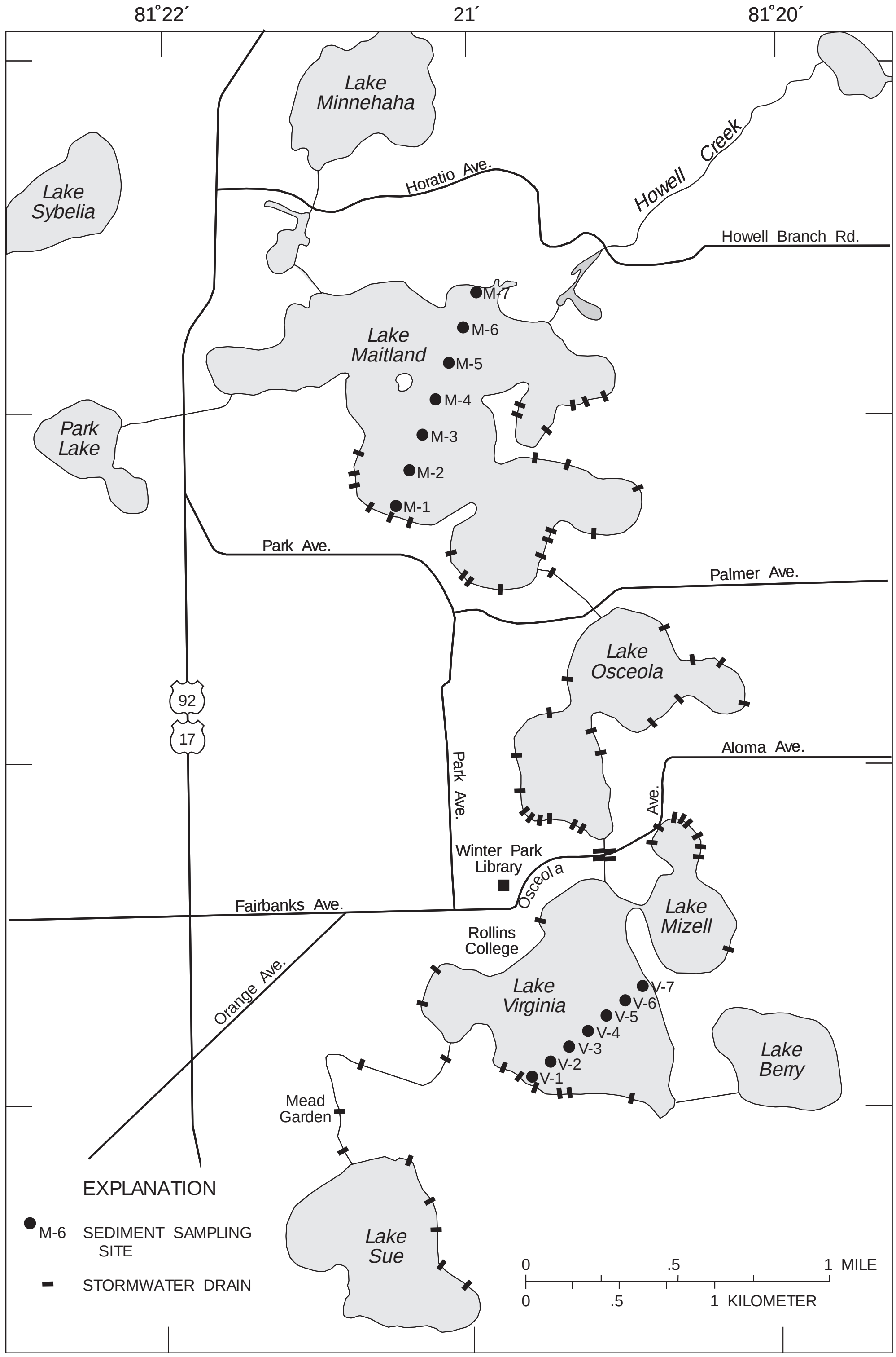

Figure 3. Bottom-sediment sampling sites and location of stormwater drains.

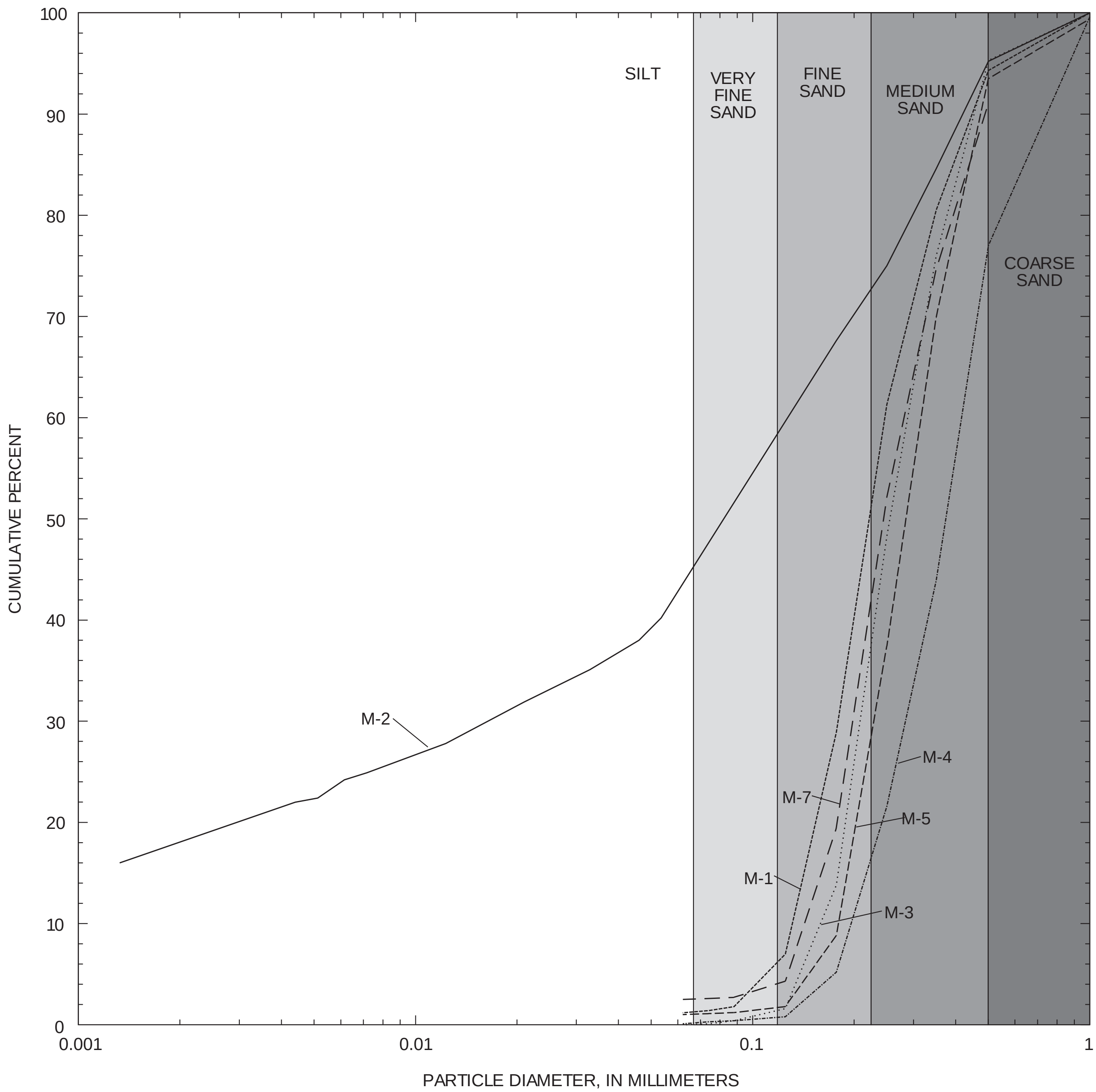

Figure 4. Lake Maitland bottom-sediment size distribution based on sieve and hydrometer analysis, October 1991 (site numbers are from fig. 3).

WATER BUDGET

Inflow to, outflow from, and volume changes in the lakes were measured or estimated for 3 years (water years October 1, 1989, to September 30, 1992) to calculate flow and nutrient budgets for the Winter Park chain of lakes. The locations of surface water data-collection sites are shown in figure 6 and information about the types of data collected at each site is listed in table 3. Rainfall was measured at the Winter Park Library (fig. 6). The flow data were combined to estimate water budgets for the chain of lakes for water years 1990-92. A simple water budget can be written as:

$$\text{Rainfall} + \text{Surface Inflow} + \text{Stormflow} \\ + \text{Ground-water Inflow} = \text{Evaporation} \\ + \text{Surface Outflow} + \text{Ground-water Outflow} \\ + \text{Storage Change.} \qquad (1)$$

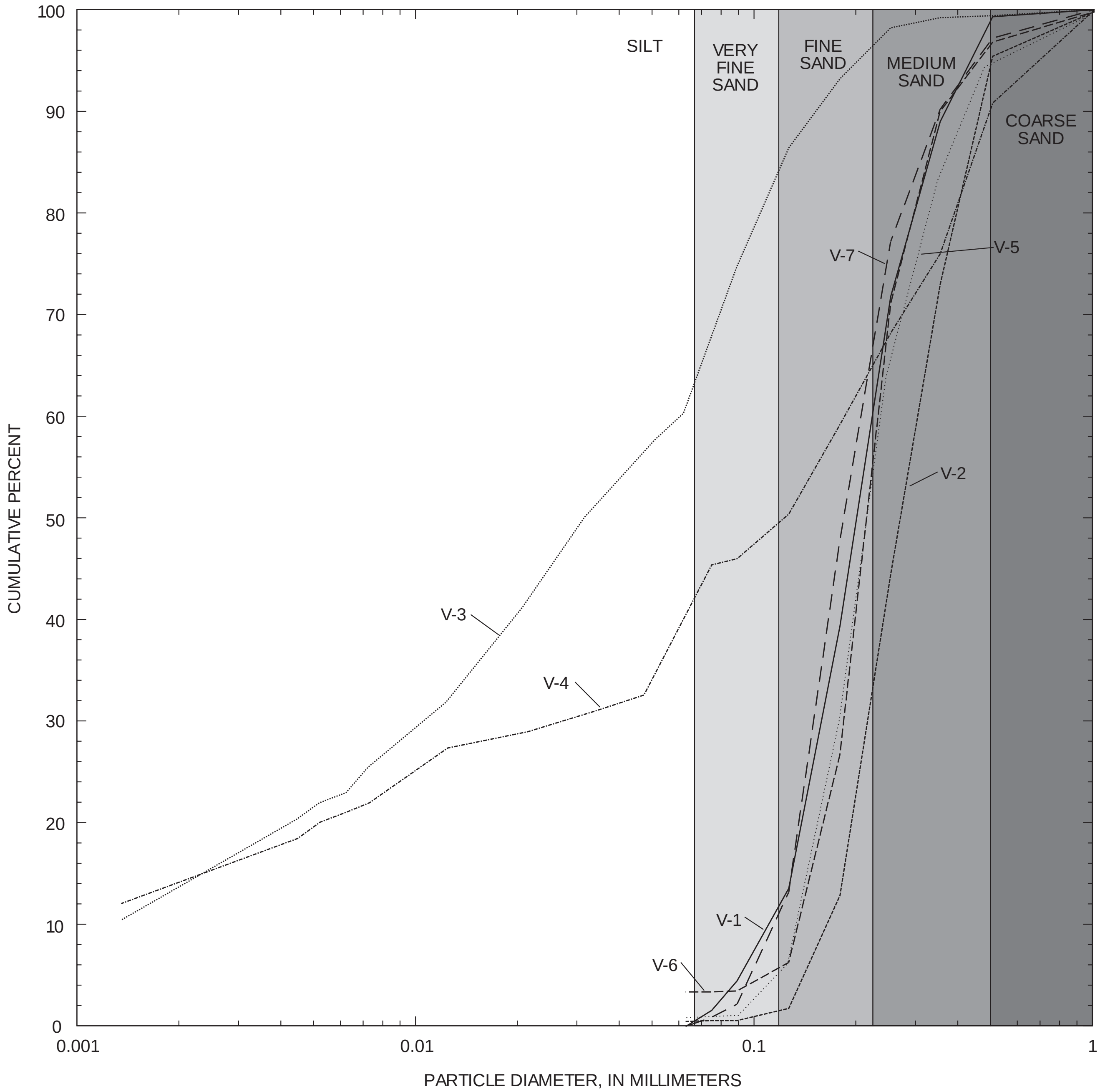

Figure 5. Lake Virginia bottom-sediment size distribution based on sieve and hydrometer analysis, October 1991 (site numbers are from fig. 3).

Input

The lakes receive water from direct precipitation, stream inflow from other lakes, stormflow including direct runoff from land adjacent to the lakes and water from storm drains, and from ground-water seepage. Rainfall and surface inflow were measured directly during the study. Stormflow and ground-water seepage, more difficult to measure, were estimated for the 3 years of the study.

Rainfall

A tipping-bucket rain gage, installed on the roof of the Winter Park Library, measured rainfall near the lakes during the study (fig. 6). The gage was placed near the center of the roof to minimize the effects of updrafts near the sides of the building. Measured rainfall was 37.96 in. for water year 1990, 58.49 in. for 1991, and 47.50 in. for 1992. The average rainfall at the Winter Park Library during the 3 years of the study

Table 2. Chemical analysis of bottom sediments from Lakes Virginia and Maitland

[Site numbers are from figure 3. mg/kg, milligrams per kilogram; g/kg, gram per kilogram; µg/g, micrograms per gram; <, less than]

Site number	Site identification number	Moisture content, dry weight (percent of total)	Nitrogen, NH_4 total in bottom material (mg/kg as N)	Nitrogen, NH_4 + organic, total in bottom material (mg/kg as N)	Nitrogen, NO_2+NO_3 total in bottom material (mg/kg as N)	Phosphorus, total in bottom material (mg/kg as P)	Carbon, inorganic + organic, total in bottom material (g/kg as C)	Lead, recovered from bottom material (µg/g as Pb)	Zinc, recovered from bottom material (µg/g as Zn)
V-1	283505081204900	82	27	9,900	<2.0	1,600	120	110	70
V-2	283508081204500	72	62	5,400	<2.0	680	67	90	70
V-3	283510081204100	90	220	19,000	<2.0	1,800	270	160	130
V-4	283513081203700	90	200	20,000	7.0	1,500	240	150	50
V-5	283516081203300	52	17	1,700	<2.0	230	16	20	20
V-6	283518081202900	21	1.3	280	3.0	<40	1.8	<10	<1
V-7	283521081202500	71	17	4,700	12	42	46	40	30
M-1	283641081211100	31	25	1,100	<2.0	590	34	40	30
M-2	283648081210900	85	94	12,000	13	4,400	260	50	80
M-3	283655081210700	77	41	5,900	<2.0	1,700	69	40	30
M-4	283702081210500	43	6.6	1,400	<2.0	71	15	<10	<1
M-5	283708081210300	21	1.0	240	<2.0	<40	1.1	<10	<1
M-6	283715081210000	31	2.6	860	<2.0	79	8.1	<10	<1
M-7	283722081205800	84	260	6,600	<2.0	660	58	<10	40

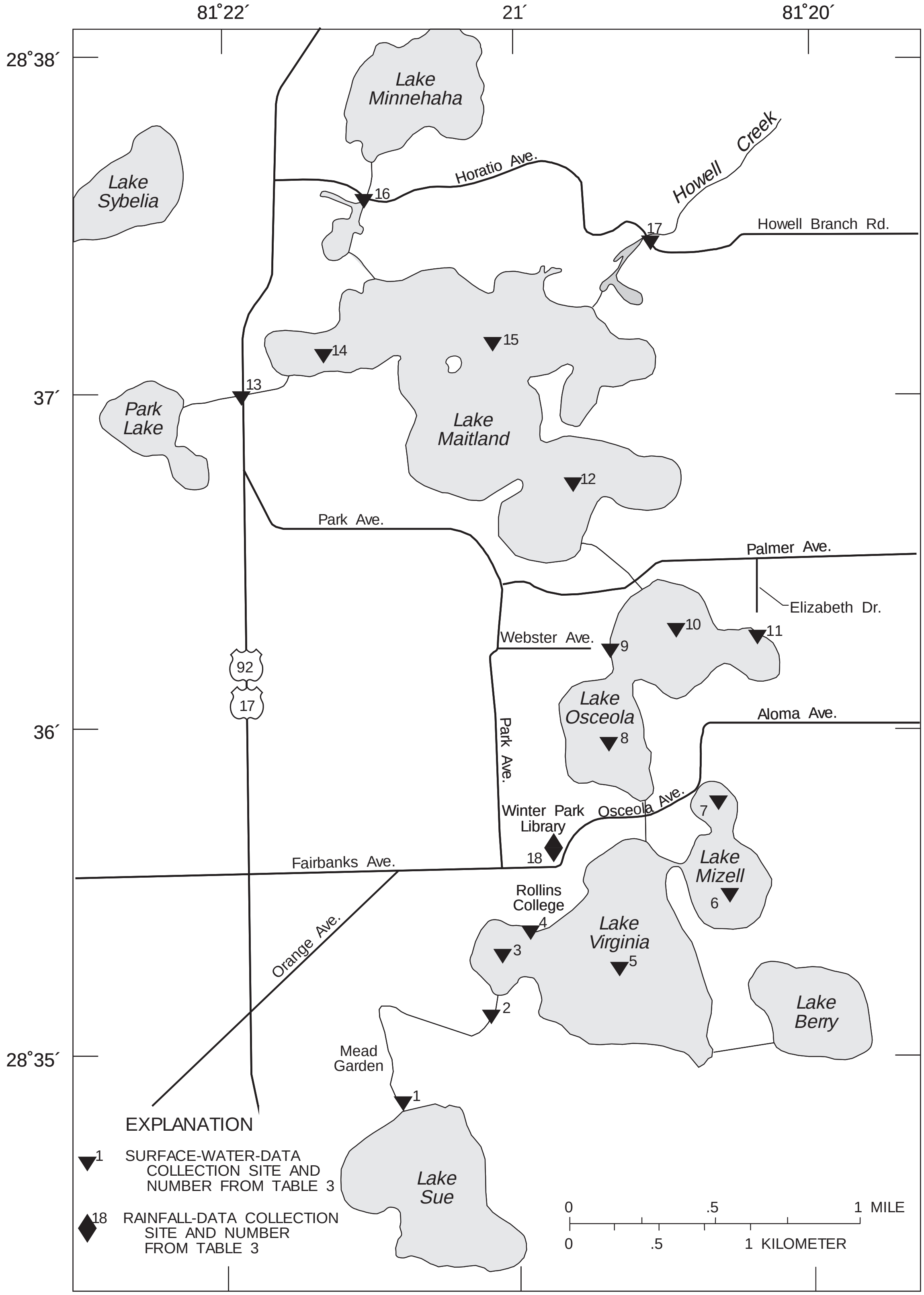

Figure 6. Surface water data-collection sites.

Table 3. Surface-water data-collection sites in the Winter Park area

[Map numbers are from figure 6. S, continuous stage; D, discharge computed; QW, bimonthly water-quality samples; ST, stormwater-inflow water-quality samples; SS, stage for selected storms; SD, discharge for selected storms; R, rainfall]

Map number	Site identification number	Site name	Data types
1	283452081212401	Lake Sue outflow canal at Lake Sue	S, D, QW
2	02234263	Lake Sue outflow canal at Winter Park	S, D, QW
3	283518081210201	Lake Virginia west	QW
4	02234264	Lake Virginia staff gage	S
5	283517081204001	Lake Virginia	QW
6	283534081201801	Lake Mizell	QW
7	283545081201901	Lake Mizell north	QW
8	283556081204101	Lake Osceola south	QW
9	283613081204501	Webster Dr.	ST, SS, SD
10	283615081202801	Lake Osceola north	QW
11	283617081200901	Elizabeth Dr.	ST, SS, SD
12	283644081204901	Lake Maitland south	QW
13	02234287	Park Lake outflow canal	S, D, QW
14	283708081214201	Lake Maitland west	QW
15	283709081210401	Lake Maitland north	QW
16	02234299	Lake Minnehaha outflow canal	S, D, QW
17	283727081203501	Lake Maitland outflow	S, D, QW
18	283542081204701	Winter Park Library	R

was 47.98 in. Average yearly rainfall at the Orlando International Airport (about 12 mi south of Winter Park) is about 48 in. Rainfall at the airport was 35.38 in., 59.61 in., and 49.44 in., during water years 1990, 1991, and 1992, respectively. During water year 1992, rainfall near the Winter Park chain of lakes was about average, but was about 10 in. less than average in 1990, and about 10 in. more than average in 1991. A graph of rainfall at Winter Park and water level in Lake Virginia during the 3 years of the study is shown in figure 7.

The stage of Lake Virginia rapidly responds to rainfall as indicated in figure 8, which shows cumulative rainfall and lake stage with time during April 11-12, 1992. Several storms contributed more than l in. of rainfall per day during that time. The stage of the lake rapidly responded to the first storm on April 11 and generally responds to rainfall within an hour after the rainfall event. The increase in lake stage between 8-9 am on April 12 does not correspond to a rainfall event and could be the result of ground-water inflow or of rainfall from an earlier event in another part of the basin. Maximum stage of the lake during the study was about 66.94 ft and minimum stage was about 64.84 ft.

Surface Inflow

Inflows from Lake Sue, Park Lake, and Lake Minnehaha were measured during the three water years. Continuous measurements of stage were made at sites 2, 13, and 16 (table 3 and fig. 6) and daily discharge was computed. The mean daily inflows for water years 1990-92 are as follows:

	Lake Sue (ft^3/s)	Park Lake (ft^3/s)	Lake Minnehaha (ft^3/s)	Total (ft^3/s)	Total (in.)
1990	4.8	0.8	1.0	6.6	56
1991	6.2	1.3	1.2	8.7	73
1992	5.9	1.0	1.1	8.0	67

A hydrograph showing daily flow from Lakes Sue and Minnehaha and Park Lake is presented in figure 9. Negative flow as shown on the hydrograph for Lake Minnehaha results when water flows from Lake Maitland to Lake Minnehaha, instead of from Minnehaha to Maitland. This condition can occur during prolonged dry periods.

Stormflow

Direct measurement of stormflow runoff is difficult because more than 68 storm drains enter the Winter Park chain of lakes (fig. 3), making measurement of flow from all storm drains impractical. Therefore, runoff was calculated using data from the Lake Virginia stage hydrograph for rainfall events greater than 0.1 in., based on the assumption that rainfall amounts less than this threshold would not result in runoff. Runoff was estimated from the change in lake stage corrected for rainfall, and for inflow and outflow, with the assumption that the effects of evaporation and ground-water seepage during the event were negligible. The runoff rate calculated for 1990 was 4 in.; 1991, 32 in.; and 1992, 15 in.

The effects of variations in rainfall are evident from the estimated runoff values. Runoff was very low during 1990, which had 10 in. less than average (48 in.) rainfall; runoff was much greater in 1991 with rainfall 10 in. above average; and 1992, a year with average rainfall, had an estimated runoff of about 15 in.

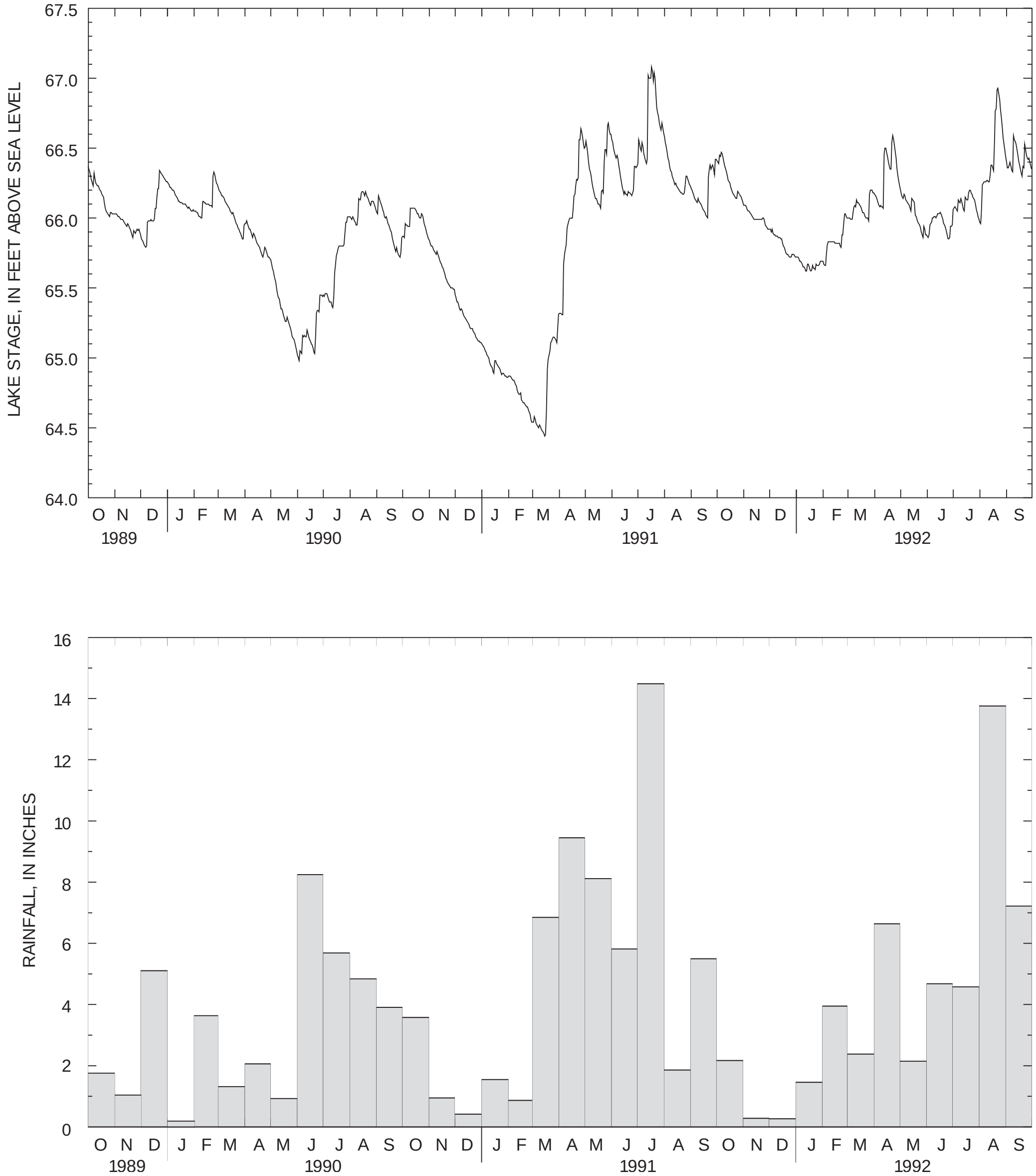

Figure 7. Monthly rainfall at Winter Park Library and water level in Lake Virginia, water years 1990-92.

Ground-Water Inflow

Lateral inflow of water from the surficial aquifer system to the lakes is an important component of the flow budget for the lakes, but probably the one with the most uncertainty. Flow occurs because of the head difference between the water table and the lake level. Lateral inflow occurs through approximately 13 mi of lake shoreline (table 1). Surficial ground water flows laterally from all directions into the lakes, except in a few very localized areas where the lake level is higher than the water table. The relation between the lakes and the ground-water system is shown as a generalized section in figure 10. Surficial ground-water inflow to the lakes was calculated using Darcy’s equation and hydrogeologic data collected in 1992. Because of uncertainties in some of the hydrogeologic parameters and the problem of applying data from one water year to other water years having very different hydrologic conditions, inflow was also calculated as the residual of the flow budget for each water year.

Inflow of surficial ground water to the lakes can be estimated using Darcy's equation in the form:

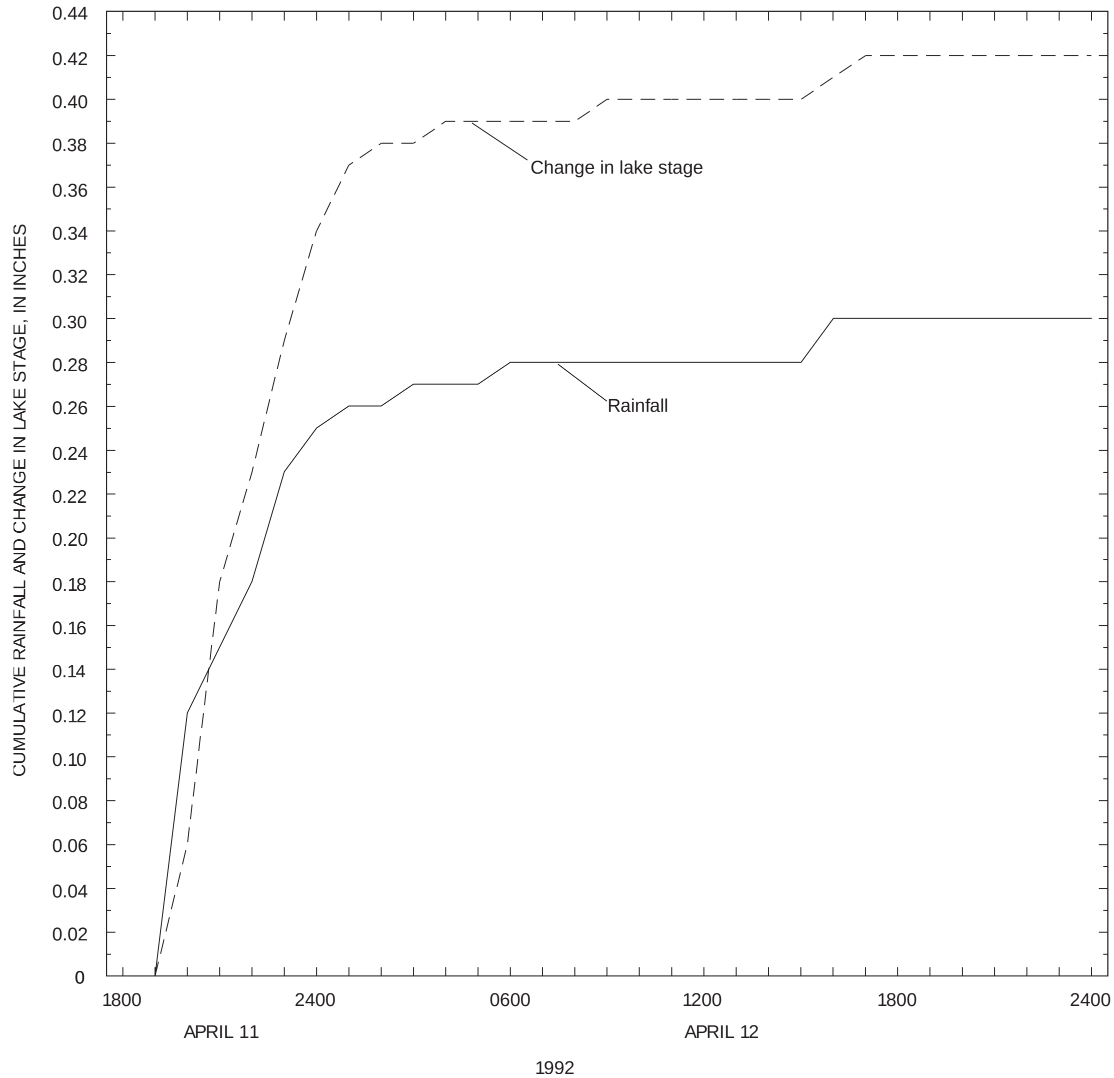

Figure 8. Cumulative rainfall and change in stage of Lake Virginia, April 11-12, 1992.

$$Q = K\ I\ A \qquad (2)$$

where

Q is inflow, in cubic feet per day,
K is hydraulic conductivity, in cubic feet per day per square foot of cross sectional area, which reduces to feet per day,
I is hydraulic gradient, dimensionless, and
A is area across which flow occurs, in feet squared.

The horizontal hydraulic conductivity of the surficial sediments was estimated from the grain-size analysis of sediments collected from the bottoms of Lakes Virginia and Maitland (figs. 4 and 5). The predominate grain-size range for 10 of 13 samples was .09 to 1.0 mm, typical of fine-to medium-grained sand. The hydraulic conductivity for a similar grain-size distribution, calculated from field permeability (Davis and DeWiest, 1966, figure 11.3 and table 11.1), is about 60 ft/d. Using the same relation, the hydraulic conductivity corresponding to the grain size distribution of the three samples that had a greater percentage of fine material is about 15 ft/d. The estimated range of hydraulic conductivity of the surficial sediments is therefore 15 to 60 ft/d. A uniform hydraulic conductivity of 20 ft/d was assumed for simplicity because the bottom sampling method probably was biased toward larger grain sizes.

The hydraulic gradient that controls surficial ground-water seepage to and from a lake is determined by the head difference between the water table and the

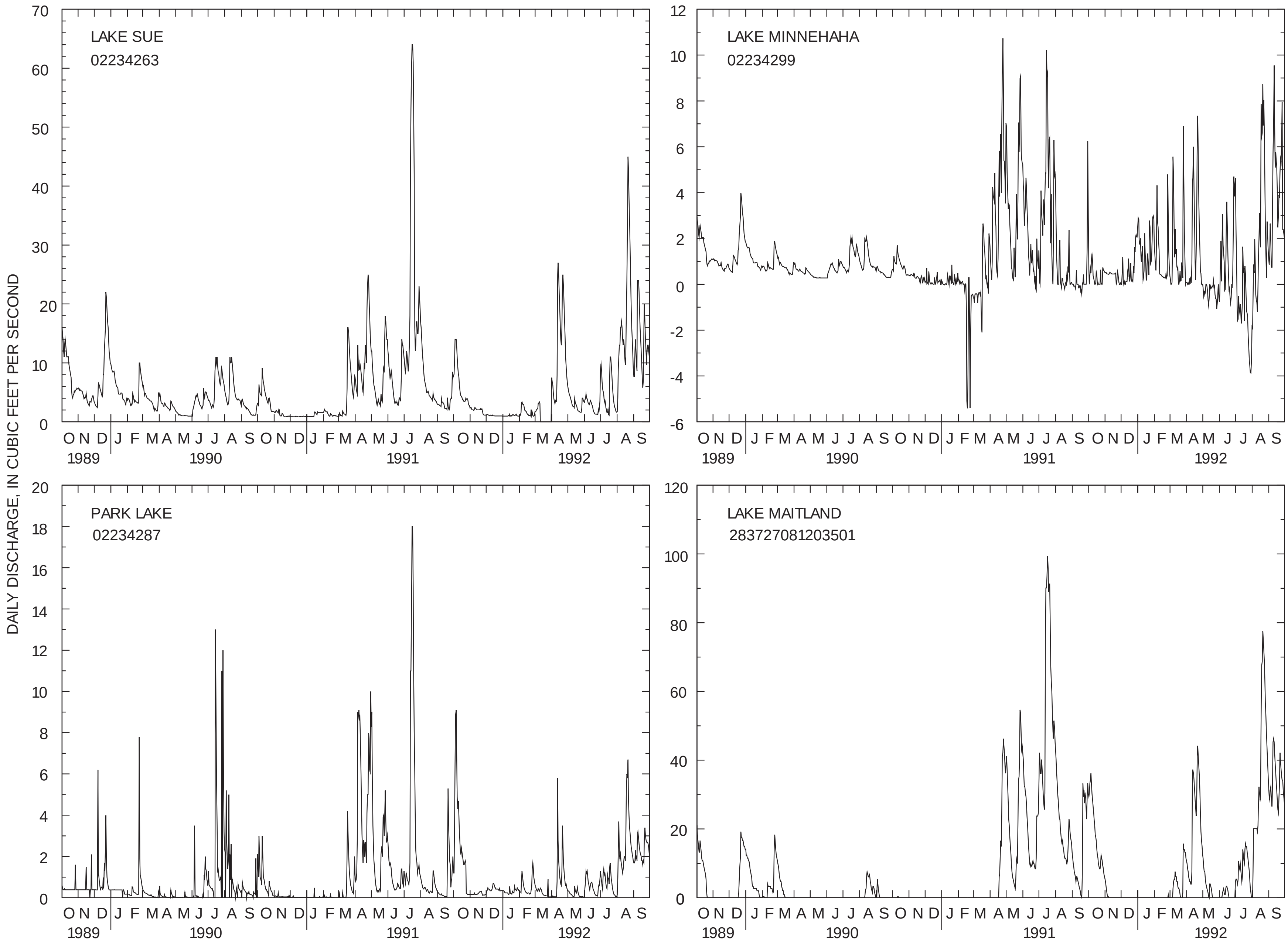

Figure 9. Daily discharge from Lake Sue, Lake Minnehaha, Park Lake, and Lake Maitland, October 1, 1989-September 30, 1992 (locations described in table 3 and shown in fig. 6).

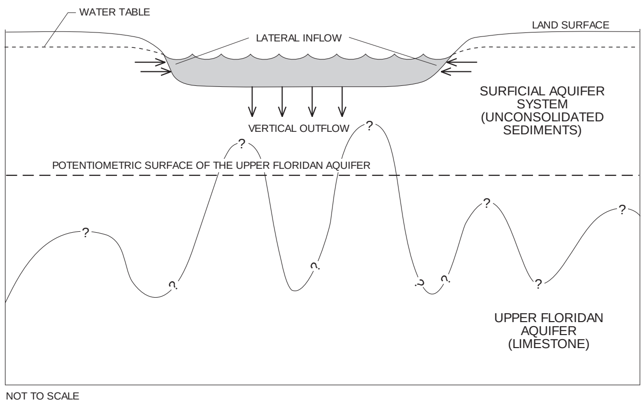

Figure 10. Relation of water table to potentiometric surface of the Upper Floridan aquifer and components of ground-water flow.

lake stage. The gradient was measured in February-May 1992 at 20 sites around the lakes (fig. 11) by measuring the head difference between the water table and the lake using a drive-point manometer. Gradient values ranged from -2.71 x 10^{-3} to 6.59 x 10^{-1} (table 4), with a median gradient value of 1.10 x 10^{-2}. A negative gradient is an indication of water moving from the lake to the surficial aquifer, rather than from the surficial aquifer to the lake. Negative gradients occurred at sites 3, 6, 8, and 9; at site 2 the heads in the lake and the surficial aquifer were equal.

The effective lake depth across which ground-water inflow occurs is important to the calculation because the area (A) in equation 2 is computed by multiplying the total length of lake shoreline by the effective depth. The effective depth depends on lake morphology and the relation of the local flow system to regional flow and may be difficult to estimate. Kerfoot (1984) used an effective depth of 15 ft for a pond in glacial outwash on Cape Cod, Massachusetts. In a study of Lake Lucerne in Polk County, Florida, an effective depth of 16 ft was used (T. Lee, U.S. Geological Survey, written commun., 1993). The topography around Lake Lucerne has more relief than that around the Winter Park chain of lakes. Based on methodology described by McBride and Pfannkuch (1975), the effective depth across which flow occurs in the Winter Park lakes was estimated to be 10 ft.

