DESIGN, OPERATION, AND MONITORING CAPABILITY OF AN EXPERIMENTAL ARTIFICIAL-RECHARGE FACILITY AT EAST MEADOW, LONG ISLAND, NEW YORK

by Brian J. Schneider and Edward T. Oaksford

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations
Report 84-4321

Prepared in cooperation with the

NASSAU COUNTY DEPARTMENT OF PUBLIC WORKS

Syosset, New York

1986

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply inch-pound units	by	To obtain SI units
inch (in)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	929.0	square centimeter (cm^2)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
foot per day (ft/d)	0.3048	meter per day (m/d)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius (°C)
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)

Equivalent concentration terms

microgram per liter (μg/L) = parts per billion (ppb)
microsiemens per centimeter at 25° Celsius
(μS/cm at 25°C)

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ABSTRACT

Artificial recharge with tertiary-treated sewage is being tested at East Meadow to evaluate the physical and chemical effects on the ground-water system. The recharge facility contains 11 recharge basins and 5 injection wells and is designed to accept 4 million gallons of reclaimed water per day. Of the 11 basins, 7 are recently constructed and will accept 0.5 million gallons per day each. An observation manhole (12-foot inside diameter and extending 16 feet below the basin floor) was installed in each of two basins to enable monitoring and sampling of percolating reclaimed water in the unsaturated zone with instruments such as tensiometers, gravity lysimeters, thermocouples, and soil-gas samplers.

Five shallow (100-feet deep) injection wells will each return 0.5 million gallons per day to the ground-water reservoir. Three types of injection-well design are being tested; the differences are in the type of gravel pack around the well screen. When clogging at the well screen occurs, redevelopment should restore the injection capability.

Flow to the basins and wells is regulated by automatic flow controllers in which a desired flow rate is maintained by electronic sensors. Basins can also operate in a constant-head mode in which a specified head is maintained in the basin automatically.

An observation-well network consisting of 2-inch- and 6-inch-diameter wells was installed within a 1-square-mile area at the recharge facility to monitor aquifer response to recharge.

During 48 days of operation within a 17-week period (October 1982 through January 1983), 88.5 million gallons of reclaimed water was applied to the shallow water-table aquifer through the recharge basins. A 4.29-foot-high ground-water mound developed during a 14-day test; some water-level increase associated with the mound was detected 1,000 ft from the basins. Preliminary water-quality data from wells affected by reclaimed water show evidence that mechanisms of mixing, dilution, and dispersion are affecting chemical concentrations of certain constituents, such as nitrogen and trichloroethane, in the shallow aquifer beneath the recharge area.

INTRODUCTION

Ground water derived from precipitation is the sole source of drinking water in Long Island's two largest counties--Nassau and Suffolk (fig. 1). The ground water is plentiful and generally suitable for most uses.

During Long Island's early period of development, the primary method of waste disposal from households and commercial establishments was through shallow cesspools. With population growth, however, especially in Nassau County, this practice caused a widespread degradation in chemical quality of shallow ground water. To prevent further contamination, centralized sewer systems have been constructed in densely populated areas. The water collected by these sewer systems is piped to wastewater-treatment plants, where it is treated and discharged to the ocean. Although this process protects the ground-water reservoir from sewage contamination, it does not return water to the aquifers as cesspools did and therefore decreases the ground-water supply. This, in turn, could cause ground-water levels to decline and streamflow to decrease or cease.

Artificial recharge of aquifers is one potential means of replenishing Long Island's ground-water supply. Stormwater basins have been used on the island since 1934 to recharge the shallow aquifer with storm runoff that would otherwise have been diverted to streams. Another method is through the reclamation of wastewater, which is done by filtration and purification at the sewage-treatment plants, then injection or infiltration of this water to the aquifer. This method not only can provide a large and continuous supply of reclaimed water to replenish the ground-water reservoir, but may also improve the degraded water of the shallow aquifer by dilution.

The need for potable ground water will increase in the near future as municipal consumption increases from the growth of industry and population. Reclaimed wastewater could help meet that demand. The artificial-recharge program described herein was designed to explore the physical and chemical effects of using tertiary-treated wastewater for this purpose. A successfully managed and monitored artificial-recharge program could serve as a model for other geologically similar areas that are experiencing water-supply shortages.

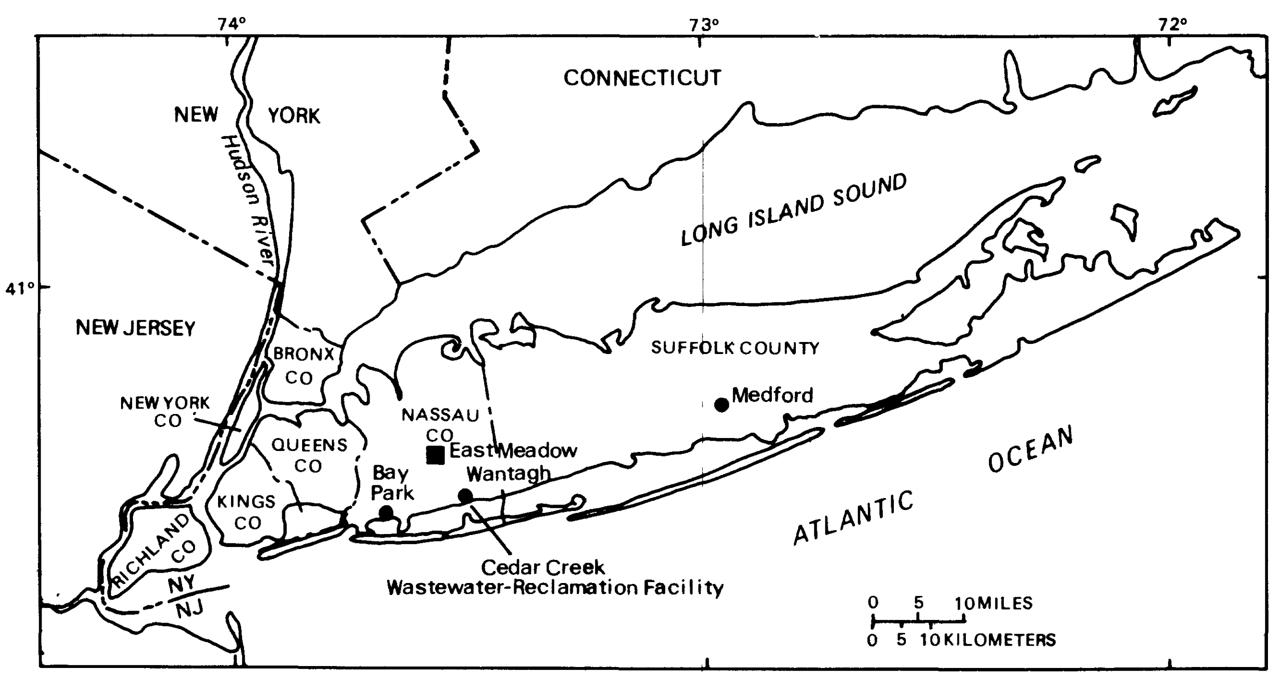


Figure 1.--Location and major geographic features of Long Island, N.Y.

The recharge facilities at East Meadow were designed and built to (1) enable study of the injection and infiltration processes and their effect on the shallow aquifer system, and (2) develop management practices that would most efficiently dispense the water provided to the site. The U.S. Geological Survey, in cooperation with Nassau County, began a series of investigations in 1975 to meet these objectives. The purpose of the study described herein was to observe the hydrologic and chemical effects of reclaimed water on the unsaturated-zone material and on shallow ground water beneath.

Purpose and Scope

This report describes the construction and instrumentation of the East Meadow artificial-recharge facility and gives examples of the kinds of data that were obtained from several recharge experiments during the first 17 weeks of operation (October 6, 1982 through January 31, 1983). Attention is given to the degree of ground-water mounding and to changes in ground-water quality after the addition of reclaimed water through recharge basins. (Injection wells were not operated during this period.) Statistical summaries of water quality of the shallow aquifer, reclaimed water, and ground water affected by reclaimed water are presented in tables, and the degree of ground-water mounding beneath the recharge area is shown on regional contour maps. Examples of data collected from the unsaturated zone during nonrecharge conditions are also presented; these provide a background data base for future studies. Also included is a description of the design and layout of instrumentation to evaluate recharge tests.

Previous Studies

The concept of artificial recharge has long been a part of Long Island's water-management strategy, and many reports have been published on the history and the physical and chemical aspects of this procedure on Long Island.

The history of artificial-recharge technology and considerations for its application on Long Island are described in Greely and Hansen (1963) and Holzmacher, McLendon, and Murrell (1980). The disposal of ground water pumped for cooling purposes through shallow diffusion basins or through diffusion wells is described in Leggette and Brashears (1938) and Sandford (1938).

The use of stormwater basins on Long Island to intercept storm runoff that would otherwise flow to streams and tidewater is discussed in several reports, for example, Brice and others (1956), Seaburn (1969, 1970, 1971), Prill and Aaronson (1973), Seaburn and Aronson (1974), and Aronson and Seaburn (1974).

The first experiments in deep-well injection of tertiary-treated wastewater were done at Bay Park on Long Island's south shore to directly recharge the Magothy aquifer and thereby impede the inland advance of saltwater into the aquifer. The design of the injection system is described by Koch and others (1973); the microbiological and water-quality aspects of deep-well injection are discussed in Vecchioli (1970, 1976), Ragone (1977), and Ku and others (1975); overall hydraulic effects of deep-well injection are discussed in Vecchioli and others (1980).

