MEANS FOR PROTECTING THE DRINKING WATER QUALITY OF LAKE GEORGE, NEW YORK

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Donald B. Aulenbach
Department of Chemical and Environmental Engineering
Rensselaer Polytechnic Institute
Troy, New York 12181

Nicholas L. Clesceri
Director, Fresh Water Institute
Rensselaer Polytechnic Institute
Troy, New York 12181

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ABSTRACT

Lake George is both a beautiful recreational lake and a drinking water supply for residents and business establishments around the lake. Many individual homeowners drink the water directly from the lake with no treatment whatsoever; however, state law requires that all surface waters for public use must be chlorinated, which is the only treatment provided. There are no restrictions on swimming, fishing, scuba diving or boating on the lake, other than no waste discharges from boats are permitted. The greatest population is centered around Lake George Village, at the southernmost end of the lake, which is served by a treatment plant in which the equivalent of tertiary treatment is achieved by applying the secondary treated effluent onto sand using the rapid infiltration technique. Another population center in Bolton Landing provides similar treatment. Other areas are served by septic tanks which are monitored by New York States' Lake George Park Commission. Restrictions on nutrient levels to prevent excessive algae growths are much stricter than those for public health standards. The morphology of the lake and in particular the relatively small watershed area of the lake is an important factor in controlling the quality of the water in Lake George. In addition constant vigilence has preserved the water quality of Lake George as a drinking water supply without limiting recreational use of the lake.

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INTRODUCTION

Because of the high regard placed on drinking water quality by citizens of this country, various methods have been instituted to provide an adequate supply of water of a high quality and to preserve both the healthful aspects and esthetic qualities of the water. In many instances, surface water impoundments, both natural and artificial, have been used to provide an adequate supply of potable water with the utilization of means ranging from control of the up-land watershed to direct control of use of the water body itself to preserve the quality of the water in these storage reservoirs. Restriction of the use of a lake generally creates controversy by potential users of the lake, since there are many conflicting uses of water, including water supply, recreation, flood control, irrigation, low water augmentation, and navigation. Thus, a minimum of restriction is attempted, but the most important provision is to maintain a safe and desirable drinking water supply. The number and type of restrictions which must be applied to any specific water supply reservoir vary with the individual reservoir. This paper describes the control measures which have been applied to Lake George, New York.

DESCRIPTION OF THE SYSTEM

Lake George, a beautiful natural lake located in the eastern Adirondack Mountains of New York State, (Figure 1) is noted for the clarity of its waters and the beauty of its shoreline. The lake is situated in a

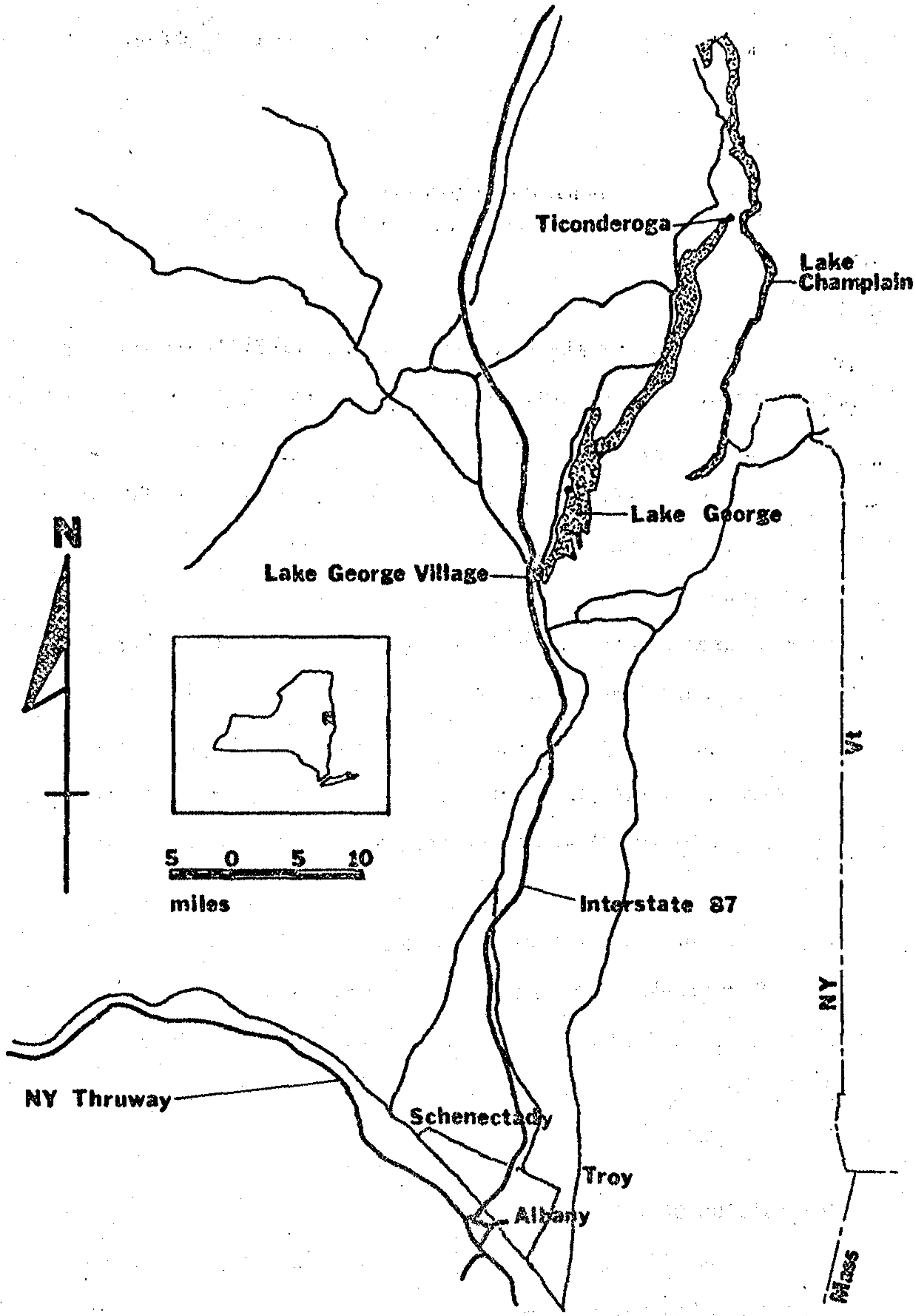

Ticonderoga
Lake
Champlain
Lake George
N
Lake George Village
5 0 5 10
miles
Interstate 87
Vt
NY
NY Thruway
Schenectady
Troy
Albany
Mass

