SOURCES OF NITROGEN AND PHOSPHORUS IN THE LAKE GEORGE DRAINAGE BASIN: A DOUBLE LAKE

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Introduction

Lake George is located near the eastern border of New York State, approximately halfway between New York City and Montreal, Canada (see lower right hand corner of Fig. 1) i.e., in the southeastern part of the Adirondack State Park in New York. The lake, known as the Queen of American Lakes, is renowned for the clarity of its water and has thus gained a reputation as an excellent recreational site for summer activities of swimming, boating, and fishing, and recently, winter sports on the ice.

The lake (Fig. 1), which is long and somewhat narrow with its major axis extending in a north by northeasterly direction, is divided into two nearly equal basins, South Lake George (L.G.)(Fig. 2), and North Lake George (L.G.)(Fig. 3), which are separated by an island-studded area called The Narrows. The shores of the lake are irregular, steep and rocky with mountains which reach an elevation of 716 m (2345 ft) above the lake level, which is 97.2 m (319 ft) above mean sea level.

Part of the uniqueness and beauty of the Lake George region may be attributed to its geological origin which dates back to the Pre-Grenville rock assemblages,

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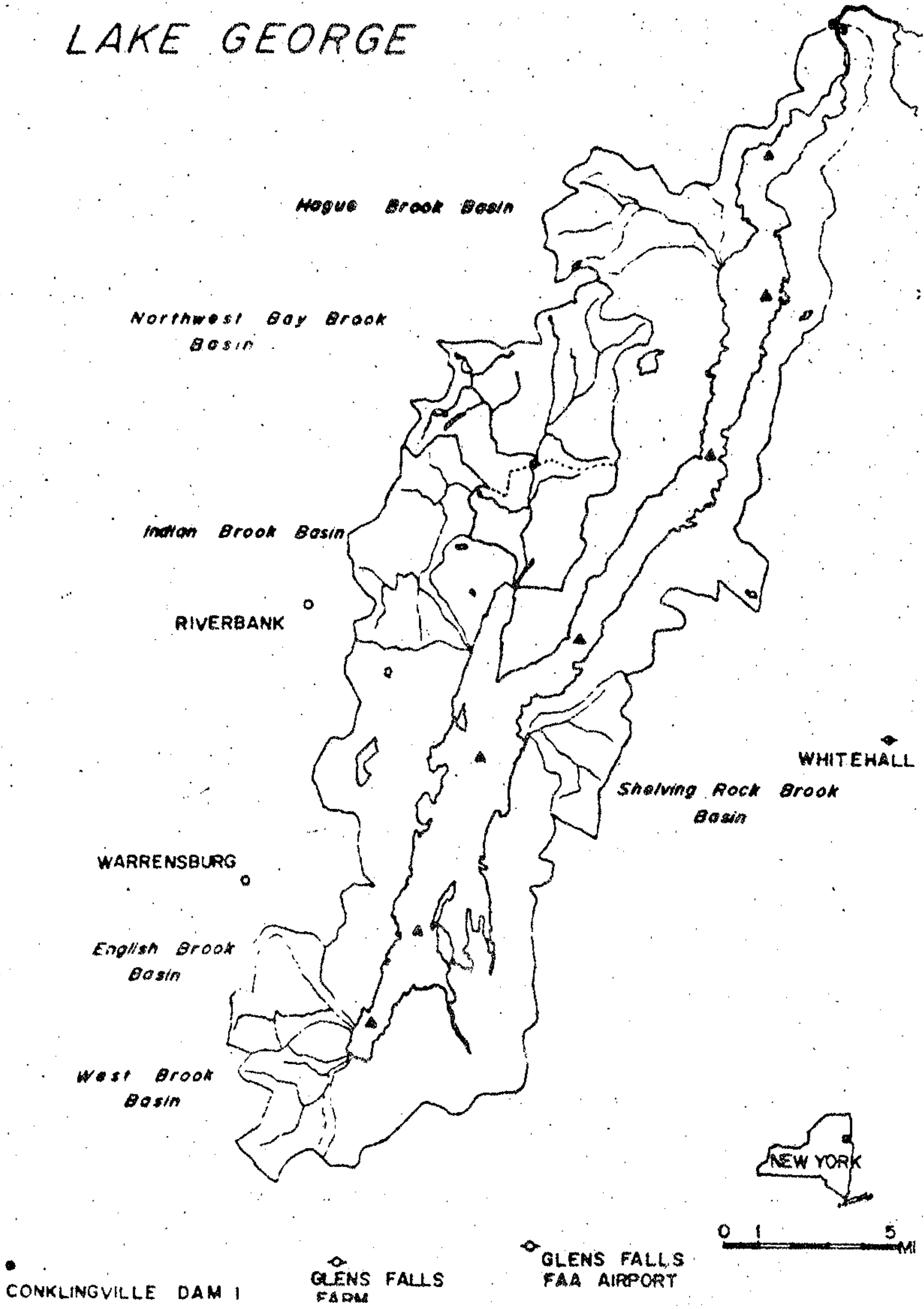
Figure 1.


