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I. ORGANIC CONTENT OF LAKE GEORGE SEDIMENTS

II. THE NITROGEN AND PHOSPHORUS BALANCE OF LAKE GEORGE

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ORGANIC CONTENTS OF LAKE GEORGE SEDIMENTS

by Manfred Schoettle and Gerald M. Griedman

A study was made to determine the distribution of the sediments on the bottom of Lake George. The purpose was to relate sediment distribution to lake processes past and present including the effect of man's impact upon the lake. Samples were secured on a dense grid pattern and the size-frequency distribution of the sediment particles as well as the organic matter making up a large faction of the sediment were measured. In addition, the mineralogy of the sediment particles was determined in an effort to relate this to the mineralogy of the bedrock or glacial sediments in the area.

Two types of sediment floor the lake: 1) relict glacial sediment; and 2) modern sediment. The relict sediment includes varved glacial lake clays with iron-manganese nodules and sandy sediments derived from moraines, drumlins or deltas. Most of the lake is underlain by glacial lake clays. However, these clays have become concealed beneath a cover of modern organic-rich silty clay. Active currents have kept the glacial lake clays exposed in the Narrows between the north and south Lake George basins for at least 3,300 years as determined by radioactive carbon dating. The bottom sediment of most of the lake consists of organic-rich silty clays. Fig. 1 is a classification diagram which depicts the grain-size range of the bottom sediments. This diagram shows that most of the bottom sediment consists of silty clay. Pure sands also underly the lake mostly near the shore, but most sands contain silt and clay size factions. These silt and clay size factions tend to be present in near equal amounts in many sandy sediments. Tree bark, spore capsules, leaves and needles compose much of the structural organic matter of the near shore bottom sediments. This organic material enters the lake mostly in the fall as part of the annual crop of organic material contributed by the vegetation in the drainage basin. In the deeper parts of the lake, structural organic matter cannot be identified with certainty because of advanced decomposition.

Fig. 2 shows the generalized pattern of the size distribution of the sediments in Lake George based upon the amount of clay size particles present. In the south basin, bottom sediments containing more than 50% clay occur near the east shore of the lake and underly the large central expanse of the lake. Bottom sediments with less than 25% clay, hence mostly sandy, are restricted to the west shore of the south Lake George basin, although in two places, a tongue of sandy sediment passes beneath the central area of the lake. The eastern Narrows are rich in clay, whereas the western Narrows are rich in sand. The southern part of the north basin is underlain by clay-rich sediments. The central part of the north basin has clay in the middle of the lake and sand closer to the shoreline. In the northernmost part of the north basin, near Ticonderoga, the bottom sediments consists mostly of sand. As a general rule, the sand concentration is inversely proportional to the clay concentration of the sediments.

Fig. 3 shows the generalized distribution of the organic carbon in the bottom sediments. As a general rule, the organic carbon content varies directly with the clay content of the sediments. In the south Lake George basin, most of the bottom sediments contain between 5 and 10% organic carbon. However, close to the east shore and in bays along the east shore, the organic carbon content exceeds 10%. By contrast, near the west shore and in the two sandy tongues that pass beneath the central part of the lake, the organic content is less than 5%. The bottom sediments of the Narrows are mostly depleted in organic carbon whereas the bottom sediments of the north basin contain between 5 and 10% organic carbon in the center of the lake but less than 5% near the shore. Near Ticonderoga, the bottom sediments of the northernmost part of Lake George contain less than 5% organic carbon.

The organic matter content of the bottom sediments of southern Lake George by and large exceed that of the northern basin. This increase in organic matter correlates with increasing phytoplankton productivity in the southern basin. Increasing phytoplankton productivity relates to man's impact on the waters of the southern basin. Organic matter together with other fine-grained clay size particles such as quartz and clay minerals gets trapped, especially in the deeper parts of the lake where it accumulates on the lake floor.

