LAND APPLICATION OF SECONDARY EFFLUENT AT LAKE GEORGE, NY

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ABSTRACT

Public Law 95-217 requires consideration of land application of wastewater as an alternative to conventional waste treatment. Unfortunately, little information is available concerning the long term effects of the discharge of sanitary wastes onto the land. The Lake George Village Sewage Treatment Plant has been in operation continuously since 1939 discharging unchlorinated secondary effluent onto natural delta sand beds by the rapid infiltration technique. Studies made tracing the effluent through the sand show the complete removal of phosphates, BOD, coliforms, and suspended solids. Organic and ammonia nitrogen is oxidized to nitrate with some nitrate removal being observed. Soluble materials such as chloride pass through the system. The beds are dosed intermittently. The depth of applied wastewater varies from 14 to 89 m/yr. Actual infiltration rates are in the order of 0.1 to 0.2 m/day with a depth of 0.3 m of water on the sand beds. The rapid infiltration system provides the equivalent of tertiary treatment to the applied wastewaters with no apparent loss of ability of the sand to continue this degree of treatment.

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KEY WORDS: sewage treatment; infiltration; ground water; water quality; sands; seepage.

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INTRODUCTION

Public Law 95-217 known as the Clean Water Act of 1977 mandates that consideration must be made of the possibility of using land application techniques for all future sewage treatment before approval of any treatment system is made by the Environmental Protection Agency (EPA). Whereas it may be shown that land application may not be practical for some situations, this form of sewage treatment must at least be considered because of its many advantages. One of the current problems in considering land application of wastewaters is that little information is presently available concerning the long term ability of a land application system to continue to provide adequate treatment without despoiling the environment. One of the places where information is available is the Lake George Village Sewage Treatment Plant (LGVSTP) which has been in operation since 1939 continuously applying secondary settled trickling filter effluent to a series of delta sand beds by the rapid infiltration technique. Studies were begun in 1968 to evaluate the degree of treatment afforded by this system and have continued through the present time. This paper proposes to review the operation

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of the treatment plant, to demonstrate the degree of treatment afforded by the Lake George system and to identify methods which may be used to evaluate any rapid infiltration system of land application of domestic wastes.

THE LAKE GEORGE VILLAGE SEWAGE TREATMENT PLANT

In response to concern over the quality of the water of Lake George and in view of the prohibition of the discharge of sewage or sewage effluent into Lake George or any tributaries to Lake George[3], the citizens of the Village of Lake George, located at the most populated area of the south end of Lake George, investigated the possibility of a sewage collection system and treatment plant in 1936. The treatment plant put into operation in 1939 consisted of flow measurement, sedimentation in two-compartment settling tanks providing sludge digestion in the lower chamber, trickling filter treatment followed by secondary sedimentation and the application of the secondary settling effluent onto one of six rapid infiltration sand beds located in a natural delta sand deposit southwest of the Village of Lake George. The sewage is collected by gravity to a central pumping station from which it is conveyed through a 1.5 mi (2.4 km) force main with a lift of 180 ft (55 m). In 1965 the sewers were extended to the surrounding Towm of Lake George which provided a separate wet well and force main to lift the sewage to the existing treatment plant. Along with this a double Parshall flume was constructed to provide measurement of the flow of the sewage from both the Village and from the Town of Lake George. The present treatment plant is shown in Figure 1 and reveals the additions to the sand beds which have been made in the ensueing years. The initial six sand beds are designated as bed N1 through 6. Bed N7 was added in 1947, beds N8 and 9 were added in 1950, beds N10, 11 and 12 were added in 1956, south beds 1 through 6 and north beds 13 and 14 were added with the major plant expansion in 1965 and the final bed S7 was added in 1970.

The Lake George area is a popular tourist attraction. The initial treatment plant was built in triplicate with the concept that the summertime flows were approximately 3 times the wintertime flows due to the summer tourist population. Recently, however, winter sports have increased and, in particular, there is a winter carnival on Lake George during the week-ends of February. This has increased the winter flows to the treatment plant also. There are no water consuming industries in the drainage basin, thus, the sewage is strictly domestic.