FIGURE 1

rather narrow valley with fairly steep mountain slopes along most of the shoreline. These slopes are forested and in some areas too steep to accommodate intensive housing. There are also some areas of cliffs in which there is no human habitation. The lake is approximately 51 km (32 mi) long and averages 2.3 km (1.4 mi) in width. The morphological characteristics of the lake are shown in Table 1 [1]. It is interesting to note from this table that the total drainage basin is only approximately 4 times the total surface area of the lake. This is a relatively small value compared to most lakes. Also, the lake may be considered as two lakes - a North Lake and a South Lake, separated by an island studded area called The Narrows. The characteristics of the two lakes are quite similar in area, volume and maximum depth. They differ in the tributary watershed areas with a greater watershed area contributing to the South Lake. Prior to the last glacial age, the area consisted of two separate streams. One stream flowed from what is now Northwest Bay (Figure 2) through Dunham Bay into the present Hudson River. The other stream originated in approximately The Narrows and flowed northward through Rogers Rock and ultimately to Lake Champlain. With receding of the last glacier approximately 10,000 years ago, the discharge at Dunham Bay was blocked by glacial moraine, as was the discharge of the north flowing river at Rogers Rock. The stream flowing out of Northwest Bay gradually filled the river valley until it overflowed through the lower hills of The Narrows and then flowed northward through the North Lake. This then found a new outlet over a natural rock barrier just south of the present Village of Ticonderoga. The water level was raised above this natural control by an artificial dam constructed in 1903 [2]. This raised the water level in the lake by about 0.6 m (2 ft) and provided for a better water level control in the lake. By means of proper operation of this control dam an attempt is made to control the water level in Lake George at 319 $\pm$

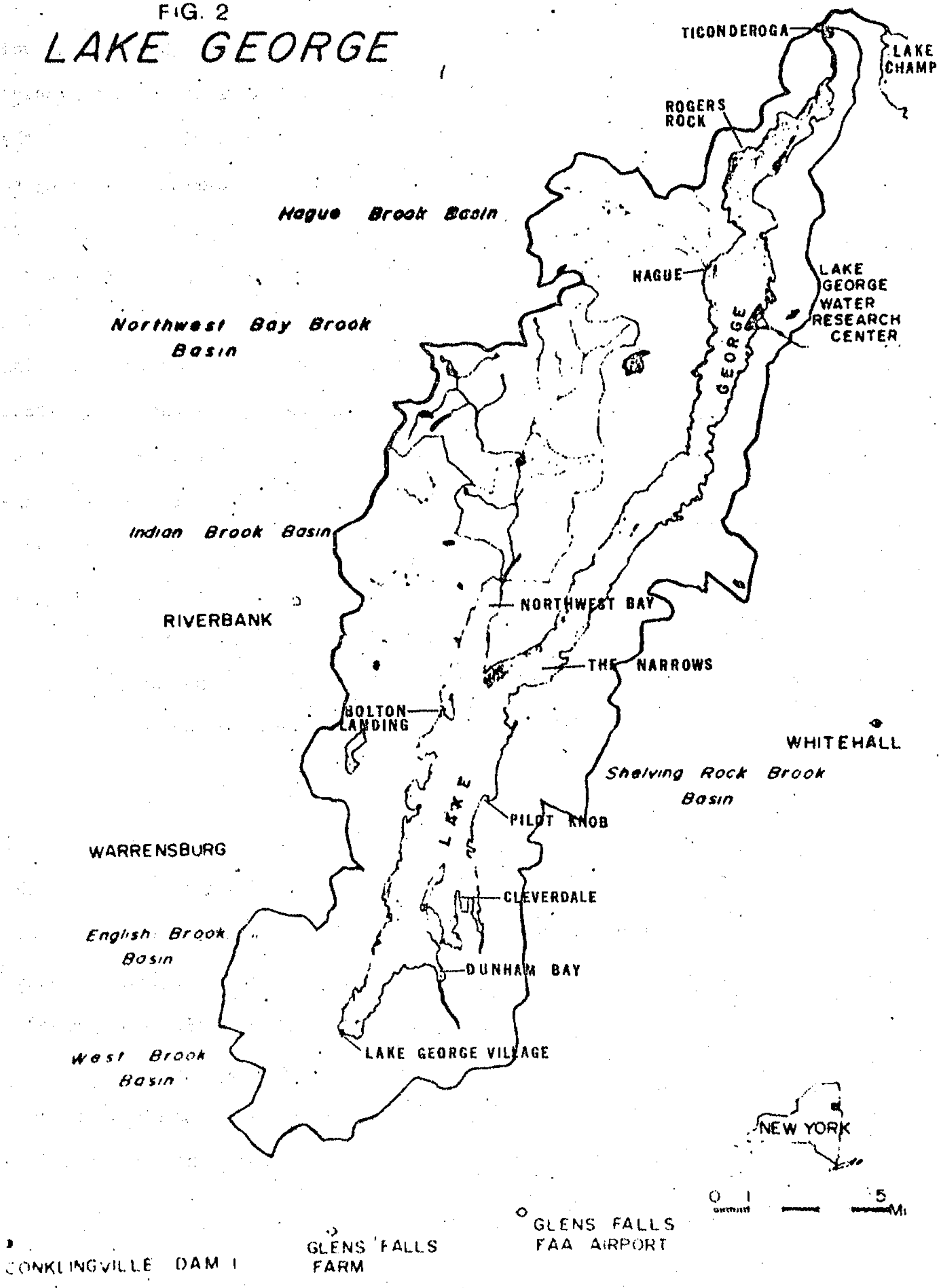
TABLE 1

MORPHOMETRIC COMPARISON OF SOUTH AND NORTH LAKE GEORGE

	SOUTH LAKE		NORTH LAKE		TOTAL LAKE	
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 m	175 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

FIG. 2

LAKE GEORGE



1 ft above sea level (97.2 $\pm$ 0.3 m). This control has been fairly well maintained with the exception of unusually heavy rain storms and prolonged droughts

