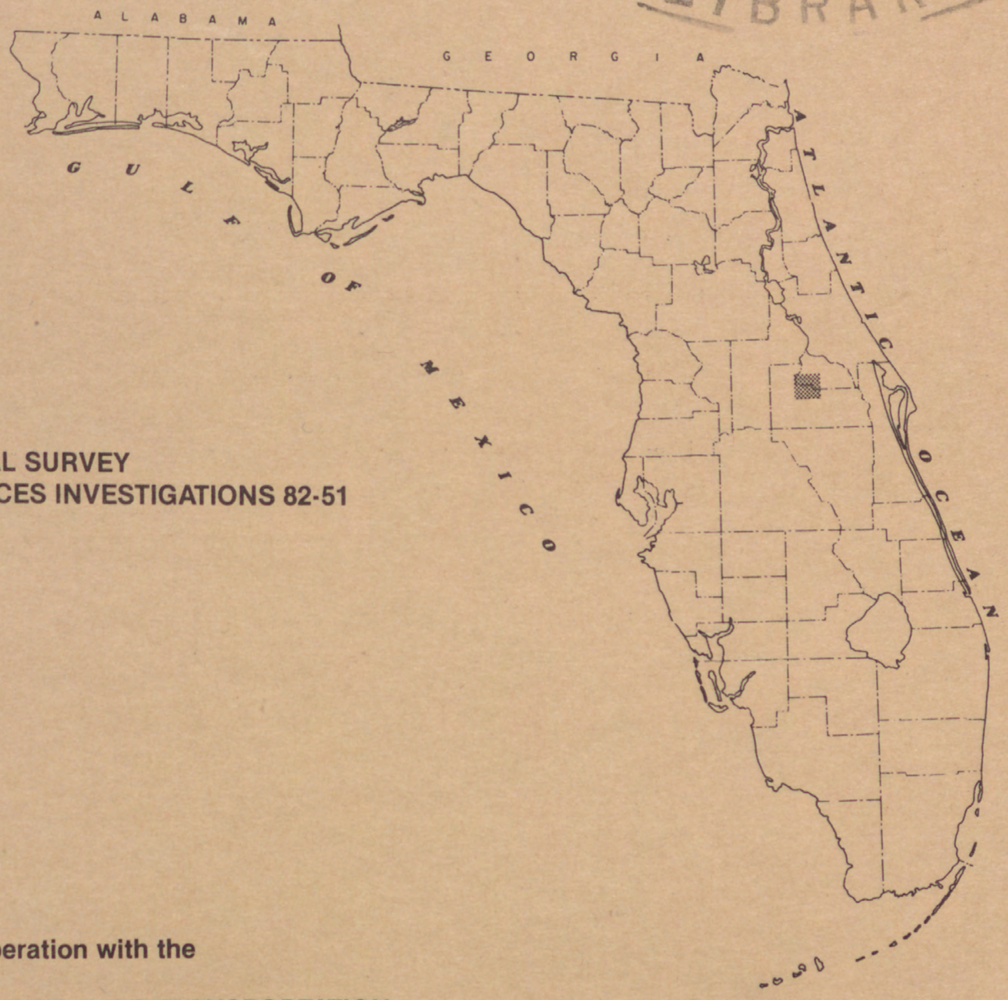
WATER QUALITY OF LAKES FAITH, HOPE, CHARITY, AND LUCIEN, 1971-79, IN AN AREA OF RESIDENTIAL DEVELOPMENT AND HIGHWAY CONSTRUCTION AT MAITLAND, FLORIDA



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WATER-RESOURCES INVESTIGATIONS 82-51

Prepared in cooperation with the

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82-51 WATER QUALITY OF LAKES FAITH, HOPE, CHARITY, AND LUCIEN, 1971-79, IN AN AREA OF RESIDENTIAL DEVELOPMENT AND HIGHWAY CONSTRUCTION AT MAITLAND, FLORIDA 82-51

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As part of an ongoing study of lakes in central Florida, Lakes Faith, Hope, and Charity were sampled from April 1971 to June 1979 to monitor water quality before, during, and after construction of Maitland Boulevard and the Interstate Highway 4 interchange. Lake Lucien was added to the study in April 1975.

Chemical quality of the lakes varies little in comparison with surface runoff, bulk precipitation, and the surficial aquifer.

Surface runoff supplied about 19 percent of the direct inflow to the lakes and contributed a total of about 2,000 pounds per acre of lake surface of dissolved solids from April 1971 to June 1979, while bulk precipitation contributed about 1,170 pounds per acre.

Water quality in the lakes changed during the study, generally for the better. However, an infestation of elodea (Hydrilla verticillata) developed in Lake Hope near the end of the study and has interfered with recreational use of the lake.

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By Edward R. German

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CONTENTS

ILLUSTRATIONS

TABLES

ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System (SI) of metric units and abbreviation of units.

Multiply	By	To obtain
inch (in)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare (ha)
pound (lb)	0.4526	kilogram (kg)

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

Temperature in degrees Celsius can be converted to degrees Fahrenheit as follows:

$$°F = 9/5\ °C + 32$$

WATER QUALITY OF LAKES FAITH, HOPE, CHARITY, AND LUCIEN, 1971-79, IN AN AREA OF RESIDENTIAL DEVELOPMENT AND HIGHWAY CONSTRUCTION AT MAITLAND, FLORIDA

By Edward R. German

ABSTRACT

As part of an ongoing study of lakes in central Florida, Lakes Faith, Hope, and Charity were sampled from April 1971 to June 1979 to monitor water quality before, during, and after construction of Maitland Boulevard and the Interstate Highway 4 interchange. Sampling of Lake Lucien was added to the study in April 1975.

Chemical quality of the lakes varies little in comparison with chemical quality of surface runoff to the lakes, bulk precipitation, and water from the surficial aquifer. However, there is variation in water quality among the lakes; dissolved solids have averaged about twice as high in Lake Charity as in Lake Lucien. High sulfate concentrations in Lake Charity may be because of inflow of high sulfate water from the surficial aquifer in an area of citrus groves.

Surface runoff supplied about 19 percent of the direct inflow to Lakes Faith, Hope, and Charity and contributed a total of about 2,000 pounds of dissolved solids per acre of lake surface from April 1971 to June 1979, while bulk precipitation contributed about 1,170 pounds per acre. Nitrogen loading of the lakes was greater through rainfall (140 pounds per acre) than through surface runoff (average of 78 pounds per acre).

Water quality in the lakes changed during the study, generally for the better. However, an infestation of *Hydrilla verticillata* or elodea, in Lake Hope has interfered with recreational use of the lake. Trends in water quality in the lakes include (1) decreasing dissolved solids (and, hence, specific conductance) in Lakes Faith, Hope, and Charity, (2) decreasing total nitrogen concentration in all four lakes, (3) decreasing daily variation in dissolved oxygen concentration in Lakes Hope and Charity, (4) decreasing densities of phytoplankton in Lakes Hope and Lucien, and (5) decreasing relative proportion of pollution-tolerant algae in Lakes Lucien, Faith, and Hope.

Results of this study could have some applicability to other lakes in central Florida where highway construction and other development could affect water quality.

INTRODUCTION

Construction of an interchange to I-4 (Interstate Highway 4) and a four-lane road connecting I-4 with U.S. Highways 17 and 92 at Maitland was proposed by the Florida Department of Transportation in 1970. The work started in 1974 and was completed in April 1977. The new road, Maitland Boulevard, passes near the south shores of Lakes Faith, Hope, and Charity. Storm runoff from Maitland Boulevard and the I-4 interchange is carried into holding ponds that overflow into Lakes Faith, Charity, and Lucien as shown in figure 1. Because of concern over possible adverse effects of highway construction and use on water quality in Florida lakes, the Florida Department of Transportation and the U.S. Geological Survey began a cooperative study to monitor the quality of water in Lakes Faith, Hope, Charity, and Lucien. The report should have broad application to other lakes in the area where highway construction or other development resulting in severe alteration of the land surface is planned.

The water-quality monitoring program, which provided for periodic data collection to identify the physical, chemical, and biological characteristics of the lakes, bulk precipitation, water in the surficial aquifer, and storm runoff to the lakes, began in April 1971. This report summarizes the data collected from April 1971 through June 1979 for the following purposes: (1) document the quality of water in Lakes Faith, Hope, Charity, and Lucien, before, during, and after the start of road construction; (2) determine the quality and quantity of storm runoff entering the lakes; (3) determine the quality and quantity of bulk precipitation falling on the surface of the lakes; (4) determine the quality of water in the surficial aquifer around the lakes; and (5) determine the loads of materials carried into the lakes by storm runoff and bulk precipitation. A previous report (Gaggiani and Lamonds, 1978) summarizes water quality for the period 1971-74, prior to the start of construction.

METHOD OF INVESTIGATION

The monitoring program began in April 1971 and initially was centered around Lakes Faith, Hope, and Charity. Lake stages and rainfall were monitored continuously. Samples from the lakes and from storm drains conveying runoff from residential areas to each lake were collected three times per year. Composite samples of bulk precipitation (rainfall and dry fallout) were collected beginning in June 1972.

Initially, Lakes Faith, Hope, and Charity were sampled before and after a major rainfall during April, August, and December each year. The program was modified in August 1973 to provide for more comprehensive analyses of the samples. At that time, the lake sampling before a major rainfall was dropped and the lakes were analyzed for a more comprehensive suite of physical and chemical characteristics, coliform bacteria, and phytoplankton. Sampling of Lake Lucien began in May 1974, and sampling

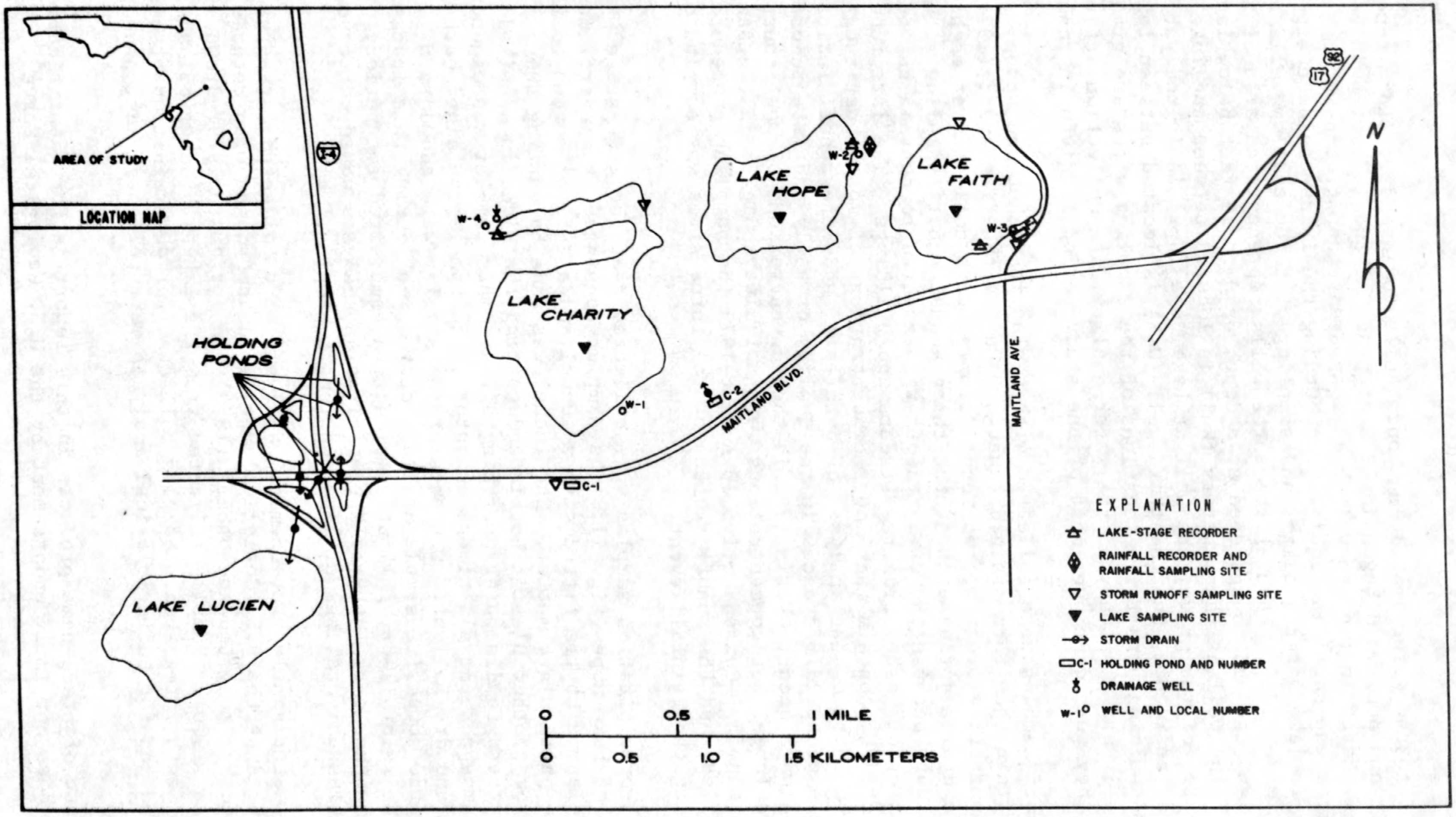

Figure 1.--Study area and location of data-collection sites.

of runoff to and water in holding ponds built to intercept storm runoff from Maitland Boulevard began in 1975 at pond C-1 and 1977 at pond F-1 (fig. 1). Later in the study it became apparent that ground-water inflow from the surficial aquifer surrounding the lakes could be significant to lake water quality, and sampling of three shallow wells was begun in March 1978. Each of the three wells represents an area of uniform land use and is screened at a depth of 8 to 10 feet below land surface. The well at Lake Charity (W-1) is located between the lake and a cultivated citrus grove, the well at Lake Hope (W-2) is in the yard of a lakeside residence, and the third well (W-3) is located between Lake Faith and holding pond F-1. Locations of the sampling sites are given in figure 1, and a summary of the water-quality data collection activities as they were done over most of the study period is given in table 1.

Runoff samples were collected with a plastic bucket and scoop placed within the storm-drain discharge. During the first year (1971) of the monitoring program, two runoff samples were collected at each of the three drains during each of the three annual runoff sampling events. This was done because the early runoff was expected to contain the bulk of the material washed from the streets and buildings. The late runoff was expected to contain much lower concentrations of most constituents. However, results of the analyses of both early and late runoff indicated that the expected differences in the quality of early and late runoff did not always occur. Variations in the concentrations of most constituents were large, but concentrations were not always higher in the samples of early runoff. Consequently, in August 1973 the sampling procedure was modified, and the runoff at each of the three sites was sampled only once during the rainfall event.

Bulk-precipitation samples were collected near the lake-stage recorder on Lake Hope (fig. 1). The sampler consisted of a narrow-mouth 4-liter plastic bottle fitted with a funnel and a Teflon[1/] screen to keep out large particulate matter. The funnel was made by cutting the bottom from another plastic bottle and cutting the sides in a spiked zigzag pattern to discourage perching birds. This sampler was exposed to the atmosphere at all times, therefore, the sample contained both rainfall and dry fallout. Contents of the sampler were added to a refrigerated composite sample at least once a week during this investigation. The rainfall-dry fallout samples were composited for periods of about 4 months so that the bulk precipitation analyses would correspond to the triannual analyses of lake and runoff samples.

All water samples for chemical analysis were collected, preserved, and analyzed by the U.S. Geological Survey in accordance with methods prescribed by Skougstad and others (1979) and, prior to 1979, Brown and others (1970). Samples collected from the lakes for chemical analysis were depth integrated. Samples collected for determination of oil and grease and for bacteriological analysis were collected just beneath

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[1/]The use of brand-name products in this report is for identification only and does not imply endorsement by the U.S. Geological Survey.

Table 1.--Summary of types of water-quality data collected

[Sampling schedule given here is applicable to most of the study period]

[The "Sampling began" date refers to earliest date of any sample and does not necessarily apply to all types of samples. All sampling ended June 1979]

Sampling points	Sampling began	Feb.	Apr.	June	Aug.	Oct.	Dec.
Lakes:							
Faith	Apr. 1971	C,F,G	All but E	C,F,G	All but E	C,F,G	All
Hope	do.	C,F,G	All but E	C,F,G	All but E	C,F,G	All
Charity	do.	C,F,G	All but E	C,F,G	All but E	C,F,G	All
Lucien	May 1974	C,F,G	C,F,G	C,F,G	C,F,G	C,F,G	C,F,G
Holding ponds:							
F-1	Dec. 1977		A,B,F		A,B,F		A,B,E,F
C-1	Feb. 1975		A,B,F		A,B,F		A,B,E,F
Runoff to:							
Lake Faith	Aug. 1971		A,B,F		A,B,F		A,B,F
Lake Hope	do.		A,B,F		A,B,F		A,B,F
Lake Charity	do.		A,B,F		A,B,F		A,B,F
Holding pond F-1	Dec. 1977		A,B,F		A,B,F		A,B,F
Holding pond C-1	Apr. 1975		A,B,F		A,B,F		A,B,F
Bulk precipitation	June 1972		A,B,F		A,B,F		A,B,F
Surficial aquifer:							
Well W-1	Mar. 1978	A,F	A,F	A,F	A,F	A,F	A,F
Well W-2	do.	A,F,	A,F	A,F	A,F	A,F	A,F
Well W-3	do.	A,F	A,F	A,F	A,F	A,F	A,F

Types of data

A - Major constituents and properties
B - Trace metals
C - Phytoplankton
D - 24-hour dissolved oxygen studies
E - Bottom sediments analysis
F - Nutrients
G - Dissolved oxygen and temperature
H - Bacteria

the surface. Bacteriological analyses were performed by the U.S. Geological Survey using the membrane filter method as described by Greeson and others (1977). Water samples for phytoplankton analysis were collected from just beneath the surface and were composited from equal amounts of water collected near the center of the lake, near the windward shore, and near the lee shore. Phytoplankton in the lakes were identified by Jackson L. Fox, formerly of the University of Florida at Gainesville.

DESCRIPTION OF THE STUDY AREA

Summary of Development

The construction of Maitland Boulevard and the associated interchange with I-4 was started in May 1974 and was completed in April 1977. This construction, which was south of Lakes Faith, Hope, and Charity, and north and east of Lake Lucien, was not the only development taking place within the drainage basins. Other activities which were altering the land use and drainage of the watershed included residential development along the north shore of Lake Hope and condominium construction along the southwest shore of Lake Faith. The condominium project on Lake Faith was under construction in 1973 and 1974, and resulted in conversion of about 8 acres of land used for citrus cultivation to a residential area. Runoff from paved surfaces in the condominium complex is discharged through storm drains onto a grassy bank leading to Lake Faith. About 24 acres, mostly in citrus groves, on the north shore of Lake Hope were converted to a single-family housing development in 1978 and 1979. Storm runoff from the development is directed through storm drains to a vertical culvert which serves as a sediment trap and overflows into Lake Hope.

Construction of Maitland Boulevard and the I-4 interchange resulted in removing from citrus production about 25 acres of land south of Lakes Faith, Hope, and Charity, and about 60 acres north of Lake Lucien. This construction affected percentages of the lake basins ranging from 1 percent of the Lake Hope basin to 12 percent of the Lake Lucien basin (see table 2). Storm runoff from the interchange is intercepted by a series of holding ponds located within the interchange, which overflow to Lake Lucien (fig. 1). The three holding ponds that intercept runoff from Maitland Boulevard are along or near Maitland Boulevard in the vicinity of Lakes Faith and Charity. Overflow from these holding ponds would enter either Lake Charity or Lake Faith (see fig. 1).

Lake Drainage, Morphology, and Land Use

Lakes Faith, Hope, Charity, and Lucien are of sinkhole origin and are closed basin lakes. At normal stages, the lakes have no surface outflow. At very high stages (about 74.0 feet above sea level), Lake Faith overflows into Lake Hope, and Lake Hope overflows into Lake Charity

Table 2.--Physical characteristics of the lakes and drainage basins in 1979

Lakes	Approximate drainage area (acres)	Surface area (acres)	Shoreline (miles)	Depth near center (feet)	Percentage of drainage basins (1979) in:				
					Citrus groves	Residential development	Undeveloped	Lake surface	Other
Lucien	474	57	1.2	24	28	11	37	12	1/ 12
Faith	212	34	0.9	22	5	64	10	16	2/ 5
Hope	192	35	1.0	8	21	57	3	18	2/ 1
Charity	423	63	1.8	12	46	35	1	15	2/ 3

1/ Interstate Highway 4 and the Maitland Boulevard interchange.
2/ Approximate percentage of the basin occupied by the Maitland Boulevard pavement, median, and shoulder.

at a stage of 66.6 feet above sea level. Lake Charity is controlled by a drainage well into the Floridan aquifer which accepts water at a stage of 67.0 feet. At high stages, Lake Lucien is connected by a marsh to Harvest Lake, about 0.1 mile southwest of Lake Lucien.

Some physical characteristics of the lakes and drainage basins are summarized in table 2. Lake Charity has the largest surface area of the four lakes, and Lake Lucien has the largest drainage basin. Lakes Lucien and Faith are relatively deep lakes, compared to Lakes Hope and Charity. Lakes Hope and Lucien have extensive populations of rooted aquatic weeds, and Lakes Faith and Charity are largely free of weeds.

Surface runoff from citrus groves and undeveloped areas is low chiefly because of the high permeability of the sandy soil. Much of the surface runoff to the lakes is through the storm drains serving the residential areas north of Lakes Faith, Hope, and Charity. The areas served by storm drains to Lakes Hope and Charity have curb and gutter street drains and most of the street runoff is carried into the lakes. The area north of Lake Faith does not have curb and gutter drainage. Street runoff from that area is collected in swales so that part of the runoff infiltrates into the ground.

