## INTRODUCTION

Lake Tohopekaliga is one of the major lakes in central Florida. This multipurpose lake provides flood control in the upper Kissimmee River basin, recreation for fishermen and boaters, water for livestock in surrounding pastureland, esthetic surroundings for homesites, and serves as a receiving body for treated effluent from municipal sewage treatment plants.

A series of hydrologic reconnaissance studies of Florida lakes has been initiated as a part of the cooperative program between the U.S. Geological Survey and the South Florida Water Management District. In 1976–77, Cypress Lake was studied (Gaggiani and McPherson, 1978). Because of its large size and popularity for recreation, Lake Tohopekaliga was chosen to be the second lake studied in the series.

The purpose of this study is to provide governmental officials and the public with a general reconnaissance of the lake's hydrology. Because the study was completed within a year (October 1979 to September 1980), major emphasis was put on evaluating existing geologic, hydrologic, and water-quality data, rather than collecting new data pertaining to specific problems in the lake.

Stage and flow data for the lake and its tributaries have been collected by the U.S. Geological Survey for varying periods from 1942 to 1980. Lake water-quality samples were collected from 1954 to 1977. Only a small amount of historical information about ground water in the area is available, but several studies of the ground-water resources of Osceola County have resulted in some data collection during the period 1974 to 1980.

To supplement the antecedent information, new data collected during the study included (1) measurement of lake bottom elevations, (2) measurement of the thickness of lake-bottom detritus and collection of five sediment samples, (3) collection of water-quality samples from several areas of the lake, and (4) monitoring the dissolved-oxygen concentration in the lake during a 24-hour (diel) cycle.

## GEOGRAPHIC SETTING

The Kissimmee River basin is a generally flat area of sandy prairie and intermittent marsh. Remnant shoreline terraces, sandhills, beach ridges, and dunes of Pleistocene age control drainage and shallow ground water and affect vegetation and soil types, thus influencing present-day land usage in the basin (Parker and others, 1955, p. 122).

The many lakes of the upper Kissimmee River basin were formed when sea level receded at the end of the Pleistocene Epoch (approximately 10,000 years ago) and shallow depressions in the former sea floor became filled with freshwater from surface- and ground-water drainage. Under natural drainage conditions, the numerous shallow lakes of the upper Kissimmee River were connected only during periods of high rainfall. Flow in the basin was characterized by slow overland drainage to the lakes. Canals were constructed in the late 1800s to make a navigable waterway from the town of Kissimmee to Lake Okeechobee. In the early 1960s, the canals were improved and control structures constructed to provide flood control in the lower Kissimmee River basin and Lake Okeechobee.

The drainage area of Lake Tohopekaliga is approximately 620 mi² (fig. 1). Land use immediately surrounding the lake is mostly pasture and cropland (Gaggiani and McPherson, 1978, fig. 2). The drainage area also includes the urban areas of Kissimmee and part of the city of Orlando.

The average annual rainfall at Kissimmee is about 52 inches. The greatest rainfall is usually from June through September (fig. 2), during which time daily thunderstorms are common. The least rainfall usually occurs from December through February.

## GEOLOGY AND GROUND-WATER CONDITIONS

All of the Florida peninsula is underlain by a thick sequence of limestone and dolomite. Where water bearing, these rocks are called the Floridan aquifer. In the area of Lake Tohopekaliga, the Floridan aquifer is about 200 feet below land surface. Wells drilled to a depth of nearly 2,000 feet do not penetrate the bottom of the aquifer. Geologic formations which comprise the aquifer are the Lake City, Avon Park, and Ocala Limestones (Eocene, about 38–55 million years old) and, where present, the Suwannee Limestone (Oligocene, about 24–38 million years old). Overlying the Floridan aquifer are sediments ranging in age from Miocene to Holocene, including the Hawthorn Formation (Miocene, about 5–24 million years old), and surficial deposits (post-Miocene, less than 5 million years old) primarily composed of sand and shell. Geohydrologic sections for the area surrounding Lake Tohopekaliga were constructed using existing geologic and geophysical well logs (fig. 3).

Contours showing the potentiometric surface of the Floridan aquifer in May 1979 are shown in figure 1. The potentiometric surface shows the altitude to which water levels will rise in tightly cased wells that penetrate the aquifer. In some areas along the western shore of Lake Tohopekaliga, the potentiometric surface is above land surface, and Floridan aquifer wells flow. As indicated by the potentiometric contours in figure 1, ground-water movement in the aquifer is generally from west to east. Recharge to the aquifer occurs west of the study area where the aquifer is at or near land surface. Fluctuations of the potentiometric surface are related to changes in pumpage and rainfall. Figure 2 shows the long-term hydrograph for a well in the upper part of the Floridan aquifer located near Davenport in Polk County (fig. 1) approximately 12 miles west of Lake Tohopekaliga. It was chosen because it is the well closest to the lake for which a long-term record exists. The similar trends in the well and lake hydrographs indicate the response of the hydrologic system to rainfall. The lake level is affected directly by rainfall, surface-water inflow and outflow, and evapotranspiration, while the aquifer is affected by recharge, ground-water discharge, and pumpage; the latter usually increases during periods of little rainfall.

Most of the local public water supply is obtained from the Floridan aquifer. The water is generally of good quality, but eastward and southward, in Osceola and adjacent counties, the quality deteriorates (chloride concentration and dissolved-solids concentrations increase) and the water cannot be used for drinking.

Throughout much of Florida, the Floridan aquifer is confined by the Hawthorn Formation (Miocene), which consists of clay, sand, sandy clay, and, locally, some shell and limestone. The Hawthorn Formation is characterized by green or blue clay and the presence of phosphate pebbles. In the area of Lake Tohopekaliga, the Hawthorn is approximately 100 to 180 feet thick (fig. 3) but thins to the west, and is not present in much of adjacent Polk County. Local discontinuous beds of limestone in the Hawthorn often provide sufficient water for domestic wells. The clay beds of the Hawthorn generally act as a confining unit, and, therefore, there is probably little hydraulic interaction between the lake and the Floridan aquifer. In most of the lake area, the potentiometric surface of the Floridan aquifer is below the elevation of the lake. Thus any leakage through the Hawthorn would be downward, rather than upward. Along the western shore of the lake, where Floridan wells flow, some water may be contributed to the lake by upward leakage or from uncapped flowing wells.

Overlying the Hawthorn (or where the Hawthorn is absent, directly over the Floridan) are approximately 100 to 200 feet of undifferentiated clastic deposits of Pliocene(?) to Holocene age. Frazee (1980) reports that there are several distinct water-bearing zones in the surficial deposits, occurring at differing depths in different areas of Osceola County. Some of the deeper surficial wells may provide an adequate domestic water supply. The water table usually occurs within 10 feet or less of land surface in the area of the lake. Numerous marshes in the area surrounding the lake indicate that the water table is at land surface in those areas. Gradient of the water table beneath the lake is about 5 feet per mile.

## PHYSICAL AND FLOW CHARACTERISTICS

Lake Tohopekaliga is one of the larger lakes in central Florida, having a surface area of approximately 29 mi² and a drainage area of 620 mi². Some physical parameters of the lake are summarized in table 1.

Figure 2 shows the long-term hydrograph for Lake Tohopekaliga. Average stage of the lake for the entire period of record is 53.26 feet above sea level. An extreme drought in 1962 caused the lake stage to drop to its lowest unregulated level since recordkeeping began. Construction of water level control structures by the U.S. Army Corps of Engineers was begun in 1962, and in January 1964 the South Florida Water Management District took over regulation of the lake level. Comparison of the lake stages before and after regulation shows a decrease in the range of stage of about 3 feet:

| | Maximum stage | Minimum stage | Range |
|---|---|---|---|
| Unregulated | 59.40 | 48.93 | 10.47 |
| Regulated | 56.09 | 48.37 | 7.72 |

Low water levels in 1971 and 1979 were the result of controlled drawdowns undertaken as an experimental technique to improve fish habitat in the lake. Figure 4 shows stage-duration curves for the lake before (1942–62) and after (1963–79) regulation.

Inflow to the lake comes from Shingle Creek and through the St. Cloud Canal from East Lake Tohopekaliga. Outflow is into the Southport Canal to Cypress Lake (fig. 1). Figure 5 shows flow-duration curves for Shingle Creek, St. Cloud Canal, and Southport Canal.

Computing an inflow-outflow budget for the lake is difficult because the period of flow records for all tributaries do not coincide. An estimated budget is shown in table 1. Other means by which water enters or leaves the lake include: flow of ungaged tributaries; direct drainage from adjacent land or bank overflow; ground-water recharge or discharge; and rainfall and evapotranspiration. All of these are difficult or impossible to measure directly and must be estimated when calculating a budget.