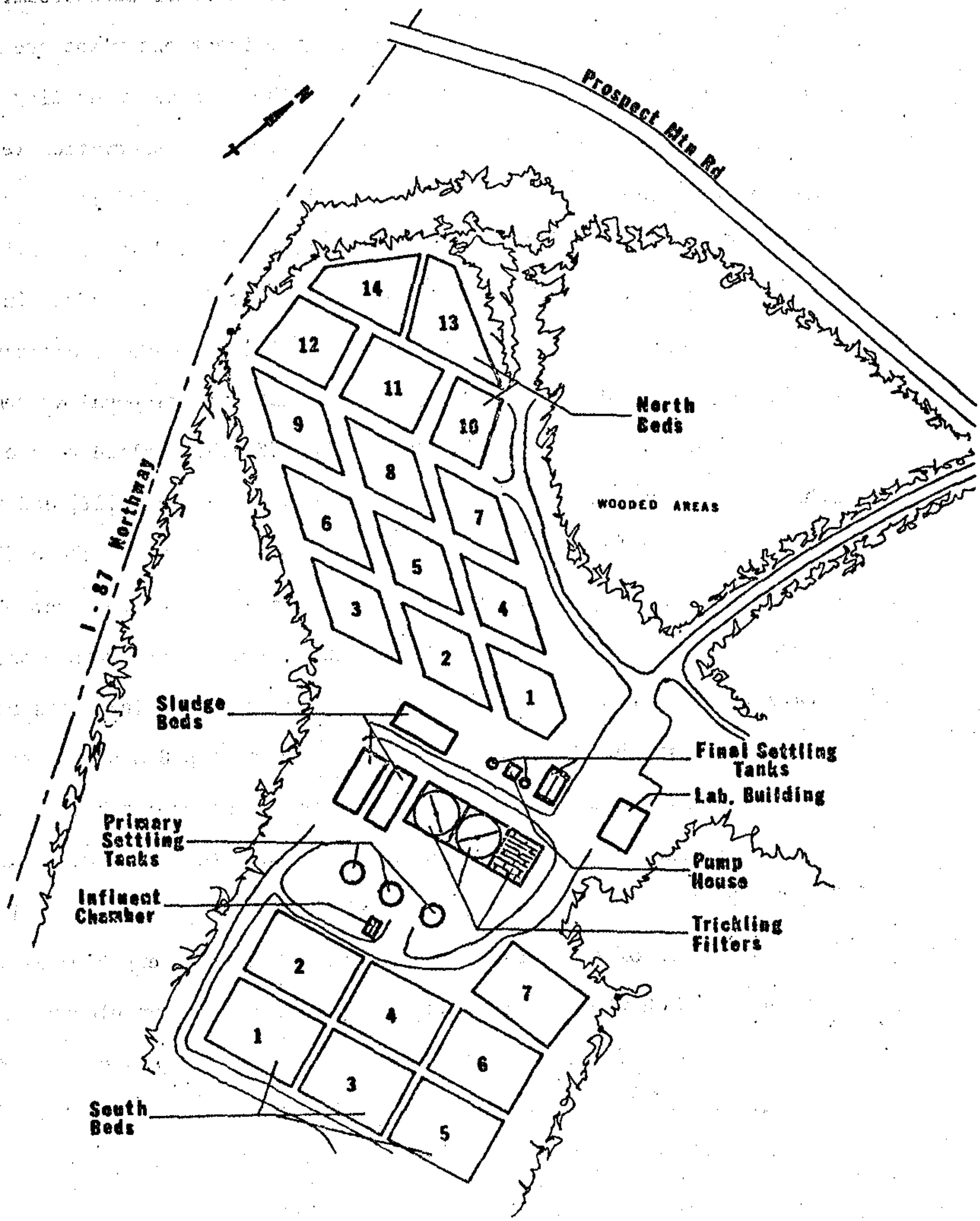
Lake George is used as a drinking water supply by most of the individual residents surrounding the lake and the communities along the shores. State law [3] requires that all surface waters be chlorinated prior to public usage. However, no other treatment is required for the water. Many individual homeowners along the shores of the lake use the water from the lake directly with no treatment whatsoever. This has resulted in no determinable health hazard to individuals who consume the water without treatment or to any of the residents of the communities who drink the water with a minimum of chlorination. Consideration of the use of the Lake George for a drinking water supply for areas outside of the immediate drainage basin area has been made since at least 1881 when an extensive study was made of the use of Lake George water for New York City [4]. Up to the present time there has been no diversion of the waters from Lake George to other areas outside of the basin for drinking water.

POLLUTION CONTROL MEASURES

Obviously the water was a high quality initially, otherwise it would not have been chosen as a water supply without treatment. Much of the credit for maintaining the high quality of the waters within the lake is attributed to the contined efforts of the local homeowners association, the Lake George Association, which was founded in 1885. This group has recognized the benefits of maintaining the high quality of the waters of Lake George and has encouraged individuals to do their utmost to cooperate in this effort. Becauso of their efforts, the state has designated the waters of Lake George as class AA, indicating that the water may be used for direct consumption with no treatment other than chlorination [3]. It also restricts the discharge of any waste water into the lake directly or into any stream which discharges into the lake [6]. This has resulted in sub-surface disposal being the only acceptable means for discharge of wastes in the watershed. There are no major industrial establishments within the basin, thus, all of the wastes are considered of domestic nature. The major industry of the area is tourism, which, of course, provides only a greater flow of domestic wastes. Sub-surface disposal of wastes initially took the form of septic tank systems for the individual homeowners. However, improved transportation by automobile made it easier for tourists to reach Lake George and the population around the lake began to increase. The greatest areas of population are along the southern border of the lake from approximately Pilot Knob on the eastern shore around and up to Bolton Landing on the western shore (Figure 2). Lake George Village at the very southern tip of the lake became the greatest population center on the entire lake. In 1936, it was concluded that the number of individual septic tanks in the Lake George Village area was exceeding the capacity of the soil and a sewer system with a treatment plant was designed. The gravity sewers throughout the village lead to a central pumping station in a park area along the shore of the lake. This facility does not detract from the surroundings, but rather provides a pleasant location for viewing the lake. By means of a 1.6 km (1 mi) force main, the sewage is raised approximately 55 m (180 ft) in two stages to the existing treatment plant which was completed in 1939. In 1965 the Caldwell sewer district was created to serve the adjacent population areas in the Town of Lake George surrounding the Village. This utilizes a separate force main pumping the wastes to the same treatment plant.