The approximate percentages of the major land use categories within the drainage basins at the end of the study (June 1979) are listed in table 2. Land use in the Lakes Faith and Hope drainage basin is dominated by residential developments, which account for 64 and 57 percent of their respective basins. Lake Charity has the largest area of land in citrus groves, with nearly half of the drainage basin being utilized in this manner. Much of the drainage basin (37 percent) of Lake Lucien is undeveloped, and I-4 and the Maitland Boulevard interchange account for an appreciable part (12 percent) of the drainage area.

HYDROLOGIC PROPERTIES AND BUDGET

Rainfall and Estimated Lake Evaporation

Total rainfall at the Lake Hope rain gage (fig. 1) was 33.1 feet during the study period (April 1971 to June 1979), or about 90 percent of normal based on NOAA (National Oceanic and Atmospheric Administration) records for the period 1941-70. According to the NOAA data (U.S. Department of Commerce, 1978) averaged for Orlando and for Sanford (10 miles north of Lake Hope), normal rainfall was 52.27 inches per year, and monthly normal averages of Orlando and Sanford accumulated over the study period amount to 36.21 feet of rainfall.

Seasonal distribution of the rainfall at Lake Hope was typical of central Florida, with more than half of the yearly total rainfall occurring during June through September. On the average, April has been the driest month with 1.06 inches, and July the wettest with 10.35 inches.

Lake evaporation was estimated from NOAA pan evaporation data for Lisbon, Fla. (about 30 miles northwest of the study area). Monthly pan coefficients determined by Kohler (1954) at Lake Okeechobee were used to convert pan evaporation to estimated lake evaporation. Average annual estimated lake evaporation was about 48.7 inches during the study period, and the total estimated lake evaporation accumulated over the study period was 34.81 feet, or an excess of evaporation over rainfall of 1.71 feet.

Lake Water-Level Fluctuations

Water-surface hydrographs for Lakes Faith, Hope, and Charity are shown in figure 2 with a graph of the cumulative difference between rainfall and estimated lake evaporation. The lake water-surface hydrographs correspond to the rainfall minus evaporation graph in seasonal and long-term pattern of flucuation; however, short-term changes in lake water-surface altitudes are noticeably greater in magnitude than changes which can be attributed directly to rainfall and evaporation. These relatively sharp fluctuations in water-surface altitudes of the lakes probably reflect the runoff to the lakes during rains and the seepage of water from the lakes to the underlying Floridan aquifer during dry periods. A hydrograph of the altitude of the potentiometric surface in the Floridan aquifer, as measured by well W-4 on the west shore of Lake Charity (fig. 1), indicates that the potentiometric surface in the Floridan aquifer was always several feet lower than the water-surface altitude in any of the lakes (fig. 2).

During the study, lake water-surface altitudes fluctuated over a range of a few feet with the lowest water-surface altitudes occurring in the spring of 1974 as the result of a continuing deficit of rainfall since the study began in April 1971. Heavy rains in the spring and summer of 1974, and again in 1975, resulted in higher water-surface altitudes, with the maximum levels of the study occurring in the fall of 1975. In October 1975, the water-surface altitude in Lake Charity reached the intake level of the drainage well, and the lake continued to drain to the Floridan aquifer through January 1976. This was the only time during the study that Lake Charity overflowed into the drainage well.

The water-surface altitude of Lake Hope reached the point of overflow to Lake Charity (66.6 feet above sea level) several times during the study, in wet periods during 1974-76 and 1978. Water-surface altitudes in Lakes Charity and Hope coincided for several weeks in 1975 and 1976.

Surface Runoff

Much of the surface runoff to the lakes is through storm drains which serve the residential areas around Lakes Faith, Hope, and Charity. Drainage from Maitland Boulevard is discharged into holding ponds which

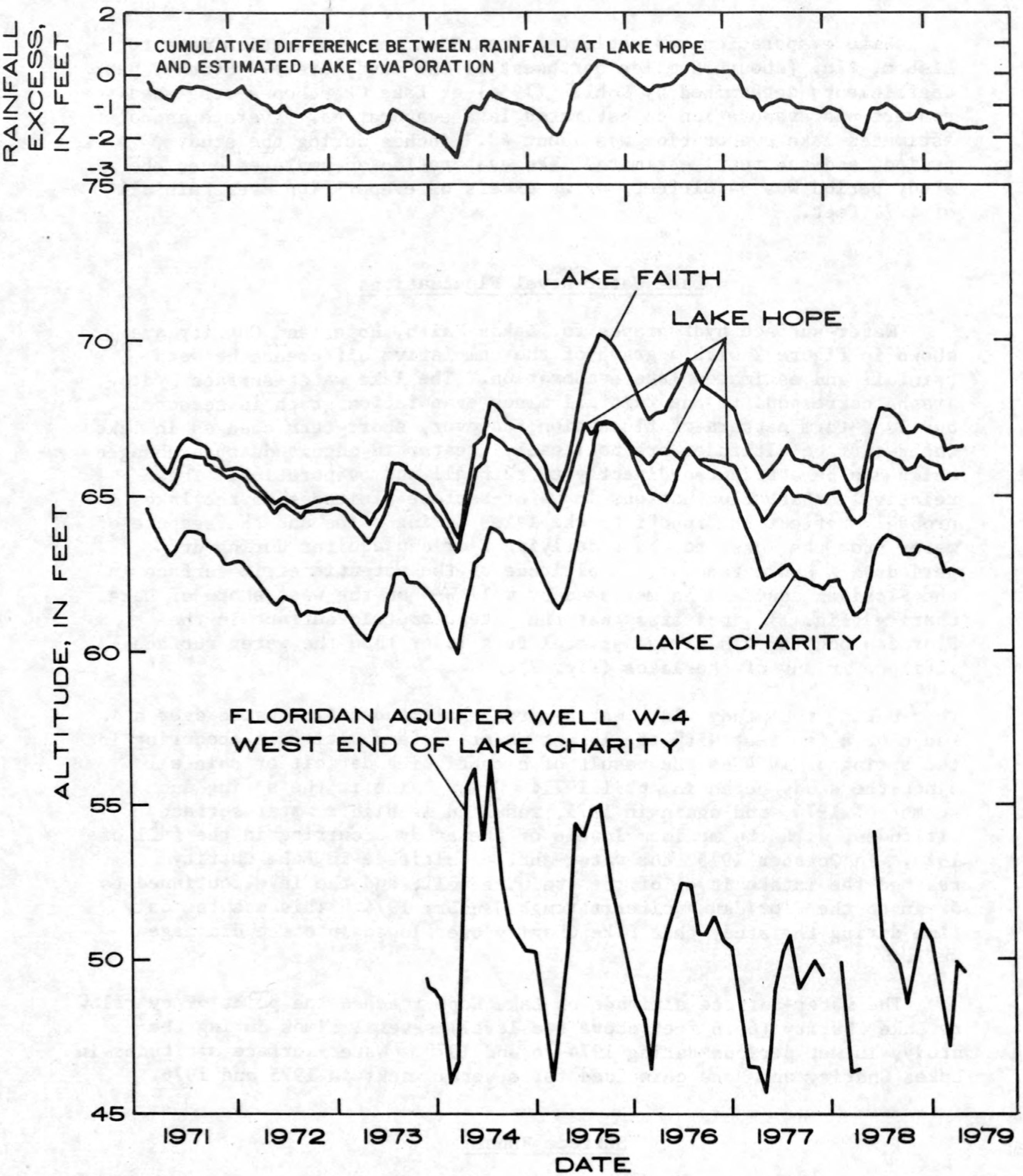


Figure 2.--Lake water-surface altitude, potentiometric surface in the Floridan aquifer, and cumulative excess of rainfall over evaporation, April 1971 to June 1979.

would overflow to Lakes Charity and Faith during periods of extremely heavy rainfall. Lake Lucien receives overflow from holding ponds which intercept runoff from the Maitland Boulevard and the I-4 interchange. Although quantitative data on water levels in the holding ponds are not available, it is probable that the ponds overflowing to Lakes Faith and Charity retain the entire amount of runoff from many, if not all, storms. Overflow was not observed at holding ponds C-1 or F-1 during any of the storm-runoff sampling events.

In order to assess the impact of surface runoff on lake water quality, it is necessary to determine the quantity and quality of the runoff. Runoff to the lakes cannot be measured directly but can be estimated from continuous records of lake stages. Because lake stages rise rapidly in a storm, the evaporation and seepage contribution during the brief period of rising stages may be considered negligible. Runoff is then estimated as the rise in lake stage which is in addition to that attributable to rainfall on the lake surfaces. Lake Lucien was not equipped with a continuous stage recorder, so runoff to the lake was not estimated. During the study period, Lakes Hope and Charity each received 8.1 feet of runoff, and Lake Faith received 7.3 feet of runoff.

Generalized Water Budget

Input of water to the lakes through rainfall on the lake surface and surface runoff from the watershed surrounding the lakes was determined from records of rainfall and changes in lake stage. Water evaporated from the lakes was estimated from records of pan evaporation for a station operated by NOAA near Lisbon, Fla. Two other items in the water budget, which must be considered but which are not so easily estimated, are seepage of water to the lakes from the surficial aquifer around the lakes, and seepage of water from the lakes to the Floridan aquifer underlying the surficial aquifer. It is not possible to determine both of these seepage terms from the hydrologic data collected during this study, but the net effect of seepage can be estimated from the generalized water budget expressed as follows:

$$Q_R + Q_{SR} + Q_{GI} = Q_E + Q_{GO} + \Delta S$$

where

Q_R = rainfall on the lake surfaces,

Q_{SR} = surface runoff to the lakes,

Q_{GI} = ground-water inflow,

Q_E = evaporation from the lakes,

Q_{GO} = ground-water outflow,

ΔS = change in storage, defined as the difference in lake stages at the beginning and end of the study.

Overflow of water from Lake Hope to Lake Charity, and from Lake Charity to the Floridan aquifer by way of the drainage well, are other terms which should be included in the water budget; however, these quantities have not been measured or estimated and are considered to be quantitatively insignificant in comparison with the other terms in the budget.

By rearranging the terms in the water budget, the net seepage can be defined as follows:

$$\text{net seepage} = (Q_{GO} - Q_{GI}) = Q_R + Q_{SR} - Q_E - \Delta S$$

This relation shows that, although the net seepage, or difference between seepage in and seepage out, can be determined, the magnitudes of the two seepage terms are not given.

Magnitudes of the components in the water budget are given in table 3. Rainfall accounted for more than 80 percent of the inflow to the lakes and evaporation accounted for more than 80 percent of the water leaving the lakes. The average net ground-water seepage out of the three lakes was 6.9 feet; it should be emphasized that this indicates nothing about the quantities of seepage to and from the lakes. For example, seepage rates of 10 feet into the lakes and 16.9 feet out of the lakes, or 100 feet in and 106.9 feet out, would both result in a net seepage out of 6.9 feet.

WATER QUALITY IN THE LAKES, SURFACE RUNOFF, BULK PRECIPITATION, AND THE SURFICIAL AQUIFER

General Summary of Water Quality

In this section of the report, water quality of the lakes, the surface runoff, bulk precipitation, and in the surficial aquifer are described and compared, using all data collected over the period of the study. Sampling of water in the surficial aquifer was begun relatively late in the project (March 1978), so conclusions based on comparison of water quality in the surficial aquifer with water quality of the lakes, surface runoff, and bulk precipitation should be regarded as tentative.

Specific Conductance and Nutrients

Specific conductance is a measure of the ability of the water to conduct an electric current, and is related to the dissolved solids content of the water. Dissolved solids concentration can be estimated from specific conductance by multiplying the specific conductance by a factor. This factor, which has averaged from 0.56 at Lake Faith to 0.64 at Lake Charity, has an average value of 0.60 for all of the samples from the lakes. The factor is higher for runoff samples, and has averaged from 0.66 for runoff to Lake Faith to 0.80 for runoff to Lake Charity, with an average value of 0.75 for all runoff samples. For bulk precipitation, the factor has had an average value of 0.68.

Table 3.--Generalized water budget for Lakes Faith, Hope, and Charity, April 1971 to June 1979

[All quantities are in feet]

	Lake Faith	Lake Hope	Lake Charity
Rainfall	33.1	33.1	33.1
Surface runoff	7.3	8.1	8.1
Total inflow	40.4	41.2	41.2
Change in storage	-0.17	-0.26	-2.10
Evaporation	34.8	34.8	34.8
Net seepage	5.8	6.7	8.5
Total outflow	40.6	41.5	43.3

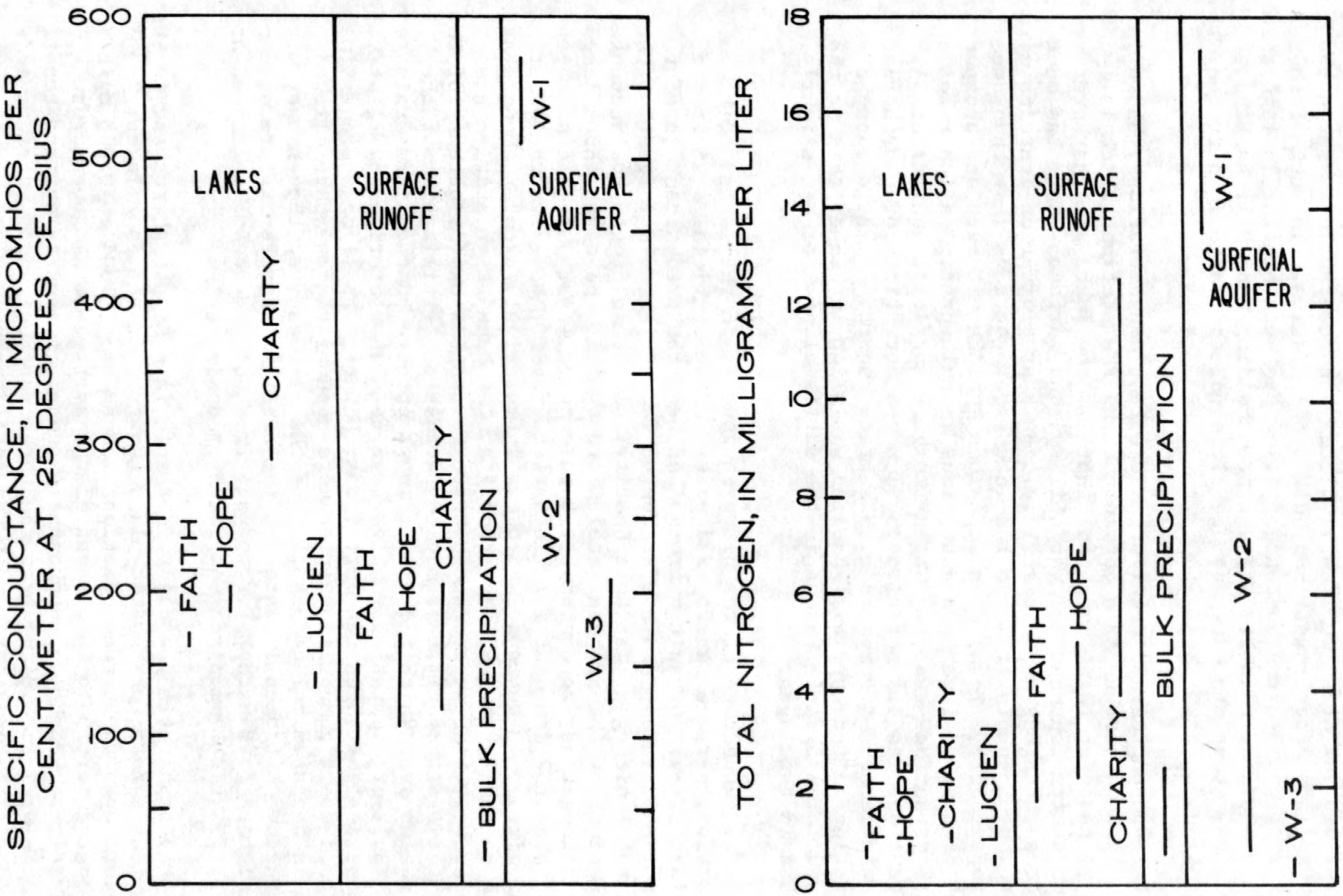
Measurements of specific conductance of the lakes, runoff to the lakes, and bulk precipitation are summarized for the study period in figure 3. These data show that specific conductance differed among the lakes, being lowest at Lake Lucien and highest at Lake Charity. Variance in specific conductance at all four lakes and in rainfall was low, as shown by the small range of the 95 percent confidence interval for the mean. Lake Charity has had the largest variance in specific conductance with the 95 percent confidence interval for the mean spanning the range 290 to 314 μmhos/cm (micromhos per centimeter at 25°C).

In contrast to the lakes, surface runoff has been characterized by relatively large variations in specific conductance. Figure 3 shows that the 95-percent confidence interval for the mean specific conductance of runoff has included a range of from 56 to 86 μmhos/cm, or more than two times the largest confidence interval for mean specific conductance of the lakes. The mean specific conductance of surface runoff ranged from 123 to 162 μmhos/cm; low in comparison with mean specific conductance of Lakes Hope and Charity, but similar in magnitude to mean specific conductance of Lakes Faith and Lucien.

The mean specific conductance of bulk precipitation, determined from 15 composite samples each representing a 4-month composite period, was 22 μmhos/cm. This is much lower than mean specific conductance of the lakes or the runoff.

The specific conductance of water in the surficial aquifer varies widely according to land use. Water from W-1, downslope from a citrus grove, is very high in specific conductance (mean 540 μmhos/cm) in comparison with the other wells, lakes, surface runoff and bulk precipitation. The range of variation in specific conductance of water from the individual wells in the surficial aquifer was higher than the range for individual lakes and bulk precipitation and about the same as the range in surface runoff to individual lakes.

Total nitrogen concentrations, as shown in figure 3, averaged less than 1.0 mg/L as N for the lakes, 2.6 mg/L or greater for surface runoff, and 1.5 mg/L for the bulk-precipitation composite samples. The lower concentrations of nitrogen in the lakes, compared to surface runoff and bulk precipitation, are probably the result of biological activity including uptake of nitrogen by rooted and suspended aquatic plants. Variation in total nitrogen concentrations was low in the lakes in comparison with the bulk precipitation and surface-runoff samples. Surface runoff at the Lake Charity station was highly variable in total nitrogen concentration; at this station the 95 percent confidence interval of the mean total nitrogen concentration included an interval that was more than three times as large as that for the second most variable station (surface runoff to Lake Hope). The reason for the large difference in variability of total nitrogen between the Lake Hope and Lake Charity surface-runoff stations is not known; both stations represent surface runoff from residential areas with a curb- and gutter-street drainage.



NOTE: Bars represent 95-percent confidence interval of the mean value.

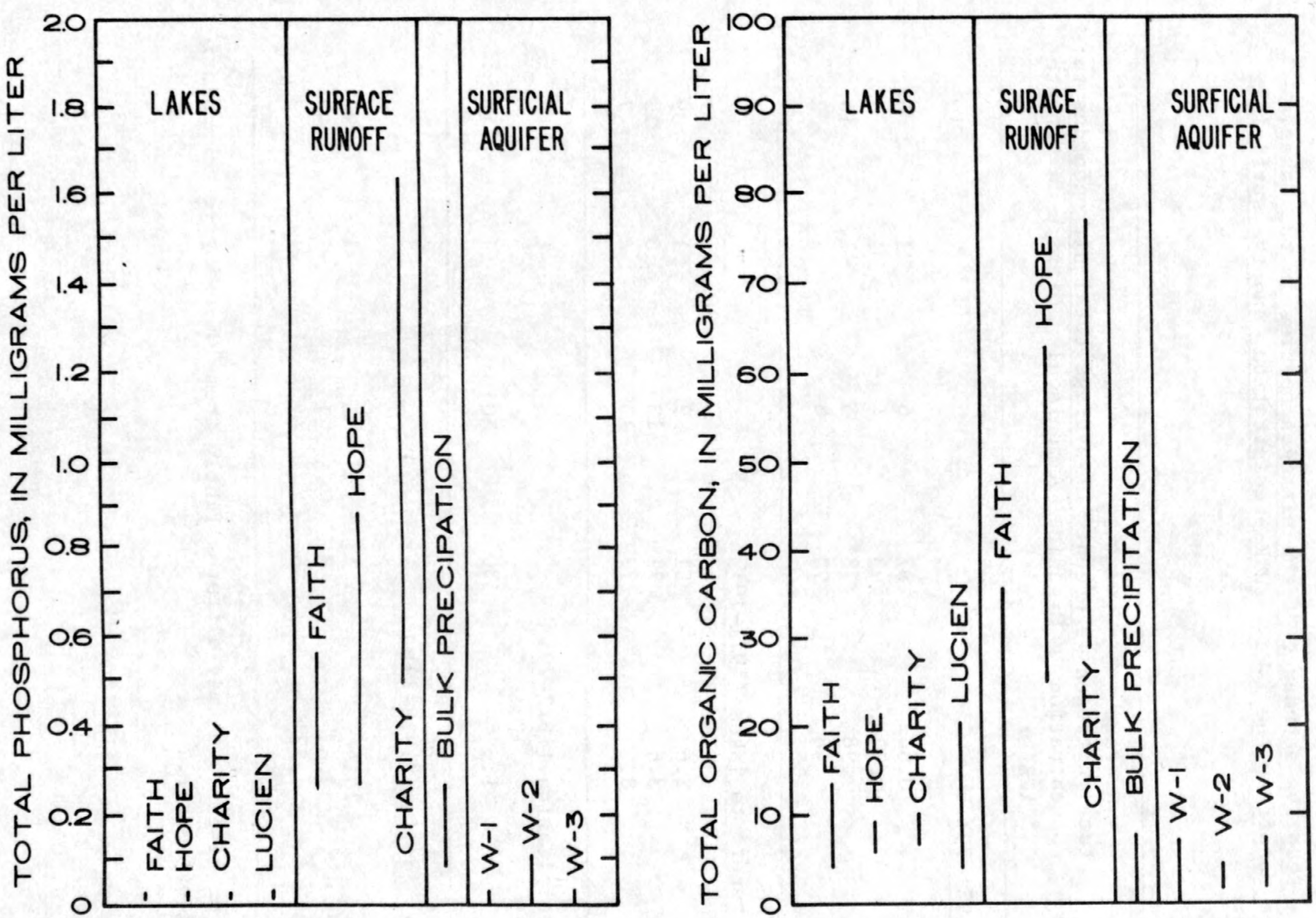
Figure 3.--Average specific conductance and total nitrogen for the lakes, surface runoff to the lakes, bulk precipitation, and the surficial aquifer.