A marked decrease in annual flow of St. Cloud and Southport Canals began in about 1962–64, which coincided with the beginning of flow regulation. The ratio of preregulation flow to postregulation flow is 0.742, according to a study prepared by the U.S. Environmental Protection Agency (1980, p. 4). Those workers noted a decrease in average annual rainfall of 4.5 percent, but attributed the decrease in flow to regulation.

Relations between annual rainfall and runoff in Florida (Pride and others, 1966, p. 95–99) show that when the average annual rainfall is in the range of 50–52 inches, the annual runoff varies almost directly with rainfall. Thus, a 4.5 percent reduction in average annual rainfall would result in a like reduction in average annual runoff.

Flow records for unregulated streams in central Florida were examined for the periods 1951–62 and 1965–74 (G.H. Hughes, written commun., 1980). The mean ratio of post-1965 flow to pre-1962 flow for Peace River at Arcadia, St. Johns River near Christmas and near Melbourne, Catfish Creek near Lake Wales, and Arbuckle Creek near De Soto City was 0.7. Thus the decrease in postregulation runoff of St. Cloud and Southport Canals corresponds to a regional decrease in flow of natural streams which was primarily due to decreased rainfall.

A recording fathometer was used to measure lake depth in February–March 1980. Figure 6 shows the depth contours below 53.85 feet above sea level, the lake elevation at the time the data were collected. Vegetation made use of the fathometer impracticable in water less than 6 feet deep. Maximum depth recorded was about 13 feet. Mean depth of the lake at a surface elevation of 53.0 feet is about 5 feet (U.S. Environmental Protection Agency, 1980, p. 3).

Because of lake stage fluctuations with time, absolute depths will also vary. As an aid in contouring lake depth, an uncontrolled mosaic was made using aerial photographs taken by the Florida Department of Transportation, April 16–17, 1979, when the lake stage was at 48.46 feet as a result of a managed drawdown. The lake-bottom areas emergent at that lake stage were thus assumed to be covered to a depth of 5.39 feet or less when the lake stage had risen to 53.85 feet.

## LAKE BOTTOM MATERIALS

Lake-bottom cores were collected, using a plastic coring tube, at several sites (fig. 6) in February 1980. Wegener and Williams (1974a, p. 4–7) reported several areas of the lake where the buildup of organic material occurred rapidly, so some of those areas were sampled. At most sites, the bottom cores consisted of some organic debris such as plant stems or roots, and black sandy clay underlain by white sand. In some areas the organic material was coarse and peatlike. The thickness of the organic material was generally 3 to 5 inches and up to about 7 inches in some areas. These figures are in agreement with the thicknesses of organic material observed by Wegener and Williams (1974a, p. 4–9 through 4–11). They noted (p. 4–12) that organic material was not only compacted during the 1971–72 drawdown but much of it was oxidized or eroded by wind or rain, and concluded that about 1–4 inches of debris were probably deposited from 1972–74. Most of the sites sampled in this study were emergent during the 1979 drawdown, but it was not possible to differentiate between recently deposited material and old material that had expanded after the lake refilled. Much of the organic material appears to be produced by plants in the lake, so a limiting factor to the rate of deposition would be the rate of plant growth.

Samples of lake-bottom sediments were collected at five sites in April 1980 (fig. 6) and analyzed for pesticide residue and nutrient concentrations. Four of the sampling sites coincided with sites analyzed for pesticide residues during the 1971–72 drawdown. Table 2 shows a comparison of the results for 1972 and 1980. As indicated in the table, pesticide residue buildup in the lake bottom sediments does not appear to have occurred. Residues of chlordane, which were not detected in 1972, were detected at two sites in 1980. However, this is probably because pesticide residues are very erratically distributed in bottom materials, rather than because of an actual increase in the amount of chlordane present.

Results of sampling for nitrogen and phosphorus in bottom materials are shown in table 3. Concentrations were highest at site 4 near the center of the lake. For comparison, nitrogen and phosphorus concentrations in sediments from two sites in Cypress Lake, the lake below Lake Tohopekaliga in the Kissimmee River chain of lakes, in September 1975 (Gaggiani and McPherson, 1978, table 6) were:

| | Near Southport Canal | Center of Cypress Lake |
|---|---|---|
| Nitrite + nitrate as N (mg/kg) | 1.5 | 0.0 |
| Total phosphorus as P (mg/kg) | 280 | 150 |
| Organic carbon (g/kg) | .6 | 6.8 |

## LAKE PROCESSES

The biological, geological, and chemical processes of lakes are closely related and depend to some degree on such factors as climate, lake morphology, and the quality and quantity of water and sediments entering the lake.

Photosynthesis (production of oxygen by plants) and respiration (consumption of oxygen) by animals and plants are important biological processes of lakes. Because photosynthesis requires light, the production of oxygen fluctuates on a daily and seasonal cycle. If an adequate supply of plant nutrients (mainly carbon, nitrogen, and phosphorus) are present, an excessive growth of phytoplankton algae (commonly as an algal bloom) can occur, resulting in a large increase in oxygen production. When conditions can no longer support the algae, they die and decomposition of their bodies by bacteria depletes the dissolved oxygen. Thermal stratification of lakes can accentuate the problem by preventing reaeration of water in the bottom of the lake.

Eutrophication is the process by which lakes become enriched by nutrients and gradually become filled by sediments, ultimately becoming dry land. This is a natural aging process and is the fate of most lakes. As nutrients and sediment deposits accumulate, vegetation growth increases and the depth of the lake decreases. As the lake becomes shallower, the eutrophication process accelerates and the lake becomes a bog or swamp, and, finally, dry land.

Unenriched lakes, called oligotrophic, have high concentrations of dissolved oxygen at all depths and low concentrations of dissolved chemicals, particularly the nutrients, which limit plant production and thus limit the abundance of animal life. In the second stage, called mesotrophic, a lake is characterized by increased dissolved materials and plant growth, but not so excessively that plants become a nuisance to man's activities. The third and final stage of enrichment, eutrophication, is characterized by high concentrations of dissolved nutrients and chemicals, large numbers of phytoplankton (small plants of which algae are the most commonly known variety) and possible oxygen depletion with depth.

Man can speed up the eutrophication process by adding nutrients to lakes (through sewage effluent or enriched runoff) or by poor construction methods which increase the rate of sedimentation, or can possibly slow the process by dredging (removal of sediments), by plant and animal management, or by control of the quality of the inflow water. The eutrophication process can take anywhere from tens of years to thousands of years.

The terms oligotrophic, mesotrophic, and eutrophic are somewhat subjective, although attempts have been made to quantify these classifications through the use of trophic indices. Some of the methods are summarized by Wanielista (1978, p. 342–349). The trophic state of Lake Tohopekaliga is discussed in more detail in another section of this report.

## AQUATIC VEGETATION

The littoral zone of a lake is defined as the area in which light can penetrate to the lake bottom, thus permitting photosynthesis and plant growth (Britton and others, 1975, p. 2). (In common usage "littoral" may mean merely "close to the shore.") One way of estimating the depth of light penetration is to measure the depth at which the black and white pattern of a Secchi disk can be distinguished. The euphotic zone is that region which receives 1 percent or more of the incoming surface light. Its maximum depth can be estimated by multiplying the Secchi disk depth by 5 (Greeson and others, 1977, p. 249). Secchi disk measurements for Lake Tohopekaliga are shown in table 4. Using the mean Secchi disk depth of 53 inches, the maximum depth of the euphotic zone would be 265 inches, or 22 feet. Therefore, the entire lake would be considered euphotic, and vegetation can live at any depth in the lake.

Macrovegetation occurs over large areas of the lake's surface. Field observations of aquatic vegetation were made in March 1980 by U.S. Geological Survey hydrologist B.F. McPherson and the author. The dominant aquatic plant is panic grass *Paspalidium sp.* or *Panicum sp.* which covers large areas as a single species stand. Panic grass extends further lakeward than any other aquatic plant, being able to grow in water up to about 6 feet deep. Smartweed *Polygonum sp.* is also abundant and occurs in a definite band landward of the panic grass. Smartweed was found in water about 3 to 5 feet deep.

Other plants observed included alligator weed *Alternanthera philoxeroides*, water lettuce *Pistia stratiotes*, pennywort *Hydrocotyle umbellata*(?), pickerelweed *Pontedera lanceolata*, and small, scattered stands of bulrush *Scirpus californicus*. In some areas spikerush *Eleocharis baldwinii* was abundant as a submerged plant in water 1 to 2 feet deep. Little water hyacinth *Eichhornia crassipes* was observed because it was heavily sprayed with herbicides during the 1979 growing season.