The treatment plant itself is somewhat unique. It was initially determined that the summer time flows of approximately 0.5 mgd (1,900 m^3/day) were approximately 3 times the winter flows of 0.15 mgd (600 m^3/day) [7]. Thus, the plant was built in triplicate so that one-third of the complete system could be utilized during the winter and the entire system used during the summer. The plant (Figure 3) consisted of three circular Imhoff type settling tanks with a sludge digestion compartment, three dosing siphons, three trickling filters, two of the standard rotary arm type and one fixed nozzle type (which is utilized exclusively during the winter covered with boards on sawhorses to prevent freezing), and final clarification in two circular secondary sedimentation tanks. Probably the most unique feature was the fact that the final effluent from the secondary sedimentation tanks was applied without any chlorination to one of six rapid sand infiltration beds consisting of natural delta sand located in the area. These sands were deposited by the high runoff from the melting glacier. Thus, the effluent was discharged into the ground and not to the lake or any streams flowing into the lake and "the final effluent becomes ground water which in all probability seeps eventually, to some water course as a highly purified liquid which cannot be identified as a sewage effluent" [7]. Since that time the treatment plant has been expanded with the addition of two rectangular secondary clarifiers with moving sludge scrapers and the addition of 15 sand infiltration beds. The present treatment plant is designed to handle a flow of 1.75 mgd [8] (6,600 m^3/day) but the maximum flow seldom exceeds 1.3 mgd (5,000 m^3/day). At present the summer time flows are approximately 2 times the winter flows [9].

Little was known of the ultimate fate of the secondary effluent discharged onto the natural sand beds at the Lake George Village Sewage Treatment Plant until a recent investigation conducted by the authors [10]. During the spring of 1973 a significant seepage of ground water to the surface water was observed along the south banks of the flood plain at West Brook approximately 600 m (2,000 ft) from the sewage treatment plant. This seepage flowed from two separate areas into West Brook which ultimately flows



SEWAGE TREATMENT PLANT LAYOUT

FIGURE 3

into Lake George approximately 0.7 km (1.2 mi), farther downstream. These seepage areas, West Brook, Lake George and the treatment plant are shown in Figure 4. In order to conduct the study of the changes in quality of the water from the sand beds to the seepage, a series of observation wells was placed between these points as shown in Figure 5. In addition to studying the quality of the effluent as it flows through the saturated aquifer in the ground by means of observation wells, studies of the changes in water quality with depth in one of the deeper sand filters were also conducted. These extensive studies [10-16] have shown that this disposal system provides the equivalent of tertiary treatment of the effluent applied to the sand. Orthophosphate removal occurs in the top 10 m of the sand [11] and results in less than 0.01 mgP/1 (99% removal) at the point at which the effluent re-emerges from the ground approximately 600 m from the treatment plant along the banks of West Brook [15]. Ammonia- and organic nitrogen are oxidized to nitrate in the top 3 m of the sand [11]. During the spring, this resulting nitrate is diminished to less than 1 mgN/1 in the top 8 m of the sand, but during the summer and fall there appeared to be conversion back to NH_3 and organic N at the 10 m depth within the sand bed. This NH_3 and organic N was not significantly removed until approximately the 18 m depth within the sand. Reduction of nitrates to gaseous nitrogen is an expected biological reaction in which the organisms utilize the nitrate as an electron acceptor and convert some of the inorganic nitrogen to proteins and cell material as well. The amount of increase in organic nitrogen at approximately the 8 m depth within the sand bed represents a large biological growth which was not anticipated. Not all of the sand beds, however, have 20 meters of unsaturated flow above the ground water table. The various depths of the sand beds may indicate the source of the various nitrogen compounds found in the saturated flow between the sand beds and the seepage at West Brook. For