The role of the unsaturated zone during recharge through a small test basin at Medford, in Suffolk County, was studied by Prill and others (1979); the instrumentation used in that study is described by Oaksford (1983).

Knowledge gained in the studies mentioned above has culminated in the large-scale pilot recharge study in East Meadow, the design, instrumentation, and preliminary results of which are described herein.

Acknowledgments

Since the study's inception, the Nassau County Department of Public Works and the U.S. Geological Survey have worked to develop an alternative water source and method of returning that water to the ground-water system. Sincere thanks are extended to Francis J. Flood, Director of Environmental Engineering, Nassau County Department of Public Works, and James Oliva, Chief Sanitary Engineer at the Cedar Creek Advanced Wastewater Treatment Plant, for their expertise during the operational phases of the study. Thanks are also extended to William Lahey, Supervisor of Advanced Wastewater Treatment Plant maintenance, and to his crew, for maintenance of recharge equipment; and to Erick Kurz, Vincent Alonge, and the Advanced Wastewater Treatment Plant Laboratory for the chemical analyses for volatile organic compounds in the treated wastewater and ground water.

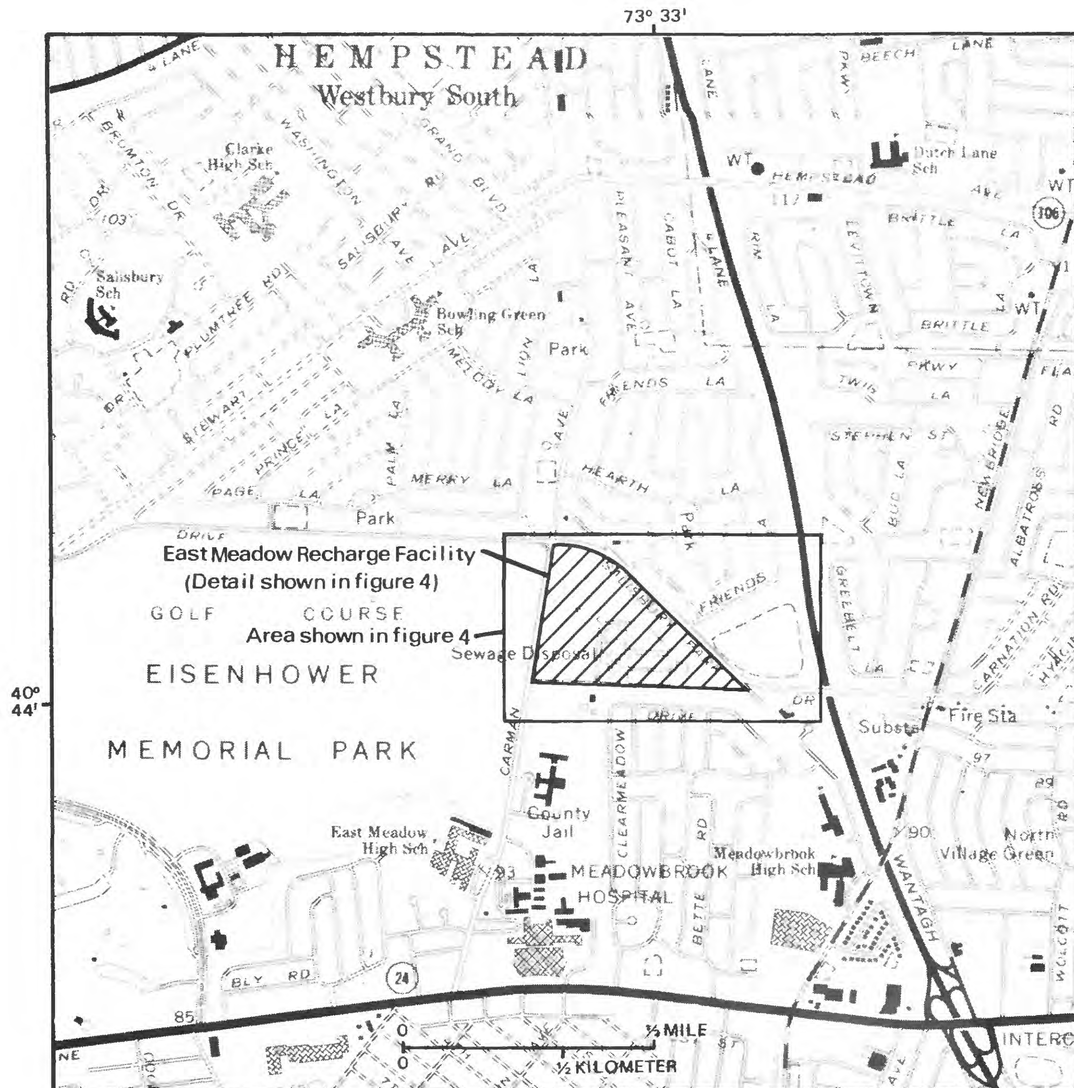
LOCATION AND HYDROGEOLOGY

The recharge facilities are in the Town of Hempstead on a 35-acre triangular plot owned by Nassau County in East Meadow (fig. 2). The site was selected because the hydrologic and geologic conditions are favorable for recharge and because county-owned property was readily available for construction of the site and transmission main. The transmission main links the site to the source of water supply at Wantagh (fig. 1). A total of 4 Mgal/d of treated wastewater is expected to be available for recharge.

The two hydrogeologic units receiving artificial recharge at the site are the upper glacial, or water-table, aquifer and the underlying Magothy aquifer. Aquifer properties are summarized by Aronson, Lindner and Katz (1983). The upper glacial aquifer beneath the recharge facility consists of unconsolidated sand and gravel of Pleistocene age. These deposits are generally less than 80 ft thick and have medium to high permeability. The Magothy aquifer, which underlies the upper glacial aquifer, is the principal aquifer on Long Island and consists of as much as 1,000 ft or more of mostly fine to medium-gray quartoze sand interbedded with gray clay and silt of Late Cretaceous age. The sands that form this aquifer have medium permeability; the silts and clays have low to very low permeability.

Since the study by Aronson and others (1983), new lithologic information has been compiled from core samples obtained during the installation of 2-inch observation wells. The lithologic and geophysical logs shown in a geologic section (fig. 3) suggest that the upper glacial aquifer beneath the site contains a discontinuous lens of dark-gray clay with varying amounts of silt and sand. Clay layers as much as 20 ft thick are present in the western part of the geologic section at a depth of 65 ft below land surface. The lower vertical permeability associated with clay layers could cause unusual mounding patterns above these layers.

The hydrogeology of Long Island has been studied by the U.S. Geological Survey in cooperation with the State of New York and County agencies for nearly 50 years and has been described in several reports. These include Suter, deLaguna, and Perlmutter (1949), Perlmutter and Geraghty (1963), Swarzenski (1959), Isbister (1966), McClymonds and Franke (1972), and Franke and McClymonds (1972).



Base from U.S. Geological Survey
Freeport, NY, 1:24,000, 1979

Figure 2.--Location and major features of recharge facility in East Meadow (General location is shown in fig. 1.)

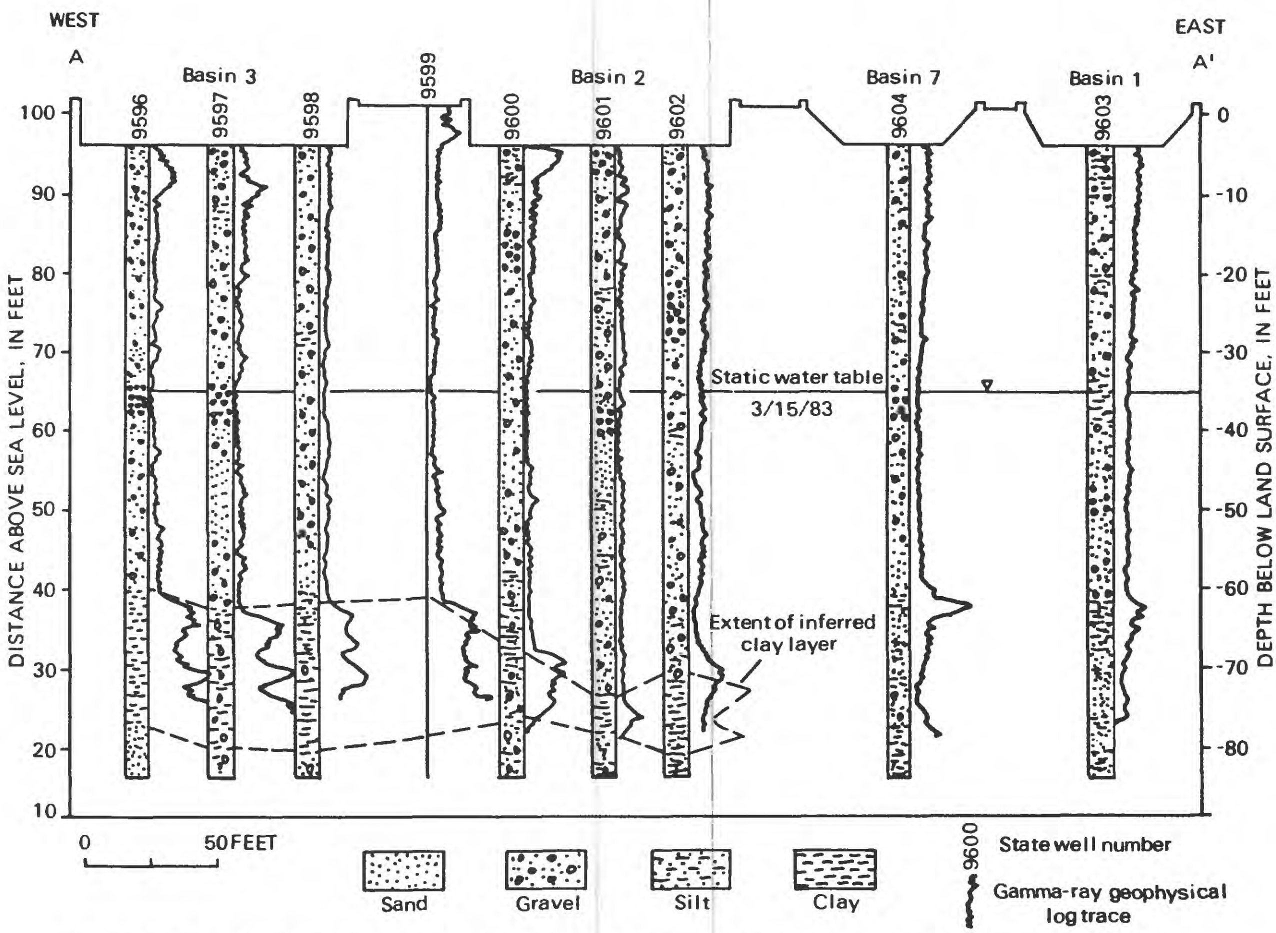


Figure 3.--Geologic section beneath southern part of recharge facility as determined from geophysical logs and cores. (Locations of section, wells, and basins are shown in fig. 4.)