The flows of sewage to the LGVSTP have been increasing throughout the years as shown in Figure 2. At the present time the maximum daily summer flows approach 1.3 mgd (5×10^6 L/day) and the ratio of the summer to the winter flows approximates 2 to 1. The design capacity of the treatment plant is 1.75 mgd (6.6×10^6 L/day). Although the conventional portion of the treatment plant has not yet

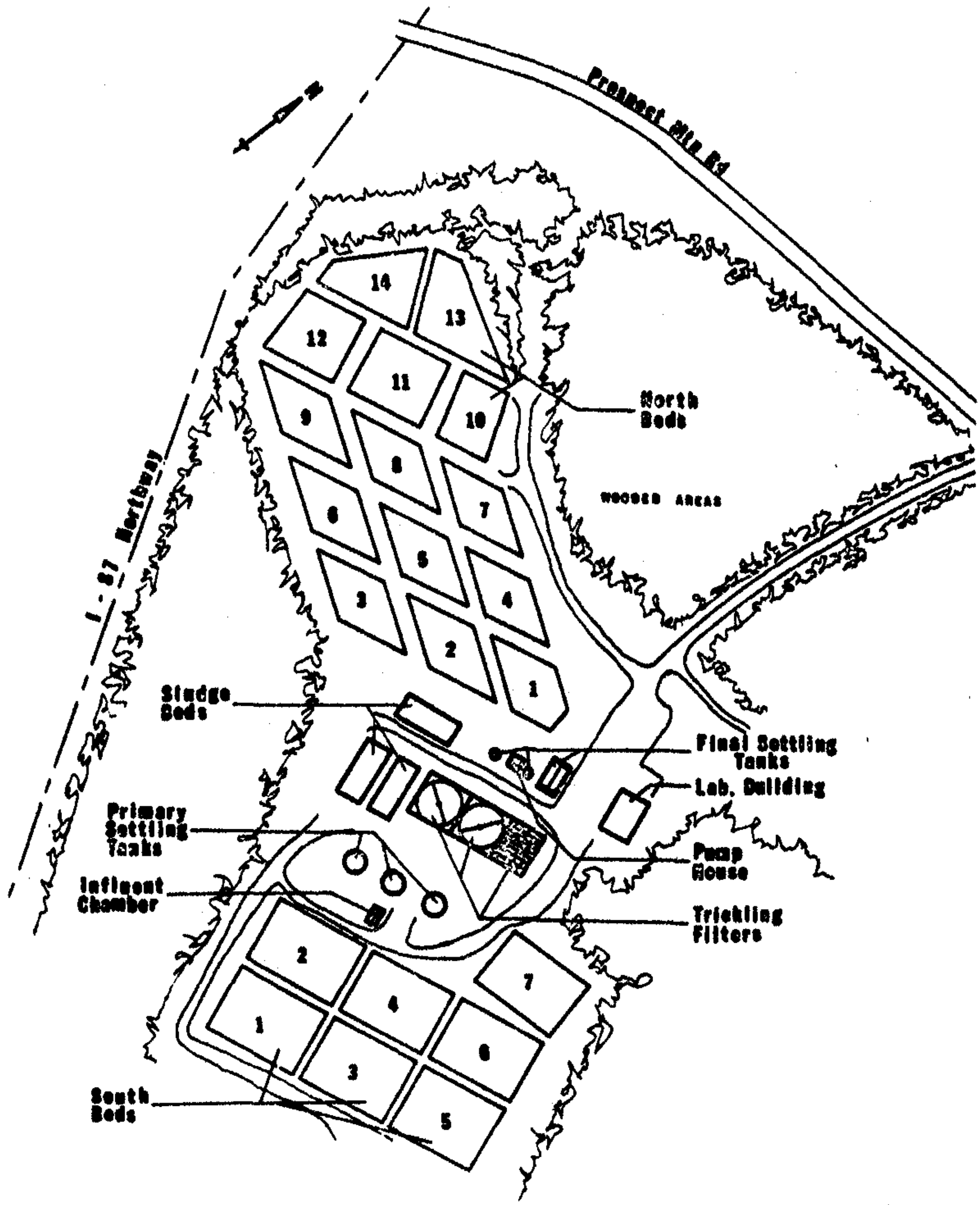

FIG 1.- Plan of the Lake George Village Sewage Treatment Plant

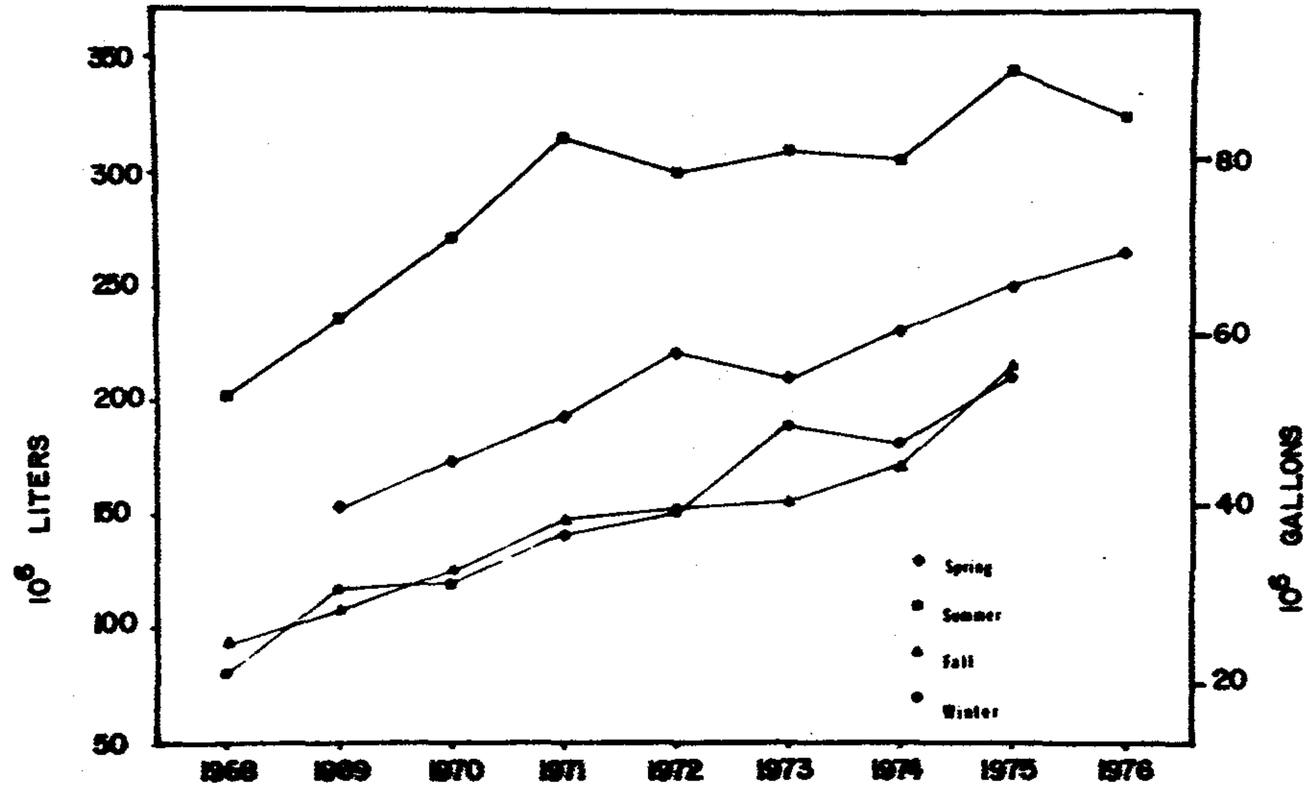

FIG 2.- Seasonal Flows to the Lake George Village Sewage Treatment Plant

reached its capacity, there have been occasions during the peak summer flows when all of the sand beds were filled and an adjacent field had to be pressed into service to provide additional infiltration capacity. In addition, some problems are encountered at the treatment plant due to the fact that the pumps at the two force mains are either off or on at 1.0 and/or 1.5 mgd (3.785 and/or 5.7 x 10^6 L/day), respectively. Thus, at certain times there will be no inflow to the plant, but when the two pumps are operating together the rate of flow to the plant is 2.5 mgd (9.5 x 10^6 L/day), which is in excess of the design capacity. This creates some turbulent flow in the primary settling tanks which interferes with proper sedimentation and increases the suspended solids load to the trickling filters.

An interesting operation of the treatment plant is that the two rotating high rate trickling filters are used exclusively during the summer and the fixed nozzle low rate trickling filter is used exclusively in the winter. The fixed nozzle filter is covered by boards on saw horses which prevent complete freezing of the trickling filter during the severe winters encountered in this area. Even under extended periods of sub-freezing temperatures (up to 30 days and temperatures as low -30°F [-35°C]), this cover prevents freeze-up. Ice does form on the surfaces of the sand beds while water is standing on the bed while infiltration takes place. However, with the application of the relatively warm effluent to a sand bed, the warm water flows under the ice, floating it up, thawing the infiltration surface of the sand bed and allowing effective infiltration to take place.

Normal operation of the sand beds is to dose one north and one south bed from 8 am to 4 pm and another set of north and south beds from 4 pm to 8 am. Due to fluctuations in flow at the treatment plant it is assumed that during a normal day each sand bed dosed receives approximately 1/4 of that day's flow. During week-ends and holidays, multiple sets of sand beds are dosed for 24 hour periods. There is no specific system for determining which bed will be dosed at any particular time. This is left up to the discretion of the operator. Normally the procedure is to allow the beds to remain dry for 1-2 days before applying a new dose of sewage effluent.

