THIRTY-FIVE YEARS OF CONTINUOUS DISCHARGE OF SECONDARY TREATED EFFLUENT ONTO SAND BEDS

presented at

The Second Annual Technical Meeting of
the National Water Well Association

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ABSTRACT

THIRTY-FIVE YEARS OF CONTINUOUS DISCHARGE
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The Lake George Village sewage treatment plant has been discharging trickling filter effluent onto natural delta sand beds for a period of thirty-five years. The applied sewage apparently appears near the banks of West Brook approximately 600 m (2000 ft) from the lower sand beds. Wells have been placed between the recharge beds and the appearance of the seepage at West Brook. The quality of the water in the wells has been evaluated over the period of slightly over one year.

The groundwater appears to be aerobic at all times indicating that the oxygen demand of the applied effluent has been adequately reduced before it reaches the groundwater. This should afford adequate and proper tertiary treatment for the applied effluent.

The phosphorus concentration was significantly reduced at the first well downstream (groundwater) approximately 150 m (500 ft) from the sand beds. The phosphorus in well 2 approximately 600 m (2000 ft) from the lower sand beds reached a high value of 150 µg/l during the late fall but was less than 100 µg/l during the rest of the year.

Some of the nitrogen in the applied effluent was apparently oxidized to nitrate which was very little removed by the sand system. The highest nitrate concentration found was 14 mg N/l in well 3C during the Spring, whereas well 3A had almost consistently the lowest concentration of nitrate.

THIRTY-FIVE YEARS OF CONTINUOUS DISCHARGE OF SECONDARY TREATED EFFLUENT ONTO SAND BEDS

INTRODUCTION

When the Lake George Village sewage treatment plant was constructed in the late 1930's, laws were already in effect in the Lake George area preventing the discharge of any sewage, raw or treated, into the waters of Lake George or into any streams discharging into this beautiful recreational lake. Therefore, extra efforts were made to provide for "complete" treatment of the sewage collected. The basic treatment plant is not unusual, consisting of circular Imhoff tanks providing for primary sedimentation and sludge digestion, trickling filters, and secondary sedimentation of the trickling filter effluent. The unique portion of the plant, other than its dual pumping system lifting the sewage approximately 200 feet from the collection point at the lake to the treatment lake, is the discharge of the effluent from the secondary sedimentation tanks directly onto natural sand beds without chlorination. The sand beds were described as being "more than 25 feet in depth"(1). "The final effluent becomes groundwater, which in all probability, seeps eventually to some water course as a highly purified liquid which cannot be identified as a sewage effluent."(1)

When the original treatment plant was designed and constructed, the population estimate for the area varied from approximately 1500 persons in winter to about 5000 at the peak of the summer tourist season. In order to allow for this approximate threefold increase in population, the treatment system was built essentially in triplicate, using one-third of the system for wintertime flows and the entire plant for summertime flows.