Mapping the various bands of vegetation as they occurred in March 1980 would have been of little value because of water-level fluctuations which are constantly affecting the distribution of vegetation; at any given time the distribution is related to water levels during the growing season (Holcomb and Wegener, 1971, p. 582). Holcomb and Wegener also note that "The lakeward limit of perennial emergents is related to historically low water elevations" (p. 570).

Managed drawdowns of Lake Tohopekaliga such as the one in 1971 improved littoral substrate, increased the density and diversity of desirable aquatic vegetation and stimulated production of fish food organisms (Wegener and Williams, 1974b, p. 160).

Other factors in addition to lake stage which affect littoral vegetation include herbicide spraying, the activities of fish and animals (such as cattle grazing along the lake shore) and input of nutrients to the lake.

## WATER QUALITY

Water-quality samples were collected periodically at a site near the center of Lake Tohopekaliga from 1954 to 1977. The data collected are summarized in table 4. Additional data collected at several sites (fig. 5) in 1980 are shown in table 5. Water-quality data collected in Shingle Creek at Campbell (1969–80), in East Lake Tohopekaliga (1954–79), and Cypress Lake (1954–79) also are shown in table 4. All samples are depth-integrated.

The quality of water from Floridan aquifer wells near the lake is summarized in table 6. There were insufficient data to compile a table, of water quality for the surficial aquifer, but the analysis of water from one surficial aquifer well is included in table 6. In general, water from the limestone or shell in the Hawthorn Formation is of similar quality to water from the Floridan. Water from the upper surficial deposits usually has less hardness than water from the Floridan and may have a high iron concentration.

Comparing some parameters of water from the Floridan aquifer (table 6) and Lake Tohopekaliga (table 4), some differences are apparent, especially in specific conductance, hardness, and dissolved solids. In general, the concentrations of these parameters are less in surface water than in ground water. However, if the specific conductance and hardness of the water from the surficial well in table 6 are considered to be representative of surface water, then the influence of Floridan aquifer water in the lake is apparent. For example, hardness of water from the surficial aquifer well was 9 mg/L, while the mean hardness for lake water was 44 mg/L. The amount of water contributed to the lake by upward leakage from the Floridan aquifer through the thick confining bed is probably very small in comparison to other sources. A major part of Floridan aquifer water in the lake probably is public supply water which enters the lake as effluent from sewage treatment plants. Small amounts may also come from ground-water discharge to tributaries of the lake during periods of low flow.

The quality of gaged surface inflow to the lake is shown in tables 4 and 5. Water from Shingle Creek, which accounts for about one-third of the inflow to the lake, has a mean specific conductance of 260 micromhos/cm and a high mean phosphorus concentration (1.5 mg/L). The quality of inflow through the St. Cloud Canal is shown in a general way by data collected in East Lake Tohopekaliga. Although the outfall from the St. Cloud sewage treatment plant is downstream from the data collection point and an increase in nutrient and dissolved solids concentrations would be expected, the volume discharged from the plant is about 0.8 Mgal/d (1.24 ft³/s) (Williams, 1980, p. 4), less than 1 percent of the canal flow. The quality of outflow through the Southport Canal is reflected by the data collected in Cypress Lake. The discharge from Southport Canal contributes about 70 percent of the total inflow to Cypress Lake.

Linear regression methods were used to analyze the lake water-quality data and examine the relationships between parameters, particularly between various quality parameters and lake stage and time. There is a statistically significant inverse relationship between specific conductance and lake stage, and dissolved solids and lake stage, but variation in lake stage by itself explains only about 33 percent of the variation in dissolved solids and only about 17 percent of the variation in specific conductance since 1954. Specific conductance has tended to increase with time, and inclusion of both lake stage and date of sample in a linear equation explained about 54 percent of the observed variation in specific conductance since 1955.

Various combinations of water-quality parameters are often used to classify a lake as oligotrophic, mesotrophic, or eutrophic. Shannon and Brezonik (1972, p. 97–110) developed a classification system for Florida lakes in which the interpretation of several water-quality parameters depends on whether the lake water is clear or colored. Because the mean color level of Lake Tohopekaliga is 78 platinum-cobalt units, on the borderline between clear and colored lakes, Shannon and Brezonik's indicators were not considered. A frequently used model proposed by Vollenweider (Vollenweider and Dillon, 1974) was used by the U.S. Environmental Protection Agency (1977; 1980) to determine that the lake is eutrophic. Such quantitative models usually are based on lake inflows and outflows, so application to Lake Tohopekaliga may be difficult because there are insufficient data to compile an accurate budget for the lake.

Rather than attempting to classify the trophic state of the lake during this investigation, the concentration of plant nutrients (primarily nitrogen and phosphorus) present in the water were examined. Sources of phosphorus to surface water include deposits of phosphate pebbles and phosphate mining operations, human wastes (about 1 pound per person per year), detergents (about 3½ pounds per person per year), industries and drainage from urban areas, fertilized areas, feedlots, and atmospheric fallout (U.S. Environmental Protection Agency, 1976, p. 186–190). Major sources of nitrogen to water bodies include municipal and industrial wastewater, septic tanks, and feedlots. Diffuse (nonpoint) sources include farm fertilizer and animal wastes, lawn fertilizer, leachate from landfills, and atmospheric fallout (U.S. Environmental Protection Agency, 1976, p. 107–110).

High concentrations of phosphorus are often associated with accelerated eutrophication. To prevent development of biological nuisances, phosphates (as phosphorus) should not exceed 0.025 mg/L within a lake or reservoir or 0.05 mg/L in a stream at the point at which it enters a lake or reservoir (U.S. Environmental Protection Agency, 1976, p. 188). Eutrophication problems may occur in waters where the phosphorus concentration is less than the recommended level and conversely, some natural phenomena (such as heavy sediment loading or coloration which reduce light penetration, or morphic features such as steep banks, great depth, and large flows) may reduce the threat of eutrophication in lakes where the concentration exceeds the recommended level.

The U.S. Environmental Protection Agency (1976, p. 109) has determined that nitrate levels less than 90 mg/L have no adverse effects on warm-water fish and nitrite levels less than 5 mg/L are not known to be dangerous to most warm-water fish. These levels are not known to occur, and would be unlikely to occur, in natural waters.

Nutrient data were collected for Lake Tohopekaliga from 1970 to 1977 at a site near the center of the lake (table 4). Data collected in May 1980 at six sites in the lake and one site at Shingle Creek at Campbell are shown in table 5. The range for selected nutrients in Lake Tohopekaliga from the six sites, compared to the mean values for those parameters from the site near the center of the lake in mg/L are:

| | Range May 1980 | Mean for 1970–77 |
|---|---|---|
| Total organic nitrogen as N | 0.71–2.3 | 1.5 |
| Nitrate + nitrite as N | 0.01–0.05 | 0.03 |
| Ammonia as N | 0.02–0.14 | 0.10 |
| Total phosphorus as P | 0.07–1.10 | 0.30 |

Comparison of nutrient concentrations in Lake Tohopekaliga with concentrations in other lakes in the area may also be a relative indication of the lake's trophic state. Table 7 shows the nutrient concentrations for 10 lakes in south-central Florida for May–June 1978 and 1979. Nutrient concentrations in Lake Tohopekaliga (table 4, site near center of lake) are generally higher than for the other lakes. Phosphorus particularly is much higher in Lake Tohopekaliga than in the other lakes: mean phosphorus in Lake Tohopekaliga was 0.30 mg/L. Of the ten selected lakes in table 7, only Cypress Lake and Lake Marian had a phosphorus concentration higher than 0.10 mg/L.

Wanielista and others (1976, p. IV-7) found relatively high background concentrations of total phosphorus in Shingle Creek (greater than 2.0 mg/L), which they suggest may result from natural deposits of phosphorus in the soil. Phosphorus concentrations of shallow ground water in the area have never been measured. However, water sampled in St. Johns County from sediments being mined for phosphate and from phosphate-bearing sediments not being mined had total orthophosphate concentrations of 0.00 and 0.02 mg/L, respectively (Paul Hampson, oral commun., 1980). Orthophosphate is the component of total phosphorus that results from dissolution of phosphorus-bearing sediments. If the orthophosphate concentration in water in contact with phosphorus-rich sediments is in the range 0.00–0.02 mg/L, then it is unlikely that dissolution of phosphorus-bearing sediments is a major source of phosphorus in the creek.