DESIGN AND OPERATION OF ARTIFICIAL-RECHARGE FACILITY

The recharge site contains seven recently constructed shallow recharge basins, four older recharge basins, five shallow injection wells, and a control building (fig. 4). The injection wells release water to the lower part of the upper glacial aquifer to achieve immediate aquifer recharge; water in the basins percolates through the basin floors and reaches the water table several hours later.

Distribution of Reclaimed Water

Reclaimed water from the treatment plant at Wantagh is pumped through 6.25 mi of 24-inch-diameter pipeline that enters the recharge facility at its southeast corner; from there the water is piped to a 38,000-gal reservoir for temporary storage. Water from the reservoir is distributed to the recharge basins by gravity through lines buried beneath the facility; distribution to the injection wells is through a 16-inch line into the operation building, from which it is pumped to the injection wells 0.5 mi or less to the west (fig. 4).

Operations Building

The operations building houses the recharge pumps, a laboratory for water-quality testing, and a control room. The control room contains instruments that activate and monitor flow-control systems, water-level controllers, flow-rate controllers, water-quality sampling, and meteorological conditions. The operations building also houses a computerized system that continuously monitors all electronic instrumentation.

Observation Manholes

Specially instrumented observation manholes within two of the recharge basins enable detailed monitoring of the physical and chemical condition of reclaimed water as it percolates downward through the unsaturated zone. The manholes, instrumentation, and data collection are discussed in detail in a subsequent section.

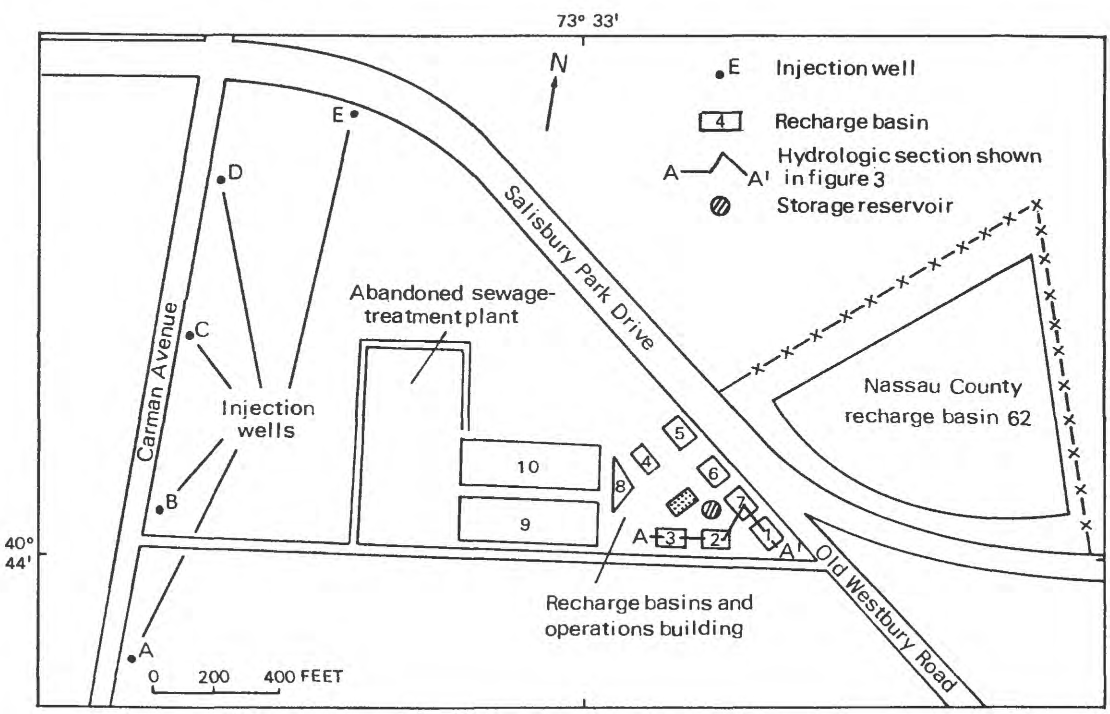


Figure 4.--Location of recharge basins, injection wells, and geologic section A-A' shown in fig. 3. (Modified from Beckman and Avendt, 1973.)

BASIN DESIGN, OPERATION AND MONITORING CAPABILITY

Basin Design and Operation

Seven recharge basins were constructed on the site, each 5 ft deep, with a floor area 50 ft x 100 ft (5,000 ft^2). The basins are large enough to accept 0.5 Mgal of reclaimed water per day. Five of the basins (nos. 1, 4, 5, 6, and 7, see fig. 4) were constructed with sloping walls (fig. 5) to provide a greater storage area; the sides were lined with impermeable Hypalon[1] to ensure that water would infiltrate only at the basin floor, which aids in the calculation of infiltration rates. The other two basins (nos. 2 and 3) have vertical concrete walls and contain an observation manhole from which to monitor the movement and chemical quality of recharge water and the soil-moisture characteristics during and after water application.

Four other basins (nos. 8, 9, 10, and 62) are available in the event that clogging significantly limits the capacity of the first seven basins, and one basin (no. 8, see fig. 6) is available for deep-ponding experiments. This basin is 15 ft deep and has a floor area of 3,213 ft^2 and a total area of 17,322 ft^2. It is to be used later in the study to examine the relationship between ponding depth and infiltration rate.

Basins 9 and 10 (fig. 4) are shallow basins that were formerly used for ponding of effluent from a secondary sewage-treatment plant that was shut down in 1979. These basins are to be used primarily for containment of water exceeding the capacity of basins 1 through 8.

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[1] Use of the brand name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Figure 5.--Typical shallow ponding basin at recharge facility. (View from southwest.)

The remaining basin, Nassau County stormwater basin 62 (fig. 4), provides emergency storage in the event that one or more basins need to be bypassed for maintenance. This basin may be used to evaluate the effectiveness of using storm-runoff basins for supplemental recharge with reclaimed wastewater.

When no basins with sufficient infiltration capacity are available, flow to the recharge facility can be reduced by throttling the main pumps that send water to the recharge facility. This procedure can maintain flow at a reduced rate until a basin becomes available.

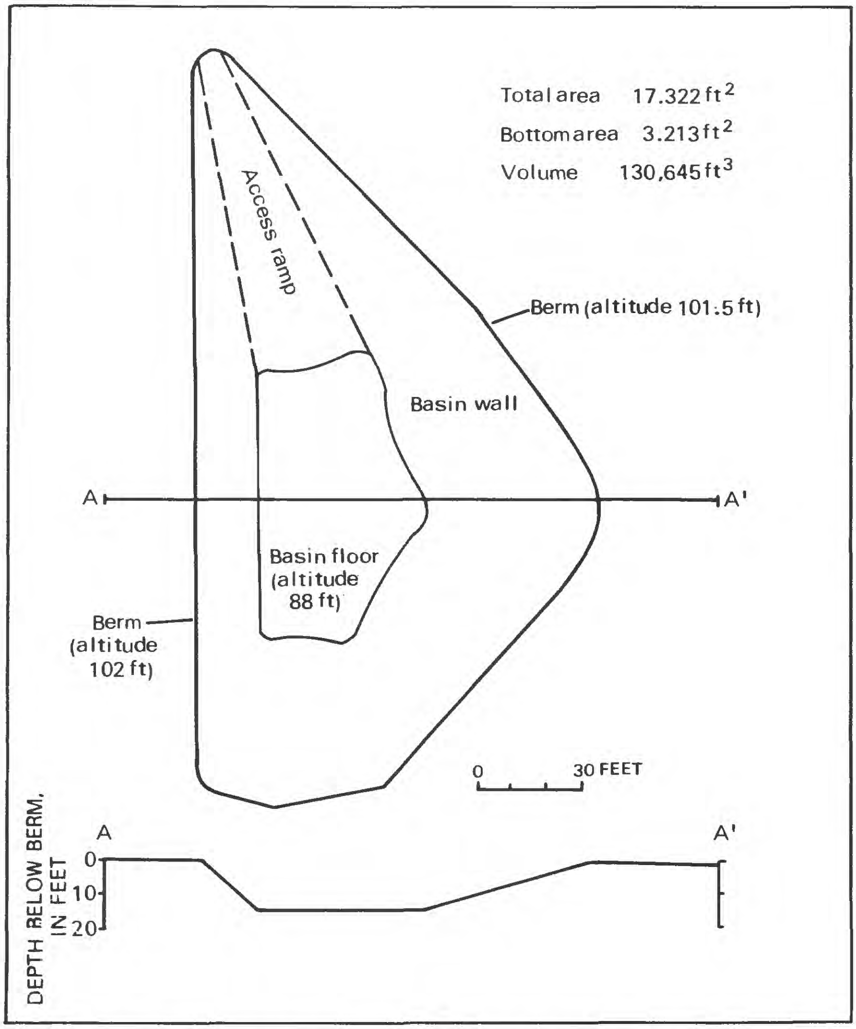

Figure 6.--Planar and cross-sectional views through basin 8. (Location is shown in fig. 4.)