The individual sand infiltration beds vary in area as shown in Table 1. On the basis of bed dosing records and the daily flows, the estimated amount of effluent applied to each bed during each season and the total for the year are also shown in Table 1. In general it may be stated that the beds receiving the highest hydraulic loading are the ones with the most rapid infiltration rate. Bed S1 received by far the greatest hydraulic loading indicating that it has the highest infiltration rate. Similarly, beds N7, N13, N14, N8, and N9 had the lowest infiltration rates. However, beds 13 and 14, which are always operated together, can be flooded only by means of a valve which is not readily accessible; therefore, these beds are used only when all other beds are full. However, as a generality the beds which receive the greatest dosing are the ones with the highest infiltration rates.

Calculations were made of the additional amount of loading caused by precipitation directly on the beds. On a yearly average this was approximately 2.6% of the flow to the beds and thus was not considered to be a significant amount on an annual basis. However, during August of 1976 at a period of peak sewage flow there was a large rainfall occurrence which increased the infiltration to the sewer system and, thus, resulted in an overload to the entire treatment plant.

The amount of effluent applied to a sand bed does not truly indicate the rate of infiltration through the bed. Studies were made using Stevens Water Level Recording Gauges to determine the rate of infiltration during the normal loading period of the infiltration beds. Some representative values are shown in Figure 3. It may be seen that the infiltration rates varied between 0.3 and 1 ft/day (0.1 and 0.3 m/day). Higher rates of up to 2.5 ft/day (0.75 m/day) were observed immediately after cleaning a sand bed by scraping and removing the top cm (0.5 in), discing, and releveling. It must be pointed out that in the calculation of the infiltration rates, the values measured do not include the initial infiltration rate while the bed is being flooded. Particularl with a freshly cleaned bed, it takes a while until the bed flooding rate exceeds the infiltration rate. It is only

