MONITORING FOR LAND APPLICATION OF WASTEWATER

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ABSTRACT

In order to assure adequate performance and warn of potential ground water contamination, land application systems must be monitored. The monitoring system for the Lake George Village Sewage Treatment Plant land application system is described, including suction lysimeters, observation wells and tracer studies.

MONITORING FOR LAND APPLICATION OF WASTEWATER

INTRODUCTION

The 1972 amendments to the Water Pollution Control Act (PL92-500) indicated that land application of wastewaters should be considered as an alternative to conventional means of wastewater treatment. However, very little attention was paid to this portion of the regulation until EPA Director, Douglas Costle issued a memo on October 3, 1977[1] reaffirming EPA's stand that land application must be considered as an alternative in wastewater treatment. This was further substantiated by the Clean Water Act of 1977 (PL95-217) in which it was stated that innovative and alternative methods of wastewater treatment must be considered in all plans for treatment facilities before approval or funding for any proposed system could be made. Land application was considered to be one of the acceptable innovative or alternative treatment methods. Not only did the law encourage the consideration of innovative and alternative methods, it promised a bonus of 10% additional funding for all treatment facilities which would incorporate such treatment methods. Thus, it became worthwhile for the design engineer to consider the feasibility of such a treatment system in the design of any wastewater treatment facilitiy.

Land application of wastewater is normally considered to take one of three forms: 1) irrigation, in which the partially treated wastewater is applied to the soil during the growing season in order to enhance crop production, but not to recharge ground water; 2) overland flow, in which treatment is afforded by flowing settled wastewater overland through the vegetated area with no infiltration into the soil, and 3) rapid infiltration, which involves the spreading of the partially treated effluent onto beds containing coarse sand which allows the liquid to infiltrate the soil and percolate to the ground water, thereby recharging the ground water. To a certain degree the use of septic tanks may also be considered a method of land application of wastewater, albeit subsurface application. Since in a normal system the effluent from a septic tank is distributed into the soil where its flow pattern is generally unknown, it may be assumed that it probably percolates through the soil to mix with the ground water. The studies described herein relate primarily to the rapid infiltration technique of land application, but they also have application to septic tank systems in which the water applied to the distribution system ultimately reaches a ground water course.

One of the prime concerns is what happens to the liquid effluent after it enters the ground? It is difficult to follow the flow of liquids through the soil, but the possible contamination of any ground water supplies due to the soluble materials carried through the soil in the liquid phase is an important area for investigation. In order to identify any possible contamination before it interferes with any subsequent use of the ground water, a monitoring system must be established. This monitoring system must be able to identify the liquid being applied as well as sample it for analysis to determine the quality of the water. It is such a system which is described herein.

BACKGROUND

The Lake George Village Sewage Treatment Plant has been providing land application by the rapid infiltration technique of the secondary treated effluent of wastes from the southern tip of Lake George since 1939. The preliminary treatment involves sedimentation in clarigesters which are two-compartment tanks providing for sludge digestion, application to trickling filters, secondary sedimentation, and rapid infiltration of the unchlorinated secondary sedimentation effluent onto one of the 21 sand beds. The layout of the sewage treatment plant is shown in Figure 1. The original infiltration area consisted of the first 6 sand beds at the north end of the treatment plant. These and the other sand beds at the north side