Modes of Operation

Inflow to the basins can be regulated by two methods--control of flow rate and control of water depth within the basin. Each is explained in detail in the operation and maintenance manual for the recharge facility (Consoer, Townsend and Associates, 1978). The first method, which determines inflow to basins 1 through 7, is controlled by individual Venturi-type flow meters and associated pressure transmitters in the transmission lines to the basins. The desired flow rate (up to 700 gal/min) for each basin can be set in the control room of the operations building (fig. 7). The desired flow rate is maintained through automatic electronic modulation of motor-controlled butterfly valves in the transmission lines to the basins. Computations of infiltration rate when basins are operated in this mode must take into account the wetted area or changes in storage if ponding occurs. The total amount of water entering each basin is indicated by the recharge-meter panel in the operations building.

The second mode of operation, referred to as the constant-head mode, enables water levels in the basin to be maintained at a specified height. Under the normal operating conditions in this mode, a stage indicator sends a signal to the inflow indicator, which in turn modulates the motor-operated valve in the water-supply line to maintain the preset water level in the basin. Computation of infiltration rates is unnecessary in this mode because the inflow rate is equivalent to the infiltration rate as long as the stage remains constant.

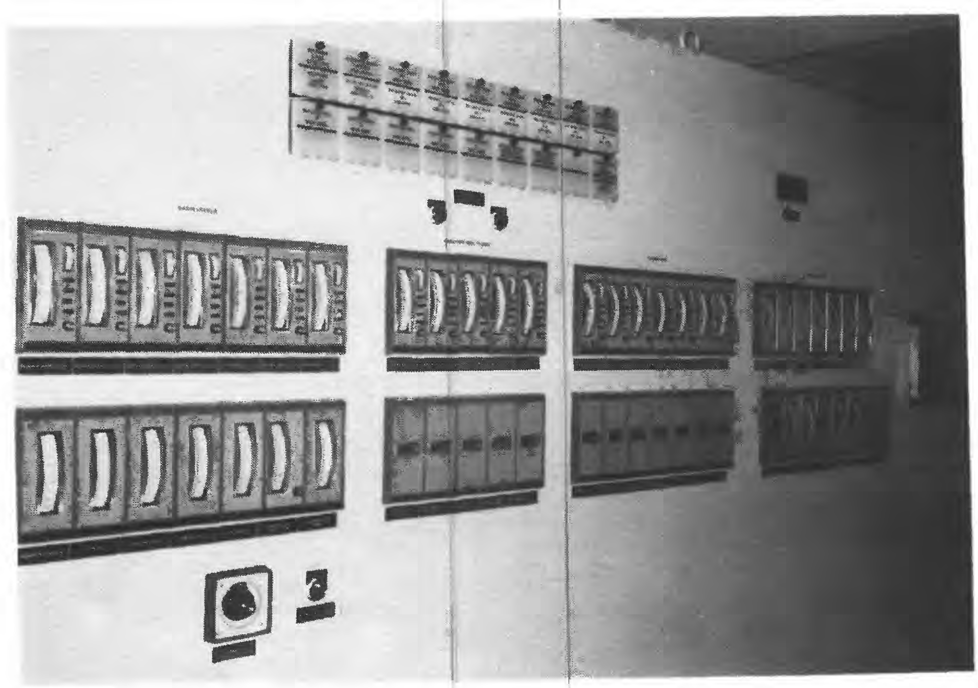

Figure 7.--Recharge-meter panel in control room of operations building.

Description of Manholes

Two specially designed identical observation manholes were installed within basins 2 and 3 to enable detailed monitoring and sampling of reclaimed water as it percolates through the unsaturated zone. Instrumentation within the manholes permits evaluation of infiltration rates, soil moisture, clogging, and water sampling for chemical analysis as water passes through the unsaturated zone.

The observation manholes are composed of a stack of three reinforced concrete rings, each 8 ft high, with an inside diameter of 12 ft and a wall thickness of 1 ft. Each ring weighs 25 tons and was set in place by a crane. Sand and gravel within the concrete rings was removed by a crane-operated shovel and manually by shovel, which allowed the rings to sink under their own weight. The lower end of each bottom ring is 16 ft below the basin floor. The top of each manhole is 8 ft above the basin floor and is covered with a fiberglass instrumentation housing. A catwalk leads from the basin edge to the manhole (fig. 8). A spiral staircase provides access to two working levels within the manhole--one 6 ft below the basin floor and the other 16 ft below the basin floor. Subway grating forms the floor for the 6 ft-level, and a concrete floor with a central drain forms the bottom level. Three 12-inch-diameter access holes were made in the floor for installation of 6-inch PVC observation wells so that water samples could be obtained, probes for pH, dissolved oxygen, and temperature could be mounted, and a continuously recording water-level recorder could be installed.

Conventional drilling methods could not be used here because space was insufficient for a drill rig and because the depth to water below the manhole floor (10 ft) prevented use of a hand auger. A method similar to conventional cable-tool drilling was used, whereby a flange assembly forced the casing into the ground while a sand pump created a cavity below it (written commun., A. A. Giaimo, U.S. Geological Survey, 1982). Locations of the observation wells within the two manholes are shown in figure 9.

A cross section through basin 3 (fig. 10) shows the manhole design and the position of observation wells, neutron-access holes, and lysimeters (discussed later). Top views through the two manholes showing the position of the instrumentation, described below, are also shown in figure 10. A summary of the instrumentation is given in table 1.

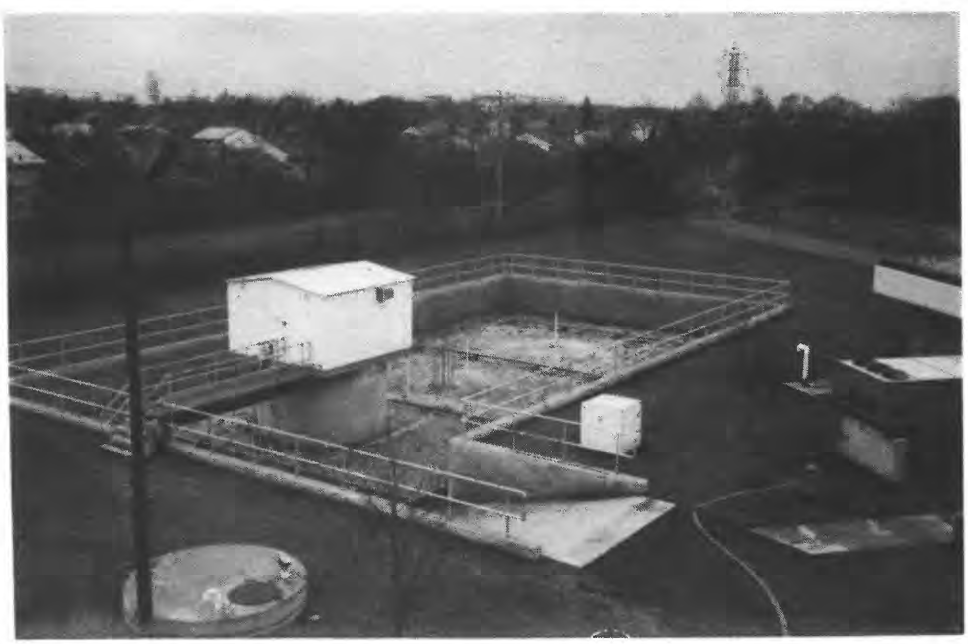

Figure 8.--Fiberglass housing over observation manhole at basin 3.

Table 1.--Type and depth of instruments in manhole at basins 2 and 3.