LAKE GEORGE
TICONDEROGA B MILL
Hogue Brook Basin
Northwest Bay Brook Basin
Indian Brook Basin
RIVERBANK
WHITEHALL
Shelving Rock Brook Basin
WARRENSBURG
English Brook Basin
West Brook Basin
NEW YORK
0 1 5 MI
CONKLINGVILLE DAM I
GLENS FALLS FARM
GLENS FALLS FAA AIRPORT

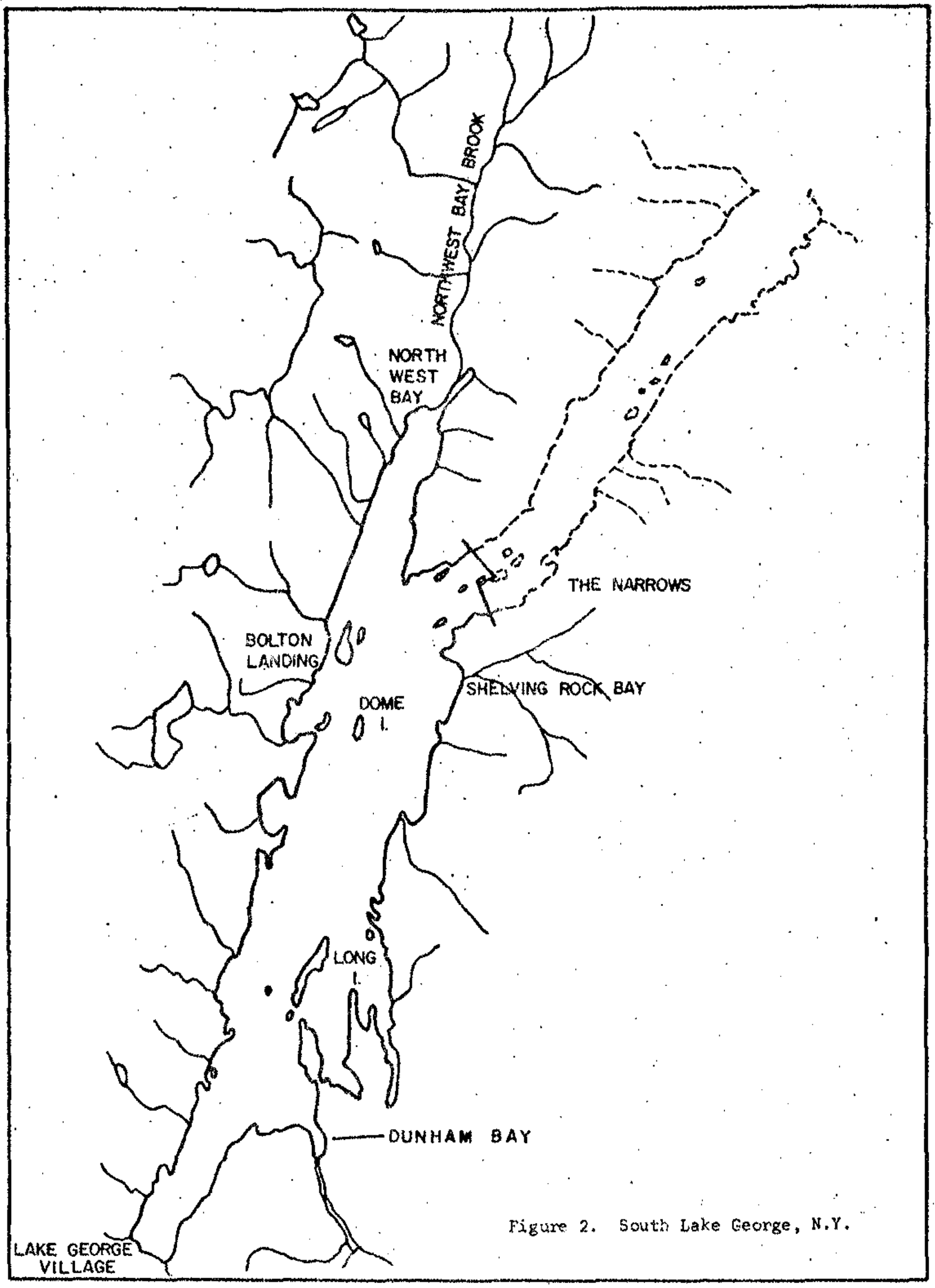


Figure 2. South Lake George, N.Y.