Water from the surficial aquifer is characterized by very high nitrogen concentration downgradient from the citrus grove (well W-1). In the residential area (well W-2), nitrogen concentrations are in the range found in surface runoff and bulk precipitation. In both of these areas, variation in nitrogen concentration has been similar in magnitude to that for surface runoff. Seepage from holding pond F-1, sampled at well W-3, has about the same average nitrogen, and range in nitrogen concentration, as the lakes.

Total phosphorus and total organic carbon concentrations, shown in figure 4, have a pattern of occurrence among the stations which is similar to that for total nitrogen; that is, the lakes are characterized by low concentrations and low variability, and surface runoff has much higher concentrations and variability. Bulk precipitation contains more nitrogen and phosphorus than do the lakes, but contains less than does the surface runoff. Total organic carbon, unlike nitrogen and phosphorus, has been present in lower concentrations in bulk precipitation than in the lakes or surface runoff. Water from the surficial aquifer at all three locations was characterized by low concentrations of phosphorus and organic carbon as compared with surface runoff. Average phosphorus concentration in the surficial aquifer was slightly higher than in the lakes, and total organic carbon in the surficial aquifer was slightly lower than in the lakes.

Relative abundance of the nitrogen species in the lakes, bulk precipitation, surface runoff, and water in the surficial aquifer are listed in table 4. Organic nitrogen has been the predominant form of nitrogen in the lakes, and has accounted for at least 78 percent of the average total nitrogen. At Lake Charity, nitrate nitrogen has accounted for 16 percent of the average total nitrogen. At the other three lakes, nitrate nitrogen has accounted for 6 percent or less. Organic nitrogen has also been the dominant form in surface runoff; however, the other forms of nitrogen have tended to occur in relatively greater amounts as compared to the lakes. Surface runoff at the Lake Faith station has been relatively high in average nitrate concentration (39 percent of the average total nitrogen); this may be because of fertilization of the grassy swales over which the runoff moves enroute to the storm drain inlets. Bulk-precipitation samples have been characterized by relatively high ammoniacal-nitrogen concentrations; however, the long storage time while the 4-month composite samples were accumulated may have allowed changes in the chemical composition of the samples even though they were refrigerated. Nitrogen in water in the surficial aquifer is predominantly in the nitrate form except for seepage from holding pond F-1 sampled at well W-3, in which ammoniacal-nitrogen predominates.

Orthophosphate is the major inorganic form of phosphorus and is the most available form for aquatic plant growth. In the four lakes, average orthophosphate concentrations ranged from 0.004 to 0.008 mg/L and accounted for 20 to 40 percent of the average total phosphorus concentration. Average orthophosphate concentrations in surface runoff ranged from 0.27 to 0.84 mg/L at the three surface runoff stations and accounted for 68 to 79 percent of the total phosphorus concentrations.



NOTE: Bars represent 95-percent confidence interval of the mean value.

Figure 4.--Average total phosphorus and total organic carbon for the lakes, surface runoff to the lakes, bulk precipitation, and the surficial aquifer.

Table 4.--Relative abundance of the nitrogen species in the lakes, surface runoff to the lakes, bulk precipitation, and the surficial aquifer

	Average total nitrogen concentration (mg/L)	Percent[1/] of average total nitrogen due to: Organic	Ammoniacal	Nitrite	Nitrate
Lakes (1971-79)					
Faith	0.64	87	6	1	6
Hope	.73	93	4	1	3
Charity	.98	78	5	1	16
Lucien	.48	90	8	1	2
Surface runoff to lakes (1971-79)					
Faith	2.6	51	9	1	39
Hope	3.6	71	13	3	13
Charity	8.2	77	13	4	7
Bulk precipitation (1972-79)					
	1.5	30	50	1	19
Surficial aquifer (1978-79)					
Well W-1	15.4	1	<1	<1	99
Well W-2	3.6	8	<1	<1	92
Well W-3	.37	35	62	<1	3

[1/] Sum of percentages may differ slightly from 100 owing to accumulati of round-off error.

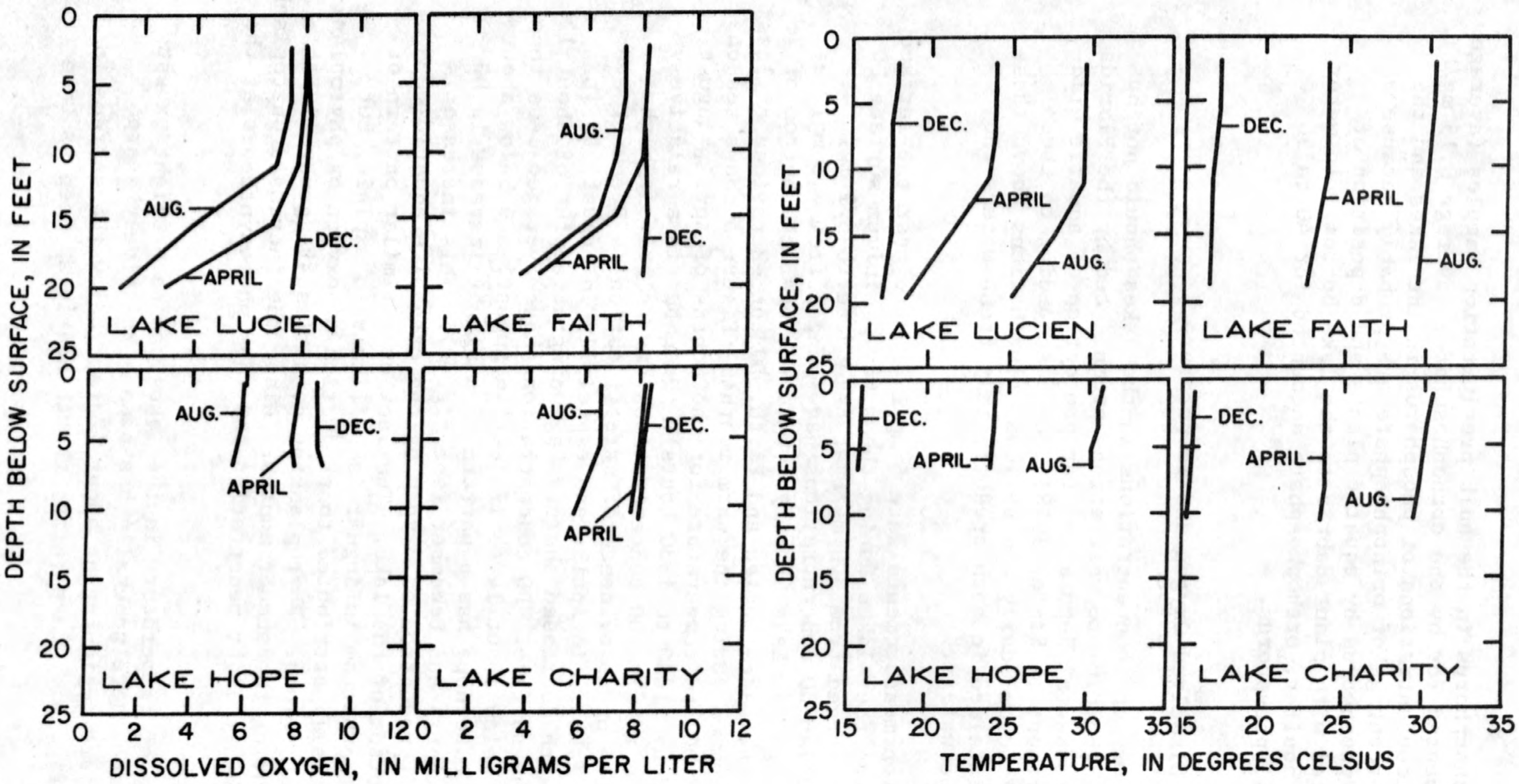
st of the total phosphorus in the bulk precipitation samples (average 17 mg/L) was accounted for by the orthophosphates (average 0.15 mg/L). e relatively low concentrations of phosphorus in the lakes and the latively small percentage of orthophosphate are probably because of ilization of the phosphorus by aquatic plants and deposition of osphorus associated with plant debris to the lake bottom. In water om the surficial aquifer, orthophosphate accounted for 40 to 50 rcent of the total phosphorus.

Dissolved Oxygen and Temperature

DO (dissolved oxygen) concentrations in the lakes should not be ss than 5.0 mg/L according to regulations promulgated by the Florida partment of Environmental Regulation for protection of aquatic wild-fe (Florida Department of State, 1978). Also according to these gulations, "* * * normal daily and seasonal fluctuations above these vels shall be maintained in both predominately fresh waters and edominately marine waters."

DO concentration measurements were 5 mg/L or more near the surface ipper 2 feet) at the four lakes during the study. Minimum surface DO ncentrations have ranged from 5.0 mg/L at Lake Hope to 6.1 mg/L at ike Lucien, and median DO concentrations have ranged from 7.8 mg/L at ike Lucien to 8.3 mg/L at Lake Charity. However, near the bottom of ie two deepest lakes, Lakes Lucien and Faith, DO concentrations of less ian 5.0 mg/L are common during the warm months. Figure 5 shows seasonal 'erage profiles of DO and temperature for the months of April, August, id December at midday (1030 to 1330 hours). December is a relatively ol month, and as a result, DO concentrations are relatively high. lso, there is little or no evidence of stratification in December even ı the two deepest lakes. In April, and especially in August, DO in ikes Lucien and Faith decreased sharply beginning at depths of about 12) 15 feet below the surface. DO concentrations have averaged less than .0 mg/L at depths below about 14 to 17 feet in August, and below about 7 feet in April. Lake Hope has a pattern of a slight increase in DO ear the bottom in April and December (see fig. 5). This increase is robably because of production of oxygen by the extensive aquatic weed rowths near the bottom of the lake. The lack of a similar pattern of ncreased DO near the bottom in August is difficult to explain, but erhaps can be partially attributed to production of oxygen by phytoplankton hroughout the water column. Phytoplankton densities are generally at a easonal maximum during the summer months. Also, the increased phytoplankton ensities could inhibit light penetration and thus photosynthesis at the ake bottom.

Stratification of temperature in the lakes has been slight except t Lake Lucien, where there generally has been a relatively sharp ecline in temperature beginning at about 12 feet below the surface in pril and August (fig. 5). Lake Faith, though nearly as deep as Lake



NOTE: Data plotted are average of triannual samples for 1971-79.

Figure 5.--Seasonal average profiles of dissolved oxygen and temperature for the lakes at midday (1030-1330 hours), 1971-79.

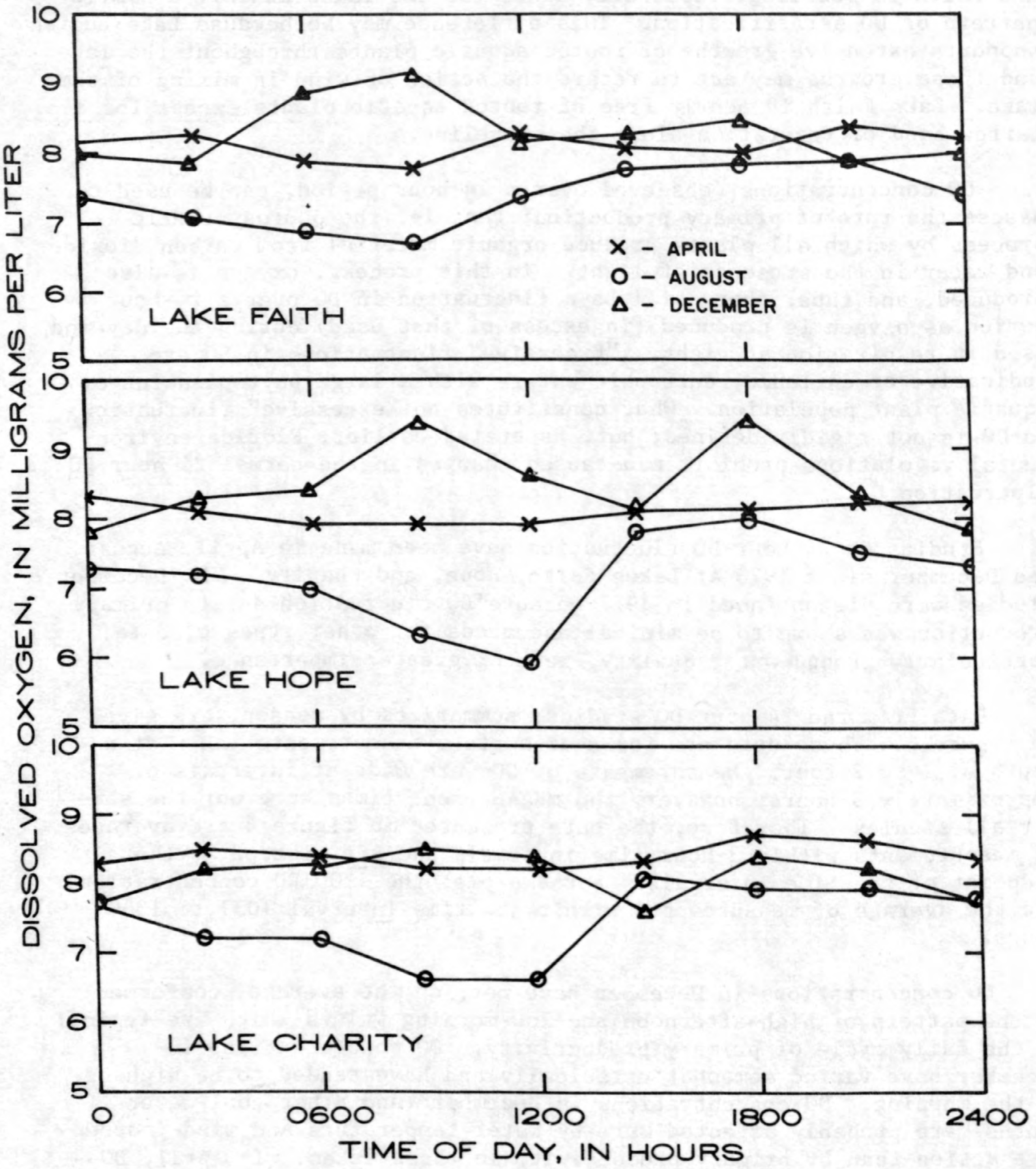
Lucien, has not been as stratified with respect to temperature. The difference in the degree of temperature stratification in Lakes Lucien and Faith is puzzling, especially since the two lakes exhibit a similar pattern of DO stratification. This difference may be because Lake Lucien supports extensive growths of rooted aquatic plants throughout the lake and these growths may act to retard the action of wind in mixing of the lake. Lake Faith is nearly free of rooted aquatic plants except for a narrow band of vegetation along the shoreline.

DO concentrations, observed over a 24-hour period, can be used to assess the rate of primary production; that is, the photosynthetic process by which all plants produce organic material from carbon dioxide and water in the presence of light. In this process, oxygen is also produced, and thus, there will be a fluctuation in DO over a 24-hour period as oxygen is produced (in excess of that used) during the day and used in respiration at night. "Excessive" fluctuations in DO are indicative of enriched, eutrophic waters with a large phytoplankton or aquatic plant population. What constitutes an "excessive" fluctuation in DO is not rigidly defined; but, as stated earlier, Florida environmental regulations prohibit man-caused changes in the normal 24-hour DO fluctuation.

Studies of 24-hour DO fluctuation have been made in April, August, and December since 1973 at Lakes Faith, Hope, and Charity. The December studies were discontinued in 1977 because DO fluctuation due to primary production was shown to be minimal and needs for other types of data, particularly ground-water quality, were of greater importance.

Data from the 24-hour DO studies, summarized by season, are given in figure 6. These data are for near-surface measurements taken at a depth of 1 to 2 feet. Measurements of DO were made at intervals of approximately 3 hours; however, the measurement times were not the same for all studies. Therefore, the data presented in figure 6 are averages of measurements within 3-hour time intervals and are plotted at the midpoint of the time intervals. For example, the 1200 DO concentrations are the average of measurements within the time interval 1031 to 1330 hours.

DO concentrations in December have not, on the average, conformed to the pattern of high-afternoon and low-morning values which are typical of the daily cycle of primary productivity. DO concentrations in December have varied somewhat erratically and have tended to be highest in the morning. DO concentrations in December (and other cool-water months) are probably affected more by water temperature and wind-induced wave action than by primary productivity in these lakes. In April, DO fluctuations over the 24-hour period have been, on the average, relatively small and, except at Lake Charity, have not followed the pattern to be expected if production and use of oxygen by plants were the main factor affecting DO concentration. The studies in August have shown a DO variation which is in step with the daily cycle of primary productivity, and the largest variations in DO have occurred during August. Minimum DO concentrations in August have occurred late morning or midday,



NOTE: Data plotted are average of triannual samples for 1971-79.

Figure 6.--Seasonal average dissolved oxygen in Lakes Faith, Hope, and Charity at a depth of 1 to 2 feet over a 24-hour period, 1971-79.

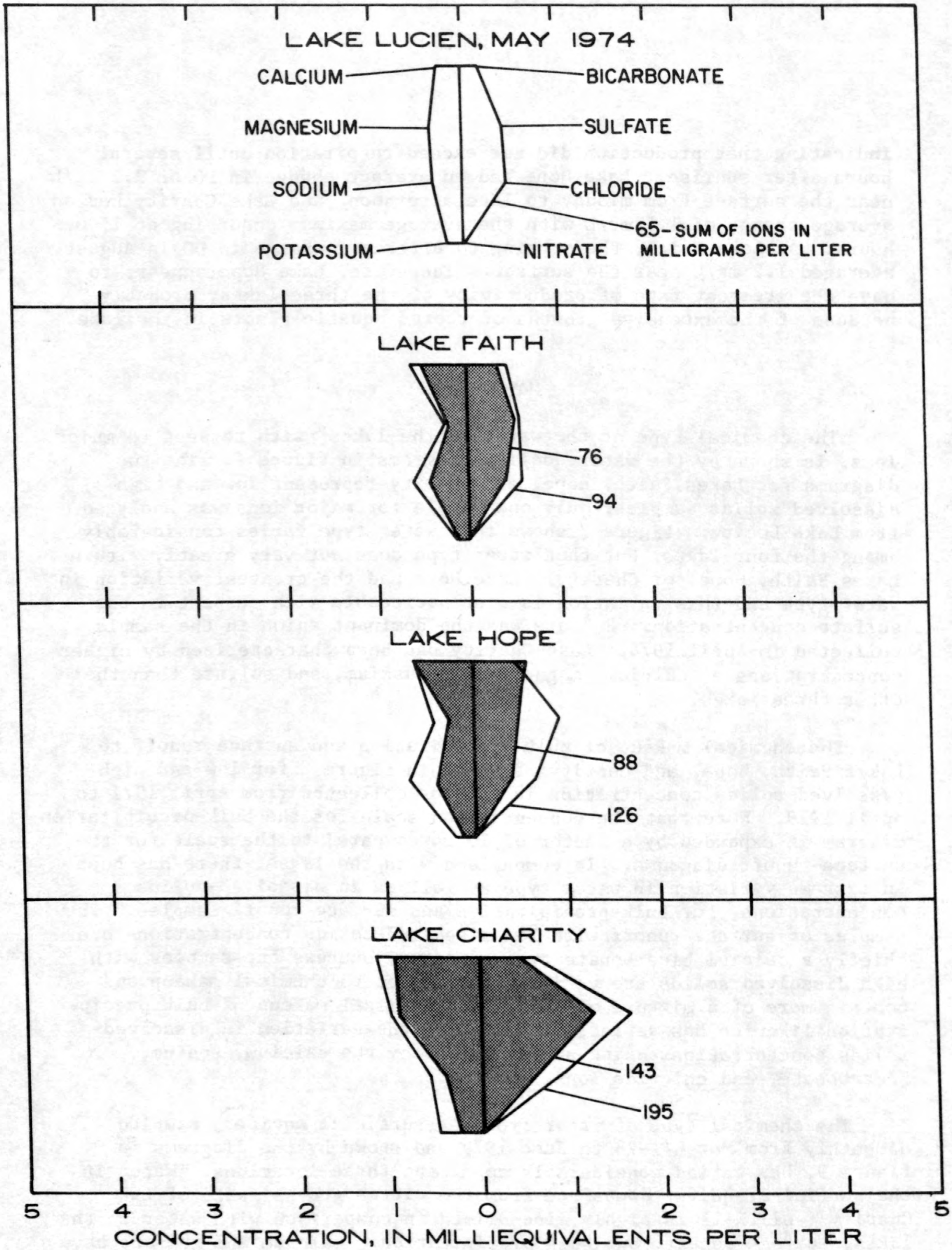
indicating that production did not exceed respiration until several hours after sunrise. Lake Hope had an average change in DO of 2.2 mg/L near the surface from midday to late afternoon, and Lake Charity had an average change of 1.5 mg/L with the average maximum occurring at 1500 hours. At Lake Faith, the morning to afternoon change in DO in August averaged 1.2 mg/L near the surface. Therefore, Lake Hope appears to have the greatest rate of productivity of the three lakes, probably because of the extensive growths of rooted aquatic plants in the lake.