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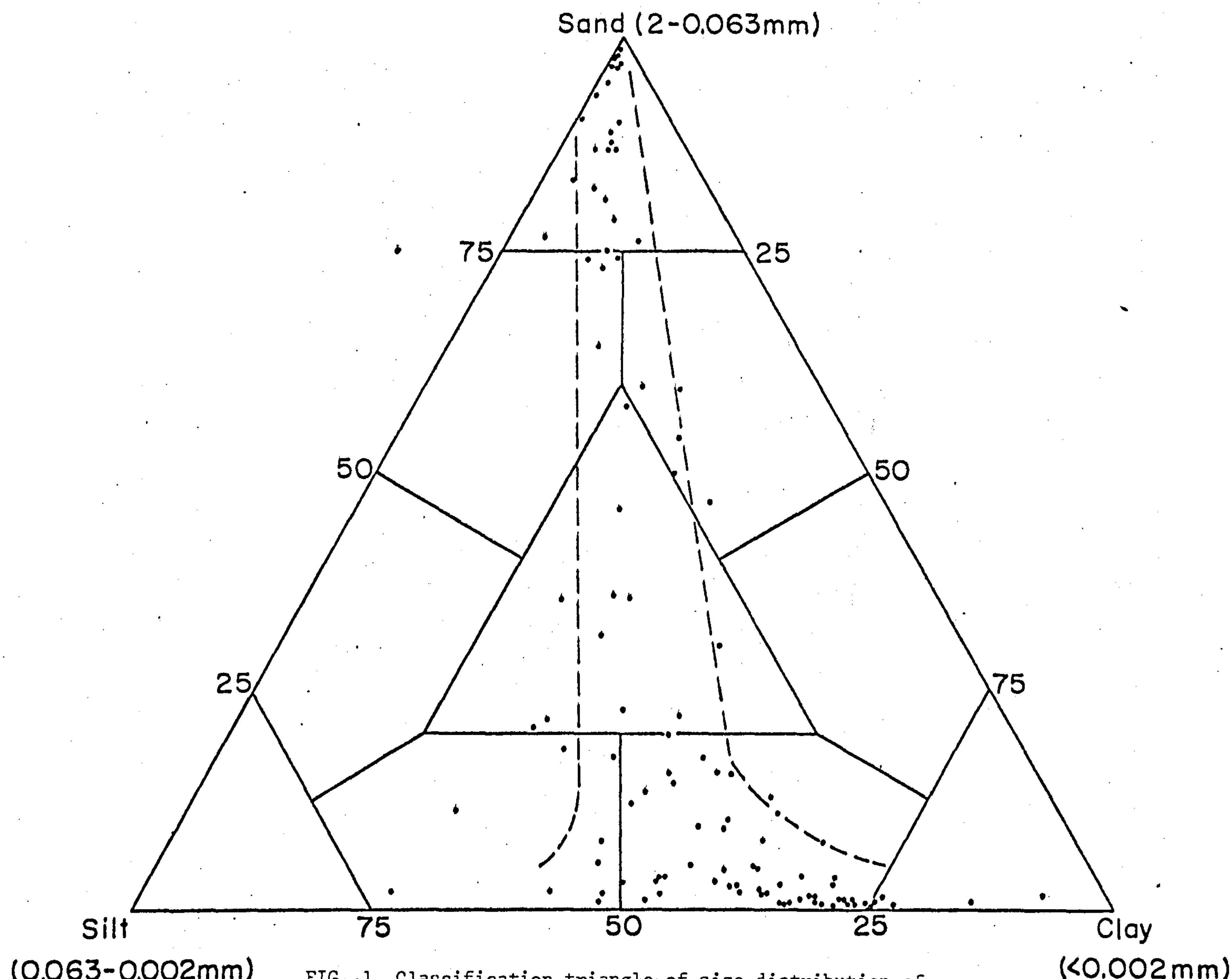

FIG. 1 Classification triangle of size distribution of Lake George bottom-sediments.

