A Facility Designed to Monitor the Unsaturated Zone During Infiltration of Tertiary-Treated Sewage, Long Island, New York

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply SI units	By	To obtain inch-pound units
	Length	
millimeter (mm)	0.039	inch (in.)
centimeter (cm)	0.39	inch (in.)
meter (m)	3.281	foot (ft)
square meter (m^2)	10.76	square foot (ft^2)
liter (L)	0.264	gallon (gal)
liter per second (L/s)	15.85	gallon per minute (gal/min)
cubic meter per second (m^3/s)	22.84	million gallons per day (Mgal/d)

A FACILITY DESIGNED TO MONITOR THE UNSATURATED ZONE

DURING INFILTRATION OF TERTIARY-TREATED SEWAGE,

LONG ISLAND, NEW YORK

by

R. C. Prill, E. T. Oaksford, and J. E. Potorti

ABSTRACT

A facility consisting of a circular recharge basin 6.10 meters in diameter with a central observation manhole was developed on Long Island to study the role of the unsaturated zone during aquifer recharge with tertiary-treated sewage. The manhole extends through most of the 7.5-meter-thick unsaturated zone, which is composed of glacial outwash sand and gravel, and enables collection of water samples and monitoring of dynamic characteristics of the unsaturated zone during recharge experiments. The system contains instrumentation for monitoring infiltration rate, pressure-head distribution, soil-moisture content, ground-water levels, and soil gases.

The 24.55-square-meter recharge basin has operated in all seasons intermittently since April 1975 and, as of April 1978, has transmitted 62 million liters of tertiary-treated effluent to the water-table aquifer. Overall performance of the facility indicates that it is suitably designed for monitoring the unsaturated zone during artificial-recharge experiments.

INTRODUCTION

Ground water, the only source of fresh water for a population of more than 2 million in the eastern four-fifths of Long Island, is obtained from sand and gravel aquifers within the sequence of unconsolidated deposits that form the island. These deposits, which may be as thick as 600 m locally, are underlain by crystalline bedrock. Primary recharge to the aquifer system is maintained by local precipitation.

Since shortly after World War II, this part of Long Island has experienced a fourfold increase in population and a corresponding increase in ground-water development. The resulting large-scale increase in domestic and industrial waste, much of which is still returned to the ground through septic tanks and cesspools, has raised concern over the chemical quality of water in the shallow aquifer. As a consequence, regional sewer systems and sewage-collection facilities have been constructed to divert significant amounts of the sewage to treatment plants and from there to sea. Although this protects the aquifers from further contamination, it produces a net draft on the ground-water system, which results in a lowering of the water table and the shortening or disappearance of streams fed by ground water.

One of the approaches taken by local government agencies to counteract these effects is the development of tertiary-treatment facilities to process the wastewater so that it can safely be returned to the freshwater aquifer system. The high cost and limited availability of land on Long Island require that recharge systems provide rapid infiltration rates. Because much of the surficial material consists of permeable glacial outwash deposits that permit rapid infiltration, recharge basins are a practical and economical approach.

This recharge study has been supported by Federal research funds since 1974, when the U.S. Geological Survey was granted access to an advanced wastewater-treatment plant in Suffolk County under the auspices of the Suffolk County Executive's Office, Special Projects Unit. Subsequently, the Geological Survey has conducted studies at this site to evaluate the role of the unsaturated zone in controlling infiltration rates and modifying the chemical composition of effluent during aquifer recharge. This report describes the design, construction, and operation of the experimental recharge facilities developed through those studies and outlines the equipment used to monitor soil and water characteristics during recharge experiments.

HYDROGEOLOGIC SETTING

The recharge studies are being conducted at an advanced wastewater-treatment plant at Medford, N.Y., in south-central Suffolk County. The location of the site is shown in figure 1; figure 2 shows the hydrogeology of the area (section A-A' in fig. 1). Bedrock, which in this area is 480 m below sea level, is overlain by unconsolidated sedimentary deposits. The major hydrogeologic units above the bedrock at the site, in ascending order, are the Lloyd aquifer, Raritan clay, Magothy aquifer, and the upper glacial aquifer (fig. 2).

The hydrogeologic unit of principal concern in basin recharge is the upper glacial aquifer, which in this area is about 50 m thick. The sediments that form the upper glacial aquifer are primarily outwash deposits of predominantly sand and gravel size.

The recharge facility was designed to monitor the movement of tertiary-treated sewage as it percolates through the unsaturated zone to the unconfined upper glacial aquifer.