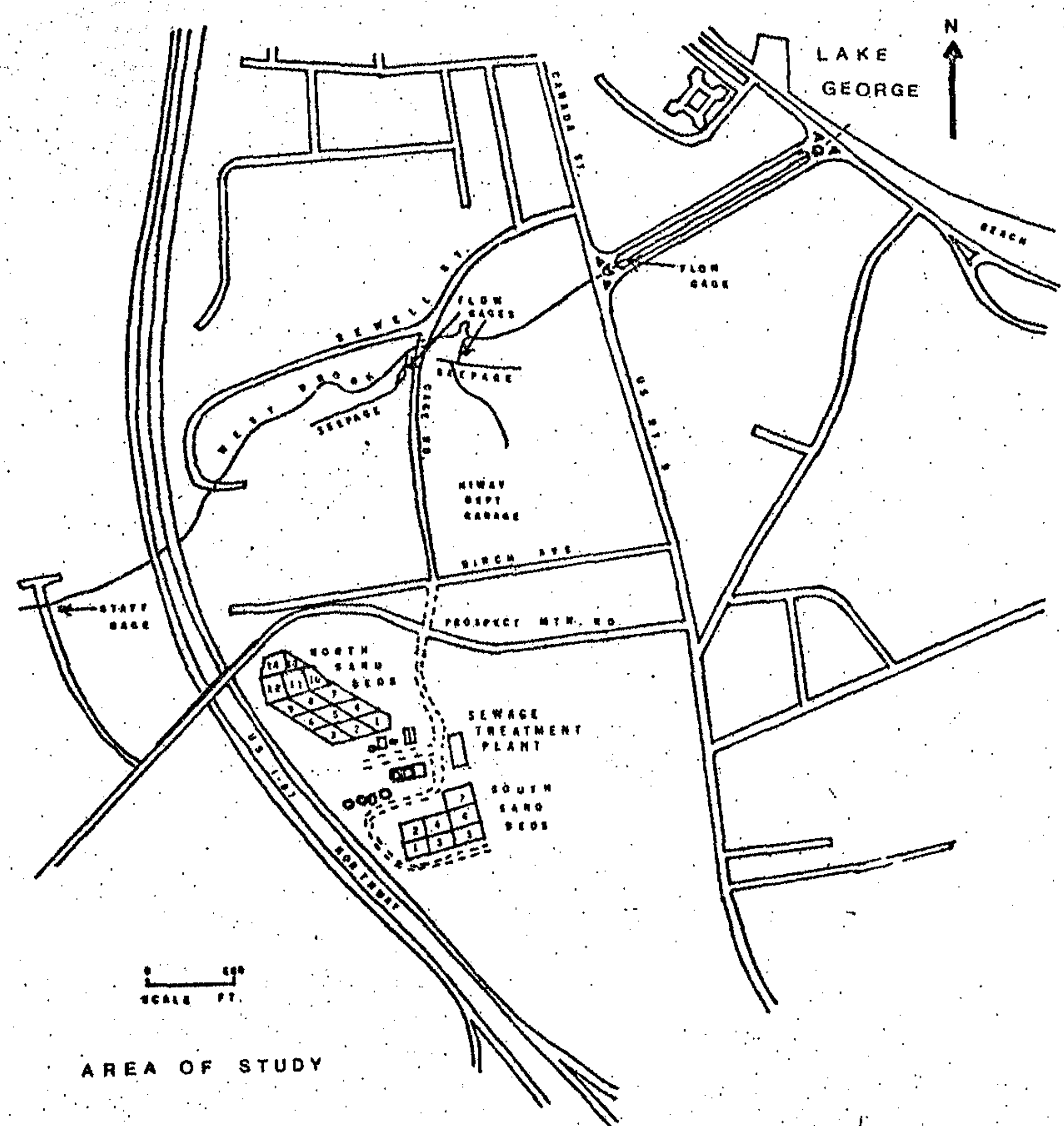

LAKE GEORGE
N
CANADA ST.
SEWELL ST.
FLOW GAGES
FLOW GAGE
SEEPAGE
WEST BROOK
BEACH
US RT 9
HIWAY DEPT GARAGE
BIRCH AVE
PROSPECT MTN. RD.
STAFF GAGE
NORTH SAND BEDS
SEWAGE TREATMENT PLANT
SOUTH SAND BEDS
NORTHWAY
SCALE FT.
AREA OF STUDY

FIGURE 4

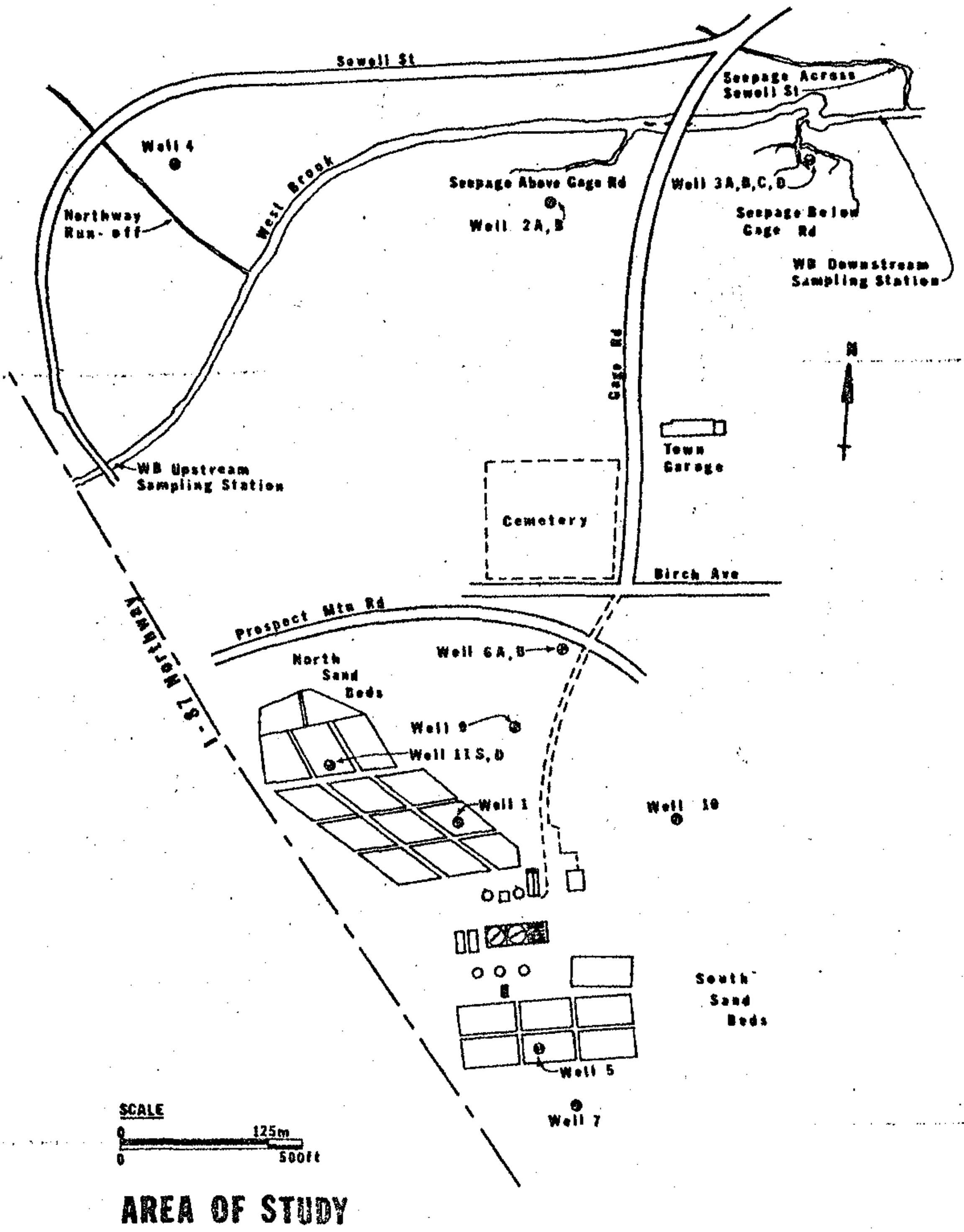

Sewell St
Seepage Across Sewell St
Well 4
West Brook
Seepage Above Gage Rd
Well 3A,B,C,D
Well 2A,B
Seepage Below Gage Rd
Northway Run-off
WB Downstream Sampling Station
Gage Rd
N
Town Garage
WB Upstream Sampling Station
Cemetery
Birch Ave
I-87 Northway
Prospect Mtn Rd
North Sand Beds
Well 6A,B
Well 9
Well 11S,D
Well 1
Well 10
South Sand Beds
Well 5
Well 7
SCALE
0
125m
0
500ft
AREA OF STUDY