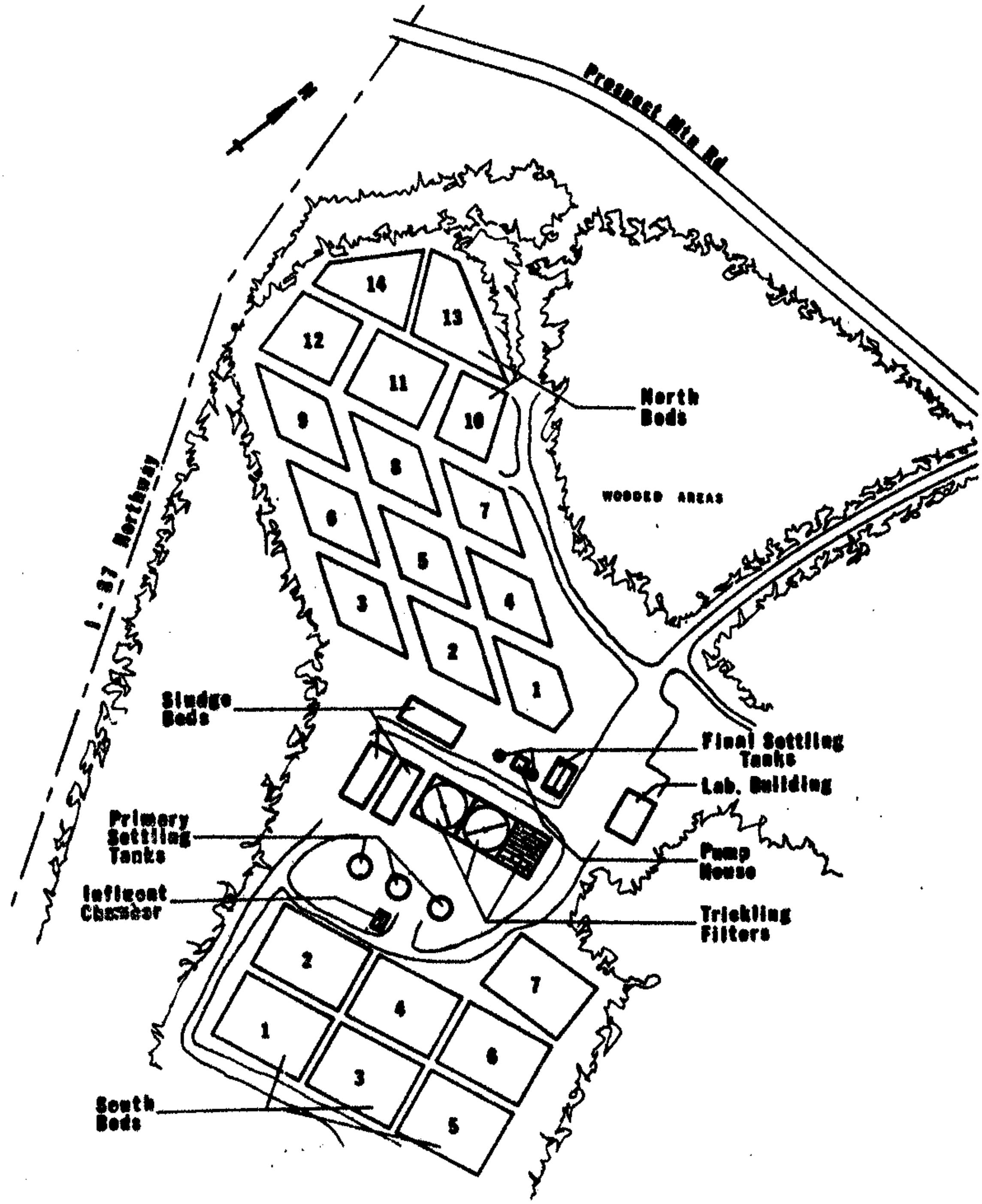


FIGURE 1
PLAN OF THE LAKE GEORGE SEWAGE TREATMENT PLANT

of the treatment plant are all fed by gravity. Later enlargements to the sewer system dictated significant expansion of the sand bed area and the creation of the beds at the south end of the plant, which are dosed by means of a pump. Normal operation of the sand beds is to operate them intermittently, dosing one north and one south bed during the daytime period of 8 am to 4 pm and another similar pair of beds from 4 pm to 8 am. On week-ends or holidays two pairs of beds are dosed for a 24 hour period. At times during peak summer flows, additional beds are placed into service as needed. Under normal operation the beds dry in from 1 to 3 days and then are allowed to dry for 1 to 3 days before being dosed again. Periodically, the beds are allowed to dry thoroughly, the top layer of clogging material scraped off, the beds disked and raked back to a level condition, and then put back into use. Numerous studies have shown that these sand beds continue to remove all of the BOD, coliforms, suspended solids, and phosphorus from the wastewater and approximately 50% of the total nitrogen applied to the sand beds.[2-11] These studies have confirmed the original statement made by Vrooman[12] in 1940 who, in his initial description of the treatment plant, stated that "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". However, it took considerable time and effort in recent years to confirm Vrooman's original statement. It is the monitoring system that was used to obtain the results to confirm Vrooman's statement that is described in this report.

MONITORING SYSTEM AT LAKE GEORGE

A monitoring system for evaluating the ground water from a land application system must provide two features: 1) it must provide access to the water which is being applied to the ground, preferably both in its percolation in the unsaturated zone and its flow in the saturated zone; and 2) there must be some assurance that the liquid being sampled is truly that which is being applied to the ground. Several monitoring systems were utilized at Lake George and studies were conducted to confirm that the samples being secured actually did originate from the land application system.

The greater problem is securing samples in the unsaturated zone. In a rapid infiltration system, a sand bed is usually dosed with 0.5 to 1 m of water which infiltrates the soil downward to the ground water table. There may be an upper layer of sand which is saturated with water, but this condition rapidly transform to an unsaturated condition as the liquid migrates downward. When the ground water table is reached or mounding caused by the application of the water occurs, saturated conditions appear in the soil. It is in the unsaturated zone that it is difficult to secure representative samples.

One technique for securing samples is the surface driving of a well point with a screen and appropriate sections of pipe. At Lake George numerous well points of this type were installed by hand using 1 1/4" (3.175 cm) drive pipe. A drive cap was placed at the top of the upper section of pipe and this was pounded into the ground by means of a 114 kg (250 lb) weight which was supported by a tripod and raised by means of a cathead, thereby, driving the point into the sandy soil. The maximum depth that could be achieved by this technique in the sandy Lake George soil was approximately 17 m (55 ft).

Well points of this type were installed in bed N-11 at the Lake George Village Sewage Treatment Plant (see Figure 2). These wells were installed at 2 ft (0.6 m) depth intervals from 2 to 14 ft (0.6-4.25 m). The representative depths are shown in Figure 3. Of these well points, samples were secured in only the shallowest point. This can be readily understood in considering that the pipe is vertical and that any liquid