[Depths are in feet below basin floor (94.94 feet above sea level); position of instruments is shown in fig 10]

Basin 2				Basin 3			
Instrument	Depth	Instrument	Depth	Instrument	Depth	Instrument	Depth
Tensiometer		Thermocouple		Tensiometer		Thermocouple	
1	0.91	1	0.00	1	.60	1	0.00
2	1.94	2	.94	2	1.94	2	.81
3	2.81	3	1.94	3	2.93	3	1.81
4	3.97	4	2.94	4	3.88	4	2.81
5	4.80	5	4.94	5	4.91	5	3.81
6	5.93	6	6.94	6	6.04	6	4.81
7	6.97	7	8.94	7	6.91	7	6.81
8	7.86	8	10.94	8	7.97	8	9.81
9	8.86	9	12.94	9	8.79	9	11.81
10	9.87	10	14.94	10	9.92	10	13.81
11	10.89			11	10.56		
12	11.90	Gas-sampler port		12	11.71	Gas-sampler port	
13	12.83			13	12.98		
14	13.93	1	.90	14	13.87	1	.75
		2	2.90			2	2.75
Lysimeter		3	4.90	Lysimeter		3	4.75
		4	6.90			4	6.75
1	2.5	5	8.00	1	2.5	5	8.79
2	5.3	6	9.90	2	5.3	6	10.75
3	8.2	7	11.90	3	8.2	7	12.75
4	11.0	8	13.90	4	11.0	8	14.75
Soil port		Turbidimeter	0.00	Soil port		Turbidimeter	0.00
1	2.5	Basin-stage port	0.00	1	2.5	Basin-stage port	0.00
2	5.3			2	5.3		
3	8.2			3	8.2		
4	11.0			4	11.0		

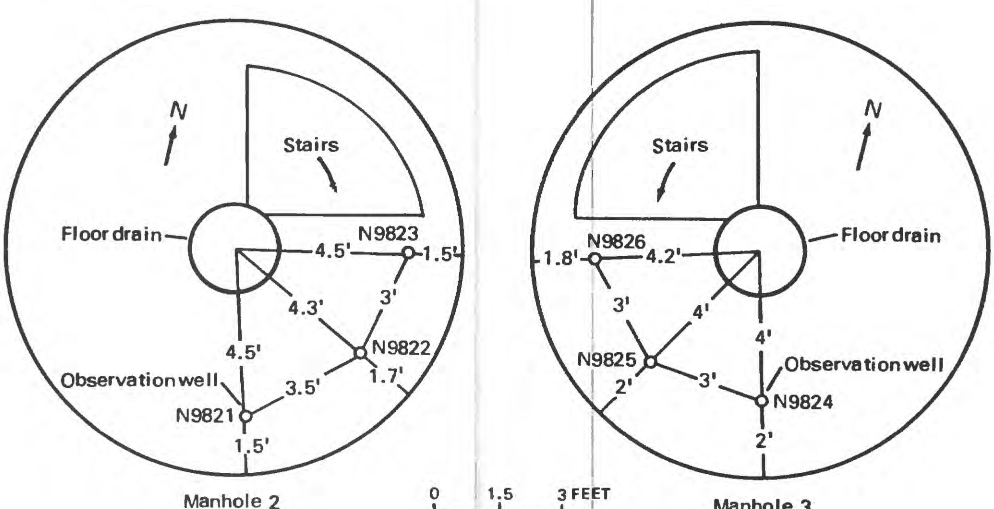

Figure 9.--Location of 6-inch observation wells within manholes at basins 2 and 3. (Basin locations are shown in fig. 4.)

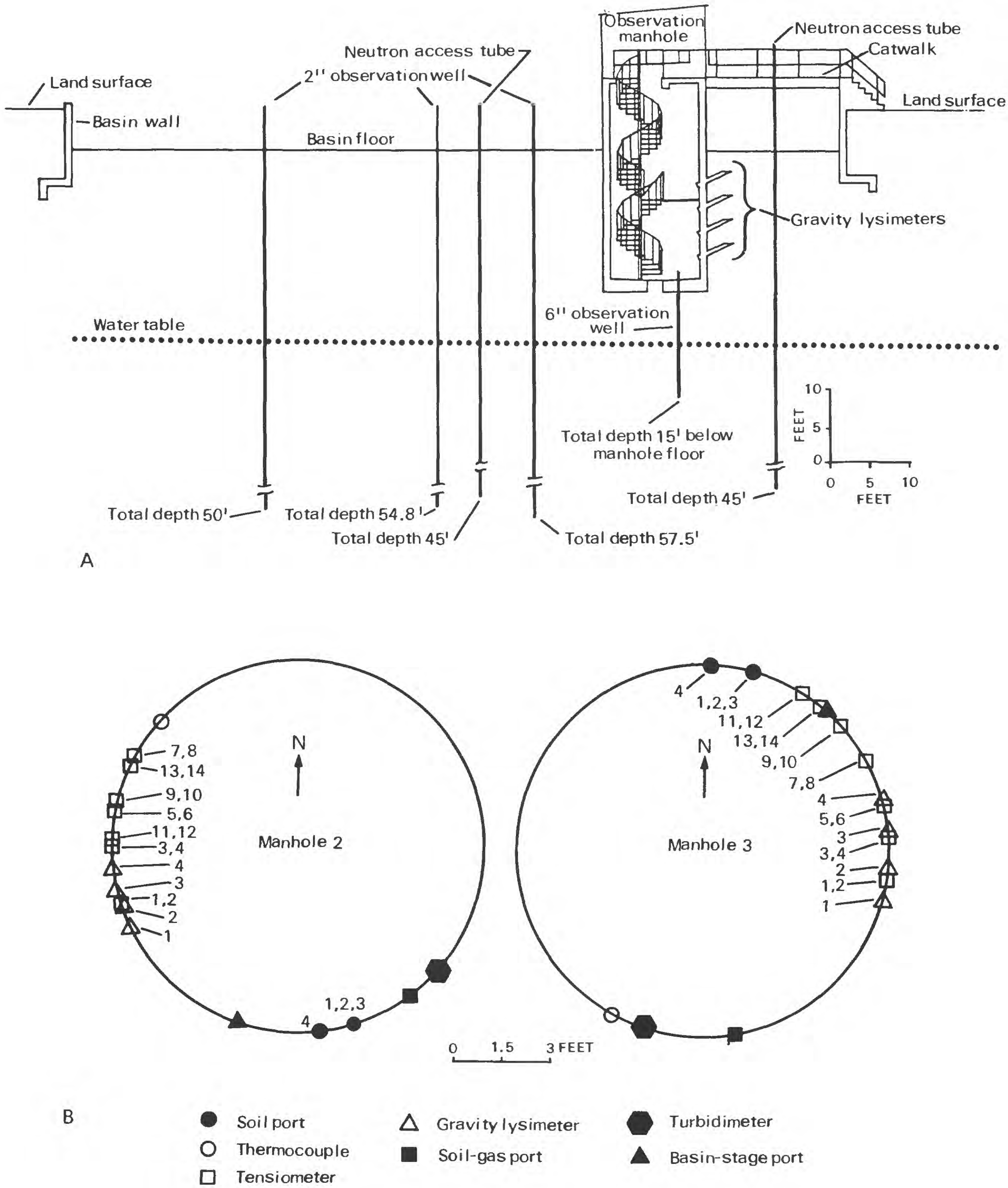

Figure 10.--A. Cross section through basin 3 showing location of observation wells, neutron-access holes, and lysimeters. (Looking north). B. Top view through manholes in basins 2 and 3 showing position of instrumentation along the manhole walls. (Basin locations are shown in fig. 4.)

Monitoring Capability

Water Sampling

Samples of the percolating water can be obtained from several depths within the manholes to study the chemical and physical effect of the unsaturated zone on reclaimed water. Four inclined gravity lysimeters were installed through the wall of each manhole at depths of 2.5, 5.3, 8.2, and 11 ft below the basin floor (table 1) to capture water samples under virtually undisturbed soil conditions. Comparison of water samples collected at different depths and time intervals during and after ponding can provide data on the movement and changes in dissolved and suspended-solids concentrations during recharge.

The design and function of inclined gravity lysimeters are described in Oaksford (1983). A typical sampler (fig. 11) consists of (1) a 6-inch-diameter tube of 14-gauge stainless steel that extends diagonally upward through the manhole wall into the soil, (2) a screened plate assembly within the tube to prevent dislodgment of the soil, (3) a purging system that can be used to redevelop the lysimeter should it become clogged, and (4) an airtight endcap that prevents exchange of air between the manhole and the soil. Driving the tube into place does not disturb the soil significantly. The collection end of the tube is beveled to form a horizontal, elliptical plane of capture when the tube is in place; the major axis of the ellipse is 1.1 ft and the minor axis 0.5 ft (fig. 11). To obtain maximum capture efficiency, the tubes are inclined in accordance with the head gradient required for downward flow under the pressure head in the formation at the time of

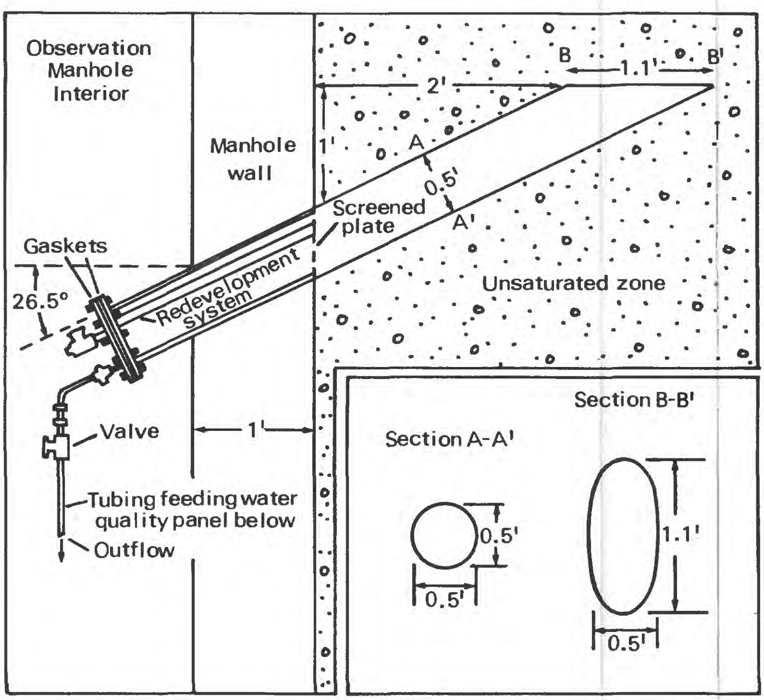

Figure 11.--Cross section through typical gravity lysimeter used for soil-water sampling. (From Schneider and others, 1984.)

sampling. Soil material from the unsaturated zone fills the tube to the screened plate assembly.