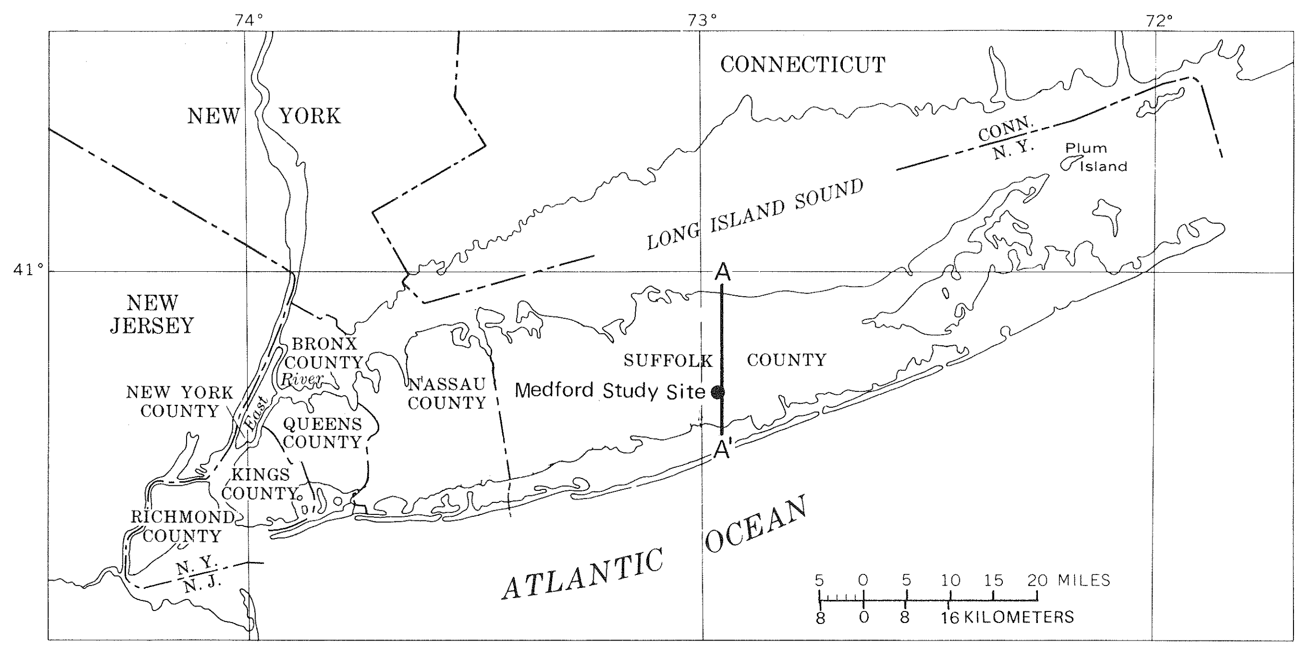

Figure 1.--Location of study site, Medford, Suffolk County, N.Y.