FIGURE 5

example, some of the sand beds are approximately 5 m in depth. At this depth the ammonia and organic nitrogen would have been converted to nitrate but the nitrate would not have been reduced. Thus, this nitrate would enter the ground water and be carried along in this form. In other beds which are in the order of 10 m in depth, the secondary growth of organic and ammonia nitrogen would be the form in which the nitrogen would enter the saturated ground water flow. This organic and ammonia nitrogen appears to be oxidized slowly within the ground water, since measurements made at Well 6 indicated high ammonia and organic nitrogen, whereas these reduced nitrogen compounds were not found in the wells closer to West Brook. The combination of the nitrate which enters the ground water directly and that which is produced by oxidation within the ground water results in a final nitrate nitrogen content of approximately 8 mg/l in the seepage at West Brook. This produces an increase in the nitrate N content of West Brook of approximately 0.5 to 1 mg/l, for a final nitrate N concentration of 0.6 to 1.3 mg/l in West Brook downstream from the influences of the sewage treatment plant [17]. With further dilution in Lake George itself no deleterious effects of this nitrogen have been found in Lake George. Through this system there is complete recycling of the wastewater back to Lake George where it is reused as a drinking water supply. Parameters such as BOD and coliforms are quantitatively removed from the effluent in this sand infiltration system. Soluble materials such as chloride pass through the system unchanged. Salt from raod deicing in the winter contributes about 5 times as much as salt to the drainage basin as does the treatment facility [8].

Another population center in the drainage basin, Bolton Landing, is also served by a sewage treatment plant of the same design as the Lake George Village Treatment Plant. However, the sand beds are less deep and no studies have been conducted up to the present time of the degree of removal of nutrients by this system. Plans are presently underway to conduct a study of the degree of treatment achieved by the Bolton Landing Treatment Plant. However, based upon the operation of the Lake George Village Sewage Treatment Plant it is assumed that an adequate degree of treatment is achieved and that the impact of the nutrients upon Lake George when the ground water eventually reaches Lake George is minimal. Recently it was found that a significant water user inadvertantly connected its sewer line to a storm drain with the result that raw sewage reached Lake George directly. This has been corrected with the flow now being directed through the treatment plant. This has resulted in improving the appearance and quality of Lake George in this area.

The remaining areas of the lake not readily accessible to the sewers of Lake George Village and Bolton Landing are served by septic tanks. The approximate number of persons served by septic tanks in the Lake George drainage basin is shown in Table 2 [1]. The remoteness of the areas around the North Lake becomes obvious when it is observed that all of the residents in this area are served by septic tanks. Despite the two sewage treatment plants serving the southern portion of Lake George, approximately 12,000 persons living in this area also rely upon septic tanks for disposal of their wastes. Little information is available as to the ability of a complete septic tank system to remove pollutional materials and nutrients in this setting. The same degree of nutrient removal can be expected for septic tank systems as for the sand infiltration sewage treatment plants of Lake George and Bolton Landing; however, one of the important features of those treatment plants is the depth of sand through which the effluent percolates prior to reaching any water course. Many areas of Lake George have little to no soil cover on top of the bed rock. Also the distance from the septic

TABLE 2

POPULATION DISTRIBUTION IN THE LAKE GEORGE BASIN

	SOUTH LAKE			NORTH LAKE		
	SEWERED	UNSEWERED	TOTAL	SEWERED	UNSEWERED	TOTAL
PERMANENT YEAR ROUND	2,930	1,515	4,445	0	1,130	1,130
SUMMER CAMP	1,750	7,025	8,775	0	3,205	3,205
RESORT HOTEL & MOTEL	9,111	3,447	12,558	0	47	47
TOTAL SUMMER	13,791	11,987	25,778	0	4,382	4,382

1. BASED ON A NORMAL SUMMER OCCUPANCY OF 5 PERSONS PER CAMP.

tanks to the lake is frequently less than desired, due primarily to older installations which predate the present more stringent regulations. Traditionally it is considered that a septic tank system is functioning properly if the liquid effluent does not appear at the surface of the ground or does not obviously overflow into any body of water in the immediate area. Thus, a standard technique for determining the failure of a septic tank system is a dye tracer placed in the home drain and observation made to determine whether or not the dye appears at the surface of the ground. If no dye is obvious, the system is assumed to be operating satisfactorily.

Presently, the control of septic tanks is begun when a home owner wishes to build a house requiring a septic tank, or an existing septic tank system fails and is planned to be replaced. Approval is required from either the town health inspector, if one exists, or from the state health officials. Within the Lake George drainage basin, approval is given only after inspection to assure that there is adequate land available for a seepage system, i.e., 30 m (100 ft) minimum to any surface water, and that there is sufficient ground cover in the seepage area to prevent direct overland flow to the lake. Where insufficient ground cover is available, which represents a large portion of the lake drainage area, approval is not given for a waste disposal system, unless built-up leach areas are constructed or in some cases, holding tanks are installed. This has minimized, as well as controlled the expansion of many commercial interests such as motels and restaurants. Many of the original properties around the lake are large estates which could be subdivided into small lots for homes or motels, but some have not been able to do so due to sewage disposal restrictions. Existing septic tank systems are monitored by the Lake George Park Commission with notification letters of any identified violations or overflow being sent to the individual violators. A time limit, usually two weeks, is set for correction of any violation and thereafter fines are imposed or commercial establishments closed down.

An intensive survey of private dwelling septic tank systems around Lake George was conducted by the New York State Department of Environmental Conservation (NYSDEC) during the summer of 1973 [19]. A total of 3,273 dwellings was surveyed in this study, representing more than 97% of the private residences of the lake front or in close proximity to the lake. Dye was used in 730 systems whoe integrity was in doubt. Surveys of residences on tributaries were limited to those areas of high population density in the immediate vicinity of the lake itself. The inspection indicated slightly over 2% of the systems studied were failing and in need of alteration to eliminate further overflows. It was considered possible that the unusually dry weather during July and August of 1973 reduced the number of systems which were found failing. Some homeowners indicated that during wetter years they did experience some temporary failure. An additional 18% of the systems surveyed were characterized as questionable for vaious reasons. Many systems were reported to be located very close to the shoreline, e.g., approximately 46% in areas recommended for public sewers are less than 30 m (100 ft) from the lake.

A separate inspection of all motels, hotels and food establishments not on public sewers was conducted by the Glens Falls District Office of the New York State Department of Health. That department reported 14 violations were discovered.

The concern for the potential pollution of Lake George by domestic sewage was exhibited by the efforts of the Lake George Association to establish a program to prevent the sale of phosphate-containing detergents in stores in the Lake George area beginning in 1972. Their effort was carried forward by a complete ban on phosphate-containing detergents in New York State beginning June 1, 1973. Since most of the sewage in the

Lake George area consists of purely domestic wastes, this is expected to have reduced the phosphate content of the sewage by approximately 30-50%.