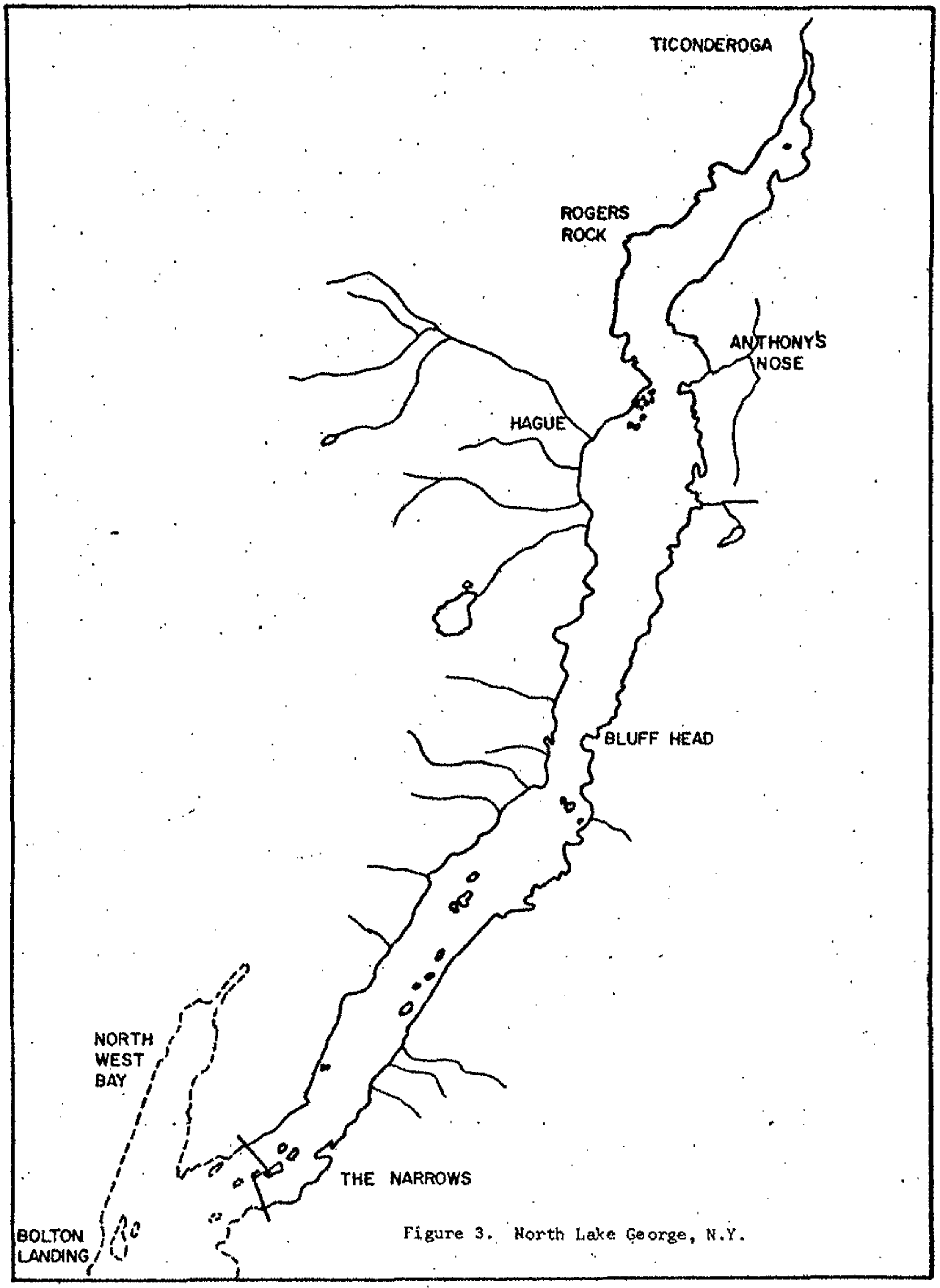


Figure 3. North Lake George, N.Y.

some 3.5 billion years ago. This entire area was covered by the Primordial Sea which deposited sand, muds, and marls. The Pre-Cambrian period included outbreaks of igneous activity which wrinkled and squeezed the earth's crust, producing mountains and highlands with molten matter intrusions during the Grenville uplift. These rocks comprise most of the rock mass including the high ranges of the Lake George area. The last portion of the Pre-Cambrian period and the beginning of the Cambrian period submerged the lower elevations with sediments deposited along the sides of the mountains. Crustal disturbances and faulting produced two large depressions. Each resulted in a separate river drainage area. The one originated in what is now the Northwest Bay area and flowed southward through what is presently the Dunham Bay area, nearly due South to the present Hudson River less than 9 mi. away. The other basin flowed from what is now The Narrows in a north-northeasterly direction, ultimately discharging into Lake Champlain, probably through the present-day Rogers Rock campsite. During the glacial period, this entire area was covered by ice. The retreating and melting ice blocked both ends of these two drainage basin areas, but apparently deposited more till in the Dunham Bay area. Thus, as the southernmore depression filled, the water flowed out over the barrier of The Narrows and into the more northerly basin, from which the water of both basins now overflowed at Ticonderoga. The natural rock barrier near Ticonderoga still exists. However, the present artificial dam was built in 1903 by a paper plant at Ticonderoga raising the water level in the lake by approximately 0.6 m (2 ft)(13). This principal dam along with five other auxiliary dams controls the present lake level.