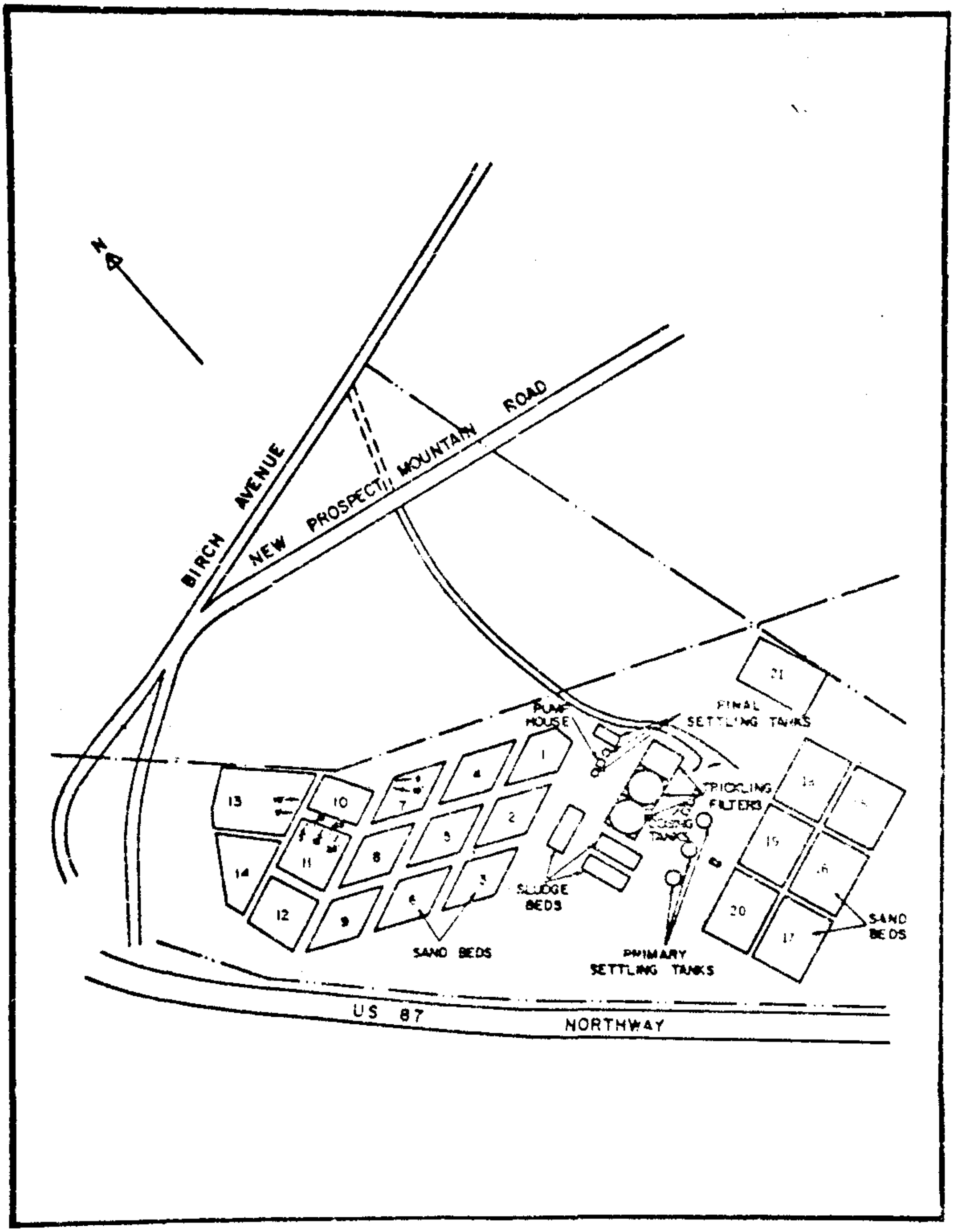
The present population estimates[2] being served by the treatment system are 2,100 persons in winter and 12,300 in summer. Initially, there were six sand beds at the treatment plant with a total area of approximately 72,000 sq ft (6,690 sq m). Presently, there are 14 sand beds in the area where the original six were located plus an additional seven sand beds at a higher elevation above the primary settling tanks. The total area of these combined beds is 6.4 acres = 279,000 sq ft (2.6 hectares = 26,000 sq m). The general layout of the plant is shown in Figure 1.

When the original plant was built, the primary concerns in sewage treatment were the disposal of the liquid effluent and the sanitary quality as measured by the coliform count. Twenty-five feet of soil was considered adequate to remove the coliform bacteria which also meant the absence of pathogenic bacteria. However, no tests had ever been performed to show positively the removal of coliforms by passing through the sand beds. In recent years we have realized that sanitary quality is not the only parameter by which to judge the efficiency of a treatment system. Inorganic compounds present in the sewage may be unaffected or even increased by normal sewage treatment processes. When these are discharged to a receiving body of water, they may act as nutrients which may stimulate biological growth in these waters. Nitrogen and phosphorus compounds are recognized as being present in sewage treatment plant effluents. Very frequently, these compounds are limiting nutrients in a lake. Therefore, it is expedient to be sure that the inputs of nitrogen and phosphorus to Lake George are kept to a minimum.

PREVIOUS STUDIES

In a continuing effort to evaluate the efficiency of treatment by

FIGURE 1



LAKE GEORGE VILLAGE SEWAGE TREATMENT PLANT the Lake George Village sewage treatment plant, numerous studies have been conducted by Rensselaer Polytechnic Institute (RPI), the New York State Health Department and the New York State Department of Environmental Conservation. The original studies by RPI in the late 1960's showed the quality improvement as the sewage effluent passed through the first top 10 ft of the sand beds(3). The results showed there was adequate removal of coliforms, BOD, ammonia nitrogen and Kjeldahl nitrogen and apparent oxidation of the reduced nitrogen to nitrate. The phosphorus seemed to be better removed in a bed which had been idle for a period of time rather than a bed that had been in continuous use. More recently, resistivity studies were conducted to determine the direction of flow of the water after it was discharged onto the sand beds. These results(4) indicated that the flow was northerly from the sewage treatment plant along Gage Road in the direction of West Brook which ultimately flows into Lake George. Further investigation revealed considerable seepage from the ground onto the areas adjacent to West Brook. This instigated the installation of wells and the monitoring of the water in the wells and from the seepage along the banks of West Brook. This last study(5) indicated the quality of the groundwater as it passed from the treatment plant to West Brook during the summer of 1973. It also indicated some changes which could be made to improve the usefulness of the results. This present study includes a full year's collection of data from April of 1973 through May of 1974. In addition, two new wells have been installed in order to improve the data as recommended in the last report.