Total annual inflow calculated using a horizontal hydraulic conductivity of 20 ft/d and the median lateral hydraulic gradient of 1.10 x 10^{-2} was 17 in/yr. By comparison, the ground-water inflow for water year 1992 calculated as the residual of the flow budget was 40 in. Although the calculations based on Darcy's equation were not used in the flow budgets, they are useful in pointing out the possible sources of error in ground-water flow estimates and the effect such errors might have on the flow and constituent budgets. For example, if the hydraulic gradient were increased one order of magnitude (while keeping the effective depth and hydraulic conductivity the same), the calculated inflow rate would have been 170 in/yr. On the other hand, if the hydraulic conductivity were increased from 20 to 40 ft/d and the hydraulic gradient and effective depth kept the same, the calculated inflow would have been 34 in/yr.

Output

Water from the lakes is lost to evaporation and to surface and ground-water outflow. Only surface outflow can easily be measured directly.

Lake Evaporation

Evaporation of water from lake surfaces is an important element of the flow budget. The rate of evaporation depends on many factors, including temperature, the amount of solar radiation, vapor pressure, and wind speed at a particular site. Some water also is transpired by plants, so the lake evaporation rate may depend on the amount and type of vegetation present. In the following discussion the term lake evaporation refers to the total loss of water by evaporation and transpiration. A common way to estimate lake evaporation is to measure evaporation from a standard pan and then derive an empirical relation between observed pan evaporation and estimated lake evaporation.

Monthly rainfall, pan evaporation, and stage of Lake Virginia were measured in 1977 (Ross, 1979, p. 48). The best correlation between lake stage and pan evaporation determined in that study resulted from estimating evaporation to be 0.8 times pan evaporation. This correlation compares favorably with the mean annual pan-to-lake-coefficient of 0.81 calculated for Lake Okeechobee by Kohler (1954, table 24). Monthly coefficients calculated in that study ranged from 0.69 for February to 0.91 for July and August.

A detailed study of evaporation was made at Lake Lucerne in Polk County (T. Lee, U.S. Geological Survey, written commun., 1993). Measurements of lake and ground-water levels, rainfall, and pan evaporation were made for the 1986 water year (October 1, 1985, to September 30, 1986). During that year,

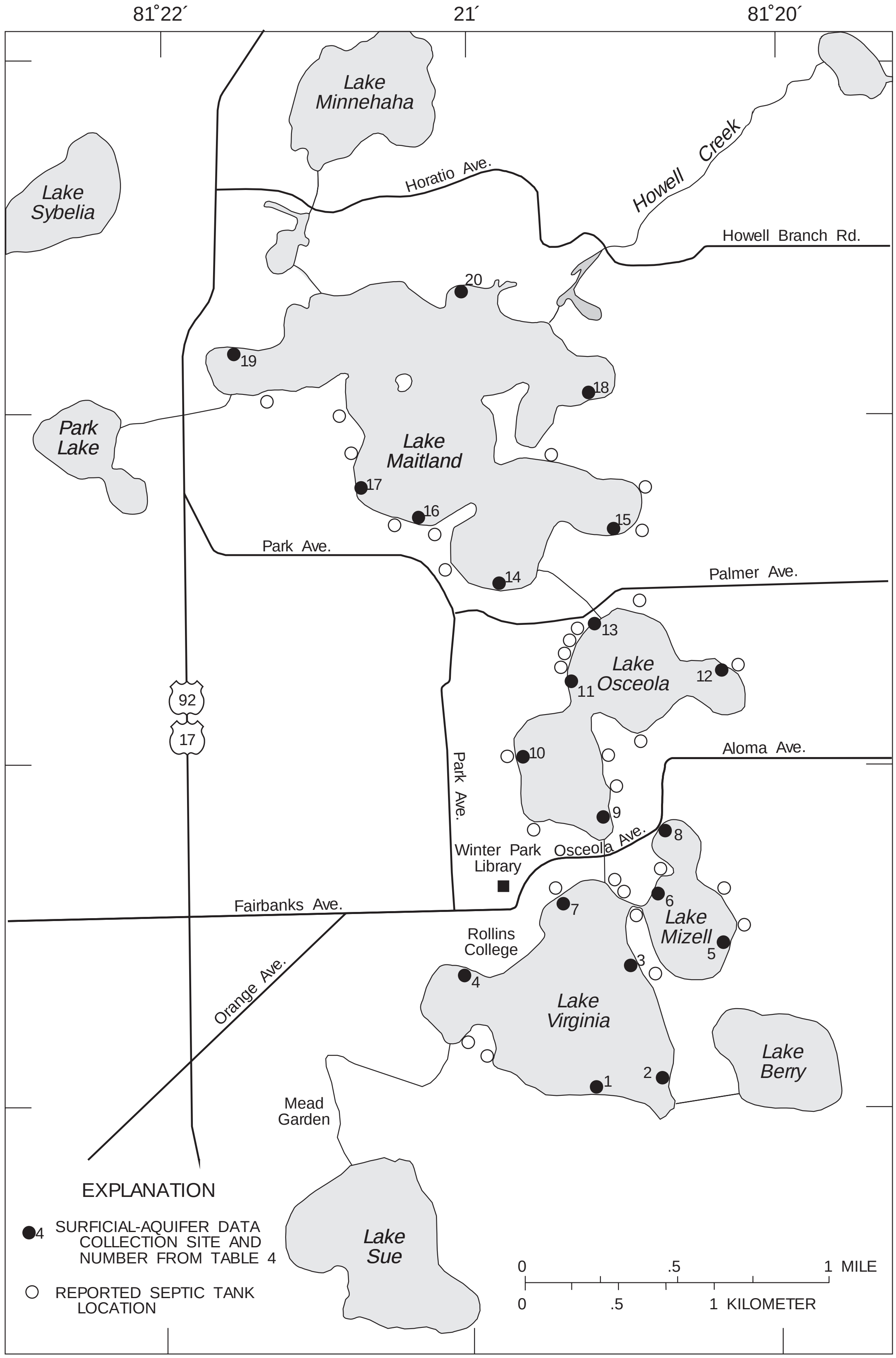

Figure 11. Surficial aquifer data-collection sites and reported septic tank locations.

Table 4. Surficial aquifer sampling sites and head difference between lakes and the surficial aquifer

[Map numbers are from figure 12. in., inch; ft/ft, feet per foot]

Map number	Site identification number	Site name	Description	Head difference (in.)	Gradient (ft/ft)
1	283503081203701	Lake Virginia S., Laurel Rd.	10 ft onshore	2.56	2.10×10^{-2}
2	283506081202201	Lake Virginia S.E.	1 ft offshore	0	0
3	283523081202701	Lake Virginia N.E.	10 ft offshore	-0.16	-1.31×10^{-3}
4	283525081210001	Lake Virginia W., Lakeview Dr.	2 ft onshore	0.32	1.29×10^{-2}
5	283527081201001	Lake Mizell S.E.	2 ft offshore	0.55	2.30×10^{-2}
6	283537081202401	Lake Mizell S.W.	0.5 ft onshore	-0.32	-5.20×10^{-2}
7	283537081204101	Lake Virginia, Dinky Dock	9 ft onshore	0.83	7.69×10^{-3}
8	283547081202201	Lake Mizell N.	0.5 ft onshore	-0.59	-9.80×10^{-2}
9	283549081203201	Lake Osceola S.E., Trismen Ter.	12 ft onshore	-0.39	-2.71×10^{-3}
10	283600081205001	Lake Osceola S.W., Canton Ave.	5 ft onshore	6.50	1.08×10^{-1}
11	283610081204501	Lake Osceola, Webster Dr.	3 ft onshore	0.94	2.61×10^{-2}
12	283617081200902	Lake Osceola N.E., Elizabeth Dr.	6 ft onshore	0.79	1.10×10^{-2}
13	283625081203501	Lake Osceola N.W., Palmer Ave.	1 ft onshore	5.52	4.59×10^{-1}
14	283630081205401	Lake Maitland S., Olde England Dr.	1 ft onshore	4.33	3.61×10^{-1}
15	283641081202901	Lake Maitland, Alabama Dr.	1 ft offshore	7.88	6.59×10^{-1}
16	283642081211101	Lake Maitland S., New York Ave.	10 ft onshore	0.87	7.25×10^{-3}
17	283647081212301	Lake Maitland S.W., Green Cove Rd	2 ft onshore	1.77	7.40×10^{-2}
18	283702081203701	Lake Maitland E., Pinetree Rd.	4 ft onshore	2.68	5.58×10^{-2}
19	283713081214701	Ft. Maitland Park	5 ft offshore	0.39	6.50×10^{-3}
20	283723081210201	Lake Maitland N., Adams Dr.	4 ft onshore	0.20	4.17×10^{-3}

annual lake evaporation estimated from an energy budget was about 58 in., about 8 in. higher than long-term estimates for the region. The rate may have been higher than expected because of drier than normal conditions: rainfall for the 1986 water year at Lake Lucerne was about 10 in. less than normal. The lowest evaporation rate calculated from a weekly energy budget was about 0.04 in/d in early January 1986. The highest rate was about 0.26 in/d in early May 1986.

Pan evaporation at the National Oceanic and Atmospheric Administration (NOAA) weather station in Lisbon, Lake County, Florida (fig. 1), was used to estimate evaporation for the Winter Park lakes. Pan evaporation at Lisbon in May and July 1989 was 8.11 and 8.87 in., respectively, compared to the maximum Lake Lucerne rate (0.26 in/d) which is equivalent to 8.06 in/mo. The lowest rate at Lake Lucerne (0.04 in/d) corresponds to a monthly total of 1.24 in., compared to 1.98 in. at Lisbon in December 1989. Annual lake evaporation was estimated to be 0.8 times pan evaporation. Pan evaporation rates at Lisbon for water years 1990-92 were 62.88, 60.63 and 58.63 in., respectively. Evaporation rates calculated as 80 percent of pan evaporation were 50.3, 48.5 and 46.9 in. Because there is some uncertainty in the evaporation rates, 51 in. was used for 1990 and 48 in. for 1991 in order to balance the flow budgets.

Surface Outflow

Nearly all of the surface-water outflow from the Winter Park chain of lakes discharges through a canal controlled by a weir near site 17 into Howell Creek (fig. 6) except for rare reverse flow from Lake Maitland to Lake Minnehaha. Previously, discharge from Lake Maitland was estimated using a theoretical weir-design rating. To provide more accurate discharge estimates, a continuous stage recorder was installed and periodic discharge measurements made so that a stage-discharge rating could be determined. From May 30, 1991, to August 20, 1992, 5 discharge measurements were made at site 17:

Date	Stage (ft)	Discharge (ft^3/s)
05/30/91	66.54	45
06/17/91	66.20	8
07/15/91	67.00	95
08/06/91	66.40	26
08/20/92	66.76	58

Outflow rates calculated for water years 1990-92 were 20, 103, and 90 in., respectively. Daily discharge rates from Lake Maitland are shown in figure 9.

Ground-Water Outflow

Water also leaves the Winter Park lakes by outflow to the ground-water system. Although some of the ground-water outflow occurs as lateral flow to the surficial aquifer system, most of the ground-water outflow occurs as downward leakage through the surficial and Miocene sediments to the underlying Upper Floridan aquifer (fig. 10).

The rate of downward leakage depends on the vertical hydraulic gradient (the head difference between the surficial and Upper Floridan aquifers per foot of sediments separating the two aquifers) and the hydraulic conductivity of those sediments. The leakage rate can be calculated directly using Darcy’s equation or it can be estimated from the recession of the lake-stage hydrograph. Leakage rates calculated using either method can then be compared to rates used in ground-water flow models. The rate of downward leakage was assumed to be constant throughout the year because both the lake level and the potentiometric surface respond similarly during the wet and dry seasons and the head difference remains relatively constant. Continuous stage measurements of Lake Virginia from October 1, 1989, to September 30, 1992, show that the lake stage fluctuated slightly more than 4 ft (between 62.65 and 66.93 ft above sea level). During the same period, the potentiometric surface of the Upper Floridan aquifer fluctuated in a range of about 5 ft (from about 49 to 55 ft above sea level). The highest lake and potentiometric-surface levels usually occur at the end of the summer rainy season (August or September) and the lowest levels at the end of the winter dry season (May). Some lag can occur between changes in either the lake or potentiometric levels. The head difference between the lake and the Upper Floridan ranged from about 17 to 22 ft during 1990-92.

It is assumed that there is negligible lateral inflow of surficial ground water to the lakes during dry periods so the change in lake stage during those times depends almost totally on loss of water to evaporation and to downward leakage. This assumption is based on the fact that the stage of Lake Virginia stops rising within 24 hours after a rainfall event. Additionally, the horizontal hydraulic gradient toward the lake is very low. During several short dry periods in 1991, the daily stage drop, minus the correction for evaporation, equalled about 0.09 in/d or about 33 in/yr of downward leakage. The rate of downward leakage from the lakes estimated from lake hydrographs is consistent with downward leakage rates from detailed ground-water flow models of the area (L.C. Murray, U.S. Geological Survey, oral commun., 1993).

The possible vertical leakage rates computed using Darcy’s equation can have a wide range of values because of the possible range of the estimated hydraulic conductivity and thickness of sediments separating the lake bottoms from the Upper Floridan aquifer. The sediment thickness can be estimated from the geophysical logs of nearby wells and probably ranges from about 75-150 ft. Because the surface of the Upper Floridan has been eroded, the altitude of the surface can vary widely, as shown schematically in figure 10. Using a head difference of 15 ft and an estimated sediment thickness of 100 ft, the gradient is 0.15. For a thickness of 150 ft, the vertical hydraulic gradient is 0.10; and if the thickness is 50 ft, the gradient is 0.3.

Estimates of the vertical hydraulic conductivity of the sediments also can vary greatly. At Lake Lucerne in Polk Country, Florida, the vertical hydraulic conductivity calculated for sediments underlying the lake was 0.09 ft/d plus or minus 0.08 (T. Lee, U.S. Geological Survey, written commun., 1993). Hydraulic conductivity estimates for the Winter Park area from regional computer modeling range from 0.01 to 0.03 ft/d with a confining-bed thickness of 100 ft (Tibbals, 1990, fig. 30). Downward leakage rates calculated using various combinations of these estimates of vertical hydraulic conductivity and sediment thickness range from 5 to more than 300 in/yr. Assuming a vertical head difference of about 15 ft, a sediment thickness of about 100 ft (resulting in a vertical gradient of 0.15) and a vertical hydraulic conductivity of 0.05 ft/d, the calculated leakage rate (about 33 in/yr) is consistent with the rate estimated from the hydrograph recession and with ground-water flow-modeling studies. Because the head difference, and thus the vertical hydraulic gradient, remained relatively constant, ground-water outflow was kept constant for the 3 water years while other components were adjusted slightly. For example, slight adjustments were made in the evaporation rate to balance the flow budgets.

Budget Summary

Annual flow budgets for the Winter Park chain of lakes were estimated for water years 1990-92 using the information described in the previous sections (table 5). Rainfall and surface inflow and outflow measured at the lakes are considered to be reliable. The calculated values of runoff and evaporation are estimated with less certainty. The most difficult components to estimate, and the least reliable, are the rates of ground-water inflow and outflow. In water year 1990 (a dryer than average year), the ground-water inflow rate, calculated as the residual of the flow budget, was zero, which seems unlikely. Probably the actual evaporation rate was higher than estimated from pan evaporation for that year.

Based on the mean values from water years 1990-92, about 31 percent of the inflow to the Winter Park Lakes comes from rainfall, about 11 percent from stormflow, 42 percent from inflow through surface streams, and 16 percent from ground-water inflow. Evaporation accounts for about 32 percent of the outflow, ground water for about 21 percent, and outflow to surface streams about 46 percent. On average, there is no change in lake storage. The relative contributions by the flow budget components are shown in figure 12. Using the 1992 total inflow rate for the lakes, 170 in/yr (table 5), and the total volume of the lakes (48.4×10^7 ft^3, table 1), the average residence time for the lakes is about 310 days.

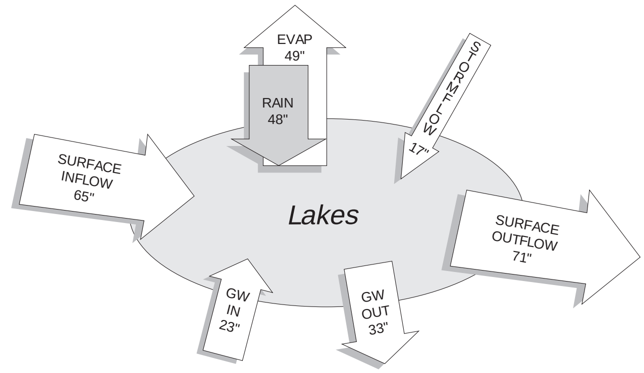

Figure 12. Mean flow-budget components.

WATER QUALITY

Water-quality data, as well as flow data, are needed to calculate constituent budgets for the chain of lakes. Data from previous studies were examined and bimonthly samples were collected at sites in the lakes and at inflow sites for 3 years. Samples also were collected at different depths in the lakes in April and June 1992. Samples of surficial ground water were collected once and existing chemical data for precipitation were compiled. Water samples were collected using standard U.S. Geological Survey techniques described by Wood (1976) and Fishman and Friedman (1989).

Water samples from the Winter Park chain of lakes have been collected by the Orange County Environmental Protection Department and by personnel from Rollins College. Those sampling efforts were systematic and continued for time periods ranging from 4 to more than 20 years. Additionally, a few samples have been collected as part of other studies of the lakes made by consultants to the city of Winter Park.

The Orange County Environmental Protection Department has sampled numerous lakes on a quarterly

Table 5. Estimated flow budgets for the Winter Park chain of lakes, water years 1990-92

[All measurements are in inches]

Inflow	1990	1991	1992	Mean	Outflow	1990	1991	1992	Mean
Rainfall	38	58	48	48	Evaporation	51	48	47	49
Stormflow	4	32	15	17	Surface outflow	20	103	90	71
Surface inflow	56	73	67	65	Estimated ground-water outflow	33	33	33	33
Estimated ground-water inflow	0	28	40	23	Lake storage change	-6	7	0	0
Total	98	**191**	**170**	**153**	**Total**	**98**	**191**	**170**	**153**

basis since 1972. Samples are collected at the midpoints of each lake and usually at the surface, although occasional surface, mid-depth, and near-bottom samples are collected. The samples are analyzed for major ions, nutrients, metals, bacteria, chlorophyll, and plankton. The four lakes of the Winter Park chain are included in the county sampling network, but no analyses of the county data have been published.

The Biology Department of Rollins College began the first of several ecological studies of the Winter Park chain of lakes in 1976. The most comprehensive of these was made in cooperation with the city of Winter Park from 1984-88. Monthly samples of near-surface and near-bottom water were collected at random locations in each lake beginning in October 1984. Sampling of Lakes Osceola and Maitland was discontinued after 2 years; sampling of Lakes Virginia and Mizell continued until June 1988. Field measurements of dissolved oxygen, temperature, specific conductance, and transparency (Secchi disk) were made. The samples were analyzed for pH, specific conductance, total Kjeldahl nitrogen (TKN, ammonia-plus-organic nitrogen), nitrate nitrogen, total phosphorus, orthophosphate, and alkalinity. In addition to water-quality sampling, the Rollins College study included sampling for bacteria, phytoplankton, zooplankton, benthic fauna, and fish species.

The data collected for Lakes Virginia and Mizell in the Rollins College study are summarized by Small, Richard, and Gregory (1988, p. 6-9 and table 4). They concluded that the water quality of Lakes Virginia and Mizell was similar. However, specific conductance was higher in Lake Mizell than in Lake Virginia; the mean of near-surface specific conductance in Lake Virginia for water years 1985-87 ranged from 181 to 209 μS/cm, compared to 251 to 267 μS/cm in Lake Mizell. They also noted seasonal changes in such constituents as dissolved oxygen, pH and specific conductance, and most nutrient concentrations in both lakes.

The chlorophyll-*a* and Secchi-disk transparency data also were used to calculate Carlson indices, a measure of a lake's trophic state (Carlson, 1977). Small and his colleagues (1988) concluded that the Carlson indices calculated for Lakes Virginia and Mizell indicate that the lakes are in the early stages of eutrophication.

Precipitation

Samples of rainfall have been collected and analyzed by the U.S. Geological Survey at several sites in Florida (Irwin and Kirkland, 1980). German (1983) analyzed samples of rainfall at Lake Hope in Maitland, Florida (fig. 1). No new analyses were made during this study.

The bulk precipitation sampled at Lake Hope (German, 1983) had a range of specific conductance from 13 to 58 μS/cm with a mean of 23 μS/cm. The pH of the samples ranged from 5.0 to 7.5 and chloride concentrations ranged from 0.6 to 2.7 mg/L, with a mean of 1.6 mg/L. Total nitrogen ranged from 0.19 to 6.8 mg/L, with a mean of 1.6 mg/L, and total phosphorus ranged from 0.01 to 0.89 mg/L, with mean of 0.18 mg/L. Total organic carbon (TOC) ranged from 1.0 to 20 mg/L, with a mean of 4.0 mg/L. The samples collected at Lake Hope were composites collected over 3-mo periods. Because of uncertainties about the preservation of nutrient samples during the composite sampling periods, atmospheric deposition rates for Florida lakes given by Baker and others (1981) were used for nitrogen and phosphorus, rather than analyses of precipitation samples.

Surface Inflow and Lakes

The U.S. Geological Survey collected water samples bimonthly at 14 sites in the chain of lakes (fig. 6 and table 3) from October 1989 to June 1992. Surface-water discharge into or out of the lakes was sampled at five of the sites. The other sampling sites were distributed within the lakes. Field measurements of dissolved oxygen were made 1 ft below the water surface at each site. A depth-integrated sample was collected and field determinations were made of pH, specific conductance, and temperature. The samples were analyzed in the laboratory for major ions, nutrients, organic carbon, color, turbidity, alkalinity, and chlorophyll-*a* and -*b*. A series of samples also was collected from different depths in the lakes. In April 1992 samples from Lakes Virginia, Mizell, and Osceola were analyzed for the same constituents listed above. Samples collected in June 1992 in Lakes Virginia, Mizell, and Maitland were analyzed for pH, specific conductance, dissolved oxygen, and nutrients. All of the water-quality data collected during this study are listed in the appendix. A statistical summary of data for all surface-inflow and lake sites is shown in table 6. In the following discussion, the lake sites are emphasized. Data for the inflow, outflow, and lake sites (appendix and table 6) were used to calculate the constituent budgets.

Table 6. Statistical summary of selected water-quality data for the Winter Park chain of lakes, 1989-92

[Concentrations are in milligrams per liter unless otherwise noted. Nitrogen species are reported as nitrogen (N); phosphorus species are reported as phosphorus (P). °C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; <, less than; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Water-quality constituent	Site name and identification number											
	Lake Sue outlet at Winter Park 02234263				Park Lake outlet 02234287				Lake Minnehaha outlet 02234299			
	Sample size	Maxi-mum	Mini-mum	Median	Sample size	Maxi-mum	Mini-mum	Median	Sample size	Maxi-mum	Mini-mum	Median
Water temperature (°C)	17	31.0	13.5	24.5	15	31.0	13.5	27.0	15	30.5	14.5	23.5
Turbidity (NTU)	17	10.0	.17	.83	15	2.4	.15	.72	15	7.4	.18	1.5
Color (Pt-Co Units)	17	25	<5	10.0[a]	15	30	5	10.0	15	30	<5	10.0[a]
Specific conductance (µS/cm)	17	294	184	204	15	385	196	225	15	214	171	195
Oxygen, dissolved (mg/L)	14	11	3.6	5.5	12	9.4	3.8	6.8	13	8.7	4.2	6.4
pH, Wh, field (SU)	17	8.0	6.8	7.4	15	8.5	6.9	7.4	15	8.0	7.2	7.5
Nitrogen, nitrite	17	.03	<.01	.01[a]	15	.04	<.01	.01[a]	15	--	--	--
Nitrogen, ammonia + organic	17	1.5	.48	.78	15	2.1	.59	.76	15	1.8	.56	.92
$NO_2 + NO_3$, total	17	.19	.04	.13	15	.60	<.02	.08[a]	15	.37	<.02	.02[a]
Phosphorus, total	17	.09	<.01	.06[a]	15	.16	.04	.06	15	.10	<.01	.04[a]
Carbon, organic, total	17	6.6	3.3	4.9	15	8.5	4.0	6.0	15	7.1	2.3	5.7
Calcium, dissolved	17	38	22	23	15	44	26	31	15	24	18	21
Magnesium, dissolved	17	7.5	3.1	4.0	15	6.3	3.1	3.5	15	4.2	2.6	3.0
Sodium, dissolved	17	11	7.8	9.8	15	18	7.1	8.0	15	12	8.0	9.4
Potassium, dissolved	17	2.7	1.7	2.2	15	4.3	2.0	2.7	15	3.7	2.3	3.0
Chloride, dissolved	17	19	14	16	15	36	12	13	15	23	16	19
Sulfate, dissolved	17	15	12	14	15	25	12	13	15	20	11	14
Fluoride, dissolved	2	.10	.10	--	2	.10	.10	--	2	.10	.10	--
Boron, total (µg/L)	2	40	30	--	2	50	40	--	2	50	30	--
Molybdenum total (µg/L)	2	2.0	1.0	--	2	2.0	1.0	--	2	--	--	--
Phosphorus, ortho, total	17	.07	<.01	.02[a]	15	.08	<.01	.03[a]	15	.03	<.01	.01[a]
Alkalinity (mg/L as $CaCO_3$)	17	11	50	57	15	103	64	79	15	52	39	45

Table 6. Statistical summary of selected water-quality data for the Winter Park chain of lakes, 1989-92--Continued

[Concentrations are in milligrams per liter unless otherwise noted. Nitrogen species are reported as nitrogen (N); phosphorus species are reported as phosphorus (P). °C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; <, less than; µS/cm, microsiemens per centimeter at 25 °C ; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Water-quality constituent	Site name and identification number							
	Lake Maitland outflow 283727081203501				Lake Sue outflow canal at Lake Sue 283452081212401			
	Sample size	Maxi-mum	Mini-mum	Median	Sample size	Maxi-mum	Mini-mum	Median
Water temperature (°C)	9	30.5	13.0	27.5	14	33.0	17.0	26.0
Turbidity (NTU)	9	3.0	.56	1.7	14	4.2	--	.86[a]
Color (Pt-Co Units)	9	30	5.0	20	14	15	<5	10.0[a]
Specific conductance (µS/cm)	9	300	192	203	14	210	167	185
Oxygen, dissolved (mg/L)	8	8.1	5	6.0	12	9.5	5.4	7.9
pH, Wh, field (SU)	9	9.0	7.3	7.6	14	9.1	7.3	8.3
Nitrogen, ammonia	9	.40	<.01	.02[a]	14	.09	<.01	.04[a]
Nitrogen, nitrite	9	.16	<.01	.01[a]	14	.01	<.01	.01[a]
Nitrogen, ammonia + organic	9	1.7	.61	.95	14	1.8	.52	.86
NO_2 + NO_3, total	9	.44	<.02	.02[a]	14	.09	<.02	.02[a]
Phosphorus, total	9	.14	<.01	.04[a]	14	.05	<.01	.04[a]
Carbon, organic, total	9	9.2	4.6	6.1	14	6.4	3.7	5.3
Calcium, dissolved	9	40	21	22	14	24	18	21
Magnesium, dissolved	9	4.7	3.0	4.0	14	3.6	2.7	3.2
Sodium, dissolved	9	11	7.8	9.3	14	12	8.2	10.0
Potassium, dissolved	9	4.0	2.2	2.9	14	2.8	1.9	2.5
Chloride, dissolved	9	21	14	18	14	19	14	18
Sulfate, dissolved	9	20	9.3	15	14	17	13	14
Fluoride, dissolved	2	.10	.10	--	2	.10	10.0	--
Boron, total (µg/L)	2	40	40	--	2	50	40	--
Molybdenum, total (µg/L)	2	--	--	--	2	--	--	--
Phosphorus, ortho, total	9	.08	<.01	.02[a]	14	.03	<.01	.10[a]
Alkalinity (mg/L as $CaCo_3$)	9	105	47	50	14	56	42	49

Table 6. Statistical summary of selected water-quality data for the Winter Park chain of lakes, 1989-92--Continued

[Concentrations are in milligrams per liter unless otherwise noted. Nitrogen species are reported as nitrogen (N); phosphorus species are reported as phosphorus (P). °C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; <, less than; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Water-quality constituent	Site name and identification number											
	Lake Virginia 283517081204001				Lake Virginia West 283518081210201				Lake Mizell 283534081201801			
	Sample size	Maxi-mum	Mini-mum	Median	Sample size	Maxi-mum	Mini-mum	Median	Sample size	Maxi-mum	Mini-mum	Median
Water temperature (°C)	16	33.0	17.0	25.7	14	32.5	18.0	25.5	16	33.0	17.5	26.0
Turbidity (NTU)	16	4.4	.13	1.3	14	4.4	.15	1.3	16	3.5	.16	.89
Transparency (inches)	16	78	20	40	14	76	20	40	16	124	20	43
Color (Pt-Co Units)	16	20	<5	10.0[a]	14	20	<5	10.0[a]	16	20	<5	5.0[a]
Specific conductance (µS/cm)	16	231	191	202	14	231	192	204	15	260	229	250
Oxygen, dissolved (mg/L)	14	10.0	6.7	8.9	13	10.0	6.4	9.0	14	10.0	6.3	8.9
pH, Wh, field (SU)	16	9.1	7.6	8.2	14	9.1	7.7	8.3	16	9.4	7.6	8.3
Nitrogen, ammonia	16	.07	<.01	.01[a]	14	.08	<.01	.01[a]	16	.06	<.01	.01[a]
Nitrogen, nitrite	16	--	<.01	--	14	--	<.01	--	16	--	<.01	--
Nitrogen, ammonia + organic	16	1.7	.52	.82	14	1.6	.57	.79	16	1.7	.53	.84
$NO_2 + NO_3$, total	16	--	<.02	--	14	--	<.02	--	16	--	<.02	--
Phosphorus, total	16	.05	<.01	.03[a]	14	.05	<.01	.03[a]	16	.05	<.01	.02[a]
Carbon, organic, total	16	6.6	3.5	5.0	14	6.5	3.7	5.0	16	7.5	4.0	5.6
Calcium, dissolved	16	27	21	23	14	27	21	23	16	24	21	23
Magnesium, dissolved	16	4.7	3.6	4.0	14	4.7	3.5	4.0	16	7.2	5.8	6.6
Sodium, dissolved	16	11	8.6	9.9	14	11	9.0	10	16	11	8.3	9.5
Potassium, dissolved	16	3.0	2.2	2.6	14	2.9	2.1	2.6	16	9.5	7.4	8.4
Chloride, dissolved	16	19	15	17	14	19	16	18	16	25	21	23
Sulfate, dissolved	16	17	14	15	14	18	15	16	16	36	28	31
Fluoride, dissolved	2	.10	.10	--	2	.10	.10	--	2	.10	.10	--
Boron, total (µg/L)	2	50	30	--	2	40	40	--	2	70	50	--
Molybdenum, total (µg/L	2	2.0	2.0	--	2	2.0	2.0	--	2	--	--	--
Phosphorus, ortho, total	16	.02	<.01	.01[a]	14	.02	<.01	.01[a]	16	.03	<.01	.02[a]
Chlorophyll-*a* phytoplankton (µg/L)	15	32	4.3	14	13	28	5.6	15	15	26	1.0	10.0
Chlorophyll-*b* phytoplankton (µg/L)	15	1.7	--	.60[a]	13	2.0	--	.50[a]	15	1.0	--	.37[a]
Alkalinity (mg/L as $CaCO_3$)	16	66	50	54	14	66	52	56	16	50	42	47

Table 6. Statistical summary of selected water-quality data for the Winter Park chain of lakes, 1989-92--Continued

[Concentrations are in milligrams per liter unless otherwise noted. Nitrogen species are reported as nitrogen (N); phosphorus species are reported as phosphorus (P).

°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; <. less than; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Water-quality constituent	Site name and identification number											
	Lake Mizell North 283545081201901				Lake Osceola South 283556081204101				Lake Osceola North 283615081202801			
	Sample size	Maxi-mum	Mini-mum	Median	Sample size	Maxi-mum	Mini-mum	Median	Sample size	Maxi-mum	Mini-mum	Median
Water temperature (°C)	15	32.5	18.0	25.5	16	32.0	17.5	25.5	16	32.0	17.5	25.5
Turbidity (NTU)	14	3.9	.24	.80	16	2.3	.27	1.0	16	3.7	.28	1.0
Transparency (inches)	14	98	18	44	16	62	19	39	16	57	20	38
Color (Pt-Co Units)	14	20	<5	7.5[a]	16	20	<5	5.0[a]	16	20	<5	7.5[a]
Specific conductance (µS/cm)	15	259	226	250	16	233	194	208	16	230	195	208
Oxygen, dissolved (mg/L)	14	10.0	5.9	9.2	14	11	6.1	9.0	14	10.0	6.0	9.2
Ph, Wh, field (SU)	15	9.4	7.5	8	16	9.2	7.5	8.2	16	9.2	7.0	8.2
Nitrogen, ammonia	14	.22	<.01	.01[a]	16	.30	<.01	.01[a]	16	.12	<.01	.01[a]
Nitrogen, nitrite	14	--	<.01	--	16	--	-<.01	--	16	--	<.01	--
Nitrogen, ammonia + organic	14	1.7	.51	.99	16	1.7	.70	.90	16	1.6	.73	.91
NO_2 + NO_3, total	14	--	<.02	--	16	--	<.02	--	16	--	<.02	--
Phosphorus, total	14	.06	<.01	.03[a]	16	.16	<.01	.03[a]	16	.05	<.01	.03[a]
Carbon, organic, total	14	7.9	3.1	5.6	16	6.8	1.4	5.2	16	8.1	4.0	5.1
Calcium, dissolved	14	23	21	23	16	27	21	24	16	26	22	23
Magnesium, dissolved	14	7.0	5.8	6.4	16	4.7	3.8	4.2	16	4.6	3.8	4.2
Sodium, dissolved	14	11	8.8	9.6	16	11	8.5	9.7	16	11	8.6	10.0
Potassium, dissolved	14	9.3	7.4	8.2	16	2.9	2.2	2.6	16	3.0	2.2	2.7
Chloride, dissolved	14	25	21	24	16	19	16	18	16	20	17	18
Sulfate, dissolved	14	36	27	30	16	19	15	16	16	20	15	17
Fluoride, dissolved	2	0.10	0.10	--	2	0.10	0.10	--	2	0.10	0.10	--
Boron, total (µg/L)	2	70	50	--	2	50	30	--	2	50	30	--
Molybdenum, total (µg/ L)	2	--	--	--	2	3.0	2.0	--	2	3.0	3.0	--
Phosphorus, ortho, total	14	.03	<.01	.01[a]	16	.03	<.01	.01[a]	16	.03	<.01	.01[a]
Chlorophyll-*a* phytoplankton (µg/L	13	31	3.5	9.6	15	36	5.6	17	15	28	5.4	18
Chlorophyll-*b* phytoplankton (µg/L)	3	1.4	<.1	.30[a]	15	1.2	<.1	.80[a]	15	1.1	<.1	.36[a]
Alkalinity (mg/L as $CaCO_3$)	14	50	41	46	16	81	52	57	16	61	50	55

Table 6. Statistical summary of selected water-quality data for the Winter Park chain of lakes, 1989-92 --Continued

[Concentrations are in milligrams per liter unless otherwise noted. Nitrogen species are reported as nitrogen (N); phosphorus species are reported as phosphorus (P). °C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; <, less than; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Water-quality constituent	Site name and identification number											
	Lake Maitland South 283644081204901				Lake Maitland West 283708081214201				Lake Maitland North 283709081210401			
	Sample size	Maxi-mum	Mini-mum	Median	Sample size	Maxi-mum	Mini-mum	Median	Sample size	Maxi-mum	Mini-mum	Median
Water temperature (°C)	16	31.5	17.0	25.5	14	31.0	17.5	25.5	16	31.5	17.0	25.2
Turbidity (NTU)	16	3.9	.17	1.0	14	4.1	.19	1.4	16	4.4	.18	1.5
Transparency (inches)	16	68	27	43	14	65	28	41	16	70	28	39
Color (Pt-Co Units)	16	20	<5	5.0[a]	14	20	<5	10[a]	16	20	<5	7.5[a]
Specific conductance (µS/cm)	16	228	195	208	14	230	190	206	16	230	190	206
Oxygen, dissolved (mg/L)	14	9.6	6.1	8.5	13	10.0	6.6	7.9	14	9.5	6.5	8.4
Ph, Wh, field (SU)	16	8.8	7.3	8.0	14	9.1	7.6	8.1	16	8.5	7.8	8.1
Nitrogen, ammonia	16	.13	<.01	.01[a]	14	.05	<.01	.01[a]	16	.02	<.01	.01[a]
Nitrogen, nitrite	16	--	<.01	--	14	--	<.01	--	16	--	<.01	--
Nitrogen, ammonia + organic	16	1.4	.47	.80	14	1.6	.63	.82	16	1.2	.62	.91
NO_2 + NO_3, total	16	--	<.02	--	14	--	<.02	--	16	--	<.02	--
Phosphorus, total	16	.06	<.01	.03[a]	14	.06	<.01	.04[a]	16	.20	<.01	.04[a]
Carbon, organic, total	16	6.6	1.2	5.2	14	6.5	4.3	5.5	16	6.9	2.0	5.6
Calcium, dissolved	16	25	22	23	14	25	21	22	16	25	21	22
Magnesium, dissolved	16	4.4	3.8	4.1	14	4.4	3.6	4.0	16	4.5	3.6	4.0
Sodium, dissolved	16	11	8.7	10.0	14	11	8.8	10.0	16	11	8.8	9.9
Potassium, dissolved	16	3.4	2.2	2.9	14	4.8	2.2	3.0	16	3.4	2.2	2.9
Chloride, dissolved	16	21	16	19	14	21	17	19	16	21	17	19
Sulfate, dissolved	16	20	16	18	14	21	15	18	16	20	15	17
Fluoride, dissolved	2	0.10	0.10	--	2	0.10	0.10	--	2	0.10	0.10	--
Boron, total (µg/L)	2	50	30	--	2	50	30	--	2	50	30	--
Molybdenum, total (µg/L)	2	2.0	2.0	--	2	2.0	2.0	--	2	2.0	2.0	--
Phosphorus, ortho, total	16	.03	<.01	.01[a]	14	.03	<.01	.01[a]	16	.03	<.01	.01[a]
Chlorophyll-*a* phytoplankton (µg/L)	15	26	5.0	12	13	19	5.8	12	15	26	7.6	12
Chlorophyll-*b* phytoplankton (µg/L)	15	1.2	<.1	.30[a]	13	.90	<.1	.30[a]	15	1.4	<.1	.30[a]
Alkalinity (mg/L as $CaCO_3$)	16	55	--	52[a]	14	54	48	51	16	54	48	50

[a]Value is estimated by using a log-probability regression to predict the values of data below the detection limit.
If the number of observations above the detection limit is less than 5, the estimated values are considered unreliable and are not reported.
If the number of observations is greater than 1 and less than or equal to 5, only the maximum and minimum are reported.
If the number of observations is equal to 1, only the maximum is reported.