Water collected by the four gravity lysimeters in each basin flows to a specially designed water-quality-monitoring panel (fig. 12) mounted on the wall at the bottom level. Water from each lysimeter passes through a set of continuously recording sensors that measure pH, dissolved oxygen, and suspended-solids concentration. All pH probes were calibrated electronically as well as with known pH solutions. Dissolved-oxygen probes were calibrated with zero dissolved-oxygen solutions. As was the case with the majority of instruments within the manholes, rigorous field testing will not be conducted until recharge tests begin at these basins. Until that time, electronic calibration will be the major form of testing. Bypass valves enable collection of samples for a more detailed laboratory analysis when indicator values so dictate.

Quality of ponded water within the basin is monitored through use of a refrigerated composite sampler whereby a peristaltic-type pump in the housing above the manhole collects basin-water samples at specified intervals for complete laboratory analysis.

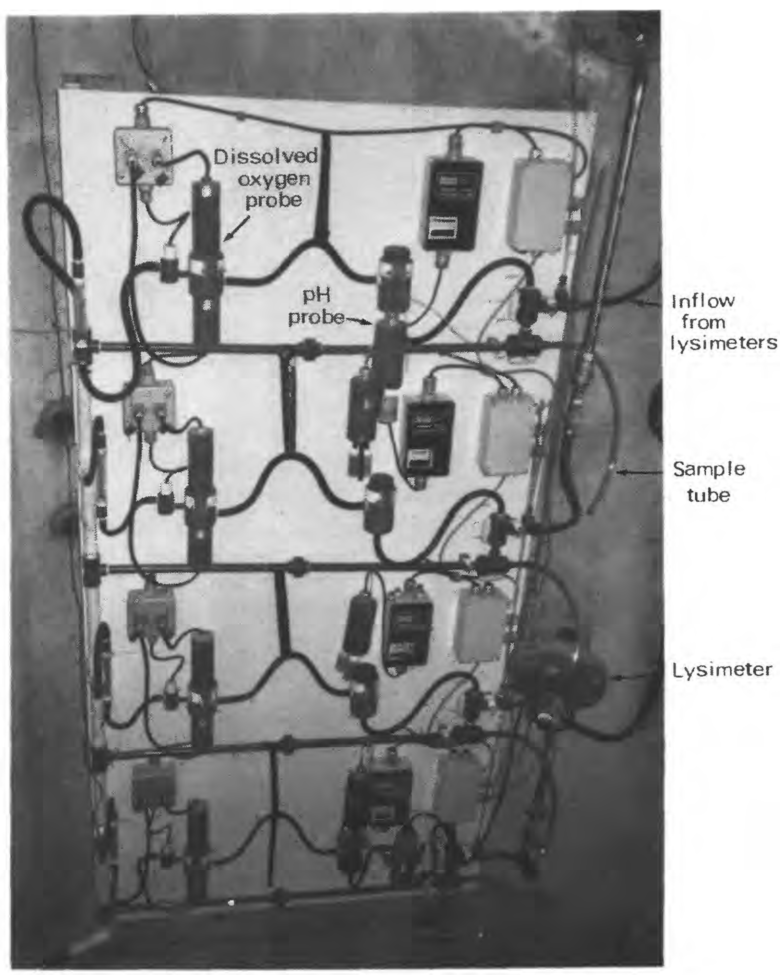

Figure 12. Water-quality-monitoring panel in basin 3.

Pressure-Head Measurement

Soil-moisture tension, the negative equivalent of pressure head, is a measure of the force by which water is held within the soil pores and also indicates the degree of saturation, or moisture content, of the soil. Pressure-head distribution within the upper part of the unsaturated zone can be used to detect the development of clogging in the unsaturated zone during recharge.

Fourteen horizontal water-manometer tensiometers were installed through the walls of each manhole at varying depths to measure soil-moisture tension in the upper 14 ft of the unsaturated zone. The tensiometer apparatus consists of a porous ceramic cup affixed to the end of a circular plastic tube that is filled with gas-free water and then sealed with a ventable valve. The ceramic cups are set 4 ft beyond the outside edge of the manhole wall at the depths shown in table 1. Tubing connects the valve end to a water manometer that indicates pressure head within a range of −25 to +25 inches. Connected to the water manometers are differential pressure transducers that ideally operate within low and medium pressure ranges. The pressure transducers transmit continuous signals to a carrier demodulator that balances, amplifies, and filters the signal. The signal is then converted back to inches and, when calibrated, is the same as the pressure-head value in the manometer.

Manual readings of manometers are taken on a daily basis and are compared to computer-generated readings to monitor the stability of electronic signals. A monthly fine-tuning calibration of transducer signals is necessary to maintain accuracy within a $\pm$0.1-inch error.

Soil-Gas Sampling

Soil-gas samplers are positioned at varying depths (table 1) to measure oxygen content of the soil atmosphere during recharge. This procedure can detect clogging zones and related chemical and bacterial activity. The samplers consist of an open-ended rigid plastic tube 1 inch in diameter with a gas-permeable screen affixed to the outer end. The tube extends 10 inches into the soil through the manhole wall. Portable pumps circulate gas from the soil through a continuously monitoring digital oxygen analyzer (fig. 13). Calibration consisted of testing the probe in air.

Soil Sampling

Soil samples can be collected from the unsaturated zone for analysis of physical and chemical changes resulting from the passage of reclaimed water. Soil properties, including pH, cation-exchange capacities, exchangeable cations, and selected acid-extractable metals at selected depths were examined before recharge; results are given in table 2. These data can be compared with those from samples taken after cessation of recharge to reveal the changes in soil chemistry. Soil-sampling ports are positioned at four depths within each manhole. (See table 1.) When sampling is required, the port covers are removed, and a small amount of soil collected.

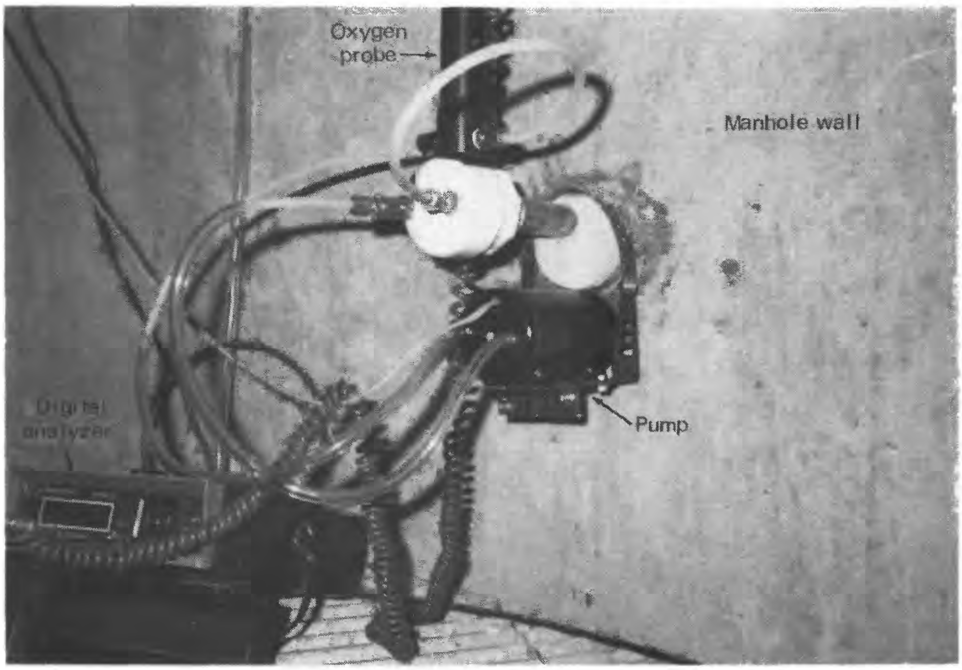

Figure 13A.--Portable digital oxygen analyzer used for measuring soil gases with gas collector in position.

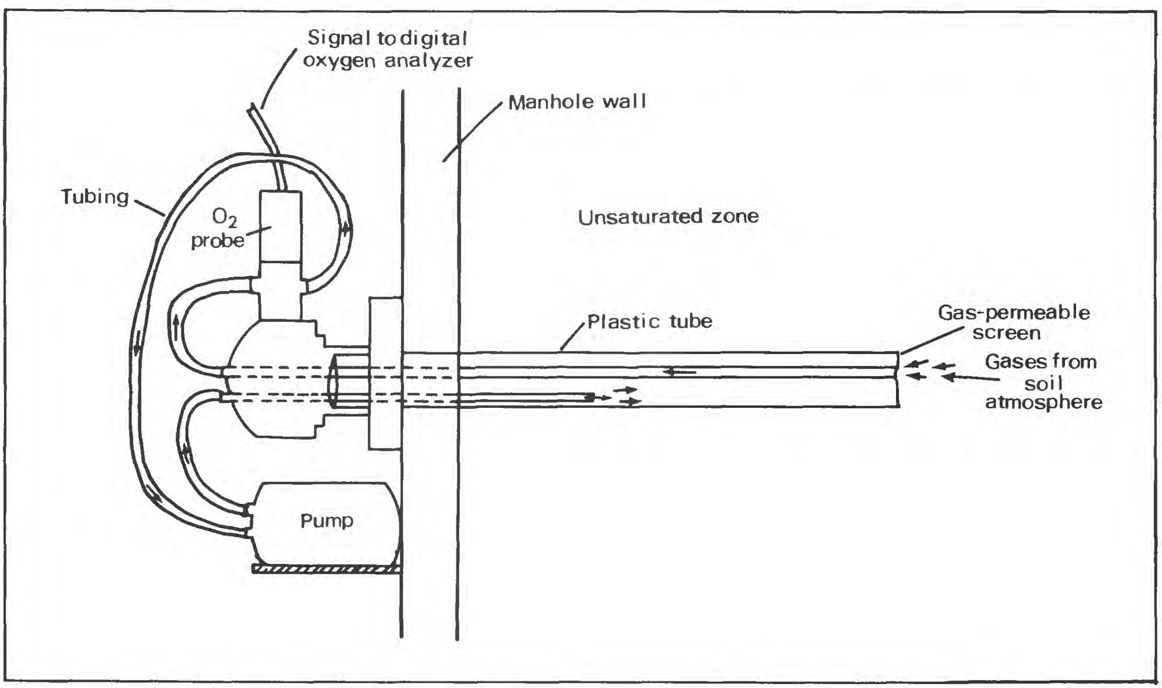

Figure 13B.--Cross section through gas-collection system.