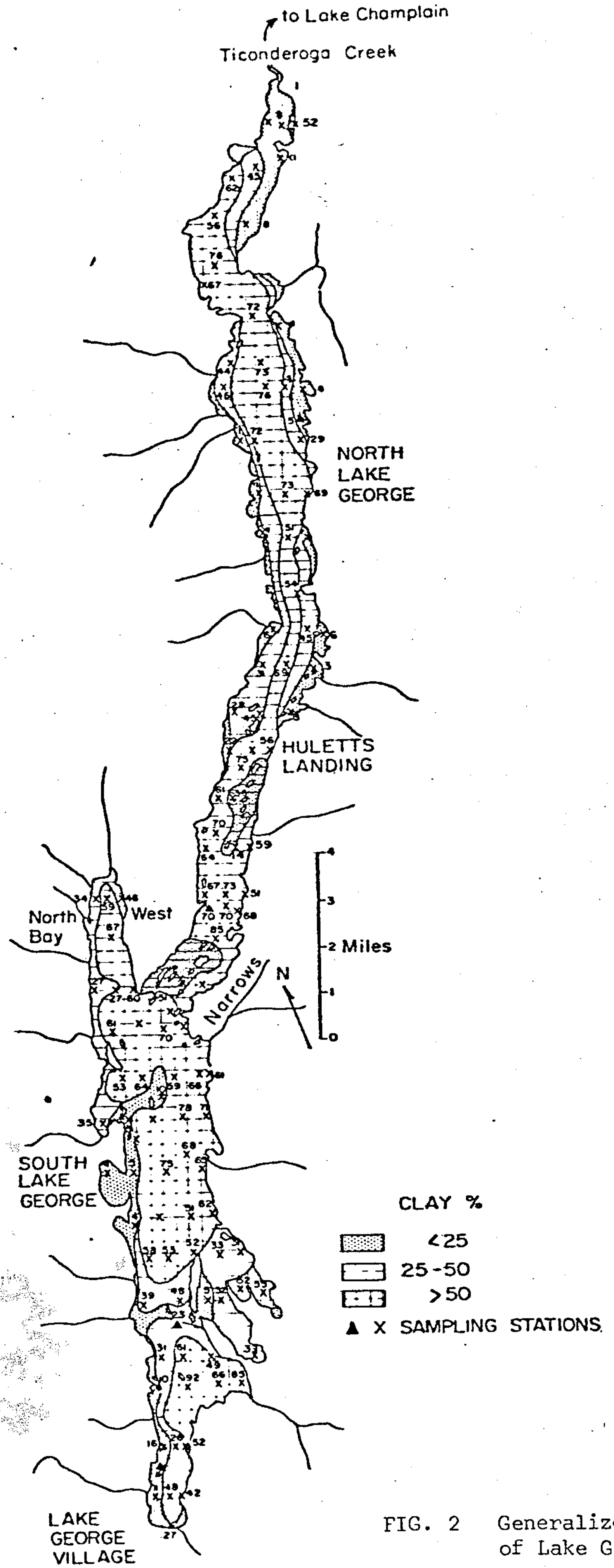

FIG. 2 Generalized size-distribution of Lake George bottom-sediments.