Odum (1953, p. 7–8) shows a high correlation between dissolved phosphorus in surface waters and the outcrop areas of phosphate-bearing sediments in Florida. In his figure 1, Odum shows the outcrop of phosphate-bearing sediments in Florida. The outcrop area extends nearly to the Polk-Osceola County line, but a surface drainage divide at about the same location causes almost all drainage from the outcrop area to flow westward, rather than eastward toward Lake Tohopekaliga. During periods of high flow, some drainage may cross the divide, but would then flow through Reedy Creek to Cypress Lake, not through Shingle Creek to Lake Tohopekaliga. Odum also points out that some relatively high phosphorus concentrations in areas not associated with phosphate rock are due to "pollution."

Changes of nutrient concentrations with time were also examined. Linear regression was used to determine whether or not there was a significant increase in phosphorus with time in Lake Tohopekaliga and Cypress Lake. There were insufficient data to determine whether or not a significant increase occurs in Lake Tohopekaliga but more numerous data from Cypress Lake indicate a significant increase with time. Because Cypress Lake receives all of the outflow from Lake Tohopekaliga, it seems possible that this increase in phosphorus in Cypress Lake is due to a similar increase in Lake Tohopekaliga. Concentrations of total organic nitrogen, total ammonia, and total organic carbon in Lake Tohopekaliga do not seem to be increasing with time.

Odum (1953, table 3) also shows the mean total phosphorus concentrations for lakes inside the phosphate mining districts (0.290 mg/L) and outside (0.038 mg/L). In August 1978, phosphorus concentrations measured by the U.S. Geological Survey in Lake Hancock near Lakeland (in the phosphate district) ranged from 0.75 to 0.95 mg/L. In lakes outside the phosphate mining district, concentrations in 1978–79 ranged from 0.02 to 0.20 mg/L (table 7) and the mean concentration was 0.06 mg/L. In comparison, a sample collected by the U.S. Geological Survey from Lake Tohopekaliga in 1950 had a total phosphorus concentration of 0.042 mg/L (Odum, 1953, appendix, p. 39), while phosphorus concentrations in 1980 ranged from 0.07 to 1.1 mg/L (table 5). Thus, in 1950, the phosphorus concentration in Lake Tohopekaliga was similar to the concentrations in other lakes outside the phosphate-mining district, but by 1980 the concentrations are more similar to the lake in the mining district than to the lakes in table 7, all of which are outside the mining district.

The dissolved-oxygen concentration of a lake can also be an important water-quality indicator. If oxygen is not available for respiration, animals and plants cannot live in the lake. According to the water-quality standards of the Florida Department of Environmental Regulation (Florida Administrative Code, 1978, chapter 17-3), the dissolved-oxygen concentration in freshwater should not be less than 5 mg/L. All dissolved-oxygen measurements made during this study exceeded 5 mg/L (5-5-80 data, table 5). Near-surface dissolved-oxygen concentrations less than 5 mg/L have been measured in Lake Tohopekaliga only three times since 1967, always in August or September. The mean value for (near-surface) dissolved oxygen shown in table 4 is 7.6 mg/L at the site near the center of the lake, indicating that low dissolved-oxygen concentrations are not generally a problem in the lake.

Daily (diel) fluctuations of dissolved oxygen also occur because plants produce oxygen only when light is available for photosynthesis. At night, respiration by the plants and animals of the lake community draws on the oxygen already dissolved in the water. An extreme diel fluctuation of dissolved oxygen may indicate excessive numbers of phytoplankton, which can become a water-quality problem when the algae begin to die and their bodies are decomposed by bacteria, using dissolved oxygen and releasing organic matter into the lake. Another indicator of the "good health" of a lake using diel oxygen fluctuations is to compare the rate of photosynthetic production of oxygen to the rate of oxygen consumption by respiration, called the P/R ratio. If the P/R ratio is greater than 1, the lake is called autotrophic (more oxygen is produced in a 24-hour cycle than is consumed by respiration). If the ratio is less than 1, heterotrophic conditions exist and the community as a whole degrades organic compounds through oxygen metabolism at a greater rate than the rate of oxygen production by photosynthesis (Greeson and others, 1977, p. 288).

The dissolved-oxygen concentration was measured for a diel cycle at sites 1, 4 and 9 in Lake Tohopekaliga (fig. 6) in May 1980. At each site the oxygen concentration was measured at three depths: 1 foot below the surface, midway between surface and bottom, and 1 foot above the bottom. The fluctuation of dissolved-oxygen concentration and near-surface pH for the three sites is shown in figure 7. (The discrete data points have been fit to a smooth curve by a computer program.) Because the lake is shallow and apparently well mixed from top to bottom, there was little fluctuation of dissolved-oxygen concentration with depth. The greatest fluctuation in dissolved-oxygen concentration occurs at site 4 in the middle of the lake.

A computer program developed by Stephens and Jennings (1976) was used to calculate the P/R ratio for the three sites. At the north (site 1) and south (site 9) the ratio was greater than 1 (1.012 and 1.403, respectively), indicating autotrophic conditions. At site 4, however, the ratio was 0.833. Net production of oxygen for each site was: site 1, 0.065 (g/m²)/d (grams per meter squared per day); site 4, 1.421 (g/m²)/d; site 9, 2.200 (g/m²)/d. These values were computed assuming a vertical dispersion constant for oxygen of 0.3 cm²/s (centimeters squared per second) and a surface diffusivity of 0.8 (g/m³)/h (grams per meter cubed per hour).

Other parameters in addition to net oxygen production vary from place to place in the lake. Figure 8 shows the variation of selected parameters in May 1980. For example, the near-surface specific conductance varied from 115 micromhos at the outlet of the St. Cloud Canal (site 5) to 250 micromhos north of Grass Island (site 1) on May 5, 1980. The lowest value of near-surface pH on that day also occurred at the canal outlet (there was no flow from the canal at the time the samples were taken). Secchi disk readings varied throughout the lake, and also showed considerable range at the individual sites. At site 4, for example, where four measurements were made during the diel oxygen sampling, the Secchi disk readings ranged from 18 to 42 inches. The near-surface pH readings at site 4 also fluctuated more during the diel sampling than at the other sites (fig. 7). Nutrient concentrations (depth-integrated) also varied, with the highest total organic nitrogen level (1.8 mg/L) occurring at site 9 (in the south part of the lake) and the lowest concentration (1.1 mg/L) at site 5 (St. Cloud Canal outlet). Phosphorus, however, was highest at site 1 (1.1 mg/L) and lowest at site 5 (0.2 mg/L). These variations in chemical parameters are probably caused by areal circulation patterns, which in turn depend on variations in inflow from the major tributaries (Shingle Creek and St. Cloud Canal) and lake morphology. The outline of emergent lake bottom during the April 1979 drawdown, shown approximately by the 6-foot depth contour in figure 6, indicates that the northern part of the lake and the eastern arm are restricted, and mixing of these waters with the water in the rest of the lake probably occurs very slowly. Mixing is probably also restricted by the large shallow areas and islands in the northern part of the lake, which could account for fluctuations in concentrations of chemical parameters at site 4. The variations in concentrations observed in this study indicate the need for caution in basing conclusions about the lake's water quality on the historic data summarized in table 4, which were collected at one site only.

## REFERENCES

Britton, L. J., Averett, R. C., and Ferreira, R. F., 1975, An introduction to the processes, problems, and management of urban lakes: U.S. Geological Survey Circular 601-K, 22 p.

Florida Department of State, 1978, Rules of the Department of Environmental Regulation, Water Quality Standards, Chapter 17-3, *in* Florida Administrative Code: Tallahassee.

Frazee, J. M., Jr., 1980, Ground water in Osceola County, Florida: U.S. Geological Survey Water-Resources Investigations 79-1595, 1 map sheet.

Gaggiani, Neville, and McPherson, B. F., 1978, Limnological characteristics of Cypress Lake, upper Kissimmee River Basin, Florida: U.S. Geological Survey Water-Resources Investigations 77-45, 1 map sheet.

Greeson, P. E., and others, editor, 1977, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter 4A, 332 p.

Holcomb, Dennis, and Wegener, William, 1971, Hydrophytic changes related to lake fluctuations as measured by point transects: 25th Annual Conference of the Southeastern Association of Game and Fish Commissioners Proceedings, p. 570–583.

Hughes, G. H., and Frazee, J. M., Jr., 1979, Surface-water features in Osceola County and adjacent areas, Florida: U.S. Geological Survey Water-Resources Investigations Open-File Report 79-1289, 1 sheet.

Kaufman, M. I., 1969, revised 1975, Generalized distribution and concentration of orthophosphate in Florida streams: Florida Bureau of Geology Map Series 33, 1 sheet.