In choosing Lake George as a major research site, consideration was taken of the existence of the two major basins within the lake, which are compared in Table 1. The information from which the data for South L.G. were derived is much more detailed, and therefore much more precise than the approximations used for the similar information concerning North L.G. North L.G. is slightly longer and narrower than South

TABLE 1

Morphometric Comparison of South and North Lake George

	South Lake(11)		North Lake		Total Lake(6,7)	
Length	22.4 km	13.9 mi	28.6 km	17.8 mi	51 km	32 mi
Mean Breadth	2.6 km	1.6 mi	2.0 km	1.2 mi	2.3 km	1.4 mi
Max. Breadth	4.0 km	2.4 mi	3.2 km	2.0 mi	4.0 km	2.4 mi
Area	57.6 km^2	22.2 mi^2	56.4 km^2	21.8 mi^2	114 km^2	44 mi^2
Max. Depth	58 m	191 ft	53.3(4) m	175(4) ft	58 m	191 ft
Mean Depth	15.5 m	50.9 ft	20.5 m	67.3 ft	18 m	59 ft
Length of Shoreline	76 km	47.2 mi	133.6 km	84.5 mi	209.6 km	131 mi
Volume	1.02 km^3	0.24 mi^3	1.08 km^3	0.26 mi^3	2.1 km^3	0.5 mi^3
Watershed Area (land)	313.2 km^2	121.0 mi^2	178.8 km^2	69.0 mi^2	492 km^2	190 mi^2
Watershed Area (including lake)	370.8 km^2	143 mi^2	235.2 km^2	90.6 mi^2	606 km^2	234 mi^2

L.G., but the total surface area of the two lakes is very nearly the same. The maximum depth is nearly the same in both lakes, although the mean depth of North L.G. is slightly greater. Due to the greater length and the many bays, the length of the shoreline of North L.G. is nearly double that of South L.G. The total volume in both lakes is nearly identical. Due primarily to the fact that two watersheds,(the largest in the L.G. basin, Northwest Bay Brook, and also Shelving Rock Brook) whose areas partly surround both the North and South lakes, flow southward into South L.G., the drainage area of South L.G. is considerably greater than that of North L.G. Thus, it may be seen that Lake George consists of two major lakes, both of which are quite similar in their physical characteristics.

As similar as the two lakes may be in their physical characteristics, they differ in both nutrient quality and stresses due to human habitation. The population tributary to the South and North lakes is summarized in Table 2. Whereas the permanent population of South L.G. is approximately four times that of North L.G., the total average summer population of South L.G. is approximately six times that of North L.G. It may be seen that the largest sources of population are first the hotels and motels, and second, the summer camps. It must also be pointed out that the total average summer population in South L.G. is approximately six times that of its permanent year-round population.

Further, attention should be given to the figures for sewered and total populations. There are two sewage treatment plants in the L.G. drainage basin. One is operated by Lake George Village and the other by the Town of Bolton Landing. The Lake George Village sewage treatment plant provides primary sedimentation and secondary treatment by means of trickling filters. The Bolton Landing treatment plant is equipped with circular Imhoff tanks. What is rather unique is that both treatment plants discharge their final effluent onto natural sand beds which have no man-made underdrain. Whereas it is not certain what is the exact quality of

TABLE 2

Population Distribution in the Lake George Basin

	South Lake		North Lake	
	Sewered	Total	Sewered	Total
Permanent year round population[1]	2,930	4,445	0	1,130
Summer camp population[2] (14)	1,750	8,775	0	3,205
Resort hotel and motel population(12,19)	9,111	12,558	0	47
Total Avg. Summer population	13,791	25,778	0	4,382

1. Data (14) adjusted to conform to drainage basin lines.
2. Based on a normal summer occupancy of 5 persons per camp.

the effluent which passes through the soil, it is certain that the liquid from both treatment plants ultimately reaches Lake George. Inasmuch as the largest concentration of hotels and motels is located in the Lake George Village area, it is understandable that the greater percentage of these is sewered. On the other hand, the summer camps are quite temporary consisting of both tents and lean-to's, whose sanitary facilites are not connected to any sewer system. Some of the summer camps included in this number are located on State-operated campsites on State-owned islands within the lake itself. All of the wastes which are collected by sewers are treated in one of the sewage treatment plants mentioned. All areas which are not sewered employ septic tank systems for disposal of their wastewater.

Of prime concern in any recreational lake, is the problem of undesirable algal growths whose effects may be both direct and indirect. The direct effects are the production of a large number of one or a few species of algae commonly called a "bloom". This frequently causes a green coloration, although other colors such as red and brown are not uncommon. Besides the aesthetic effects, algae tend to clog rapid sand filters in water treatment plants. Certain algae may also be toxic to other biological systems. The indirect effects are generally the result of the decomposition of large masses of algae which have completed their life cycle. This decomposition utilizes dissolved oxygen (DO). This situation becomes of concern where lakes undergo thermal stratification during the summer and re-aeration of the hypolimnetic waters is not possible. Therefore, the DO in the hypolimnion may be diminished, thus, decreasing the number of species of fish which can survive in a lake.