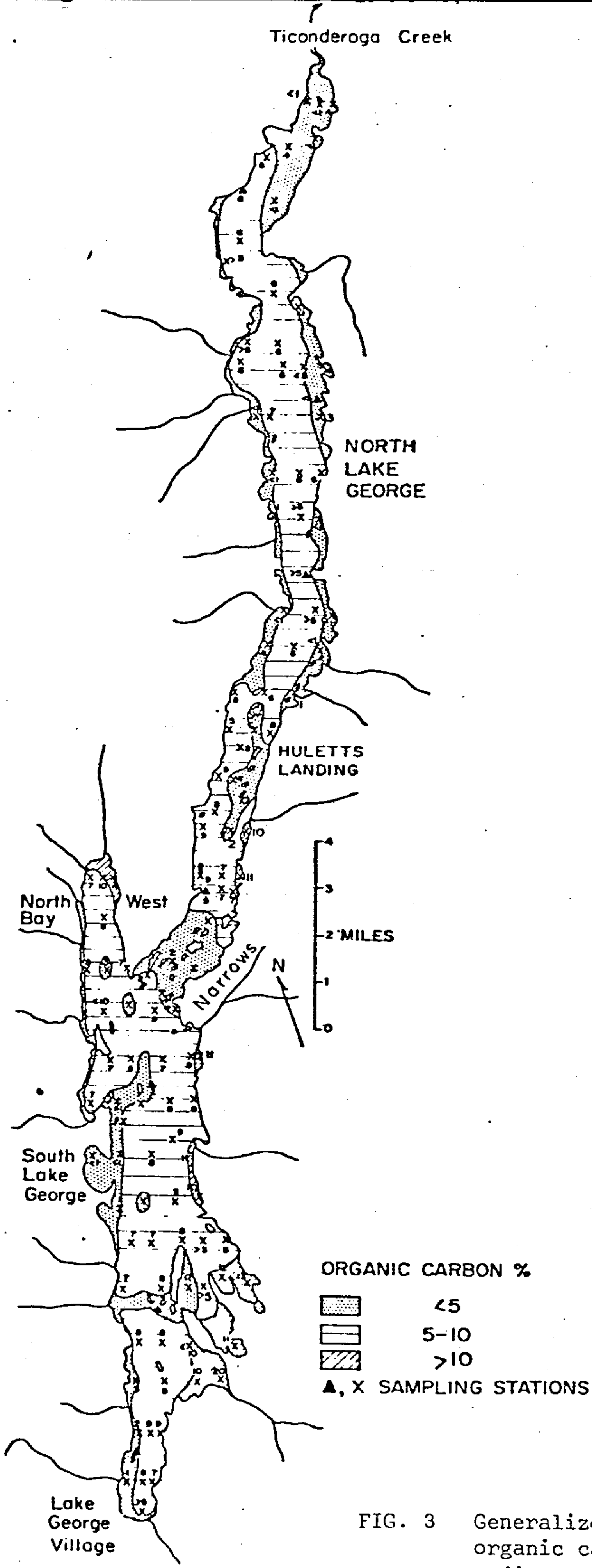

FIG. 3 Generalized distribution of organic carbon in the bottom-sediments of Lake George.

THE NITROGEN AND PHOSPHORUS BALANCE OF LAKE GEORGE

by Donald B. Aulenbach

Measurements of the nitrogen and phosphorus content of the waters of Lake George were begun as early as 1967 as a part of the unsponsored research conducted by Sherman Williams. Beginning in 1969, a minimum amount of support through the IBP program was used to continue these studies first as a lead time study and the following year as a separate research study. The data summarized in this talk includes primarily the data secured during the 1969-71 period. This includes measurements of the nitrogen and phosphorus in Lake George itself, in the precipitation, and in the runoff into the lake. These latter measurements in the runoff were conducted by the New York State Health Department. Measurements of the nitrogen and phosphorus concentration of the treated sewage effluent from the Town of Lake George Sewage Treatment Plant were made by two students working together on a study of the treatment plant. One student was supported by a grant from Columbia, South America and the other by the United State Public Health Service.

The data are summarized in the table. It must be emphasized that the numbers in the table are not intended to be precise values but are "ballpark" figures to show the approximate levels of nitrogen and phosphorus in the aqueous ecosystem. The values represent average values and not necessarily weighted averages. The nitrogen and phosphorus concentrations in the water of the lake itself represent the average of nearly 1,000 samples. The concentration in the precipitation represents the average of approximately 50 individual storms. The values from the runoff into the lake may be in somewhat greater error since the concentrations of these chemicals varied considerably from stream to stream and no consideration was made of the amount of stream flow as related to the nitrogen and phosphorus concentrations. Thus, average values for the nitrogen and phosphorus and the total stream flow were used to achieve the estimate of the stream contributions to the lake. The values for the contribution from the Lake George waste treatment plant are quite reliable due to the numerous analyses and the metered flow at the treatment plant.