Kenner, W. E., 1964, Maps showing depths of selected lakes in Florida: Florida Geological Survey Information Circular 40, 81 p.

Lamonds, A. G., 1975, Chemical characteristics of the lower Kissimmee River, Florida—with emphasis on nitrogen and phosphorus: U.S. Geological Survey Water-Resources Investigations 45-75, 132 p.

Laughlin, C. P., Hayes, E. C., and Schiner, G. R., 1980, Potentiometric surface map of the Floridan aquifer in the St. Johns River Water Management District and vicinity, Florida, May 1979: U.S. Geological Survey Open-File Report 80-69, 1 map sheet.

Lichtler, W. F., 1972, Appraisal of water resources in the east-central Florida region: Florida Bureau of Geology Report of Investigations 61, 52 p.

Odum, H. T., 1953, Dissolved phosphorus in Florida waters: Florida Bureau of Geology Report of Investigations 9, pt. I, p. 1–40.

Parker, G. G., Ferguson, G. E., Love, S. K., and others, 1955, Water resources of southeastern Florida: U.S. Geological Survey Water-Supply Paper 1255, 965 p.

Pride, R. W., Meyer, F. W., and Cherry, R. N., 1966, Hydrology of Green Swamp area in central Florida: Florida Geological Survey Report of Investigations 42, 137 p.

Shannon, E. E., and Brezonik, P. L., 1972, Limnological characteristics of north and central Florida lakes: Limnology and Oceanography, vol. 17, p. 97–110.

Stephens, D.W., and Jennings, M. E., 1976, Determination of primary productivity and community metabolism in streams and lakes using diel oxygen measurements: U.S. Geological Survey Computer Contributions, Program J330.

Stewart, H. G., Jr., 1966, Ground-water resources of Polk County, Florida: Florida Geological Survey Report of Investigations 44, 170 p.

Stringfield, V. T., 1966, Artesian water in Tertiary limestone in the southeastern states: U.S. Geological Survey Professional Paper 517, 226 p.

U.S. Environmental Protection Agency, 1976, Quality criteria for water: Washington, D.C., 256 p.

_____1977, Report on Lake Tohopekaliga, Osceola County, Florida: Region IV Working Paper 277, 15 p. and apps. A–E.

_____1980, Eutrophication analysis of Lake Tohopekaliga, Florida: report from Region IV, Water Division, Water Quality Management Branch, 72 p.

U.S. Geological Survey, 1978, Water-resources data for Florida, 1978, vols. 2A-2 and 3A-2.

Vollenweider, R. A., and Dillon, P. J., 1974, The application of the phosphorus loading concept to eutrophication research: National Research Council of Canada Publication 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Wanielista, M. P., 1978, Stormwater management: Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 383 p.

Wanielista, M. P., and others, 1976, Nonpoint source effects: Florida Department of Environmental Regulation Report ESEI 76-1 and 2.

Wegener, William, and Williams, Vincent, 1974a, Fish population responses to improved lake habitat utilizing an extreme drawdown: 28th Annual Conference of the Southeastern Association of Game and Fish Commissioners Proceedings, p. 144–160.

_____1974b, Lake Tohopekaliga drawdown study: Florida Game and Freshwater Fish Commission report.

Williams, Vincent, 1980, Impact of sewage plant discharge on lakes of the upper Kissimmee River basin: Florida Game and Freshwater Fish Commission report, 12 p.

## ABBREVIATIONS AND CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in the report are listed below:

| *Multiply* | *By* | *To obtain* |
|---|---|---|
| mile | 1.609 | kilometer (km) |
| square mile (mi²) | 2.590 | square kilometer (km²) |
| foot | 0.3048 | meter (m) |
| inch | 25.40 | millimeter (mm) |
| cubic foot per second (ft³/s) | 0.02832 | cubic meter per second (m³/s) |
| million gallons/per day (Mgal/d) | 0.04381 | cubic meter per second (m³/s) |
| cubic foot per second per square mile [(ft³/s)/mi²] | 0.01093 | cubic meter per second per square kilometer (m³/s)/km |
| micromho (µmho) | 1.000 | microsiemens (µS) |

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

**Table 1.**—*Physical parameters of Lake Tohopekaliga*

| Description | Statistics |
|---|---|
| Approximate surface area | 29.4 mi² |
| Natural drainage basin area | 620 mi² |
| Drainage area-surface area ratio | 21 |
| Mean depth | 5.1 ft. |
| Maximum depth | 13 ft |
| Volume | $4.09 \times 10^9$ ft³ |
| Drainage area-volume ratio | 4.2 |
| Average stage | 53.26 ft |

Approximate inflow-outflow budget

| Component | 1951–62 | 1965–70, 1973–75 |
|---|---|---|
| Shingle Creek at Campbell | [2,3] ~148 ft³/s | [2] ~ 127 ft³/s |
| Direct drainage, small tributaries, net rainfall to lake surface | [3] ~131 | [1] ~ 92 |
| St. Cloud Canal | [3] ~256 | 168 |
| Sum of inflow | 535 | 387 |
| Southport canal (outflow) | 484 | [1] 344 |
| Difference | 51 | 43 |
| Basin runoff | 0.75 (ft³/s)/mi²<br>10.1 in/yr | 0.67 (ft³/s)/mi²<br>9.1 in/yr |
| Water renewal time | 107 days | 137 days |

[1]U.S. Environmental Protection Agency, 1980, p.39.
[2]Period of record was 1969–79.
[3]This term was estimated by assuming that the magnitude of flow had decreased by a factor of 0.7 after 1965, as described in the text of this report.

The budget is approximate because direct drainage, flow of small tributaries, and net rainfall to the lake surface have never been measured. Also, the period of flow records for gaged tributaries do not coincide. The period of record for St. Cloud and Southport Canals is 1942–74. Flows for 1963–64 were omitted because of construction of control structures during that period. Flows for 1971–72 were omitted from the calculations because of the controlled lake drawdown during those years. The period of flow records for Shingle Creek was 1969–79. Flow for 1951–62 was estimated by assuming that the magnitude of flow had decreased by a factor of 0.7 after 1965.

**Table 6.**—*Chemical data for selected wells near Lake Tohopekaliga, 1972–79*
[Units are milligrams per liter except as indicated]

| Parameter | 280950081161501 | 280905081270101 | 281146081211701 | 281653081221101 | 281937081250101 | 281937081245901 | 280820081213901 |
|---|---|---|---|---|---|---|---|
| | USGS well identification numbers | | | | | | |
| Well number in figure 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Depth (ft) | 65 | 403 | 582 | 700 | 458 | 1,200 | ? |
| Aquifer | Surficial | Floridan | Floridan | Floridan | Floridan | Floridan | Floridan |
| Sample date | 6-21-72 | 3-20-79 | 3-27-79 | 12-13-78 | 3-20-79 | 3-20-79 | 3-20-79 |
| Specific conductance (µmho/cm at 25°C) | 72 | 195 | 295 | 312 | 225 | 245 | 240 |
| pH (units) | 5.2 | 7.7 | 7.6 | 7.5 | 7.5 | 7.4 | 7.6 |
| Alkalinity | 4 | 128 | 160 | 224 | 140 | 140 | 130 |
| Nitrite, dissolved as N | — | .00 | .00 | — | — | .00 | .00 |
| Nitrite, total as N | .003 | — | — | — | .00 | — | — |
| Nitrate, dissolved as N | — | .00 | 00 | — | — | .00 | .00 |
| Nitrate, total as N | .00 | — | — | — | .00 | — | — |
| Phosphorus, total as P | — | .04 | .04 | .09 | .06 | — | — |
| Hardness, total | 9 | 88 | 110 | 170 | 93 | 100 | 110 |
| Calcium, dissolved | 1.9 | 26 | 34 | 54 | 29 | 31 | 33 |
| Magnesium, dissolved | 1.1 | 5.6 | 6.1 | 7.8 | 5.0 | 5.4 | 5.3 |
| Sodium, dissolved | 7.7 | <3.0 | 5.6 | 15 | 4.0 | 4.7 | 4.0 |
| Potassium, dissolved | 0.6 | 1.0 | 1.2 | 1.2 | 0.7 | 0.9 | 1.1 |
| Chloride, dissolved | 13 | 4.2 | 7.3 | 17 | <4.0 | 4.2 | 7.3 |
| Sulfate, dissolved | 0.4 | 30 | 32 | 10 | 6.5 | 17 | 26 |
| Iron, dissolved (micrograms/liter) | 0.1 | — | — | — | — | — | — |
| Dissolved solids (residue at 180°C) | — | 128 | 138 | 236 | 125 | 158 | 176 |