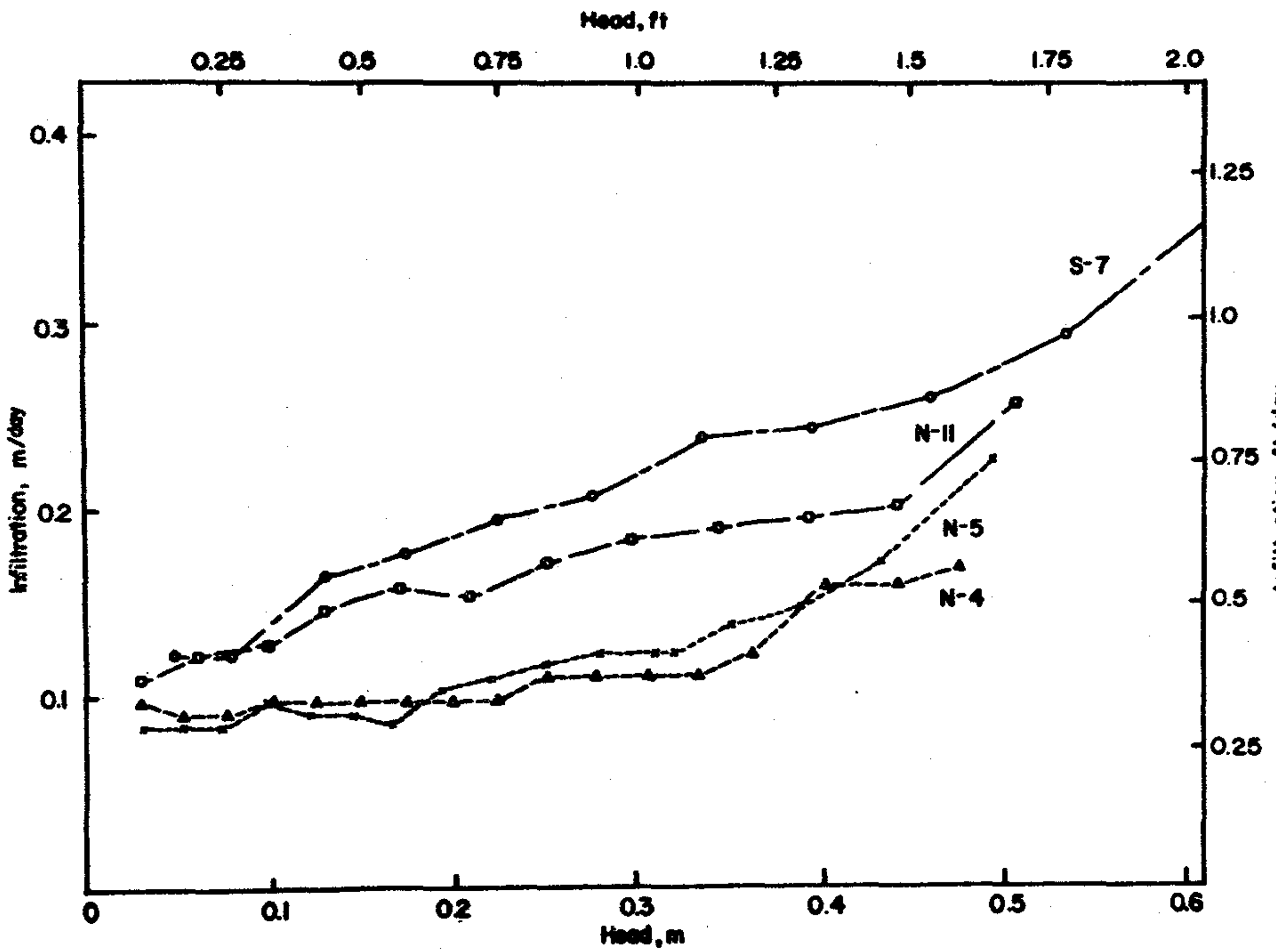

FIG 3.- Infiltration Rates of Several Sand Beds in Normal Use

after there is some slight clogging of the surface of the bed that there can be a built-up of effluent on the bed sufficient to measure the infiltration rate. Thus, the values shown are already reduced to a certain degree of clogging of the beds.

Based on the infiltration rates shown in Figure 3 and the estimated loadings shown in Table 1, a few revealing calculations were made. Using bed N5 with an average infiltration rate of 0.3 ft/day (0.1 m/day) as an example of a slow bed and the total annual loading of 75 ft (22.98 m) for that bed, the average annual loading rate of bed N5 is 63% of its infiltration capacity. However, during the summer of 1976, 28 ft (8.66 m) was applied, which is 94% of its capacity. Bed S1 received the highest loading and may be considered as an example of a fast bed. Based on an infiltration rate of 1 ft/day (0.3 m/day), the usage of an annual basis was 82% of its infiltration capacity, and during the summer of 1976 it reached 100% of its capacity. Although these values are estimated, it may be seen that during the summer the loading rate is reaching the capacity of the infiltration rate.

Some studies were also made of the effect of grass growing in the sand beds. It is the objective of plant personnel to remove grass growths as soon as possible. However, in some instances the growths have occurred. In a comparative study between two sand beds it was shown that at bed loading depths exceeding 1 foot (0.3 m) the infiltration rates were higher in a grass covered sand bed, whereas

TABLE 1.-Sand Bed Areas and Hydraulic Loading

Sand Bed	Area		Total Loading Depth, in meters (1 m = 3.28 ft)				
	square meters	square feet	1975 Fall	1976 Winter	1976 Spring	1976 Summer	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
N-1	908	9,774	12.32	9.47	9.68	7.98	39.45
N-2	986	10,613	7.31	6.82	12.77	12.03	38.93
N-3	853	9,178	8.19	9.20	7.69	17.51	42.59
N-4	1037	11,160	7.23	8.22	8.73	12.76	36.94
N-5	1185	12,754	5.49	3.59	5.24	8.66	22.98
N-6	955	10,824	11.24	5.21	18.60	18.64	53.69
N-7	1730	18,619	3.95	2.63	3.37	4.06	14.01
N-8	1062	11,427	4.36	4.54	5.83	6.96	21.69
N-9	964	10,373	10.73	10.77	12.48	16.93	50.91
N-10	809	8,704	11.91	13.02	11.89	16.93	53.75
N-11	1361	14,646	7.46	8.49	11.06	12.04	39.05
N-12	1154	12,425	12.52	15.44	15.05	16.26	59.27
N-13-14	1500	16,151	5.85	4.08	6.37	5.09	21.39
S-1	1118	12,035	17.37	21.66	22.91	27.58	89.52
S-2	1118	12,035	13.42	10.73	12.98	21.54	58.67
S-3	1135	12,218	9.26	18.79	19.36	22.16	69.57
S-4	1135	12,218	11.86	5.28	18.46	18.07	53.67
S-5	1193	12,846	12.43	11.42	5.99	24.05	53.89
S-6	1200	12,915	11.81	12.30	18.53	20.03	62.67
S-7	1234	13,248	11.28	10.43	13.17	8.27	43.15
Total North Beds	14502	146,150					
Total South Beds	8134	87,551					
TOTAL	22636	233,656					

at loading depths of less than 0.3 m the infiltration rates were lower than with comparable bare sand beds.