The total volume of the water in Lake George is 2.1 cubic kilometers. Whereas it is difficult to envision this volume of water, it may be safely said that this is a large volume. Using the mean values of 110 μg/l of total nitrogen in the lake waters, this amounts to a total standing mass of 231,000 kg of nitrogen in the lake water at any one time. Likewise with 5 μg/l of phosphorus, this represents 10,500 kg of phosphorus in the waters of the lake.

The total precipitation in the entire watershed of the Lake George basin has been calculated to be 0.547 km^3 per year. This is an average value and it must be remembered that the precipitation at the northern end of the lake is considerably less than that at the southern end. Again a weighted average for the individual volumes times the concentrations was not used to determine the total weight of nitrogen and phosphorus present due to the precipitation. The nitrogen concentration in the precipitation was rather high being 1,350 μg/l or 1.35 mg/l. This represents a total potential input of 738,000 kg of nitrogen per year to the basin. Similarly, the phosphorus content of 10 μg/l represents a potential input of 5,470 kg of phosphorus per year. However, it must be recognized that not all of the precipitation which falls on the basin reaches the water directly. On the basis of the 44 square miles of surface area of the lake, the calculation was made to show that the total amount of precipitation which falls directly on the water and would produce a direct input of nitrogen and phosphorus to the lake was 0.105 km^3/yr. Based upon the amounts of nitrogen and phosphorus in the precipitation, this represents a total contribution of nitrogen into the lake of 142,000 kg and of phosphorus of 1,050 kg/yr. Not all of the precipitation on the land reaches the lake directly. A best estimate from stream flow data shows that the mean stream flow into the lake is in the order of 0.181 km^3 per year. Subtracting the precipitation over the water directly from the precipitation over the entire basin indicates that 0.442 km^3 falls on the land area during the year. The difference between this value and the 1.81 km^3 which appears as stream flow may be attributed to both sub-surface groundflow into the lake and evapotranspiration of the water before it has a chance to reach the lake itself. The calculation indicates that approximately 40% of the precipitation on the land appears as runoff. This value is reasonable for a rocky area and is well within normally recorded values. It will be noted that the mean concentration of nitrogen in the runoff of 80 μg/l is considerably less than that in the precipitation and results in a total input to the lake of 14,450 kg per year. This great reduction in the nitrogen as the water passes over and through the ground may be attributed to the uptake of nitrogen by the plants growing on the land. The reduction in the phosphorus content to 7 μg/l is not so outstanding as the reduction in the nitrogen. This represents a contribution of 1,267 kg of phosphorus per year through the stream flow. The combination of the reduction of nitrogen and phosphorus and also the reduction in flow as the precipitation flows over the terrestrial portion of the watershed results in a marked decrease in the amount of nitrogen and phosphorus which actually reach the lake as compared to the potential amounts from the rainfall.

The total contribution from sewage is calculated by the combination of several estimated values. An estimate of average values of nitrogen and phosphorus in domestic sewage was used and these values were weighted by the estimated summer and winter populations. The estimates indicate 10,500 kg of nitrogen and 8,415 kg of phosphorus are contributed to the lake per year from sewage. The data from the Lake George treatment plant are much more reliable. The 0.0007 km^3 of sewage produced per year is an actual value of the flow in the sewer for the water year ending October 1971. The 10 mg/l of nitrogen in this effluent represents a total weight of 8,840 kg of nitrogen per year whereas the concentration of 8 mg/l of phosphorus represents a contribution of 7,065 kg per year. By difference from the value for the total sewage concentration, it appears that a best estimate for the contribution of nitrogen and phosphorus from sewage in the remainder of the lake is 1,660 and 1,350 kg respectively.

A space is indicated for the potential contribution from fertilizers. This is an extremely difficult value to measure or estimate. Actually very little of the drainage basin is farmed at the present time although there are numerous cottages whose owners fertilize their lawns for the beautiful green look. This item in included to remind ourselves that this is another potential source of nitrogen and phosphorus but one whose values we are not now able to estimate.