Field Measurements

Properties of surface inflow and lake water measured in the field included dissolved oxygen, pH, temperature, specific conductance, and Secchi-disk depth. Those properties generally varied with lake stage and season, and, to some extent, from lake to lake. For the purpose of comparing the water quality characteristics of the lakes, the median concentrations for all sites in each lake on each sampling date was used. For example, the median of the three sites in Lake Maitland was compared with the medians of the two sites each in Lakes Mizell, Osceola and Virginia.

Specific conductance ranged from about 190 to about 230 μS/cm for Lakes Maitland, Osceola, and Virginia and from 226 to 260 μS/cm in Lake Mizell (fig. 13). The higher specific conductance in Lake Mizell is probably because it is isolated from

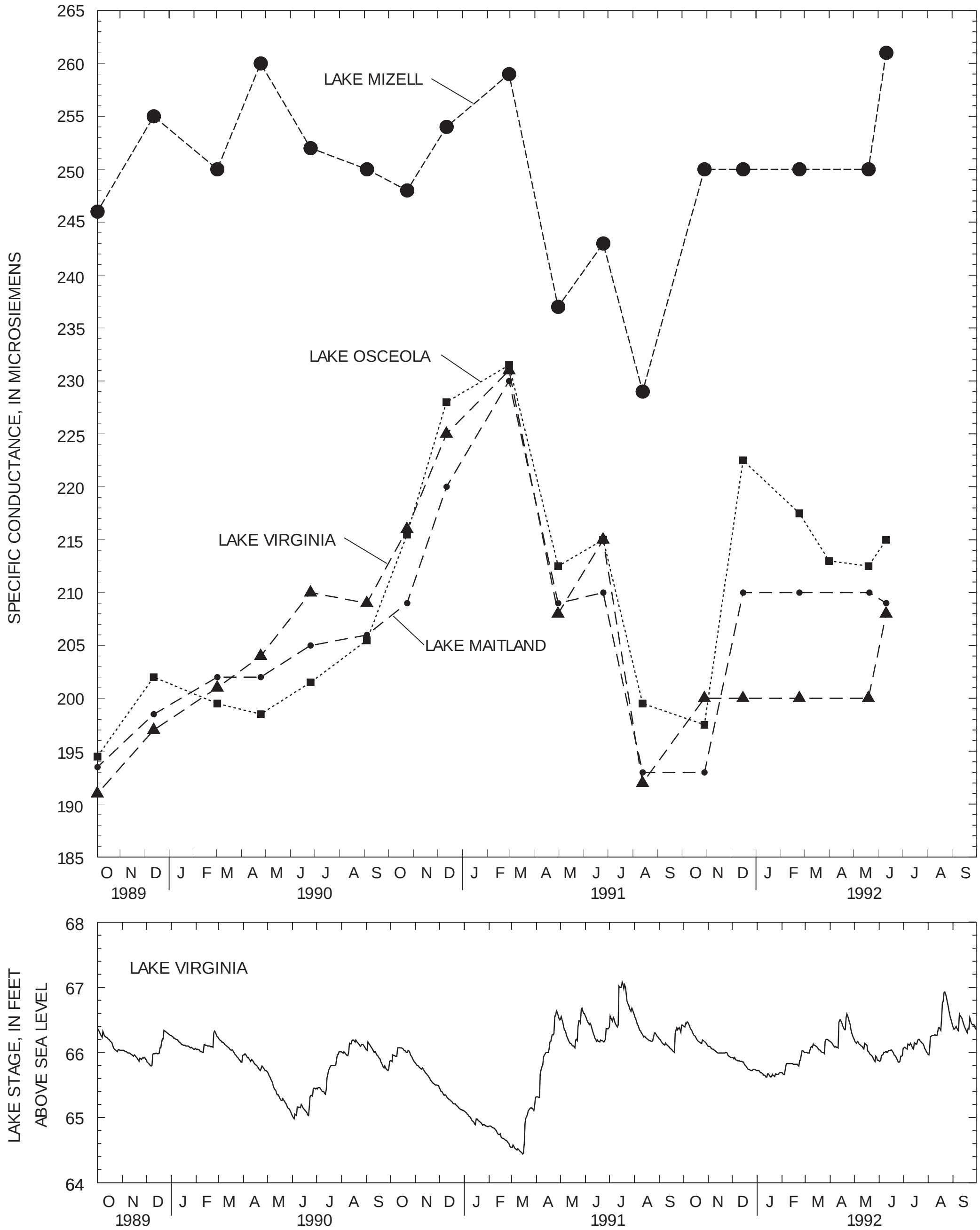

Figure 13. Median specific conductance of the Winter Park lakes and stage of Lake Virginia, 1989-92.

the surface-water flow system of the other 3 lakes. There is no surface inflow to Lake Mizell, only direct stormflow from land around the lake, stormflow from 9 storm drains, and ground-water inflow. The peak of specific conductance in all 4 lakes occurs at about the same time as the lowest lake stage measured during the study in March 1991. This probably is because during very dry weather there is little inflow of surface-water or stormflow, which generally have a lower specific conductance than ground water.

Secchi-disk depth, which is a measure of the transparency of the lake water, fluctuates seasonally, but does not seem to be related to fluctuations in lake stage (fig. 14). The highest Secchi-disk values (indicating the clearest water) generally occurred in February-March and might be related to the dying of algae in the winter.

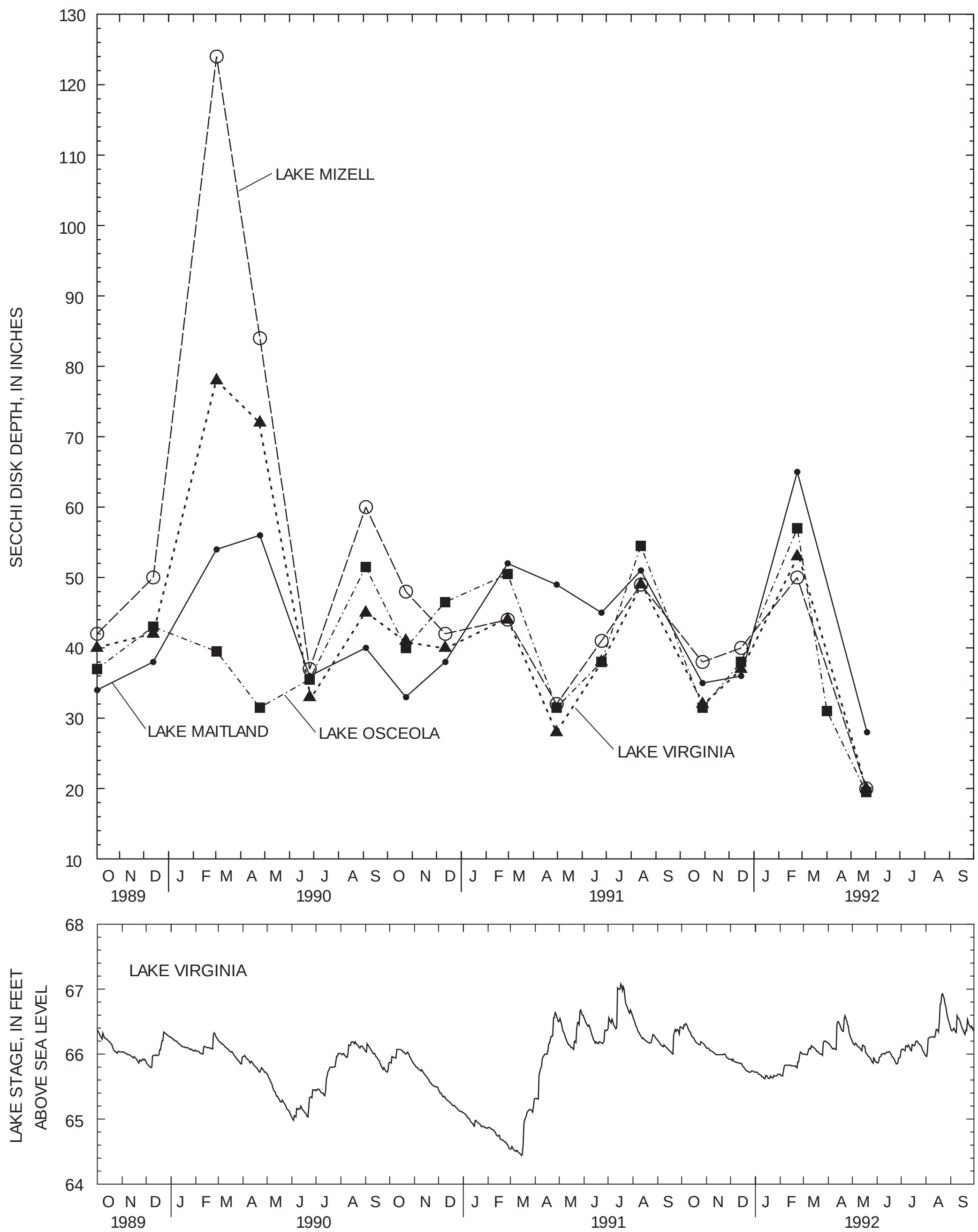

Figure 14. Median Secchi disk depth for the Winter Park lakes and stage of Lake Virginia, 1989-92.

Dissolved oxygen concentration also fluctuates seasonally and probably is related to productivity of algae. Generally, the lowest dissolved oxygen concentrations occur in the summer when water temperature is highest (figs. 15 and 16), although the amount of rainfall which affects lake flushing also can be important. For example, the relatively high dissolved oxygen concentrations in June 1991 could have been due to the large spring and early summer rainfall amounts. Because of the subtropical climate in central Florida and the relatively shallow lake depths, the lakes are not stratified and do not exhibit the spring and fall turnover (disappearance of thermal stratification) observed in lakes in temperate climates. Dissolved oxygen concentrations in the water of the Winter Park chain of lakes generally are higher than the 5 mg/L standard for the preservation of aquatic habitats in surface waters established by the Florida Department of Environmental Protection (1983).

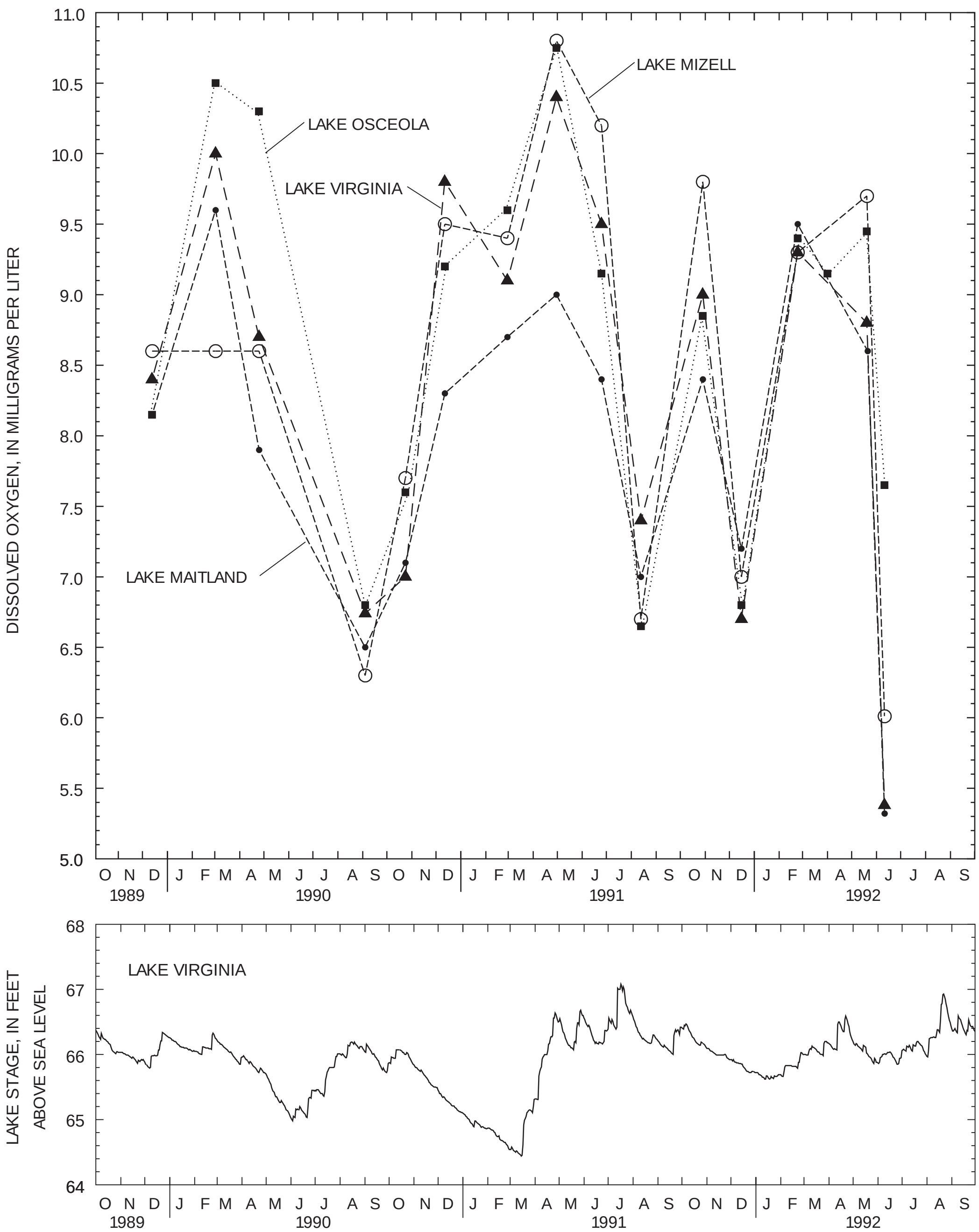

Figure 15. Median dissolved oxygen concentrations for the Winter Park lakes and stage of Lake Virginia, 1989-92.

Some comparisons between the characteristics of the largest lake (Maitland) and the smallest (Mizell) were also made (fig. 16). As mentioned previously, the specific conductance of water in Lake Mizell is generally higher than in Lake Maitland. The temperature of the two lakes is similar. Dissolved oxygen concentrations generally follow a similar trend, although from August 1990 to August 1991 dissolved oxygen was consistently higher in Lake Mizell than in Lake Maitland. During that time, chlorophyll-*a* concentrations in Mizell were lower than in Maitland, except for a peak in Mizell in late April 1991. Secchi-disk depths in both lakes were similar except for the unusually high value in Mizell in late February 1990.

Chemical and Biological Characteristics

The bimonthly sampling of surface inflow and lake sites also included analysis for major ions (calcium, sodium, magnesium, potassium, chloride,

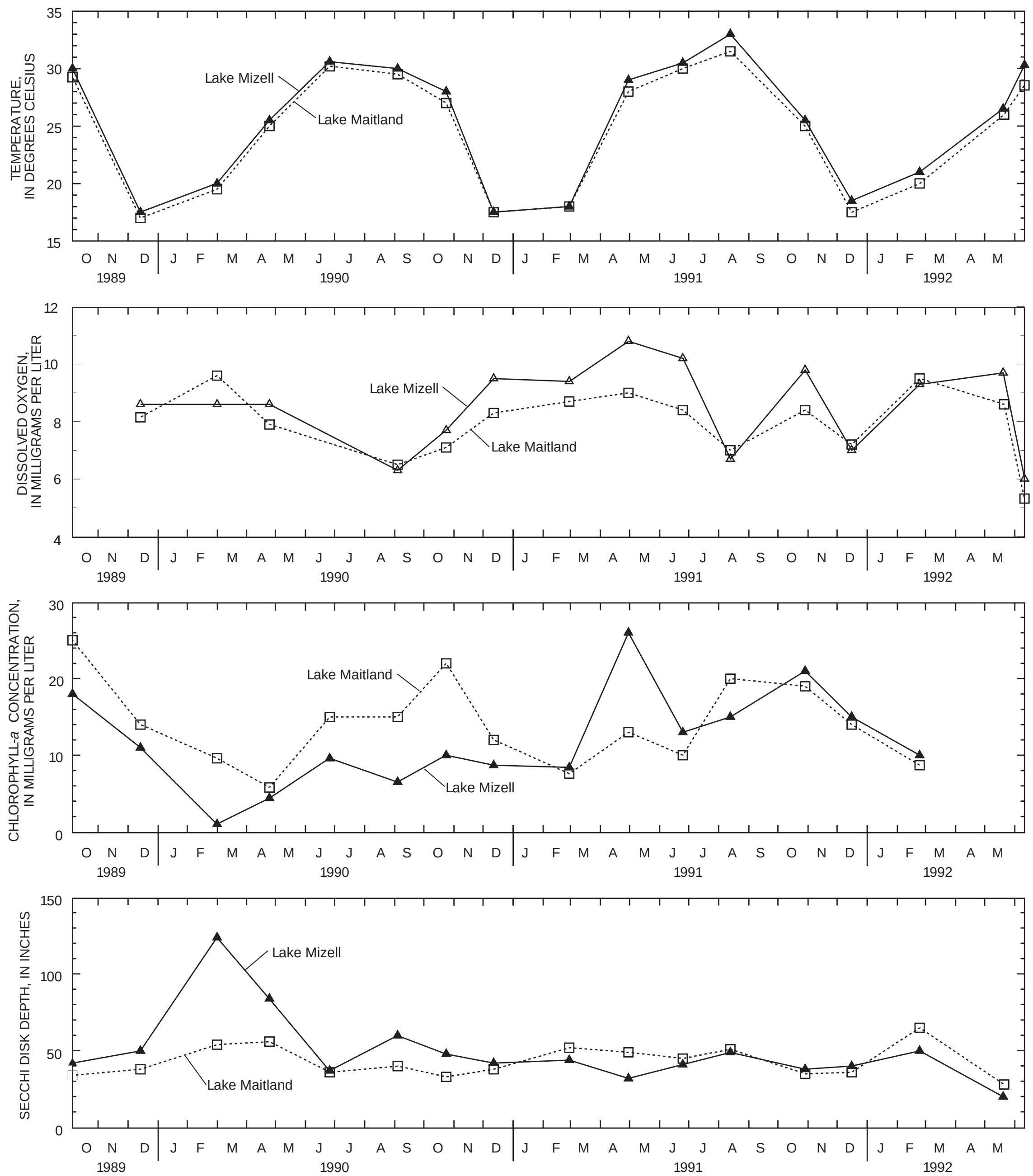

Figure 16. Temperature, Secchi disk depth, and dissolved oxygen and chlorophyll-*a* concentrations for Lakes Maitland and Mizell, 1989-92.

sulfate, and fluoride), nutrients (nitrogen and phosphorus), organic carbon, and chlorophyll-*a* and -*b*. Major ion concentrations were similar for all the lakes except for magnesium, potassium, and sulfate concentrations in Lake Mizell (table 6 and fig. 17). Those constituents were noticeably higher in Lake Mizell, which is consistent with the generally higher specific conductance in the lake. Although total nitrogen was about the same in Lake Mizell as in the other lakes, chlorophyll-*a* concentrations were somewhat lower and Secchi-disk transparency generally was higher than in the other lakes.

Concentrations of total ammonia-plus-organic nitrogen ranged from 0.470 to 1.7 mg/L, with median concentrations in all lakes ranging from 0.79 to 0.99 mg/L (table 6). Nitrate, nitrite, and ammonia concentrations were low (most were less than the laboratory detection limit), indicating that most of the nitrogen in the lakes is organic nitrogen. Median total phosphorus concentrations ranged from 0.02 to 0.20 mg/L. The fluctuation of median total Kjeldahl nitrogen and total phosphorus concentrations for all the sites in each lake and the stage of Lake Virginia are shown in figure 18. The nitrogen concentrations in all the lakes generally follow a similar trend with time, as do the phosphorus concentrations, but the trends of both nutrient concentrations in any particular lake usually are not the same. An exception is from March-August 1991 when nitrogen and phosphorus concentrations both increased in the early part of the summer, then decreased in August. No relation between nutrient concentrations and lake stage is apparent from the graphs.

Samples were collected at different depths in April and June 1992 to determine the variations of major ion and nutrient concentrations with depth. Water samples from the deepest levels had lower temperature and dissolved oxygen, and higher specific conductance and ammonia concentrations (tables 7 and 8). Total phosphorus concentrations were slightly higher in the water samples from deeper levels, but total orthophosphorus concentrations were about the same. In April dissolved oxygen concentrations near the lake bottoms ranged from 0.2 to 5.1 mg/L but in June, when the water was warmer, all bottom concentrations were 0.2 mg/L or less. Ammonia concentrations were higher in deeper water samples, especially in June, when ammonia concentrations exceeding 1 mg/L were found at several sites. The higher ammonia concentrations in deeper water samples probably are the result of the low dissolved oxygen concentrations in those samples.

Fluctuations in nutrient concentrations might be expected to influence the concentrations of phytoplankton (algae) in lakes. Chlorophyll-*a* is the primary photosynthetic pigment of all oxygen-producing green plants and is present in all algae (Greeson and others, 1977, p. 209). A measurement of chlorophyll-*a* concentration is therefore an indicator of the quantity of living microorganisms (biomass) in an aquatic environment, which can in turn be an indicator of water quality. Chlorophyll-*a* concentrations might be expected to fluctuate seasonally, but their variation seems to be more complex (fig. 19). For example, a peak of chlorophyll-*a* concentration occurred in Lake Osceola in March 1990, while levels in the other lakes were relatively low. High levels occurred in all the lakes during the summer of 1991, a year with higher than average rainfall. Chlorophyll-*a* seems to increase with temperature and increased lake levels, possibly associated with increased discharge and nutrient loading.

Time Trends

There has been concern that nutrient concentrations have been increasing in the Winter Park chain of lakes. To examine possible long-term trends, data were retrieved from the U. S. Environmental Protection Agency's (USEPA) STORET data base, which includes data collected by Orange County Environmental Control and the U. S. Geological Survey. Data collected by Rollins College from 1984-87 apparently were not included in STORET, so those data do not appear on the plots. The nitrogen and phosphorus data collected by Rollins College for Lake Virginia were compared to the data from STORET. Nitrogen data fit the plot of STORET data very well, but there is more scatter in the Rollins phosphorus data than in the STORET data. Plots of total nitrogen, total phosphorus and chlorophyll-*a* concentrations and Secchi-disk transparency are shown for each lake in figures 20a.-20d. There is some evidence for decreasing Secchi-disk transparency in Lakes Maitland and Virginia and increasing chlorophyll-*a* in Lake Maitland. In Lake Virginia, there are not as many early chlorophyll-*a* samples, so a trend is not apparent. Phosphorus and transparency had somewhat cyclic patterns but no apparent increasing trends. The nitrogen data were more ambiguous, possibly showing increasing trends in Lakes Virginia and Mizell.

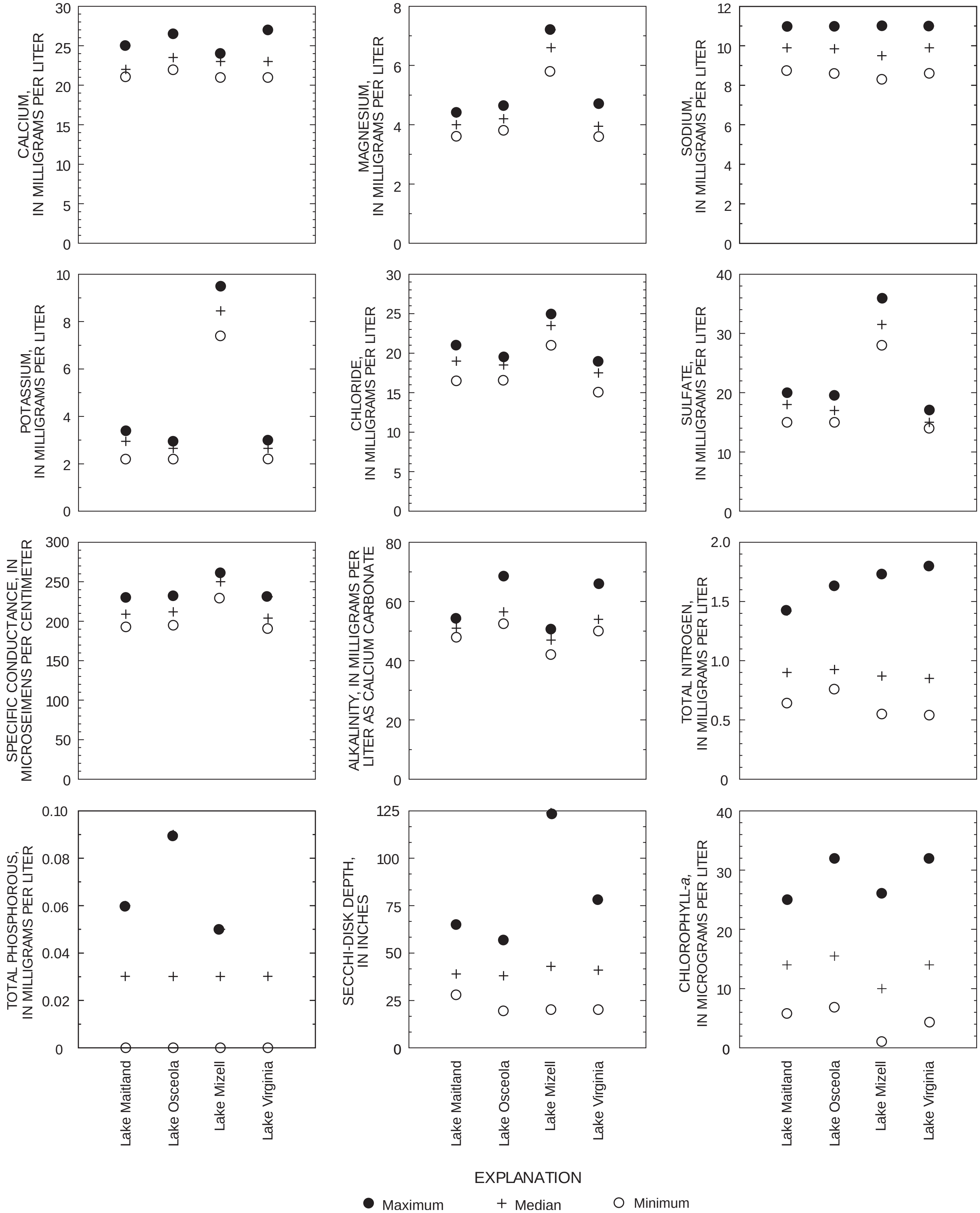

Figure 17. Range of medians of selected water-quality constituents for the Winter Park lakes (total phosphorus concentrations less than the detection limit of 0.01 mg/L are plotted as 0).

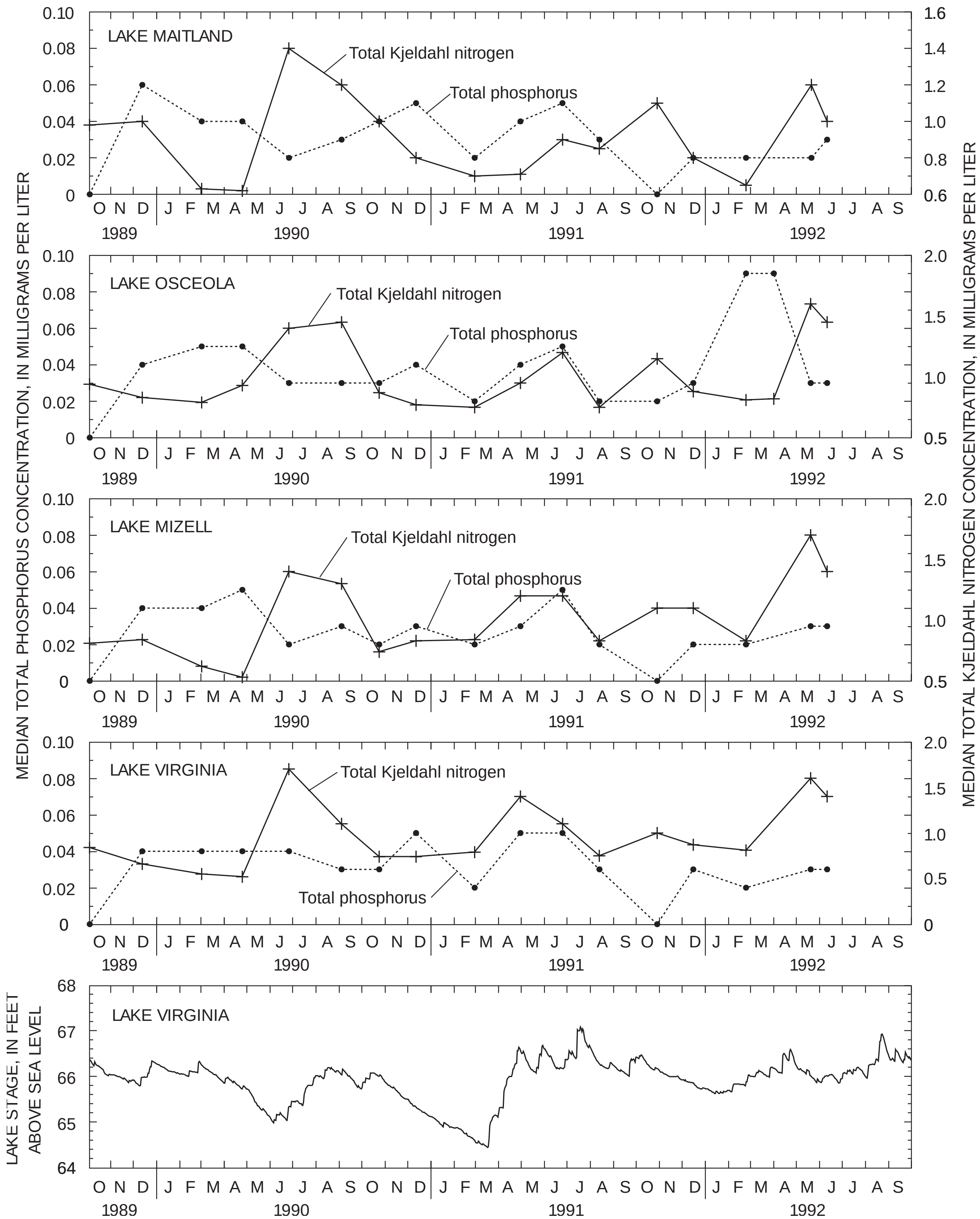

Figure 18. Median total phosphorus and total Kjeldahl nitrogen concentrations for the Winter Park lakes and stage of Lake Virginia, 1989-92 (total phosphorus concentrations less than the detection limit of 0.01 mg/L are plotted as 0).

Table 7. Water-quality variations with sampling depth in the Winter Park chain of lakes, April 1, 1992

[°C, degrees Celsius; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; <, less than; --, not determined]

Sampling depth (feet)	Temperature, water (°C)	Turbidity (NTU)	Color (platinum-cobalt units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH whole-water, field (standard units)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen NO_2 + NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L) as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Phosphorus, ortho total (mg/L as P)	Alkalinity lab (mg/L as $CaCO_3$)
Lake Virginia (site number 283513081203700)																					
1.7	22.5	1.4	10	202	10.8	9.1	.01	<.01	.95	<.02	.08	5.7	22	4.0	10.0	2.7	19	17	.10	.010	53
8.7	21	--	--	201	9.6	8.8	.01	<.01	.86	<.02	.08	4.6	--	--	--	--	--	--	--	.10	<.1
19.0	20.5	2.0	10	203	5.1	7.3	0.050	<0.010	0.91	<0.020	0.080	5.0	23	3.9	9.6	3.0	19	16	0.10	0.010	54
Lake Mizell North (site number 283545081201901)																					
1.0	23.0	2.0	10	249	10.0	8.7	.01	<.01	.78	<.02	.09	5.0	23	6.6	9.6	8.4	24	32	.10	.010	48
2.7	22.5	--	--	249	10.0	8.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4.9	22	--	--	248	10.1	8.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6.6	22	--	--	248	9.6	8.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8.8	21	--	10	246	8.2	7.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12.5	20.5	2.6	10	248	2.8	7.1	.01	<.01	.92	<.02	.09	4.9	23	6.6	9.6	8.4	23	31	.10	.020	49
Lake Osceola South (site number 283556081204101)																					
1.1	22.5	2.0	10	214	10.8	9.0	.01	.01	.80	<.02	.08	5.1	25	4.4	10.0	2.7	19	18	.10	.010	58
7.8	21.5	--	--	213	9.9	8.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10.1	20.5	--	--	213	8.7	8.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13	20	--	--	213	4.2	7.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	19.5	1.3	10	221	0.2	6.8	.09	<.01	.84	<.02	.09	4.1	24	4.4	10.0	2.7	19	18	.10	.010	58

Table 8. Water-quality variations with sampling depth in the Winter Park chain of lakes, June 11, 1992

[°C, degrees Celsius; µS/cm; microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; SU, Standard Units; <, less than]

Site identification number	Sampling depth (feet)	Tem-perature, water (°C)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, whole water, field (SU)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia+ organic, total (mg/L as N)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Phospho-rus, total (mg/L as P)	Phospho-rus, ortho total (mg/L as P)
Lake Virginia											
283517081204001	1.0	30.5	211	8.4	8.8	0.02	<0.01	1.4	0.02	0.03	0.04
	7.8	30.0	208	5.4	7.8	.02	<.01	1.4	<.02	.03	.05
	15.6	23.5	235	.1	7.5	.99	<.01	2.0	<.02	.03	.04
Lake Virginia West											
283518081210201	1.0	30.5	211	8.2	8.2	.02	<.01	1.3	<.02	.03	.04
	8.0	28.0	208	2.0	7.3	.02	<.01	1.3	<.02	.03	.04
	16.0	24.0	265	.1	7.4	1.1	<.01	2.6	<.02	.07	.03
Lake Mizell											
283534081201801	1.0	30.5	260	7.9	9.0	.02	<.01	1.4	<.02	.02	.04
	5.9	30.5	261	6.0	7.7	.01	<.01	1.4	<.02	.03	.04
	12.1	25.0	273	.2	7.2	.28	<.01	1.3	<.02	.05	.04
Lake Mizell North											
283545081201901	1.0	30.5	256	7.6	8.7	.01	<.01	1.5	<.02	.05	.04
	6.0	30.0	254	5.8	7.3	.01	<.01	1.5	<.02	.04	.04
	11.8	25.0	322	.6	7.2	1.3	<.01	4.0	<.02	.15	.03
Lake Osceola South											
283556081204101	1.0	30.0	215	7.6	6.9	.04	<.01	1.3	<.02	.03	.04
	11	25.5	225	.1	6.9	.21	<.01	1.5	<.02	.04	.05
	22.0	21.0	291	.1	7.1	2.5	<.01	4.0	<.02	.10	.02
Lake Osceola North											
283615081202801	1.0	30.5	215	7.7	7.4	.15	<.01	1.6	<.02	.03	.05
	9.9	26.5	207	.1	7.0	.02	<.01	1.4	<.02	.03	.05
	20.0	22.0	259	.1	6.6	2.3	<.01	3.3	<.02	.04	.03
Lake Maitland South											
283644081204901	1.0	30.5	216	8.5	9.2	.02	<.01	1.2	<.02	.03	.03
	10.3	27.0	210	1.4	7.2	.02	<.01	1.1	<.02	.05	.03
	20.6	23.0	285	.2	7.1	1.5	<.01	3.2	<.02	.22	.02
Lake Maitland West											
283708081214201	.9	30.5	209	8.2	8.9	.02	<.01	.97	<.02	.03	.03
	7.0	28.5	209	5.6	7.5	.02	<.01	1.0	<.02	.03	.03
	14.3	26.5	259	3.7	7.2	.19	<.01	1.1	<.02	.05	.04
Lake Maitland North											
283709081210401	1.0	31.0	208	8.8	9.2	.02	<.01	1.0	<.02	.03	.02
	9.1	29.0	209	5.3	8.2	.02	<.01	.96	<.02	.03	.03
	18.5	26.0	285	.1	7.2	.83	<.01	2.0	<.02	.08	.04

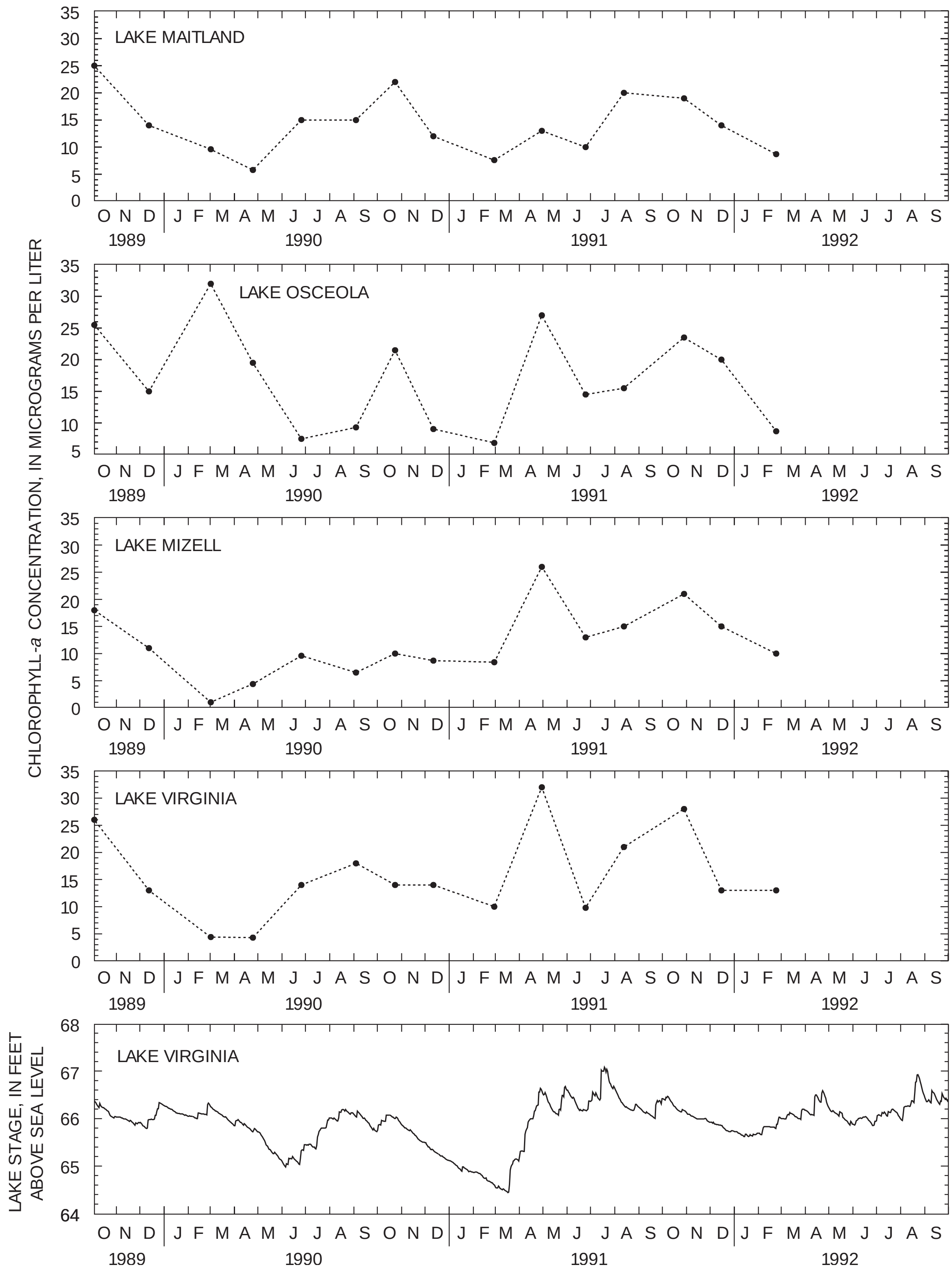

Figure 19. Median chlorophyll-*a* concentrations for the Winter Park lakes and stage of Lake Virginia, 1989-92.