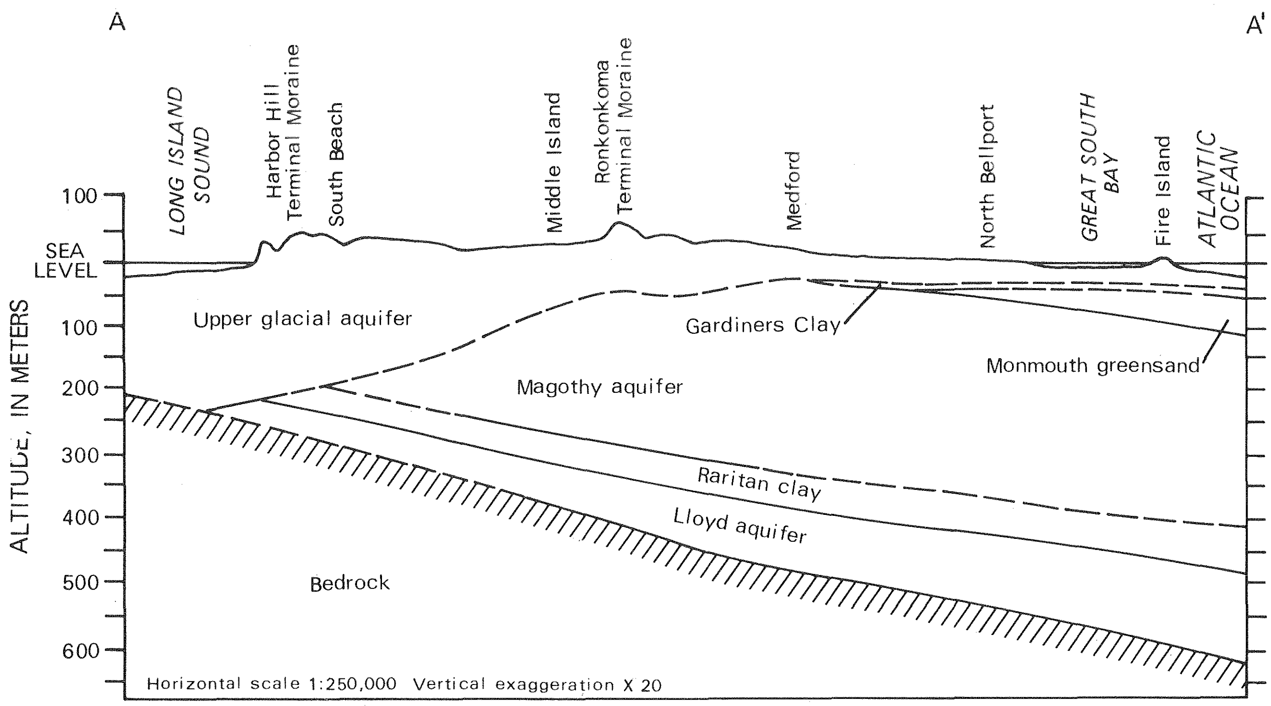

Figure 2.--Hydrogeology of study area (section A-A' in fig. 1). (Modified from Jensen and Soren, 1974.)

WASTEWATER-TREATMENT PLANT

The treatment plant from which effluent is drawn for recharge at the experimental facility is designed to serve a population of 12,400 and has a daily capacity of 4.69 million liters. The plant incorporates an activated-sludge process to produce a highly treated, denitrified effluent. The treated effluent is added to the ground-water system through recharge basins. Figure 3 shows the layout of the wastewater-treatment-plant and the location of the U.S. Geological Survey recharge facilities.

The sequential steps through which the wastewater is processed are depicted in figure 4. The tanks for primary, intermediate, and final clarification are similar in design and construction, and all are equipped with collectors that scrape the settled sludge into sludge hoppers and skim floating materials into screen troughs. All sludge from the primary clarifier, and some of the sludge from the intermediate and final clarifiers, is pumped to the sludge thickner, from which the thickened sludge is conveyed to the aerobic sludge digester for bacterial decomposition. Sludge that is not readily digested is trucked to disposal lagoons.

The aeration-nitrification and denitrification units are biological systems. Procedures for recycling and disposing of activated sludge insure sufficient biological growth in both processes. In the aeration-nitrification unit, air is introduced to provide an oxygen supply to promote the microorganisms that oxidize carbon and convert ammonium to nitrate (nitrification). In the denitrification unit, methanol is added as a food source for bacteria that convert nitrate to nitrogen gas (denitrification).

Effluent leaving the final clarifier is passed through a filter composed of garnet, quartz, and anthracite and is then chlorinated and conveyed to one of several large recharge basins. The final effluent to be used for testing is pumped from the chlorine-contact tank through a separate transmission system to the Geological Survey study site.

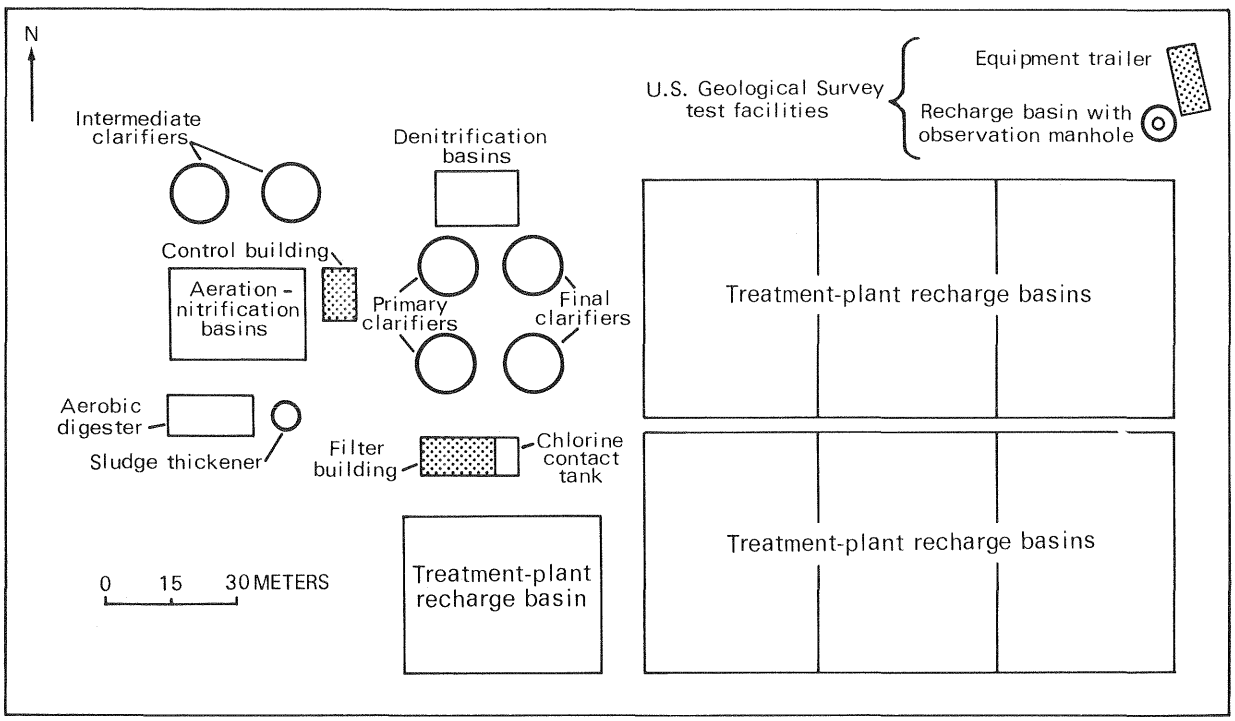

Figure 3.--Layout of advanced wastewater-treatment plant and U.S. Geological Survey testing facilities.