Comparison of chemical parameters from Floridan aquifer wells and Lake Tohopekaliga

| | Conductance | pH | Hardness | Ca | Mg | Na | K | Cl | $SO_4$ | Dissolved solids residue |
|---|---|---|---|---|---|---|---|---|---|---|
| Wells (range) | 195–312 | 7.4–7.7 | 88–170 | 26–54 | 5.0–7.8 | <3–15 | 0.7–1.2 | <4–17 | 6.5–32 | 138–236 |
| Lake (mean) from table 4 | 143 | 7.4 | 44 | 12.1 | 3.2 | 10 | 1.6 | 17 | 10.8 | 111 |

**Table 4.**—*Summary of selected chemical data for Lake Tohopekaliga, Shingle Creek at Campbell, East Lake Tohopekaliga, and Cypress Lake, 1954–80*
[Units are milligrams per liter (mg/L) unless noted]

| Sampling location | Statistics associated with the site | Specific conductance (µmhos/cm at 25°C) | pH (units) | Alkalinity | Turbidity (Jackson turbidity units) | Color (Platinum cobalt units) | Secchi disk (inches) | Biochemical oxygen demand (5-day at 20°C) | Oxygen, dissolved | Hardness, total | Chloride, dissolved | Sodium, dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Tohopekaliga, near center of lake | Mean | 143 | [1]7.4 | 28 | 22 | 78 | 53 | 3.7 | 7.6 | 44 | 17 | 10 |
| | Maximum | 268 | 10.2 | 89 | 93 | 200 | 118 | 11.2 | 12.4 | 92 | 26 | 18 |
| | Year observed | 71 | 73 | 71 | 74 | 55 | 75 | 74 | 73 | 62 | 72 | 73 |
| | Minimum | 68 | 6.3 | 7 | 0 | 0 | 18 | 0.9 | 3.5 | 17 | 6.0 | 4.7 |
| | Year observed | 54 | 74 | 70 | 72 | 71 | 75 | 74 | 75 | 54 | 56 | 59 |
| | Number of observations | 79 | 81 | 65 | 46 | 66 | 9 | 34 | 89 | 34 | 62 | 26 |
| | Period of record | 54–77 | 54–77 | 54–75 | 70–77 | 54–75 | 73–77 | 70–75 | 67–77 | 54–75 | 54–75 | 58–75 |
| Site 2 | Mean | 188 | [1]6.8 | 29 | 23 | 180 | | | 8.3 | 51 | 24 | 18 |
| | Maximum | 235 | 7.6 | 36 | 50 | 320 | 20 | 1.4 | 9.5 | 56 | 28 | 23 |
| | Year observed | 71 | 72 | 71 | 71 | 71 | 72 | 72 | 71 | 71 | 72 | 71 |
| | Minimum | 110 | 6.0 | 19 | 9 | 100 | | | 7.1 | 46 | 15 | 10 |
| | Year observed | 71 | 71 | 71 | 72 | 72 | | | 71 | 72 | 71 | 71 |
| | Number of observations | 9 | 4 | 3 | 9 | 3 | 1 | 1 | 13 | 2 | 3 | 3 |
| | Period of record is 1970–1972 for all parameters | | | | | | | | | | | |
| Site 9 | Mean | 163 | [1]6.6 | 13 | 10 | 30 | | | 8.2 | 29 | 26 | 18 |
| | Maximum | 185 | 7.5 | 25 | 30 | 55 | 18 | 4.1 | 9.5 | 34 | 30 | 21 |
| | Year observed | 72 | 72 | 72 | 71 | 72 | 72 | 72 | 72 | 72 | 70 | 72 |
| | Minimum | 115 | 5.7 | 8 | 2.0 | 20 | | | 7.4 | 21 | 20 | 12 |
| | Year observed | 70 | 71 | 71 | 71 | 71 | | | 72 | 70 | 70 | 70 |
| | Number of observations | 10 | 5 | 4 | 12 | 4 | 1 | 1 | 12 | 3 | 4 | 4 |
| | Period of record is 1970–1972 for all parameters | | | | | | | | | | | |
| Shingle Creek at Campbell | Mean | 260 | [1]7.2 | 52 | 21 | 171 | 65 | 1.9 | 6.4 | 65 | 29 | 26 |
| | Maximum | 480 | 8.3 | 86 | 42 | 320 | 98 | 10.4 | 11.4 | 79 | 58 | 31 |
| | Year observed | 78 | 80 | 75 | 72 | 75 | 75 | 72 | 73 | 70 | 72 | 70 |
| | Minimum | 112 | 6.3 | 29 | 1.0 | 80 | 26 | 0.3 | 3.5 | 49 | 15 | 20 |
| | Year observed | 74 | 75 | 74 | 70 | 75 | 72 | 72 | 75 | 69 | 74 | 79 |
| | Number of observations | 46 | 37 | 29 | 27 | 27 | 4 | 17 | 38 | 3 | 27 | 2 |
| | Period of record | 69–80 | 70–80 | 70–79 | 70–75 | 70–79 | 72–75 | 70–75 | 69–80 | 69–79 | 69–79 | 70–79 |
| East Lake Tohopekaliga | Mean | 104 | [1]6.3 | 6.2 | 4.4 | 57 | 56 | — | 8.4 | 20 | 14 | 8.8 |
| | Maximum | 165 | 7.8 | 8 | 7 | 240 | 84 | — | 10.4 | 36 | 22 | 13 |
| | Year observed | 62 | 77 | 57 | 76 | 76 | 76 | — | 77 | 62 | 77 | 79 |
| | Minimum | 49 | 5.3 | 1.0 | 3.0 | 10 | 42 | — | 6.1 | 12 | 8 | 4.3 |
| | Year observed | 60 | 76 | 63 | 77 | 77 | 80 | | 76 | 54 | 60 | 60 |
| | Number of observations | 67 | 39 | 27 | 5 | 28 | 10 | — | 46 | 25 | 26 | 16 |
| | Period of record | 54–80 | 54–80 | 54–79 | 76–77 | 54–79 | 76–80 | — | 67–80 | 54–79 | 54–79 | 58–79 |
| Cypress Lake | Mean | 125 | [1]6.8 | 11 | 10 | 75 | 23 | — | 8.5 | 24 | 17 | 11 |
| | Maximum | 250 | 9.7 | 23 | 35 | 180 | 40 | — | 12.4 | 43 | 29 | 18 |
| | Year observed | 71 | 77 | 76 | 75 | 56 | 76 | — | 73 | 78 | 77 | 77 |
| | Minimum | 16 | 4.6 | 0 | 4 | 20 | 9 | — | 3.2 | 10 | 6 | 3.2 |
| | Year observed | 78 | 56 | 60 | 71 | 56 | 79 | — | 78 | 60 | 60 | 60 |
| | Number of observations | 112 | 57 | 41 | 38 | 41 | 11 | — | 60 | 41 | 41 | 31 |
| | Period of record | 54–80 | 54–80 | 54–79 | 70–77 | 54–79 | 76–80 | — | 67–80 | 54–79 | 54–79 | 58–79 |