INSTALLATION OF WELLS

In order to evaluate the quality of the groundwater, a series of wells was installed in the sand beds, between the sand beds and West Brook, and at a location which is unlikely to be affected by the discharge onto the sand beds. The location of these wells is shown in Figure 2. Well 1 is located

LOCATION OF WELLS RELATIVE TO THE

LAKE GEORGE VILLAGE SEWAGE TREATMENT PLANT

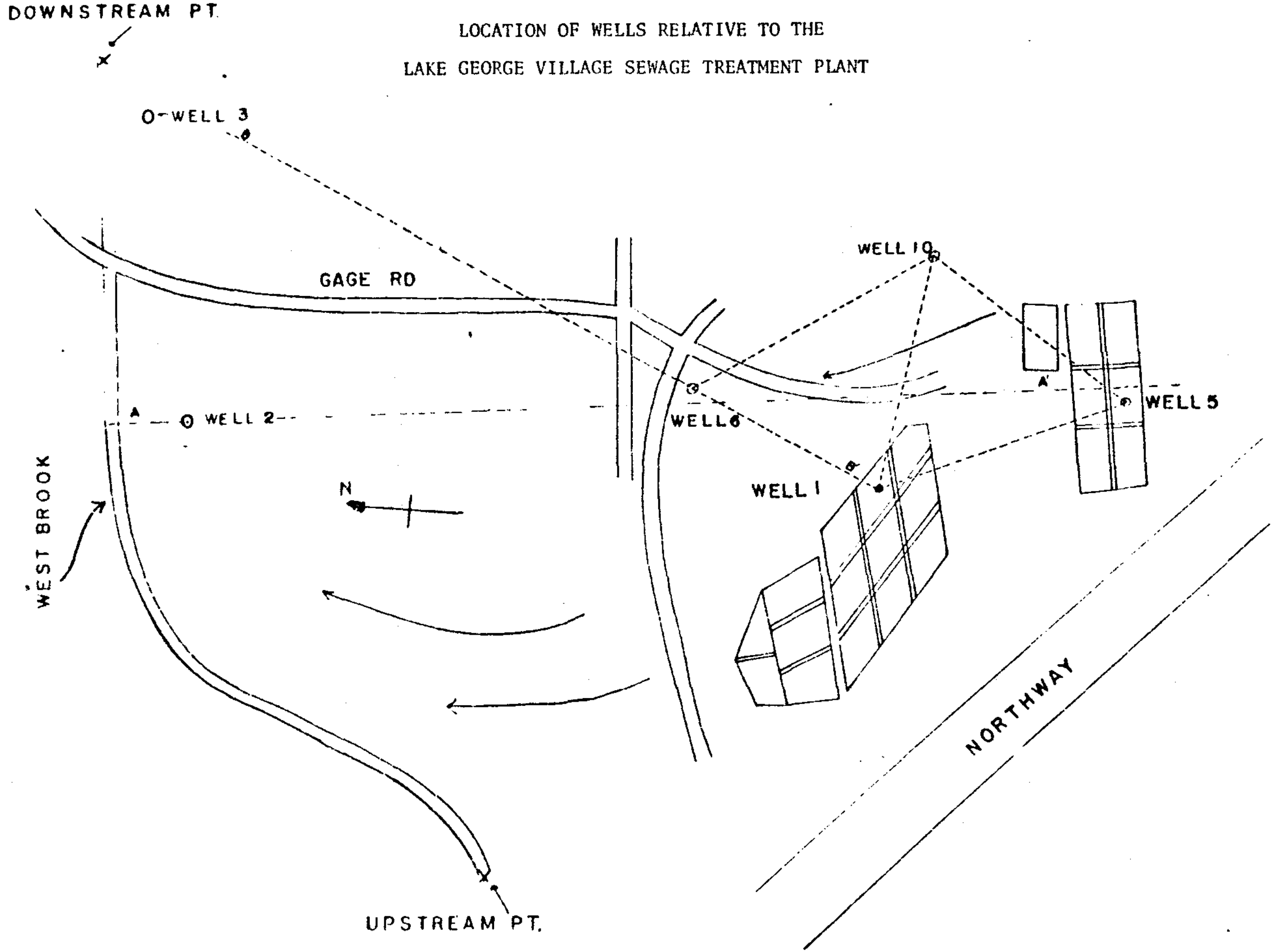


FIGURE 2

approximately in the center of the lower seepage bed no. 4. Wells 2 are located approximately halfway down the steep portion of the slope which forms the valley of West Brook. At the location of wells 3, there are four points at four different elevations: well 3A being the uppermost and 3D being the deepest. These wells are located adjacent to a significant seepage of water from the base of the hill along the bank of West Brook. Well 4 - intended to be installed upstream from all potential sources of groundwater contamination north of West Brook, near Sewell Street, and close to the Northway - was never installed due to encountering rocks before the water level was reached. Well 5 is located in upper sand bed no. 16. Well 6 consists of two different depths. The original well was labeled well 6 and is now 6B since it is at a deeper level than the new well, 6A. The shallower well was installed as a result of the previous studies which indicated that the depth of the point was quite deep into the aquifer and may not necessarily have represented the effect of the sewage seeping through the sand beds to the groundwater. There are no wells numbered 7, 8, and 9. Well 10 is located in a field slightly east of the sewage treatment plant and was intended to represent uncontaminated groundwater. Samples were also taken in West Brook where Sewell Street crosses the stream above any areas of seepage, and at a location sufficiently far downstream to insure adequate mixing of the seepage which enters West Brook in this area. Specific data indicating the depth, surface elevation, groundwater elevation, bottom of the well point, and the bedrock elevation are summarized in Table I and visualized in Figure 3. From Figure 3, it may be seen that the water depth of the aquifer in wells 5 and 10 is quite shallow; it is medium in