The Florida Department of Environmental Protection assesses the quality of surface waters of the State at 2-year intervals. This assessment is submitted to the U.S. Environmental Protection Agency in accordance with the Federal Clean Water Act (Florida Department of Environmental Protection, 1994). The lakes are assessed using a trophic state index (TSI) that is based on the classification system developed by Carlson (1977). The TSI defines lake quality in terms of chlorophyll-*a*, total nitrogen, and total phosphorus concentrations, and Secchi-disk transparency. Lake-water quality is classified according to TSI values, with values in the range of 0 to 59 considered indicative of good water quality, 60 to 69 considered fair, and 70 or greater considered poor. Using median values for these measurements of water quality for the Winter Park lakes during the 3-year sampling period results in the TSI values listed below. All of the TSI values are indicative of good water quality, except for Secchi-disk transparency, which falls within the fair category.

	Chlorophyll-*a* (µg/L)	Secchi-disk transparency (in.)	Total nitrogen (mg/L)	Total phosphorus (mg/L)
Median value, all lakes	12	40	0.84	0.03
TSI	53	60	53	45

Correlation Analysis

A rank correlation analysis was done to determine the relation of lake water quality to short and long-term runoff. Rank correlation analysis uses the relative rank of the water-quality characteristic in relation to all samples, rather than the concentration or value. For example, the lowest value for each characteristic is assigned a rank of 1, and the highest value is replaced with the number of samples in the data set (17 for most water-quality characteristics). This use of ranks eliminates effects from the type of data distribution (normal or not normal). The correlation of water quality with the total rainfall for a period of 2 weeks before the sample date was selected as a measure of short-term runoff effects. The use of a 2-week period is arbitrary and other periods might show a different correlation to lake water quality. Lake stage was selected as an indicator of long-term runoff quantities because the total volume of water in the lakes is a function of runoff quantities for a relatively long (but unspecified) period of time.

Non-zero coefficients of correlation indicate that there is a relation between the parameters being compared. The probability that a coefficient of correlation was significantly different from zero was determined and the correlation was considered to be significant if there was less than a 5 percent chance that the coefficient of correlation could actually be zero (the coefficients were significant at the 5-percent level). A positive coefficient of correlation indicates a direct relation between the variables being tested; a negative coefficient indicates an inverse relation.

None of the water-quality characteristics were related to 2-week antecedent rainfall at a 5-percent significance level, indicating that short-term runoff does not significantly affect lake water quality. However, several characteristics, listed in the table below, were related to lake stage at a 5-percent significance level, indicating a correlation to long-term runoff. The coefficients of rank correlation are listed only if they are significant at the 5-percent level.

The rank-correlation analysis indicates that specific conductance and some major-dissolved constituent concentrations tend to be lower at higher lake stages (negative coefficient of rank correlation). This is an indication of the dilution effects caused by rainfall and storm runoff on lake water.

Lake	Water temperature	Specific conductance	pH	Calcium	Magnesium	Sodium	Potassium	Alkalinity	Chloride	Sulfate	Chlorophyll-*a*
	Coefficient of rank correlation with lake stage										
Virginia	0.55	--	--	--	--	--	-0.56	-0.55	-0.52	-0.71	--
Mizell	.50	-.74	--	-.69	--	-.65	--	--	--	--	0.53
Osceola	.50	-.55	--	--	-.57	-.62	-.53	--	--	-.62	.77
Maitland	--	-.54	.51	--	-.57	-.59	--	--	--	--	--

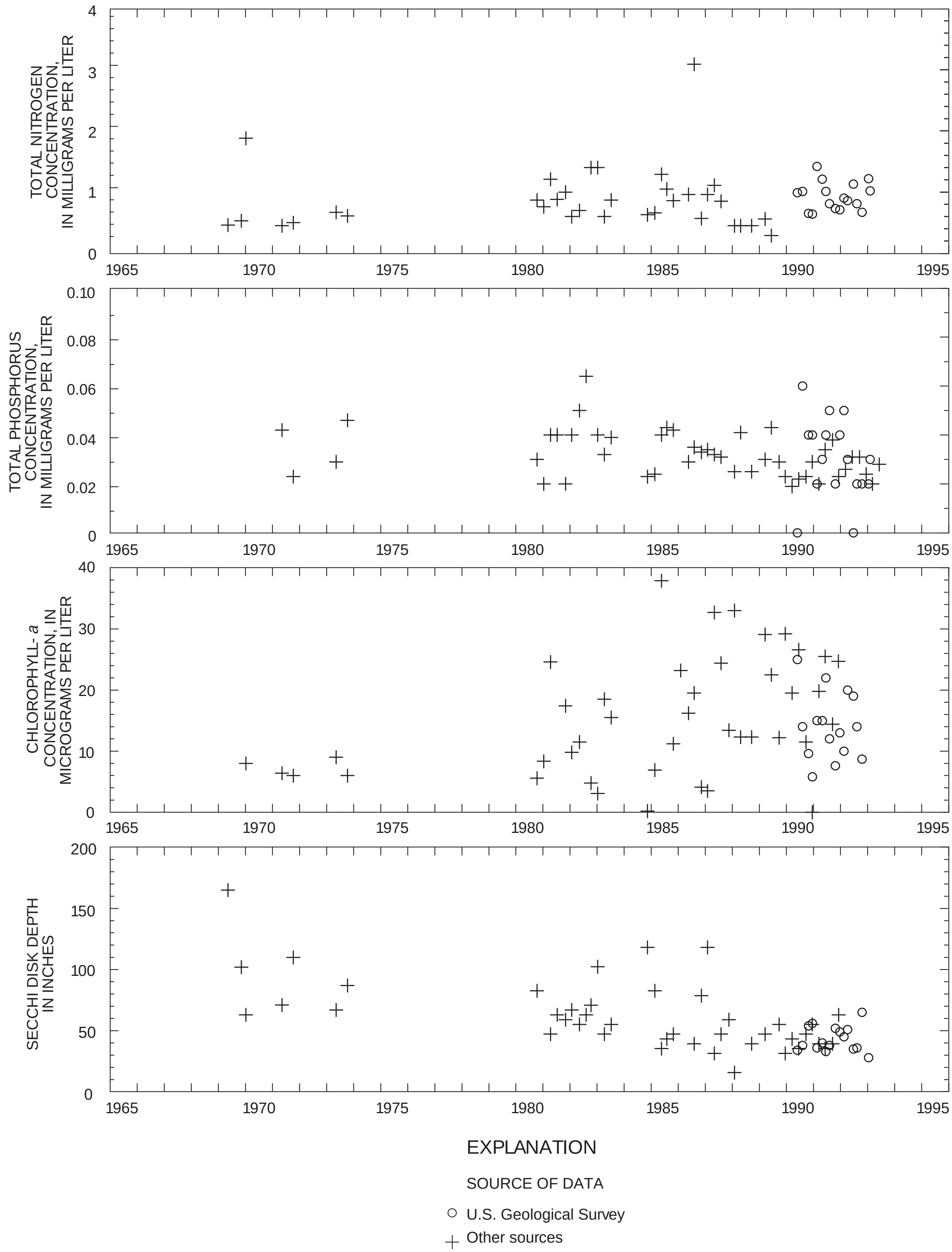

Figure 20a. Selected water-quality constituents for Lake Maitland, 1967-92.

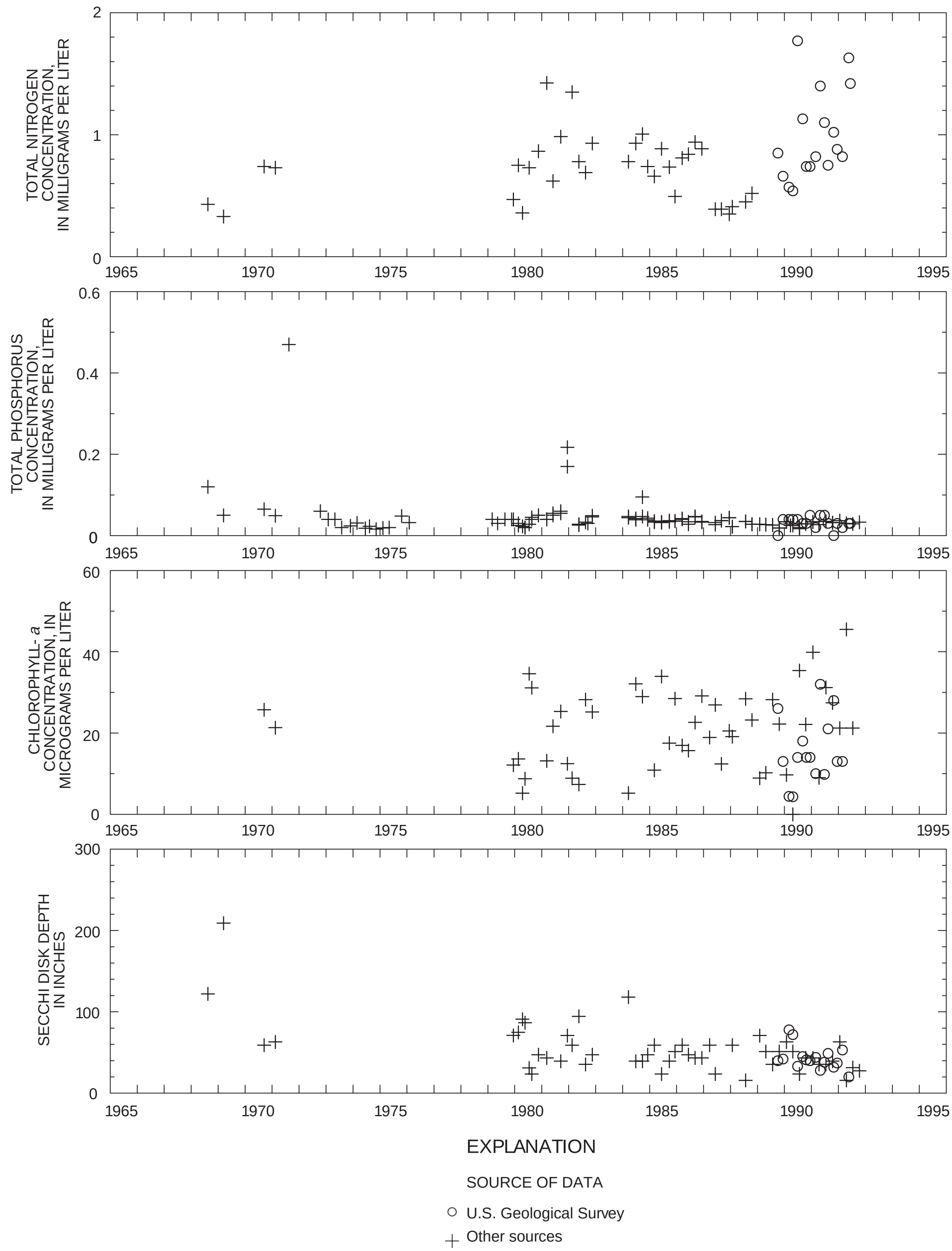

Figure 20b. Selected water-quality constituents for Lake Virginia, 1967-92.

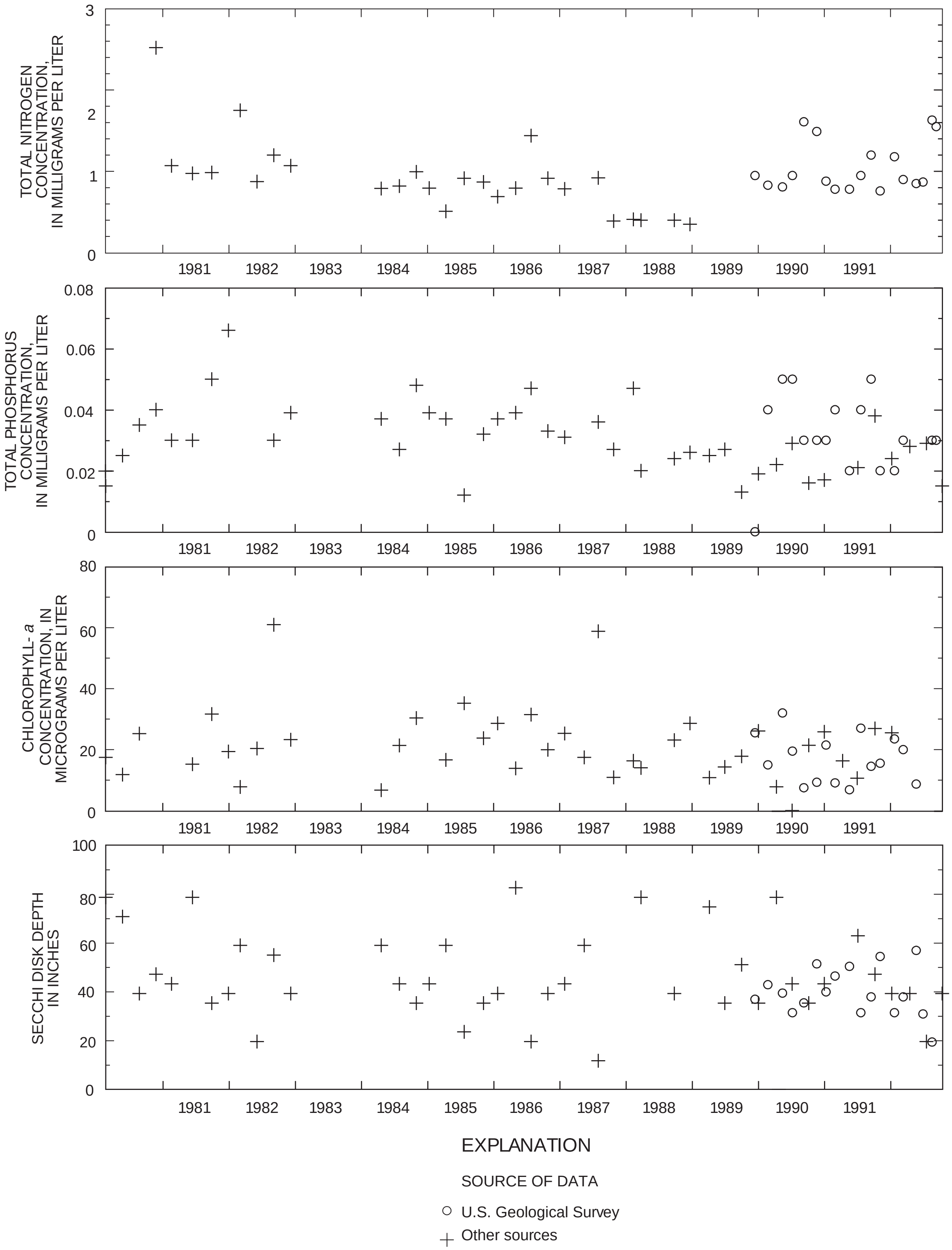

Figure 20c. Selected water-quality constituents for Lake Osceola, 1980-92.

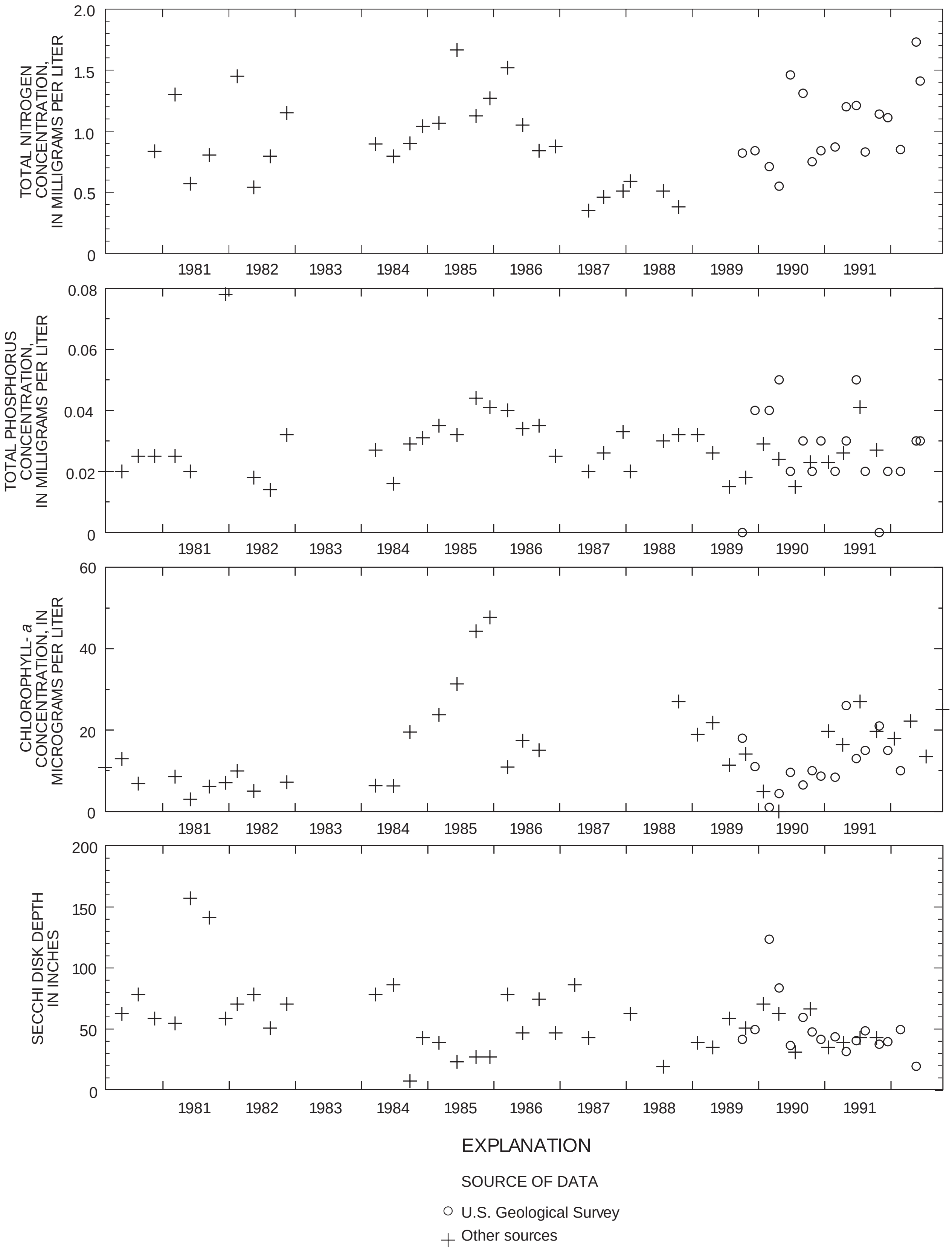

Figure 20d. Selected water-quality constituents for Lake Mizell, 1980-92.

There is a positive rank correlation between chlorophyll-*a* concentration and lake stage in Lakes Mizell and Osceola. This could indicate that the cumulative effect caused by nutrients washed into the lakes stimulates algae growth and causes a higher chlorophyll-*a* concentration. However, the positive relation between chlorophyll-*a* and lake stage may be indirect and may be the result of a common seasonality effect. That is, the higher lake stages tend to occur during warmer months when algae growth is more pronounced. This possibility is supported by the relation between water temperature and lake stage in all but one lake. The positive correlation between water temperature and lake stage indicates that higher lake stages occur during warmer periods (the summer rainy season).

Stormwater

All of the storm drains in the city of Winter Park are equipped with plastic screen to prevent leaf and other stormwater-borne debris from entering the lakes. At least 68 storm drains empty into the Winter Park chain of lakes (fig. 3). Stormwater quality was sampled at sites 9 and 11 (fig. 6), both on storm drains discharging into Lake Osceola. The sites were selected because of the convenience in measuring discharge and installing and operating the automatic sampling equipment. They also were typical of stormwater discharge at other locations in the chain of lakes in terms of size and adjacent land use. All samples of stormwater were discharge-weighted composites for individual storms.

Method of Sampling

Storm discharge and accumulated stormwater volume for each storm were estimated at sites 9 and 11 from measurements of stage above a V-notch weir, made at 1-min intervals using a micrologger. The weirs were installed in the storm drains at an elevation that was higher than the maximum lake elevation. Discharge was computed from a stage-discharge relation derived from the theoretical sharp-crested weir function (Brater and King, 1976) for the weir and for the culvert walls, when stage exceeded the depth of the weir notch. The micrologger activated a sampler each time accumulated stormwater discharge reached a selected volume. The sampler then pumped a selected volume of water from the storm sewer into a 40-L vessel. The pumped volume and the accumulated stormwater volume were selected to provide an adequate volume of water for laboratory analysis from storms producing about 0.2 in. to 2.0 in. of rain.

Because the lake level occasionally exceeded the elevation of the mouth of the storm drain at site 11, the part of the drain where the sampler intake was located sometimes contained lake water. To avoid sampling before the lake water was flushed from the storm drain by stormwater, specific conductance of the water present at the sampler intake was monitored by the micrologger at 1-min intervals. The sampling event was not begun until the specific conductance of the water had fallen to less than 100 µS/cm, indicating that most of the lake water had been flushed from the system. The specific conductance of the lake water generally was greater than 200 µS/cm.

The composite samples of stormwater were removed from the sampler within a few hours of the end of the storm and chilled to 4 °C. Samples were analyzed for total nitrogen, total phosphorus, suspended solids, and specific conductance. For selected storms, additional samples were analyzed for dissolved nitrogen and phosphorus, and for screenable nitrogen, phosphorus, and solids. The samples for dissolved nitrogen and phosphorus were filtered through a 0.45-micron membrane filter. The samples for screenable material were prepared by passing a well-mixed aliquot of the sample though the plastic screening material used in construction of the stormwater-debris traps. The screened water was then analyzed for total nitrogen, total phosphorus, and suspended solids.

Chemical Characteristics

Water-quality analyses of composite samples from site 9 for 17 storms are given in table 9, and table 10 gives the results for composite samples from site 11 for 16 storms. Box plots of total nitrogen and phosphorus in unfiltered stormwater are given in figure 21.

Nitrogen and phosphorus concentrations were of comparable magnitude at the two stormwater sites. The median total nitrogen concentration was 2.23 mg/L at site 9 and 3.06 mg/L at site 11 (tables 9 and 10, fig. 21). The median total phosphorus concentration was 0.40 mg/L at site 11 and 0.34 mg/L at site 9. The relatively small differences in concentrations between these two sites is an indication that the data collected at these two sites is transferrable to other locations around the lakes.

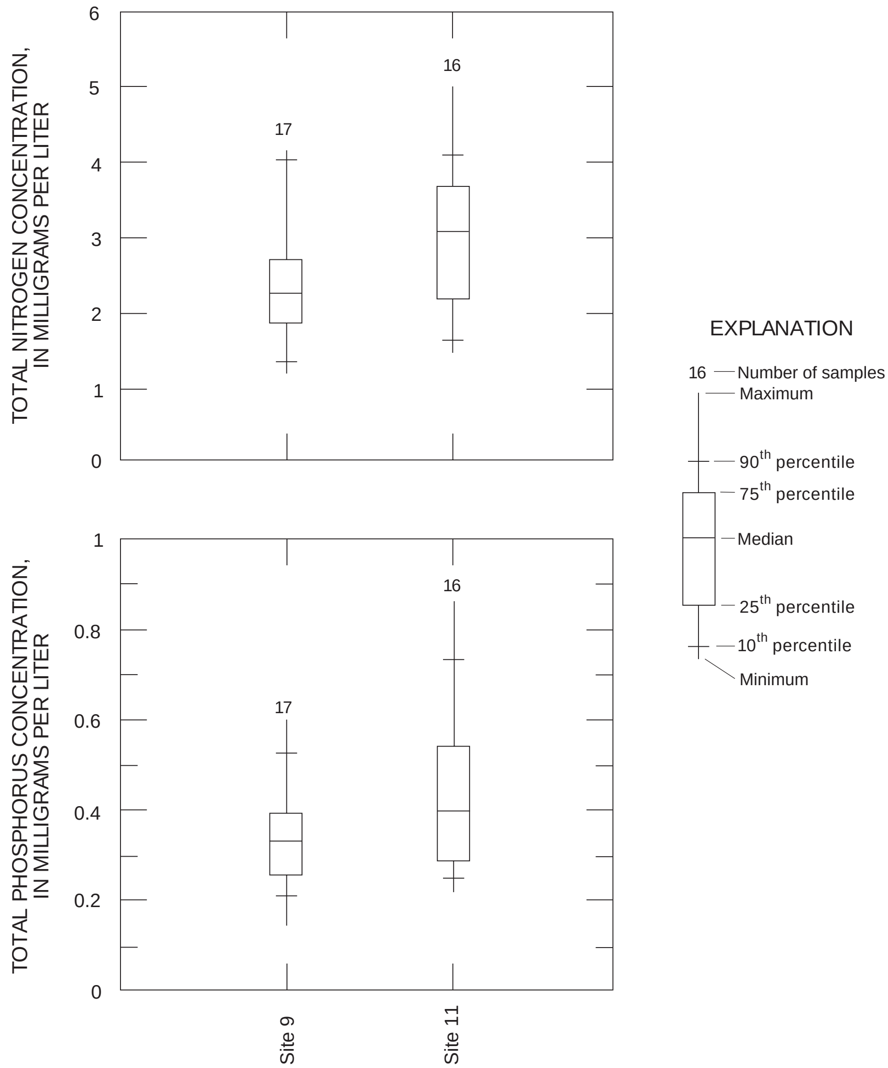

Figure 21. Total nitrogen and phosphorus concentrations in unfiltered stormwater at two sites near Lake Osceola (site numbers are from fig. 6).

Comparison of the screened and filtered samples indicates that most of the suspended solids, nitrogen, and phosphorus in stormwater is carried by particles smaller than the debris-trap screen-pore size (about 25 µm) and larger than the filter-pore size (0.45 µm), as summarized in the following table. This indicates that the debris traps are not very effective in reducing nutrients in stormwater. Screening the stormwater-through debris-trap screening material removed only about 7 to 16 percent of the total nitrogen and about 7 to 11 percent of the total phosphorus. A filtering system that could remove particles as small as 0.45 µm would still allow 30 to 40 percent of the nitrogen and phosphorus loads to enter the lakes as dissolved constituents.

Site	Total nitrogen		Total phosphorus		Suspended solids
	Percent remaining after screening	Percent remaining after filtering	Percent remaining after screening	Percent remaining after filtering	Percent remaining after screening
9	93	32	89	31	78
11	84	33	93	41	79

Table 9. Water-quality characteristics of stormwater at site 9 (Webster Drive) near Lake Osceola

[All concentrations are in milligrams per liter. Specific conductance is given in microsiemens per centimer at 25 °C. in, inches; rw, raw water; sw, screened water; fw, filtered water; --, no sample taken]

Date	Storm rainfall, (in.)	Total nitrogen (rw)	Total nitrogen (sw)	Total nitrogen (fw)	Total phos-phorus, (rw)	Total phos-phorus, (sw)	Total phos-phorus, (fw)	Sus-pended solids, (rw)	Sus-pended solids, (sw)	Specific conduct-ance
91-03-31	0.72	2.79	2.64	0.96	0.60	0.58	0.32	--	--	102
91-04-06	2.34	2.03	1.68	.32	.34	.29	.09	121	63	63
91-04-07	.69	1.30	1.10	.47	.25	.23	.11	36	31	65
91-04-17	1.07	2.24	2.23	.67	.38	.35	.14	72	60	83
91-04-23	2.30	2.17	2.00	.64	.40	.40	.11	133	83	53
91-05-01	.55	1.85	1.88	.42	.21	.21	.07	83	35	61
91-05-19	1.01	2.66	2.26	.59	.40	.38	.14	100	84	60
91-05-21	.07	1.74	--	--	.28	--	--	77	--	65
91-06-02	.06	2.36	--	--	.26	--	--	60	--	105
91-06-06	.65	1.20	1.07	.45	.19	.18	.07	39	32	66
91-06-25	.38	2.23	--	1.16	.30	--	.15	44	--	78
91-07-27	.53	2.67	--	--	.28	--	--	66	--	85
91-08-18	.19	3.29	--	--	.46	--	--	147	--	102
91-08-24	.47	1.65	1.52	.83	.24	.23	.12	74	53	65
92-02-05	1.61	2.01	1.71	.84	.35	.31	.14	78	64	57
92-05-27	.99	4.01	--	--	.53	--	--	112	--	140
92-06-02	.38	4.13	4.12	1.61	.51	.45	.08	108	86	120
Median		2.23	1.88	.66	.34	.31	.12	78	62	66
Median[a]		2.03	1.88	0.64	0.35	0.31	.11	80	62	--

[a]For dates when rw, sw, and fw determinations were made.

The actual effectiveness of the stormwater-screening process cannot be determined precisely from these data because the automatic samplers that collect the water samples for analysis restrict the size and total volume of debris. Thus, the data are biased toward debris small enough to be pumped through the 3/8-in. diameter sampling tubing. However, an estimate of the effectiveness of debris removal can be made by calculating the nutrient loads removed, based on the volume of debris collected and on the nutrient content of the debris.

Quantities of debris removed from storm-drain screens are measured in units of 30-gal containers by the city of Winter Park. To convert this volumetric measure to a mass of phosphorus and nitrogen, the dry-mass-to-volume ratio and the nutrient content of the debris was determined. The dry-mass-to-volume ratio was estimated by collecting the debris from 8 traps after a storm in February 1992. Most of the debris were oak-tree leaves, but some twigs and grass also were present. A volumetric measure of the debris was made using a 2-gal bucket, and the dry weight of the debris was obtained by first air-drying, then weighing, the material. The dry-mass-to-volume ratios of the debris ranged from 0.39 to 1.02 lb/gal, and averaged 0.71 lb/gal.

Three different estimates of the nutrient content of the debris were made. The estimates differ substantially in technique, and represent different possible interactions between the debris and the lakes. The estimates provide a better understanding of the possible range of the nutrient content of debris available to the lakes.

One estimate of the nutrient content of debris was derived from analysis of live plant material reported by the University of Florida (Morris and Pritchett, 1982). Trunk, branch, and foliage samples of trees, including two species of oak trees that grow near the Winter Park lakes, were analyzed for several constituents, including total nitrogen and phosphorus.

Table 10. Water-quality characteristics of stormwater at site 11 (Elizabeth Drive) near Lake Osceola

[All concentrations are in milligrams per liter. Specific conductance is given in microsiemens per centimer at 25 °C. in, inches; rw, raw water; sw, screened water; fw, filtered water; --, no sample taken]

Date	Storm rainfall, (in.)	Total nitrogen (rw)	Total nitrogen (sw)	Total nitrogen (fw)	Total phos-phorus, (rw)	Total phos-phorus, (sw)	Total phos-phorus, (fw)	Sus-pended solids, (rw)	Sus-pended solids, (sw)	Specific conduct-ance
91-06-07	.27	2.08	1.88	0.37	0.25	0.23	0.04	61	50	69
91-06-19	.47	3.02	2.36	.94	.27	.26	.10	8	44	88
91-06-25	.38	2.99	--	1.35	.40	--	.13	60	--	92
91-06-26	1.76	2.27	1.78	.16	.42	.47	.10	92	79	47
91-07-20	2.33	1.46	1.36	.56	.31	.28	.09	61	45	40
91-07-28	.84	1.68	1.69	.94	.21	.20	<.01	32	28	55
91-08-13	.24	3.10	--	--	.32	--	--	45	--	80
91-08-18	.19	2.56	--	--	.35	--	--	67	--	80
91-08-24	.47	1.60	1.59	.83	.27	.24	.13	30	38	80
92-01-14	.48	3.82	3.53	1.69	.71	.69	.29	94	90	124
92-01-23	.15	3.09	--	--	.42	--	--	80	--	92
92-02-23	.94	3.50	2.79	.60	.73	.67	.22	96	82	80
92-03-25	.97	5.17	--	--	.86	--	--	162	--	90
92-05-14	.79	4.10	--	--	.48	--	--	52	--	98
92-05-27	.99	3.78	--	--	.60	--	--	188	--	80
92-06-02	.38	3.42	--	--	.40	--	--	40	--	--
Median		3.06	1.83	.83	.40	.27	.13	61	48	80
Median[a]		2.18	1.83	0.72	0.29	0.27	0.12	61	48	--

[a]For dates when rw, sw, and fw determinations were made.

The percent of the dry mass of nitrogen and phosphorus in the leaves is given below:

Species	Nitrogen, in percent of dry mass	Phosphorus, in percent of dry mass
Quercus latifolia	1.34	0.066
Quercus nigra	1.39	0.060

Another estimate of the nutrient concentration of the debris was made by collecting some dry, dead debris--mostly fallen oak-tree leaves--from the street near one of the debris traps. Leaves from the land surface were selected rather than leaves from the traps because of the possibility that nitrogen and phosphorus could have been leached from the mostly submerged debris in the traps before removal. The leaves were rinsed with distilled water to remove surface dirt, placed in a blender, and pulverized. The material was then digested and ten sample splits were analyzed for total ammonia-plus-organic nitrogen and total phosphorus using analytical methods for bottom material (Fishman and Friedman, 1989). The percent of total dry mass ranged from 0.057 to 0.084 for nitrogen, with a mean of 0.066 percent. For phosphorus, the range was 0.021 to 0.026 percent and the mean was 0.023 percent.

A third estimate of the nutrient content of debris was made by placing dead, fallen leaf debris collected from streets into water from the lakes and determining the amount of nutrients leached. This was done by placing 30-g samples of debris (mostly oak leaves) in 4-L containers that were filled with water from Lake Virginia and capped, leaving no air space. One container was sampled almost immediately (within 45 min) and the others were stored in the absence of light at room temperature (22-25 °C). At selected time intervals, a container was opened and a 250 mL aliquot of water was removed for analysis of total nitrogen and phosphorus content. Results are given below:

Leaching time, days	Nitrogen, concentration, mg/L	Nitrogen, leached, mg/kg	Nitrogen, leached, in percent of dry mass	Phosphorus, concentration, mg/L	Phosphorus, leached, mg/kg	Phosphorus, leached, in percent of dry mass
0.02	0.86	120	0.012	0.09	10	0.001
3	2.8	370	.037	1.9	250	.025
10	4.8	640	.064	2.5	330	.033
10 (duplicate)	4.5	600	.060	2.2	290	.029

These data indicate that some nitrogen and phosphorus are leached from the leaves almost immediately and that additional nitrogen and phosphorus are leached after 3 days and after 10 days, respectively. Although the amounts of nitrogen and phosphorus leached after 10 days may not represent the total amounts available through complete digestion of the leaves, comparison of the leaching data with that from the previous analyses of leaf debris indicates similar amounts of material: 0.06 percent nitrogen leached after 10 days compared with a mean nitrogen content of 0.066 percent in digested samples, and 0.03 percent phosphorus leached compared with 0.023 in the digested samples.

To estimate the amount of nutrients removed by the debris traps, the data for nutrient contents derived from the third method mentioned were used. The rounded values of 0.06 percent nitrogen and 0.03 percent phosphorus were used to make the following estimates of total mass removal for calender years 1989-91:

Year	Amount of debris removed (gallons)	Estimated dry mass (pounds)	Estimated phosphorus mass (pounds)	Estimated nitrogen mass (pounds)
1989	1,560	1,100	--	--
1990	2,580	1,800	--	--
1991	6,700	4,800	--	--
Mean	3,610	2,600	1.56	0.78

These data indicate that, although the debris traps are useful for removing large organic debris and nonbiodegradable material, the mass of nutrients removed from stormwater is very small.

Ground Water

Although there are uncertainties in the calculations of the amount of ground-water inflow, ground water probably makes up, on average, about 15 percent of the total inflow to the lakes (table 5). Therefore, the quality of the ground water can have a significant impact on the quality of water in the lakes. Twenty samples of surficial ground water were collected from the periphery of the lakes in February-June 1992. The locations of sites sampled are shown in figure 11 and the analyses of the samples are given in table 11.

The quality of the surficial ground water was highly variable. The specific conductance ranged from about 200 to 740 μS/cm. The water was generally acidic, probably because of organic matter in the surficial sediments. The pH ranged from 4.6 to 7. Calcium concentrations ranged from less than 10 to 140 mg/L and sulfate from less than 1 to 130 mg/L.

The variation of surficial ground-water quality can be seen by comparing diagrams of major ion concentrations (figs. 22-25). The diagrams, which are grouped by lake, do not show any obvious changes from lake to lake. The ground-water samples collected from around Lake Maitland (fig. 22), show slightly less variation than the other lakes, but this could be the result of random variations, rather than an actual difference in ground-water quality between lakes.

The most unusual samples came from sites 4, 8 and 11 (one each from near Lakes Virginia, Mizell, and Osceola, respectively). Those samples all had relatively high specific conductance, calcium, and alkalinity. The influence of water from the Upper Floridan aquifer at those sites is unlikely because the vertical hydraulic gradient is downward and Upper Floridan irrigation water probably is not used at the sites. A possible explanation is that cement debris might have been used as fill along the shoreline near the sampling sites, although this was not obvious when the samples were collected.

Nitrogen and phosphorus concentrations in the surficial ground water also varied over a wide range. Comparing the sums of total ammonia and organic nitrogen, nitrate, and nitrite, the highest value occurred at site 5 (15.39 mg/L) and the lowest (less than 0.21 mg/L) at sites 17 and 18. Total orthophosphorus ranged from 0.08 mg/L at sites 8 and 20 to less than 0.01 mg/L at sites 1, 2, 10, 13, 14, 15, 17, and 19.