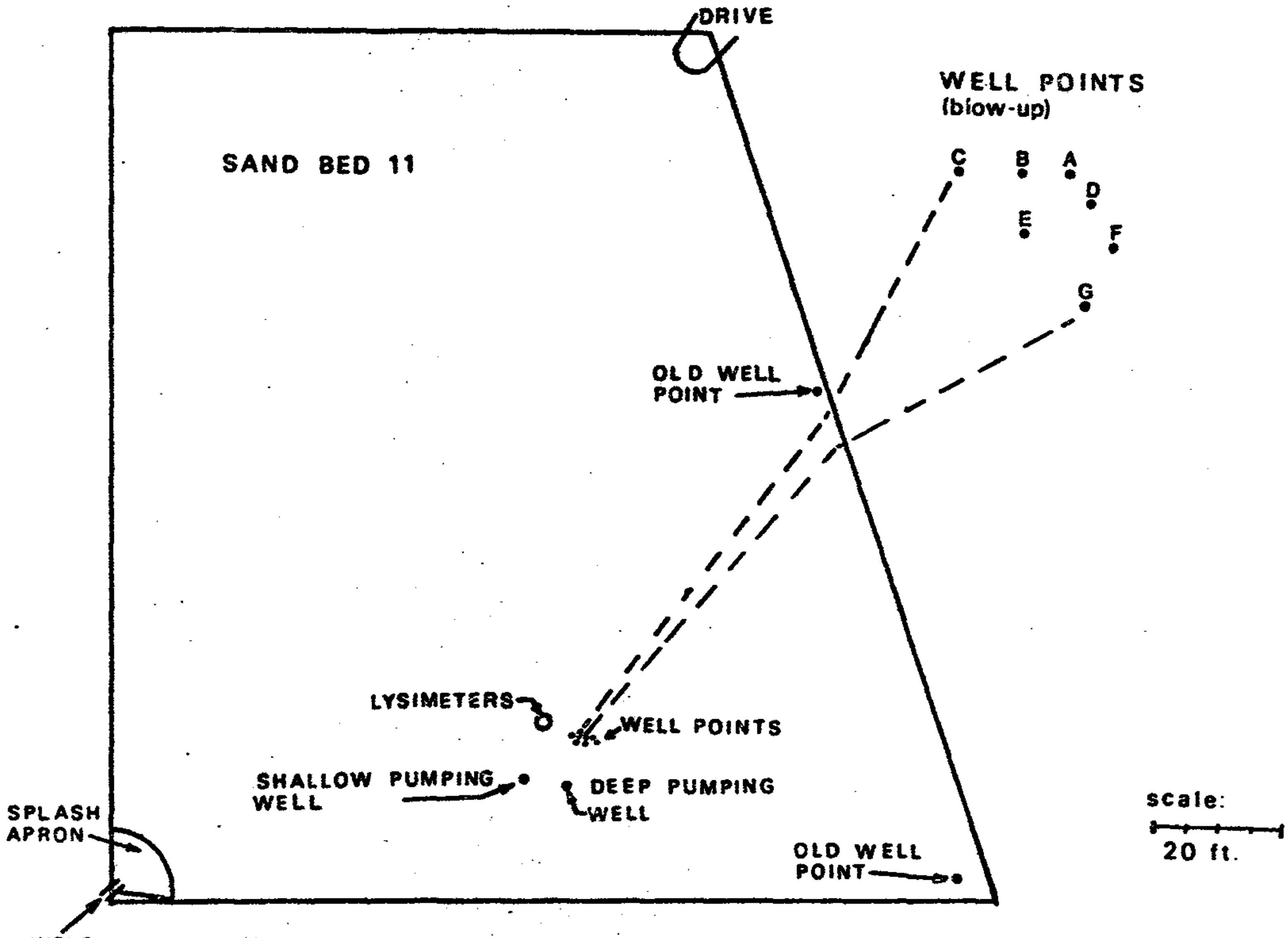
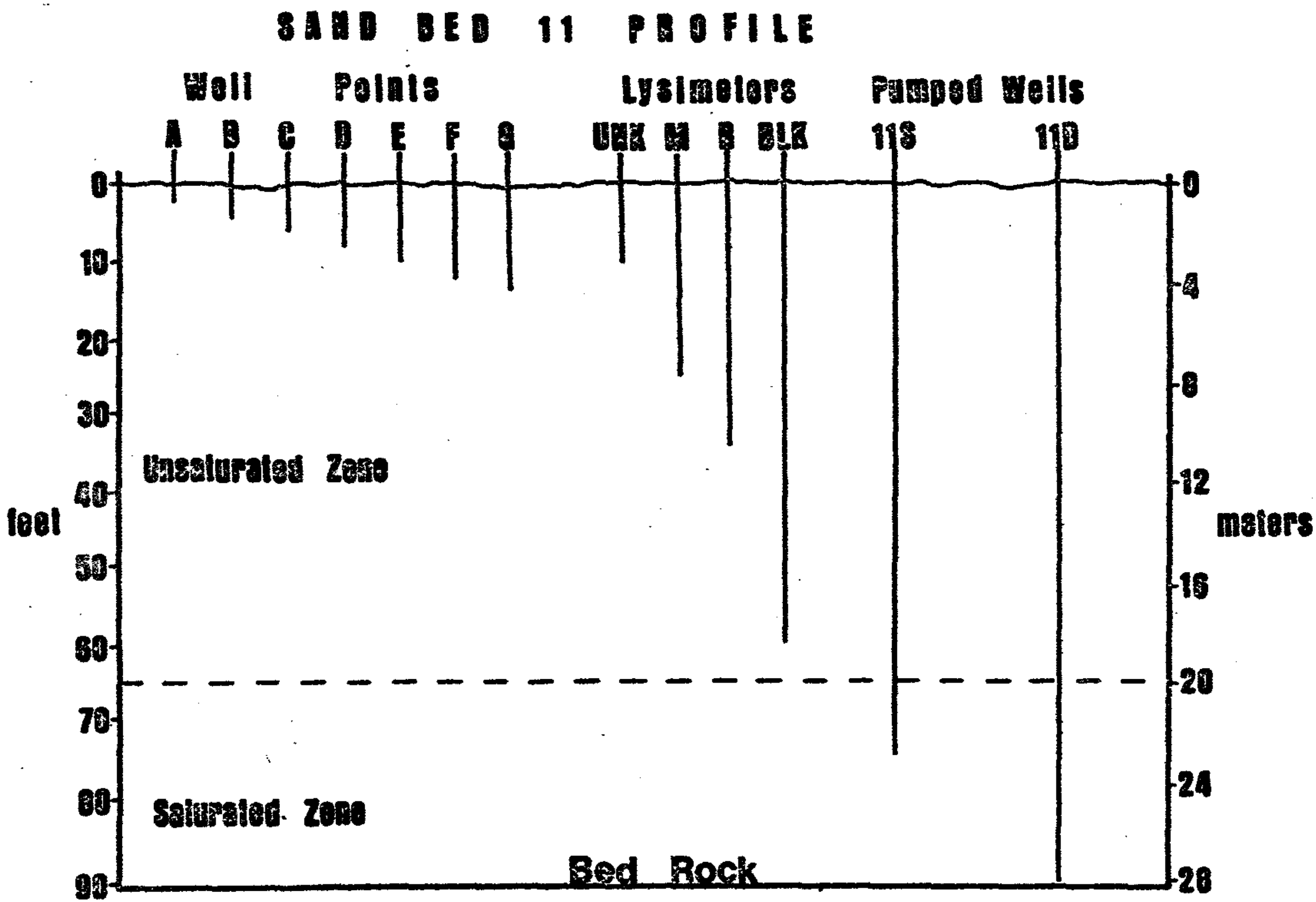


FIGURE 2
PLAN OF BED N11 SHOWING THE LOCATION OF THE DRIVEN WELL POINTS,
THE LYSIMETERS AND THE SHALLOW AND DEEP PUMPING WELLS

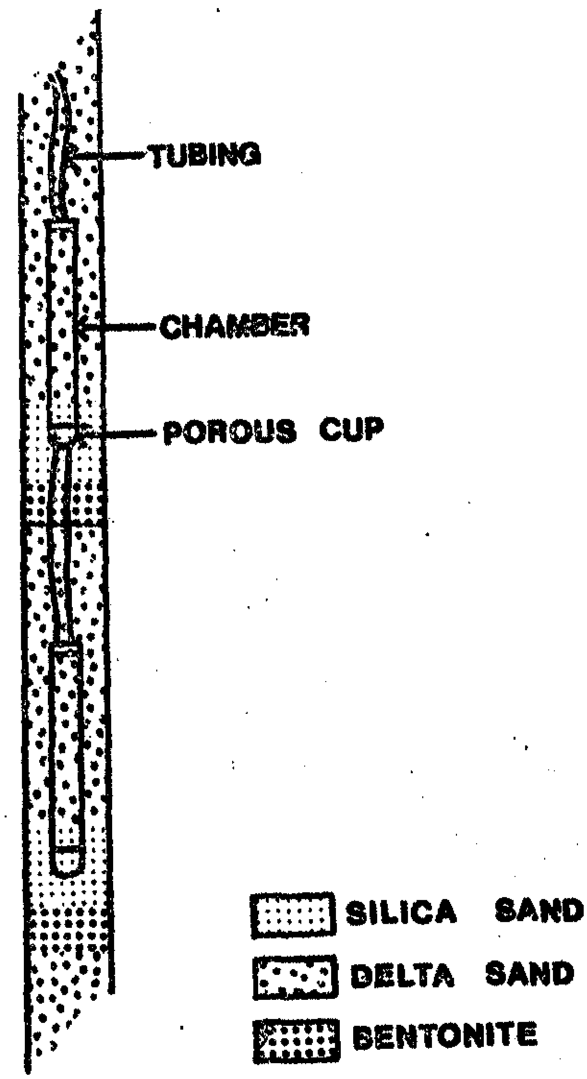
FIGURE 3
PROFILE OF SAMPLING WELLS AND LYSIMETERS WITHIN SAND BED N11



percolating through the sand would also flow in a vertical pattern. Some of the liquid which would flow down the pipe may enter the screen and be collected in the point. However, the amount of this could be expected to be very small. In all the instances that samples were secured from the shallowest well point, the amount collected was indeed quite small. Surprisingly, in previous studies by Glavin and Romero Rojas[13] they were able to secure samples from well points at depths of 5 and 10 ft (1.5 and 3 m). It is possible that during their studies, due to continued use of this sand bed, the bed was saturated with water to these depths. Thus, more water flowed into the screen and was collected in the well points. Even then, large volumes of water were not collected. In general, it may be stated that this type of collector well is not satisfactory for use in unsaturated areas to collect water percolating vertically through the soil.