Major Ions

The chemical type of the water in the lakes, with respect to major ions, is shown by the water-quality diagrams in figure 7. The two diagrams for Lakes Faith, Hope, and Charity represent low and high dissolved solids samples; only one sample for major ions was analyzed from Lake Lucien. Figure 7 shows that water type varies considerably among the four lakes, but that water type does not vary greatly within Lakes Faith, Hope, or Charity. Lake Hope had the greatest variation in water type and this variation is most noticeable with respect to the sulfate concentration. Sulfate was the dominant anion in the sample collected in April 1974. Lake Charity has been characterized by higher concentrations of calcium, magnesium, potassium, and sulfate than the other three lakes.

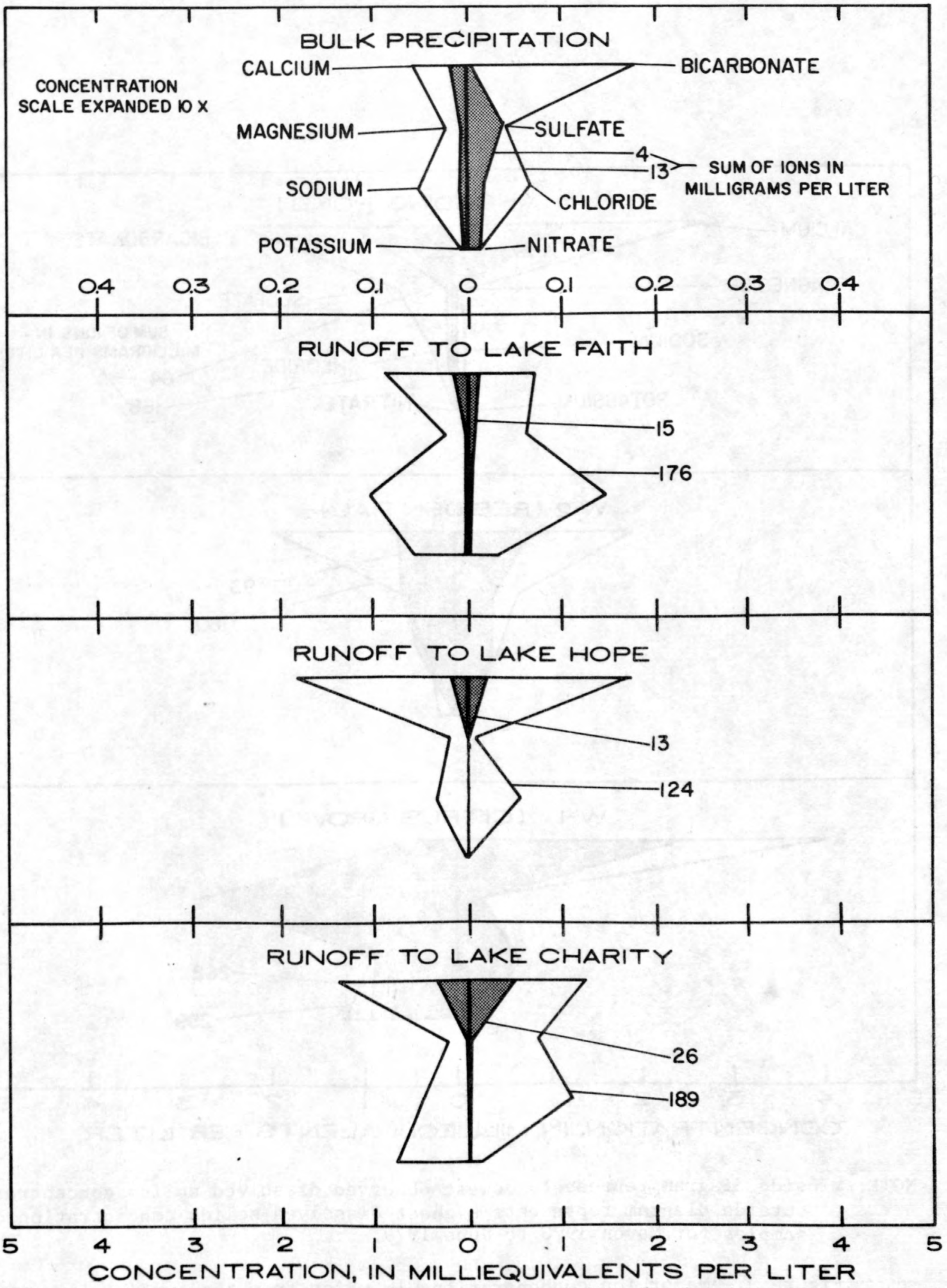
The chemical makeup of bulk precipitation and surface runoff to Lakes Faith, Hope, and Charity is shown in figure 8 for low and high dissolved-solids concentration in samples collected from April 1971 to April 1979. Note that the concentration scale for the bulk-precipitation diagram is expanded by a factor of 10 as compared to the scale for the surface-runoff diagrams. In comparison with the lakes, there has been an extreme variation in water type as well as in dissolved-solids concentrations, for bulk-precipitation and surface-runoff samples. The samples of surface runoff with low dissolved-solids concentrations are chiefly a calcium bicarbonate type of water, whereas the samples with high dissolved solids are varied with respect to chemical makeup and contain more of a mixture of ions. The chemical makeup of bulk precipitation likewise has varied, with most of the variation in dissolved-solids concentrations being accounted for by the calcium, sodium, bicarbonate, and chloride ions.

The chemical type of water from the surficial aquifer, sampled bimonthly from March 1978 to June 1979 and shown by the diagrams in figure 9, has varied considerably among the three locations. Water in the surficial aquifer downslope from the citrus groves south of Lake Charity (well W-1) is highly mineralized in comparison with water in the lakes, surface runoff, and bulk precipitation. Calcium and sulfate have been the predominant ions, and nitrate also has been a significant part of the dissolved-solids concentration. These characteristics could be the result of fertilization of the citrus groves. In the residential area, water from the surficial aquifer (well W-2) has been a calcium



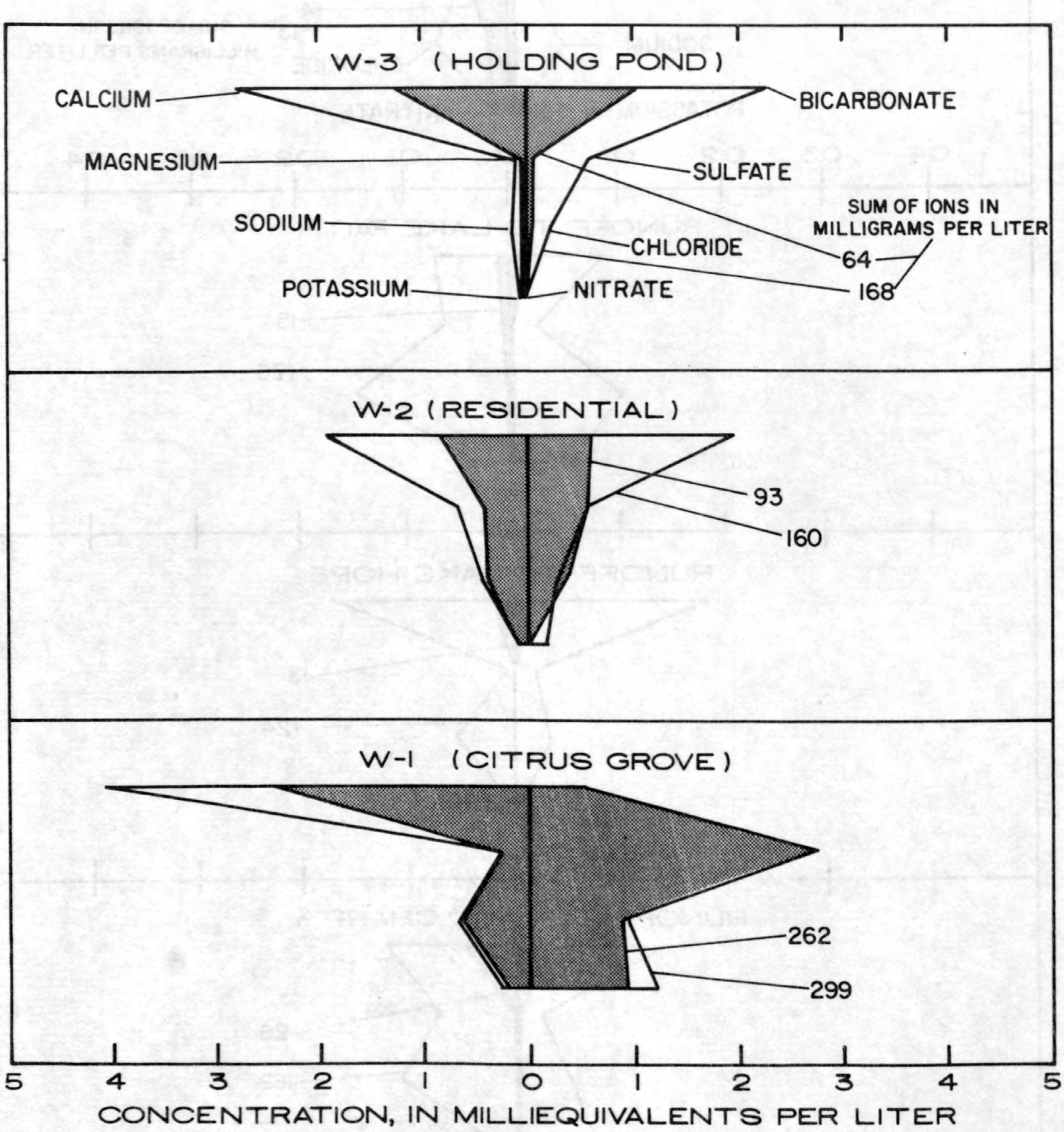
NOTE: Inside diagrams for samples collected December 1978, outside diagrams for samples collected April 1974; represent low and high dissolved solids periods.

Figure 7.--Major ion concentrations in the lakes.



NOTE: Inside diagram represents lowest observed dissolved solids concentration, outside diagram represents highest dissolved solids concentration of samples for 1971-79.

Figure 8.--Major ion concentrations in bulk precipitation and surface runoff to the lakes.



NOTE: Inside diagram represents lowest observed dissolved solids concentrations; outside diagram represents highest dissolved solids concentration of samples for March 1978 to June 1979.

Figure 9.--Major ion concentrations in water from the surficial aquifer.

bicarbonate type, but the other ions (except for potassium and nitrate) also make up a considerable part of the dissolved solids. Seepage from holding pond F-1, sampled from a shallow well between the holding pond and Lake Faith (well W-3), is primarily a calcium bicarbonate type of water, probably due to solution of the dry-concrete mix in bags used to stabilize the overflow spillway. Variations in dissolved-solids concentrations at the three shallow aquifer sites have been characterized chiefly by changes in calcium, bicarbonate, and sulfate at W-3, calcium and bicarbonate at W-2, and calcium and nitrate at W-1.

Trace Metals

Water from the lakes, surface runoff, and bulk precipitation composite samples have been analyzed for a wide variety of trace metals, some included in the Florida water-quality standards applying to the lakes (Florida Department of State, 1978, p. 19-24; 37-41). Knowledge of occurrence and toxicity of metals has been developing during the study with the result that coverage of the metals data is not uniform; some metals were added to the analytical schedule and others were dropped at various dates during the study. A summary of the trace metals data is given in table 5.

The most abundant trace metals in the lakes, listed in order of the decreasing median total-recoverable concentration (50th percentile concentration), were: aluminum, strontium, iron, manganese, and zinc. These elements were present in half of the samples from lakes in concentrations of 10 μg/L (micrograms per liter) or greater. In surface runoff, the trace metals for which median concentrations were 10 μg/L or greater included, in order of decreasing median total-recoverable concentration: iron, aluminum, lead, zinc, strontium, manganese, and copper. Except for strontium and manganese, concentrations of these trace metals in the surface runoff were considerably higher than in the lakes. Bulk precipitation contained at least detectable amounts of all the metals listed in table 5 in one or more samples. The predominant metals, in order of decreasing median total-recoverable concentrations, were: zinc, strontium, aluminum, iron, and lead. Median total-recoverable concentrations of these metals in bulk-precipitation samples were 9 μg/L or greater.

A comparison of median concentrations of the trace metals in the lakes with median concentrations in bulk precipitation and surface runoff indicates that for some of the trace metals, the load transported to the lakes in rainfall and surface runoff is not remaining in suspension or in solution in the lakes. Ten of the trace metals were determined in the lakes, in bulk precipitation, and also in surface runoff; for six of these trace metals (copper, iron, lead, mercury, nickel, and zinc) the lowest median concentrations were in the lakes or were equal in the lakes and in bulk-precipitation samples.

Table 5.--Range of concentration of trace metals in the lakes, surface runoff to the lakes, and bulk precipitation

[All concentrations are in micrograms per liter. Number of samples precede colon; 5th, 50th, and 95th percentile concentrations follow colon. Nth percentile concentration is not exceeded in N percent of the samples]

Constituent	Lakes	Surface runoff	Bulk precipitation
Aluminum, dissolved.	93: 0,30,160	87: 0,50,400	19: 0,20,50
Aluminum, total recoverable. . . .	58: 30,80,220	58: 130,390,2400	17: 0,30,100
Arsenic, dissolved	90: 0,3,10	87: 0,1,20	18: 0,0,1
Arsenic, total recoverable	66: 2,3,10	75: 0,2,19	16: 0,0,1
Cadmium.	27: 0,0,0	29: 0,0,0	--
Chromium, hexavalent, dissolved.	35: 0,0,0	32: 0,0,0	--
Copper, dissolved.	94: 0,0,20	90: 0,10,50	20: 0,5,11
Copper, total recoverable.	57: 0,2,10	52: 6,19,56	16: 2,6,17
Iron, dissolved.	94: 0,0,40	90: 0,40,170	20: 0,0,20
Iron, total recoverable.	55: 0,20,250	58: 80,400,1200	17: 0,20,60
Lead, dissolved.	94: 0,2,13	90: 3,38,310	20: 0,8,18
Lead, total recoverable.	54: 0,6,37	58: 25,200,660	16: 0,9,43
Manganese, dissolved	93: 0,0,10	90: 0,10,80	20: 0,0,10
Manganese, total recoverable . . .	58: 0,10,30	58: 0,20,80	16: 0,0,20
Mercury, total recoverable	97: 0,0,0.5	89: 0,0.1,1.3	15: 0,0.1,0.5
Molybdenum, dissolved.	33: 0,0,1	37: 0,0,43	--
Molybdenum, total recoverable. . .	7: 0,0,1	6: 0,0,0	--
Nickel, dissolved.	88: 0,0,5	84: 0,2,10	19: 0,0,2
Nickel, total recoverable.	58: 0,2,21	56: 0,5,19	17: 0,4,24
Strontium, dissolved	61: 30,70,160	57: 30,70,230	14: 0,40,110
Vanadium, dissolved.	32: 0,1,3	29: 0,2,4	--
Zinc, dissolved.	94: 0,10,50	90: 0,30,270	20: 0,30,80
Zinc, total recoverable.	57: 0,10,60	53: 20,120,340	15: 7,40,100

Selected metals (aluminum, copper, iron, lead, manganese, nickel, and zinc) were determined both as the dissolved amount (capable of passing through a 0.45 micrometer pore-size filter) and the total recoverable amount, which includes the material sorbed on solid material suspended in the water. Median total-recoverable concentrations were, as would be expected, higher than the median dissolved concentrations for all metals on which both determinations were made. Rainfall and lake waters are relatively low in suspended solids concentrations as compared to surface runoff. Therefore, differences in total recoverable and dissolved concentrations in the lakes and in bulk-precipitation samples were small compared to differences in total recoverable and dissolved concentrations in surface runoff. Ratios of total recoverable to dissolved concentrations of metals in surface runoff ranged from about 2 to 10 for metals with median concentrations equal to or greater than 10 µg/L (aluminum, copper, iron, lead, manganese, and zinc).

The maximum allowable concentrations of trace metals in water depends on the expected usage of the water and varies considerably among the metals. Lakes Faith, Hope, Charity, and Lucien are classified by the Florida Department of Environmental Regulation as waters for recreation and propagation of wildlife, and maximum allowable concentrations (Florida Department of State, 1978) for the trace metals determined at the lakes are listed in table 6. Also listed in table 6 are exceedence rates, or percentage of the samples which exceeded allowable concentrations at the lake, bulk precipitation, and surface-runoff sampling sites. These limiting concentrations apply, of course, only to the lakes; however, these limits are a convenient standard of comparison for assessing differences among the lakes and the input to the lakes. Oil and grease is another water-quality parameter included in the list of constituents for which maximum allowable concentrations have been set, and is included in table 6.

Oil and grease exceeded water-quality standards in the lakes more frequently than any other constituent. The rate at which oil and grease concentrations have exceeded the 5,000 µg/L standard has ranged from 31 percent at Lake Hope to 48 percent at Lake Faith. Some metals in the lakes have exceeded the water-quality standards; these are, in order of decreasing average rate of exceedence: zinc (20 percent), lead (10 percent), mercury (5 percent), and copper (2 percent). It should be noted that the water-quality standard for mercury is 0.2 µg/L and this concentration is lower than the analytical detection limit (0.5 µg/L). Therefore, exceedence rates for mercury given in table 6 is for mercury in excess of 0.5 µg/L and thus may be misleading. Copper exceeded the water-quality standard of 30 µg/L only at Lake Charity, and in only 1 of the 19 samples. In surface runoff to the lakes, 7 of the 11 constituents listed in table 6 exceeded water-quality standards for the lakes at times. These are, in order of decreasing average exceedence rate: lead (95 percent), zinc (92 percent), oil and grease (42 percent), copper (24 percent), mercury at detection limit (17 percent), aluminum (11 percent), and iron (7 percent). Only two of the metals in bulk precipitation composite samples exceeded lake water-quality standards: zinc (60 percent) and lead (12 percent).

Table 6.--Maximum allowable concentrations and exceedence rates for trace metals and oil and grease in the lakes, surface runoff to the lakes, and bulk precipitation

[Maximum allowable concentrations, set by Florida Department of Environmental Regulation (Florida Department of State, 1978) apply only to the lakes and are given in micrograms per liter]

Constituent	Maximum allowable concentration	Percent of samples in which maximum allowable concentration was exceeded/total number of samples						
		Lakes			Surface runoff to lakes			Bulk precipitation
		Faith	Hope	Charity	Faith	Hope	Charity	
Aluminum	1,500	0/19	0/19	0/19	5/19	6/17	21/19	0/17
Arsenic	50	0/21	0/22	0/22	0/22	0/20	0/22	0/16
Cadmium, dissolved	0.8	0/9	0/9	0/9	0/5	0/5	0/5	--
Hexavalent chromium, dissolved	500	0/12	0/11	0/12	0/5	0/6	0/6	--
Copper	30	0/19	0/19	5/19	31/16	20/15	22/18	0/16
Iron	1,000	0/18	0/17	0/19	11/19	0/17	11/19	0/17
Lead	30	11/18	6/18	12/17	89/19	100/17	95/19	12/16
Mercury	0.2	9/32	3/32	3/32	21/24	9/23	20/25	0/15
Nickel	100	0/19	0/19	0/19	0/18	0/17	0/19	0/17
Zinc	30	16/19	21/19	22/18	94/17	93/15	89/18	60/15
Oil and grease	5,000	48/31	31/32	38/32	33/23	50/20	43/23	0/2

1/ Data are for total recoverable concentrations in a water-suspended sediment mixture except as noted.

Phytoplankton

Phytoplankton, commonly called algae, are the community of suspended or swimming plants which convert inorganic chemicals into living organic matter using solar energy. This community of organisms is the base of the food chain for most aquatic animals, and therefore, is necessary for a diversified aquatic community. However, the phytoplankton population can respond to enrichment of a lake through pollution (or any process which adds essential plant nutrients) through periodic explosive growths commonly known as blooms. Phytoplankton blooms give the water a turbid appearance and restrict light penetration. Some adverse effects of blooms can be:

1. Toxins produced by some species of phytoplankton may be toxic to fish.
2. Noxious odors and unpleasant tastes may be produced.
3. Light penetration may be restricted to the point that rooted aquatic plants cannot survive and some desirable fish species are inhibited.
4. Respiration and decay of the phytoplankton may exert such a demand on DO that fish may be asphyxiated in large numbers.

The subject of phytoplankton, what levels of nutrients are necessary to cause explosive growth, and at what phytoplankton concentration undesirable effects begin to occur, is complex and not well understood. The Florida Department of Environmental Regulation, in the regulations applying to nutrient concentrations in Lakes Faith, Hope, Charity, and Lucien, state that "* * * in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora and fauna." (Florida Department of State, 1978.)

Samples of phytoplankton have been collected, generally at bimonthly intervals, since June 1971 at Lakes Faith, Hope, and Charity, and since May 1974 at Lake Lucien. These samples were analyzed for total cell densities in water and identification of the phytoplankton to the genus level of classification. A summary of the phytoplankton densities for each lake, based on all of the samples, is given in table 7, with the percentage of the total cell count for all samples accounted for by the various phytoplankton divisions. Median, or 50 percentile phytoplankton densities, have been lowest in Lakes Hope and Lucien and highest in Lakes Faith and Charity. The highest phytoplankton densities among the four lakes have occurred at Lake Charity, where in about 5 percent of the samples, densities exceeded 14,200 cells/mL (cells per milliliter). These densities of phytoplankton are very low in comparison to many Florida lakes. For example, Lake Okeechobee (Joyner, 1974) and Lake Dicie (Lamonds, 1974) have, at times, had densities of phytoplankton in excess of 450,000 cells/mL. Other lakes in Florida are sampled by the U.S. Geological Survey once or twice a year for phytoplankton. According to data for water year 1978 (U.S. Geological Survey, 1979) for nine lakes in the central Florida area, total phytoplankton densities have ranged from 820 to 7.5 million cells/mL, with four of the nine lakes having densities in excess of 1 million cells/mL.