**Table 4.** (continued)

| Sampling location | Statistics associated with the site | Calcium, dissolved | Magnesium, dissolved | Potassium, dissolved | Sulfate, dissolved | Nitrogen, total as N | Nitrogen, total organic as N | Ammonia, total as N | Nitrate, total as N | Nitrite, total as N | Nitrogen, total Kjeldahl | Nitrate + Nitrite, total as N | Carbon, total organic | Orthophosphate, total as P | Phosphorus, total as P | Dissolved solids, (residue at 180°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Tohopekaliga, near center of lake | Mean | 12 | 3.2 | 1.6 | 11 | 1.6 | 1.5 | 0.10 | 0.05 | 0.004 | 1.48 | 0.03 | 16 | 0.15 | 0.30 | 111 |
| | Maximum | 28 | 6.0 | 3.7 | 30 | 2.3 | 3.1 | 0.25 | 0.24 | 0.012 | 1.93 | 0.12 | 40 | 1.00 | 0.45 | 155 |
| | Year observed | 71 | 62 | 75 | 75 | 74 | 74 | 73 | 75 | 73 | 75 | 74 | 73 | 72 | 75 | 74 |
| | Minimum | 4.0 | 0.2 | 0.6 | 2.0 | 1.2 | 0.4 | 0.0 | 0.0 | 0.0 | 1.23 | 0.01 | 3 | 0.01 | 0.14 | 68 |
| | Year observed | 54 | 64 | 63 | 75 | 75 | 72 | 74 | 72 | 77 | 75 | 74 | 71 | 74 | 73 | 66 |
| | Number of observations | 34 | 34 | 26 | 60 | 6 | 47 | 44 | 44 | 43 | 5 | 5 | 39 | 42 | 12 | 18 |
| | Period of record | 54–75 | 54–75 | 58–75 | 54–75 | 74–75 | 70–77 | 70–77 | 70–77 | 70–77 | 74–75 | 74–75 | 70–77 | 72–77 | 72–77 | 66–75 |
| Site 2 | Mean | 12 | 3.7 | 2.6 | 16 | — | 1.69 | 0.07 | 0.05 | 0.01 | — | — | 24 | 0.59 | 0.69 | 139 |
| | Maximum | 14 | 5.0 | 3.2 | 26 | — | 3.60 | 0.16 | 0.20 | 0.01 | — | — | 28 | 0.78 | 0.88 | 175 |
| | Year observed | 71 | 71 | 71 | 71 | — | 71 | 71 | 71 | 72 | — | — | 70 | 71 | 71 | 71 |
| | Minimum | 8.6 | 2.4 | 2.0 | 4 | — | 0.23 | 0.02 | 0.0 | 0.01 | — | — | 20 | 0.46 | 0.51 | 100 |
| | Year observed | 71 | 71 | 72 | 71 | — | 72 | 72 | 72 | 72 | — | — | 72 | 72 | 72 | 71 |
| | Number of observations | 3 | 3 | 3 | 3 | — | 9 | 5 | 5 | 2 | — | — | 2 | 5 | 5 | 3 |
| Site 9 | Mean | 5.6 | 3.3 | 2.5 | 17 | — | 1.5 | 0.04 | 0.00 | 0.002 | — | — | 15 | 0.06 | 2.1 | 104 |
| | Maximum | 7.0 | 3.9 | 2.9 | 19 | — | 3.2 | 0.10 | 0.00 | 0.01 | — | — | 20 | 0.13 | 14.0 | 122 |
| | Year observed | 72 | 72 | 71 | 71 | — | 71 | 72 | | 72 | — | — | 72 | 71 | 72 | 72 |
| | Minimum | 4.0 | 2.5 | 2.0 | 14 | — | 0.28 | 0.00 | 0.00 | 0.000 | — | 0 | 10 | 0.03 | 0.05 | 80 |
| | Year observed | 70 | 70 | 70 | 70 | — | 70 | 72 | | 72 | — | 0 | 70 | 72 | 72 | 70 |
| | Number of observations | 4 | 4 | 4 | 4 | — | 12 | 7 | 7 | 5 | — | 0 | 3 | 7 | 7 | 4 |
| Shingle Creek at Campbell | Mean | 17 | 5.1 | 2.1 | 16 | 1.7 | 1.1 | 0.17 | 0.25 | 0.008 | 1.18 | 0.50 | 27 | 1.3 | 1.5 | 196 |
| | Maximum | 21 | 6.3 | 2.8 | 28 | 3.2 | 3.1 | 0.72 | 2.0 | 0.03 | 1.52 | 2.01 | 77 | 3.5 | 3.5 | 207 |
| | Year observed | 70 | 70 | 79 | 70 | 80 | 72 | 75 | 80 | 78 | 79 | 80 | 79 | 78 | 78 | 70 |
| | Minimum | 13 | 3.9 | 1.4 | 2.0 | 1.1 | 0.4 | 0.00 | 0.01 | 0.001 | 0.56 | 0.08 | 12 | 0.5 | 0.6 | 186 |
| | Year observed | 69 | 69 | 70 | 75 | 78 | 70 | 70 | 72 | 75 | 78 | 79 | 74 | 73 | 79 | 79 |
| | Number of observations | 3 | 3 | 2 | 22 | 9 | 38 | 35 | 34 | 35 | 9 | 9 | 27 | 33 | 10 | 2 |
| | Period of record | 69–79 | 69–79 | 70–79 | 69–79 | 78–80 | 70–80 | 70–80 | 0.25 | 70–80 | 78–80 | 78–80 | 72–80 | 72–80 | 72–80 | |
| East Lake Tohopekaliga | Mean | 4.7 | 2.1 | 1.4 | 11 | 0.8 | 0.73 | 0.03 | 0.01 | 0.003 | 0.77 | 0.017 | 12 | 0.01 | 0.03 | 72 |
| | Maximum | 10 | 4.8 | 2.4 | 29 | 1.5 | 1.30 | 0.08 | 0.11 | 0.02 | 1.33 | 0.13 | 26 | 0.03 | 0.05 | 90 |
| | Year observed | 62 | 77 | 77 | 62 | 76 | 76 | 78 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 79 |
| | Minimum | 2.4 | 1.0 | 0.5 | 1.8 | 0.5 | 0.51 | 0.01 | 0.00 | 0.000 | 0.52 | 0.00 | 7 | 0.00 | 0.02 | 60 |
| | Year observed | 56 | 57 | 59 | 55 | 77 | 77 | 76 | 76 | 76 | 77 | 76 | 77 | 77 | 77 | 67 |
| | Number of observations | 25 | 25 | 16 | 26 | 10 | 11 | 11 | 11 | 11 | 10 | 10 | 11 | 11 | 11 | 7 |
| | Period of record | 54–79 | 54–79 | 58–79 | 54–79 | 76–79 | 76–80 | 76–80 | 76–80 | 76–80 | 76–79 | 76–79 | 76–80 | 76–80 | 76–80 | 66–79 |
| Cypress Lake | Mean | 5.7 | 2.3 | 1.6 | 9.8 | 1.7 | 1.44 | 0.05 | 0.03 | 0.01 | 1.67 | 0.07 | 24 | 0.04 | 0.09 | 106 |
| | Maximum | 10 | 4.3 | 3.6 | 19 | 3.0 | 3.00 | 0.23 | 0.29 | 0.05 | 3.02 | 0.34 | 50 | 0.08 | 0.21 | 134 |
| | Year observed | 78 | 74 | 77 | 78 | 75 | 75 | 77 | 75 | 75 | 75 | 75 | 79 | 75 | 74 | 78 |
| | Minimum | 2.8 | 0.4 | 0 | 0 | 0.5 | 0.33 | 0.02 | 0 | 0.0 | 0.46 | 0.01 | 12 | 0.00 | 0.01 | 88 |
| | Year observed | 60 | 60 | 60 | 60 | 79 | 70 | 72 | 71 | 79 | 79 | 76 | 76 | 73 | 73 | 74 |
| | Number of observations | 41 | 41 | 31 | 41 | 22 | 44 | 37 | 36 | 36 | 19 | 19 | 12 | 36 | 36 | 16 |
| | Period of record | 54–79 | 58–79 | 58–79 | 54–79 | 73–80 | 70–80 | 71–80 | 71–80 | 71–80 | 74–80 | 74–80 | 76–80 | 71–80 | 76–80 | 67–79 |

[1] Median value for pH.

**Table 3.**—*Nutrients in lake bottom sediments, April 1980*
[Units are milligrams per kilogram unless otherwise noted]

| Parameter | Site 2 | Site 4 | Site 6 | Site 8 | Site 9 |
|---|---|---|---|---|---|
| Carbon, total (g/kg) | 9.8 | 127 | 6.5 | 6.9 | 114 |
| Nitrogen, total as N | 4,910 | 22,500 | 4,110 | 5,310 | 16,400 |
| Carbon, inorganic (g/kg) | .0 | .0 | .0 | .0 | .2 |
| Carbon, organic (g/kg) | 9.8 | 127 | 6.5 | 6.9 | 114 |
| Nitrate + Nitrite as N | 6.9 | 40 | 9.3 | 11 | 16,400 |
| Ammonium + Organic nitrogen as N | 4,900 | 22,500 | 4,100 | 5,300 | 16,400 |
| Phosphorus, total as P | 170 | 2,500 | 110 | 110 | 430 |
| Ammonium as N | 6.3 | 11 | 10 | 9.7 | 11 |