Suction cup lysimeters have been recommended for securing samples in the unsaturated zone. A typical lysimeter and its installation are shown in Figure 4. The lysimeter consists of a porous cup attached to a hollow chamber. Two tubes are attached to the hollow chamber, one for drawing a vacuum on the system for sampling and then for applying pressure to remove the collected samples via the second tube. A hole is first

FIGURE 4
LYSIMETER INSTALLATION



drilled in the sand with a casing being placed in the hole if it is subject to collapse or if deep holes are required. The lysimeter is placed within the hole and if a casing has been used this is removed as the back-filling of the hole continues. Backfilling is conducted in a manner to surround the porous cup with 100 mesh silica sand. Above this silica sand, sand removed from the bed during the drilling operations may be replaced in the hole. Somewhere along the system, a plug of bentonite clay is used to prevent liquid flowing down along the pipe and directly to the lysimeter cup. This is particularly important where several lysimeters are installed within the same hole but at different depths. The capacity of the lysimeter chamber is approximately 900 mL. Vacuum is applied to the system and approximately a week later the sampler returns to obtain the sample, after which the vacuum is again applied for the next sample. Lysimeters were placed in bed N-11 as shown in Figures 2 and 3. Whereas the lysimeters are more capable of securing samples in the unsaturated zone, they are still subject to certain difficulties. One is that due to the pore size of the porous cup, essentially only soluble materials are collected in the lysimeter. Another problem is that the collected sample remains within the chamber for a period of 1-7 days. More frequent removal of the contents is possible but the sample size is appropriatly smaller. In the case of the studies conducted at Lake George, the minimum sample volume needed for analysis was approximately 1 liter. Thus, samples were secured normally at one week intervals. It is possible that some biological activity may take place within the lysimeter chamber during this whole week period. In addition, studies[14] have shown that there may be as much as 30% error in nitrogen measurement and 17% error in phosphorus measurement due to adsorption in a lysimeter. Phosphorus seems particularly to be one of the problems. In studies conducted by Giencke[15], lysimeters located at the 1.4 and 2.4 m depths consistently indicated zero phosphorus content while lysimeters located above and below these depths always revealed some phosphorus content. Thus, it becomes obvious that for some reason or another the lysimeters at the 1.4 and 2.4 m depth either adsorbed phosphorus in or on the cup or the chamber, or in some manner prevented the phosphorus from entering the porous cup. Thus, while suction cup lysimeters provide a good means for obtaining a sample in the unsaturated zone, some of the results obtained from samples collected in this manner remain suspect in terms of water quality.

There is another technique which may be applied for obtaining samples in the unsaturated zone. This, however, involves considerably more expense and construction. There are two modifications of this. Vaughn and Landry[16] at Brookhaven, Long Island installed concrete manholes to provide a vertical caisson within a sand bed. From this caisson they installed horizontal collector pipes at a slight angle as shown in Figure 5. This allowed the percolating water to enter the collector pipe and be conducted to the caisson where samples could be secured essentially continually. This has the advantage of providing a somewhat larger sample than from lysimeters and avoids the cumulative delay in the time of collection of samples. If necessary, a refrigerated sampling collector could be installed within the manhole in order to preserve the samples until sufficient volume is collected for analysis. A slightly modified but similar system is being proposed for further studies at Lake George as shown in Figure 6. The north edge of all the Lake George Village Sewage Treatment Plant sand beds is somewhat raised above the existing land. Instead of a concrete manhole, a 10 ft (3 m) corrugated steel pipe is intended to be installed vertically to provide the caisson. Instead of installing it within the sand bed, it would be installed just beyond the outer edge of the sand bed to take advantage of the natural slope.

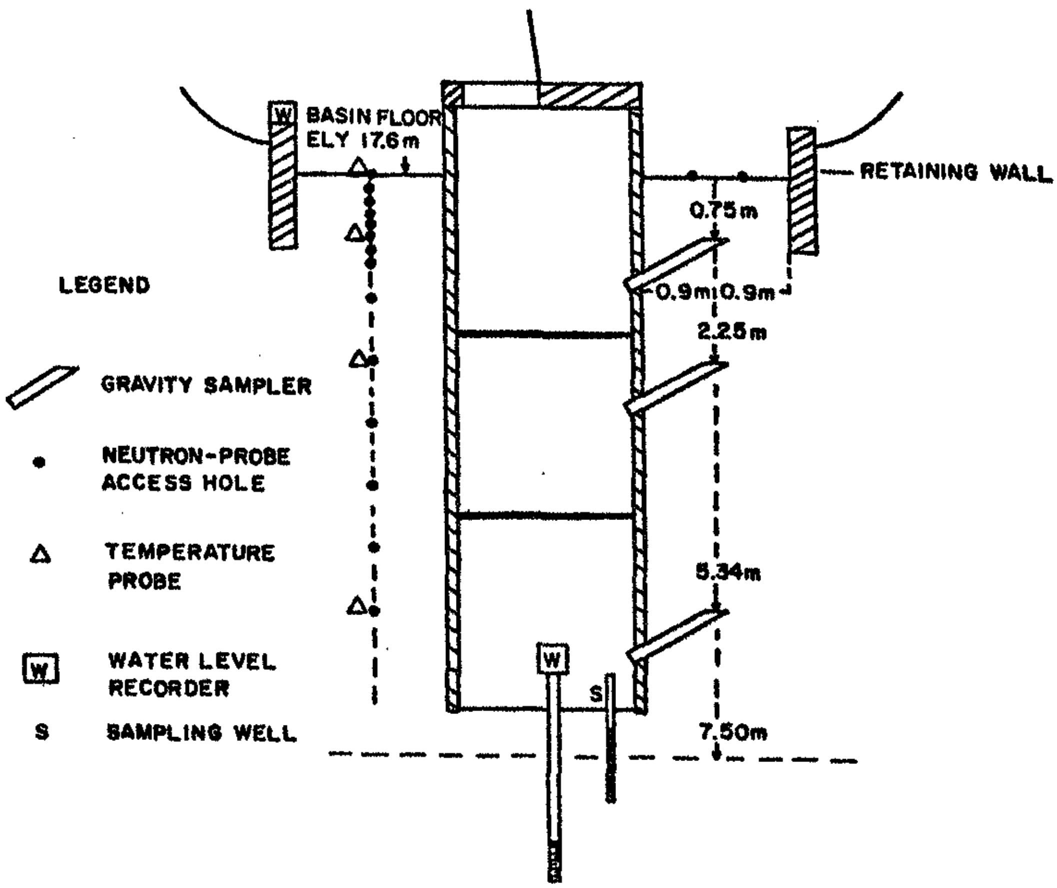


FIGURE 5
SCHEMATIC OF THE TEST BASIN FACILITY.[16]