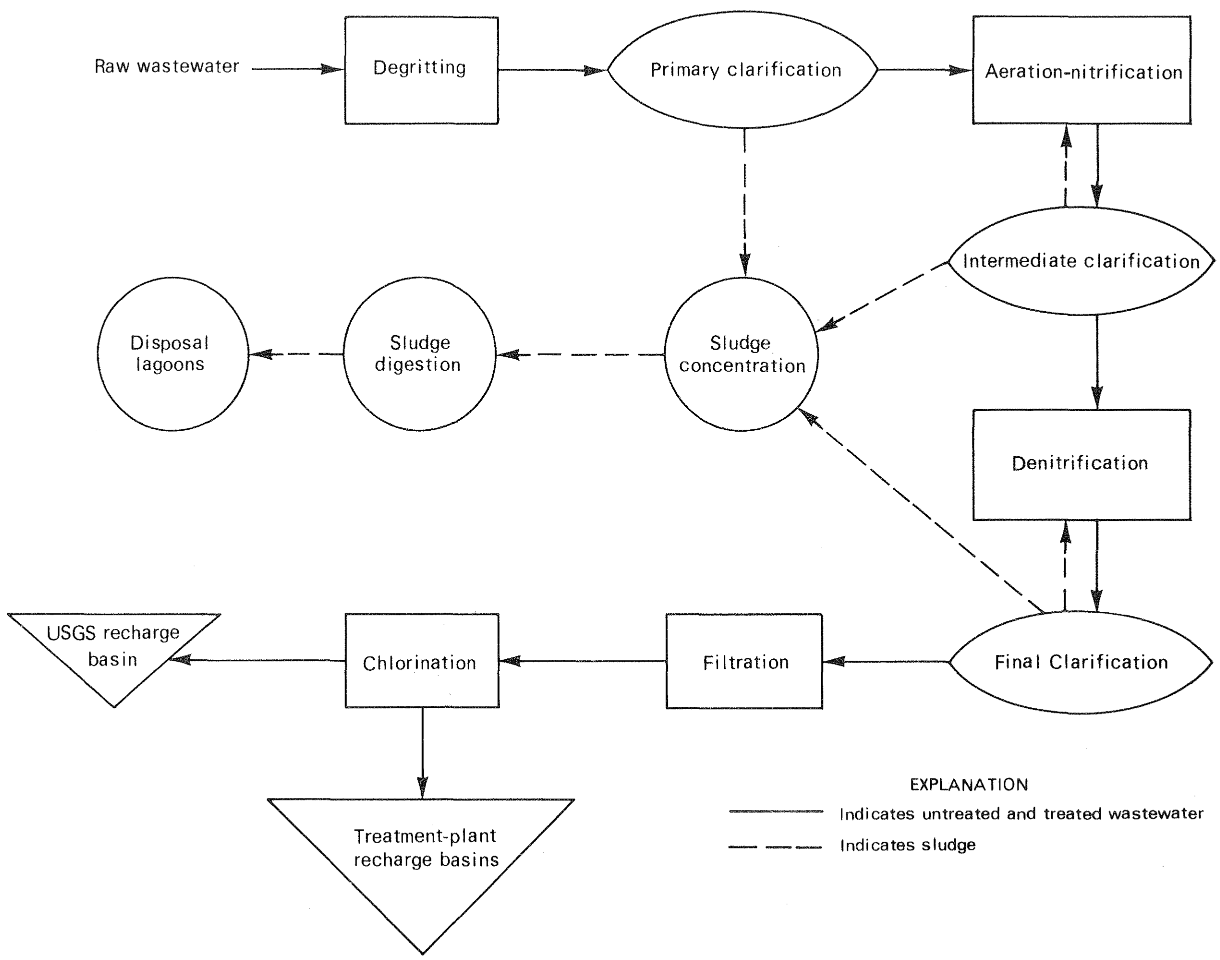

Figure 4.--Major steps of wastewater-treatment process.

RECHARGE-MONITORING FACILITIES

The recharge basin is circular and contains a central observation manhole (fig. 5A). Effluent is contained within the 1.83-m trough between the manhole and the retaining wall. The outside diameter of the manhole is 2.44 m; the inside diameter of the retaining wall is 6.10 m. The retaining wall extends to 0.61 m above the basin floor, is 0.30 m thick, and extends 0.91 m below land surface. The wetted area of the basin is 24.55 m^2.