There are no restrictions on the recreational use of Lake George. A public bathing beach was constructed in 1951 at the south end of the lake at Lake George Village. There are no restrictions on the size or types of power boats on the lake with the exception that there may be no discharge of any wastes from any boats in the lake. All boats normally equipped with a discharge pipe, such as from a toilet or a sink, must have this line sealed before being launched in this lake. Random inspection of boat sanitary facilities is made by the Lake George Park Commission and certificates of approval are given for compliance or summonses issued for violations.

Private boats may be equipped with self-contained toilets. Pump-out facilities are located at various marinas around the lake so that the toilets may be emptied and the contents treated in a large treatment system which usually consists of a septic tank and leach field. The large excurision boats have holding tanks which are pumped directly to the sanitary sewer system of Lake George Village.

Sailing, canoeing, water skiing, scuba diving and fishing are other popular recreational activities at Lake George. There are three large exucrsion boats and other smaller excursion boats which ply the waters of the lake on a regular basis during the summer. One private sea plane is normally berthed on Lake George.

Historically water travel was more than recreational. For example, mail delivery was provided by boat to certain homeowners around the lake who had no access by highway to their summer residences. Some homes and all the island campsites are still accessible only by boat.

The island campsites are of particular concern from the standpoint of sanitary wastes. Nearly all the islands in Lake George are presently state owned and, with the exception of Dome Island which is a nature conservancy, all the state-owned islands are available for picnicing or camping. The larger islands are designated for camping and reservations must be made to occupy the campsite. Somewhat smaller islands are provided with picnic facilities. Both these and the larger islands are equipped with docks in the summer so that the campers and picnickers may gain access to the island by boat. Other smaller islands have no docking facilities but may be used by recreationists who can reach them. These islands represent the tops of mountains which protrude above the water line. In general, they are solid rock with very little soil cover. Thus, it is impossible to provide any conventional source of waste treatment system for human wastes which accrue on the islands. Thus, pit privies have been constructed and a scow visits the islands on a periodic basis to pump out the pit privies. The sewage removed from these systems is conveyed to an on-land treatment system for treatment and disposal.

SOURCES OF NUTRIENTS

Considerable monitoring of the nutrient concentrations and the quality of the water within Lake George has been conducted by the Rensselaer Fresh Water Institute since 1967 [20-26]. The results have shown some stresses and increased nutrient levels in the South Lake where the greatest concentration of population occurs. The North Lake, which is the outflow of the lake, has slightly better water quality. The exact reason for the better water quality in the northern or downstream end of the lake is not exactly clear. One reason could be the smaller total drainage basin area discharging to the North Lake as compared to the South Lake. Another reason could be the lower population density tributary to the North Lake. However, since the general flow of water in the lake is from the south to the north, the higher nutrient levels in the South Lake may ultimately flow toward the North Lake, unless natural uptake of the nutrients by the biota precludes this from happening.

Extensive studies were conducted by Gibble [26] to evaluate the sources of the nitrogen and phosphorus entering Lake George and estimate the percentage of contribution from each source. It has subsequently been realized that the precipitation data included in Gibble's study consisted primarily of wet fallout collected in a Wong sampler. This sampler opens only during precipitation and closes when the precipitation ceases; therefore, it does not measure dry fallout. Other studies [27] have estimated that the amount of nitrogen and phosphorus in dry fallout is approximately equal to that in the wet fallout or precipitation. Thus, Gibble's data have been revised as shown in Table 3 to account for the additional nitrogen and phosphorus contributions to the lake due to dry fallout. It may be seen that the wet and dry fallout are the greatest sources of both nitrogen and phosphorus inputs to Lake George. In total the precipitation (wet and dry) represents nearly 68% of the nitrogen and 48% of the phosphorus to Lake George, being divided evenly between the wet fall and dry fall by definition. It must be pointed out that this input of nitrogen and phosphorus to Lake George represents precipitation which falls directly on the surface of the lake itself. Thus, it is very difficult to prevent this amount of nutrient from entering the lake, and any pollution control would have to be exercised at the source of these nutrients to the atmosphere.

The runoff to the lake from the streams surrounding the lake itself contributes about 20% of both nitrogen and phosphorus to the lake. The value shown represent the concentrations of nitrogen and phosphorus and the volume of runoff from representative streams extrapolated to the entire basin. Inasmuch as the land area of the basin is approximately 4 times the water surface area of the lake, it may be estimated that 840,000 kg of nitrogen and 16,800 kg of phosphorus fall on the watershed every year.

TABLE 3

ESTIMATE AVERAGE ANNUAL

WATER BUDGET AND NUTRIENT LOADINGS FOR LAKE GEORGE, N.Y. (26)

INPUT		NITROGEN			PHOSPHORUS		
Sources	Volume (km^3)	Conc. (μg/l)	Quantity (kg)	Percent of Total	Conc. (μg/l)	Quantity (kg)	Percent of Total
Runoff	0.181	340	61,500	19.9	10	1,800	20.5
Precipitation							
wet fall	0.105	1,000	105,000	33.9	20	2,100	24.0
dry fall (27)			105,000	33.9		2,100	24.0
Groundwater	0.025	340	8,500	2.7	10	250	2.8
STP Effluents	--		18,000	5.8		0	0
Septic Tanks	--		9,580	3.1		2,300	26.3
Lawn fertilizer	--		2,080	0.7		208	2.4
Total	0.311		309,660	100.0		8,758	100.0
OUTPUT							
Evaporation	0.069						
Outflow	0.225	250	56,250	100.0	8	1,800	100.0
Total	0.294						

81.8% retention of N

2.72 $g/m^2/yr$ of N

79.4% retention of P

0.077 $g/m^2/yr$ of P

Thus, the small amount of nitrogen and phosphorus in the runoff represents a large uptake of these nutrients in the terrestrial system prior to the runoff's reaching the streams which flow into Lake George. For the nitrogen this represents a 92% removal and for the phosphorus this represents a 89% removal of the amount which falls on the land. Thus, the terrestrial system removes a significant amount of nutrients preventing them from reaching the lake.