Table 7.--Range in phytoplankton densities and distribution among divisions

[Computations based on 43 phytoplankton samples for Lakes Faith, Hope, and Charity, and 32 samples for Lake Lucien]

Lake	Nth percentile[1/] phytoplankton concentrations			Percent of total cell count accounted for by division:				
	N=5	50	95	Chlorophyta (green algae)	Euglenophyta (euglenoids)	Pyrrhophyta (desmokonts)	Chrysophyta (diatoms)	Cyanophyta (blue-green algae)
Faith	468	2,450	10,800	22	<1	1	8	69
Hope	108	675	6,330	24	2	<1	3	71
Charity	512	2,983	14,200	10	<1	<1	2	88
Lucien	145	1,010	2,670	19	<1	3	14	64

[1/] Concentration, expressed in cells per milliliter, not exceeded in N percent of the samples (50th percentile=median concentration).

The distribution among the five divisions represented by the phytoplankton community has been similar among Lakes Faith, Hope, Charity, and Lucien in that division Cyanophyta, commonly known as the blue-green algae, has been dominant. Lake Lucien has had the lowest proportion of Cyanophyta (64 percent of the total cell count of all samples) and Lake Charity has had the highest (88 percent). Division Cyanophyta are generally considered to be the most troublesome, nuisance-producing type of phytoplankton: They are largely inedible by other aquatic organisms and may even be toxic; they may impart an objectionable odor and taste to water if present in sufficient concentrations; and they contain gas vacuoles which enable them to rise to the water surface where they sometimes aggregate in thick masses. Another common characteristic of the phytoplankton community at the four lakes is a very low percentage (3 percent or less) of the divisions Euglenophyta and Pyrrhophyta. Differences among the four lakes include a relatively low percentage of division Chlorophyta (green algae) at Lake Charity and low percentages of division Chrysophyta at Lakes Hope and Charity compared to Lakes Faith and Lucien.

Summaries of the genera identified in Lakes Faith, Hope, Charity, and Lucien are given in tables 8 through 11. Listed in these tables are all genera which accounted for 1 percent or more of the total cell count of all samples. Phytoplankton communities at all four lakes have been dominated by Anacystis. In all the lakes except Lake Lucien, Anacystis accounted for more than half the total cell count of all samples, and in all four lakes, it has been reported in more than 95 percent of the samples.

A composite list of all the genera which have accounted for at least 1 percent of the total cell count of all samples at each lake is given in table 12. Three other phytoplankton genera, in addition to Anacystis, have been ubiquitous to all four lakes. These are Agmenellum, Ankistrodesmus, and Chlorella. All four of these genera have been described by various studies as being pollution tolerant or characteristic of enriched waters (Palmer, 1969). Lake Charity has been characterized by the highest percentage of pollution-tolerant genera; all six of the identified genera which have accounted for at least 1 percent of the total cell count of all samples have been labeled as pollution tolerant. At Lakes Faith, Hope, and Lucien, the proportion of the pollution-tolerant genera among the identified genera accounting for at least 1 percent of the total cell count of all samples has been 62, 64, and 77 percent, respectively.

The significance of these pollution-tolerant phytoplankton genera as indicators of enrichment has not been determined for Florida lakes. The list compiled by Palmer (1969) from studies throughout the world, does not take into account the possibility of climatic effects on phytoplankton populations. The pollution-tolerant phytoplankton found in Lakes Faith, Hope, Charity, and Lucien are widespread in Florida waters and determination of the actual significance of these organisms in Florida waters deserves further study.

Table 8.--Phytoplankton genera which accounted for at least 1 percent of the total cell count of all samples--Lake Faith

Division	Genus	Percent of total count--all samples	Percent of all samples in which genus was reported
Chrysophyta	Synedra	1.0	40.0
Chlorophyta	Staurastrum	1.2	44.2
Do.	Elakatothrix	1.2	7.0
Do.	Tetraedron	1.2	48.8
Do.	Oocystis	1.5	58.1
Do.	Scenedesmus	1.7	72.1
Do.	Unidentified	2.2	72.1
Do.	Ankistrodesmus	2.3	62.8
Chrysophyta	Dinobryon	2.7	41.9
Cyanophyta	Agmenellum	2.8	51.2
Chlorophyta	Chlorella	2.9	65.1
Chrysophyta	Cyclotella	3.1	55.8
Chlorophyta	Chodatella	5.7	4.6
Cyanophyta	Anacystis	62.8	100
	Total	92.3	---

Table 9.--Phytoplankton genera which accounted for at least 1 percent of the total cell count of all samples--Lake Hope

Division	Genus	Percent of total count--all samples	Percent of all samples in which genus was reported
Chlorophyta	Quadrigula	1.0	2.3
Chrysophyta	Cyclotella	1.0	25.6
Cyanophyta	Agmenellum	1.1	23.3
Chlorophyta	Oocystis	1.4	34.9
Euglenophyta	Chroomonas	1.5	9.3
Chlorophyta	Selenastrum	1.6	30.2
Cyanophyta	Unidentified	1.8	32.6
Chlorophyta	Scenedesmus	2.4	41.9
Do.	Unidentified	2.7	62.8
Do.	Ankistrodesmus	3.0	55.8
Do.	Tetrallantos	3.1	18.6
Do.	Chlorella	5.0	67.4
Cyanophyta	Anacystis	65.3	95.3
	Total	90.9	---

Table 10.--Phytoplankton genera which accounted for at least 1 percent of the total cell count of all samples--Lake Charity

Division	Genus	Percent of total count--all samples	Percent of all samples in which genus was reported
Cyanophyta	Unidentified	1.3	27.9
Chlorophyta	do.	1.3	58.1
Cyanophyta	*Oscillatoria*	1.6	39.5
Do.	*Agmenellum*	1.7	41.9
Chlorophyta	*Chlorella*	1.8	65.1
Do.	*Ankistrodesmus*	3.5	65.1
Cyanophyta	*Lyngbya*	13.2	37.2
Do.	*Anacystis*	68.8	100
	Total	93.2	---

Table 11.--Phytoplankton genera which accounted for at least 1 percent of the total cell count of all samples--Lake Lucien

Division	Genus	Percent of total count--all samples	Percent of all samples in which genus was reported
Chlorophyta	Botryococcus	1.0	6.2
Do.	Scenedesmus	1.4	40.6
Cyanophyta	Oscillatoria	1.4	28.1
Chrysophyta	Synedra	1.4	15.6
Chlorophyta	Selenastrum	1.6	37.5
Do.	Ankistrodesmus	2.6	56.2
Pyrrhophyta	Peridinium	2.7	50.0
Cyanophyta	Agmenellum	3.3	53.1
Chlorophyta	Chlorella	4.3	56.2
Chrysophyta	Dinobryon	4.6	53.1
Chlorophyta	Unidentified	4.7	65.6
Chrysophyta	Cyclotella	6.6	40.6
Cyanophyta	Lyngbya	17.3	37.5
Do.	Anacystis	40.6	100
	Total	93.5	---

Table 12.--Composite list of phytoplankton genera, including identification of pollution-tolerant genera

[Genera which have been described as being characteristic of enriched water (Palmer, 1969) are marked with an asterisk]

("X" indicates genus accounted for at least 1 percent of the total cell count of all samples)

Genus		Lakes			
		Faith	Hope	Charity	Lucien
Agmenellum	*	X	X	X	X
Anacystis	*	X	X	X	X
Ankistrodesmus	*	X	X	X	X
Botryococcus					X
Chlorella	*	X	X	X	X
Chodatella		X	X		
Chroomonas			X		
Cyclotella	*	X			X
Dinobryon		X			X
Elakatothrix		X			
Lyngbya	*			X	X
Oocystis	*	X	X		
Oscillatoria	*			X	X
Peridinium					X
Quadrigula			X		
Scenedesmus	*	X	X		X
Selenastrum	*		X		X
Staurastrum		X			
Synedra	*	X			X
Tetraedron		X			
Tetrallantos			X		

Another way in which phytoplankton communities may indicate trophic state, or degree of enrichment, is through their degree of diversity. Oligotrophic, or nutrient-poor waters, may be highly diversified, having relatively few organisms which are of many different types. Conversely, eutrophic, or nutrient-rich waters, may display lesser diversity, having many organisms but of only a relatively few different types. Figure 10 shows cumulative percentages of the genera which have accounted for at least 1 percent of the total cell count of all samples at each lake. A completely diversified community would be represented by equal percentages of a large number of genera and would plot as a straight line on the cumulative-percentage graph. A poorly diversified community would, conversely, show a few genera accounting for most of the density and the cumulative-percentage graph would rise sharply as the most dominant genera were added into the curve. All lakes show a high degree of domination by one or two phytoplankton genera, but Lake Charity appears to be the most poorly diversified, having a relatively few genera and a relatively high degree of domination by only one or two genera. Lake Lucien appears to be the most diversified with respect to phytoplankton genera; this lake has the smoothest cumulative percentage curve, showing relatively large contributions to the total phytoplankton density by several genera.

The assemblages of phytoplankton genera in Lakes Faith, Hope, Charity, and Lucien indicate that the lakes are enriched and that Lake Charity is probably the most enriched of the four lakes and that Lake Lucien is probably the least enriched (P. E. Greeson, oral commun., 1980). However, phytoplankton densities had not reached "nuisance" levels during the study and cell counts were low in comparison with some other lakes in central Florida.

Nutrients and Metals in Bottom Sediments

Annual analyses since 1973 of nitrogen, phosphorus, and selected metals in bottom sediments of Lakes Faith, Hope, and Charity are summarized in table 13.

There generally was a large variation in nitrogen and phosphorus concentrations among sampling locations within the individual lake. Except for phosphorus in Lake Charity, the median concentrations within each lake have differed by a factor of 10 or more from lowest to highest. Median nitrogen concentrations were always highest near the center of the lakes, but the highest phosphorus concentrations occurred near the shores except at Lake Faith. For the eight metals which were determined in bottom sediments, the highest median concentrations were generally in the center of the lakes.

The relatively high concentrations of metals and nitrogen in samples from the center of the lakes compared to samples from near the shores are probably related to the differences in both chemical and physical

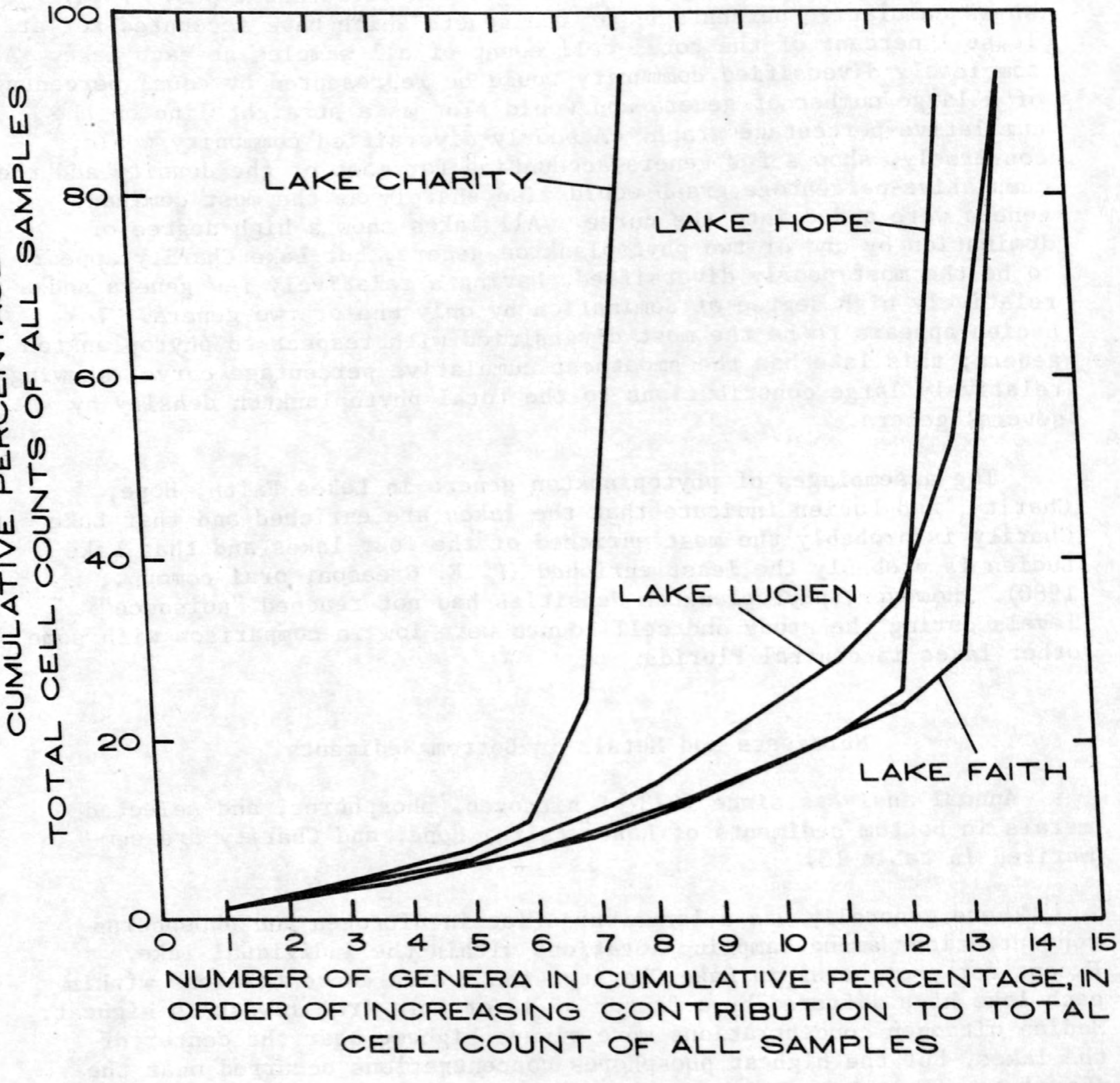


Figure 10.--Cumulative percentage plot of phytoplankton genera.

Table 13.--Median concentrations of nutrients and metals in bottom materials in Lakes Faith, Hope, and Charity

[All concentrations in micrograms per gram. Number of samples = 6, except as noted]

Constituent	Lake Faith			Lake Hope			Lake Charity		
	East	Central	West	East	Central	West	East	Central	West
Nitrogen	910	10,000	710	2,400	25,000	17,000	2,100	19,000	1,600
Phosphorus	37	1,200	92	140	1,100	1,600	110	320	340
Aluminum	520	21,000	840	1,200	17,000	6,400	1,400	3,000	2,000
Arsenic	0	1/ 5	1	2	6	1/ 3	2	5	1
Copper	<10	39	1/ <10	<10	20	20	<10	20	20
Iron	80	2,700	50	370	2,300	1,100	250	950	430
Lead	<10	80	<10	10	25	<20	<10	<10	<10
Manganese	<10	25	<10	<10	40	30	20	20	10
Nickel	<10	<10	<10	<10	<10	<10	<10	<10	<10
Zinc	<10	90	10	10	50	40	10	20	20

1/ Five samples.

characteristics of the bottom sediments. The bottom sediments near the center of the lakes consist largely of organic material of a small particle size, whereas sediments near the shore contain more sand with a relatively large particle size. The organic materials apparently are high in nitrogen content and, because of the small particle size, have a relatively large surface area and capacity for sorbtion of metals. The two most abundant metals in the bottom sediments were aluminum and iron, both of which have had median concentrations in excess of 1,000 µg/g (micrograms per gram) at some locations. Other metals (copper, lead, manganese, and zinc) were present in lesser quantities, with median concentrations in the 10 to 90 µg/g range. The center of Lake Faith had the highest metals concentrations in bottom sediments of the three lakes; this is probably because Lake Faith is the deepest of the three lakes and has the steepest bottom slope, thereby facilitating transport of materials toward the center of the lake where they accumulate.

Loading of the Lakes Through Surface Runoff and Bulk Precipitation

Materials which determine the chemistry of the lakes are transported to the lakes by precipitation on the lake surface and by surface and subsurface runoff. If there was no development in the area surrounding the lakes, surface runoff would have little effect on the lakes either in terms of quantities of water or in quality, because of the high permeability of the sandy soils. Because of the development of the residential areas and the discharge of storm sewers draining these areas into the lakes, surface runoff, principally from streets and other impervious areas, has become a significant source of input to the lakes. During the study, there was a total of 122.8 feet of water input to the three lakes from surface runoff and direct rainfall (see table 3), and 23.5 feet (or about 19 percent) of this input was surface runoff.

Accumulated loads to Lakes Faith, Hope, and Charity from surface runoff and from bulk precipitation were estimated for the period April 1971 to June 1979 for selected constituents which either comprised a major part of the total material load or were significant in terms of water-quality standards for the lakes. In estimating these accumulated loads, seasonal mean concentrations for February to May, June to September, and October to January were multiplied by the total amount of water input to the lakes for these months. These estimated loads, expressed in pounds per acre of lake surface, are listed in table 14. Loads for the major cations and anions were determined from dissolved concentrations and loads for nitrogen, phosphorus, and the trace metals (aluminum, copper, iron, lead, and zinc) include dissolved and suspended material. Part of the suspended load will settle to the lake bottom with perhaps no immediate effect on water quality. However, the interactions between water and bottom sediments are complex and not fully understood. Materials washed into lakes and associated with sediment may not be permanently removed from the water and ecosystem.

Table 14.--Accumulated loads of selected constituents to the lakes from surface runoff and bulk precipitation, April 1971 to June 1979

[Loads are expressed in pounds per acre of lake surface]

Constituent	Surface runoff			Bulk precipitation
	Faith	Hope	Charity	(all lakes)
Calcium	240	360	320	95
Magnesium	21	22	34	27
Sodium	92	63	76	84
Potassium	88	73	120	43
Bicarbonate	760	1,160	1,060	440
Chloride	160	130	140	140
Sulfate	180	180	230	230
Dissolved solids, residue at 180°C	1,520	2,160	2,370	1,170
Suspended sediment	1,080	6,770	4,380	--
Total nitrogen	48	65	120	140
Total phosphorus	7	11	16	15
Aluminum	10	10	21	4
Copper	.5	.3	.5	.8
Iron	9	6	11	4
Lead	4	4	6	2
Zinc	6	2	2	5
Oil and grease	170	230	180	--

These bulk-precipitation and runoff loadings should be regarded as only estimates, perhaps even only gross approximations of the true situation. This is because of variation in water quality of surface runoff and bulk precipitation from storm to storm, and the small number of samples (three per year). Also, the determination of bulk-precipitation quality is subject to some uncertainty and results obtained may be influenced by sampling methodology. A study by Irwin and Kirkland (1980) of precipitation-quality data collected by the U.S. Geological Survey at several sites in Florida indicated that at least some of the variation in chemical characteristics among the sites could have been because of differences in sampling procedure.

The loading from surface runoff, averaged for the lakes, has exceeded the loading from rainfall for calcium, potassium, bicarbonate, dissolved solids (residue at 180°C), aluminum, iron, and lead. Nutrient loading of the lakes was greater through rainfall than through surface runoff; nitrogen and phosphorus in bulk precipitation accounted for 64 and 57 percent, respectively, of the average total of surface-runoff load and bulk-precipitation load for the three lakes. Loading of two metals, copper and zinc, averaged higher in bulk precipitation than in surface runoff.

The seasonal pattern of loading is shown by the annual seasonal average loads given in table 15 for some aggregate water-quality parameters (dissolved solids, oil and grease, suspended sediments, total nitrogen, and phosphorus) and the two metals which most frequently were in violation of water-quality standards in the lakes (lead and zinc). Samples of these parameters and constituents were classified into seasonal groups representing the periods February through May, June through September, and October through January 1971-79. The composite samples of bulk precipitation were not classified into seasonal groups because the composite period did not always correspond to the selected seasonal grouping of months during the first 2 years of the study, and also because there was relatively little variation in concentration of most constituents in bulk precipitation from sample to sample.

Analysis of variance testing was applied to the average seasonal concentrations of the selected constituents, pooled for the three residential area runoff sites, to determine if the seasonal averages were, in fact, significantly different in comparison to variation between samples. For the seven constituents listed in table 15, all but three did have a significant difference among seasonal average concentrations. Suspended sediment, zinc, and oil and grease concentrations were not significantly different seasonally at a 5 percent confidence level. That is, there is more than a 5 percent probability that the differences in seasonal averages computed for these constituents could have occurred even if the true seasonal averages were equal.

Table 15.--Average lake loading by season for selected constituents in surface runoff and bulk precipitation

[Loads are expressed as pounds per acre of lake surface]

Constituent	Season	Surface runoff: Average concentration, mg/L	Surface runoff: Average accumulated load	Bulk precipitation: Average concentration, mg/L	Bulk precipitation: Average accumulated load	Sum of surface runoff and bulk precipitation: Average accumulated load
Dissolved solids, residue at 180°C	Feb-May	180	98	13	29	127
	June-Sept	66	106	13	91	197
	Oct-Jan	105	43	13	21	64
Oil and grease	Feb-May	1/ 14	7	--	--	7
	June-Sept	8	13	--	--	13
	Oct-Jan	4	2	--	--	2
Suspended sediment	Feb-May	1/ 131	71	--	--	71
	June-Sept	226	360	--	--	360
	Oct-Jan	95	39	--	--	39
Total nitrogen, as N	Feb-May	8.8	5	1.5	3	8
	June-Sept	2.0	3	1.5	10	13
	Oct-Jan	3.1	1	1.5	2	3
Total phosphorus, as P	Feb-May	1.2	.7	.17	.4	1.1
	June-Sept	.28	.4	.17	1	1.4
	Oct-Jan	.70	.3	.17	.3	.6
Lead	Feb-May	.41	.2	.018	.04	.24
	June-Sept	.15	.2	.018	.1	.30
	Oct-Jan	.20	.08	.018	.03	.11
Zinc	Feb-May	1/ .15	.08	.05	.1	.18
	June-Sept	.17	.3	.05	.3	.60
	Oct-Jan	.14	.06	.05	.08	.14

1/ Seasonal averages not significantly different at a 5-percent confidence level.