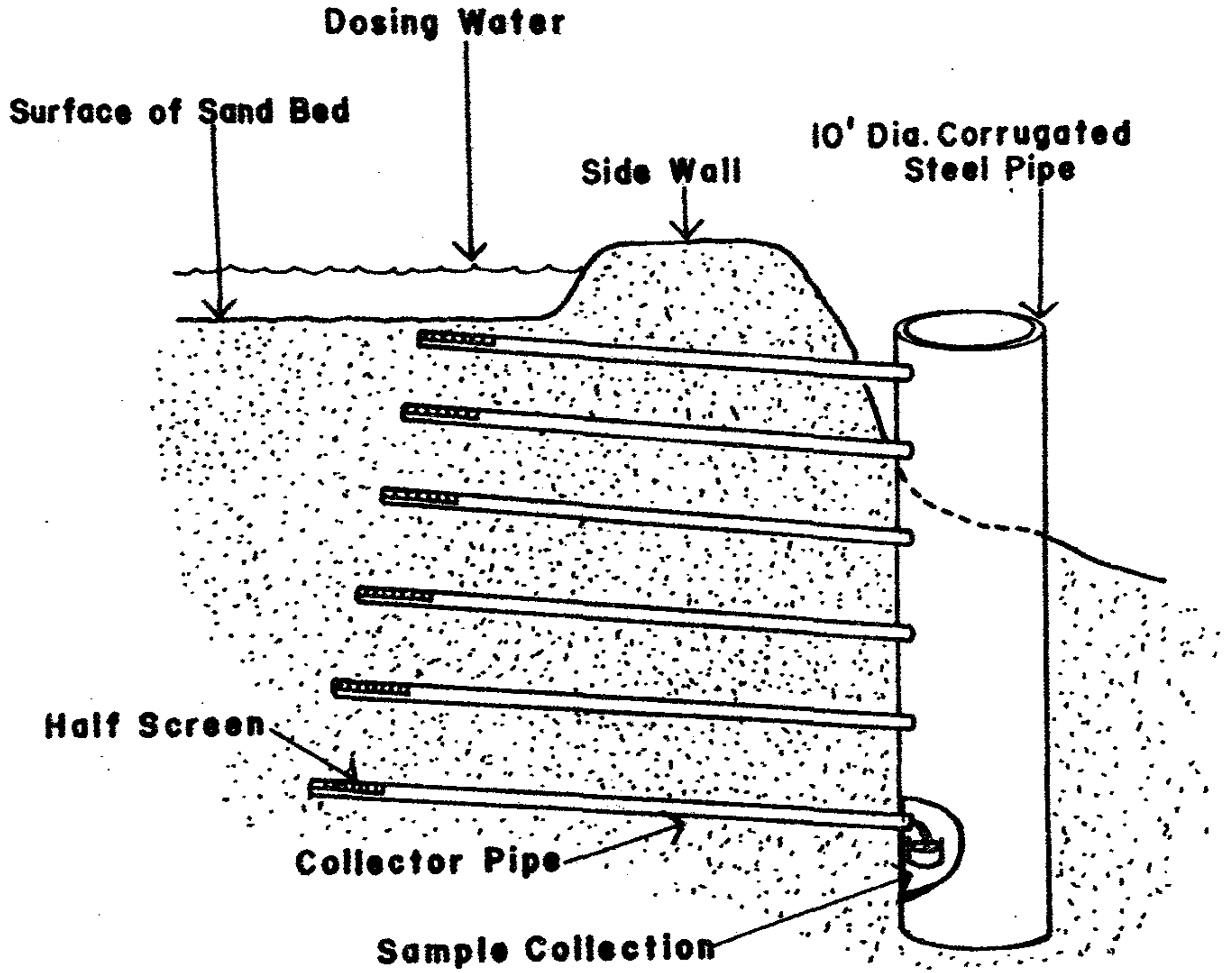
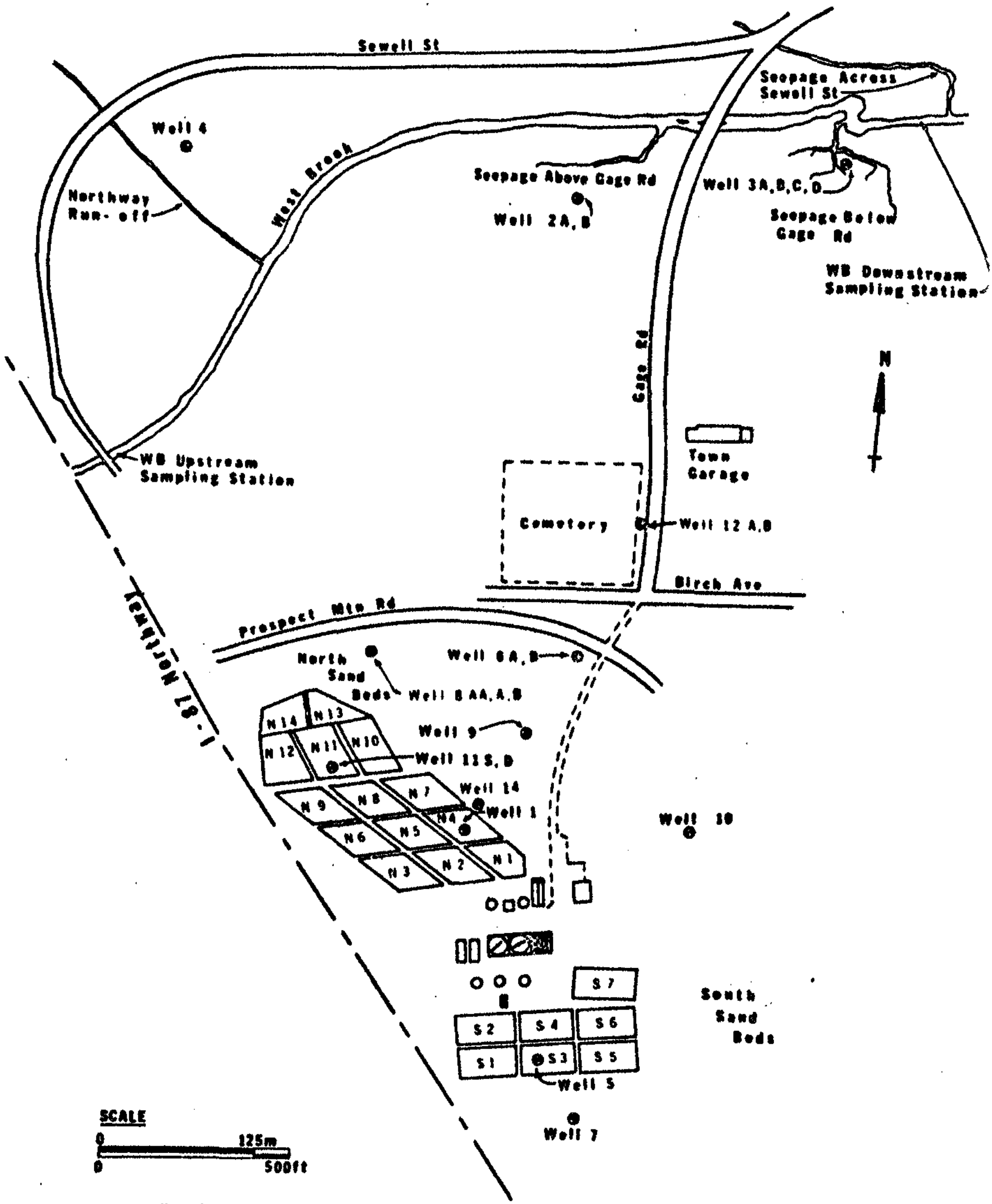