Table 11. Surficial ground-water quality in the vicinity of the Winter Park chain of lakes

[°C degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum -cobalt units; µS/cm, microsiemens per centimeter at 25 °C; Wh, whole water; SU, standard units; mg/L, milligrams per liter; µg/L, micrograms per liter; --not analyzed; <, less than]

Site identification number	Date	Map no.	Temperature, water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	pH, Wh, field (SU)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia,+ organic total (mg/L as N)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L) as Na)	Potassium, dissolved (mg/L as K).	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Alkalinity lab (mg/L as Ca CO_3)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
283503081203701	05-04-92	1	--	<1.0	<5	210	4.6	0.010	<0.010	0.36	4.60	0.040	<0.010	0.3	12.0	3.8	10.0	4.1	32	16	<0.10	2.3	30	<1.0
283506081202201	05-20-92	2	25.0	4.6	35	710	6.2	..030	<.010	.30	.040	.020	<.010	3.4	56	34	16	30	68	130	.10	129	200	<1.0
283523081202701	05-20-92	3	24.0	<1.0	35	200	6.0	4.20	.020	5.0	<.020	.120	.040	5.7	20	3.4	7.0	4.0	10.0	7.4	<.10	73	30	<1.0
283525081210001	05-04-92	4	26.0	3.9	<5	400	7.0	.080	<.010	.38	.070	.140	.050	1.3	81	1.5	4.8	.70	4.6	3.2	<.10	212	<20	<1.0
283527081201001	06-10-92	5	23.0	2.2	5	475	4.9	.020	<.010	.39	15.0	.030	.010	2.0	52	12	4.8	24	18	130	<.10	4.1	120	<1.0
283537081202401	06-10-92	6	25.0	<1.0	30	275	6.0	2.20	.010	2.8	<.020	.050	.060	8.5	30	9.4	4.5	7.0	10.0	15	<.10	104	--	<1.0
283537081204101	02-21-92	7	21.5	--	--	250	--	.100	<.010	.27	<.020	.020	.010	--	26	8.6	3.5	.80	36	6.8	<.10	52	--	--
283547081202201	06-10-92	8	26.0	29	30	740	6.4	.980	<.01	1.7	<.020	.110	.080	16	140	7.2	11	2.5	30	.60	<.10	357	40	<1.0
283549081203201	05-05-92	9	24.0	<1.0	15	210	6.3	.090	<.010	.46	.040	.090	.070	5.2	21	3.6	10.0	4.3	20	7.0	.10	59	20	<1.0
283600081205001	05-06-92	10	--	<1.0	<5	275	6.2	<.010	<.010	<.20	.020	.030	<.010	1.2	31	6.1	10.0	3.5	24	37	<.10	61	30	1.0
283610081204501	02-21-92	11	20.0	--	--	550	--	.120	.010	.64	.140	.100	.020	--	96	5.7	13	3.5	28	25	<.10	223	--	--
283617081200902	05-05-92	12	24.0	<1.0	<5	225	5.5	.040	<.010	.31	<.020	.050	.020	5.6	14	6.1	14	3.4	29	37	<.10	16	40	2.0
283625081203501	05-07-92	13	22.0	1.1	35	200	5.4	.030	<.010	1.0	<.020	.040	<.010	13	22	5.4	6.8	.60	20	41	<.10	21	40	<1.0
283630081205401	05-07-92	14	20.0	1.9	<5	245	5.8	<.010	<.010	.38	3.60	.060	<.010	.6	21	5.8	8.0	4.1	28	28	<.10	19	30	<1.0
283641081202901	06-11-92	15	25.5	62	10	373	4.8	.02	<.010	.26	7.6	.600	<.01	.9	23	14	17	5.1	36	70	<.10	4.6	40	<1.0
283642081211101	05-06-92	16	26.0	1.8	10	470	6.1	.100	.010	.55	<.020	.110	.060	6.0	63	6.7	15	5.7	43	74	<.10	95	40	<1.0
283647081212301	05-07-92	17	20.0	<1.0	<5	240	4.8	<.010	<.010	<.20	.030	.040	<.010	.2	15	6.5	12	1.7	33	41	<.10	7.0	<20	<1.0
283702081203701	05-07-92	18	23.0	3.6	5	215	4.9	<.010	<.010	<.20	.400	.110	.050	0.7	9.6	4.8	16	3.2	26	36	<0.10	8.4	30	1.0
283713081214701	05-21-92	19	24.5	14	50	250	4.7	.560	.010	.81	<.020	.080	<.010	2.1	9.8	6.3	14	9.9	34	48	<0.10	<0	50	<1.0
283723081210201	05-07-92	20	22.0	1.9	60	210	5.4	.540	<.010	1.1	<.020	.070	.080	13	15	4.0	11	5.1	29	24	<0.10	18	<20	<1.0

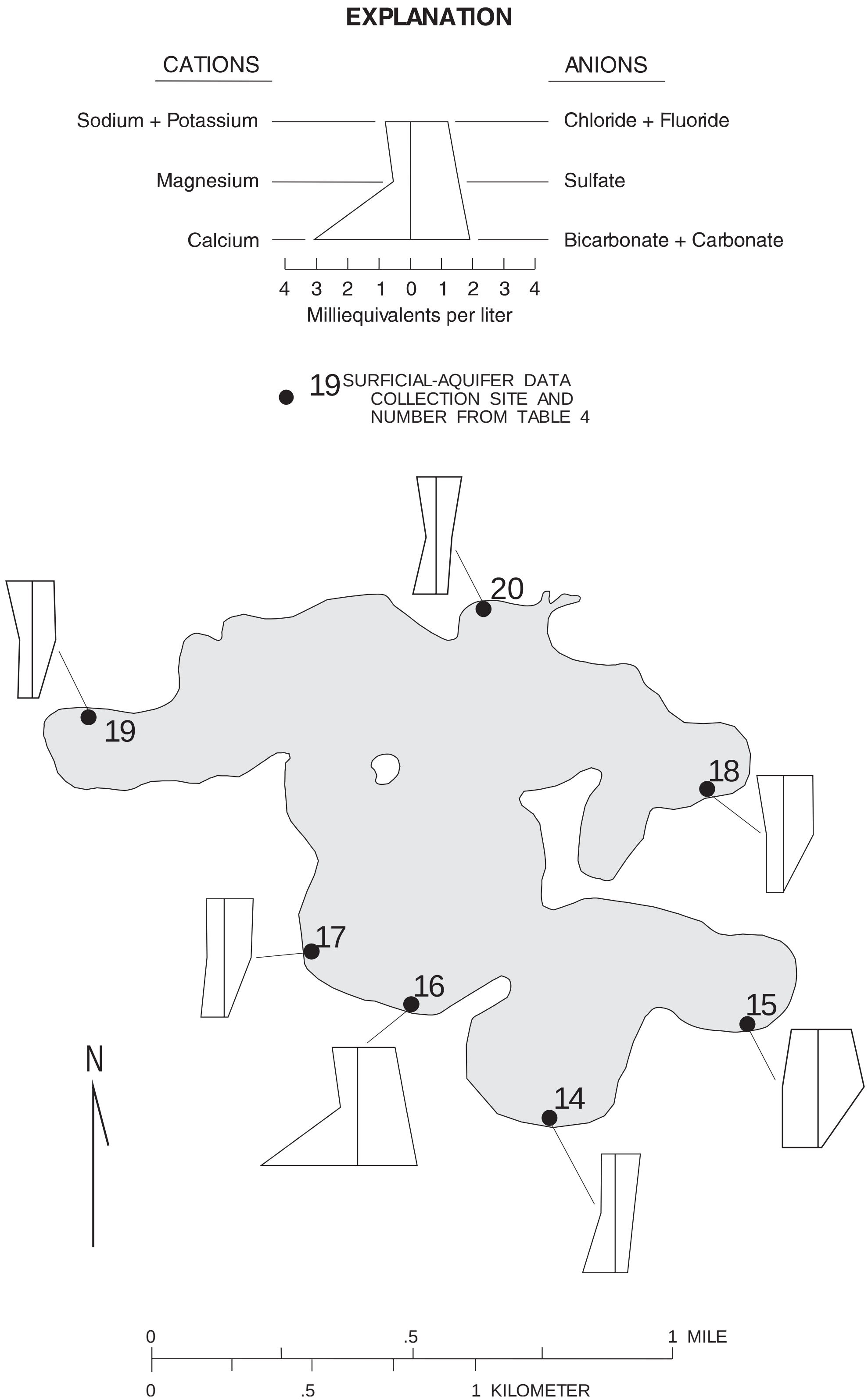

Figure 22. Major ion concentrations in water from the surficial aquifer near Lake Maitland (site numbers are from fig. 11).

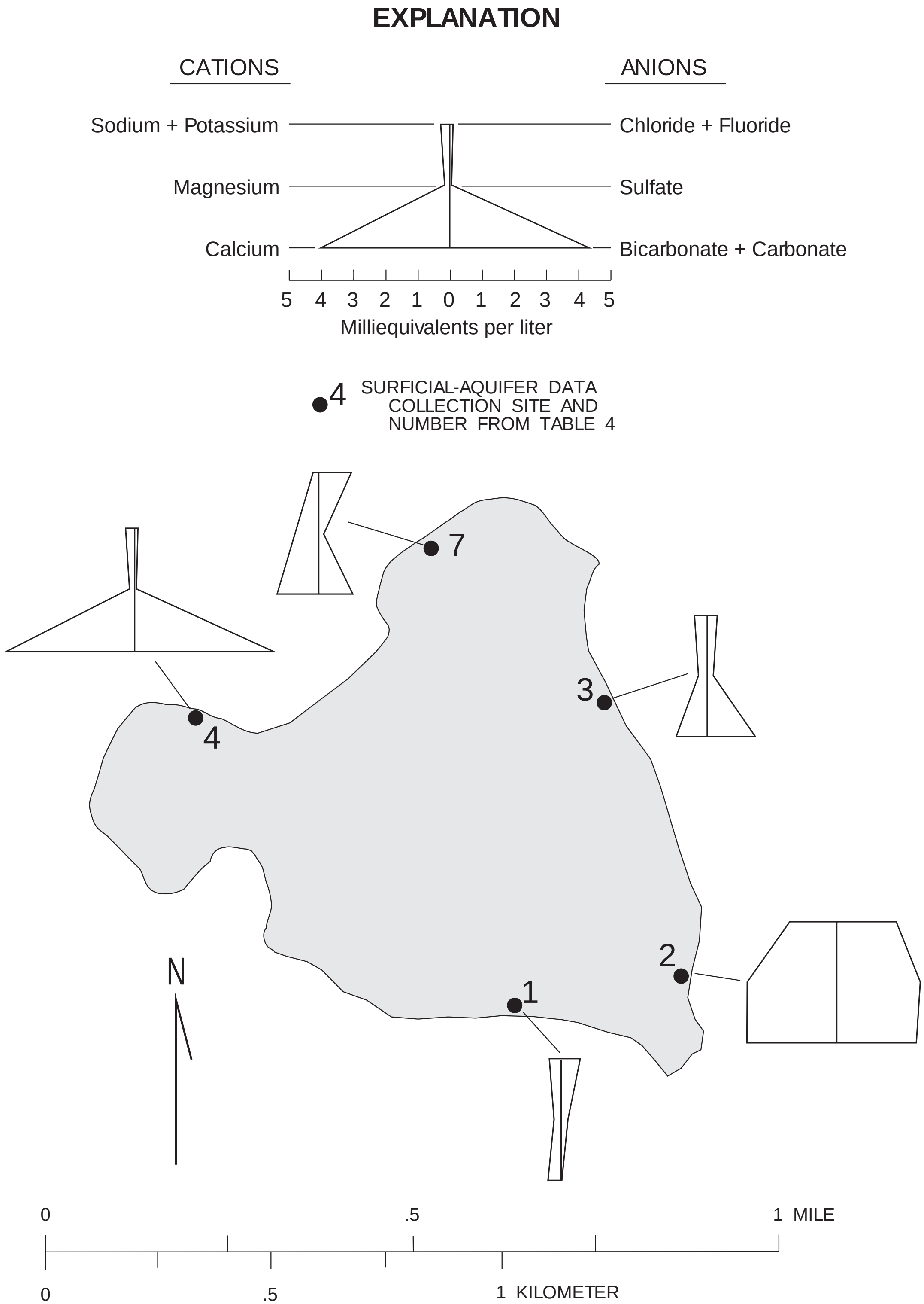

Figure 23. Major ion concentrations in water from the surficial aquifer near Lake Virginia (site numbers are from fig. 11).

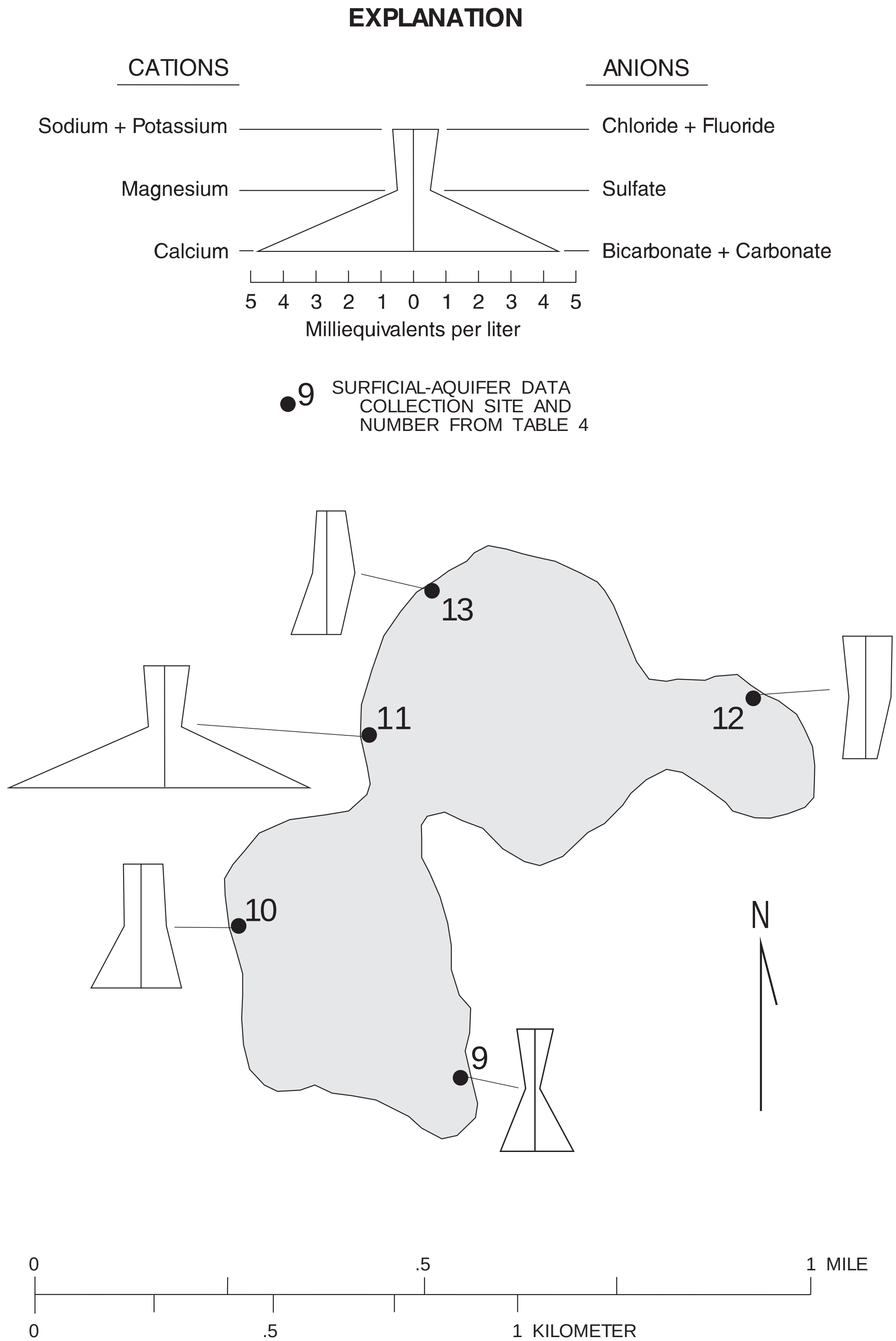

Figure 24. Major ion concentrations in water from the surficial aquifer near Lake Osceola (site numbers are from fig. 11).

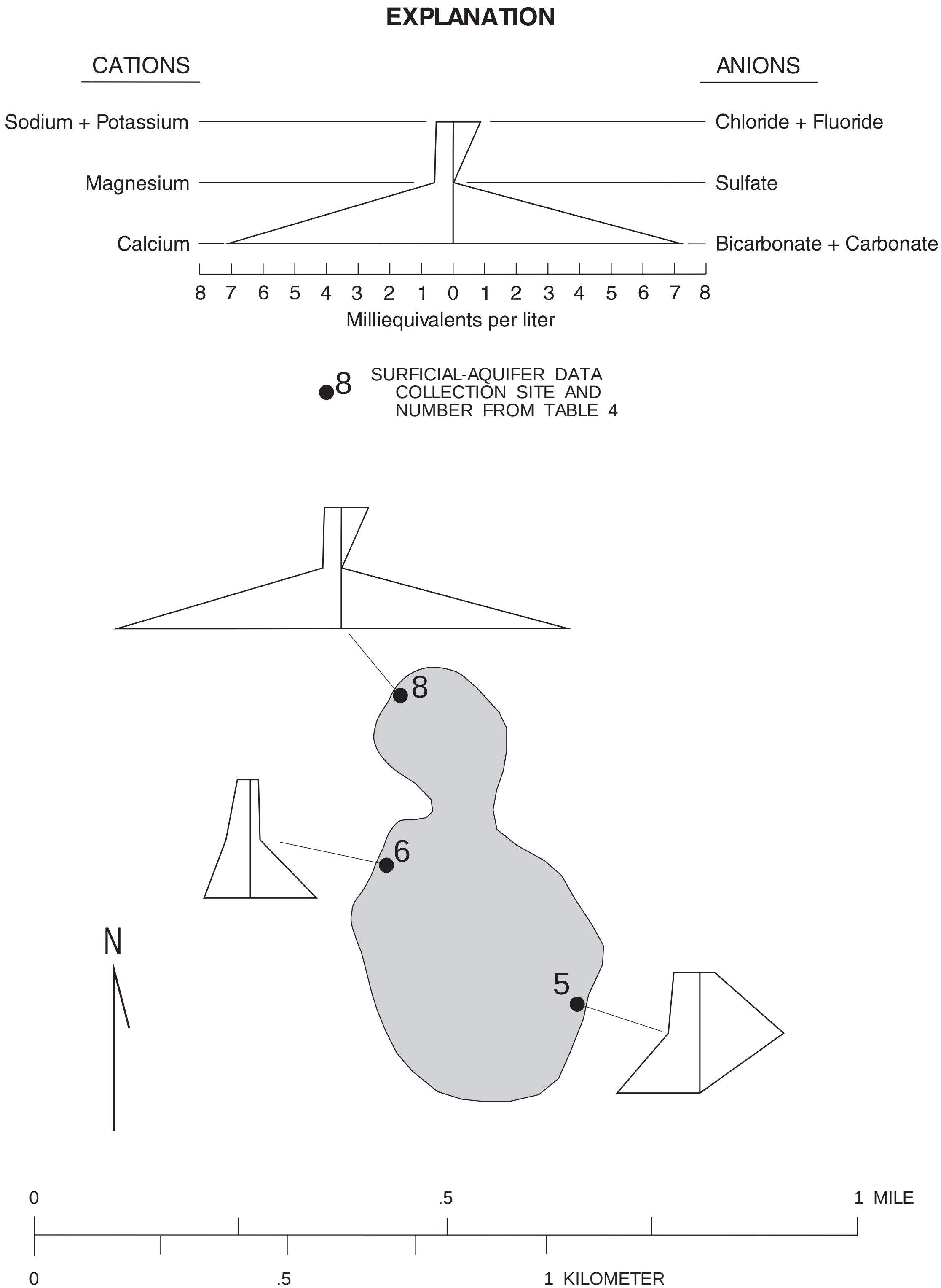

Figure 25. Major ion concentrations in water from the surficial aquifer near Lake Mizell (site numbers are from fig. 11).

The nutrient concentrations in surficial ground water apparently were not related to the proximity to property with a septic tank (fig. 11). The highest nitrogen and phosphorus concentrations occurred at sites that do not have septic tanks. This indicates that fertilizer applications probably are the primary source of nutrients in the surficial ground water. The highest nitrogen concentration was at a site near an orange grove.

The surficial ground water also was analyzed for boron and molybdenum because those elements do not naturally occur in ground water in Florida. Boron and molybdenum are trace elements added to fertilizer. Borax (which contains boron) is an ingredient of laundry soap and thus could indicate the effects of outflow from septic tanks. The results of analyses for molybdenum were not conclusive. The highest concentration of boron, 200 µg/L, was at site 2, and the second highest concentration was 120 µg/L at site 5. Neither site is near a septic tank. The boron at those sites probably is the result of fertilizer application to nearby land. For comparison, the boron concentration in treated wastewater in southwest Orange County was 190 µg/L (L.A. Bradner, U.S. Geological Survey, oral commun., 1993).

ANALYSIS OF NUTRIENT LOADING

Simple steady-state input-output models can be used to predict the trophic status of a lake and nutrient concentrations as functions of inflow loading. Commonly used models of this type include the Vollenweider model (1968), and the Dillon-Rigler model (1974). These models were originally developed using data for lakes in more temperate parts of North America, and the applicability of the models to subtropical lakes (such as in Florida) has been questioned. Baker and others (1981) have extensively investigated the use of simple input-output models and have developed modifications that improve the applicability of the models to Florida lakes. These models have been formulated in terms of both total nitrogen and total phosphorus. In order to apply steady-state input/output models, the flow and nutrient budgets for the lakes must be calculated. Flow budgets were discussed in a previous section. This section describes the development of nutrient budgets and their application to a steady-state loading model.

Constituent Budgets

The discharge and water-quality data for the Winter Park chain of lakes were combined to calculate chloride and nutrient budgets for the lakes. Budgets were calculated for the chemically conservative (nonreactive) constituent chloride to estimate the validity of the hydrologic budgets.

The concentrations of chloride, nitrogen, and phosphorus for surface inflow and outflow used in the calculations were the medians of all the samples collected at the respective sites during the study (table 6). Ground-water inflow concentrations were the medians of the 20 samples collected (table 11). The concentrations used for ground-water outflow were medians of the water samples collected near the lake bottoms (tables 7 and 8). The concentrations used for the change in lake-storage terms were derived from the medians of all samples collected in all the lakes. The data for chloride concentration in rainfall are from Lake Hope in Maitland (Irwin and Kirkland, 1980, p. 63)(fig. 1). Data for atmospheric deposition of nitrogen and phosphorus are from Baker and others (1981), who estimated deposition rates for urban areas in Florida. The chloride concentration for stormflow (7 mg/L) was from data collected at Lakes Faith, Hope, and Charity by German (1983) (fig. 1).

Net loads were calculated for water years 1990-92 (table 12 and fig. 26). Water year 1990 was a dryer-than-average year, 1991 was wetter-than-average, and 1992 was about average. Because chloride is a conservative constituent, the difference between inflow and outflow of chloride is an indication of the accuracy of the constituent budgets. These differences, with respect to inflow loads, ranged from 3 percent in 1992 to 18 percent in 1991. The differences probably are because of a combination of uncertainties in the water budget and in chemical characterization of the inflow waters.

The percent of the total loads contributed by each source of inflow for water year 1992 is different for each of the three constituents studied. For example, ground water probably contributed 47 percent of the total chloride load to the lakes, but only about 20 percent of the nitrogen and 15 percent of the phosphorus. Rainfall contributes 3 percent of the chloride, 19 percent of the nitrogen, and 15 percent of the phosphorus. Stormflow, in contrast, contributes 4 percent of the chloride, 24 percent of the nitrogen, and 44 percent of the phosphorus. Surface inflow contributes 45 percent of the chloride, 37 percent of the nitrogen, and 26 percent of the phosphorus.

Table 12. Estimated chloride and nutrient budgets for the Winter Park chain of lakes, water years 1990-1992

[Chloride concentration data for rainfall and stormflow are from German, 1983. Nitrogen and phosphorus loads were computed from areal loading rates from Baker and others (1981), and are 0.76 grams per square meter per year for nitrogen and 0.05 grams per square meter for phosphorus. Lake area used to calculate loads is 4.5 x 10^7 ft^2. in/yr, inch per year; mg/L, milligrams per liter; tons/yr, tons per year; --, no contribution or not applicable]

	Flow (in/yr)	Chloride concentration (mg/L)	Total nitrogen concentration (mg/L)	Total phosphorous concentration (mg/L)	Chloride load (tons/yr)	Nitrogen load (tons/yr)	Phosphorus load (tons/yr)
1990 Inflow:							
Rainfall	38	1.6	--	--	7.1	3.5	0.23
Stormflow	4	7	2.6	.37	3.3	1.2	0.17
Surface inflow	56	16	.9	.05	104.7	5.9	0.33
Estimated ground-water inflow	0	28	.8	.05	0	0	0
Total	98				115.1	10.6	0.73
1990 Outflow:							
Evaporation	51	--	--	--	--	--	--
Surface outflow	20	18	.85	.05	42.0	2.0	0.12
Estimated ground-water outflow	33	21	2.0	.07	81.0	7.7	0.27
Lake storage change	-6	19	.84	.04	-13.3	-0.7	-0.03
Total	98				109.7	9.0	0.36
				Net change:	+5.4	+1.6	+0.37
1991 Inflow:							
Rainfall	58	1.6	--	--	11.0	3.5	0.23
Stormflow	32	7	2.6	.37	26.2	9.7	1.38
Surface inflow	73	16	.9	.05	136.4	7.7	0.43
Estimated ground-water inflow	28	28	.8	.05	91.6	2.6	0.16
Total	191				265.2	23.5	2.20
1991 Outflow:							
Evaporation	48	--	--	--	--	--	--
Surface outflow	103	18	.85	.05	216.6	10.2	0.60
Estimated ground-water outflow	33	21	2.0	.07	81.0	7.7	0.27
Lake storage change	7	19	.84	.04	16.0	0.6	0.02
Total	191				313.6	18.5	0.89
				Net change:	-48.4	+5.0	+1.31
1992 Inflow:							
Rainfall	48	1.6	--	--	9.0	3.5	0.23
Stormflow	15	7	2.6	.37	12.3	4.6	0.66
Surface inflow	67	16	.9	.05	125.2	7.0	0.39
Estimated ground-water inflow	40	28	.8	.05	130.8	3.7	0.23
Total	170				277.3	18.8	1.51
1992 Outflow:							
Evapotranspiration	47	--	--	--	--	--	--
Surface outflow	90	18	.85	.05	189.2	9.0	0.53
Estimated ground-water outflow	33	21	2.0	.07	81.0	7.7	0.27
Lake storage change	0	19	.84	.04	--	--	--
Total	170				270.2	16.7	0.80
				Net change:	+7.1	2.1	+0.71

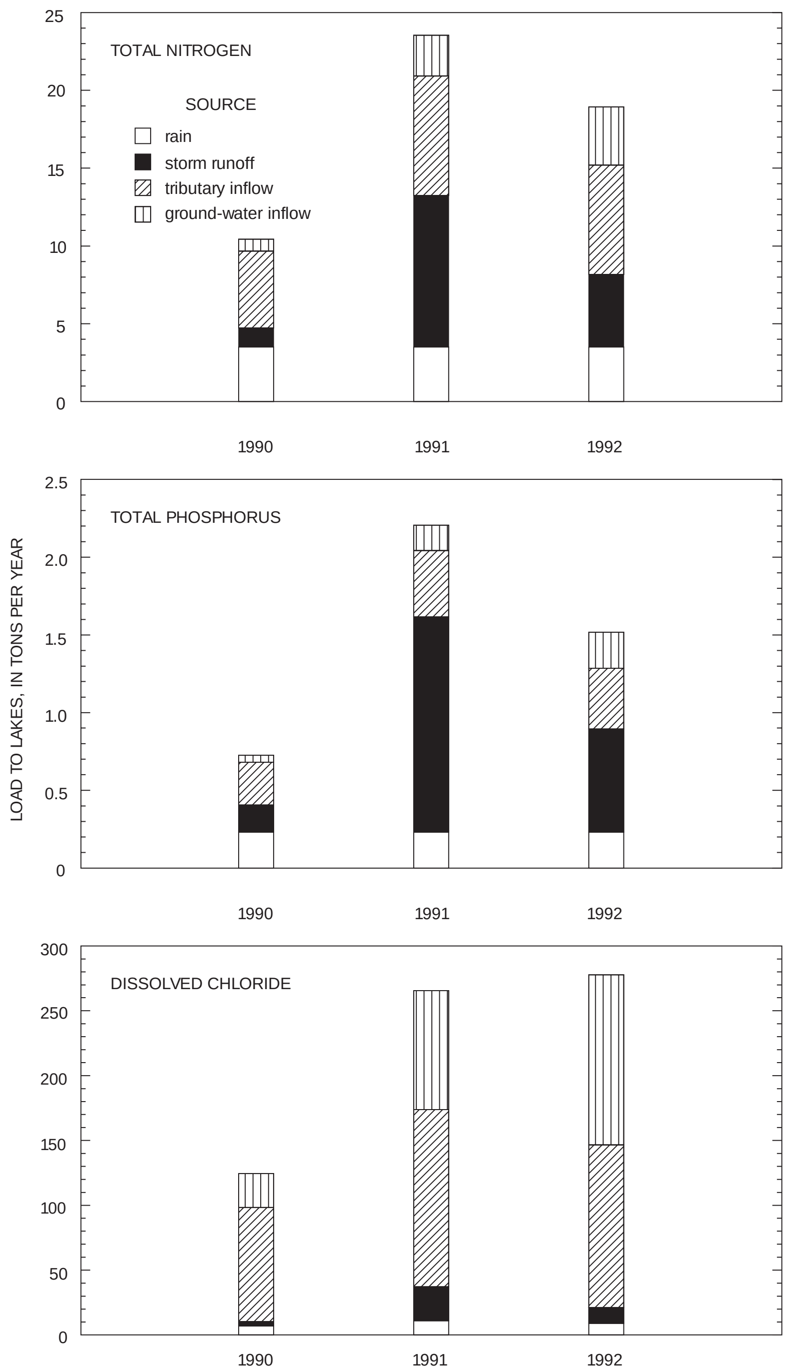

Figure 26. Total nitrogen, phosphorus, and dissolved chloride loads to the Winter Park lakes, 1990-92.

The most variable source of nitrogen and phosphorus loading to the lakes is stormwater (table 12 and fig. 26). The total 1990 annual rainfall was only 38 in. and stormwater contributed about 12 percent of the nitrogen and 23 percent of the phosphorus to the lakes, less than the amount contributed by bulk precipitation or tributary inflow. The total annual rainfall was 59 in. in 1991 and stormwater contributed about 63 percent of the phosphorus load and 41 percent of the nitrogen load, more than any other inflow component.

Errors in the estimates of various flow-budget components can result in errors in the constituent-load budgets. To determine the effect of such errors, a sensitivity analysis was made using the data for water year 1992, a year of about average rainfall and no change in lake storage. The estimated values for several components of the flow budget were varied to determine the effect on the constituent-load budget. As part of the sensitivity analysis, ground-water inflow and stormwater inflow were increased but not decreased, because the estimates used in the flow budgets were thought to be minimum values. Although several components were evaluated in the analysis, only ground-water inflow and stormwater inflow had any significant effect on the constituent-load budget. Increasing the ground-water inflow rate by 50 percent resulted in an increase in the ground-water component of the chloride load of 10 percent (from 47 to 57 percent); however, the nitrogen load increased only 7 percent (from 20 to 27 percent) and the phosphorus load increased only 8 percent (from 16 to 22 percent). Increasing stormwater inflow by 25 percent resulted in an increase in the chloride load from 4 to 6 percent, in the nitrogen load from 24 to 29 percent, and in the phosphorus load from 43 to 50 percent. Increasing or decreasing both surface inflows and outflows by 10 percent had little effect on the load budgets, changing the loads of all components by only 1 to 2 percent.

Modified Dillon-Rigler Model

Baker and others (1981) reported that the best model for predicting nitrogen and phosphorus concentrations for lakes where input and output can be measured was a modification of the Dillon-Rigler model. This model requires the determination of a retention coefficient and is not applicable to lakes for which a flow and nutrient budget has not been determined. The flow and nutrient budget can be estimated for the Winter Park chain of lakes, so the Dillon-Rigler model was selected for predicting the response of the lakes to changes in nutrient-inflow loading.

Generally, the quantity of either total nitrogen or of total phosphorus in lake water is more important than the other in controlling the rate of algal growth in lakes. In the majority of temperate-zone lakes, phosphorus is the limiting nutrient (Baker and others, 1981). However, nitrogen may be the more common limiting nutrient in Florida. Algal bioassays of 31 lakes in Florida, part of the National Eutrophication Survey by the U.S. Environmental Protection Agency during the early 1970’s, indicated that 74 percent of the 31 lakes were nitrogen limited (U.S. Environmental Protection Agency, 1977). In the absence of algal bioassays, ratios of total-soluble-inorganic-nitrogen to total-soluble-reactive-phosphate (SIN:SRP) indicate which nutrient (nitrogen or phosphorus) is limiting. SIN:SRP ratios of less than 10:1 indicate nitrogen limitation and ratios greater than 20:1 indicate phosphorus limitation.

No algal bioassays were made for the Winter Park lakes, but the low ratios of nitrogen to phosphorus indicate that the lakes probably are nitrogen limited. Using median concentrations for all water samples for the lakes, the ratios of ammonia-plus-nitrate-plus-nitrite nitrogen to orthophosphate ranged from 0.5 to 1.0. Although this low nitrogen-to-phosphorus ratio can indicate that nitrogen control is more important than phosphorus control, the response of lake productivity to nutrient input is so complex that control of both nitrogen and phosphorus input probably is desirable, and analysis of both nitrogen and phosphorus input-output models is discussed in this section.

The Dillon-Rigler equation which has been used for simulating nitrogen or phosphorus concentration in Florida lakes is (Baker and others, 1981):

$$C = A_1[L(1-R)/Q_s]^{A_2} \tag{3}$$

where

- C is predicted constituent concentration, in milligrams per liter;
- L is constituent input load to the lakes, in grams per square meter per year;
- R is retention coefficient (dimensionless);
- Q_s is hydraulic loading rate, or the sum of all input volumes to lakes divided by total lake area, in meters per year;
- A_1 and A_2 are empirical coefficients used to optimize the agreement between predicted and actual in-lake concentrations (Baker and others,1981)

The retention coefficient, R_n for nitrogen or R_p for phosphorus, is defined by:

$$R = 1 - P_{out}/P_{in} \tag{4}$$

where

P_{out} is the amount of nitrogen or phosphorus leaving the lake (mass), and

P_{in} is the amount of nitrogen or phosphorus entering the lake (mass).

No attempt was made to find the values for A_1 and A_2 that give the best agreement between simulated and actual concentration. Rather, the equation was used in its basic form (A_1 and A_2 equal to 1) to simulate total nitrogen and total phosphorus concentrations in the Winter Park lakes, as a function of input loading. A comparison of the actual and simulated in-lake total nitrogen and total phosphorus concentrations for the entire lake system as a unit is given below. In these simulations, the retention coefficients were determined for each year and the simulated nitrogen and phosphorus concentrations were computed using the constituent input load and the hydraulic loading for the year. For convenience, hydraulic loading rates were converted to feet per year.

Year	Total nitrogen, median for all lakes (mg/L)		Total phosphorus, median for all lakes (mg/L)	
	Actual	Model	Actual	Model
1990	0.88	0.85	0.04	0.03
1991	0.83	0.80	0.03	0.04
1992	1.10	0.84	0.03	0.04

The simulated and actual total nitrogen and total phosphorus concentrations in lake water generally are in close agreement. The largest discrepancy between simulated and actual concentrations is for total nitrogen in 1992. The reason for this relatively large discrepancy may be related to the seasonality of nitrogen concentrations (fig. 18). Total nitrogen concentrations tend to peak in spring and early summer, and in 1992 two sets of samples were taken during this peak. No further samples were taken that year, so the median of the nitrogen concentrations for water year 1992 may be higher than a seasonally-representative median.

The values for R_n and R_p can vary in relation to the relative contribution for the various sources of nutrients. For example, nitrogen and phosphorus in storm runoff resulting from large particles (such as leaf fragments) might be deposited on the lake bottom, buried, and thus removed from further reaction in the lakes; however, nutrients transported into the lake in dissolved or fine-particulate form would not be removed by settling and burial. Thus, R could be higher during years with more stormwater inflow.

The possibility that R varies according to the amount of storm runoff seems to be indicated by estimates of R_n and R_p for each of the 3 years of study (fig. 27). The R_n ranged from 0.07 in 1990 to 0.24 in 1991. A similar pattern occurred for R_p: the R_p for both 1990 and 1992 was about 0.47 while the R_p for 1991 was 0.60. The hydraulic loading rate for the lakes was 8.2 ft (98 in.) in 1990; 16.0 ft (192 in.) in 1991; and 14.2 ft (170 in.) in 1992. Of these totals, the stormwater input to the lakes in 1990 was 4 in.; 1992, 15 in.; 1991, 32 in. These data indicate that R_n and R_p can vary with the amount of stormwater inflow to the lakes, but might be relatively constant below a threshold stormwater input of 15 in.

The R_n values calculated for the Winter Park lakes are in the lower range of values computed for other Florida lakes (fig. 27). This could indicate that the Winter Park lakes are more effective in fixing nitrogen than other lakes, or it could indicate an error in the nitrogen budget. However, the R_n values are not extremely low compared to other Florida lakes. The R_p values calculated for the Winter Park lakes are within the range of those calculated for other lakes with similar hydraulic loading (fig. 27). This general similarity of R_n and R_p values for the Winter Park chain of lakes to those estimated for other lakes suggests that estimates of nutrient inputs to the Winter Park lakes are not widely in error. This supports the use of the modified Dillon-Rigler model for predicting changes in lake nutrient concentrations in response to changes in inflow nutrient loading.

Potential Effects of Stormwater Treatment

Reduction of nutrients in stormwater inflow to the lakes probably would be the most practical method for improving or maintaining lake water quality because the other sources of nutrients are more diffuse and generally contain lower concentrations. The Dillon-Rigler model was used to predict steady-state lake nitrogen and phosphorus concentration as a function of percent nutrient removal in stormwater. In judging the significance of lake nutrient-concentration reductions, the criteria of Baker and others (1981) for Florida lakes are used: lakes are considered to be in a mesotrophic state (moderately enriched) if nitrogen

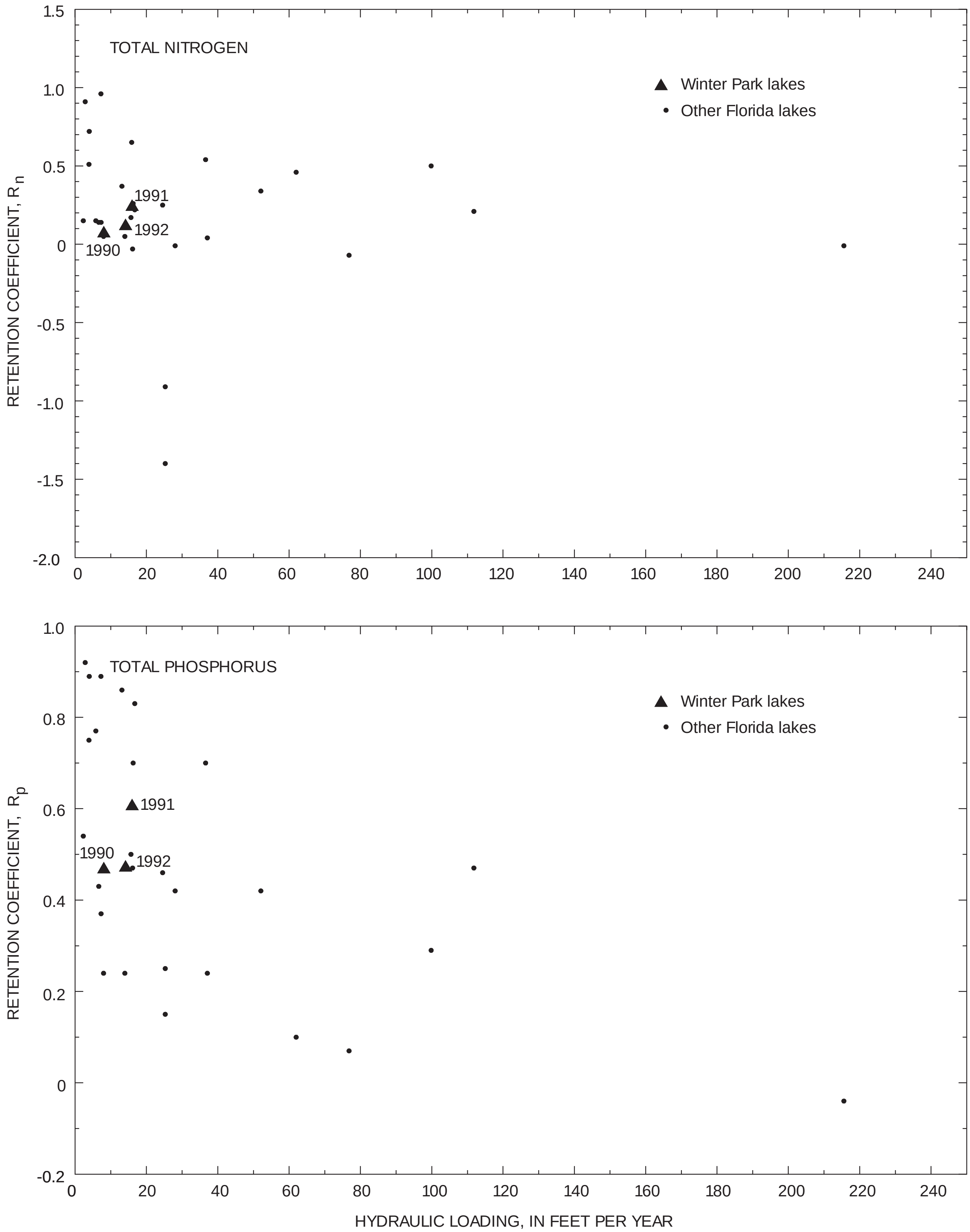

Figure 27. Nitrogen and phosphorus retention coefficients in Florida lakes (Data for other Florida lakes are from U.S. Environmental Protection Agency, 1977).

concentrations are 0.5 mg/L or higher, or phosphorus concentrations are 0.025 mg/L or higher; and the lakes are considered to be in a eutrophic state (highly enriched) if the nitrogen concentrations are 1.0 mg/L or higher, or phosphorus concentrations are 0.05 mg/L or higher. Because the 3 study years represented a wide range in precipitation and storm runoff, predicted effects of stormwater treatment were made for each year using the retention coefficients determined for that year.