Seasonal annual loads were computed by multiplying the concentrations by the average seasonal total amounts of rainfall and surface runoff for the study period. The average seasonal totals of surface runoff and rainfall were:

Season	Average annual rainfall, in feet	Average annual surface runoff to the lakes, in feet
February-May	0.82	0.20
June-September	2.57	.59
October-January	.60	.15

Average loadings from surface runoff were generally greatest during June through September because of the large amount of surface runoff for this period which compensates for the lower concentrations of some constituents in the runoff. Total nitrogen and phosphorus seasonal average surface-runoff loads were, however, highest in the relatively dry February through May periods because of the high concentrations which occurred during these months. These high nitrogen and phosphorus loads could be related to application of fertilizers to lawns and gardens at the start of the growing season, and also to deposition of leaves from trees and shrubs in late winter. Estimated loadings from bulk precipitation were, of course, highest from June through September, because of the large amounts of rainfall during this time and because seasonal variations in concentrations in rainfall were not considered.

Comparison of Lake Water Quality with Loadings from Surface Runoff, Bulk Precipitaton, and Ground-Water Seepage

Water quality in the lakes is determined by water quality of the inflow components (surface runoff, ground-water seepage, and bulk precipitation). For dissolved conservative constituents, a mass balance based on the hydrologic budget should account for the concentrations in the lake water. Neglecting changes in storage, the hydrologic budget is expressed as follows:

$$Q_R + Q_{GI} + Q_{SR} = Q_{GO} + Q_E \qquad (1)$$

where

Q_R, Q_{GI}, and Q_{SR} represent inflow of water to the lakes from rainfall, ground-water seepage, and surface runoff,

and

Q_{GO} and Q_E represent ground-water outflow and evaporation from the lakes.

Loads to and from the lakes must also balance if the assumption of steady-state water quality is made, and, from equation (1), the mass balance equation is:

$$C_R \times Q_R + C_{GI} \times Q_{GI} + C_{SR} \times Q_{SR} = C_{GO} \times Q_{GO} \qquad (2)$$

where the "C" terms represent concentrations of the conservative constituents in the flow components. The evaporation term from equation (1) does not appear in equation (2) because the loss of the conservative constituents to the atmosphere is assumed to be zero. If the lakes are well mixed, C_{GO}, the concentration in the ground-water outflow, is the concentration in the lake. Equations (1) and (2) can be combined and rearranged to the following equation:

$$C_{Lake} = \frac{C_{GI} \times Q_{GI} + C_R \times Q_R + C_{SR} \times Q_{SR}}{Q_{GI} + Q_R + Q_{SR} - Q_E} \quad (3)$$

Equation (3) gives concentrations of conservative constituents in the lakes as a function of inflow and outflow quantities of water and concentrations in the inflow and outflow components, assuming steady-state conditions of inflow, outflow, and concentrations.

Ground-water seepage quantities from the surficial aquifer to the lakes were not determined, therefore, equation (3) cannot be used to compute lake-water quality as a function of the ground-water inflow component. Also, the three wells are probably not adequate to define the water quality of all of the ground-water inflow. However, by excluding the ground-water inflow terms in equation (3), and then comparing computed lake-water quality using only the surface runoff and bulk precipitation terms with the actual water quality as determined from samples from the lakes, some qualitative conclusions concerning effect of ground-water inflow on the lakes may be reached.

It is stressed that conclusions based on comparison of lake-water quality with mass balance of the inflow components are qualitative and somewhat speculative. This is because of the small number of samples of surface runoff and bulk precipitation, and also because of possible problems in representative sampling of bulk precipitation as mentioned by Irwin and Kirkland (1980).

Figure 11 shows a comparison between actual lake-water quality and the computed water quality based on the mass balance of surface runoff and bulk precipitation for the major ions (those making up the bulk of the dissolved solids). Many of these ions may not be strictly conservative because of the possibility of ion exchange reactions with soils and sediment materials, uptake by aquatic plants, or precipitation. However, in the range of concentrations present in the lakes, precipitation of compounds of the major ions should not be occurring, and the sandy soils of the area are probably not conducive to ion-exchange processes. Nitrate and potassium may be taken up by aquatic plants. Comparison of the actual lake-water quality with the mass balance of surface-runoff and bulk-precipitation input to the lakes leads to the following observations:

1. Input to the lakes from surface runoff and bulk precipitation is primarily a calcium bicarbonate type of water, and is similar in dissolved solids concentrations and chemical type among the three lakes.

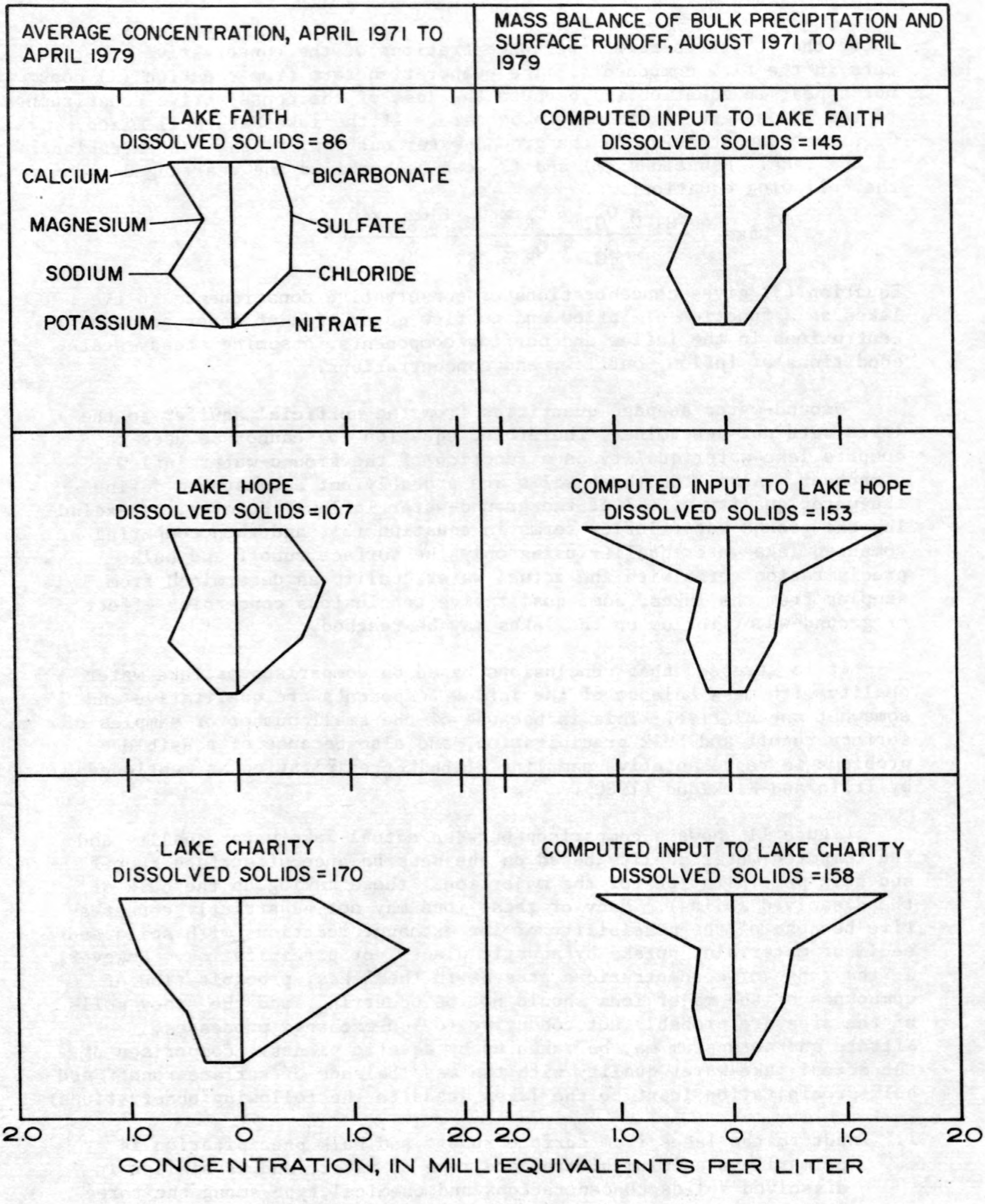


Figure 11.--Comparison of major ion concentrations in the lakes with mass balance concentrations of surface runoff and bulk precipitation.

2. Except for Lake Charity, the water in the lakes is not as highly mineralized as would be expected based on the surface-runoff, bulk-precipitation input.

3. The chemical type of the water in the lakes differs from the chemical type of the surface-runoff, bulk-precipitation input; the most noticeable difference is the lower concentrations of calcium and bicarbonate in Lakes Faith and Hope, the lower concentrations of bicarbonate in Lake Charity, and the higher sulfate and magnesium concentration in Lake Charity.

The most conspicuous difference in water quality in comparing water from the surficial aquifer (fig. 9) with water in the lakes and with the surface-runoff and bulk-precipitation input to the lakes (fig. 11) is the high calcium, sulfate, and nitrate concentration in the surficial-aquifer water near the citrus groves (well W-1). It seems probable that the relatively high sulfate concentration in Lake Charity (and possibly in Lake Hope) is due to inflow of water from the surficial aquifer underlying the citrus groves, because this seems to be the only source of water with a high sulfate concentration. Pfischner (1968) found that central Florida lakes near citrus groves were more highly mineralized, especially with respect to sulfate, than lakes in other types of land use areas. Nitrate concentration in the surficial aquifer water near the citrus groves also is high, and the fact that none of the lakes have high nitrogen concentrations probably is because of uptake of the nitrogen input to the lakes by aquatic plants.

Other chemical characteristics of the water in the lakes are harder to explain in relation to the chemistry of the inflow waters. These include the relatively low calcium and bicarbonate concentrations in the lakes compared to the inflow waters and the high concentration of magnesium in Lake Charity.

Calcium carbonate is a relatively insoluble compound with a solubility that depends on the pH of the water. Water with a low pH will dissolve more calcium carbonate than will water with a high pH because, at low pH values, the carbonate-bicarbonate equilibrium is shifted in the bicarbonate direction, and calcium bicarbonate is a relatively soluble compound. Median pH values of water in the lakes have ranged from 7.1 at Lake Lucien to 7.3 at Lake Charity. At these pH values, saturation concentrations of calcium carbonate would result in calcium and bicarbonate concentrations in the 3.6-4.5 meq/L (milliequivalent per liter) range. Therefore, calcium and bicarbonate concentrations in the lakes are not limited by solubility at the pH levels which have been observed. Some aquatic plants, including the rooted plant elodea and many species of algae, have the ability to decompose bicarbonate in the photosynthetic process, with the result that bicarbonate ions in the water are replaced by hydroxide ions. The net result is a rise in pH and the precipitation of calcium carbonate (Ruttner, 1952). If this process could produce extremely localized high pH values at the point of contact of the water with the plant surfaces, then perhaps it would be possible for precipitation of calcium carbonate to occur even though the overall pH of the lake waters were lower than precipitation levels. Calcium and bicarbonate ions produced by dissolution of the precipitated calcium carbonate on the lake bottom could then be removed in the seepage from the lake. This hypothesis seems at least feasible in Lake Hope because of the high density of the elodea plant population, and somewhat less likely at Lake Faith, which is free of aquatic weeds and has a relatively small algae population.

The high magnesium concentration in Lake Charity remains unexplained. Although magnesium is a major constituent of some citrus fertilizers, it was not present in high concentrations in samples from the surficial aquifer near the citrus groves south of Lake Charity. However, since samples were taken only at one point in the citrus-production area, it is possible that they do not represent the entire inflow of water to the lakes from this area.

Perhaps the major conclusion that can be drawn from comparison of lake-water quality with input loadings is that many factors and processes control the water chemistry of lakes.

WATER QUALITY IN HOLDING PONDS AND SURFACE RUNOFF TO THE HOLDING PONDS

Water-quality data collected since February 1975 at holding pond C-1 and since December 1977 at holding pond F-1 (see fig. 1) are summarized in table 16. These data include water quality of surface runoff to the ponds, water in the ponds (sampled 1 to 4 weeks after runoff sampling), and chemical analysis of bottom sediments.

A comparison of pond-water quality with runoff-water quality shows that, for nitrogen, phosphorus, and carbon compounds, and for most metals, concentrations are lower in the water in the ponds than in the runoff to the ponds. Thus, the ponds seem to serve as a sink for these materials. The dissolved-solids concentrations, however, are higher in the ponds than in the runoff, due to the concentrating effect of evaporation and perhaps seepage of more highly mineralized ground water into the ponds.

A comparison of water quality of surface runoff from the Maitland Boulevard-Maitland Avenue area (fig. 1) with water quality of surface runoff from the residential area north of Lakes Faith, Hope, and Charity is given in table 17. This comparison is included to show the characteristics of runoff from residential streets and driveways, and a predominantly highway area. Median values of properties and constituents for residential areas were computed using all samples from the three runoff sites north of the lakes. The median values for highway runoff were computed using samples of runoff into holding ponds C-1 and F-1 (fig. 1). The sampling period used in computing these median values is April 1975 to April 1979. Data prior to 1975 are available for the

Table 16.--Median concentration of selected constituents in surface runoff to the holding ponds, and in water and bottom sediments in the holding ponds

[Concentrations in water are total recoverable in micrograms per liter unless noted otherwise. All concentrations in bottom sediments are in micrograms per gram]

	Holding pond C-1[1]			Holding pond F-1[2]		
	Pond	Runoff	Bottom sediments	Pond	Runoff	Bottom sediments
Dissolved solids, residue at 180°C, mg/L	161	123	--	102	59	--
Total nitrogen, mg/L	1.3	1.4	1,600	0.7	1.2	720
Total phosphorus, mg/L	0.09	0.23	1,000	.07	.45	135
Total organic carbon, mg/L	7	31	--	12	26	--
Suspended sediment, mg/L	4	28	--	7	26	--
Aluminum	130	330	3,200	180	340	410
Arsenic	1	1	1	1	1	0
Copper	3	12	10	4	12	<10
Iron	70	230	580	80	360	520
Lead	17	61	<10	38	585	170
Manganese	10	15	20	10	20	<10
Mercury	<.5	<.5	--	<.5	<.5	--
Nickel	3	7	<10	10	11	<10
Zinc	20	50	10	10	110	40
Oil and grease, mg/L	0	1	--	1	1	--

[1] Based on 8 to 13 samples of water and 5 samples of bottom sediments, beginning in February 1975.

[2] Based on 3 to 5 samples of water and 2 samples of bottom sediments, beginning in December 1977.

Table 17.--Summary of water quality of surface runoff from residential and highway sites

[Concentrations are total recoverable in micrograms per liter unless noted otherwise]

	Residential[1/]		Highway[2/]	
	Number of samples	Median concentration	Number of samples	Median concentration
Dissolved solids, residue at 180°, mg/L	39	93	17	89
Total nitrogen, mg/L	35	2.2	17	1.3
Total phosphorus, mg/L	35	.34	17	.24
Total organic carbon, mg/L	35	21	18	26
Suspended sediment, mg/L	35	43	18	27
Aluminum	39	340	17	340
Arsenic	39	1	17	1
Copper	36	14	16	12
Iron	39	350	17	350
Lead	39	230	16	92
Manganese	39	20	17	20
Mercury	39	<.5	17	<.5
Nickel	39	8	17	9
Zinc	36	100	16	55
Oil and grease, mg/L	30	1	13	1

[1/] All samples of surface runoff from three sites in residential area north of Lakes Faith, Hope, and Charity (fig. 1), April 1975 to April 1979.

[2/] All samples of surface runoff to holding ponds C-1 and F-1 (fig. 1).

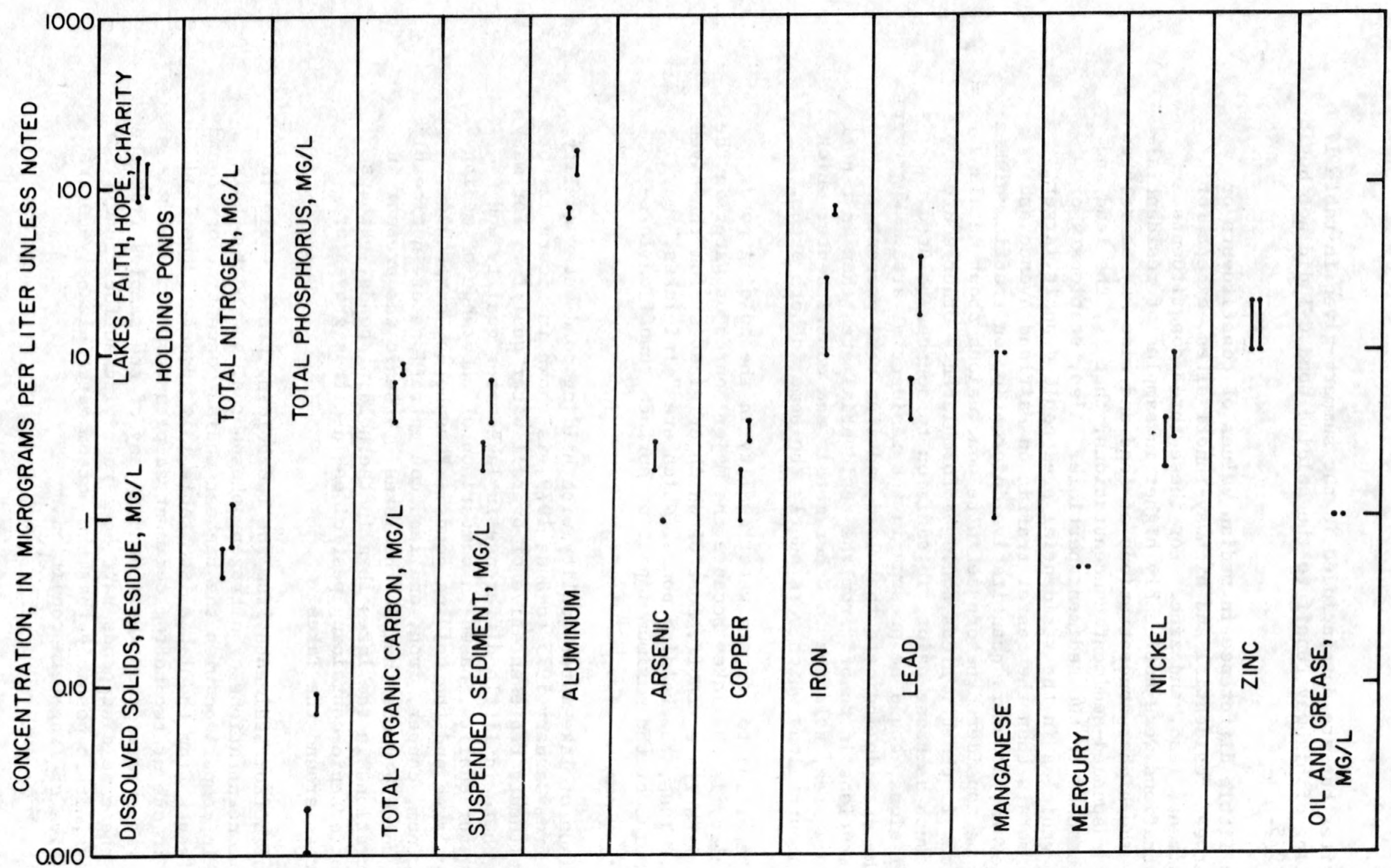
residential sites but are not included in the summary given in table 17 because sampling of highway runoff to the holding pond C-1 did not begin until April 1975.

There is little difference in median values of constituents or properties between residential and highway-runoff sites, except for suspended sediment, lead, and zinc. For these three constituents, median concentrations were noticeably higher in samples of residential-area runoff. The higher concentrations of lead and zinc may be related to the higher suspended-sediment concentrations, that is, the lead and zinc may be attached to the sediment particle. Also, stationary or slowly moving vehicles in the residential area could deposit larger quantities of metals than the faster traffic on Maitland Avenue and Maitland Boulevard; however, quantitative information on traffic volumes would have to be considered before definite conclusions about metals deposition rates in the two areas could be formulated. Other sources of lead and zinc such as house paint, in addition to sources related to vehicular emmissions, could be present in the residential area. Whatever the reason, the data do indicate that lead and zinc were present in higher concentrations in runoff from the residential area than in runoff from the highway area, relative to other metals and constituents, which had median concentrations which were nearly the same in both areas.

It is interesting to compare water quality in the holding ponds with water quality in the lakes because the major source of water in the holding ponds is surface runoff, most of which originates from the paved road surfaces. Thus, the holding ponds, which are "mini-lakes," may represent examples of the maximum impact of surface runoff on lake-water quality.

A comparison of lake-water quality with holding pond-water quality, using samples from January 1975 to June 1979, is shown in figure 12 for selected constituents representative of overall water quality. For many constituents, there is little difference in lake-water quality and holding pond-water quality, based on comparison of the range of median values for the lakes and the holding ponds. Phosphorus, suspended sediment, aluminum, copper, iron, and lead concentrations are noticeably higher in the holding ponds than in the lakes. Arsenic was present in higher concentrations in the lakes than in the holding ponds, perhaps due to usage of arsenic-containing pesticides in citrus groves or residential areas around the lakes.