The first phase of construction entailed removal of the 1-m soil horizon above the sand and gravel outwash deposits; the next phase involved construction of the manhole within the unsaturated zone. The manhole is composed of a stack of five concrete rings, each about 1.5 m high with an inside diameter of 2.34 m and a wall thickness of 0.10 m. The rings were set in place by a crane equipped with a clam shovel. The sand and gravel within the concrete rings was removed by the clam shovel to allow the rings to settle in increments of 0.3 m. Rings were added to the stack as excavation continued until the bottom of the lowest ring was 6.6 m below the basin floor, 0.9 m above the water table. The bottom of the manhole was left open to the upper glacial formation. The top of the manhole, 0.9 m above land surface, was capped with an 0.2-m-thick concrete slab. An aluminum door was mounted in the concrete slab, and ladders were mounted on the inner walls of the manhole. Platforms made from subway grating were placed within the manhole at depths of 2.5 and 4.9 m below the top of the manhole to provide three working levels. (See fig. 5B).

Basin Operation

Treated effluent is pumped from the chlorine-contact tank to the test basin through an 8-cm-diameter flexible-plastic pipe capable of delivering 11 L/s. The quantity of effluent added to the basin is measured by an inline totalizing flowmeter. To provide even flooding within the basin, the effluent is distributed through a perforated flexible pipe that conforms to the inside of the retaining wall.

Water is delivered to the basin on demand; mechanical float switches control pump operation. The mean water level maintained in the basin during each pumping cycle is 0.3 m ± 0.025 m. Pressure head in the basin is monitored continuously by use of a Valadyne[1/] (model DP7) differential pressure transducer. The infiltration rate is computed from the rate of head decrease within the basin.

A 15-cm-diameter polyvinyl chloride observation well was installed at the base of the manhole to monitor ground-water-level fluctuations. It has a 0.3-m screen in the uppermost part of the saturated zone. A Stevens F-type water-level recorder is mounted on the well.

1/ Brand names are used for purposes of identification only and do not constitute endorsement by the U.S. Geological Survey.