It should be emphasized that input-output models, such as the Dillon-Rigler model used in this study, are relatively simple representations of lake systems and apply only to steady-state conditions. Also, there is some degree of uncertainly in quantity and quality of ground-water inflow and quantity of ground-water outflow. Therefore, the following simulations of nutrient concentrations should not be regarded as being exact, but rather as estimates intended to determine the usefulness of treating stormwater inflow to the lakes. Yearly time periods may not represent steady-state conditions, so the simulations should be regarded as representative of steady-state periods of varying amounts of runoff in assessing possible effects of stormwater treatment. Thus, 1990 should be viewed as representative of periods with low rainfall, 1991 as representative of periods of high rainfall, and 1992 as representative of periods of average rainfall. The actual time period needed to approximate steady-state conditions may be several years, so the simulations made for 1990, 1991, and 1992 should not be interpreted as representing effects of stormwater treatment that would occur within 1 year.

Stormwater inflow to the lakes was only 4 in. during 1990, or about 4 percent of the total inflow of 98 in. Because of the small quantity of stormwater inflow, predicted treatment effects are relatively small (fig. 28). The steady-state lake nitrogen and phosphorus concentrations with no stormwater treatment are predicted to be 0.85 and 0.034 mg/L, respectively, and with full treatment (all nitrogen and phosphorus removed from stormwater) the predicted lake concentrations are 0.75 mg/L (nitrogen) and 0.026 mg/L (phosphorus). Thus, even with the complete removal of nitrogen and phosphorus from stormwater, the lakes still would be in a mesotrophic state with respect to both nutrients because of the nutrient input from rainfall, ground-water seepage, and surface inflow.

Stormwater inflow to the lakes in 1991 was 32 in., or about 17 percent of the total inflow of 192 in. Stormwater inflow transported more than half of the phosphorus and about 41 percent of the nitrogen to the lakes and contributed more nitrogen and phosphorus than any other source. Without treatment, the predicted steady-state nitrogen and phosphorus concentrations are 0.80 and 0.039 mg/L, respectively. With complete nutrient removal from the stormwater inflow, the predicted steady-state lake nitrogen and phosphorus concentrations drop to 0.47 and .015 mg/L, respectively, below the mesotrophic level. Though complete nutrient removal is impractical, the model shows that reductions of nutrient levels in stormwater inflow could be beneficial to the lakes.

When the model was applied to data from 1992, a year with near-normal rainfall, results indicated that removal of nitrogen and phosphorus from stormwater inflow would lower lake nitrogen concentrations by about 0.2 mg/L and lake phosphorus concentrations by about 0.017 mg/L. Other inputs of nutrients would still cause the lakes to be in a mesotrophic state with respect to nitrogen but not phosphorus.

These modeling results indicate that reduction in nutrient content of stormwater inflow could benefit the lakes through lower lake phosphorus and nitrogen concentrations, except during periods with below-normal rainfall when other sources of nutrients are more important. However, except during high-rainfall periods, even complete removal of nutrients from stormwater could not lower lake concentrations of total nitrogen to levels below those considered to be mesotrophic.

Possible effects of uncertainties in estimates of inflow-outflow quantities on simulated nutrient concentrations were investigated by a sensitivity analysis. In this analysis, the same sets of inflow-outflow data used to assess the sensitivity of the constituent budgets to flow quantities were used. Data for 1992 were used because that year had about average rainfall and no change in lake storage.

The highest estimates of total nitrogen and phosphorus in lake water, with no removal of nitrogen or phosphorus from stormwater, are for the case where the estimate of stormwater inflow was increased by 25 percent and ground-water inflow was reduced by the amount of the added stormwater (fig. 29). The lowest estimates of total nitrogen and phosphorus were for the case where ground-water inflow was increased by 100 percent, with ground-water outflow increased by

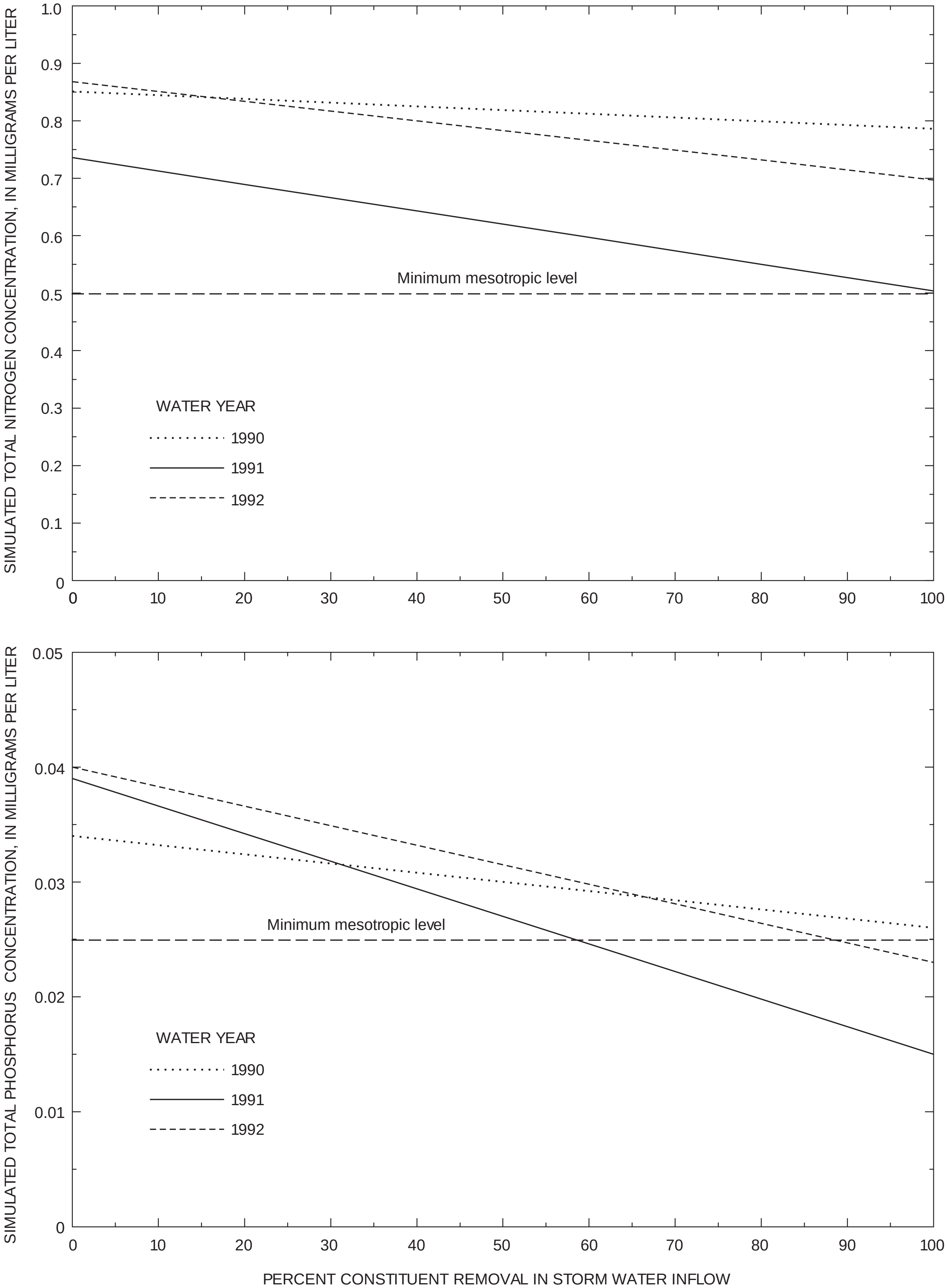

Figure 28. Simulated steady-state nitrogen and phosphorus concentrations as a function of percent removal in stormwater inflow.

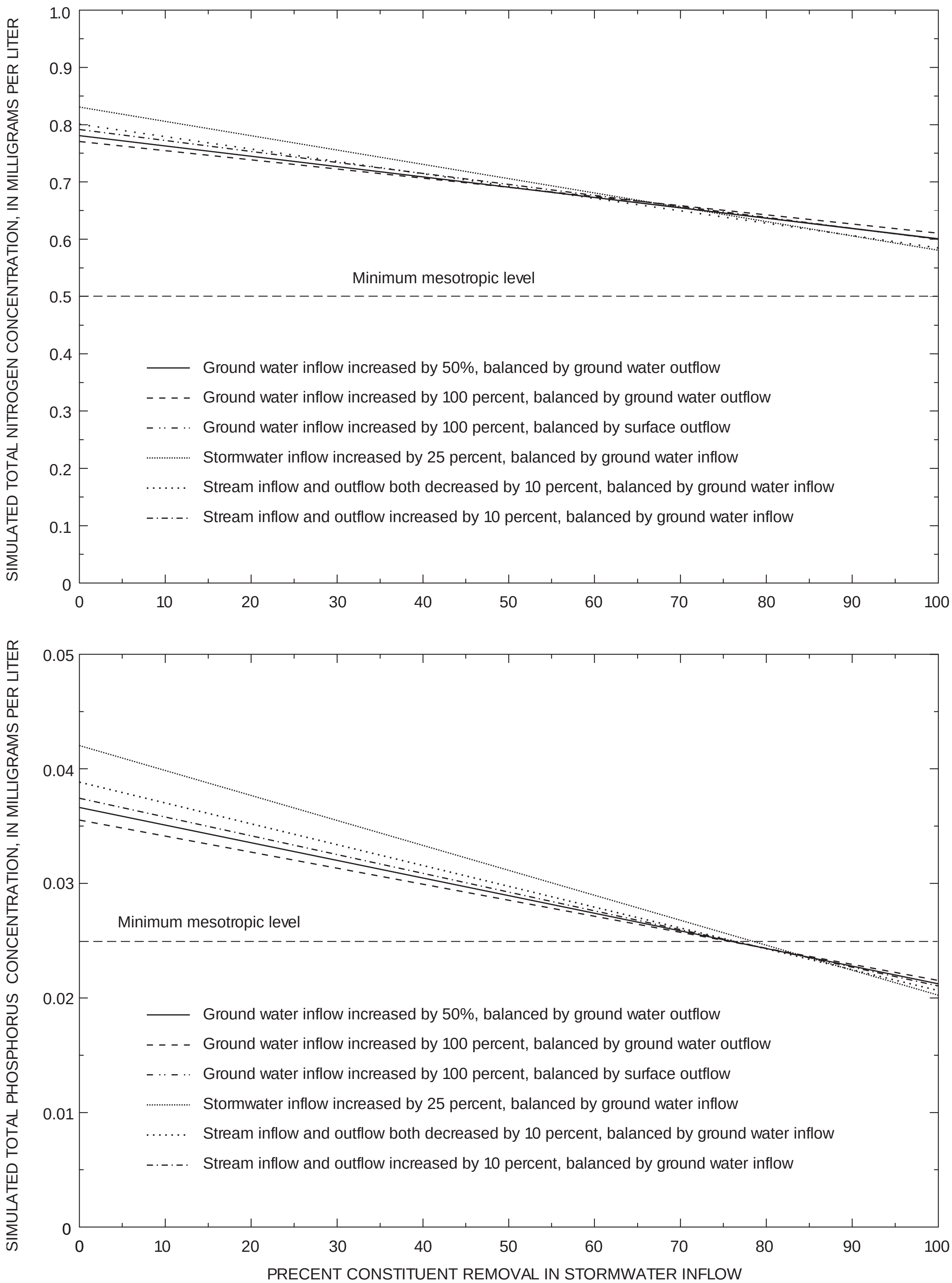

Figure 29. Sensitivity of simulated lake concentrations of total nitrogen and total phosphorus to changes in quantities of ground-water inflow and outflow, stream inflow and outflow, and stormwater inflow.

the same amount. The difference in simulated N and P (no removal of N or P from storm water) for these two extremes is only about 0.05 mg/L total nitrogen and 0.007 mg/L total phosphorus. With complete removal of nitrogen and phosphorus in storm water, the difference between the two extremes is even smaller. Therefore, the sensitivity analysis does not indicate that large errors in simulated concentrations of N and P could result from uncertainty in the flow budget.

SUMMARY AND CONCLUSIONS

The Winter Park chain of lakes (Lakes Maitland, Virginia, Osceola, and Mizell) have a combined area of about 900 acres and an immediate drainage area of about 3,100 acres. The lakes are an important recreational resource for the surrounding communities, but there is concern about the possible effects from stormwater runoff and nutrient-enriched ground-water seepage on the quality of water in the lakes.

Color fathometer surveys were used to compile bathymetric maps of the lakes. Mean depths range from about 11 to 15 feet and maximum depths range from about 30 feet in Lake Maitland to 21 feet in Lake Mizell. Three features that may be sinkholes were noted in Lake Maitland. If the hydraulic connection to the underlying Upper Floridan aquifer through such features is good, downward leakage of water through the lake bottom could be significant. Based on 14 samples of bottom sediments collected in Lakes Maitland and Virginia, the bottom material is predominately fine to medium sand (in the range of 0.1 to 1.0 millimeter).

Because the type and amount of vegetation in the littoral part of lakes can be important to the processes that affect eutrophication, a survey of littoral vegetation was made in March 1992. The most common species of emergent vegetation in terms of percent of total vegetated area include torpedo grass, cattail, and elephant ear. Plant similarity indices for the four lakes indicate little difference in terms of species present. Nuisance vegetation did not seem to be a problem in the lakes.

The lakes receive water from several sources: rainfall on lake surfaces, inflow from other surface-water bodies, stormflow that enters the lakes through storm drains or by direct runoff from land adjacent to the lakes, and from ground-water seepage. Rainfall, surface-inflow, and lake-stage data were collected from October 1, 1989, to September 30, 1992, so that flow budgets could be calculated for the lakes. Stormflow and ground-water seepage, more difficult to measure, were estimated for the 3 years of the study by evaluating stage hydrographs.

Water leaves the lakes by evaporation, by surface outflow, and by ground-water outflow. Of the three, only surface outflow can be measured directly. Lake evaporation was estimated to be 80 percent of pan evaporation. Ground-water outflow was calculated by analyzing lake stage recessions during dry periods. The results were consistent with estimates based on the head difference between the lakes and the underlying Upper Floridan aquifer, and the estimated thickness of sediments separating the two. The estimated ground-water outflow rate also is consistent with vertical leakage rates derived from ground-water flow modeling.

Flow budgets were calculated for the 3 years of the study. In water year 1992 (a year with about average rainfall), inflow consisted of rainfall, 48 inches (in.); stormflow, 15 in.; surface inflow, 67 in.; and ground water, 40 in. The calculated outflows were evaporation, 47 in.; surface outflow, 90 in.; ground water, 33 in.

In addition to flow data, water-quality data were used to calculate nutrient budgets for the lakes. Bimonthly water samples were collected for 3 years at sites in the lakes and at surface-inflow and -outflow sites, and were analyzed for physical characteristics, dissolved oxygen, pH, specific conductance, major ions, nutrients, and chlorophyll. Specific conductance ranged from about 190 to 230 microsiemens per centimeter in Lakes Maitland, Virginia, and Osceola and from about 226 to 260 microsiemens per centimeter in Lake Mizell. The difference probably is because Lake Mizell is smaller and somewhat isolated from the flow system of the other lakes. The median concentrations of total ammonia-plus-organic nitrogen in all the lakes ranged from 0.79 to 0.99 milligrams per liter (mg/L). Median total phosphorus concentrations range from less than 0.02 to 0.20 mg/L. Samples collected from near the bottom of Lakes Virginia and Osceola had lower temperature and dissolved oxygen and higher specific conductance and ammonia concentrations than the depth-integrated samples.

The water quality in the Winter Park lakes generally is fair to good, based on a trophic-state index used by the Florida Department of Environmental Protection for assessing the tropic state of Florida lakes. This index was determined from median total nitrogen, total phosphorus, and chlorophyll-*a* concentrations, and median Secchi-disk transparency for all lakes for the period September 1989 to June 1992.

Stormwater samples were collected for 17 storms at one site and 16 storms at another storm-drain site on Lake Osceola. Median total nitrogen concentrations were 2.23 and 3.06 mg/L and median total phosphorus concentrations at the sites were 0.40 and 0.34 mg/L. Experiments with leaf litter indicate that debris traps around storm drains undoubtedly reduce the volume of large debris entering the lakes. However, the traps do little to reduce the loads of nutrients entering the lakes because dissolved loads contribute the largest part of the total nutrient concentrations.

Based on a one-time sampling of 20 sites around the lakes, surficial ground-water quality is highly variable. Nutrient concentrations also were highly variable and could not be correlated to the proximity of septic tanks. Fertilizer probably is the major source of nutrients in the surficial ground water.

Nutrient budgets were calculated for the lakes for the 3 years of the study. The most variable source of nutrient loading to the lakes is stormwater. Models of nutrient loading were also calculated for the lakes using the Dillon-Rigler (1974) equation as modified by Baker and others (1981). These models indicate that the Winter Park chain of lakes are in the lower range of retention values for nitrogen compared to other Florida lakes and about average for phosphorus. The modeling indicates that reduction of nutrients in stormflow would probably improve lake-water quality; however, even with complete removal of nitrogen and phosphorus from stormwater, the lakes might still be mesotrophic during periods of below-average rainfall because of the input from the other sources of inflow to the lakes.

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Littoral Vegetation

By Brian Beckage *and* W. Scott Gain

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INTRODUCTION

The littoral zone of a lake is the area in which the gradual transition from terrestrial to submerged aquatic vegetation occurs. A section across a typical lake edge is shown in figure 1. Plant species on the landward side include overstory trees such as red maple, bald cypress, southern magnolia, and chinaberry. Toward the lake, these species give way to woody shrubs and small trees such as willow, wax myrtle, Brazilian pepper, and water primrose and, finally, to patches of cattails, various grasses, rushes, and other assorted emergent, herbaceous species. As the water deepens at the edge of the littoral zone, floating plants--such as the yellow cow lily--and submerged aquatic plants--such as tapegrass and Illinois pondweed--predominate.

Emergent littoral vegetation is rooted below the water surface for at least part of the year, but has aerial leaves and reproductive structures. This vegetation is highly productive with respect to the synthesis of organic material because it is able to utilize the resources of two environments: the higher water level and nutrient availability of the lake, and the much greater availability of atmospheric oxygen and carbon dioxide in the terrestrial environment (Wetzel, 1975, p. 355). In Florida, littoral vegetation can be particularly prolific because of the long growing season, intense solar radiation, and relatively shallow depths of lakes (Brenner and others, 1991, p. 381).

The vegetation in the littoral zone performs a variety of important functions which support other facets of the lake ecosystem. Within the lake, this vegetation is an important basal component of herbivorous and detrivorous food webs and provides a substrate for algae and other microfloral components of the lake ecosystem, as well as a protective environment for the reproduction of much of the lake fauna. The littoral zone is particularly important to fish reproduction because it provides a foraging ground as well as protection from predators. Similarly, the emergent vegetation in the littoral zone provides shelter and foraging grounds for birds, terrestrial mammals, and reptiles. Plants in the littoral zone play an important part in nutrient cycling within the lake by taking up nutrients from the sediments and releasing them into the water column where they can be utilized by other organisms. The littoral zone is a major source of organic matter into the lake because of the great productivity of emergent vegetation, along with the large amount of attached algae.

Anthropogenic changes in water quality and quantity can have a considerable effect on the diversity and abundance of emergent aquatic vegetation. Changes in land use in the drainage basin of a lake can cause increased lake-water concentrations of nitrogen and phosphorous and create conditions under which exotic plant species can displace native vegetation. The erosion and deposition of sediment associated with stormwater runoff into lakes also may be important because of the displacement of established vegetation associated with bank scouring and filling which provides conditions favorable to the establishment of invasive, exotic species.

The extent and character of emergent vegetation in a lake also is strongly affected by the variability and extremes of water levels in the lake. Many plants in the littoral zone can only germinate and become established during periods of low water or other extreme conditions. Bald cypress is one such example. After initial establishment during a period of low water, bald cypress are very tolerant of prolonged flooding as long as they are not completely submerged. Many other plant species cannot replace themselves without natural water-level fluctuations, resulting in changes in the species composition in the littoral zone as senescent plants die. Changes in sunlight intensity created by developing forest canopy and invasive species can significantly reduce the rate of development of other aquatic vegetation in streams.

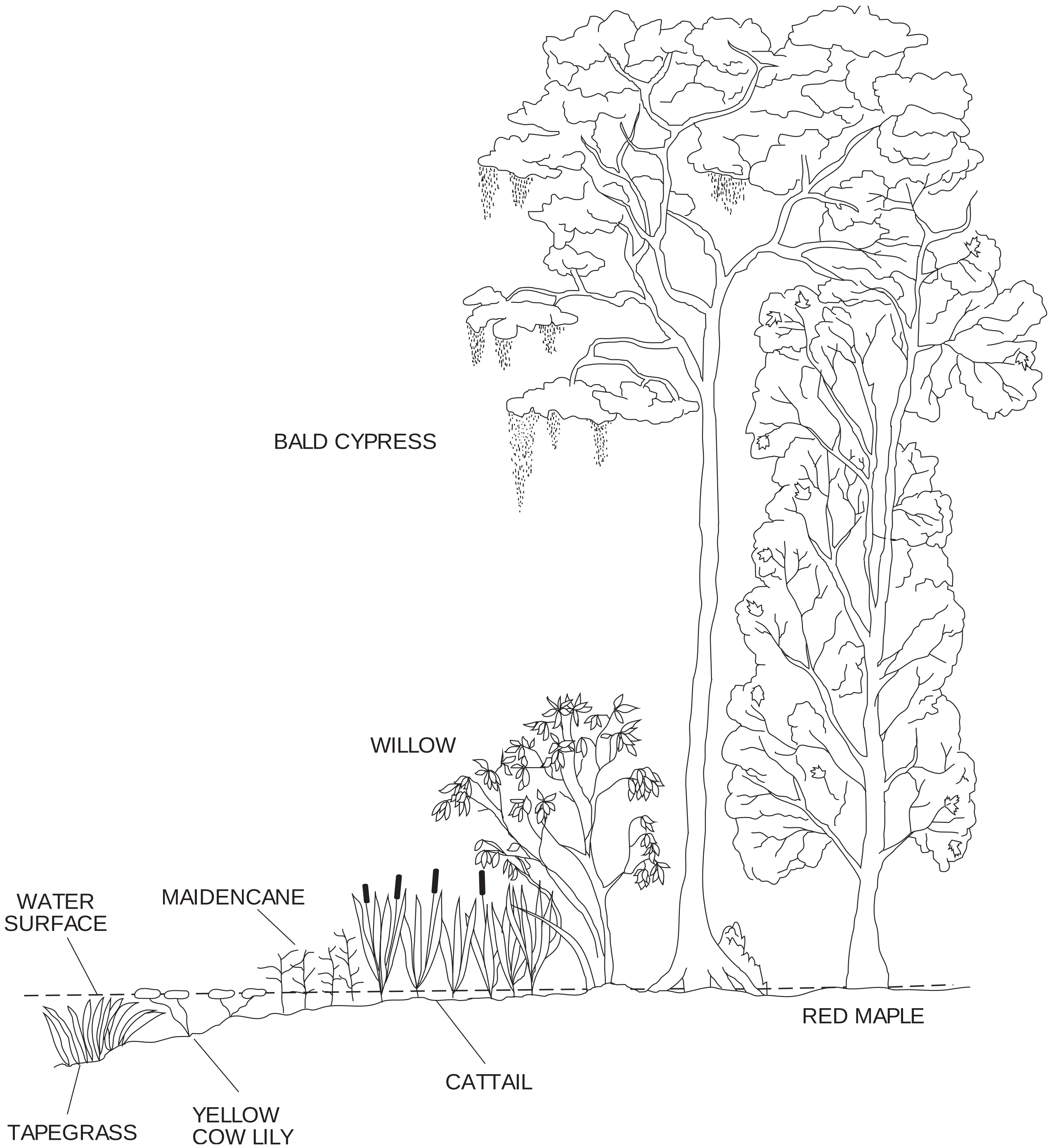

Figure 1. Section across a lake littoral zone, showing typical plant species.

Canfield and Hoyer (1987, p. 4), showed that shade provided by streambank vegetation was a dominant factor controlling the location and abundance of aquatic plants in the Little Wekiva River in Florida. Although this finding was specific to a riparian system, canopy development probably plays a similarly important role along lake margins.

METHODS

A survey of the emergent littoral vegetation in Lakes Maitland, Mizell, Osceola, and Virginia was made in March 1992 to document the approximate distribution and density of dominant emergent plant species in the littoral zone of the Winter Park chain of lakes. The results of this survey were intended to provide a baseline for evaluation of future changes in speciation in aquatic habitat in response to basin and lake water management. Prior to the field survey, the perimeter of each lake was divided into 100 ft sections on aerial photographs using topographic and other visible features. These features were used in the field to delineate the section boundaries. Within each section, the areal coverage of each species was estimated by sight. Estimates of the extent of the shoreline containing emergent vegetation and the average distance this zone extended into the lake were recorded.

Plants generally were identified to species, but in some instances only to family, using descriptions by Tarver and others (1978). Extremely abundant submerged aquatic plants also were noted. In certain instances, nomenclature follows that of Wunderlin (1992). The data were used to compute relative areal coverage and the frequency of occurrence of species in each lake. Relative areal coverage represents the percentage of the total area of emergent littoral vegetation dominated by a particular species. Woody species (trees and shrubs) were excluded from relative areal coverage values because areal coverage for woody species cannot readily be compared with areal coverage for nonwoody species. Frequency of occurrence, calculated for all species, represents the percentage of sections in each lake in which a particular species occurred.

Results

The relative areal coverage and frequencies of occurrence for individual species are given for each lake (tables 1-4) and are illustrated in figures 2-3. A species list was compiled for each lake and a similarity index, comparing the species lists for each of the four lakes, was computed (fig. 4).

Lake Maitland, the largest of the four lakes, has an area of 470 acres. Forty-four percent of the shoreline area (which constitutes less than 1 percent of the total lake area) contains emergent vegetation. In Lake Maitland, torpedo grass was present in 64 percent of the littoral sections, followed by bald cypress in 56 percent of the sections. Cattail, duck potato, and pickerelweed (*Pontederia lanceolata*) also were common: all three were found in approximately 25 percent of the lake sections. In terms of areal coverage, torpedo grass was by far the most dominant (44 percent of the vegetated littoral area), followed by cattails (27 percent). Other species, each covering less than 7 percent of the littoral area, individually comprise the remainder of the vegetated area. One submerged aquatic, Illinois pondweed, was very common, and another submerged aquatic, tapegrass, was less common.

In Lake Virginia, 62 percent of the shoreline was vegetated. This vegetated area along the shoreline represents about 1 percent of the total lake area of 224 acres. In Lake Virginia, cattails were found in 57 percent of the littoral sections, closely followed by torpedo grass in 45 percent of the sections. Elephant ear was present in 32 percent of the sections, and bald cypress, water primrose, yellow cow lily, and willow were present in 23, 21, 18, and 16 percent of the sections, respectively. In terms of areal coverage, cattails were far more abundant than any other species, covering 54 percent of the vegetated littoral area. Torpedo grass was the next most abundant species, covering 12 percent of the vegetated area; followed by yellow cow lily and maidencane, each covering 8 percent of the area; and various other species were the least abundant with individual areas covering 5 percent or less of the vegetated area.

Lake Osceola has an area of 154 acres. Forty-six percent of the shoreline area (less than 1 percent of the total lake area) contained emergent vegetation. In Lake Osceola, elephant ear was present in 49 percent of the littoral sections, closely followed by torpedo grass in 44 percent of the sections. Bald cypress, pickerelweed, flat sedge, pennywort, and water primrose were all relatively frequent, present in 35, 35, 29, 27, and 26 percent of the sections, respectively. No species was clearly dominant in terms of areal coverage. Torpedo grass, Panicum species, and yellow cow lily were most abundant in area, covering 19, 15, and 12 percent of the vegetated area around the lake, respectively. Five other species (fragrant water lily, elephant ear, pennywort, pickerelweed, and cattail) each covered more than 5 percent of the total vegetated littoral area.

Lake Mizell is the smallest of the four lakes with an area of 66 acres. In Lake Mizell, 76 percent of the shoreline area (about 2 percent of the total lake area) was vegetated. Cattails were most frequent, occurring in 78 percent of the littoral sections. Elephant ear, duck potato, water primrose, bald cypress, and water hemlock were the next most frequent, found in 39, 33, 29, 27, and 25 percent of the sections, respectively. Cattails were clearly dominant in areal coverage (82 percent of the vegetated littoral area). The next most abundant species were water hemlock and elephant ear, covering 5 and 4 percent of the vegetated area, respectively.

DISCUSSION

Many factors such as disturbance of the shoreline and its overstory, nutrient enrichment of the waters, and erosion and sedimentation, interact with natural conditions to determine the species composition of a lake. The similarity index (fig. 4) which shows the commonality of species found in each of the four lakes indicates that the lakes generally have 70-80 percent of species in common. This is not surprising considering the proximity and connection between the four water bodies, as well as the similar land use in the drainage basins of the lakes.

However, when frequency and coverage are considered, the lakes are less similar. Lake Maitland was primarily dominated by torpedo grass, followed by cattails, with bald cypress present in over 50 percent of the lake sections. Lake Virginia was dominated by cattails, followed by torpedo grass, with bald cypress and water primrose in about 25 percent of the sections. Lake Osceola was not clearly dominated by any species, but torpedo grass and other Panicum species were most prolific, with bald cypress in 33 percent and water primrose in 25 percent of the sections. Interestingly, cattails notably were suppressed, while elephant ear was quite frequent. Lake Mizell was overwhelmingly dominated by cattails, followed by water primrose. Water primrose was the most frequent woody species, closely followed by bald cypress, both present in 25-33 percent of the sections.

Table 1. Species of emergent vegetation observed in March 1992, Lake Maitland

[Total lake area, 470 acres. a, indicates a woody species; --, not present; absence of common name means species were undifferentiated]

Species code	Frequency of occurrence within sections (percent)	Relative areal coverage (percent)	Scientific name	Common name
ACRU	0.5	a	*Acer rubrum*	red maple
ALPH	--	--	*Alternanthera philoxeroide*	alligator weed
CAFL	--	--	*Castalia flava*	yellow water lily
CAOD	4.5	1.02	*Castalia odorata*	fragrant water lily
CEDE	0.5	0.04	*Ceratophyllum demersum*	coontail/hornwort
CEOC	--	a	*Cephalanthus occidentalis*	buttonbush
CIME	1.0	0.34	*Cicuta mexicana*	water hemlock
CLJA	1.5	0.09	*Cladium jamaicense*	sawgrass
COES	17.5	2.66	*Colocasia esculentum*	elephant ear
CYOD	16.5	1.67	*Cyperus odoratus*	flat sedge
CYPE	1.0	0.08	*Cyperaceae*	sedge family
EICR	0.5	0.01	*Eichhornia crassipes*	water hyacinth
GRAM	9.0	6.90	*Gramineae*	grass family
HYUM	11.5	2.05	*Hydrocotyle umbellata*	pennywort
IRHE	--	--	*Iris hexagona*	praire iris
JUEF	--	--	*Juncus effusus*	soft rush
LUOC	13.0	a	*Ludwigia octovalis*	water primrose
MAGR	--	a	*Magnolia grandiflora*	southern magnolia
MEAZ	--	a	*Melia azedarach*	chinaberry
MUSP	2.0	0.16	*Musa species*	banana
MYCE	5.5	a	*Myrica cerifera*	wax myrtle
NUAD	2.5	0.68	*Nuphar advena*	yellow cow lily
PAHE	9.0	4.46	*Panicum hemitomon*	maidencane
PAPU	2.5	0.77	*Panicum purpurascens*	para grass
PARE	64.0	43.53	*Panicum repens*	torpedo grass
PASP	1.0	0.13	*Panicum species*	
POCO	0.5	0.01	*Pontederia cordata*	pickerelweed
POHY	--	--	*Polygonum hydropiperoides*	smartweed
POLA	24.0	3.98	*Pontederia lanceolata*	pickerelweed
SALA	26.0	3.10	*Sagittaria lancifolia*	duck potato/arrowhead
SASP	6.5	a	*Salix species*	willow
SCCA	6.5	1.52	*Scirpus californicus*	giant bulrush
SCTE	--	a	*Schinus terebinthefolius*	Brazilian pepper

Table 1. Species of emergent vegetation observed in March 1992, Lake Maitland --Continued

[Total lake area, 470 acres. a, indicates a woody species; --, not present; absence of common name means species were undifferentiated]

Species code	Frequency of occurrence within sections (percent)	Relative areal coverage (percent)	Scientific name	Common name
SCVA	1.0	0.08	*Scirpus validus*	soft-stem bulrush
TADI	55.5	a	*Taxodium distichum*	bald cypress
TRFL	--	--	*Tradescantia fluminensis*	wandering jew
TYSP	26.0	26.65	*Typha species*	cattail
VISP	0.5	0.06	*Viburnum species*	

Table 2. Species of emergent vegetation observed in March 1992, Lake Virginia

[Total lake area, 224 acres. a, indicates a woody species; --, not present; absence of common name means species were undifferentiated]

Species code	Frequency of occurrence within sections (percent)	Relative areal coverage (percent)	Scientific name	Common name
ACRU	2.0	a	*Acer rubrum*	red maple
ALPH	1.0	0.09	*Alternanthera philoxeroide*	alligator weed
CAFL	1.0	0.26	Castalia flava	yellow water lily
CAOD	2.0	0.10	Castalia odorata	fragrant water lily
CEDE	--	--	*Ceratophyllum demersum*	coontail/hornwort
CEOC	--	a	Cephalanthus occidentalis	buttonbush
CIME	5.0	0.61	Cicuta mexicana	water hemlock
CLJA	--	--	*Cladium jamaicense*	sawgrass
COES	32.5	5.51	*Colocasia esculentum*	elephant ear
CYOD	4.0	0.92	*Cyperus odoratus*	flat sedge
CYPE	2.0	0.11	Cyperaceae	sedge family
EICR	4.0	0.32	*Eichhornia crassipes*	water hyacinth
GRAM	--	--	Gramineae	grass family
HYUM	10.5	1.56	*Hydrocotyle umbellata*	pennywort
IRHE	--	--	Iris hexagona	praire iris
JUEF	--	--	Juncus effusus	soft rush
LUOC	21.0	a	Ludwigia octovalis	water primrose
MAGR	1.0	a	Magnolia grandiflora	southern magnolia
MEAZ	1.0	a	*Melia azedarach*	chinaberry
MUSP	--	--	Musa species	banana
MYCE	2.0	a	Myrica cerifera	wax myrtle
NUAD	17.5	8.13	Nuphar advena	yellow cow lily
PAHE	12.5	7.68	Panicum hemitomon	maidencane
PAPU	11.5	2.32	Panicum purpurascens	para grass
PARE	45.0	11.91	Panicum repens	torpedo grass
PASP	12.5	2.76	Panicum species	
POCO	1.0	0.03	Pontederia cordata	pickerelweed
POHY	1.0	0.03	Polygonum hydropiperoides	smartweed
POLA	13.5	2.31	*Pontederia lanceolata*	pickerelweed
SALA	6.0	0.88	*Sagittaria lancifolia*	duck potato/arrowhead
SASP	15.5	a	Salix species	willow
SCCA	4.0	0.22	*Scirpus californicus*	giant bulrush
SCTE	--	a	*Schinus terebinthefolius*	Brazilian pepper
SCVA	--	--	*Scirpus validus*	soft-stem bulrush
TADI	23.0	a	*Taxodium distichum*	bald cypress
TRFL	1.0	0.04	Tradescantia fluminensis	wandering jew
TYSP	57.5	54.20	*Typha species*	cattail
VISP	--	--	Viburnum species	

Table 3. Species of emergent vegetation observed in March 1992, Lake Osceola

[Total lake area, 154 acres. a, indicates a woody species; --, not present; absence of common name means species were undifferentiated]