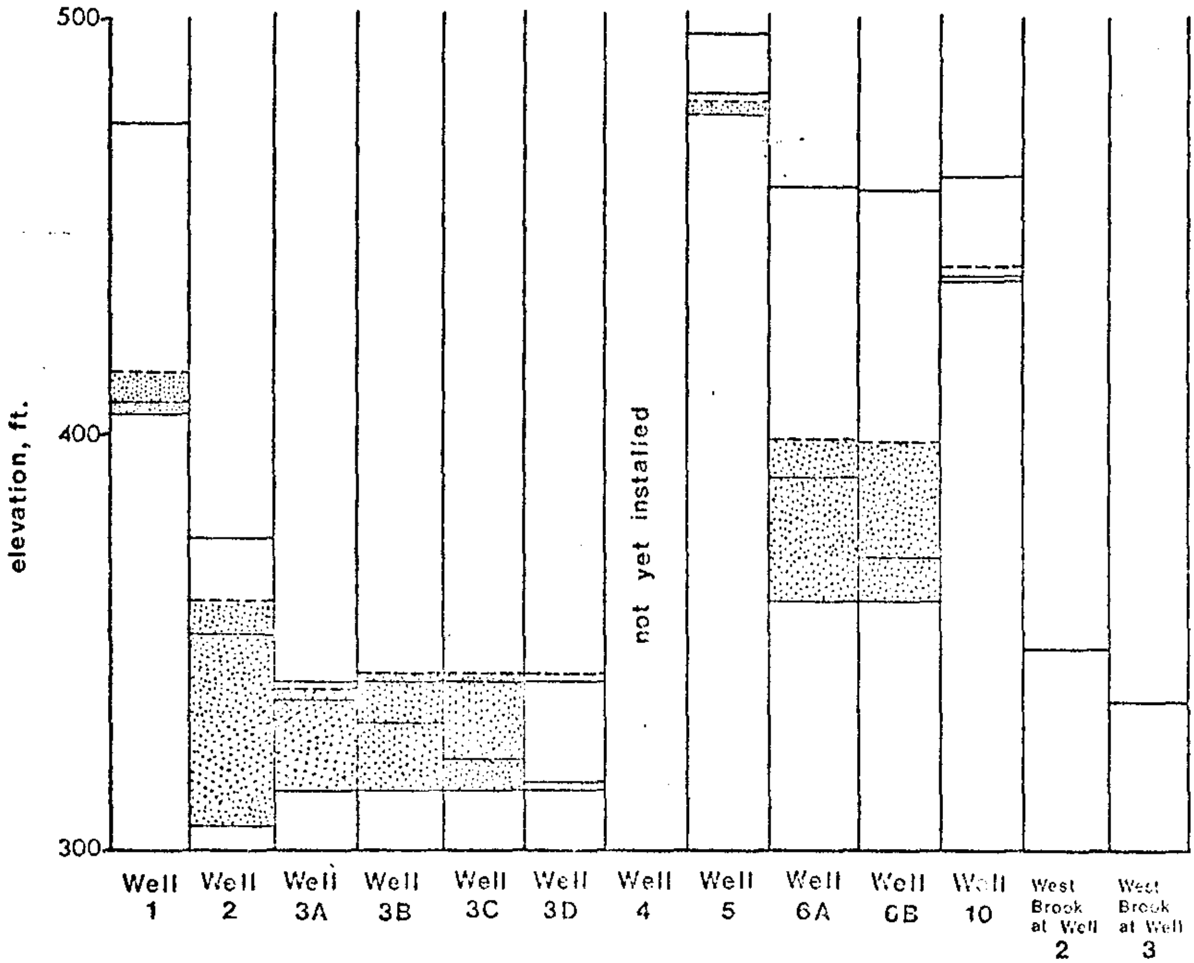
TABLE 1

WELL DATA

	Surface Elevation	Groundwater Elevation	Bottom of Point	Bedrock Elevation
Well 1	475.0	415.66	407.80	405.0
Well 2A	375.40	359.22	352.13	306
Well 2B	375.40	359.2	330.35	306
Well 3A	339.90	339.74	336.44	314
Well 3B	339.90	340.01	329.06	314
Well 3C	339.90	340.08	321.23	314
Well 3D	339.90	340.0	315.64	314
Well 4	-	-	-	-
Well 5	495.37	480.98	479.40	477.40
Well 6A	458.7	397.6	370.68	360.0
Well 6B	458.7	397.6	388.13	360.0
Well 10	462.73	441.7	438.91	438.91
West Brook at Well 2	348.0	-	-	-
West Brook at Well 3	334.9	-	-	-

FIGURE 3

WELL DATA



Upper solid line is ground surface level

Upper broken line is ground water level

Next solid line is bottom of well point

Bottom solid line is bedrock level

Shaded area represents ground water saturation well 1 and quite deep in wells 2, 3, and 6. The various depths of the well points in wells 3 and 6 are clearly shown in this figure. The newer well 2B is not shown in Figure 3. In all the figures, the designation well 2 refers to well 2A.

RESULTS

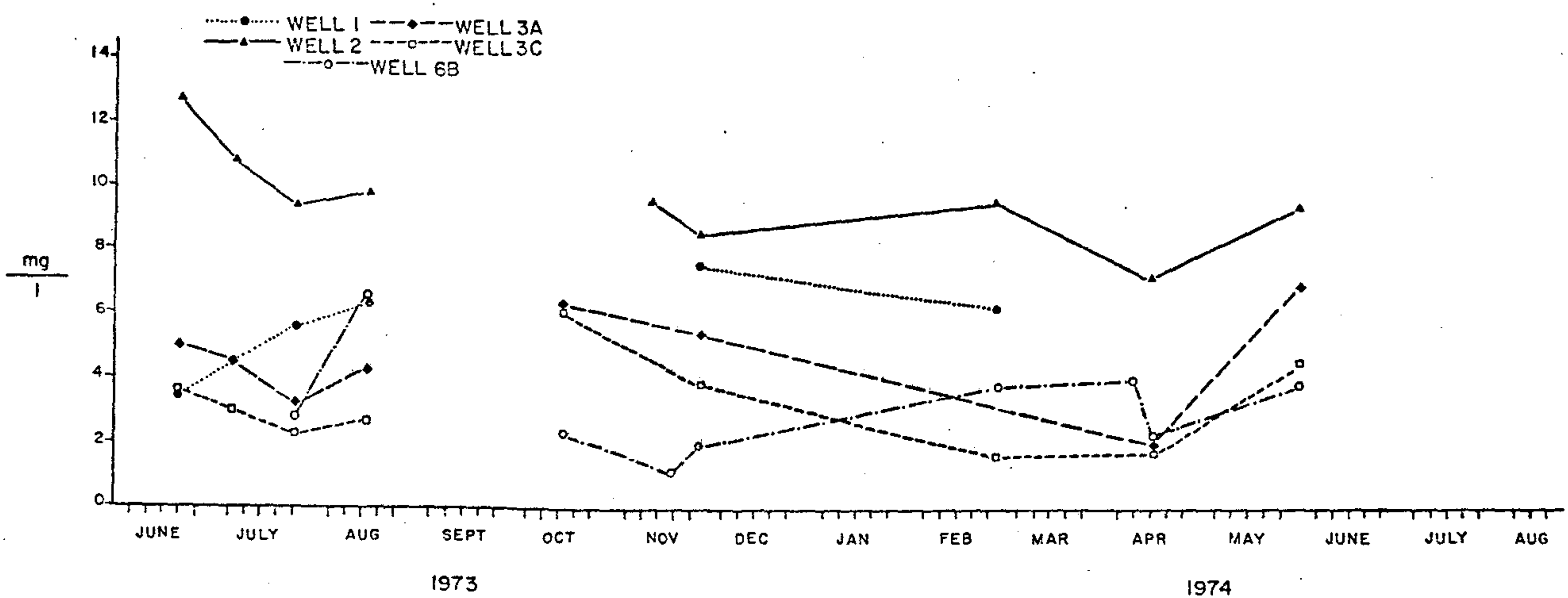
In order to provide more complete information, the initial studies from April 1973 through the middle of August 1973 are included with the more recent data which were accumulated from October 1973 through May 1974. The gap during September 1973 is indicated by a break in the lines in the figures. Samples were secured at the wells and at the upstream and downstream locations in West Brook and tested for temperature, dissolved oxygen, dissolved solids, pH, alkalinity, chloride, total soluble phosphorus, nitrate nitrogen, and total Kjeldahl nitrogen. In addition, the depth of the groundwater was measured in the wells at each sampling time. In order to condense the data for presentation, five wells were selected as representative of the quality of the groundwater as the effluent passes through the sand beds to West Brook. Well 1, located in the middle of sand bed 4, represents the quality of the groundwater immediately below the sand bed. Wells 6 are located approximately 500 ft (150 m) from the lower sand bed toward the direction of West Brook. Well 6B was chosen instead of well 6A for continuity of results from the original data. Wells 2 are located approximately 2000 ft (600 m) from the lower sand beds toward West Brook and are quite close to West Brook. Wells 3 are approximately the same distance from the sand bed as wells 2, but in a more easterly direction. They are located on the flood plain of West Brook in an area where considerable seepage occurs from the side of the hill adjacent to the flood plain. As a matter of fact, on numerous occasions the groundwater level at wells 3 was at or above the surface of the ground in the area.