Both nitrogen and phosphorus have been shown to limit algal growth under various conditions in certain lakes(20). The best information indicates that 300 µg/l of nitrogen is the critical level for control of algal blooms in a lake.

Similarly for phosphorus, 10 μg/l is considered to be the critical level above which algal blooms may occur(20,16). Studies conducted by Fuhs, et al.(11) have indicated that both nitrogen and phosphorus may be limiting at certain times in Lake George. They stated that there were indications that under certain conditions, carbon may also be limiting here. Thus, it was felt that in order to evaluate the potential of Lake George to produce algal growths, measurements of the nitrogen and phosphorus in the lake waters and identification of the sources of these nutrients must be made. The urgency of these studies was increased by the observation during May of 1972 of a significant algal growth in South L.G.(18).

In order to restrict excessive algal growths, the sources of the nutrients responsible must be identified and subsequently controlled. The report of the Task Group on "Sources of Nitrogen and Phosphorus in Water Supplies"(1) has indicated various sources of nutrients as follows: the earth itself, fertilizers, domestic wastes with special reference to synthetic detergents, industrial wastes, fuels, precipitation and runoff (both rural and urban), farm animal wastes, wild animal wastes, and precipitation of atmospheric dusts. In addition, certain algae are capable of fixing atmospheric nitrogen which is dissolved in water. Not all of these sources can be controlled. Rohlich and Uttormark(15) have indicated that wastewater is the one source which is most amenable to treatment. Techniques for removal of nitrogen and phosphorus are presently understood and may be installed at a cost which is not prohibitive. Some of these techniques which were reviewed earlier by Clesceri(5) were then just emerging as potential candidates for removal of nitrogen and phosphorus. Since that time the interest in nutrient control has sharpened considerably, and further advances in techniques and methodologies can be anticipated.

Analytical

Measurements of the nitrogen and phosphorus contents of Lake George have been conducted by associates of the Rensselaer Fresh Water Institute since 1967(2).

In all the studies herein recorded, the values of the nutrients measured are recorded as the element nitrogen or phosphorus.

The total nitrogen includes primarily the nitrate and ammonia content. The organic (Kjeldahl) nitrogen was found to be quite low in concentration and did not add significantly to the values of total nitrogen as determined by the sum of the nitrates and the ammonia. The nitrite was found to be present in only trace amounts.

The phosphorus may exist in the lake as both orthophosphate and total phosphate and in both the soluble and the insoluble form. The results recorded here are of total unfiltered phosphorus.

All of the analytical techniques used were performed according to the 13th Edition of Standard Methods(17).

Results

Various researchers have contributed information conerning the quantities of water involved in the precipitation, the runoff, the wastewater flow and the volume of the lake as well as the values for the nitrogen and phosphorus in each of these sources. Hydrometric measurements of precipitation and runoff were performed by Colon(6,7). The amount of precipitation falling on the lake surface was calculated separately from that falling on the land area of watersheds tributary to the lake. In all cases, results showed considerably greater precipitation on South L.G. than on North L.G. Although actual values of precipitation vary from year to year, the values used herein for calculation were 96.5 cm (38 in) on the south lake and 78.75 cm (31 in) on the north lake. Runoff was measured by continuous recording of streams representing 45% of the lake basin area. Total runoff into the lake was extrapolated from these values. The results of Colon(6,7) were modified to estimate the South L.G. and the North L.G. contributions. The value for the annual flow of sewage from the Lake George Village sewage treatment plant was obtained from actual flow charts at the plant for the period June 1, 1971 through May 31, 1972.

Analyses of nitrogen and phosphorus were made in approximately 50 different rainstorms(21). The concentrations of the nutrients in the stream runoff represent numerous analyses by Fuhs(9) and more recent unpublished data provided by researchers at the Rensselaer Fresh Water Institute. It must be pointed out that the majority of the analyses for nitrogen and phosphorus in the streams represent summertime conditions during which it has been shown(8) that there is a greater uptake of nutrients by plants growing on the land than during the dormant period in the winter. Values for the nutrients in the effluent from the Lake George Village sewage treatment plant were obtained during the period of 1968 and 1969(3) and updated during the summer of 1972. Values for the nutrient contribution from the remainder of the lake represent the best estimates based on summer and winter population variations. The nitrogen and phosphorus concentrations in the lake itself represent the average values of over 1000 analyses performed on the waters of Lake George.