Samples of bottom sediments from the two holding ponds (table 16) indicate that concentrations of nitrogen, phosphorus, and most metals were not high in comparison with the highest median concentrations found in bottom sediments from the lakes (see table 13). However, the lead concentration in one of two bottom sediment samples from pond F-1 was 330 μg/g, and was greater than that found in any of the samples from the lakes. Since these holding ponds have been receiving surface runoff for only a few years, it is possible that the bottom material analyses are not representative of long-term conditions.



NOTE: Bars represent range of median concentration for the lakes (left) and holding ponds (right) for samples from January 1975 to June 1979.

All median concentrations of mercury are less than the indicated detection limit. Lowest median iron and oil and grease concentrations are less than indicated detection limit. All metals concentrations are total recoverable from a water-suspended sediment mixture.

Figure 12.--Comparison of lake water quality with holding pond water quality.

WATER-QUALITY CHANGES IN THE LAKES

One of the objectives of this study was to assess impact of the highway construction (Maitland Boulevard and the interchange at I-4) on lake water quality. This objective is certainly a pertinent one, both to the study area itself and to other lakes in central Florida where development could affect water quality, but it is difficult to accomplish. Determination of the water-quality changes in the lakes is not a difficult task, however, the exact determination of what factors are responsible for the changes is impossible except in a qualitative and speculative manner.

There have been some changes in water quality in the lakes, and these changes have, with one major exception, been relatively small in magnitude and have been in the direction of improved water quality. The exception is the increase in the population of rooted aquatic weeds, particularly elodea (*Hydrilla verticillata*), in Lake Hope. During the last 2 years of the study (1978-79), growths of elodea reached nuisance levels; the growths formed tangled mats which covered considerable areas of the surface and were a hindrance to boating. Control of the weeds by spraying was attempted but was not successful, and stocking of the lake with white amur, a weed-eating species of fish, is being considered as a method of elodea control.

Median values of selected water-quality constituents and properties in the lakes are listed by phase of the Maitland Boulevard construction project in table 18. These data show that most of the water-quality parameters have remained at about the same levels throughout the study period, or have shown changes in the direction of improved water quality.

Median values of water-surface altitudes in Lakes Faith, Hope, and Charity for the days when water samples were collected show that the samples taken during construction were representative of relatively high water levels in all of the lakes as compared with the preconstruction and the postconstruction phases. Because water levels are a reflection of the amounts of rainfall and runoff, which in turn affect water quality, at least some of the differences in water quality among the construction phases are probably because of differences in the hydrologic conditions (amounts of rainfall) rather than effects of development. Specific conductance, or dissolved solids concentrations, of the water in the lakes should respond to changes in water level because rainfall and surface runoff are relatively low in dissolved solids compared to the lakes (see fig. 3). Lakes Hope and Charity, the two most mineralized lakes of the four, do show a drop in specific conductance during the relatively wet construction phase of the study; however, in Lakes Lucien and Faith there was little or no difference in median specific conductance among the construction phases.

Patterns of change common to all four lakes were a decrease in total nitrogen concentrations from the before-construction to after-construction phases of the study, and a decrease in phytoplankton concentration from the construction phase to the after-construction phase. Lake Faith was the only lake sampled before, during, and after the

Table 18.--Median concentrations of selected constituents or properties

(Reporting units are micrograms

[Preconstruction: April 1971 to April 1974.
After construction:

Constituent or property	Lake Lucien				Lake Faith		
	Phase of construction			Number of samples[1]	Phase of construction		
	before	during	after		before	during	after
Water surface altitude, in feet above sea level	--	--	--	--	65.43	67.99	66.33
Turbidity, JTU	--	2	2	0,18,13	4	3	3
Transparency, Secchi disk, in.	--	136	174	0,18,12	114	86	105
Specific conductance, μmhos/cm at 25°C	--	140	145	0,19,13	168	170	170
Dissolved oxygen, mg/L	--	7.6	8.1	0,19,13	8.3	8.3	8.0
Total nitrogen, mg/L	--	0.53	0.44	0,15,11	0.76	.52	.40
Total phosphorus, mg/L	--	0.01	0.01	0,18,13	.02	.02	.02
Aluminum, total recoverable	--	--	--	--	120	70	75
Copper, total recoverable	--	--	--	--	10	2	2
Iron, total recoverable	--	--	--	--	20	40	25
Lead, total recoverable	--	--	--	--	11	6	5
Mercury, total recoverable	--	--	--	--	0	0	.5
Zinc, total recoverable	--	--	--	--	15	10	15
Oil and grease, mg/L	--	--	--	--	7	0	1
Coliform, total, colonies/100 mL	--	--	--	--	210	30	70
Coliform, fecal, colonies/100 mL	--	--	--	--	4	10	16
Suspended sediment, mg/L	--	--	--	--	2	2	4
Phytoplankton, cell/mL	--	1,040	382	0,19,13	1,540	4,790	2,290

[1] Before, during, and after construction of Maitland Boulevard.

in the lakes before, during, and after construction of Maitland Boulevard

per liter except as noted)

During construction: May 1974 to April 1977.
May 1977 to June 1979]

Number of samples[1]/	Lake Hope			Number of samples[1]/	Lake Charity			Number of samples[1]/
	Phase of construction				Phase of construction			
	before	during	after		before	during	after	
19,18,13	65.06	66.29	65.35	19,18,13	62.10	64.50	62.58	19,18,13
19,18,13	4	2	2	19,18,13	5	4	4	19,18,13
19,18,12	72	87	87	19,18,12	60	81	100	19,18,12
19,18,13	223	179	185	19,18,13	350	289	285	19,18,13
19,18,13	8.3	7.8	7.7	19,18,13	8.4	8.0	8.3	19,18,13
19,18,13	0.95	0.54	0.44	19,18,13	1.2	0.88	0.60	19,18,13
19,18,13	0.02	0.02	0.02	18,18,13	0.02	0.02	0.02	19,18,13
4, 9, 6	135	70	70	4, 9, 6	250	70	70	4, 9, 6
4, 9, 6	3	1	1	3, 9, 6	5	2	2	4, 9, 6
3, 9, 6	180	20	20	2, 9, 6	75	10	15	4, 9, 6
3, 9, 6	8	6	7	3, 9, 6	12	4	4	2, 9, 6
17, 9, 6	0	0	0.5	17, 9, 6	0	0.1	0.5	17, 9, 6
4, 9, 6	10	20	10	4, 9, 6	10	20	10	3, 9, 6
17, 8, 6	6.3	0	0.5	17, 9, 6	8.2	0	1.0	17, 9, 6
17, 9, 5	900	20	30	17, 8, 5	680	10	190	17, 9, 5
3, 9, 6	13	6	7	3, 8, 6	33	7	35	3, 9, 6
3, 9, 3	3	2	3	3, 8, 5	7	2	2	3, 9, 5
12,18,13	2,000	855	310	12,18,13	3,210	2,950	1,750	12,18,13

construction of Maitland Boulevard which did not have a continuing pattern of decreasing phytoplankton concentration with time--at Lake Faith the highest median phytoplankton concentration was during the construction phase. Median concentrations of total recoverable aluminum and iron, oil and grease, and total coliform were highest in the before-construction phase of the study. However, changes in the sampling schedule for these parameters resulted in a relatively large variation in numbers of samples among the three phases of the study (see table 18). Therefore, at least some of the differences in median concentrations could be because of variation in sample size which varied from only 2 to 4 iron and aluminum samples in the preconstruction phase, to 8 or 9 during construction, and 5 or 6 samples after construction. The frequency of oil and grease, and total coliform sampling was reduced during the construction phase, and the sample size for these two parameters changed from 17 during the before-construction phase to 8 or 9 during construction and 5 or 6 after construction.

Time plots of selected water-quality parameters showing changes in water quality during the study are presented in figures 13 to 18. These plots provide a more complete representation of the way in which water quality has varied during the study than do the data in table 18.

Specific conductance in the lakes is plotted in figure 13. Comparison of figure 13 with the water-surface hydrographs of the lakes shows that increases in lake water levels generally have corresponded with or been followed by decreases in specific conductance, especially in Lakes Hope and Charity. The heavy rainfall in the spring and summer of 1975, and the associated rise in water levels, was accompanied by large decreases in specific conductance, especially in Lake Charity. Lake Charity overflowed into a drainage well during the summer and fall of 1975, and during this period, Lake Hope overflowed into Lake Charity with the result that Lake Charity had continuous inflow and outflow for several weeks and was therefore "flushed" to a greater extent than the other lakes. Thus, Lake Charity was the most affected of the lakes by the large amount of rainfall in 1975 as can be seen by the relatively abrupt decrease in the specific conductance in 1975 and a continuing lower level of specific conductance in 1976 and later years. A similar pattern of specific conductance decline occurred in Lake Hope, but to a lesser degree than in Lake Charity. Lake Lucien has not had a continuing pattern of decreasing specific conductance, and at Lake Faith, a trend toward lower specific conductance was only apparent after mid-1978.

Plots of total nitrogen concentrations in the lakes during the study are shown in figure 14. There is a general downward trend in nitrogen concentrations with time at each of the four lakes. This trend is least evident at Lake Lucien and most evident at Lake Charity. Also very noticeable in figure 14, is a lesser degree of variations in total nitrogen concentration after about mid-1974. Nitrogen concentration changes have not corresponded closely with water-level fluctuations, as can be seen from the relatively small variations in nitrogen concentration during the spring and summer of 1975 when water levels increased greatly.

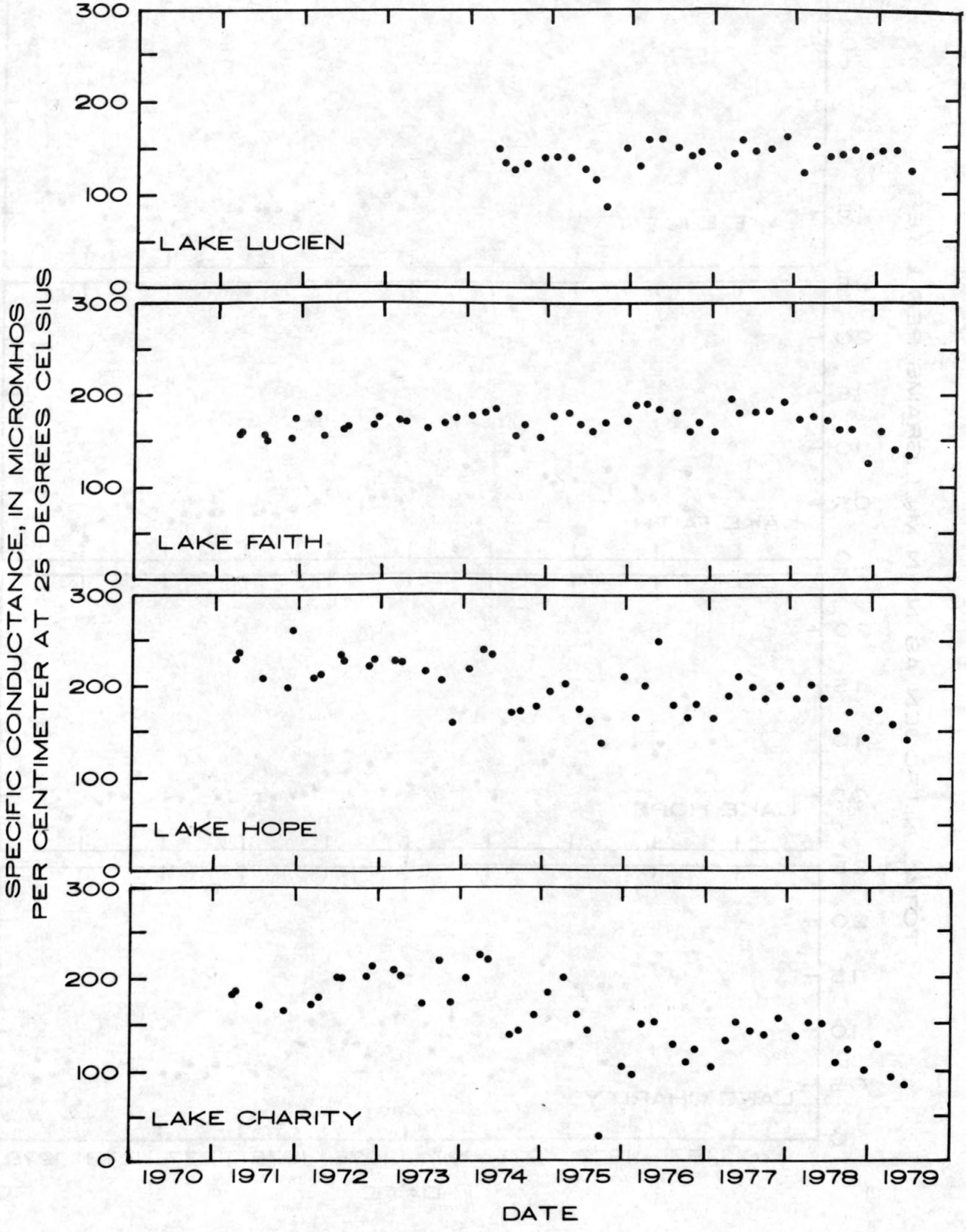


Figure 13.--Specific conductance in the lakes.

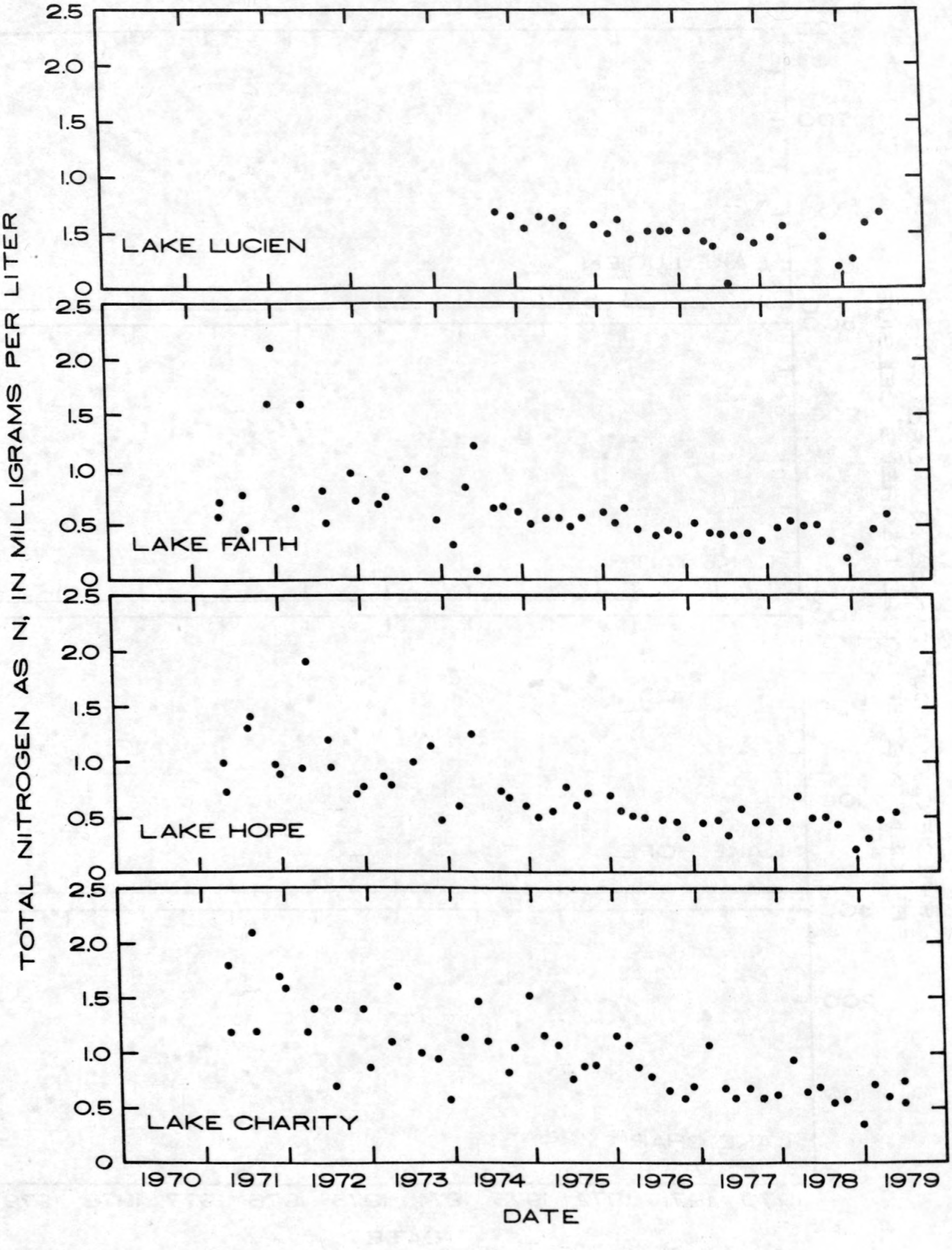


Figure 14.--Total nitrogen in the lakes.

The 24-hour DO studies, conducted to monitor primary productivity in the lakes, are summarized in figure 15. Data plotted in figure 15 are the difference in the maximum near-surface DO (1 to 2 feet below the water surface), in percent of saturation, measured from 1200 to 2000 hours, and the minimum near-surface DO measured from 0000 to 0800 hours for each study. Because the processes of plant production and respiration act to produce the highest DO values in afternoon or evening and the lowest DO values in the morning, the differences plotted in figure 15 are an estimate of the magnitude of primary productivity in the lakes. Figure 15 shows that in Lakes Hope and Charity there has been a tendency toward lesser daily DO fluctuation since 1976.

Phytoplankton densities are plotted in figure 16 for Lakes Lucien and Faith and in figure 17 for Lakes Hope and Charity. A harmonic function of the form Log_{10} (density) = M + A [SIN (P + DATE/365)] was fitted to the data to account for the seasonal variation in phytoplankton density as well as long-term trends in density. In this function, M, A, and P are constants, determined by the least squares procedure for each lake, and date is the day, expressed in elapsed days since an arbitrary starting date. Phytoplankton densities were transformed to base 10 logarithms to provide a more normally distributed set of data. The harmonic functions, plotted in figures 16 and 17, show that maximum and minimum phytoplankton densities tended to occur in June and January, respectively. The magnitude of the seasonal change was greatest in Lake Charity and least in Lake Lucien. Lakes Hope and Lucien have had a downward trend in phytoplankton densities in addition to the seasonal variations in densities. Figure 16 shows that, at Lake Faith, there was a period of consistently high phytoplankton densities from April 1974 to October 1975, perhaps as a result of nutrient inflow due to heavy rainfall during this period.

The percentages of the total phytoplankton community which were accounted for by genera which have been described as pollution tolerant, or characteristic of enriched lakes (see table 12, and Palmer, 1969), are plotted in figure 18. In each lake, the makeup of the phytoplankton community varied considerably with respect to the pollution-tolerant algae, but the overall tendency during the study was for a decrease in relative density of the pollution-tolerant genera in Lakes Lucien, Faith, and Hope. Little or no change is evident at Lake Charity.

In summary, most of the changes in water quality at Lakes Lucien, Faith, Hope, and Charity during the study period (April 1971 to June 1979) have been in the direction of better water quality. However, a pronounced aquatic-weed infestation in Lake Hope has had an adverse effect on recreation potential and on the esthetic appeal of this lake.

It is not possible to cite a single specific reason for any of the water-quality changes; rather, the changes are probably due to a combination of factors, including the following:

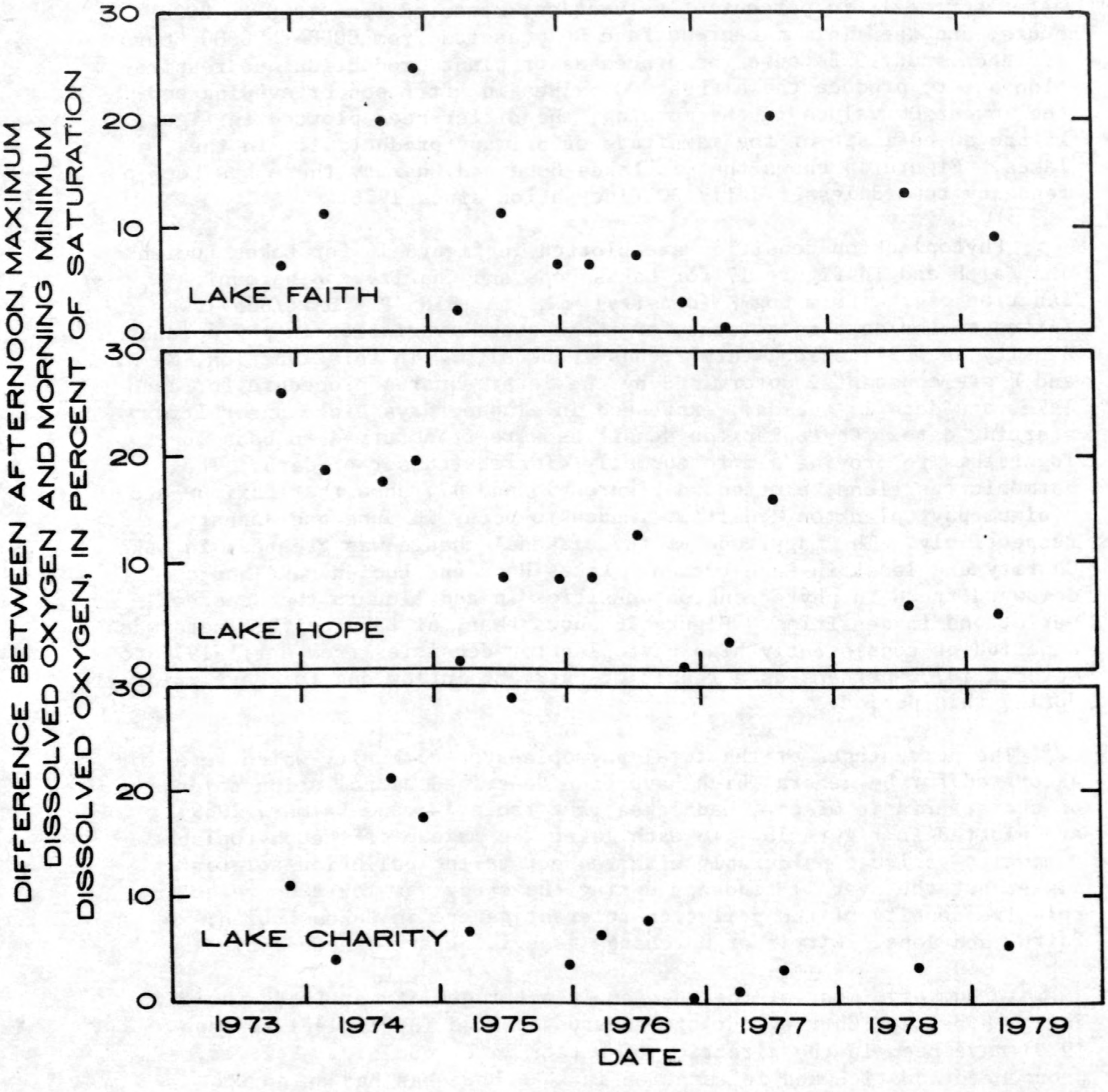


Figure 15.--Maximum daily dissolved oxygen fluctuations in Lakes Faith, Hope, and Charity.