WATER QUALITY

Studies were made of the ability of the sand system to purify the applied sewage effluent. Studies were made with both vertical and horizontal flow in the sand system. Vertical flow studies were conducted in bed N11 by means of observation wells, lysimeters and submersible pumping wells. Bed N11 is a relatively deep bed with between 65 and 72 ft (20 and 22 m) of sand above the normal ground water level and 98 ft (30 m) to bedrock, making an aquifer beneath the sand bed with a thickness of 26 to 33 ft (8 to 10 m). Dye studies were conducted using rhodamine WT to show that the applied effluent reached all of the lysimeters and the shallow pumping well but did not reach the deeper pumping well in the aquifer. Based on the dye studies the average vertical velocity in the unsaturated zone of this sand bed was 1.79 ft/day (0.55 m/day).[1]

The changes in water quality with depth may be placed in two main categories. The stable soluble materials such as dissolved solids and chloride showed little variation with depth. On the other hand substances such as nitrogen which are subject to oxidation-reduction reactions showed significant changes. The organic and ammonia nitrogen was oxidized to nitrate within the top 10 ft (3 m) of the sand bed. Thereafter, there was a reduction in the total nitrogen levels at greater depths, with total nitrogen values of less than 1 mg/L at the 65 ft (20 m) depth. The orthophosphate concentration was reduced to less than 0.1 mg/L in the top 33 ft (10 m) of the sand bed. The total phosphorus showed some fluctuations, but in general was reduced to less than 2 mg/L by the time the 59 ft (18 m) depth was reached. The pH showed no significant variations. The dissolved oxygen and the redox potential showed similar variations with high values in the top 43 ft (13 m) and relatively low values at the 59 ft (18 m) depth. The DO reached a low of approximately 3 mg/L at the 59 ft (18 m) depth which corresponded to the only negative redox potential measurement observed of -25 millivolts. It is this combination of oxygen and redox potential that is credited with the removal of the total nitrogen by reducing the nitrate produced in the top layers of the sand bed to nitrogen gas in the lower, less aerobic areas of the sand bed. This nitrogen escapes to the atmosphere and is thus removed from the aqueous system. One caution is that some of the other sand beds (particularly the south beds) are in the order of 16 ft (5 m) deep, which is the depth at which the maximum nitrification occurs. Thus, this nitrogen reaches the ground water as nitrate and apparently passes through the ground to the seepage which will be discussed subsequently. Coliform indicator organisms were effectively removed in the upper layers of the sand bed.

In order to determine the changes in quality with horizontal transport a series of observation wells was placed between the sand beds and West Brook as shown in Figure 4.