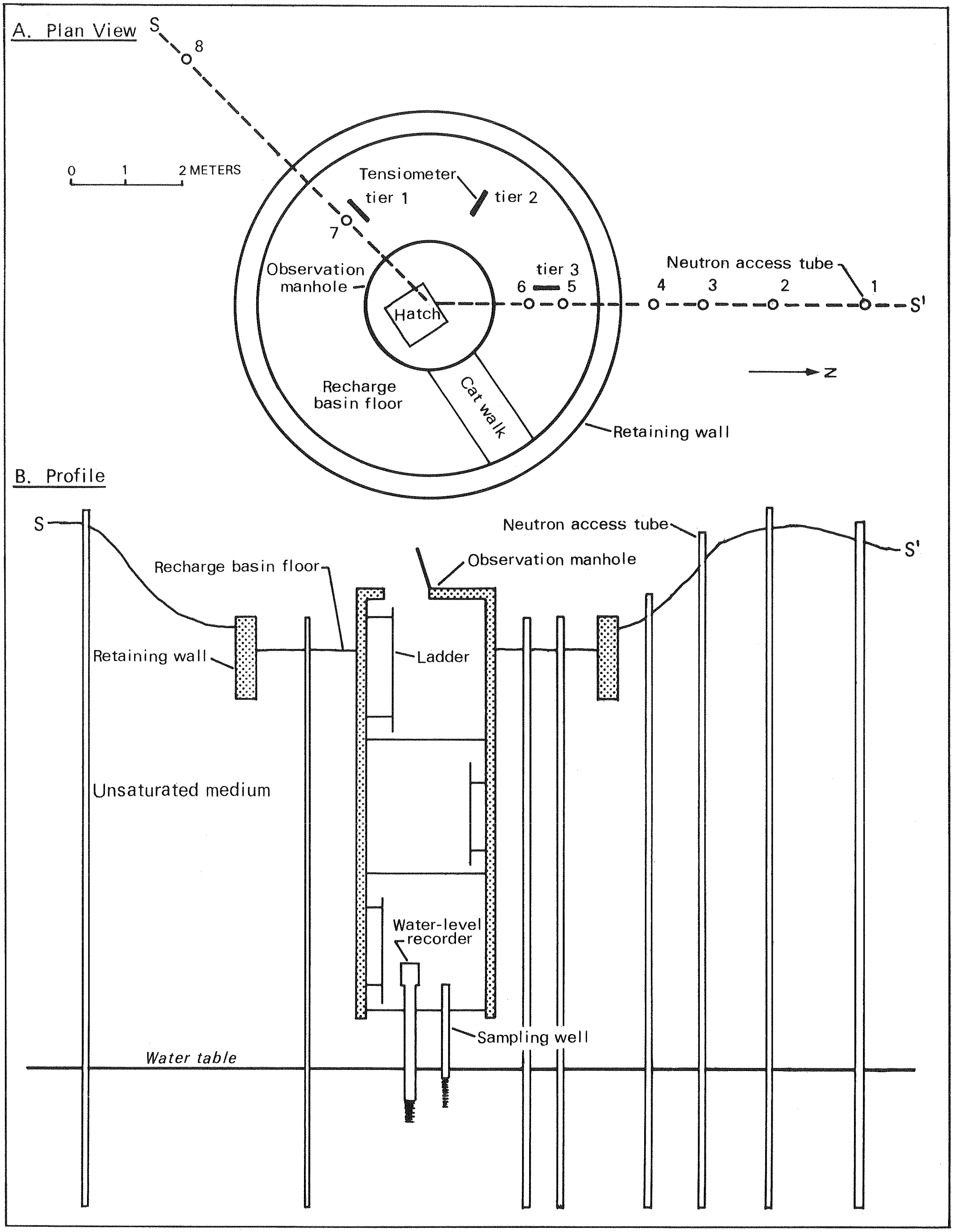

Figure 5.--Recharge-basin configuration.

Collection of Water Samples

Water samples are collected from the basin, the unsaturated zone, and the saturated zone for chemical and biological analysis. In addition to the samples taken from each zone, composite basin samples are collected with an Isco refrigerated composite sampler.

Samples from the unsaturated zone are obtained at three levels from samplers permanently positioned at depths of 0.68, 2.26, and 5.39 m below the basin floor. A typical sampler (fig. 6) consists of (1) a square tube that extends diagonally upward through the manhole wall into the formation, and (2) a screened plate within the tube at the outflow end to hold sand and gravel in place. The sampler tube is made of 14-gauge stainless steel. The collection end of the tube is beveled so that when the tube is jacked into the formation, it forms a horizontal plane of capture approximately 0.15 x 0.3 m. When in position, the center of the collection plane is 0.9 m from the outer edge of the manhole. (See fig. 6.)

The screened plate assembly consists of a perforated stainless-steel plate overlain by stainless-steel screen. It is placed inside the tube during installation and positioned at the interface between the formation and the manhole. This position is maintained as the tube is jacked past the plate into position. The tube fills with sand and gravel as it moves.

When the apparatus is installed, the vertical distance between the plane of capture and the base of the screened plate is 0.58 m. The samplers radiate from the manhole at azimuth orientations of 253°, 154°, and 331° for the upper, middle, and lower-level samplers, respectively.

Water draining from the samplers moves through a funnel into a 4-L Erlenmeyer flask. Overflow from the flask moves by gravity into a large container at the base of the manhole from which it is pumped back into the basin.

Ground-water samples are collected from a 5-cm-diameter polyvinyl chloride sampling well at the base of the manhole and screened in the upper 1 m of the saturated zone.

Water temperatures were recorded continuously in the basin and at the levels of the samplers in the unsaturated zone. The temperature sensor in the basin is positioned just above the basin floor; the sensors in the unsaturated zone are installed through the manhole wall and penetrate 0.9 m into the formation. Effluent entering the basin is monitored continually for turbidity, pH, Eh, and specific conductance. The ground water is monitored continuously for specific conductance. Water to be analyzed for other chemical or biological constituents in the basin, ground water, or unsaturated zone is obtained by grab samples and sent to the U.S. Geological Survey Central Laboratories for analysis.