FIGURE 6

TYPICAL INSTALLATION OF HORIZONTAL COLLECTOR WELLS

This would avoid disturbing the sand beds during installation. From this caisson horizontal pipes with half screens would be installed into the percolation zone in the sand bed. As of this time no information is available as to the efficiency of collecting samples with this system; however, problems encountered with the suction cup lysimeters will be avoided and larger samples should be possible. In addition, the horizontal collector screens can be placed at closer intervals and closter to the surface within the sand bed.

For sampling the saturated zone, a standard well point and screen with appropriate connecting pipe to the surface will suffice for obtaining samples. A 1 1/4 in (3.175 cm) steel drive pipe with the point driven to the ground water should usually be sufficient. The observation wells utilized in the Lake George studies are shown in Figure 7. The shallower wells were installed by means of the drive mechanism described previously for the shallow driven wells in bed N-11. For the deeper wells a professional well driller was employed who first drilled by means of an auger a 4 in (10 cm) hole down to the depth desired. Then a plastic screen and pipe was installed in the hole provided. The hole was then backfilled with the sand removed in



AREA OF STUDY

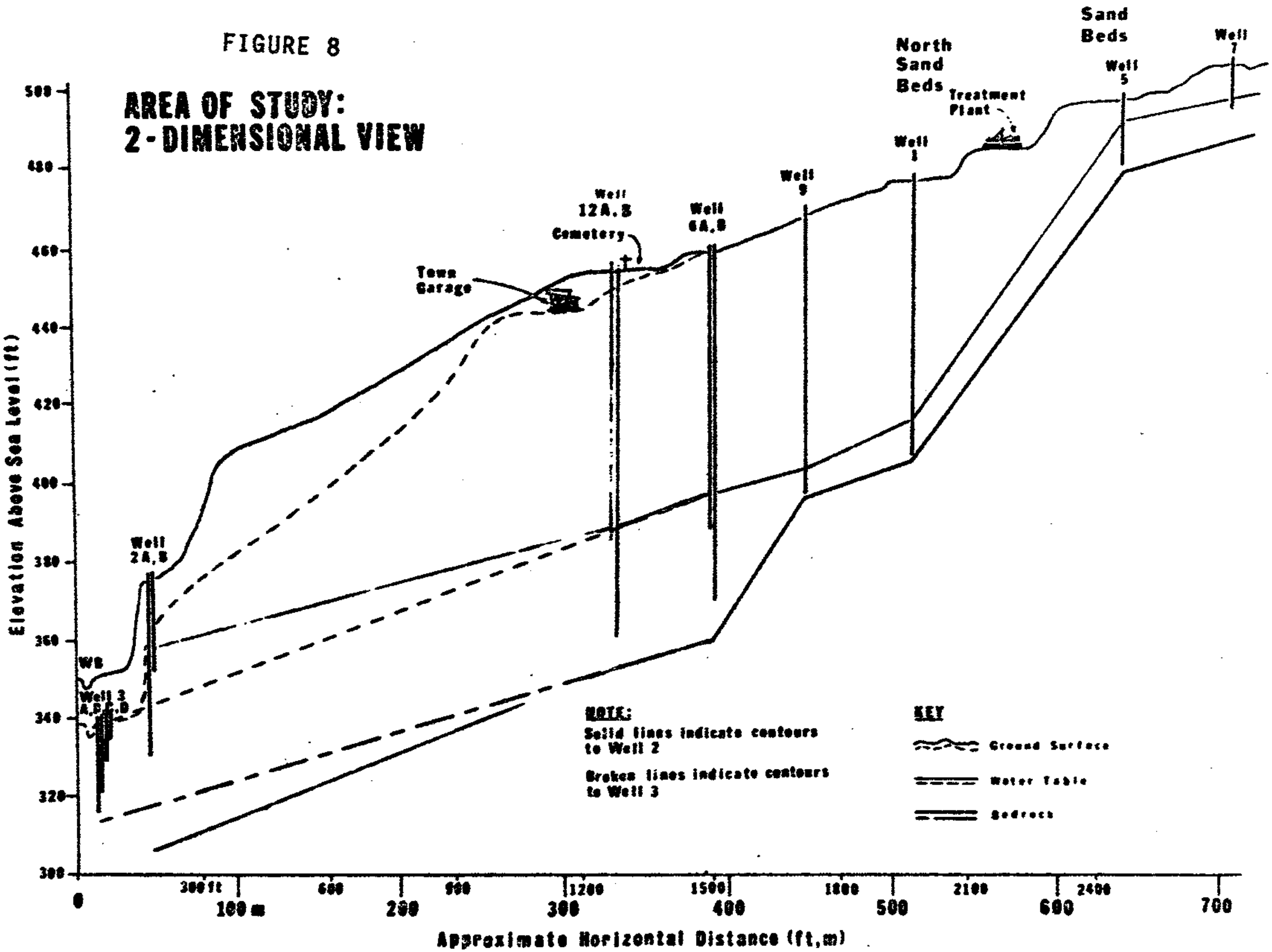
FIGURE 7

the augering process. This system has the advantage of utilizing a plastic pipe which is not subject to corrosion which would change the iron content of the sample. Its disadvantage is that professional well driller is required for installation. In some instances the ground water aquifer encountered was as much as 6 m (20 ft) thick. In such instances, it was found desirable to install at least 2 well points, one near the upper portion of the aquifer and another near the bottom, with up to 4 different depths being utilized in some cases. The relative depths of the bedrock and the ground water surface are shown in Figure 8.