Well 3A represents the surface conditions inasmuch as this is essentially at the surface whereas well 3C is 21 ft deep and represents the quality of the water at a greater depth in the aquifer. Thus by following the quality of the water from well 1 through wells 6 to wells 2 and/or wells 3, the effect of distance from the sand beds can be evaluated. The results are separated into two categories for discussion: (a) the DO indicates the condition of the water in the ground; and (b) the phosphorus and nitrogen indicate the nutrient transport to that point and/or dilution by the available groundwater. On February 28, 1974, well 3A was frozen and a sample could not be secured from it. Also, sometime between February 28 and April 16, 1974, the pipe of well 1 apparently was broken, as the well was plugged with bentonite clay similar to that used to seal the outside of the pipe. This prevented obtaining a sample from well 1 after this time.

A. Groundwater condition

It is desirable to maintain aerobic conditions in the ground. This allows for removal of pathogenic bacteria and oxidation particularly of the reduced nitrogen compounds to nitrate. Figure 4 shows the dissolved oxygen for the typical wells. In general, the DO in well 1 was intermediate between the other wells, ranging from a high of about 7 mg/l to a low of 3 mg/l in July. By the time the water reached well 2A, the dissolved oxygen was quite high, ranging in general between 8 and 13 mg/l; however, other data showed well 2B contained much less DO. Well 6B was quite low in DO, possibly indicating the utilization of dissolved oxygen from the groundwater by the organic matter in the effluent applied to the sand beds. Low dissolved oxygen contents were found in wells 3, with well 3A being consistently higher in DO than well 3C. In general, these two wells had a DO content ranging between 1 and 5 mg/l with the lowest values being observed during late winter.

FIGURE 4:
DISSOLVED OXYGEN



Although the DO content was low at certain times, there appeared to be dissolved oxygen present in the groundwater at all times during the study.

B. Nutrients

The total soluble phosphorus of the representative wells is shown in Figure 5. In all cases the phosphorus at well 1 immediately in the groundwater below the sand bed was the highest of all. The concentration ranged from about 200 to 700 μg/l with no particular trend. It is felt that this represents the influence of the sewage discharged to the sand beds. The total soluble phosphorus content of well 6B was usually low, being less than 30 μg/l with the exception of the samples on October 17 and November 29, 1973, at which times it was 100 μg/l. Wells 3A and 3C were quite similar to well 6B, both being less than 60 μg/l of total phosphorus with the exception of the high value of 100 μg/l on November 29, 1973.

Under aerobic conditions, Kjeldahl (organic plus ammonia) nitrogen should be oxidized to nitrite and then nitrate. Thus the distance from the treatment plant should result in an increase in the nitrate nitrogen, although dilution and ammonia absorption on the sand may moderate this increase. This is not the case as shown in Figure 6. There was an extreme variation in the nitrate content of well 1 from approximately 1 mg/l to over 14 mg/l. This is considered to represent the loading to the sand beds. For proper interpretation of these values, a schedule of bed loading must be included. Well 6B showed consistently low values, never exceeding 4 mg/l during the study. Well 2A was intermediate in nitrate content, ranging between 2 and 8 mg N/l. The lowest values of nitrate nitrogen were found in well 3A which never exceeded 4 mg/l of nitrogen. This suggests poor oxidation occurring at this location. On the other hand, the deeper well 3C showed nitrate concentrations in the same range as those of well 1 and in some instances, even greater values. It is possible that the very low values of nitrate in well 3A represent