A summary of the estimated annual contribution of nitrogen from various sources in South and North L.G. is shown in Table 3. The concentration of nitrogen in the precipitation was measured to be an average of 1,350 µg/l. This results in a direct contribution of 75,600 kg of nitrogen per year to South L.G. and 60,750 kg per year to North L.G. The concentration of nitrogen in streams tributary to South L.G. was estimated to be 100 µg/l whereas only 60 µg/l was estimated for those stations tributary to North L.G. Because of the higher estimated nitrogen content as well as the greater volume of inflow to South L.G., 12,200 kg of nitrogen per year is contributed to South L.G. whereas only 3,420 kg is annually contributed to North L.G. by stream flow.

The difference between the volume of water precipitated on the land and that in the runoff represents losses due to evapotranspiration and some groundwater flow directly to the lake. The difference between the nitrogen concentration in the precipitation and in the runoff represents the uptake by terrestrial vegetation.

TABLE 3

Estimated Annual Contributions of Nitrogen from Various Sources in South and North Lake George

	South Lake				North Lake			
	Quantity km^3/yr	Conc., µg/l	Tot.wt. kg/yr	% of Total Add'n. to Lake George	Quantity km^3/yr	Conc., µg/l	Tot.wt. kg/yr	% of Total Add'n. to Lake George
Sources								
Precipitation*								
Directly on Water	0.056	1,350	75,600	44	0.045	1,350	60,750	35
On Tributary Land	0.305	1,350	411,750	-	0.142	1,350	191,700	-
Entire Basin	0.361	1,350	487,350	-	0.187	1,350	252,450	-
Runoff								
Streams	0.122	100	12,200	7	0.057	60	3,420	2
Wastewater								
Lake Geo. Vil. STP**	8.198×10^{-4}	10,000	8,198	5	-	-	-	-
Remainder of Basin	-	10,000	9,600	6	-	10,000	3,520	2
Total	-	-	17,798	10	-	-	3,520	2
Total	0.178	-	105,598	61	0.102		67,690	39

	Quantity km^3	Conc., µg/l	Tot.wt. kg	% of Total Add'n. to Lake George	Quantity km^3	Conc., µg/l	Tot.wt. kg	% of Total Add'n. to Lake George
Static								
Water of Lake	1.02	110	112,200	65	1.08	93	100,440	58

* Includes wet and dry fallout
** STP = sewage treatment plant

The average concentration of nitrogen in the effluent from the Lake George Village sewage treatment plant was 10,000 µg/l, resulting in a potential contribution of 8,198 kg of nitrogen per year from that source. Based on this same concentration, and the population distribution between sewered and non-sewered areas, it was calculated that the contribution of nitrogen from the non-sewered areas represents a potential of 9,600 kg of nitrogen per year to the lake. This results in a potential total contribution of nitrogen from wastewater of 17,798 kg per year to South L.G. There are no waste treatment plants in North L.G. and the contribution of nitrogen is entirely from unsewered areas resulting in a potential contribution of 3,520 kg of nitrogen per year.

The sum of the nitrogen contributions from precipitation directly on the water, from stream runoff, and from wastewater is a total addition of 105,598 kg per year to South L.G. and 67,690 kg per year to North L.G.

In order to show the quantities of nitrogen in the waters of South L.G. and North L.G., Table 3 also contains the static levels of nitrogen in these two lakes. Based on a concentration of 110 µg/l, South L.G. contains 112,200 kg of nitrogen. The average concentration of nitrogen in North L.G. was 93 µg/l, resulting in a total of 100,440 kg of nitrogen.

Thus, it may be seen from Table 3 that 61% of the nitrogen tributary to the entirety of Lake George is discharged to South L.G. and 39% is discharged to North L.G. The total discharge to the entire lake is 173,288 kg per year. Of this, the largest portion is from rainfall directly on the surface of the lake, representing 44% of the total contribution to the lake on South L.G. and an additional 35% to North L.G. Streams in South L.G. contribute 7% of the total nitrogen tributary to the lake whereas streams in North L.G. contribute 2%. Wastewaters in South L.G. potentially contribute an additional 10% and in North L.G. an additional 2% of the entire nitrogen discharge to Lake George.

In a similar manner, the contributions of phosphorus to South and North L.G. are summarized in Table 4. The average value of phosphorus in the precipitation was found to be 10 µg/l. This results in a deposition directly on the water of 560 kg of phosphorus per year on South L.G. and 450 kg per year on North L.G. The amount contributed to the land is 3,050 kg per year tributary to South L.G. and 1,420 kg per year to North L.G.

The concentration of 30 µg/l of phosphorus in the streams tributary to South L.G. reflects the effects of urban runoff. (The use of the term "urban" runoff is not meant to depict the highly developed land use typical of cities, but is appropriate in indicating the high concentration of facilities needed for the tourist industry which has resulted from the exceptional quality of this well renowned recreational site.) Studies conducted by the Fresh Water Institute as recently as the summer of 1972, have shown even higher values of phosphorus in West Brook, a stream which partially drains an "urbanized" area, i.e. the Village of Lake George. On the other hand, streams which drain non-urban areas appear to have a slight reduction (from 10 µg/l in precipitation to 7 µg/l in runoff) in phosphorus content, probably due to plant uptake. Thus, the estimated contributions of phosphorus from stream flow is 3,660 kg per year to South L.G. and 399 kg per year to North L.G.