In wells up to approximately 8 m (25 ft) in depth, samples may be secured by means of a tube and a hand operated vacuum pump. However, for deeper wells a bailer was used. This consisted of a copper pipe with a one-way valve placed on the bottom of the pipe. This pipe was lowered into the well by means of a line and the bailer was allowed to fill. The bailer was than retrieved and the sample poured out of the copper tube. This technique requires a considerable amount of time especially when large sample volumes are required. The method, however, does allow samples to be secured without a depth limitation.

In addition to removal of samples for analysis elsewhere, certain measurements can be taken directly

FIGURE 8


AREA OF STUDY:
2-DIMENSIONAL VIEW
Elevation Above Sea Level (ft)
Approximate Horizontal Distance (ft,m)
WB
Well 3 A,B,C,D
Well 2A,B
Town Garage
Cemetery
Well 12A,B
Well 6A,B
Well 9
Well 1
North Sand Beds
Treatment Plant
Sand Beds
Well 5
Well 7
NOTE:
Solid lines indicate contours to Well 2
Broken lines indicate contours to Well 3
KEY
Ground Surface
Water Table
Bedrock

within the observation well. The depth in the well can be measured by a conductivity cell which is lowered into the well pipe on a calibrated cable. When the probe reaches the water the conductivity changes and the depth to the water can be measured. Dissolved oxygen (DO) and temperature may be measured directly within the well by means of a DO-temperature probe which can be lowered into the well pipe. Obviously, sufficient cable must be available to reach to the depth of the water in the well. Conductivity could also be measured directly in the well, although samples were retrieved for separate conductivity measurement in all our studies. Parameters such as pH, redox potential and conductivity should be measured in the field. Samples requiring other chemical analyses should be returned to the laboratory for the appropriate analysis. Samples should be refrigerated as soon as possible and preserved as appropriate.

Where power is available, pumped wells may be installed. Lift pumps may be used with small diameter pipes, whereas for submersible pumps, usually the minimum size pipe is 6 in (15 cm). Pumped wells provide a continuous sample which may be advantageous under certain circumstances. However, caution must be taken not to overpump the aquifer which would change the ground water flow pattern and distort the results. Pumped wells also have the disadvantage in that measurements such as water level, temperature, pH, DO, etc. cannot be taken directly within the well. In particular, pH and DO may be changed during pumping. Thus, pumped wells may be useful in specific situations, but their use for monitoring has limitations.

TRACERS

Just as important as installing the proper sampling and observation facilities is the confirmation that samples secured from the system are truly representative of the liquid being applied in the land application system. This is appropriate both to the rapid infiltration technique and to septic tank-leach field systems. Several studies were conducted to determine the best means of tracing the flow of the applied liquid.[17,18] Rhodamine B was found to be ineffective for use as a tracer of ground water inasmuch as this dye is apparently sorbed onto the soil particles. Tritium provides an ideal tracer in that it reacts the same as water. Thus, it is more or less used as the standard in terms of ground water flow monitoring. However, it does present some difficulties. One is the fact that it is radioactive and must be handled with caution. The second is that if it should reach a water supply in any significant concentration this would be undesirable. A third is that rather sophisticated measurement equipment is required in order to detect the tritium, i.e., samples must be returned to the laboratory for tritium analysis.

Studies were also made at Lake George using sodium chloride and potassium chloride as tracers. Since the concentrations of these added ions must exceed significantly the concentrations of these ions in the normal ground water, large quantities of these chemicals may need to be utilized in order to detect these ions above background. Calculations were made as to the quantity of these substances required for detection at Lake George, but since no significant increased concentrations of these substances could be detected in the water, obviously sorption and/or dilution was greater than anticipated. A potential problem with the use of these compounds may be their contributin to ground water contamination, particularly if extremely large quantities are required. A particular advantage would be if the increased salt concentration could be detected within the ground water by means of conductivity measurements. Thus, the use of salt may be practical in terms of identifying the ground water flow; however, at Lake George this technique was found to be unsuccessful.

In the sand formation at Lake George, the use of Rhodamine WT was found to be the most successful tracer of the ground water flow. In the studies conducted, both tritium and Rhodamine WT were used as tracers and additional observation well points were installed as shown in Figure 9. In the initial infiltration and percolation through the ground water, there appeared to be a significant reduction in the Rhodamine WT as compared with the tritium. It is not certain whether this reduction in the Rhodamine was due to ultra violet breakdown as the Rhodamine stood on the surface of the sand bed prior to its infiltration, or whether there was significant sorption or removal of the Rhodamine WT as it entered the ground and percolated to the water table. However, in the saturated zone the studies[18] showed that the Rhodamine to tritium ratio was similar (see Table 1). The Rhodamine WT was observed a distance of 321 m from the point of application. This was a greater distance than the tritium could be traced, due primarily to the fact that the amount of tritium that the New York State Department of Health allowed to be used was only one-tenth of that initially requested. Calculating the dilution factor based upon the Rhodamine WT concentration, it may be seen that at the greatest distance at which the Rhodamine WT was observed the dilution of the tritium would have been below the detectable limits. Thus, the fact that the Rhodamine WT was followed for a greater distance than the tritium is only due to the fact that a higher