Species code	Frequency of occurrence within sections (percent)	Relative areal coverage (percent)	Scientific name	Common name
ACRU	1.0	a	*Acer rubrum*	red maple
ALPH	--	--	*Alternanthera philoxeroide*	alligator weed
CAFL	--	--	*Castalia flava*	yellow water lily
CAOD	10.5	9.29	*Castalia odorata*	fragrant water lily
CEDE	--	--	*Ceratophyllum demersum*	coontail/hornwort
CEOC	1.0	a	*Cephalanthus occidentalis*	buttonbush
CIME	9.5	1.94	*Cicuta mexicana*	water hemlock
CLJA	--	--	*Cladium jamaicense*	sawgrass
COES	49.5	7.64	*Colocasia esculentum*	elephant ear
CYOD	29.5	4.89	*Cyperus odoratus*	flat sedge
CYPE	2.0	0.85	*Cyperaceae*	sedge family
EICR	--	--	*Eichhornia crassipes*	water hyacinth
GRAM	--	--	*Gramineae*	grass family
HYUM	27.5	5.11	*Hydrocotyle umbellata*	pennywort
IRHE	6.5	0.69	*Iris hexagona*	praire iris
JUEF	1.0	0.08	*Juncus effusus*	soft rush
LUOC	26.5	a	*Ludwigia octovalis*	water primrose
MAGR	1.0	a	*Magnolia grandiflora*	southern magnolia
MEAZ	--	a	*Melia azedarach*	chinaberry
MUSP	--	--	*Musa species*	banana
MYCE	2.0	a	*Myrica cerifera*	wax myrtle
NUAD	20.0	11.72	*Nuphar advena*	yellow cow lily
PAHE	9.5	2.35	*Panicum hemitomon*	maidencane
PAPU	13.5	4.84	*Panicum purpurascens*	para grass
PARE	44.0	18.56	*Panicum repens*	torpedo grass
PASP	21.0	15.17	*Panicum species*	
POCO	1.0	0.09	*Pontederia cordata*	pickerelweed
POHY	--	--	*Polygonum hydropiperoides*	smartweed
POLA	34.5	5.97	*Pontederia lanceolata*	pickerelweed
SALA	20.0	2.02	*Sagittaria lancifolia*	duck potato/arrowhead
SASP	9.5	a	*Salix species*	willow
SCCA	9.5	2.18	*Scirpus californicus*	giant bulrush
SCTE	1.0	a	*Schinus terebinthefolius*	Brazilian pepper
SCVA	4.0	0.89	*Scirpus validus*	soft-stem bulrush
TADI	34.5	a	*Taxodium distichum*	bald cypress
TRFL	--	--	*Tradescantia fluminensis*	wandering jew
TYSP	10.5	5.70	*Typha species*	cattail
VISP	--	--	*Viburnum species*	

Table 4. Species of emergent vegetation observed in March 1992, Lake Mizell

[Total lake area, 66 acres. a, indicates a woody species; --, not present; absence of common name means species were undifferentiated]

Species code	Frequency of occurrence within sections (percent)	Relative areal coverage (percent)	Scientific name	Common Name
ACRU	--	a	*Acer rubrum*	red maple
ALPH	--	--	*Alternanthera philoxeroide*	alligator weed
CAFL	--	--	*Castalia flava*	yellow water lily
CAOD	6.0	0.91	*Castalia odorata*	fragrant water lily
CEDE	--	--	*Ceratophyllum demersum*	coontail/hornwort
CEOC	2.0	a	*Cephalanthus occidentalis*	buttonbush
CIME	25.5	4.53	*Cicuta mexicana*	water hemlock
CLJA	4.0	0.10	*Cladium jamaicense*	sawgrass
COES	39.0	4.41	*Colocasia esculentum*	elephant ear
CYOD	6.0	0.23	*Cyperus odoratus*	flat sedge
CYPE	6.0	0.55	*Cyperaceae*	sedge family
EICR	--	--	*Eichhornia crassipes*	water hyacinth
GRAM	--	--	*Gramineae*	grass family
HYUM	6.0	0.15	*Hydrocotyle umbellata*	pennywort
IRHE	--	--	*Iris hexagona*	praire iris
JUEF	--	--	*Juncus effusus*	soft rush
LUOC	29.5	a	*Ludwigia octovalis*	water primrose
MAGR	--	a	*Magnolia grandiflora*	southern magnolia
MEAZ	--	a	*Melia azedarach*	chinaberry
MUSP	--	--	*Musa species*	banana
MYCE	10.0	a	*Myrica cerifera*	wax myrtle
NUAD	8.0	1.22	*Nuphar advena*	yellow cow lily
PAHE	13.5	1.48	*Panicum hemitomon*	maidencane
PAPU	--	--	*Panicum purpurascens*	para grass
PARE	6.0	0.35	*Panicum repens*	torpedo grass
PASP	2.0	0.41	*Panicum species*	
POCO	--	--	*Pontederia cordata*	pickerelweed
POHY	--	--	*Polygonum hydropiperoides*	smartweed
POLA	10.0	0.92	*Pontederia lanceolata*	pickerelweed
SALA	33.5	2.77	*Sagittaria lancifolia*	duck potato/arrowhead
SASP	17.5	a	*Salix species*	willow
SCCA	--	--	*Scirpus californicus*	giant bulrush
SCTE	2.0	a	*Schinus terebinthefolius*	Brazilian pepper
SCVA	--	--	*Scirpus validus*	soft-stem bulrush
TADI	27.5	a	*Taxodium distichum*	bald cypress
TRFL	--	--	*Tradescantia fluminensis*	wandering jew
TYSP	78.5	81.97	*Typha species*	cattail
VISP	--	--	*Viburnum species*	

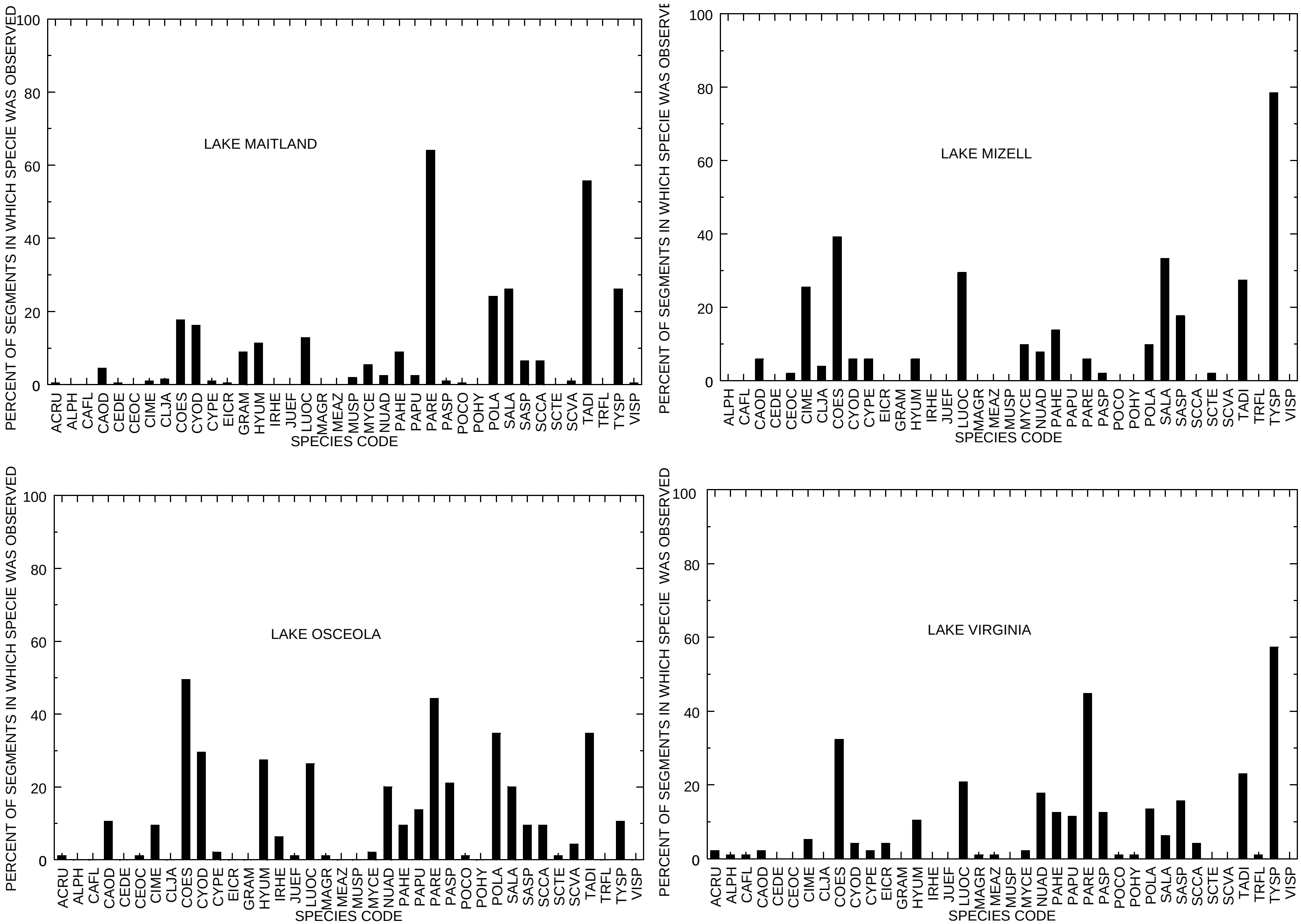

Figure 2. Frequency of occurence of emergent plant species.

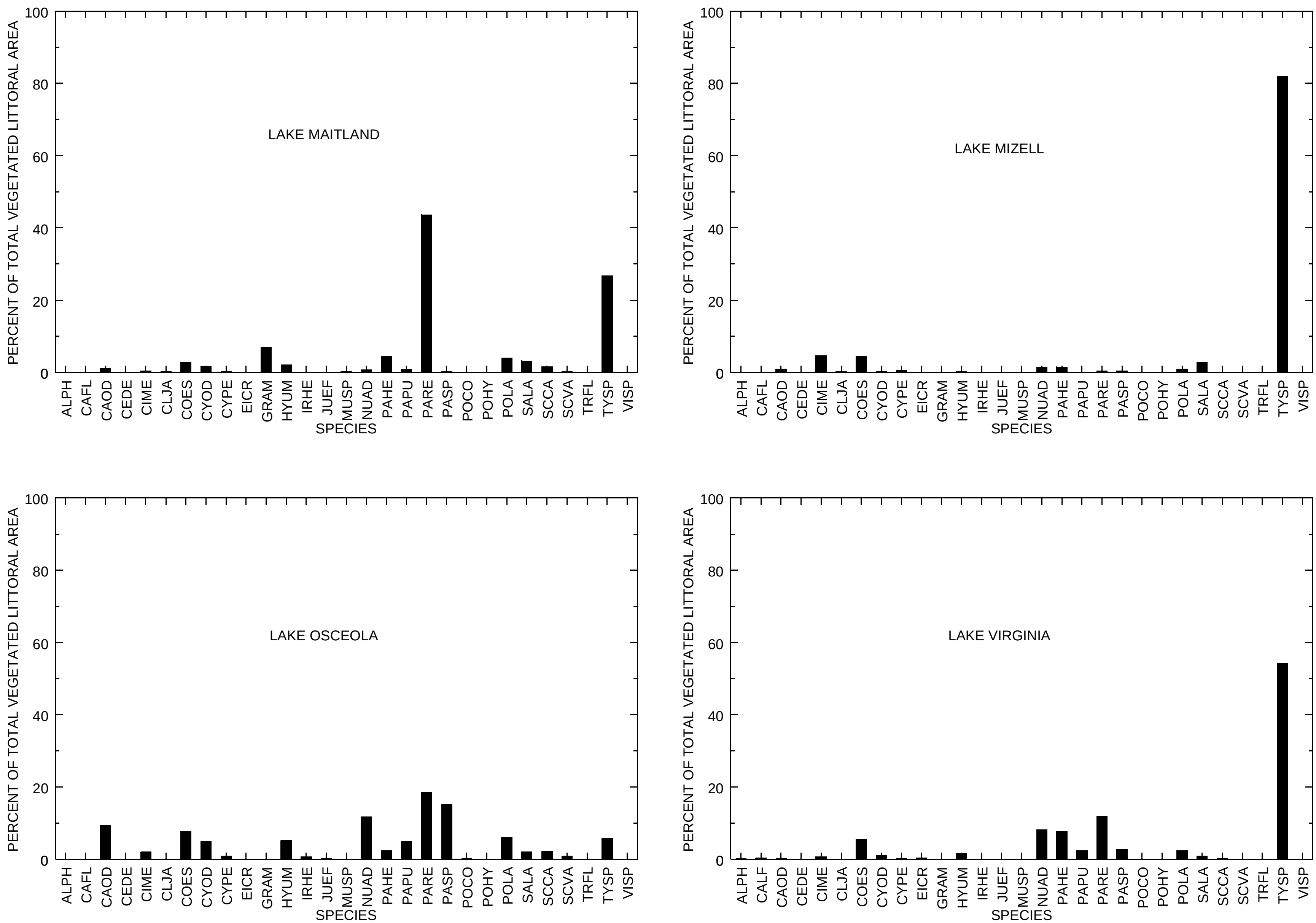

Figure 3. Relative areal coverage of emergent plant species.

Index of Similarity

	Lake Maitland	Lake Mizell	Lake Osceola	Lake Virginia
Lake Maitland	1.00	0.75	0.80	0.79
Lake Mizell	0.75	1.00	0.81	0.71
Lake Osceola	0.80	0.81	1.00	0.80
Lake Virginia	0.79	0.71	0.80	1.00

Index of similarity = 2C / (A + B)

Where A is the number of species in Lake A
B is the number of species in Lake B
C is the number of species in common between Lake A and Lake B

The index ranges from 0 to 1 with 1 indicating complete similarity
and 0 indicating complete dissimilarity.

Figure 4. Similarity indices for the Winter Park chain of lakes based on emergent plant species (based on Krebs, 1985, p. 447).

APPENDIXES

Appendix 1. Water-quality data for Lake Virginia 283517081204001

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported; <, less than].

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as $CaCO_3$)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L as N)	Nitrogen, NO_2 + NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
10-04-89	30.0	1.3.	5	191	--	8.1	50	0.010	<0.010	0.84	<0.020	<0.020	0.020	5.2	21	3.7	8.6	2.6	15	14	--	--	--
12-13-89	17.0	1.7	<5	197	8.4	7.8	53	<0.010	<0.010	0.66	<0.020	0.040	0.010	3.6	23	3.8	9.1	2.6	17	15	--	--	--
03-02-90	20.0	0.65	10	201	10.0	8.2	54	<0.010	<0.010	0.55	0.020	0.040	0.010	3.5	23	3.9	9.3	2.5	16	16	--	--	--
04-25-90	25.0	0.13	<5	204	8.7	8.8	59	0.020	<0.010	0.52	<0.020	0.040	0.010	4.5	24	4.0	9.5	2.2	17	16	--	--	--
06-26-90	30.0	1.8	5	210	--	8.2	60	0.070	<0.010	1.7	<0.020	0.040	0.020	4.9	25	4.1	10	2.7	17	16	--	--	--
09-04-90	30.0	0.58	10	209	6.7	7.7	57	0.030	<0.010	1.1	<0.020	0.030	0.020	5.1	24	4.3	10	2.6	17	15	--	--	--
10-24-90	27.5	0.64	10	216	7.0	8.0	60	<0.010	<0.010	0.74	<0.020	0.030	0.020	4.5	24	4.3	11	2.5	18	15	--	--	--
12-12-90	18.0	0.82	10	225	9.8	8.2	62	<0.010	<0.010	0.74	<0.020	0.050	0.020	5.0	25	4.4	11	2.8	19	17	--	--	--
02-28-91	17.5	1.3	5	231	9.1	8.4	66	0.010	0.010	0.79	0.020	0.020	0.010	4.2	27	4.7	11	2.8	18	17	--	--	--
04-30-91	29.5	0.94	10	208	10.4	8. 9	60	<0.010	<0.010	1.4	<0.020	0.050	0.020	4.0	25	4.1	10	2.4	17	15	--	--	--
06-25-91	30.5	0.68	5	215	9.5	9.1	53	<0.010	<0.010	1.1	<0.020	0.050	0.010	6.3	23	4.1	10	2.8	19	15	--	--	--
08-13-91	33.0	1.7	20	192	7.4	8.5	52	<0.010	<0.010	0.75	<0.020	0.030	0.010	5.7	21	3.6	9.0	2.2	16	15	--	--	--
10-29-91	25.5	4.4	15	200	9.0	8.2	53	0.020	0.010	1.0	<0.020	<0.010	<0.010	4.9	22	3.7	9.2	2.7	18	14	--	--	--
12-16-91	19.0	3.6	10	200	6.7	7.6	55	0.010	<0.010	0.87	<0.020	0.030	0.020	6.0	22	3.9	9.5	2.8	18	15	--	--	--
02-24-92	20.5	1.6	10	200	9.3	8.2	53	0.010	<0.010	0.81	<0.020	0.020	0.010	5.4	22	3.9	9.8	3.0	19	17	0.10	50	2
05-20-92	26.0	1.6	20	200	8.8	9.1	54	0.030	<0.010	1.6	<0.020	0.030	0.020	6.6	22	3.9	10	2.7	19	17	0.10	30	2

Appendix 2. Water-quality data for Lake Virginia West 28358081210201

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported; <, less than]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as Ca CO_3)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L as N)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolve (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
03-02-90	20.0	0.68	10	198	10.2	8.2	54	<0.010	<0.010	0.59	0.020	0.040	0.010	3.7	23	3.9	9.3	2.5	16	17	--	--	--
04-25-90	25.0	0.15	10	199	8.8	8.9	59	0.020	<0.010	0.57	<0.020	0.040	0.010	4.4	25	4.1	9.5	2.2	17	16	--	--	--
06-26-90	31.0	1.7	5	210	--	8.8	57	0.080	<0.010	1.3	<0.020	0.030	0.020	4.9	24	4.4	10	2.6	18	18	--	--	--
09-04-90	30.0	0.82	10	209	6.4	8.2	57	0.020	<0.010	1.2	<0.020	0.030	0.020	5.4	24	4.2	10	2.6	16	16	--	--	--
10-24-90	27.5	0.64	10	216	7.0	8.0	60	<0.010	<0.010	0.77	<0.020	0.040	0.020	4.6	24	4.3	11	2.6	18	15	--	--	--
12-12-90	18.0	1.2	10	227	9.3	8.0	62	0.010	<0.010	0.69	<0.020	0.040	0.010	5.0	26	4.5	10	2.9	19	17	--	--	--
02-28-91	18.0	1.4	10	231	9.0	8.5	66	0.010	<0.010	0.79	0.020	0.020	0.010	4.2	27	4.7	11	2.8	18	17	--	--	--
04-30-91	28.5	0.86	5	208	10.5	9.0	59	<0.010	<0.010	1.0	<0.020	0.040	0.020	4.0	24	4.0	10	2.6	17	16	--	--	--
06-25-91	30.5	0.51	5	214	9.1	9.0	54	<0.010	<0.010	0.77	<0.020	0.050	0.010	6.2	23	4.1	10	2.8	19	15	--	--	--
08-13-91	32.5	1.5	20	192	8.2	8.6	52	<0.010	<0.010	0.85	<0.020	0.030	0.010	5.8	21	3.5	9.0	2.1	16	15	--	--	--
10-29-91	25.0	4.4	15	200	7.7	7.8	53	0.020	0.010	1.2	0.020	<0.010	<0.010	5.0	22	3.7	9.2	2.7	18	15	--	--	--
12-16-91	19.0	3.0	10	200	7.3	7.7	54	0.020	<0.010	0.79	<0.020	0.050	0.020	5.4	22	3.8	9.6	2.7	18	15	--	--	--
02-24-92	20.5	2.2	10	200	9.5	8.1	54	0.010	<0.010	0.69	<0.020	0.020	0.010	5.3	22	3.8	9.9	2.8	19	18	0.10	40	2
05-20-92	26.0	1.6	20	200	9.0	9.1	55	0.020	<0.010	1.6	<0.020	0.030	0.020	6.5	22	3.8	10	2.6	19	17	0.10	40	2

Appendix 3. Water-quality data for Lake Mizell 283534081201801

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported; <, less than]

Date	Temperature water (°C)	Turbidity (Ntu))	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as Ca CO_3)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia,+ organic total (mg/L as N)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
10-04-89	30.0	1.3	5	246	--	8.2	46	0.010	<0.010	0.81	<0.020	<0.020	0.020	5.7	22	6.8	8.3	9.0	24	33	--	--	--
12-13-89	17.5	0.89	5	--	8.6	7.8	44	<0.010	<0.010	0.84	<0.020	0.040	0.010	4.0	22	6.7	9.0	9.2	23	34	--	--	--
03-02-90	20.0	0.66	5	250	8.6	7.7	45	0.030	<0.010	0.62	0.060	0.040	0.010	4.0	23	7.0	9.3	9.5	23	34	--	--	--
04-25-90	25.5	0.16	5	260	8.6	8.8	48	0.020	<0.010	0.53	<0.020	0.050	0.010	4.5	24	7.0	9.5	9.2	25	36	--	--	--
06-26-90	30.5	0.48	5	252	--	8.9	48	0.060	<0.010	1.4	<0.020	0.020	0.020	5.2	24	7.2	10	9.2	24	34	--	--	--
09-04-90	30.0	0.71	<5	250	6.3	7.6	47	0.010	<0.010	1.3	<0.020	0.030	0.030	5.5	23	6.6	9.5	8.5	22	30	--	--	--
10-24-90	28.0	0.56	<5	248	7.7	8.0	47	0.010	<0.010	0.74	<0.020	0.020	0.020	4.9	22	6.5	10	8.4	24	30	--	--	--
12-12-90	17.5	0.65	5	254	9.5	7.9	46	0.010	<0.010	0.83	<0.020	0.030	0.010	5.8	23	6.8	10	8.7	24	33	--	--	--
02-28-91	18.0	0.96	<5	259	9.4	8.5	49	0.010	<0.010	0.84	0.020	0.020	0.010	4.8	23	6.9	11	8.9	23	32	--	--	--
04-30-91	29.0	0.90	10	237	10.8	9.1	48	<0.010	<0.010	1.2	<0.020	0.030	0.020	4.6	22	6.1	9.5	7.7	22	28	--	--	--
06-25-91	30.5	0.47	5	243	10.2	9.1	42	0.010	<0.010	1.2	<0.020	0.050	0.020	7.5	21	6.1	9.8	8.1	24	29	--	--	--
08-13-91	33.0	1.0	20	229	6.7	8.0	43	<0.010	<0.010	0.83	<0.020	0.020	0.010	6.2	21	5.8	8.8	7.4	21	29	--	--	--
10-29-91	25.5	2.1	15	250	9.8	8.4	46	0.020	0.010	1.1	0.020	<0.010	<0.010	5.8	22	6.1	9.0	7.8	23	29	--	--	--
12-16-91	18.5	3.5	10	250	7.0	7.6	49	0.010	<0.010	1.1	<0.020	0.020	0.030	6.6	23	6.3	9.2	8.0	23	30	--	--	--
02-24-92	21.0	2.3	10	250	9.3	8.4	47	0.020	<0.010	0.83	<0.020	0.020	0.010	5.8	23	6.3	9.8	8.3	24	31	0.10	70	<1
05-20-92	26.5	1.2	20	250	9.7	9.4	50	0.030	<0.010	1.7	<0.020	0.030	0.020	7.0	23	6.6	10	8.0	24	33	0.10	50	1

Appendix 4. Water-quality data for Lake Mizell North 283545081201901

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported; <, less than]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as $CaCO_3$)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L as N)	Nitrogen, NO_2 $+NO_3$ total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
03-02-90	20.0	0.77	5	250	8.6	7.7	46	<0.010	<0.010	0.56	0.020	0.040	0.010	4.0	23	7.0	9.0	9.0	23	36	--	--	--
04-25-90	25.5	0.24	5	252	9.2	8.9	47	0.020	<0.010	0.51	<0.020	0.040	0.010	4.6	23	7.0	9.6	9.3	24	36	--	--	--
06-26-90	30.5	0.48	5	252	--	7.7	44	0.220	0.010	1.6	<0.020	0.030	0.030	5.6	23	6.7	10	8.9	24	34	--	--	--
09-04-90	30.0	0.44	<5	245	5.9	7.5	46	0.010	<0.010	1.2	<0.020	0.030	0.020	5.0	23	6.5	9.3	8.4	23	30	--	--	--
10-24-90	27.5	0.25	<5	246	6.7	7.7	46	<0.010	<0.010	0.68	<0.020	0.030	0.020	3.1	22	6.4	10	8.3	24	30	--	--	--
12-12-90	18.0	0.52	<5	256	9.2	7.8	46	0.010	<0.010	0.79	<0.020	0.040	0.010	5.7	23	6.8	10	8.7	25	32	--	--	--
02-28-91	18.5	1.1	10	259	9.7	8.7	48	0.010	<0.010	0.99	0.020	0.010	0.010	5.0	23	6.9	11	8.8	23	31	--	--	--
04-30-91	29.0	0.69	10	234	10.7	9.1	47	<0.010	<0.010	1.3	<0.020	0.040	0.030	4.6	22	6.0	9.3	7.5	22	27	--	--	--
06-25-91	31.0	0.83	5	241	9.3	9.1	41	<0.010	<0.010	1.2	<0.020	0.060	0.020	7.9	21	6.1	9.6	7.9	24	28	--	--	--
08-13-91	32.5	0.98	20	226	6.2	7.7	43	<0.010	<0.010	0.73	<0.020	0.030	0.010	6.0	21	5.8	8.8	7.4	21	28	--	--	--
10-29-91	25.5	1.7	10	249	9.4	8.0	47	0.030	0.010	1.1	<0.020	<0.010	<0.010	5.9	22	6.1	9.0	7.9	23	29	--	--	--
12-16-91	19.0	3.9	15	250	7.7	7.7	48	0.020	<0.010	1.0	<0.020	0.060	0.030	6.3	23	6.2	9.3	8.0	24	30	--	--	--
02-24-92	21.0	2.1	10	250	9.3	8.4	47	0.020	<0.010	0.97	<0.020	0.030	0.010	6.0	22	6.2	9.7	8.2	24	31	0.10	70	<1
05-20-92	26.0	2.1	20	250	10.0	9.4	50	0.030	<0.010	1.7	<0.020	0.040	0.030	7.3	23	6.4	10	8.0	24	32	0.10	50	1

Appendix 5. Water-quality for Lake Osceola South 283556081204101

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported; <, less than]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as $CaCO_3$)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L as N)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
10-04-89	30.0	1.5	5	194	--	8.1	54	0.010	<0.010	0.91	<0.020	<0.020	0.020	5.7	22	3.9	8.5	2.6	16	15	--	--	--
12-13-89	17.5	1.0	5	202	8.0	7.8	55	<0.010	<0.010	0.80	<0.020	0.040	0.010	3.9	23	4.0	9.1	2.6	18	15	--	--	--
03-02-90	19.5	1.3	10	199	10.0	8.3	57	<0.010	<0.010	0.85	0.020	0.080	0.010	4.2	24	4.1	9.2	2.6	17	16	--	--	--
04-25-90	25.0	0.27	5	197	10.5	9.2	59	0.020	<0.010	0.85	<0.020	0.050	0.020	5.0	24	4.1	9.9	2.3	17	17	--	--	--
06-26-90	30.0	0.45	5	200	--	8.9	56	0.300	<0.010	1.3	<0.020	0.040	0.020	5.4	24	4.4	10.0	2.6	18	17	--	--	--
09-04-90	30.0	0.58	5	207	7.0	7.7	54	0.010	<0.010	1.7	<0.020	0.030	0.020	5.3	21	3.9	8.8	2.3	16	17	--	--	--
10-24-90	27.5	0.62	5	217	7.9	7.9	59	<0.010	<0.010	0.90	<0.020	0.030	0.020	5.2	24	4.4	11	2.5	18	16	--	--	--
12-12-90	18.5	1.1	<5	229	7.6	7.6	81	0.010	<0.010	0.70	<0.020	0.030	0.010	1.4	27	4.6	10.0	2.9	19	19	--	--	--
02-28-91	17.5	0.94	5	233	9.8	8.7	64	0.010	<0.010	0.71	0.020	0.020	0.010	4.4	27	4.7	11	2.8	18	18	--	--	--
04-30-91	28.5	0.94	5	231	11.2	9.1	60	<0.010	<0.010	0.90	<0.020	0.040	0.020	4.0	25	4.3	9.7	2.5	18	17	--	--	--
06-25-91	30.0	0.60	5	216	8.8	8.9	52	<0.010	<0.010	1.2	<0.020	0.050	0.010	6.4	22	4.2	9.8	2.7	19	16	--	--	--
08-13-91	32.0	1.7	20	198	7.3	8.3	53	<0.010	<0.010	0.74	<0.020	0.020	0.010	5.6	22	3.8	9.0	2.2	16	16	--	--	--
10-29-91	25.0	2.3	15	200	9.2	8.0	57	0.030	0.010	1.2	<0.020	<0.010	<0.010	5.0	23	4.0	9.2	2.7	18	15	--	--	--
12-16-91	18.5	2.0	5	225	6.1	7.5	59	0.030	<0.010	0.90	<0.020	0.040	0.030	5.5	24	4.2	9.6	2.7	18	16	--	--	--
02-24-92	20.5	1.6	10	220	9.5	8.2	58	0.020	<0.010	0.81	0.020	0.160	0.010	5.6	24	4.2	10.0	2.7	19	17	0.10	50	2
04-01-92	19.5	1.3	10	221	0.2	6.8	58	0.090	<0.010	0.84	<0.020	0.090	0.010	4.1	24	4.4	10.0	2.7	19	18	0.10	--	--
05-20-92	26.0	1.5	20	210	9.7	9.2	56	0.020	<0.010	1.6	<0.020	0.030	0.020	6.8	23	4.2	10.0	2.6	19	18	0.10	30	3

Appendix 6. Water-quality for Lake Osceola North 283615081202801

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported; <, less than]

Date	Tem-pera-ture water (°C)	Turb-idity (NTU)	Color (Pt-Co units)	Spe-cific cond-ucta nce (µS/cm)	Oxy-gen, dis-solved (mg/L)	pH, Wh, field (SU)	Alka-linity lab (mg/L as Ca CO_3)	Nitro-gen, amm-onia total (mg/L as N)	Nitro-gen, nitrite total (mg/L as N)	Nitro-gen, ammo-nia, + organic total (mg/L as N)	Nitro-gen, NO_2 +NO_3 total (mg/L as N)	Phos-phorus, total (mg/L as P)	Phos-phorus, ortho total (mg/L as P)	Car-bon, orga-nic total (mg/L as C)	Calc-ium dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L) as Mg)	Sodi-um, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Chlo-oride, dis-solved (mg/L as Cl)	Sul-fate, dis-solved (mg/L as SO_4)	Fluo-ride, dis-solved (mg/L as F)	Boron, total recov-erable (µg/L as B)	Molyb-denum, total recov-erable (µg/L as Mo)
10-04-89	29.5	1.5	5	195	--	8.2	54	0.010	<0.010	0.96	<0.020	<0.020	0.020	6.2	22	3.9	8.6	2.6	17	15	--	--	--
12-13-89	17.5	1.9	5	202	8.3	7.8	53	<0.010	<0.010	0.85	<0.020	0.040	0.010	4.1	23	3.8	9.2	2.7	18	16	--	--	--
03-02-90	19.5	1.3	10	200	10.2	8.2	55	<0.010	<0.010	0.73	0.020	0.040	0.010	4.0	24	4.1	9.2	2.6	17	17	--	--	--
04-25-90	24.5	0.28	10	200	10.1	9.1	58	0.020	<0.010	1.0	<0.020	0.050	0.020	5.4	23	4.1	9.9	2.3	18	18	--	--	--
06-26-90	30.0	0.48	5	203	--	7.0	51	0.120	<0.010	1.5	<0.020	0.020	0.030	5.9	22	4.4	10.0	2.7	18	18	--	--	--
09-04-90	30.0	0.59	<5	204	6.6	8.0	54	0.070	<0.010	1.2	<0.020	0.030	0.020	5.0	23	4.3	10.0	2.6	18	17	--	--	--
10-24-90	27.5	0.54	<5	214	7.3	7.9	55	0.010	<0.010	0.83	<0.020	0.030	0.020	4.6	23	4.4	11	2.6	19	17	--	--	--
12-12-90	18.0	0.89	10	227	10.8	7.6	56	0.010	<0.010	0.83	<0.020	0.040	0.010	5.0	25	4.5	10.0	3.0	20	20	--	--	--
02-28-91	18.0	0.86	<5	230	9.4	8.5	61	0.010	0.010	0.79	0.020	0.020	0.010	4.6	26	4.6	11	2.8	19	19	--	--	--
04-30-91	29.0	1.0	5	212	10.3	9.1	57	<0.010	<0.010	1.0	<0.020	0.040	0.020	5.1	24	4.3	10.0	2.5	19	18	--	--	--
06-25-91	30.0	0.58	5	214	9.5	9.2	53	<0.010	<0.010	1.2	<0.020	0.050	0.020	6.6	22	4.2	9.8	2.8	19	17	--	--	--
08-13-91	32.0	1.1	15	201	6.0	8.2	52	0.010	<0.010	0.76	<0.020	0.020	0.010	5.4	22	3.8	10.0	2.2	17	17	--	--	--
10-29-91	25.5	3.7	10	195	8.5	7.8	56	0.020	0.010	1.1	<0.020	0.040	<0.010	5.0	24	4.0	9.3	2.7	19	16	--	--	--
12-16-91	18.5	3.6	10	220	7.5	7.9	57	0.010	<0.010	0.86	<0.020	0.020	0.030	5.8	24	4.1	9.7	2.7	18	17	--	--	--
02-24-92	20.5	1.6	10	215	9.3	8.2	57	0.030	<0.010	0.81	<0.020	0.020	0.010	5.1	24	4.2	10.0	2.7	19	18	0.10	50	3
05-20-92	25.5	1.3	20	215	9.2	9.2	50	0.030	<0.010	1.6	<0.020	0.030	0.010	8.1	23	4.3	11	2.8	20	18	0.10	30	3

Appendix 7. Water-quality data for Lake Maitland South 283644081204901

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported; <, less than]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as Ca CO_3)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L as N)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
10-04-89	29.5	1.7	5	195	--	8.1	51	0.010	<0.010	0.96	<0.020	<0.020	0.020	6.4	22	3.9	8.7	2.7	16	16	--	--	--
12-13-89	17.0	2.0	5	199	7.9	7.8	50	<0.010	<0.010	1.0	0.020	0.060	0.010	1.2	22	3.8	9.3	2.8	19	16	--	--	--
03-02-90	19.5	0.90	10	203	9.6	8.0	52	<0.010	<0.010	0.61	0.020	0.040	0.010	3.9	23	4.0	9.4	2.8	18	20	--	--	--
04-25-90	25.0	0.17	5	205	8.7	8.2	53	0.020	<0.010	0.47	<0.020	0.040	0.010	5.0	23	4.1	9.9	2.7	18	20	--	--	--
06-26-90	30.0	1.1	5	205	--	8.6	50	0.130	<0.010	1.4	<0.020	0.020	0.020	5.7	22	4.4	11	3.0	19	19	--	--	--
09-04-90	29.5	0.59	<5	206	6.1	7.3	53	<0.010	<0.010	0.55	<0.020	0.030	0.020	5.2	23	4.3	10.0	2.9	19	18	--	--	--
10-24-90	27.0	0.74	5	209	7.1	7.7	50	<0.010	<0.010	1.0	<0.020	0.030	0.030	6.6	22	4.3	11	2.9	20	17	--	--	--
12-12-90	18.0	0.76	10	222	8.3	7.6	52	0.020	<0.010	0.80	<0.020	0.050	0.010	5.2	24	4.4	10.0	3.2	21	20	--	--	--
02-28-91	18.0	0.95	<5	228	8.8	8.3	55	0.130	<0.010	0.70	0.020	0.010	0.010	4.8	25	4.4	11	3.4	20	20	--	--	--
04-30-91	28.0	0.30	5	214	9.4	8.6	52	0.130	<0.010	0.71	<0.020	0.030	0.020	4.1	24	4.2	10.0	3.0	20	20	--	--	--
06-25-91	30.0	0.54	5	216	9.0	8.8	48	<0.010	<0.010	0.90	<0.020	0.050	0.010	6.1	22	4.2	10.0	3.1	20	18	--	--	--
08-13-91	31.5	1.7	20	200	7.0	8.4	52	0.010	<0.010	0.76	<0.020	0.030	0.010	5.8	22	3.9	10.0	2.2	17	17	--	--	--
10-29-91	25.0	3.9	15	201	8.2	7.7	54	0.010	0.010	1.1	<0.020	<0.010	<0.010	5.2	23	3.9	9.2	2.9	19	16	--	--	--
12-16-91	18.5	3.2	10	210	6.2	7.5	55	<0.010	<0.010	0.80	<0.020	0.020	0.030	5.8	23	4.0	9.3	2.8	18	16	--	--	--
02-24-92	20.5	1.4	10	210	9.3	7.8	53	<0.010	<0.010	0.68	<0.020	0.020	0.010	4.9	23	4.0	9.8	2.9	19	18	0.10	50	2
05-21-92	26.0	1.2	10	220	9.0	8.7	<0.1	0.030	<0.010	1.4	<0.020	0.020	<0.010	5.8	23	4.2	10.0	2.7	20	19	0.10	30	2

Appendix 8. Water-quality for Lake Maitland West 283708081214201

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported; <, less than]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as Ca CO_3)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L as N)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
03-02-90	20.0	1.6	10	201	9.8	8.0	50	<0.010	<0.010	0.70	0.020	0.050	0.010	4.3	23	4.0	9.7	2.8	18	20	--	--	--
04-25-90	25.0	0.19	5	202	7.9	8.2	52	0.050	<0.010	0.66	<0.020	0.040	0.010	5.0	22	4.1	10.0	2.8	18	20	--	--	--
06-26-90	30.0	1.9	10	205	--	8.3	50	0.020	<0.010	1.4	<0.020	0.050	0.020	5.6	22	4.2	11	3.4	19	18	--	--	--
09-04-90	29.5	0.88	<5	206	7.0	8.1	51	0.010	0.010	1.6	0.020	0.040	0.030	5.6	22	4.3	10.0	3.0	19	18	--	--	--
10-24-90	27.0	0.74	5	208	6.8	7.8	50	0.010	<0.010	1.1	<0.020	0.040	0.030	5.8	22	4.3	11	3.0	21	17	--	--	--
12-12-90	17.5	1.4	10	220	6.6	7.6	51	0.010	0.030	0.78	<0.020	0.060	0.020	4.9	24	4.4	11	3.3	21	21	--	--	--
02-28-91	17.5	2.0	10	230	8.7	7.9	54	0.010	0.010	0.82	0.020	0.040	0.010	5.0	25	4.4	11	3.3	21	21	--	--	--
04-30-91	28.5	0.70	5	208	9.0	8.5	52	<0.010	<0.010	0.71	<0.020	0.040	0.020	4.5	24	4.0	10.0	3.0	19	19	--	--	--
06-25-91	30.0	0.54	5	210	7.8	8.5	48	<0.010	<0.010	0.83	<0.020	0.050	0.010	5.6	22	3.9	9.8	2.8	20	17	--	--	--
08-13-91	31.0	2.2	20	190	7.2	8.8	48	0.010	<0.010	0.85	<0.020	0.030	0.010	6.3	21	3.6	8.8	2.2	17	16	--	--	--
10-29-91	24.5	4.1	15	193	10.4	9.1	52	0.040	0.010	1.2	0.020	<0.010	<0.010	6.1	22	3.7	9.0	4.8	20	15	--	--	--
12-16-91	17.5	1.3	10	200	7.2	7.7	54	0.020	<0.010	0.80	<0.020	0.040	0.030	6.5	23	3.8	9.3	2.8	18	16	--	--	--
02-24-92	20.0	2.0	10	195	9.6	8.0	54	0.020	<0.010	0.63	<0.020	0.020	0.010	5.5	23	3.9	9.6	3.0	19	18	0.10	50	2
05-21-92	26.0	1.4	10	210	8.6	8.6	51	0.020	<0.010	1.2	<0.020	0.030	<0.010	5.4	22	4.1	10.0	2.7	20	18	0.10	30	2