The discharge from the lake at Ticonderoga of 0.225 km^3 per year is a fairly good estimate from the discharge devices at Ticonderoga. It may be noted that the discharge is approximately 10% of the total volume of the lake from which we have made the estimate that the turnover time in the lake is approximately 10 years. Based upon the nitrogen and phosphorus content of the lake waters as indicated in the 1st item, an estimate of the loss of nitrogen per year is 24,750 kg and the loss of phosphorus per year is 1,125 kg.

In order to establish some balance, one would have to add the inputs and subtract the outputs. The total estimated input of nitrogen per year is 166,950 kg with the effluent of 24,750 kg. This represents a potential net gain of 142,200 kg of nitrogen per year in Lake George. It may be seen that this is slightly over 50% of the total amount of nitrogen present in the lake at any one time. Roughly, this would indicate the potential for increasing the nitrogen content by approximately 50% every year. Similarly, the total potential input of phosphorus is 10,732 kg/yr. With the discharge in the effluent of 1,125 kg/yr, this gives a net input into the lake every year of 9,607 kg or approximately the value of the standing content of phosphorus in the lake. This gives the potential to double the present phosphorus content of the lake every year. However, although the actual values of the nitrogen and phosphorus in the lake over a period of years is still being evaluated, it is confirmed that the values in the lake are not increasing at the potential rate indicated by these calculations. The difference is obviously the nitrogen and phosphorus incorporated into cell material which either eventually died and settled to the bottom of the lake where it is building up, or was incorporated into fish flesh which was removed by man. So far, no estimate is available of the total poundage of fish removed from Lake George in a given period of time. However, we must assume that biological systems are controlling the levels of nitrogen and phosphorus in Lake George at the present time.

Another significant point may be brought out by this table. It may be seen that the largest concentration of nitrogen to the lake is from the precipitation directly over the water. The amount contributed by the runoff and the total sewage are each approximately 10% of the amount contributed due to the rainwater directly over the lake. Thus, it may be seen that to remove nitrogen at the sewage treatment plant, which is the only place where nitrogen could be effectively removed as an input to the lake, would accomplish little as compared to the effect of the nitrogen in the rainwater on the lake. On the other hand, the largest contribution of phosphorus is from the effluent of the sewage treatment plant. One of the conclusions of the studies made by Wolfgang Fuhs is that the phosphorus concentration is most likely limiting the biological growth in Lake George. Thus, it may be seen that removing the phosphorus from the effluent from the Lake George Sewage Treatment Plant would reduce significantly the total contribution of phosphorus to the lake. If truly the phosphorus is the limiting nutrient in Lake George, it would be well worthwhile to initiate phosphorus removal from this effluent before discharge into the ground.

This compilation of data provides a rough estimate of the sources of nitrogen and phosphorus into Lake George. As more information is obtained and time is available, the individual values may be refined to give more accurate values. However, these results do show the major sources of inputs and suggest a means to control them. Action may begin at once toward this control. The next major direction of study will be to show the changes in the nitrogen and phosphate contents of the lake with time. This will be correlated with the biological productivity in order to achieve the goals of the IBP.

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ESTIMATED ANNUAL NITROGEN AND PHOSPHORUS BALANCES IN LAKE GEORGE [1]

	Volume	Nitrogen	Phosphorus
Total Vol. of water in Lake, km^3	2.1		
Concentration, ug/l		110	5
Total weight, kg		231,000	10,500
Total precipitation in basin, km^3/yr.	0.547		
Concentration, ug/l		1,350	10
Total weight, kg		738,000	5,470
Pptn over water, km^3/yr.	0.105		
Total weight, kg		142,000	1,050
Runoff into lake, km^3/yr.	0.181		
Concentration, ug/l		80	7
Total weight, kg		14,450	1,267
Total sewage contribution, kg		10,500	8,415
Lake George Treatment Plant, km^3	0.0007		
Concentration, mg/l		10	8
Total weight, kg		8,840	7,065
Remainder of lake, kg		1,660	1,350
Contribution from fertilizers	?	?	?
Discharge from lake at Ticonderoga, km^3/yr.	0.225		
Concentration, ug/l		110	5
Total weight, kg		24,750	1,125

1. Figures are best estimates of average data available up to the time of compilation of this report.