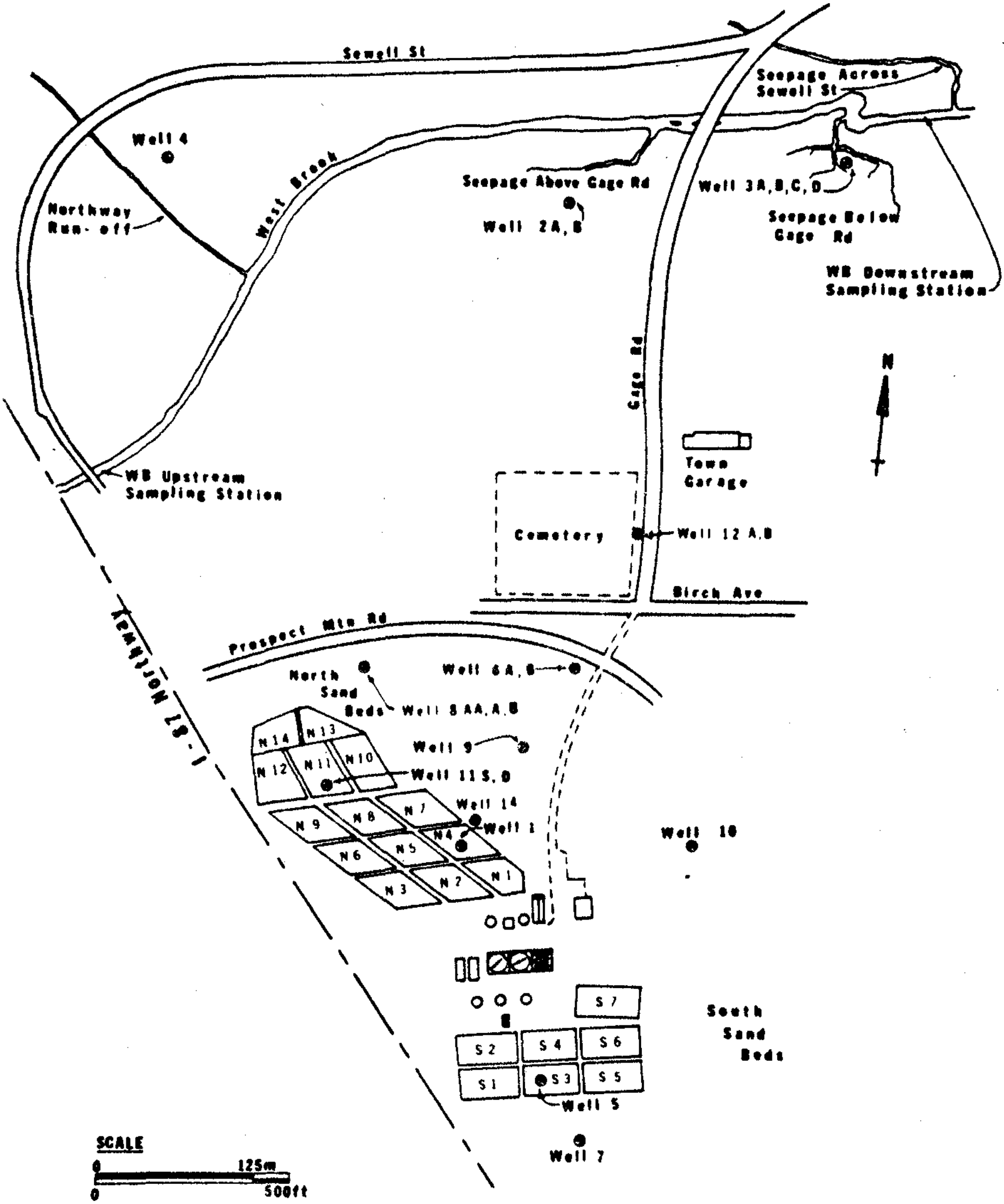

FIG 4.- Area of Study Showing the Treatment Plant, Observation Wells, and Seepage into West Brook

Previous studies[2] had indicated a region of high conductivity between the sand infiltration beds and West Brook running in a generally northerly direction along Gage Road. Observations along the southern edge of the flood plain of West Brook revealed a significant amount of seepage emanating from the base of the steep sand hill in the area. It was obvious that the sand in this area was the same delta sand deposit into which the sewage effluent was being discharged. From the quality of the seepage, particularly dissolved solids, it was concluded that this seepage represented the effluent from the treatment plant after mixture with the natural ground water in the area. Dye tracer studies were performed[1] which conclusively showed that the effluent from sand bed S3 (representative of the south sand beds) definitely flowed to observation wells 9 and 6. Although the dye could not be traced to the seepage, there is sufficient evidence to conclude that the seepage does represent the flow from the treatment plant.

The dye tracer studies using rhodamine WT gave an indication of the velocity of the horizontal flow within the saturated portion of the sand system. Although the velocities varied from one location to another within the area approximately as a function of the vertical change, the rates of flow were unusually high ranging between 10.2 and 40 ft/day (3.1 and 12.1 m/day). These high velocities within the ground provide the reason that there is little build-up of water under the sand beds in the Lake George system.

In general the quality changes with horizontal transport were similar to those with the vertical transport. The soluble materials such as chlorides, total dissolved solids, etc. showed no significant changes other than dilution by the ground water. Coliform, fecal coliform, and fecal streptococci were essentially absent in all of the monitoring wells with the exception of the two wells located directly in the infiltration beds. Virus studies were conducted but limited to the measurement of only coliphage. All wells including the control wells indicated the presence of coliphage, as did the samples in West Brook. There was no particulat pattern of coliphage occurrence and, therefore, no conclusions can be made as to the effectivenss of virus reremoval in this system. There was complete removal of BOD in the sand system.

The two factors of prime concern are the nitrogen and phosphorus which may become nutrients to Lake George. The effluent from the treatment plant eventually emerges in seepage along West Brook and then enters West Brook, returning ultimately to Lake George. Thus, the critical point in terms of evaluation of the degree of treatment of the sewage by the sand system may be summarized by the results of the studies of the two seepages and their effects upon West Brook. The seasonal averages for ammonia nitrogen in both of the seepages never exceeded 0.1 mg/L. There were no significant changes in the ammonium content of West Brook above and below the confluences with the seepages. Therefore, this leaves only nitrate as a concern as a source of nitrogen.

Thus, the impact of the nutrients nitrogen and phosphorus upon West Brook and ultimately Lake George can be summarized by showing the concentrations of nitrate ion and phosphate ion in the seepages and in West Brook above and below the confluences with the seepages as shown in Table 2. The nitrate nitrogen content of the seepage above Gage Road averaged in the range of 2 to 3 mg/L whereas that in the seepage below it averaged 7 to 9 mg/L. It may be seen that the average content of nitrate nitrogen in West Brook increased from approximately 0.2 mg/L above the seepages to approximately 0.8 mg/L below the seepages or an increase of approximately 0.6 mg/L. As for the orthophosphate, the concentrations in the seepages were approximately 9 ug/L which is slightly greater than the average of about 7 ug/L in the natural ground water in the area. This caused an almost unmeasurable increase in the orthophosphate concentration in West Brook comparing upstream and downstream results. Thus, it may be concluded that the treatment system at Lake George is contributing small amounts of nitrate to Lake George and an amount of phosphate that is barely measurable above the natural phosphate levels in the area.