Measurements made at the Lake George Village Sewage Treatment Plant have shown that there is complete removal of phosphorus in the soil system. Since Bolton Landing has a similar system it was estimated that this plant also achieves complete phosphorus removal. Thus, it may be assumed that no phosphorus from the treatment plants reaches Lake George. On the other hand, the reduced nitrogen compounds in the sewage are oxidized to nitrate which passes through the soil system and ultimately gains access to the lake. Assuming the same concentration of nitrate in the ground water at Bolton Landing as at Lake George, it is estimated that 6% of the nitrogen entering Lake George originates from the treatment plant effluents.

Septic tanks represent a somewhat unknown quantity from the standpoint of nutrient contributions to the lake. Little information is available regarding the removal of nitrogen and phosphorus in a septic tank system. Whereas it has been shown that application of sewage treatment plant effluent to the soil in aerobic conditions achieves phosphorus removal, it is difficult to predict the removal of phosphorus in the anaerobic effluent from a septic tank system. Gibble [26] made an estimate of phosphorus removal in a septic tank system based on reported distances from individual septic tanks to the lake. His calculations showed an average of 49% phosphorus removal in septic tank systems tributary to the lake. Furthermore, his calculations were made prior to the New York State ban on the use of phosphate-containing detergents in June 1973. Since most tourists do little laundry while on vacation, the exact impact of this ban on the phosphate content of sewage in the Lake George basin is difficult to evaluate. To be on the conservative side, Gibble's original data are used here without any change. Thus, it may be estimated that about 3% of the nitrogen and 26% of the phosphorus which enters Lake George has as its source septic tanks surrounding the lake.

Another source of nutrients to the lake is the extensive use of fertilizers on lawns, particularly on properties adjacent to the lake. Approximately 0.7% of the nitrogen and 2% of the phosphorus which reach the lake are attributed to this source.

It must be emphasized, however, that these loadings of nitrogen and phosphorus are overall estimates for the entire lake. Around the lake there are numerous clusters of houses with septic tanks and fertilized lawns surrounding rather small bays or poorly flushed inlets. Local problems of undersirable algae growths have been observed in some of these areas. Whereas these do not affect the lake as a whole, they may be considered very undesirable to the residents in these local areas.

NUTRIENT CONTROL

It would be difficult to achieve any major reduction in nutrient inputs to Lake George since the largest fraction of these nutrients originates in the wet and dry precipitation falling directly on the lake and on the watershed. Nutrient reduction would be an expensive undertaking, requiring the placing of all homes on a central sewage system with treatment including nutrient removal or discharge of the final effluent outside of the basin, and convincing lake shore and tributary side residents not to use excessive amounts of fertilizers on their lawns which could be carried into the lake by a subsequent rainfall.

Consideration is presently being made to sewer the more populated areas of Lake George from Cleverdale on the southeastern shore through Bolton Landing on the western shore. A presently considered option is to convey the collected wastes through a force main to the Glens Falls watershed where a treatment system would purify the wastewaters and discharge the final effluent into the Hudson River. This would certainly reduce the nutrients which reach the lake from sewage treatment plant and septic tank effluents. However, this would entail a large expenditure of money to accomplish the removal of a maximum of 9% of the nitrogen and 26% of the phosphorus which presently enters Lake George. The removal of the water from the watershed if the sewage is diverted out of the basin could create a potential problem. It is estimated that the extension of the sewer services around the southern end of Lake George would accommodate a maximum summer population of approximately 20,000 persons. Based on an average flow of 0.4 m^3/cap-day this represents a total flow of approximately 8,000 m^3/day. Extensive flow data are available on the discharge of Lake George at Ticonderoga [28]. The lowest flow ever recorded was 0.17 m^3/sec. which is the equivalent of 14,688 m^3/day. This is not particularly a singular event since a flow of 0.19 m^3/sec was also recorded on August 26, 1974. This is equivalent of 16,416 m^3/day. It may be seen that the 8,000 m^3/day of sewage diverted out of the basin could represent a significant portion of the low flow out of the basin. If it is estimated that the population of the sewered area may double by the year 2020, it may be seen that the diversion of sewage out of the basin may exceed the low dry weather flow out of the lake at Ticonderoga. This could potentially present some significant problems, including reversal of the direction of flow in the lake. Caution must be taken to interpret the discharges at Ticonderoga in view of the fact that the flow has been controlled by the paper mill which existed at this location. By means of valves, the paper mill adjusted the discharge from the lake to suit its own water supply needs, at the same time trying to maintain the water level in the lake at $\pm$ 1 ft (0.3 m). Thus, it may be that the extreme low flows recorded occurred on days when the mill was not operating and they were storing water for future use. Without going into extensive detailed flow data, it was observed that for the 2 months of October - November 1973, the discharge of the lake maintained a flow of 32 cfs [28] which is equivalent to 78,300 m^3/day. This definitely represents a continued low discharge since it occurred over a 2 month period. Thus, it may be seen that the present estimated sewage diversion flow could amount to approximately 10% of the total discharge at Ticonderoga, and, based on a doubling of the population in the next 50 year period, this could represent 20% of the continued low flow discharge at Ticonderoga. It is felt that this does represent a significant reduction in the discharge from the lake, and consideration of the ecological effects of such a large diversion should be made as part of the comprehensive sewage study presently being conducted at Lake George.

CONCLUSIONS

There are many factors which contribute toward maintaining the high quality of the waters of Lake George. Probably the most important factor is the natural morphology of the lake. Being narrow and deep, the lake has a high ratio of hypolimnion to epilimnion which helps maintain oligotrophic conditions. A significant factor is the relatively small drainage basin area in relation to the lake surface area. This helps to reduce the total input from terrestrial sources. The low nutrient content of the surface soil and the bed rock, and the probable uptake of nutrients by the forested area help to control and reduce the nutrient inputs contributed by the streams tributary to Lake George. In addition, there is concern among all the users of the lake, both private and commercial. Most individuals recognize the importance of maintaining a high quality of water within the lake. The sewering of areas of high population density with subsequent treatment plants which provide the equivalent of tertiary treatment have reduced significantly the phosphorus and somewhat the nitrogen inputs to the lake. Septic tanks are monitored to prevent direct discharges of the effluents to the lake or streams tributary to the lake. Precautions are made to prevent any discharges of any sewage from any of the boats sailing on Lake George. However, there is unlimited use of the lake for all forms of recreational activity. At the same time the quality of the water is such that it may be drunk without any treatment with the exception of required chlorination for public usage. Thus, under properly controlled conditions, full use of a lake may be made at the same time maintaining the water as a high quality water supply.

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