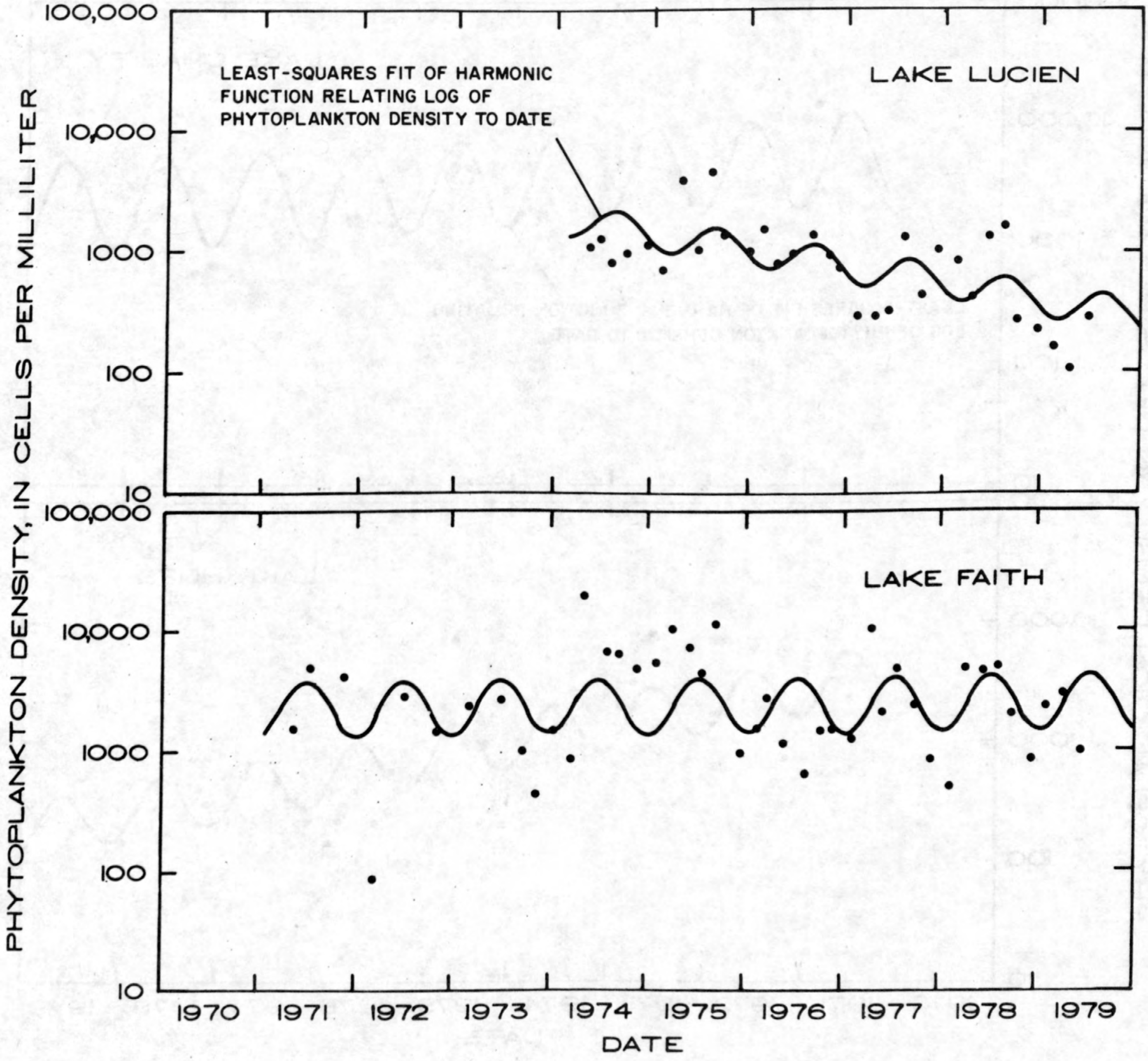


Figure 16.--Phytoplankton densities in Lakes Lucien and Faith.

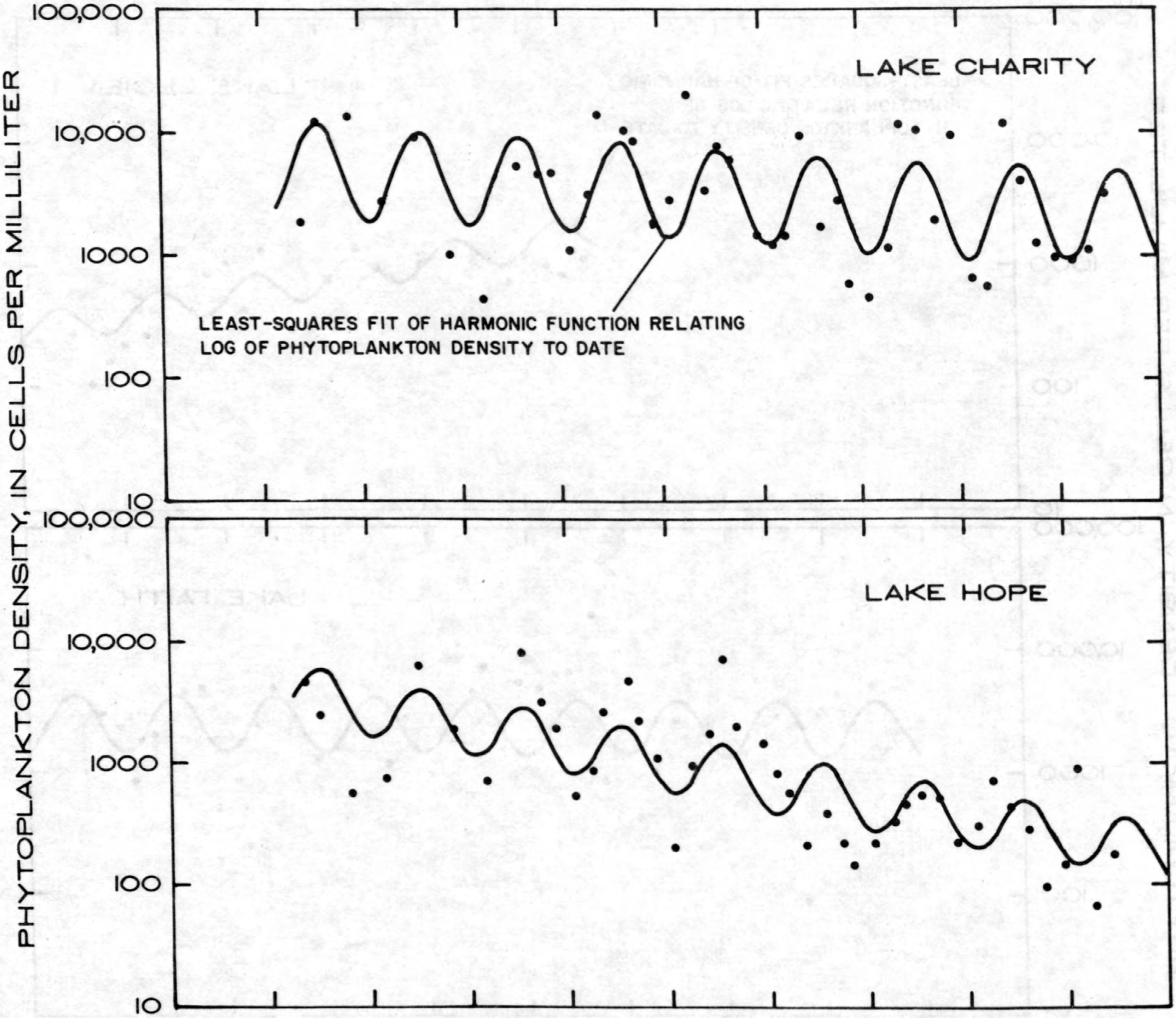
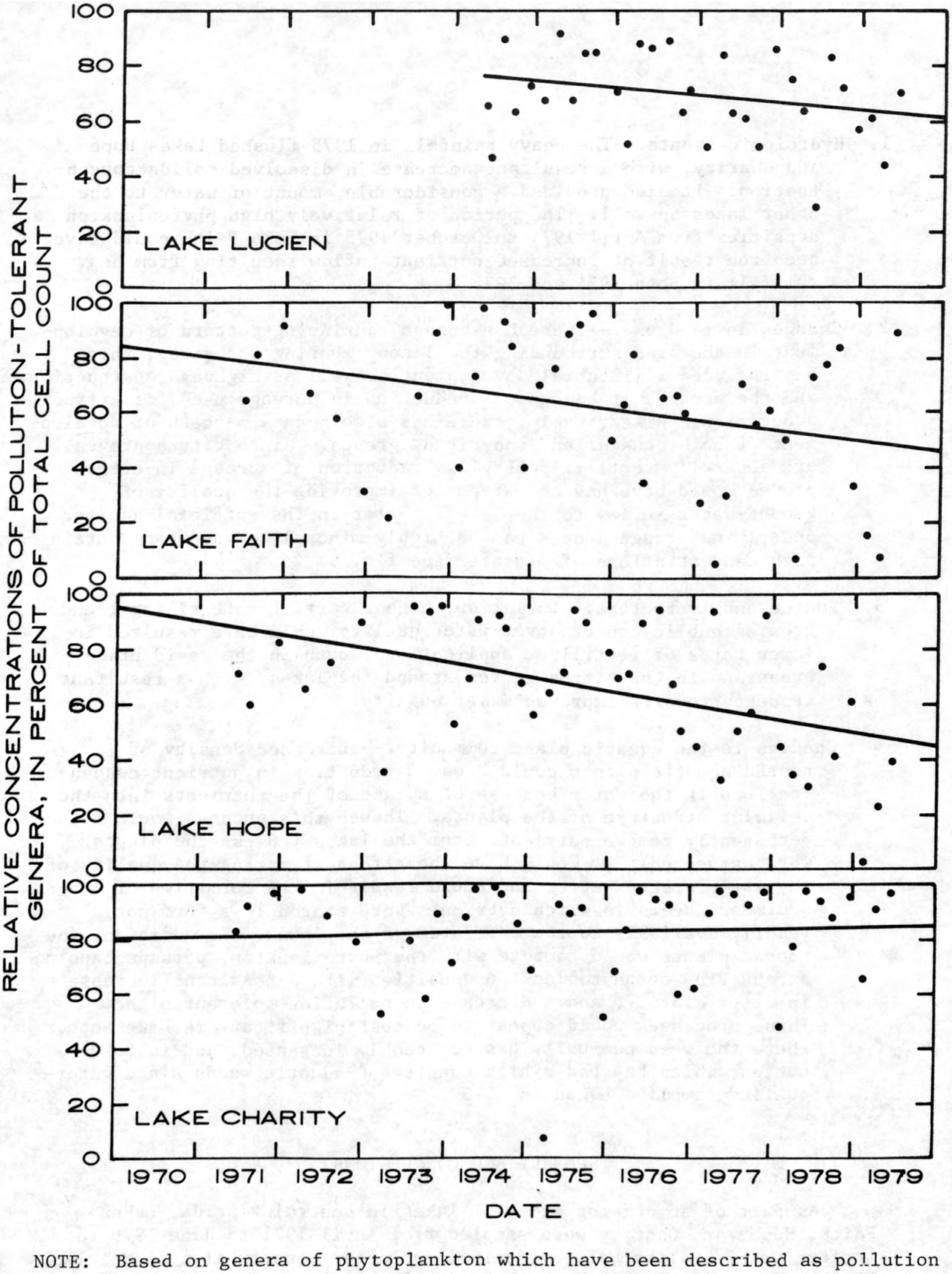


Figure 17.--Phytoplankton densities in Lakes Charity and Hope.



NOTE: Based on genera of phytoplankton which have been described as pollution tolerant by Palmer, 1969.

Figure 18.--Percentage of pollution-tolerant phytoplankton in the lakes.

1. Hydrologic events.--The heavy rainfall in 1975 flushed Lakes Hope and Charity, with a resultant decrease in dissolved-solids concentration. It also provided a considerable amount of water to the other lakes as well. The period of relatively high phytoplankton densities from April 1974 to October 1975 in Lake Faith could have been the result of increased nutrient inflow resulting from heavy rainfall in both 1974 and 1975.

2. Changes in land use.--There has been a continuing pattern of development in the area surrounding the lakes. During the study, this has included residential development as well as highway construction, and the net result has been a reduction in acreage used for citrus production. Historically, there has also been a pattern of development of both unused land and citrus groves. Since citrus groves are generally fertilized heavily, reduction of acreage in citrus groves could have had the effect of improving the quality of ground-water inflow to the lakes. Water in the surficial aquifer underlying orange groves can be highly mineralized and can contain high concentrations of nitrate (see fig. 9).

3. Socioeconomic factors.--Inflation, higher costs for fertilizer, and growing public concern over water quality could have resulted in lower rates of fertilizer applications, both in the residential areas and in the citrus groves around the lakes, with a resultant tendency towards improved water quality.

4. Changes in the aquatic plant community.--Increased density of rooted aquatic plants could cause a reduction in nutrient concentrations in the water because of uptake of the nutrients into the cellular structure of the plants. Though this process would not permanently remove nutrients from the lakes (unless the plants were harvested), it would have the effect of making the quality of the water appear better and could result in the formation of sediment layers in which nutrients were stored in a form not readily available to the ecosystem of the lakes. In addition, the rooted plants would compete with the phytoplankton, perhaps causing a reduction of phytoplankton densities with a resultant increase in water clarity, and a decrease in pollution-tolerant algae. These processes would appear to be most significant in Lake Hope, where the weed community has noticeably increased, and in Lake Lucien, which has had a high density of aquatic weeds since water-quality sampling began in 1975.

SUMMARY AND CONCLUSIONS

As part of an ongoing study of lakes in central Florida, Lakes Faith, Hope, and Charity were sampled from April 1971 to June 1979 to monitor water quality before, during, and after construction of Maitland Boulevard and the I-4 interchange. Results of this study could have some applicability to other lakes in central Florida where highway construction and other development could affect water quality.

Sampling of Lake Lucien was begun in May 1974. Surface runoff to Lakes Faith, Hope, and Charity and bulk precipitation were also sampled so that loading of the lakes from these sources could be estimated. Other types of data collected were quality of surface runoff from Maitland Boulevard and quality of water in holding ponds which intercept this runoff. Sampling of water from the surficial aquifer around the lakes was begun in 1978. The following list is a summary of the major findings of the study:

1. Total rainfall at Lake Hope for the study period (April 1971 to June 1979) was 33.1 feet, or about 90 percent of normal based on NOAA records for the period 1941-70 at Orlando and Sanford. Estimated lake evaporation for the study period was 34.81 feet, or an excess of evaporation over rainfall of 1.71 feet.

2. Surface runoff amounted to 7.3 feet at Lake Faith and 8.1 feet at Lakes Hope and Charity. The net ground-water seepage from the lakes ranged from 5.8 feet at Lake Faith to 8.5 feet at Lake Charity. The average net ground-water seepage was 6.9 feet out of the lakes from April 1971 to June 1979.

3. Chemical quality of the lakes and of bulk precipitation has been relatively constant in comparison with chemical quality of surface runoff and water in the surficial aquifer. Specific conductance, a measure of dissolved solids, has been highest in water from the surficial aquifer downgradient from a citrus grove, and lowest in bulk precipitation. Total nitrogen and phosphorus concentrations have been higher and much more variable in surface runoff, bulk precipitation, and at some locations in the surficial aquifer than in the lakes.

4. The chemical type of water in the lakes, with respect to the major dissolved constituents, has not varied greatly within Lakes Faith, Hope, or Charity, but has been considerably different between the lakes. Lake Charity has had relatively high concentrations of calcium, magnesium, potassium, and sulfate in comparison to the other lakes. Surface runoff and bulk precipitation have been extremely variable in chemical type. Water from the surficial aquifer downgradient from a citrus grove has been characterized by high concentrations of calcium, sulfate, and nitrate, perhaps as a result of fertilizer applied to the grove.

5. DO concentrations of less than 5 mg/L (the minimum legal concentration for the lakes) have not occurred near the surface at any of the lakes, but DO concentrations have averaged less than 5.0 mg/L in April and August at depths of 14 to 17 feet or more below the water surface in Lakes Faith and Lucien.

6. Of the 10 metals which were determined in the lakes, in surface runoff, and in bulk precipitation, 6 had median concentrations which were lower in the lakes than in surface runoff, and were lower than or equal to median concentrations in bulk precipitation. These metals (copper, iron, lead, mercury, nickel, and zinc) apparently do not remain in solution or suspension in the lakes.

7. Oil and grease, zinc, lead, mercury, and copper, listed in order of decreasing violation rate, have exceeded water-quality criteria for the lakes (Florida Department of State, 1978) in some samples. Oil and grease has been the most consistent violator of the criteria, with 31 to 48 percent of the samples from Lakes Faith, Hope, and Charity having concentrations in excess of the 5.0 mg/L limit. Copper has exceeded the water-quality limit of 30 μg/L in only one sample from Lake Charity.

8. Median phytoplankton densities ranged from 675 cells/mL at Lake Hope to 2,983 cells/mL at Lake Charity. Blue-green algae (division Cyanophyta) have been the dominant division at all four lakes. The _Anacystis_ genus has accounted for more than half of the total cell count of all samples in all of the lakes except Lake Lucien. The distribution of phytoplankton genera in all four lakes, and especially in Lake Charity, suggests enriched or eutrophic waters, even though the phytoplankton densities have not been high relative to other central Florida lakes.

9. Accumulated loads of calcium, potassium, bicarbonate, chloride, dissolved solids, aluminum, iron, and lead into Lakes Faith, Hope, and Charity during the study period were greater in surface runoff than in bulk precipitation on the lake surfaces. Conversely, nitrogen, phosphorus, copper, and zinc loadings were greater through rainfall than through surface runoff. Loading of the lakes from surface runoff varied seasonally, with most constituent loads being highest during the wet months (June-September). However, nitrogen and phosphorus loadings from surface runoff were highest in the February-May period.

10. Comparison of lake water quality with the mass balances of surface runoff and bulk precipitation shows that except for Lake Charity, the lake waters are not as mineralized as would be expected from the surface input, and that calcium and bicarbonate in Lakes Faith and Hope are lower than would be expected. Lake Charity has higher magnesium and sulfate concentrations than can be accounted for by surface input. Inflow of water from the surficial aquifer underlying the citrus groves south of Lake Charity could account for the sulfate in this lake, but the reason for the high magnesium concentration is not known. Likewise, the reason for the relatively low calcium and bicarbonate concentrations in the lakes is not obvious, but may be related to biological activity. Perhaps the most important conclusion to be drawn from comparing the water quality of the lakes with that of inflow is that the processes controlling the water quality in lakes are complex and that many factors are important.

11. Comparison of the water quality in holding ponds intercepting the storm runoff from Maitland Boulevard with that of Lakes Faith, Hope, and Charity shows that for many constituents, including dissolved solids, total nitrogen, total organic carbon, magnanese,

and mercury, median concentration levels in the lakes and the ponds are similar in magnitude. Phosphorus, suspended sediment, aluminum, copper, iron, and lead concentrations have been notice ably higher in the ponds.

12. There have been some changes in water quality in the lakes, and with one major exception, these changes have been in the direction of improved water quality. The exception is Lake Hope, which has become infested with aquatic weeds, mostly elodea. Noticeable trends in water quality include: decreasing specific conductance (a measure of dissolved-solids concentration) in Lakes Faith, Hope, and Charity; decreasing total nitrogen concentration in all four lakes; decreasing daily variation in DO concentration (a measure of primary productivity) in Lakes Hope and Charity; decreasing density of phytoplankton in Lakes Hope and Lucien; and a decrease in the relative proportion of pollution-tolerant algae, or those genera which have been listed as being characteristic of enriched water, in Lakes Lucien, Faith, and Hope.

These water-quality changes probably have occurred because of a combination of factors, which could include the flushing action of heavy rainfall in 1975, reduction of acreage in citrus groves, a possible reduction in fertilizer application rates because of increased costs and increased public concern for water quality, and changes in aquatic plant communities, particularly in Lake Hope and possibly in Lake Lucien.

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