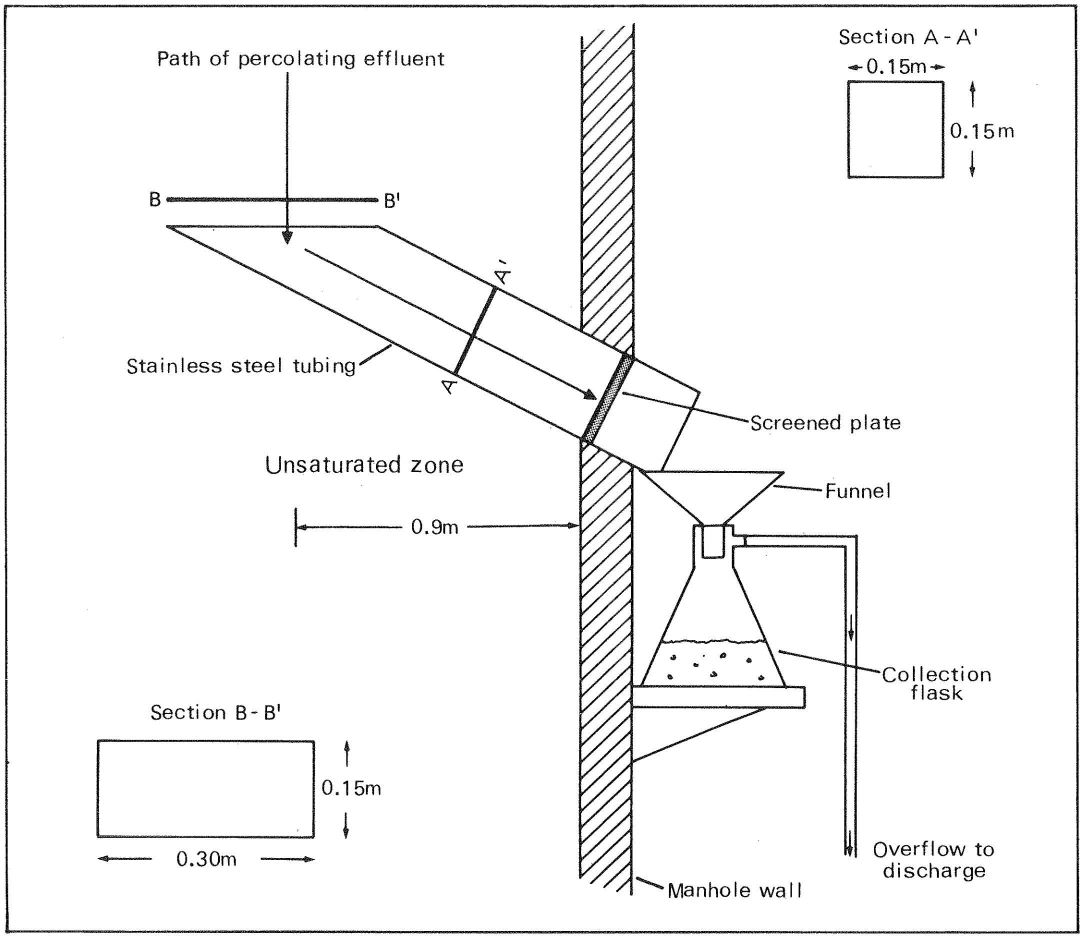

Figure 6.--Typical sampler designed to collect water from the unsaturated zone.

Measurement of Soil Moisture, Soil-Moisture Tension, and Soil Gases

Eight vertical aluminum access tubes are installed in and around the basin for measurement of soil-moisture content by a continuous-logging nuclear meter (Prill and Meyer, 1968). Holes 1 through 6 are on a north-south traverse; holes 7 and 8 are on a northeast-southwest traverse. Three of the holes (nos. 5, 6, 7) are in the basin at 1.2, 0.6, 0.9 m, respectively, from the outer edge of the manhole. The remaining five are outside the basin. Holes 2 and 8 are 3.1 m from the inside edge of retaining wall; holes 1, 3, and 4 are 4.7, 1.8, 0.9 m respectively from the inside edge of the retaining wall (fig. 5). The aluminum tubing, which has a 5-cm outside diameter and a wall thickness of 0.16 cm, extends about 3 m below the water table and is sealed at the bottom by a water-tight plug. It was installed by first driving a 7.5-cm black-iron casing, plugged at the bottom, to the proper depth, at which time the plug was knocked out. The aluminum tubing was lowered inside the casing, and the casing was then pulled. The annular space was filled with sand and gravel. Moisture-content measurements were made during recharge to determine the vertical and lateral distribution of water in the unsaturated zone.

Tensiometers are positioned throughout the adjacent unsaturated zone for measuring soil-moisture-tension (pressure-head) distribution. They consist of a porous ceramic cup attached to a plastic tube connected to a water manometer (Black, 1965). Their general configuration is shown in figure 7. Three tiers of tensiometers have been installed--one on the north side of the basin (tier 3), one on the west-northwest side (tier 2), and one on the southwest side (tier 1). The tensiometers are installed horizontally through the manhole wall at varying depths throughout the 7.5-m unsaturated zone; they are concentrated in the 0- to 1.5-m depth interval. The depths at which they are positioned are given in table 1. The porous cups are set at a distance of 0.9 m from the manhole. Tensiometers in the uppermost 0.3 m of the unsaturated section are attached to differential pressure transducers for a continuous record of soil-moisture tension. Soil-moisture-tension records reveal the development of clogging during recharge.

Table 1.--Tensiometer depths

(Depths are in centimeters below basin floor)

Tier 1	Tier 2	Tier 3
5	5	5
10	10	10
15	15	15
23	20	26
30	27	33
57	49	38
60	60	61
75	71	--
92	152	--
102	217	--
152	300	--
224	375	--
305	450	--
385	536	--
460	572	--
535	618	--
575	--	--
627	--	--