Appendix 9. Water-quality data for Lake Maitland North 283545081201901

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported; <, less than]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as Ca CO_3)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L as N)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
10-04-89	29.0	1.9	5	192	--	8.1	49	0.010	<0.010	1.0	<0.020	<0.020	0.020	6.9	21	3.8	8.8	2.8	17	15	--	--	--
12-13-89	17.0	1.7	5	198	8.4	7.8	49	<0.010	<0.010	1.0	<0.020	0.050	0.020	2.0	22	3.8	9.4	2.8	18	16	--	--	--
03-02-90	19.0	1.5	10	202	9.5	8.0	51	0.010	<0.010	0.63	0.020	0.040	0.010	4.3	23	4.0	9.5	2.9	18	20	--	--	--
04-25-90	24.5	0.18	<5	202	7.8	8.1	52	0.020	<0.010	0.62	<0.020	0.040	0.010	5.0	22	4.1	10.0	2.8	19	20	--	--	--
06-26-90	30.0	0.84	5	207	--	8.3	49	0.010	<0.010	1.0	<0.020	0.020	0.020	5.5	22	4.3	11	3.1	19	18	--	--	--
09-04-90	29.5	1.2	<5	206	6.5	8.1	51	0.010	<0.010	1.2	<0.020	0.030	0.020	6.1	22	4.3	10.0	3.0	18	17	--	--	--
10-24-90	27.0	0.64	5	210	7.8	7.9	50	0.010	0.010	1.0	<0.020	0.040	0.030	6.7	22	4.3	11	3.0	20	17	--	--	--
12-12-90	17.5	1.5	10	218	8.3	7.8	51	0.010	<0.010	0.83	<0.020	0.040	0.010	5.5	24	4.4	11	3.3	21	20	--	--	--
02-28-91	18.0	1.5	10	230	8.5	7.9	54	0.010	0.010	0.68	0.020	0.020	0.010	5.1	25	4.5	11	3.4	20	20	--	--	--
04-30-91	28.0	0.61	5	209	9.0	8.5	50	<0.010	<0.010	0.62	<0.020	0.040	0.020	4.4	23	4.0	10.0	3.0	20	20	--	--	--
06-25-91	30.0	0.49	5	209	8.4	8.5	48	<0.010	<0.010	0.97	<0.020	0.050	0.010	6.0	21	4.0	9.8	3.2	20	17	--	--	--
08-13-91	31.5	2.0	20	193	7.0	8.4	50	0.010	<0.010	0.85	<0.020	0.040	0.010	6.2	21	3.6	8.8	2.2	17	16	--	--	--
10-29-91	25.0	4.4	15	192	8.4	8.1	51	0.020	0.010	1.0	<0.020	<0.010	<0.010	5.7	22	3.7	8.9	2.9	18	15	--	--	--
12-16-91	17.5	3.4	15	210	7.3	7.8	53	0.010	<0.010	0.75	<0.020	0.020	0.020	6.1	23	3.9	9.3	2.8	18	16	--	--	--
02-24-92	20.0	2.0	10	210	9.5	8.0	53	0.020	<0.010	0.65	0.020	0.200	0.010	5.2	23	3.9	9.6	3.1	19	18	0.10	50	2
05-21-92	25.5	1.6	20	190	8.4	8.1	50	0.020	<0.010	1.0	0.050	0.020	<0.010	5.7	22	4.1	10.0	2.7	20	18	0.10	30	2

Appendix 10. Water-quality data for Lake Sue outflow at Winter Park 02234263

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Date	Tem-pera-ture water (°C)	Turb-idity (NTU)	Color (Pt-Co units)	Spe-cific cond-uct-ance (µS/cm)	Oxy-gen, dis-solved (mg/L)	pH, Wh, field (SU)	Alka-linity lab (mg/L as Ca CO_3)	Nitro-gen, amm-onia total (mg/L as N)	Nitro-gen, nitrite total (mg/L as N)	Nitro-gen, ammo-nia, + organic total (mg/L)	Nitro-gen, NO_2 +NO_3 total (mg/L as N)	Phos-phorus, total (mg/L as P)	Phos-phorus, ortho total (mg/L as P)	Car-bon, orga-nic total (mg/L as C)	Calc-ium dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L) as Mg)	Sodi-um, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Chlo-oride, dis-solved (mg/L as Cl)	Sul-fate, dis-solved (mg/L as SO_4)	Fluo-ride, dis-solved (mg/L as F)	Boron, total recov-erable (µg/L as B)	Molyb-denum, total recov-erable (µg/L as Mo)
10-04-89	30.0	1.2	5	184	--	7.4	52	0.120	0.010	.95	0.080	<0.020	0.020	6.1	22	3.6	7.8	2.3	14	12	--	--	--
12-12-89	17.0	1.1	5	194	8.8	7.5	53	.050	<.010	.90	.040	0.050	.010	4.9	23	3.1	8.6	2.3	16	13	--	--	--
03-01-90	20.0	.44	10	185	7.8	7.6	53	.050	<.010	.54	.040	0.050	.010	3.6	22	3.4	9.1	2.0	15	14	--	--	--
04-24-90	24.5	--	10	203	6.9	7.7	62	.050	<.010	.52	.060	0.060	.020	4.3	24	4.2	9.3	1.7	16	15	--	--	--
06-25-90	30.0	.64	10	207	--	7.3	60	.130	.010	1.5	.080	0.040	.020	5.5	24	4.3	10.0	2.4	17	15	--	--	--
08-31-90	31.0	.64	5	235	4.9	7.4	75	.110	.030	1.0	.180	0.060	.040	4.3	29	5.3	10.0	2.3	17	15	--	--	--
10-23-90	27.0	.74	10	219	4.9	7.5	67	.080	.010	.75	.080	0.060	.040	6.6	26	4.6	10.0	1.9	16	14	--	--	--
12-11-90	16.5	.83	5	294	6.0	7.5	110	.130	.020	.54	.130	0.090	.070	3.5	38	7.5	10.0	1.9	16	15	--	--	--
03-01-91	19.5	.71	<5	285	5.1	7.5	105	.090	.010	.48	.160	0.070	.070	3.3	37	7.5	10.0	1.9	15	15	--	--	--
04-29-91	28.0	.41	10	193	7.0	8.0	50	.040	<.010	.82	.090	0.050	.020	4.5	22	3.5	10.0	2.0	18	15	--	--	--
06-25-91	29.0	1.2	5	202	3.8	7.3	55	.080	.010	.84	.130	0.060	.020	5.4	23	4.2	9.8	2.5	18	14	--	--	--
08-14-91	29.0	.57	20	190	3.6	6.9	53	.090	.010	.75	.140	0.040	.030	4.9	22	3.6	8.8	2.0	15	14	--	--	--
10-30-91	22.5	2.6	10	210	3.6	7.0	56	.100	.020	.80	.190	<0.010	<0.01	5.0	23	4.0	9.0	2.4	17	14	--	--	--
12-17-91	13.5	1.7	10	205	11.0	7.0	57	.110	.010	.78	.190	.050	.030	5.5	23	3.6	9.8	2.5	18	14	--	--	--
02-25-91	20.5	3.9	25	195	4.5	6.8	57	.080	.010	.76	.130	.090	.060	5.7	23	3.4	7.8	2.7	14	12	0.10	40	1
05-19-92	26.5	1.2	10	210	--	6.9	55	.070	<.010	.77	.150	.090	.020	4.6	22	3.8	11	2.1	19	15	0.10	30	2

Appendix 11. Water-quality data for Park Lake outflow 02234287

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as Ca CO_3)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
10-04-89	30.0	1.3	20	210	--	7.0	69	0.150	0.020	0.95	0.320	0.040	0.030	8.0	29	3.3	7.1	2.7	12	12	--	--	--
12-12-89	17.0	.96	10	222	7.6	7.2	78	.040	<.010	.96	.050	.060	.020	7.3	31	3.1	7.6	2.8	12	12	--	--	--
03-01-90	20.0	.60	10	225	7.4	7.6	79	.030	.010	.66	.080	.060	.020	6.0	32	3.5	8.0	2.9	12	14	--	--	--
04-24-90	24.5	.15	10	236	5.9	7.7	90	.040	.010	.59	<.020	.070	<.030	6.1	35	3.4	8.4	2.7	13	13	--	--	--
06-25-90	30.0	.77	10	225	--	7.5	78	.020	.010	.90	.020	.060	.020	6.8	29	3.2	7.8	2.6	13	13	--	--	--
08-31-90	31.0	.55	20	211	9.4	8.0	76	.040	.010	1.1	.070	.060	.030	4.0	30	3.5	8.7	2.8	13	12	--	--	--
10-23-90	27.0	.48	20	231	4.7	7.4	83	.130	.010	.80	.070	.060	.030	8.5	33	3.5	8.5	3.1	14	12	--	-	--
12-11-90	13.5	.34	10	337	7.6	7.4	103	.050	.010	.64	.350	.090	.040	4.6	44	5.0	15	4.0	23	25	--	--	--
04-29-91	28.5	.72	10	211	7.3	8.1	75	.010	<.010	.80	<.020	.050	.020	5.1	29	3.6	7.9	2.4	12	12	--	---	--
06-25-91	29.0	.57	5	197	5.0	7.4	64	.050	.010	.67	.210	.070	.030	6.0	26	3.5	8.0	2.5	13	12	--	--	--
08-14-91	29.5	1.1	30	196	4.4	7.0	65	.050	.010	.73	.310	.070	.020	5.8	26	3.3	7.4	2.0	12	13	--	--	--
10-30-91	22.0	.35	20	385	3.8	6.9	101	1.50	.040	2.1	.210	.160	.080	4.4	44	6.3	18	4.3	36	20	--	--	--
12-17-91	14.0	1.4	10	240	6.3	7.3	80	.070	.010	.70	.140	.080	.060	6.1	31	3.7	8.2	2.7	13	12	--	--	--
02-25-92	21.5	2.4	10	230	7.2	7.4	80	..030	.010	.76	.600	.050	.020	6.3	31	3.6	8.0	3.0	13	14	.10	50	2
05-19-92	28.5	1.5	20	250	--	8.5	90	.040	<.010	.74	.040	0.100	.040	.5.8	34	4.0	8.7	2.5	15	13	.10	40	1

Appendix 12. Water-quality data for Lake Minnehaha Outlet 02234299

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as $CaCO_3$)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
10-04-89	28.0	2.7	10	171	--	7.3	39	0.010	<0.010	0.99	--	<0.020	<0.020	5.7	18	2.8	8.3	2.8	17	12	--	--	--
12-12-89	16.5	1.0	10	175	8.1	7.5	40	<.010	<.010	.61	--	.040	.010	6.7	19	2.8	9.0	3.0	19	13	--	--	-
03-01-90	18.5	1.5	10	180	8.7	8.0	43	.010	.010	.56	--	.050	.010	5.1	20	3.0	9.4	3.0	18	14	--	--	--
04-24-90	23.5	.18	10	185	6.0	7.6	44	.040	<.010	.57	--	.040	.010	5.6	20	3.3	9.7	2.9	18	18	--	--	--
08-31-90	30.0	1.4	<5	198	5.1	7.3	48	.010	<.010	1.8	--	.040	.020	2.3	23	3.5	11	3.3	21	17	--	--	--
10-23-90	26.0	7.4	20	192	4.2	7.3	45	.010	.010	1.2	--	.100	.030	6.4	21	3.1	10.0	3.1	19	15	--	--	--
12-11-90	14.5	.65	10	214	6.9	7.5	50	.020	<.010	.73	--	.050	.010	6.1	24	3.8	11	3.7	23	18	--	--	--
03-01-91	18.5	.42	5	212	7.6	7.7	44	.010	<.010	.99	.020	.020	.010	5.6	22	4.2	12	3.7	22	20	--	--	--
04-29-91	27.5	2.1	20	196	7.5	7.5	43	<.010	<.010	1.1	.370	.060	.030	5.1	21	3.0	10.0	3.0	20	16	--	--	--
06-25-91	29.0	.79	5	184	4.4	7.5	45	<.010	<.010	.92	<.020	.050	.020	6.4	21	3.0	9.3	3.4	20	13	--	--	--
08-14-91	30.5	1.8	30	172	5.2	7.6	47	.010	<.010	1.2	.030	.040	.020	7.1	20	2.6	8.0	2.3	16	12	--	--	--
10-30-91	23.5	4.0	20	195	6.4	7.3	50	.020	.010	.86	.030	<.010	<.010	5.6	22	2.7	8.0	2.9	17	11	--	--	--
12-17-91	14.5	1.5	20	200	6.4	7.3	52	.030	<.010	.62	<.020	.050	.020	6.9	23	3.0	8.9	3.2	18	13	--	--	--
02-25-92	21.0	2.0	20	195	7.4	7.4	48	.030	<.010	.58	.030	.030	.010	6.3	21	2.7	8.8	3.1	18	14	.10	50	<1
05-19-92	27.0	3.2	20	200	--	7.2	48	.030	<.010	1.1	.040	.050	.010	5.7	21	2.9	10.0	3.0	20	14	.10	30	<1

Appendix 13. Water-quality data for Lake Sue Outflow at Lake Sue 283452081212401

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU))	Alkalinity lab (mg/L as Ca CO_3)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L as N)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chlooride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
03-01-90	20.5	.40	10	183	9.1	8.3	51	.020	<.010	.54	.020	.040	.010	3.7	22	3.3	9.1	2.0	15	14	--	--	--
04-24-90	24.5	.25	5	180	7.9	8.8	49	.020	<.010	.52	<.020	.040	.010	4.8	21	3.2	9.6	1.9	17	15	--	--	--
06-25-90	31.5	1.6	10	185	--	8.7	49	.050	<.010	1.8	.030	.020	.020	6.4	21	3.6	11	2.7	18	16	--	--	--
08-31-90	33.0	.96	5	198	5.4	8.3	55	.090	.010	1.5	.020	.030	.020	4.5	23	3.5	10.0	2.6	17	14	--	--	--
10-23-90	28.0	0.73	5	199	7.9	8.6	53	.020	<.010	.90	.020	.040	.030	5.5	23	3.5	11	2.5	18	14	--	--	--
12-11-90	19.5	.49	10	209	9.5	8.4	56	.040	<.010	.76	<.020	.030	.010	5.4	24	3.6	11	2.7	19	16	--	--	--
03-01-91	19.0	.76	<5	210	8.3	8.1	54	.040	<.010	.74	.030	.030	.010	5.0	24	3.6	12	2.6	19	17	--	--	---
04-29-91	29.0	.51	5	185	9.3	9.1	46	<.010	.010	.75	<.020	.040	.020	4.4	20	3.0	10.0	2.3	18	15	--	--	--
06-25-91	31.5	1.2	5	180	6.4	8.9	42	.060	.010	1.0	<.020	.050	.010	6.2	19	3.2	9.8	2.8	19	14	--	---	--
08-14-91	31.0	1.2	10	167	6.4	7.9	44	.040	<.010	.70	<.020	.020	.010	5.1	19	2.7	8.2	1.9	14	13	--	--	--
10-30-91	24.5	2.2	15	180	8.1	7.8	47	.060	.010	1.2	.020	<.010	<.010	5.3	19	2.9	8.8	2.5	16	13	--	--	--
12-17-91	17.0	2.6	10	200	5.6	7.3	51	.060	.010	.83	.020	.040	.020	5.9	21	3.0	9.5	2.6	17	13	--	--	--
02-25-92	21.5	4.2	15	200	7.4	7.6	47	.050	.010	.96	.050	.050	.020	5.3	20	3.0	10.0	2.3	18	16	.10	50	1
05-19-92	27.5	<1.0	10	180	--	9.1	42	.060	<.010	1.1	.090	.030	.010	5.5	18	2.9	10.0	2.3	18	16	.10	40	2

Appendix 14. Water-quality data for Lake Maitland outflow 2837270812303501

[°C, degrees Celsius; NTU, nephelometric turbidity units; Pt-Co, Platinum-Cobalt units; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; Wh, whole water; SU, Standard Unit; µg/L, micrograms per liter; --, not reported]

Date	Temperature water (°C)	Turbidity (NTU)	Color (Pt-Co units)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, Wh, field (SU)	Alkalinity lab (mg/L as $CaCO_3$)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia, + organic total (mg/L as N)	Nitrogen, NO_2 +NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)	Carbon, organic total (mg/L as C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L) as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Boron, total recoverable (µg/L as B)	Molybdenum, total recoverable (µg/L as Mo)
10-04-89	28.0	2.0	5	192	6.4	7.5	47	0.010	<.010	1.0	--	<.020	.020	6.5	21	3.8	8.9	2.8	17	15	--	--	--
03-01-90	18.0	.60	5	195	8.1	7.6	50	<.010	.010	.61	--	.040	.010	5.6	22	4.0	9.3	2.9	17	18	--	--	--
04-29-91	27.5	3.0	10	206	8.1	8.2	50	<.010	.010	.70	--	.040	.010	4.6	23	4.1	10.0	2.7	20	20	--	--	--
06-25-91	29.5	.56	5	203	5.0	7.5	47	.010	<.010	.71	--	.050	.020	5.9	22	4.0	10.0	3.0	20	17	--	--	--
08-14-91	30.5	1.3	20	192	5.7	7.5	50	.020	<.010	1.0	--	.030	.010	6.1	21	3.4	8.8	2.2	17	16	--	--	--
10-30-91	23.5	3.0	20	200	7.8	7.3	52	.040	.010	.95	--	.010	<.010	5.8	22	3.7	8.9	2.8	18	15	--	--	--
12-17-91	13.0	.58	30	300	5.7	7.6	105	.400	.020	1.0	--	.080	.080	9.2	40	4.7	11	4.0	21	13	--	--	--
02-25-92	21.5	2.0	30	220	5.5	8.3	76	.220	.010	.78	.320	.070	.050	7.9	30	3.0	7.8	3.8	14	9.3	0.10	40	<1
05-19-92	29.5	1.7	30	255	--	9.0	83	.230	.160	1.7	.440	.140	.070	7.8	33	4.2	11	3.7	21	14	0.10	40	2

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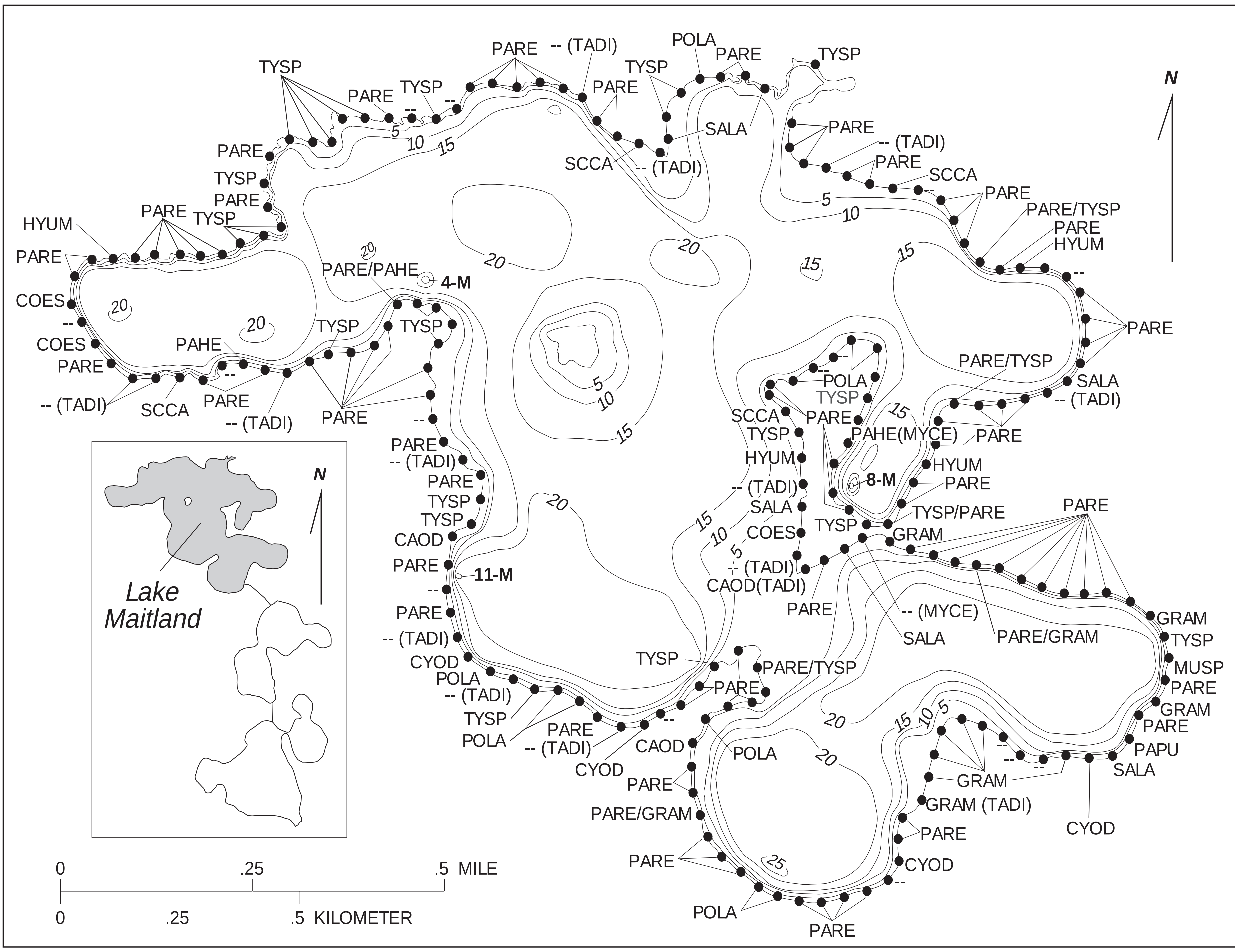

EXPLANATION

10 LINE OF EQUAL DEPTH BELOW LAKE SURFACE, MARCH 1992--Interval 5 feet. Features 4-M, 8-M and 11-M are possible sinkholes. Datum is lake-surface elevation, about 66 feet above sea level

TYSP • LITTORAL SEGMENT MIDPOINT AND SPECIES CODE FOR DOMINANT VEGETATION, MARCH 1992--Slashes indicate species are codominant. Parentheses indicate woody species. Dashes indicate no vegetation or no non-woody vegetation. If the dominant specie is woody, the most abundant non-woody specie is also given. Index to species codes below

Species code	Scientific name	Common name	Species code	Scientific name	Common name
CAOD	*Castalia odorata*	fragrant water lily	PAPU	*Panicum purpurascens*	para grass
COES	*Colocasia esculentum*	elephant ear	PARE	*Panicum repens*	torpedo grass
CYOD	*Cyperus odoratus*	flat sedge	POLA	*Pontederia lanceolata*	pickerelweed
GRAM	*Gramineae*	grass family	SALA	*Sagittaria lancifolia*	duck potato/arrowhead
HYUM	*Hydrocotyle umbellata*	pennywort	SCCA	*Scirpus californicus*	giant bulrush
MUSP	*Musa species*	banana	(TADI)	*Taxodium distichum*	bald cypress
(MYCE)	*Myrica cerifera*	wax myrtle	TYSP	*Typha species*	cattail
PAHE	*Panicum hemitomon*	maidencane			

BATHYMETRY AND LITTORAL VEGETATION OF LAKE MAITLAND, MARCH 1992

by

G.G. Phelps and E.R. German

1995

WATER-RESOURCES INVESTIGATIONS REPORT 95-4108
Bathymetry and littoral vegetation, Lake Virginia--PLATE 2
Phelps, G.G. and German, E.R., 1995, Hydrology, water quality and
constituent budgets of the Winter Park chain of lakes, Florida

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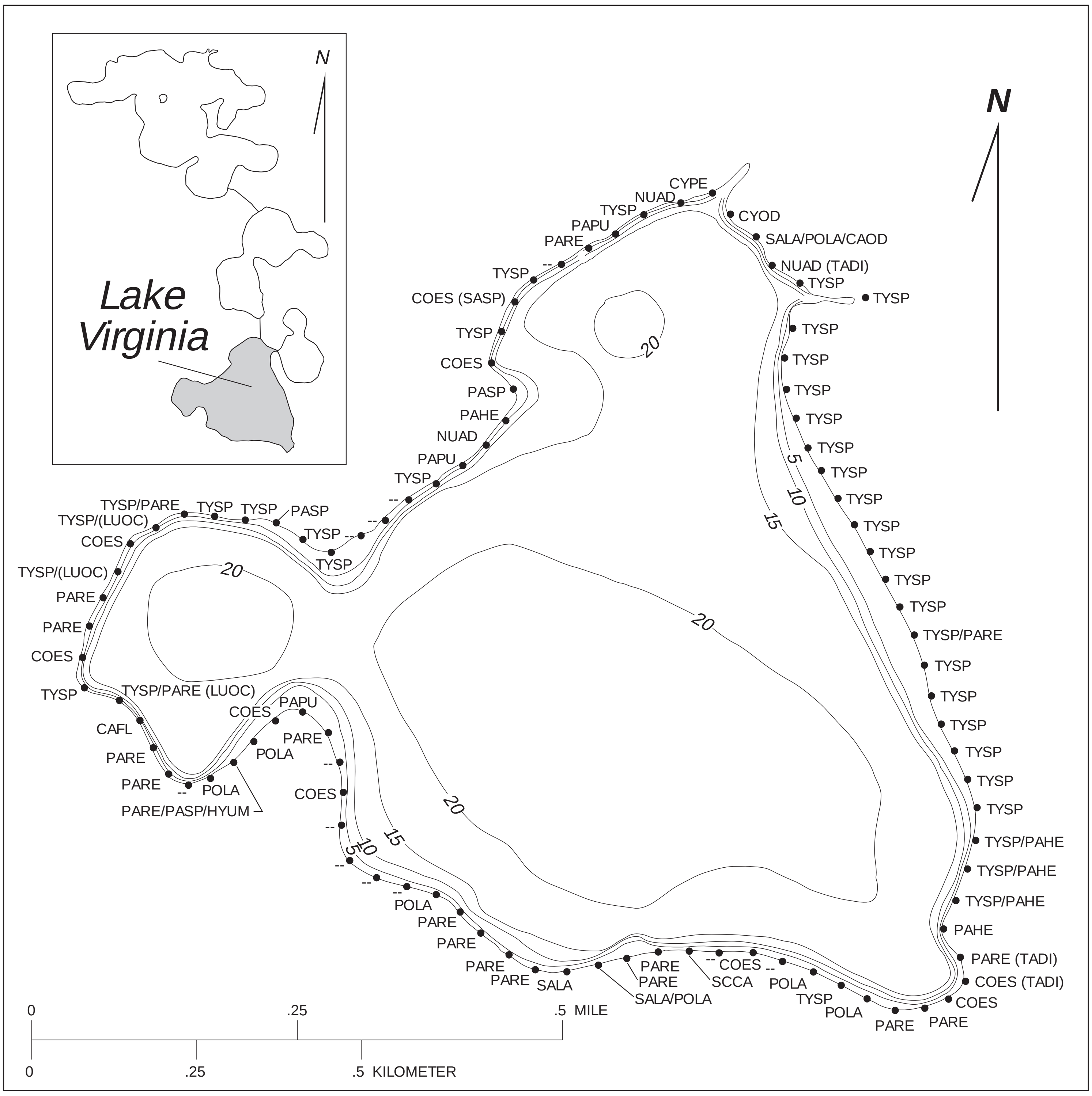


EXPLANATION

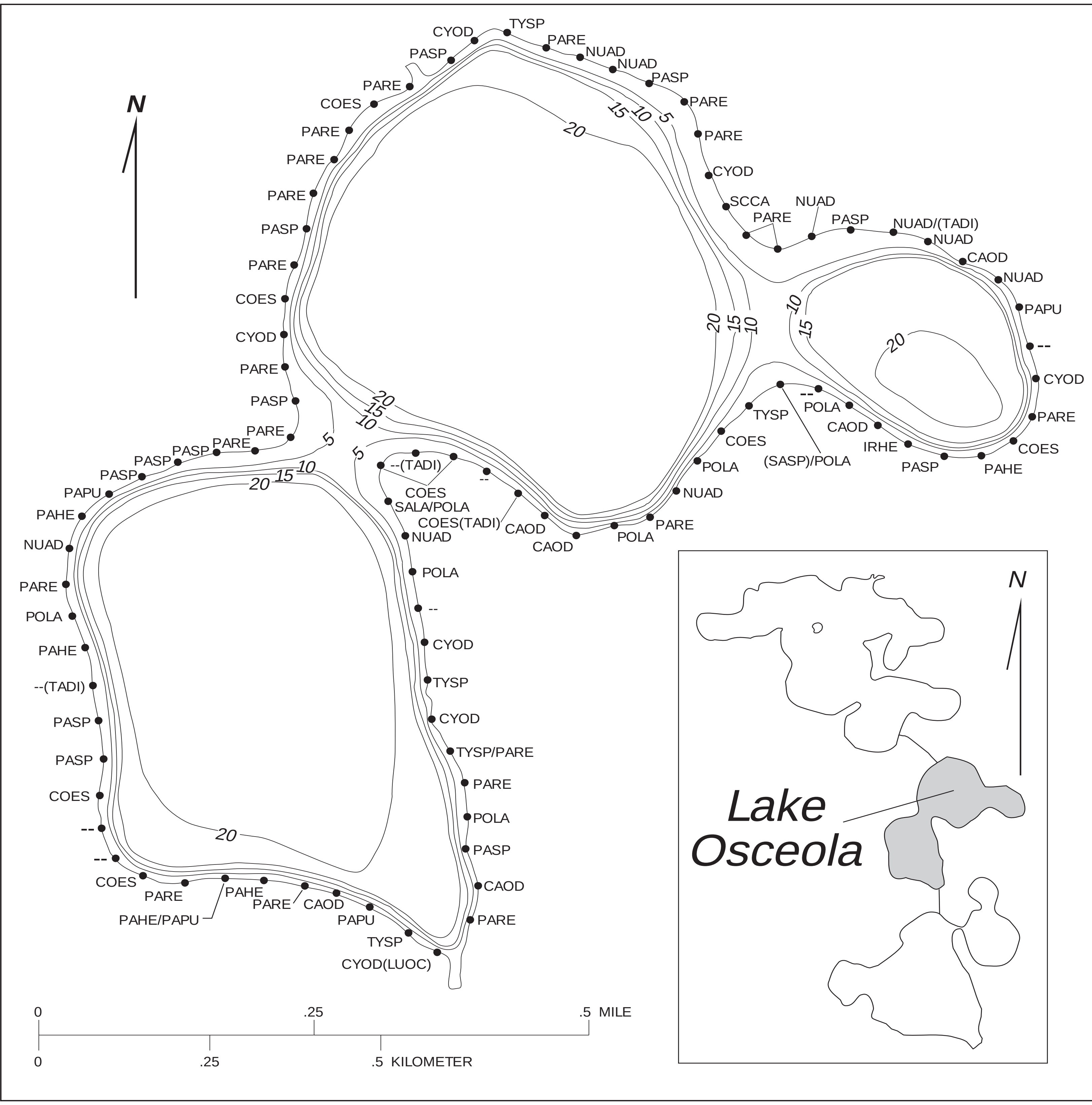
—10— LINE OF EQUAL DEPTH BELOW LAKE SURFACE, MARCH 1992--Interval 5 feet. Datum is lake-surface elevation, about 66 feet above sea level

TYSP • LITTORAL SEGMENT MIDPOINT AND SPECIES CODE FOR DOMINANT VEGETATION, MARCH 1992--Slashes indicate species are codominant. Parentheses indicate woody species. Dashes indicate no vegetation or no non-woody vegetation. If the dominant specie is woody, the most abundant non-woody specie is also given. Index to species codes below

Species code	Scientific name	Common name	Species code	Scientific name	Common name
CAFL	*Castalia flava*	yellow water lily	PAPU	*Panicum purpurascens*	para grass
CAOD	*Castalia odorata*	fragrant water lily	PARE	*Panicum repens*	torpedo grass
COES	*Colocasia esculentum*	elephant ear	PASP	*Panicum species*	
CYOD	*Cyperus odoratus*	flat sedge	POLA	*Pontederia lanceolata*	pickerelweed
CYPE	*Cyperaceae*	sedge family	SALA	*Sagittaria lancifolia*	duck potato/arrowhead
HYUM	*Hydrocotyle umbellata*	pennywort	(SASP)	*Salix species*	willow
(LUOC)	*Ludwigia octovalis*	water primrose	SCCA	*Scirpus californicus*	giant bulrush
NUAD	*Nuphar advena*	yellow cow lily	(TADI)	*Taxodium distichum*	bald cypress
PAHE	*Panicum hemitomon*	maidencane	TYSP	*Typha species*	cattail

BATHYMETRY AND LITTORAL VEGETATION OF LAKE VIRGINIA, MARCH 1992

by
G.G. Phelps and E.R. German
1995

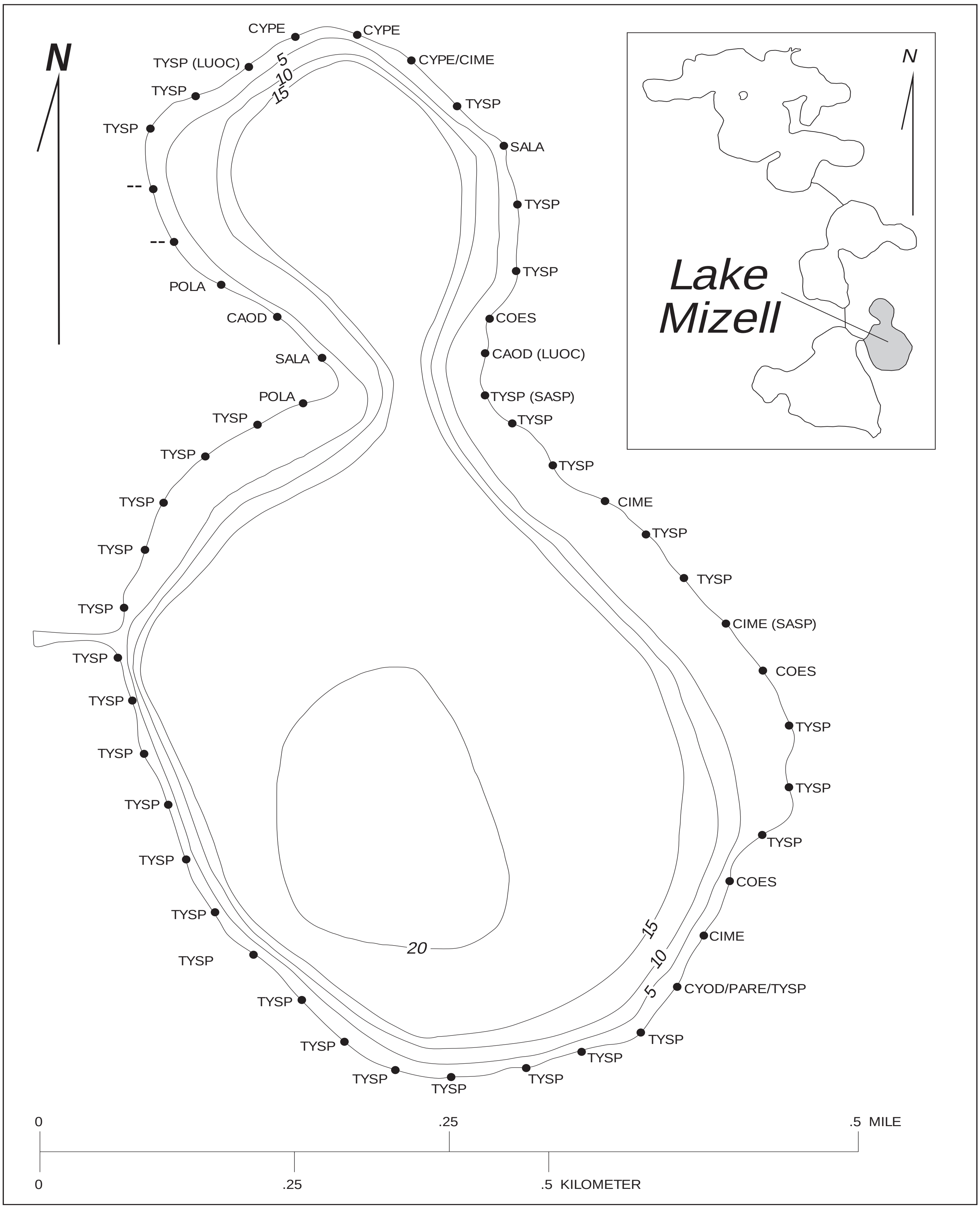


EXPLANATION

——10—— LINE OF EQUAL DEPTH BELOW LAKE SURFACE, MARCH 1992--Interval 5 feet. Datum is lake-surface elevation, about 66 feet above sea level

TYSP • LITTORAL SEGMENT MIDPOINT AND SPECIES CODE FOR DOMINANT VEGETATION, MARCH 1992--Slashes indicate species are codominant. Parentheses indicate woody species. Dashes indicate no vegetation or no non-woody vegetation. If the dominant specie is woody, the most abundant non-woody specie is also given. Index to species codes below

pecies code	Scientific name	Common name	Species code	Scientific name	Common name
AOD	*Castalia odorata*	fragrant water lily	PARE	*Panicum repens*	torpedo grass
OES	*Colocasia esculentum*	elephant ear	PASP	*Panicum species*	
YOD	*Cyperus odoratus*	flat sedge	POLA	*Pontederia lanceolata*	pickerelweed
HE	*Iris hexagona*	praire iris	SALA	*Sagittaria lancifolia*	duck potato/arrowhea
UOC)	*Ludwigia octovalis*	water primrose	(SASP)	*Salix species*	willow
UAD	*Nuphar advena*	yellow cow lily	SCCA	*Scirpus californicus*	giant bulrush
HE	*Panicum hemitomon*	maidencane	(TADI)	*Taxodium distichum*	bald cypress
PU	*Panicum purpurascens*	para grass	TYSP	*Typha species*	cattail



EXPLANATION

——— 10 ——— LINE OF EQUAL DEPTH BELOW LAKE SURFACE, MARCH 1992--Interval 5 feet. Datum is lake-surface elevation, about 66 feet above sea level

TYSP • LITTORAL SEGMENT MIDPOINT AND SPECIES CODE FOR DOMINANT VEGETATION, MARCH 1992--Slashes indicate species are codominant. Parentheses indicate woody species. Dashes indicate no vegetation or no non-woody vegetation. If the dominant specie is woody, the most abundant non-woody specie is also given. Index to species codes below

Species code	Scientific name	Common name	Species code	Scientific name	Common name
CAOD	*Castalia odorata*	fragrant water lily	PARE	*Panicum repens*	torpedo grass
CIME	*Cicuta mexicana*	water hemlock	POLA	*Pontederia lanceolata*	pickerelweed
COES	*Colocasia esculentum*	elephant ear	SALA	*Sagittaria lancifolia*	duck potato/arrowhead
CYOD	*Cyperus odoratus*	flat sedge	(SASP)	*Salix species*	willow
CYPE	*Cyperaceae*	sedge family	TYSP	*Typha species*	torpedo grass
(LUOC)	*Ludwigia octovalis*	water primrose			

BATHYMETRY AND LITTORAL VEGETATION OF LAKE MIZELL, MARCH 1992