**Table 2.**—*Concentrations of pesticide residues in lake bottom sediments*
[Units are micrograms per kilogram of dry solids]
[May 1972 data from unpublished U.S. Geological Survey records]

| Parameter | Site 2 May 1972 | Site 2 April 1980 | Site 6 May 1972 | Site 6 April 1980 | Site 8 May 1972 | Site 8 April 1980 | Site 9 May 1972 | Site 9 April 1980 |
|---|---|---|---|---|---|---|---|---|
| Aldrin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lindane | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| Chlordane | .0 | 1 | .0 | 0 | .0 | 0 | .0 | 1 |
| DDD | 1.8 | .5 | .0 | .0 | .0 | .0 | 1.0 | .5 |
| DDE | 2.2 | 1.8 | .0 | .0 | .0 | .0 | 1.2 | 1.8 |
| DDT | .0 | .0 | .0 | .0 | .0 | .0 | .2 | .0 |
| Dieldrin | .2 | .0 | .1 | .0 | .1 | .0 | .4 | .0 |
| Endrin | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| Toxaphene | .0 | 0 | .0 | 0 | .0 | 0 | .0 | 0 |
| Heptachlor | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| Heptachlor epoxide | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| PCB | — | 0 | — | 0 | — | 0 | .0 | 0 |
| Diazinon | — | .0 | — | .0 | — | .0 | — | .0 |
| Endosulfin | — | .0 | — | .0 | — | .0 | — | .0 |
| Parathion | — | .0 | — | .0 | — | .0 | — | .0 |
| Trithion | — | .0 | — | .0 | — | .0 | — | .0 |
| Ethion | — | .0 | — | .0 | — | .0 | — | .0 |
| Malathion | — | .0 | — | .0 | — | .0 | — | .0 |
| Meth parth | — | .0 | — | .0 | — | .0 | — | .0 |
| Meth trith | — | .0 | — | .0 | — | .0 | — | .0 |
| Mirex | — | .0 | — | .0 | — | .0 | — | .0 |
| Methoxychlor | — | .0 | — | .0 | — | .0 | — | .0 |
| PCN | — | 0 | — | 0 | — | 0 | — | 0 |
| Perthane | — | .0 | — | .0 | — | .0 | — | .0 |

**Table 5.**—*Chemical data for Lake Tohopekaliga and Shingle Creek at Campbell, 1980*
[Units are milligrams per liter (mg/L) unless noted]

| Parameters | 5-5-80 Site 1 | 5-28-80 Site 1 | 5-5-80 Site 2 | 5-28-80 Site 4 | 5-5-80 Site 5 | 5-28-80 Site 5 | 5-5-80 Site 7 | 5-5-80 Site 9 | 5-28-80 Site 9 | 5-5-80 Shingle Creek | 5-28-80 Shingle Creek |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Specific conductance (µmho/cm at 25°C) | 250 | — | 230 | — | 115 | — | 172 | 169 | — | 380 | — |
| pH (units) | 8.5 | — | 7.8 | — | 6.0 | — | 8.6 | 8.7 | — | 7.5 | — |
| Alkalinity | — | — | 39 | — | 2 | — | 29 | 21 | — | 92 | — |
| Turbidity (Jackson turbidity units) | — | — | — | — | — | — | — | — | — | — | — |
| Color (platinum cobalt units) | — | — | — | — | — | — | — | — | — | — | — |
| Secchi disk (inches) | 29 | — | 34 | — | 23 | — | 30 | 24 | — | 40 | — |
| Biochemical oxygen demand (5-day at 20°C) | — | — | — | — | — | — | — | — | — | — | — |
| Oxygen, dissolved | 9.5 | — | 7.8 | — | 7.6 | — | 9.8 | 10.0 | — | 8.1 | — |
| Hardness, total | — | — | 56 | — | 21 | — | 13 | 22 | — | 91 | — |
| Chloride, dissolved | — | — | 30 | — | 23 | — | 26 | 25 | — | 50 | — |
| Sodium, dissolved | — | — | 24 | — | 13 | — | 19 | 13 | — | 46 | — |
| Calcium, dissolved | — | — | 15 | — | 3.4 | — | 10 | 12 | — | 26 | — |
| Magnesium, dissolved | — | — | 4.5 | — | 3.1 | — | 4.1 | 3.1 | — | 6.3 | — |
| Potassium, dissolved | — | — | 3.4 | — | 1.9 | — | 2.8 | 2.7 | — | 4.6 | — |
| Sulfate, dissolved | — | — | 17 | — | 13 | — | 17 | 16 | — | 21 | — |
| Nitrogen, total as N | 1.43 | 1.10 | 1.63 | 2.20 | 1.29 | 0.86 | 1.33 | 1.80 | 2.40 | 1.20 | 0.96 |
| Nitrogen, total organic as N | 1.40 | 1.10 | 1.60 | 2.20 | 1.10 | 0.77 | 1.30 | 1.80 | 2.30 | 0.98 | 0.71 |
| Ammonia, total as N | 0.02 | 0.07 | 0.02 | 0.06 | 0.14 | 0.08 | 0.02 | 0.02 | 0.10 | 0.04 | 0.06 |
| Nitrate, total as N | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.01 | 0.00 | 0.00 | 0.00 | 0.21 | 0.18 |
| Nitrite, total as N | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.10 | 0.01 | 0.02 | 0.01 |
| Nitrogen, total Kjeldahl | 1.42 | 1.10 | 1.62 | 2.20 | 1.24 | 0.85 | 1.32 | 1.82 | 2.40 | 1.00 | 0.77 |
| Nitrate + Nitrite, total as N | 0.01 | 0.01 | 0.01 | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 | 0.23 | 0.19 |
| Carbon, total organic | 23 | — | 24 | — | 15 | — | 20 | 22 | — | 16 | — |
| Orthophosphate, total as P | 1.00 | 0.90 | 0.95 | 0.42 | 0.13 | 0.03 | 0.44 | 0.30 | 0.29 | 2.40 | 1.70 |
| Phosphorous, total as P | 1.10 | 0.93 | 1.00 | 0.60 | 0.18 | 0.07 | 0.53 | 0.40 | 0.45 | 2.50 | 1.70 |
| Dissolved solids, (residue at 180°C) | — | — | — | — | — | — | — | — | — | — | — |

**Table 7.**—*Nutrient concentrations in water from selected south-central Florida lakes, May–June 1878–79*
[Units are milligrams per liter (mg/L)]

| Parameter | Alligator Lake near Ashton 5-28-78 | Lake Mary Jane near Narcossee 6-2-78 | East Lake Tohopekaliga at St. Cloud 5-23-78 | East Lake Tohopekaliga 6-1-79 | Cypress Lake near St. Cloud 5-23-78 | Cypress Lake 6-1-79 | Lake Marion near Haines City 5-25-78 | Lake Marion 5-31-79 | Lake Pierce near Waverly 5-25-78 | Lake Hatchineha near Lake Wales 5-23-78 | Lake Hatchineha 6-1-79 | Lake Weohyakapica at Indian Lake Estates 5-25-78 | Lake Rosalie near Lake Wales 5-25-78 | Lake Marian near Kenansville 5-23-78 | Lake Marian 5-30-79 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen, total as N | 0.59 | 1.2 | 0.96 | 0.69 | 2.0 | 0.47 | 1.3 | 0.96 | 0.82 | 1.5 | 1.9 | 0.57 | 0.83 | 1.5 | 4.0 |
| Nitrogen, total organic as N | 0.56 | 1.2 | 0.87 | 0.64 | 1.9 | 0.44 | 1.3 | 0.94 | 0.79 | 1.4 | 1.9 | 0.53 | 0.68 | 1.5 | 4.0 |
| Ammonia, total as N | 0.03 | 0.05 | 0.08 | 0.04 | 0.10 | 0.02 | 0.04 | 0.01 | 0.03 | 0.17 | 0.03 | 0.03 | 0.07 | 0.03 | 0.02 |
| Nitrite, total as N | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.03 | 0.01 | 0.01 | 0.00 | 0.01 |
| Nitrate, total as N | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 |
| Nitrogen, total Kjeldahl | 0.59 | 1.2 | 0.95 | 0.68 | 2.0 | 0.46 | 1.3 | 0.95 | 0.82 | 1.5 | 1.9 | 0.56 | 0.75 | 1.5 | 4.0 |
| Nitrate + Nitrite as N | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.02 | 0.03 | 0.01 | 0.08 | 0.00 | 0.01 |
| Phosphorus, total as P | 0.02 | 0.02 | 0.03 | 0.03 | 0.14 | 0.20 | 0.03 | 0.04 | 0.02 | 0.10 | 0.09 | 0.04 | 0.04 | 0.06 | 0.11 |
| Carbon, total organic | 1.5 | 22 | 13 | 10 | 23 | 50 | 21 | 14 | 13 | 24 | 46 | 8.0 | 14 | 20 | 18 |
| Orthophosphate, total as P | 0.01 | 0.02 | 0.01 | 0.01 | 0.05 | 0.04 | 0.03 | 0.01 | 0.01 | 0.04 | 0.05 | 0.02 | 0.03 | 0.01 | 0.03 |

Note: All lakes are outside the phosphate mining district.

# HYDROLOGY OF LAKE TOHOPEKALIGA, OSCEOLA COUNTY, FLORIDA

By
G. G. Phelps

1982