FIGURE 5

TOTAL SOLUBLE PHOSPHORUS

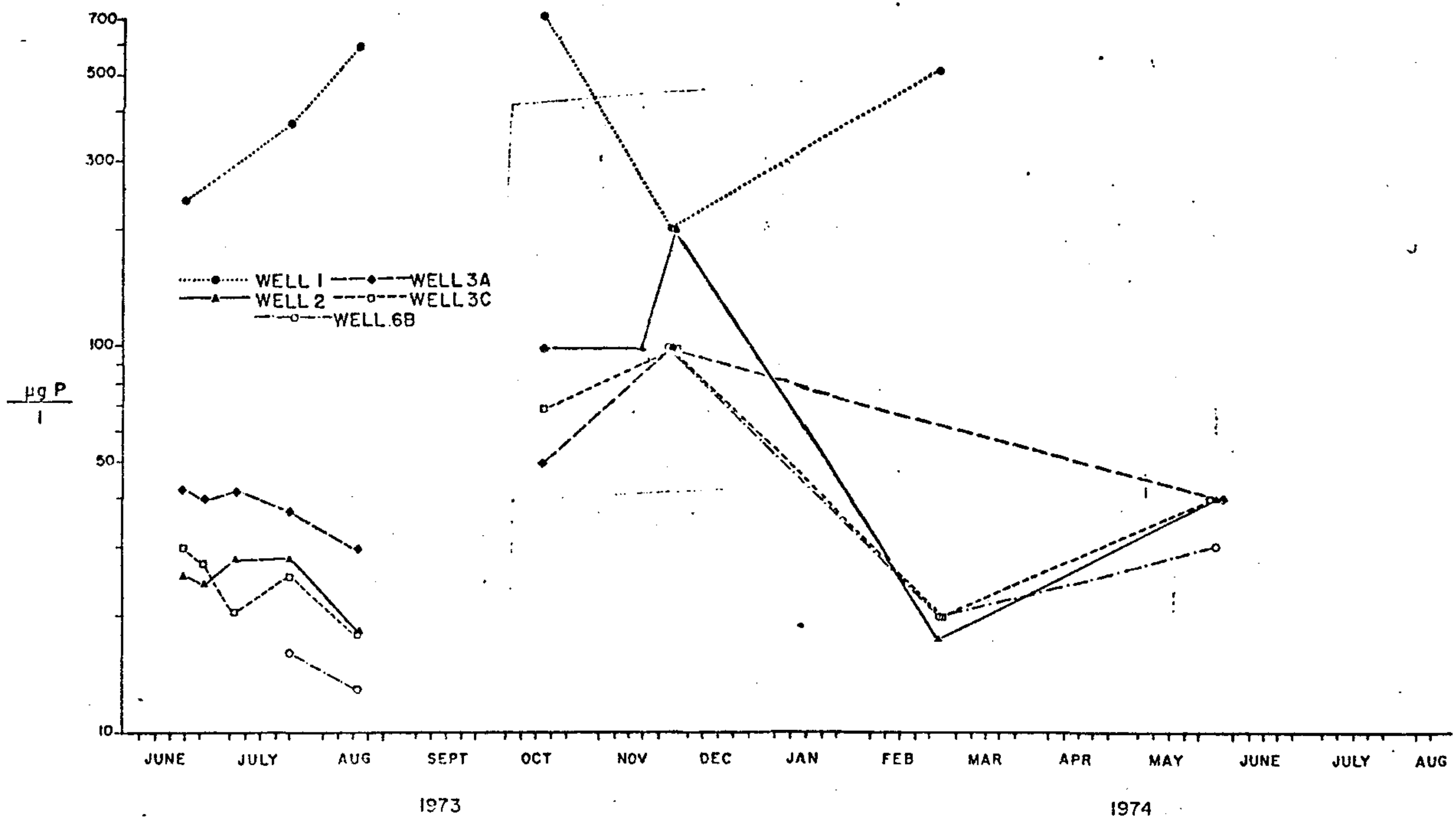
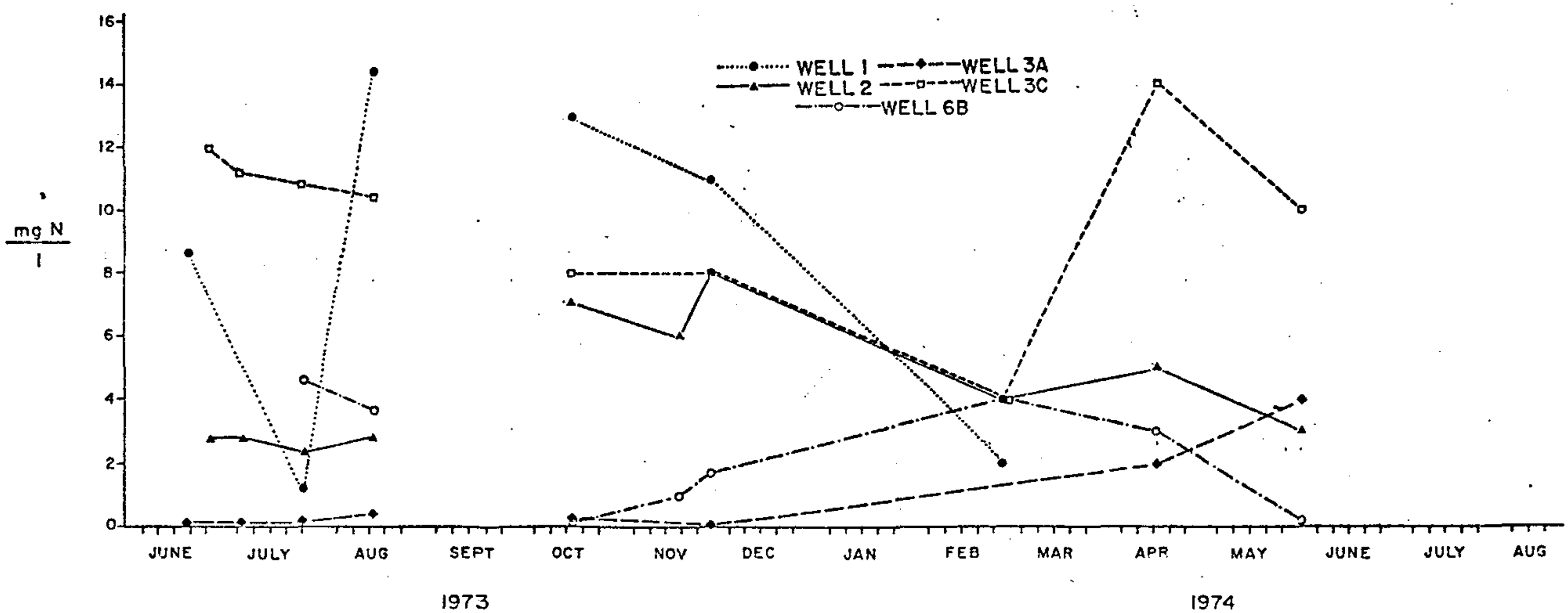