Table 2.--Chemical properties[1] of soil samples from unsaturated zone beneath basins 2 and 3.

Depth below basin floor (ft)	pH	Exchange acidity (meq/100 g)	Cation-exchange capacity (meq/100 g)	Exchangeable cations (meq/100 g)				Acid-soluble metals (µg/g)			
				Calcium	Magnesium	Sodium	Potassium	Zinc	Cadmium	Lead	Nickel
					Basin 2						
2.5	8.0	2	1.150	0.295	0.0170	0.045	0.055	49.00	0.195	2.80	1.5
5.3	7.9	1	.850	.130	.0050	.010	.050	15.20	.110	1.30	1.5
8.2	8.0	1	1.150	.185	.0060	.010	.335	4.85	.190	1.85	<1
11	8.0	1	.550	.125	.0015	< .010	.025	23.45	.040	1.25	<1
					Basin 3						
2.5	7.4	2	3.450	1.220	0.0605	0.020	0.120	17.55	0.205	7.45	7.5
5.3	7.6	1.5	1.250	.430	.0095	.010	.055	11.45	.085	3.10	2.5
8.2	6.9	1	1.800	.305	.0575	.020	.170	14.90	.160	3.65	3.5
11	6.6	1	.850	.055	.0030	< .010	.030	3.55	.070	1.40	<1

[1] Analyses by University of Cornell, Agronomy Laboratory.

Soil-Temperature Measurement

Soil temperature is measured by thermocouples at selected depths. Type-T[1] thermocouples were used here because they provided reliable measurement within the working range. The temperature sensor consists of a bimetallic junction that generates a measurable self-induced voltage proportional to temperature. Any temperature change is reflected as a change in voltage. Soil temperature is useful in plotting movement of reclaimed water and also in making viscosity adjustments in infiltration-rate computations. The thermocouples extend 3 ft into the soil through 1/4-inch stainless-steel guide tubes. Depths of the thermocouples are given in table 1.

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[1] A type-T thermocouple consists of a copper and constantan wire whose thermoelectric voltage range is from -450 to 750 °F with a limit of error of 1.5 °F as designated by the American Society for Testing and Materials.

Calibration testing of thermocouple connections and sensitivities were conducted by immersing the thermocouples into an ice bath to determine reaction and recovery time. Thermocouple wire used in this study (type T) has an error of ± 0.75°F.

Soil-Moisture Measurement

Eleven 2-in galvanized steel neutron-access tubes extending 45 ft deep are positioned at selected distances in and near the two basins, as shown in figure 14. The tubes are positioned to detect clogging beneath the basins and lateral flow above the water table outside the basins. Measurements are obtained by a neutron-logging tool that, when lowered through the access tube, detects soil-moisture conditions and transmits signals to a strip-chart recording device.

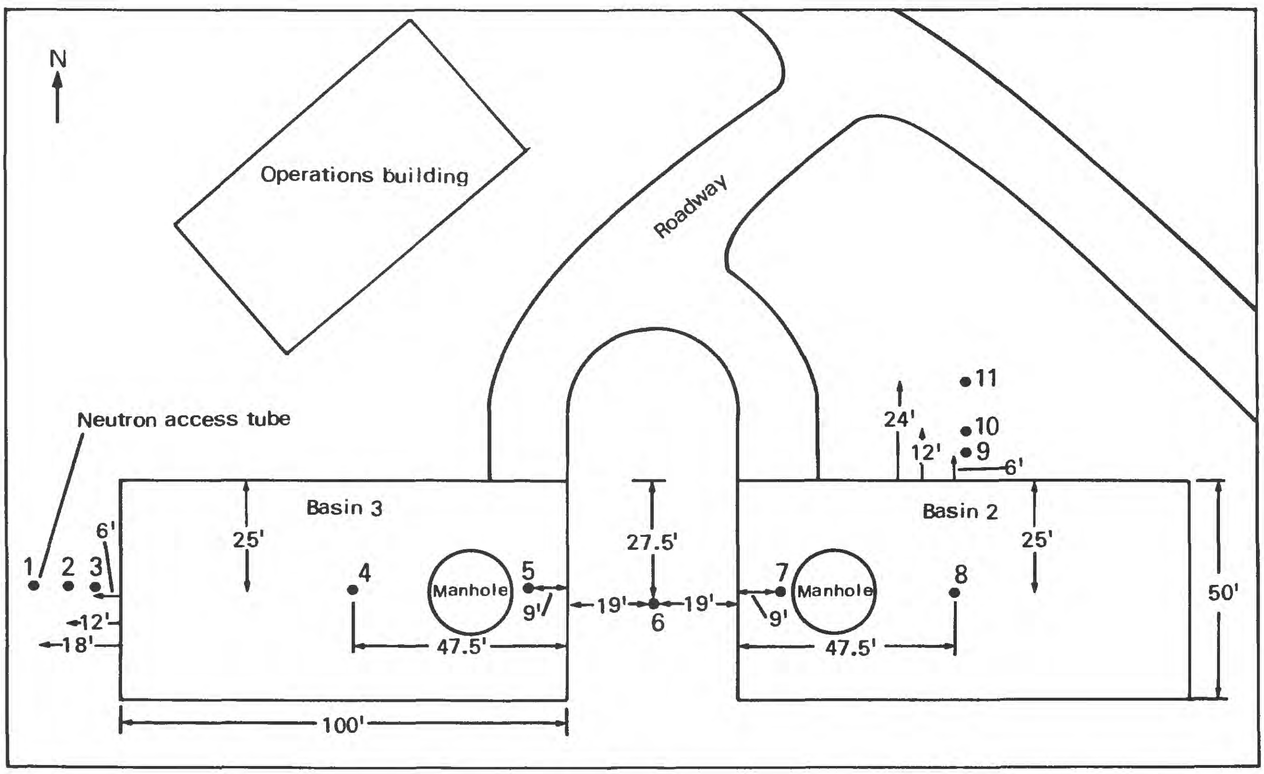


Figure 14.--Location of neutron-access holes in and adjacent to basins 2 and 3. (Modified from Schneider and others, 1984.)

Data Storage and Transmittal

Data from the instruments are fed to a unit in the instrument housing of each manhole, and the unit transmits the signals to the main computer in the operations building, which has continuous-recording capability. Data can be stored in memory or can be sent to a magnetic tape unit that can record as much as 2 weeks of data, depending on the frequency of collection. From the computer, data can be sent to a terminal equipped with several data-plotting programs or can be sent through a modem to the U.S. Geological Survey computer in Syosset, 8 miles away. The main computer can also calculate several mathematical functions pertaining to infiltration rates and hydraulic gradients within the unsaturated zone, which ultimately aid in basin management. The data-acquisition system at the recharge facility is connected to a modem that allows communication with the system from various telephone locations; this permits monitoring of all instrumentation without requiring one's presence at the recharge facility.

The overall evaluation of the design and layout of the monitoring equipment cannot be made at this time because only background information has been collected. When test results from recharge experiments within basins 2 and 3 are compiled, a complete evaluation of the instrumentation can be made.

INJECTION-WELL DESIGN AND OPERATION

The second method of artificial recharge at the East Meadow facility is the injection of reclaimed water to the basal part of the upper glacial aquifer through a system of five 12-inch-diameter wells. Four of the wells are to be in operation at any specified time with one on standby. Each well will inject 0.5 Mgal/d (350 gal/min), and the total amount of water that can be injected with four wells in operation is 2 Mgal/d. Locations of injection wells are shown in figure 4.

Well Design

The injection wells consist of fiberglass-reinforced epoxy casing 65 ft in length and 1 ft in diameter. A stainless-steel, wire-wrapped screen 30 ft long and 1 ft in diameter is attached to the casing from 65 to 95 ft below land surface. A sand trap consisting of a 5-ft length of fiberglass casing that is attached to the bottom of the screen is used on four of the five wells. The wells are of three types--three have a gravel pack, one has no gravel pack, and one has both a gravel pack and a redevelopment system. The first type (A in fig. 15) is used at well sites B, C, and D (fig. 4.) The second type (B in fig. 15) is used at well site A (fig. 4). Comparison of the operating effectiveness of the natural-pack well with that of the gravel-pack well will reveal which type is best suited for recharge operations. The generally coarse-grained texture of the upper glacial aquifer is appropriate for a natural pack, which makes well construction less costly but is also more prone to clogging at the well screen and therefore may require redevelopment more frequently. However, a gravel pack increases the effective well diameter and thus provides a larger zone over which to distribute clogging material; this could in turn reduce the frequency of redevelopment.

The third type of well (C in fig. 15) is similar to those with a gravel pack except that it has a built-in redevelopment system. This system requires installation of an eductor pipe and an air line through which compressed air is introduced to provide air-lift pumping and surging during redevelopment. To submerge the air line, the well is deepened to about 135 ft by increasing the length of casing below the screen for the sand trap. Only one well (site E, fig. 4) contains a redevelopment system.