Studies performed during 1968-69(3) showed that the Lake George sewage treatment plant effluent had a phosphorus concentration of 10 mg/l. However, more recent sampling performed by the Fresh Water Institute has indicated that 6 mg/l is a more valid present-day value. Thus, this source represents a potential contribution of 4,920 kg of phosphorus per year to South L.G. The contribution of phosphorus from the non-sewered areas has been based upon the contribution of 3 g/cap-day, as adapted from Sawyer(15); utilizing the summer-winter population distribution (Table 2), this results in an estimated 7,433 kg of phosphorus per year to South L.G. and 2,717 kg per year to North L.G. Thus, there is

TABLE 4

Estimated Annual Contributions of Phosphorus from Various Sources in South and North Lake George

	South Lake				North Lake			
Sources	Quantity km^3/yr	Conc., µg/l	Tot.wt. kg/yr	% of Total Add'n. to Lake George	Quantity km^3/yr	Conc., µg/l	Tot.wt. kg/yr	% of Total Add'n. to Lake George
Precipitation*								
Directly on Water	0.056	10	560	3	0.045	10	450	2
On Tributary Land	0.305	10	3,050	-	0.142	10	1,420	-
Entire Basin	0.361	10	3,610	-	0.187	10	1,870	-
Runoff								
Streams	0.122	30	3,660	18	0.057	7	399	2
Wastewater								
Lake Geo. Vil. STP**	8.198×10^{-4}	6,000	4,920	24	-	-	-	-
Remainder of Basin	-	***	7,433	37	-	***	2,717	14
Total	-		12,353	61			2,717	14
Total	0.178	-	16,573	82	0.102	-	3,566	18

	Quantity km^3	Conc., µg/l	Tot.wt. kg	% of Total Add'n. to Lake George	Quantity km^3	Conc., µg/l	Tot.wt. kg	% of Total Add'n. to Lake George
Static								
Water of Lake	1.02	7.5	7,650	38	1.08	6.5	7,020	35

* Includes wet and dry fallout

** STP = sewage treatment plant

*** Based on 3g/cap-day

a total of 12,353 kg of phosphorus added from wastewater to South L.G. and 2,717 to North L.G.

The total added phosphorus of 16,573 kg per year to South L.G. is slightly over four times the 3,566 kg per year added to North L.G.; the sum of these is a contribution of 20,139 kg of phosphorus per year to the entire Lake George basin.

Based on 7.5 μgP/l in South L.G. and 6.5 μgP/l in North L.G., there is a slightly greater total amount of phosphorus in the waters of South L.G. than North L.G.

Of the total addition of phosphorus to Lake George, 82% is discharged to South L.G. and 18% to North L.G. In South L.G., 3% of the total phosphorus contribution to the lake comes from precipitation, 18% from stream runoff, and 61% from wastewater. (Of all the potential contributions, the largest single point source is 24% from the Lake George Village sewage treatment plant.) In North L.G., 2% comes from precipitation, 2% from streams, and 14% from wastewater. The waters of South L.G. contain 38% as much as the total phosphorus added per year and the waters of North L.G. contain 35%.

Discussion

From the earliest considerations of Lake George as a study site, RPI has focused on the advantages of the double lake system of Lake George, i.e. the use of South L.G. as a perturbed area and North L.G. as a "stable" system have been emphasized. However, up until this time, there has been no definite proof or indication of the extent of the differences between the two portions of the lake. Some of these physical and chemical factors are discussed in the following paragraphs.

The physical characteristics of the South and North lakes are very similar. The only facet in which they differ appreciably is the amount of runoff, which is considerably greater to South L.G. (0.122 km^3/yr for South L.G. and 0.087 km^3/yr for North L.G.). This can be accounted for in that both the tributary area and the amount of precipitation are greater in South L.G. than in North L.G.

One of the main factors in the increased stress on South L.G. is the greater population there; the permanent year-round population is approximately four times that of North L.G., and the total average summer population is six times that of North L.G. The concentration of population in the Lake George Village area and the Bolton Landing area have warranted the installation of sewage collection and treatment systems for these two communities. All other areas dispose of their wastes by means of septic tank systems. In many cases around this lake basin, there is from little to no soil cover above the bedrock which results in a rather rapid transport/percolation of the septic tank or cesspool effluent to the lake itself with a concommitant minimal removal of nutrients. Additionally, there are many campsites, both along the shores of the lake and on the numerous islands of the lake, with the islands in particular presenting a problem of waste disposal. Another matter of recent concern is the expansion of marinas as weekend living facilities, viz. on board living while tied at the dock. Whereas these marinas normally provide pump-out facilities (for holding tank equipped boats) and/or land-based sanitary facilities, the expanded use of these marinas has increased the weekend summertime population, possibly even above the figures estimated in Table 2. (Note: The population figures in Table 2 do not include these weekend marina inhabitants.)