LOCATION OF SPECIAL WELLS FOR TRACER STUDIES

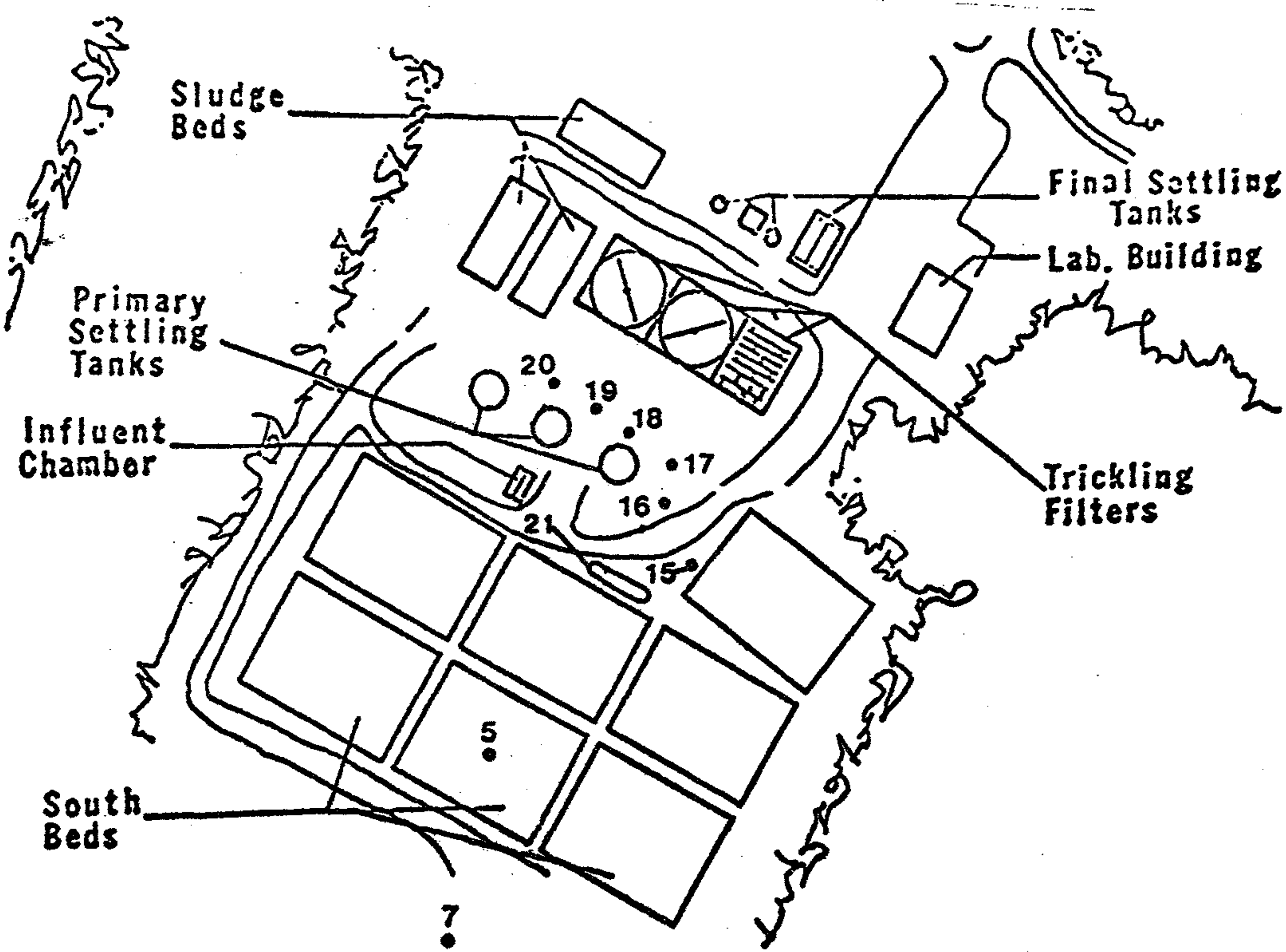


TABLE 1

CONCENTRATION RATIOS

Location:Location	Tritium Concentration	Tritium Ratio	Rhodamine Concentration	Rhodamine Ratio
Bed S-3:Well 5	914:134	6.8:1.0	15.9:1.1	14.4:1.0
Well 5:Well 17	134:149	1.0:1.1	1.1:1.1	1.0:1.1
Well 17:Well 9	---	---	1.1:0.03	36.7:1.0
Well 9:Well 6B	---	---	0.03:0.02	1.5:1.0

concentration, relatively speaking, of the Rhodamine WT was used than of the tritium. The Rhodamine WT has the advantage that at relatively high concentration (above 1 ppm) it may be observed visually. Thus, in some instances, no particular instrumentation at all is required for detection. On the other hand, by means of a fluorometer, Rhodamine WT may be detected at least as low as 1 ppb and possibly 0.1 ppb. Flurometers are available with a continuous flow-through system and where appropriate pumping facilities can be available this would provide a continuous monitor of the Rhodamine WT concentration in an observation well. Rhodamine has the further advantage in that it has been shown to be non-toxic so that even if it should reach a water supply it would not represent a health hazard.

Of interest to note is the amount of dilution which occurs in the ground. Observing the ratios of the Rhodamine at the various well points in Table 2, it may be seen that there was a dilution factor of 36.7 to 1 in passage from well 17 to well 9 (see Figures 7 and 9). There is an additional reduction of a factor of 1.5 to 1 in passing from well 9 to well 6B or a total dilution factor of 55. If it is assumed that the Rhodamine is not adsorbed in the sand in the saturated zone, then this becomes a useful factor in evaluating the impact of pollutants in a ground water system. This must be taken into account when determining the degree of treatment afforded by the ground, otherwise it would be likely to assume that any reduction represents treatment or removal, whereas in actuality it may be merely dilution. The use of Rhodamine WT does, in general, allow for an evaluation of this dilution factor.

It must be pointed out that in the studies at Lake George the tracers were added to only one sand bed. Thus, dilution is also provided by dosing of adjacent sand beds. In any case such as Lake George where there are multiple points of additions of the liquids by land application, it is difficult to determine the dilution factor if the tracer is applied to only 1 of the sand beds as opposed to all of the adjacent sand beds. However, where there is only one point of discharge, the use of Rhodamine WT for evaluation of dilution is very practical.

SUMMARY

Land application is an accepted means of treatment and disposal of domestic wastewaters. However, it is important to monitor these systems so as to prevent any undesirable contamination of ground water.

At Lake George suction cup lysimeters were shown to be effective in securing samples in the unsaturated zone. It was also indicated that the installation of horizontal

collector wells, where applicable, would be useful in terms of collecting the samples in the unsaturated zone.

In the saturated zone well points and screens may be installed at various depths within the ground water. Mounding frequently occurs beneath land application systems by the rapid infiltration technique. Thus, the thickness of the aquifer beneath the infiltration beds may be somewhat increased. Therefore, it is desirable to install wells, points, and screens at various depths within the aquifer. Means must be provided to bring the samples to the surface. In shallow wells this may be accomplished by pumping, in deep wells a bailer is required. Once samples are secured they may be analyzed for any appropriate parameter of potential contamination. Certain parameters may be measured directly within the observation well.

It is essential that some form of tracer studies be conducted to confirm that the monitoring well is truly in the path of the ground water flow. Rhodamine WT appears to be a very useful tracer for this purpose. Studies conducted at Lake George show that, at least for the sands occurring there, there was little to no sorption of the dye on the sand.

The proper monitoring system with appropriate analyses of samples is essential to assure that land application systems and septic tank systems do not contaminate ground water supplies. Sampling should continue at all times to be certain that there are no changes in conditions which would result in contamination of the ground water after continued use of a land application system.

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