CONCLUSIONS

Since 1939 the Lake George Village Sewage Treatment Plant is continuing to provide the equivalent of tertiary treatment to the trickling filter effluent applied without chlorination to a natural delta sand by intermittent dosing using the rapid infiltration technique.

TABLE 2. - Average Seasonal Nutrient Variations in the Seepages and Their Influence on West Brook.

Sample Location (1)	1975 Fall (2)	1975 Winter (3)	1975 Spring (4)	1975 Summer (5)	1976 Fall (6)	1976 Winter (7)	1976 Spring (8)	1976 Summer (9)
Nitrate-N, mg/L, milligrams per liter								
Seepage Above Gage Road	3.5	3.8	2.32	1.62	3.27	2.84	1.98	1.9
Seepage Below Gage Road	7.7	8.23	10.4	8.6	7.5	8.62	9.5	7.7
West Brook Upstream	0.2	.27	.196	.412	.114	.154	.138	.17
West Brook Downstream	1.22	.556	.714	1.27	.803	.646	.598	1.30
Orthophosphate-P, ug/L, micrograms per liter								
Seepage Above Gage Road	<2.0	9.6	9.8	13.8	9.0	9.0	8.0	18
Seepage Below Gage Road	4.0	4.6	6.3	7.7	4.0	5.0	21	6.0
West Brook Upstream	1.5	1.1	0.7	1.8	1.0	3.0	4.0	0.7
West Brook Downstream	0.9	1.8	1.2	3.0	3.0	2.0	5.0	2.0

Intermittent overloading of the primary sedimentation tanks occurs when the pumps in both force mains feeding the plant are operating simultaneously. This results in carry-over of more solids to the trickling filters, thus reducing their efficiency and possibly increasing the load to the sand beds.

During the summer the sand beds are being dosed at rates which approach their infiltration capacity. Actually during the peak of the tourist season, the infiltration capacity was exceeded in both 1976 and 1977, and effluent had to be pumped to an adjacent property containing the same sand.

The horizontal flow of the renovated water in the saturated zone is quite rapid, preventing excessive mounding of water under the sand beds. The ground water emerges as seepage along the south edge of the flood plain of West Brook. This seepage enters West Brook at two locations and then flows back into Lake George from whence it originated.

Most of the biodegradable materials in the effluent applied to the sand beds are removed in the top of the sand. Coliforms and fecal streptococci are also removed, but virus removal could not be confirmed. Nitrogenous compounds are all oxidized to nitrate, some of which is reduced to gaseous nitrogen and removed from the aqueous system in the deeper north sand beds. Phosphates are essentially completely removed in the top 33 ft (10 m) of the sand beds. Dissolved solids such as chlorides and the nitrates which are not removed in the deep sand beds pass through the soil system and reappear as seepage at West Brook. The quality of the water in the seepage meets drinking water standards. There is essentially no concern that the nitrogen and especially the phosphorus from this treatment plant could adversely effect the water quality of Lake George.

The land application system for treating wastewaters at the Lake George Village Sewage Treatment Plant is achieving excellent purification, and there is no evidence that it cannot continue to do so for many years into the future.

APPENDIX 1. - REFERENCES

1. Aulenbach, D. B., Bull, J. H., and Middlesworth, R. C., "Use of Tracers to Confirm Ground Water Flow", Ground Water, Vol. 16, No. 3, May-June 1978, p. 149.

2. Fink, W. B., and Aulenbach, D.B., "Protracted Recharge of Treated Sewage into Sand: Part II - Tracing the Flow of Contaminated Ground Water with a Resistivity Survey", Ground Water, Vol. 12, No. 4, July-Aug., 1974, p. 161.

3. "The Environmental Conservation Law", Chap. 664, Sec. 17, Title 17, Article 1709, Albany, NY.

TITLES OF FIGURES

FIG 1.- Plan of the Lake George Village Sewage Treatment Plant

FIG 2.- Seasonal Flows to the Lake George Village Sewage Treatment Plant

FIG 3.- Infiltration Rates of Several Sand Beds in Normal Use

FIG 4.- Area of Study Showing the Treatment Plant, Observation Wells, and Seepage into West Brook