FIGURE 6

NITRATE NITROGEN



dilution near the surface by water low in nitrate content. As was mentioned, the groundwater in this area is just at the ground surface.

SUMMARY AND CONCLUSIONS

With extending the studies of the wells in the neighborhood of the Lake George Village sewage treatment plant effluent through a full year, additional information has been gained as to the quality of the groundwater as it reaches and influences West Brook. There are still some inconsistencies in the data which are difficult to explain. The dissolved oxygen data indicate the aerobic condition of the wastewater as it enters the ground at well 1, then depletion of the DO in the downstream wells due to the oxidation of organic matter. However, the DO was consistently greater than 1 mg/l in all wells throughout the study. This indicates that aerobic conditions persist.

The total soluble phosphorus generally decreased from the high values found in well 1 in the sand beds; however, the decrease was not always consistent with distance. During the Fall of 1973, the phosphorus content of well 2 was higher than in any of the wells other than well 1. The very little data obtained from well 6A indicate that the phosphorus concentration in well 6A is slightly higher than that in well 6B. It is believed that when sufficient data are obtained, the phosphorus content in well 6A will be intermediate between that of well 1 and the other wells farther from the sand beds. There is little significant difference between the phosphorus content of wells 6B, 3A, and 3C. There definitely was significant reduction in the phosphorus content as compared to that observed in well 1.

Wells 1 and 3C competed with each other for the highest nitrate content. Well 2 was intermediate in nitrate content and wells 3A and 6B were generally the lowest in nitrate content. No data are available at the present time on the nitrate content of the newer well 6A which is also shallower and would represent more truly the sewage effluent that is applied to the top of the natural groundwater in the area. It is also possible that the nitrate content of well 3A is diluted by other surface water seepage to this shallow well.

Additional studies are being planned for this sand system. This includes hydrologic studies, stream flow measurements, time of passage measurement, tracer studies to confirm the flow and the time of flow from the treatment plant to West Brook, the addition of more wells in the area and the manipulation of the application of the effluent to one of the sand beds. It is anticipated that all of these additional studies will provide further information on the ability of natural delta sand deposits to provide adequate tertiary treatment of a sewage treatment plant effluent.

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