All boats on Lake George are required to have their sanitary facilities sealed and there is rigid inspection by the Lake George Patrol. Thus, it may be assumed that there is essentially no contribution of waste materials directly to the lake from boats.

Another potential source of nutrients to the lake is from the application of fertilizers on agricultural areas. At the present time, since only about 2% of the entire Lake George watershed is actively farmed, this does not represent a significant input to the lake. However, undoubtedly fertilizers are applied to some lawns bordering the lake. While it is certainly likely that some of the nutrients from these fertilizers reach the lake (and may have a marked effect upon local bays), this is not considered to be of significant impact upon the whole lake.

Of the total amount of nitrogen added to Lake George every year, 61% is added to South L.G., with the major portion, 44%, contributed by precipitation directly on the water surface. The potential contribution from sewage is only 10%, and the remaining 7% is from stream runoff. Only 39% of the total amount of nitrogen added to the lake enters North L.G. This results from precipitation directly on the lake (35%), stream runoff (2%), and 2% potentially from wastewaters. Thus, it may be seen that removal of nitrogen from treated sewage could not be expected to reduce significantly the total nitrogen input to either South L.G. or North L.G. or the entire lake.

It must be remembered that all of the waters from South L.G. flow ultimately into North L.G. This is somewhat reflected by the fact that of the total amount of nitrogen added to the lake, 65% exists in South L.G., and 58% exists in North L.G. That is, nitrogen contributed to South L.G. potentially can affect North L.G. Presently, the nitrogen contribution to South L.G. is approximately 1.5 times that to North L.G.

As for phosphorus, the ratio of the contributions to South L.G. vs. North L.G. is much greater. Of all the phosphorus added to the lake, 82% is added to South L.G. and only 18% is added to North L.G. In South L.G., the major portion is potentially from the total of wastewater discharges to the subsurface. This amounts to 61% of all of the phosphorus added to the lake. The greatest amount (37%) is from the widely dispersed sewage disposal systems surrounding South L.G. At the present time, there is no convenient method for removal of phosphorus from individual septic tank systems. The next largest source (also the largest single source) of phosphorus to South L.G. is the Lake George Village sewage treatment plant, i.e. 24%. Removal of phosphorus from this point source could be expected to reduce significantly the total phosphorus input to South L.G. In fact, if phosphorus removal were practiced at the existing sewage treatment plants, it would be highly recommended that additional sewage collection facilities be constructed, where practicable. Stream runoff also contributes a significant amount of phosphorus to the lake, but this source is not easily controlled.

Similarly, in North L.G., the largest potential source of phosphorus (14%) is from the discharge of wastewaters through septic tank systems to the soil. Since these are dispersed sources, they are difficult to control. By contrast, stream runoff to North L.G. is only 2% of the total phosphorus added to the lake.

The amount of phosphorus in the waters of South L.G. is 38% of the total phosphorus added to the lake, whereas that in North L.G. is approximately 35%. While it may be seen that the total amounts in the waters of both South and North L.G. are quite similar, what is significant is the much greater contribution of phosphorus to South L.G. as compared to North L.G.

One apparent anomaly becomes immediately noticeable. Whereas the contributions of both nitrogen and phosphorus are significantly greater to South L.G. than to North L.G., and the net flow is from South L.G. to North L.G., the actual concentrations of these two nutrients do not differ greatly in the two lakes. Thus, there must be other factors which control the levels of these nutrients in Lake George. The two normally accepted means for removing these nutrients from solution or suspension are chemical and biological precipitation(20). At the present time there are insufficient data available to evaluate these removal techniques in Lake George, but studies are underway which will provide insight on this subject.

Conclusions

The results reported here have confirmed that South L.G. is subjected to considerably greater nutrient stress than is North L.G. Since the major source of nitrogen to the lake system is from precipitation, this is more evenly distributed throughout both basins. However, the major source of phosphorus is from the wastewaters discharged into the drainage basin. This results in a marked increase in contributions of phosphorus to South L.G. The contribution of phosphorus to South L.G. is causing the concentration in that part of the lake to approach 10 ug/l which is considered to be the critical value above which algal blooms may occur.(16,20) Thus it is pertinent that consideration be given to the control of phosphorus in potential sources to South L.G. Since the effluent from the Lake George Village sewage treatment plant is the largest point source of phosphorus contribution to the lake, it would be feasible to remove phosphorus from this source. This would significantly reduce the stresses on South L.G.

Despite the fact that over four times as much phosphorus is added to South L.G., the total amount of phosphorus in the water in South L.G. is only slightly greater than that in North L.G. Thus some mechanism for phosphorus removal is apparently active within the lake itself.

Lake George, being a double lake, allows for comparative scientific studies of an aquatic ecosystem by means of a perturbed South L.G. and a stable North L.G.

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