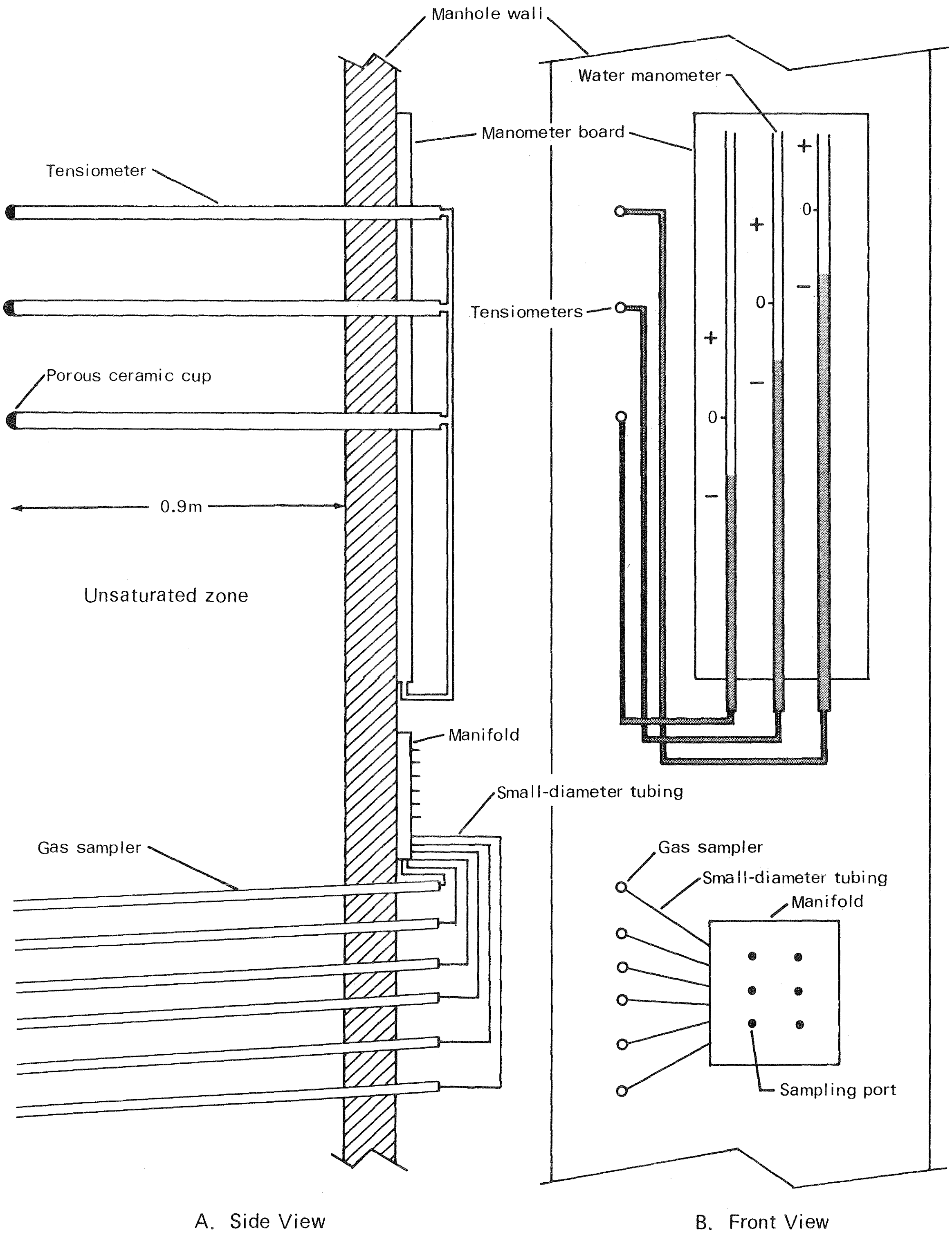

Figure 7.--Typical tensiometer and soil-gas-sampler installation.

Gas samplers are also positioned in the unsaturated zone to measure the oxygen and carbon dioxide content of the soil atmosphere. The samplers consist of an open-ended rigid plastic tube 0.6 cm in diameter installed through the manhole wall 0.9 m into the formation. The tube is inclined slightly downward and away from the manhole (fig. 7). The gas samplers are also concentrated in the upper part of the unsaturated zone. All gas samplers are attached to small-diameter flexible tubes that terminate at a common manifold to which portable gas analyzers are attached for measurement.

SUMMARY OF FACILITY PERFORMANCE

Since the project began, 13 recharge experiments ranging from 5 to 100 days in duration have been conducted. The test basin has been exposed to a wide range of variations in effluent quality and weather conditions. Objectives have been directed toward defining the physical, chemical, and biological alterations in both the soil and the percolating effluent as a result of high-rate artificial recharge. Tests indicate that the relatively inert sand and gravel can be effective in filtering out suspended solids, removing viruses, and altering nitrogen-species distribution during periods of inadequate treatment-plant performance. Clogging has been observed to be naturally reversible through biodegradation, and artificially reversible through basin-floor treatment between effluent applications. The 61,538 m^3 of effluent that has been applied to the test basin during the 13 recharge experiments is equivalent to more than 20 years of treatment-plant effluent applied at a rate of 0.054 m^3/s over the 15,400 m^2 of recharge area available at the treatment plant. The test data show that the soil medium has retained its water-transmitting properties throughout this period of intensive wastewater applications.

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