Except for the well with the self-contained redevelopment system, well redevelopment consists of surging and air-lift pumping 5-ft sections of the screen isolated between inflatable packers. After one section of screen is redeveloped, the assembly is moved and the process repeated for the next section of screen. Isolating and surging short intervals of the screen gives maximum agitation per unit screened area.

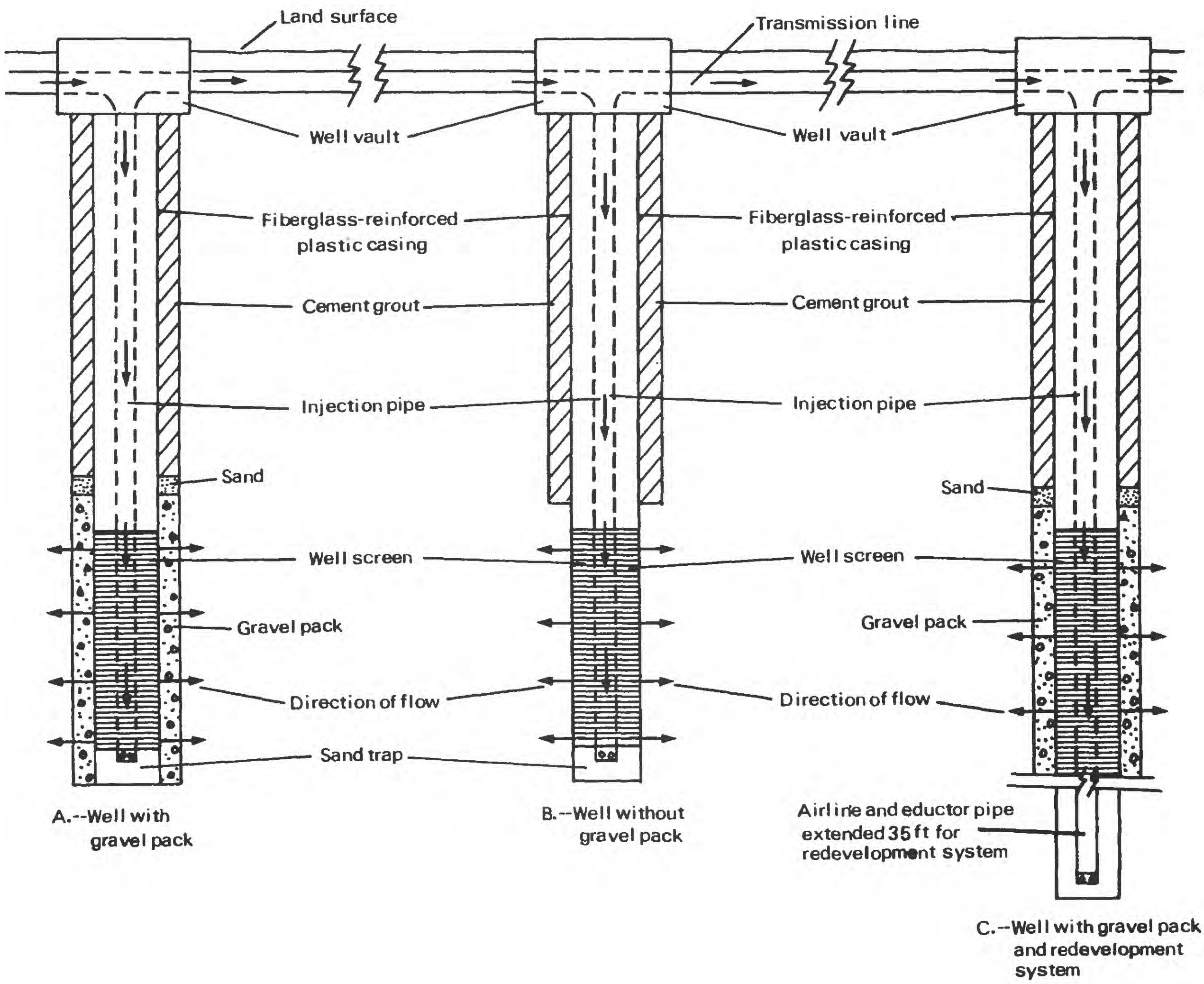


Figure 15.--Comparison of three types of injection wells. (Locations of wells are shown in fig. 4. Modified from Aronson, 1980.)

Well Operation

Two pumps (one used for injection, the other for backup) transfer part of the reclaimed water from the storage reservoir to the injection wells. The flow to each well is measured by a Venturi flow meter inside the reclaimed-water line and is indicated on the injection flow controller on the recharge-meter panel in the operations building. The desired flow rate is set on the flow controller, which in turn regulates the position of the butterfly valve in the water-supply line to maintain the desired flow.

Each injection well is equipped with a pressure transducer that functions as a well-head pressure-measuring device. Injection of reclaimed water continues until the well-head pressure reaches 25 ft of water above static, or approximately 10 lb/in^2. At this point the well is shut off and redeveloped. Should this pressure be reached unexpectedly during operation, the well is automatically shut off, and the reclaimed water routed to the recharge basins.

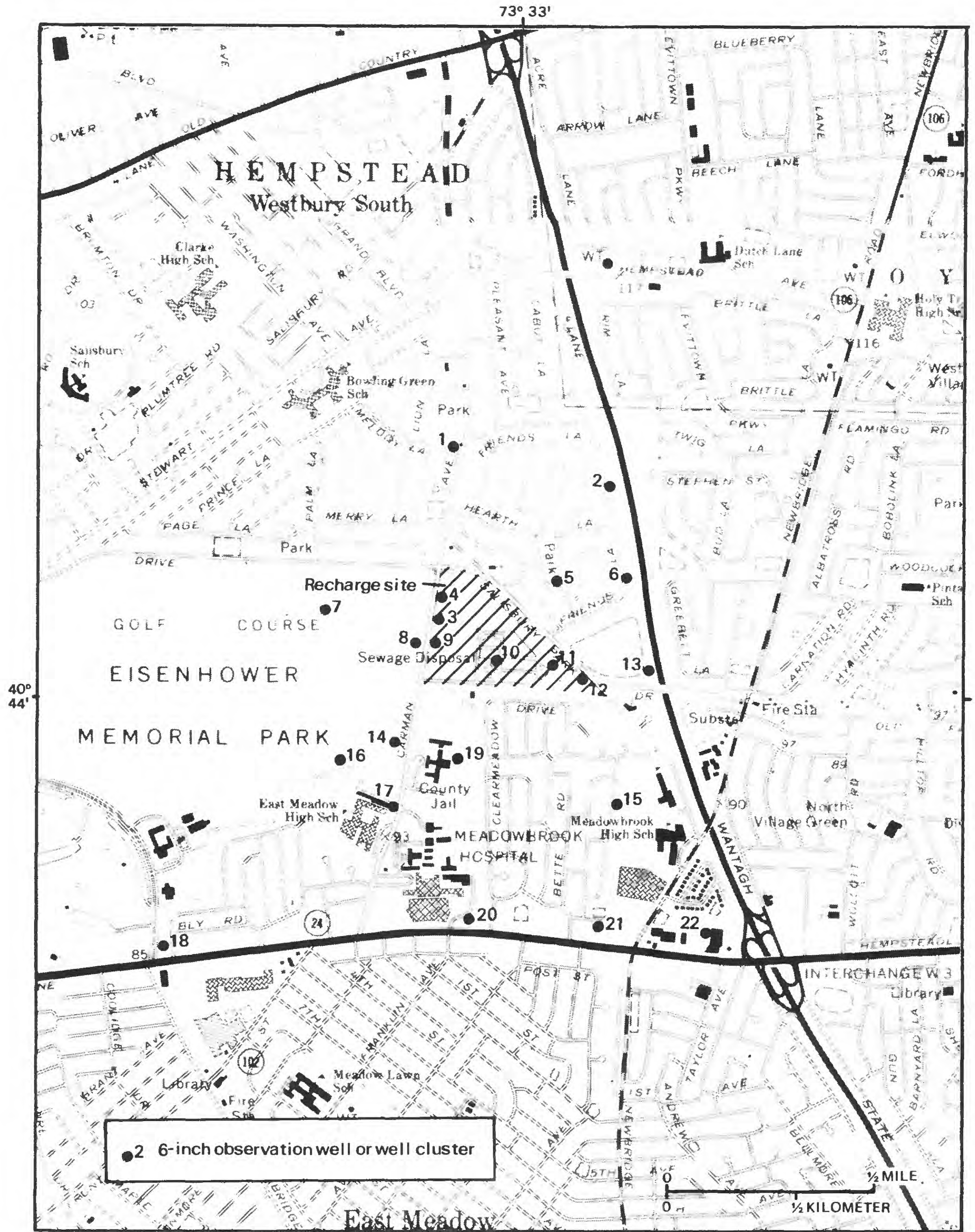
An inline water analyzer, which allows continuous monitoring of total chlorine residual, turbidity, temperature, specific conductance, dissolved oxygen, and pH of water entering the basins and wells, is designed to respond to excess turbidity because turbidity may cause clogging of the well screens. When a given level of turbidity is exceeded, an alarm on the recharge meter panel is activated, and a shutdown sequence begins. First a timer is started, and, if the turbidity is not corrected within 30 minutes, the well pump shuts down, and the butterfly valves in the inflow line close. All reclaimed water that is received for recharge will then be directed to the basins, and flow will be controlled by a preset flow rate that overrides all previous commands sent to the basins. This manual loading controller, which is used explicitly for this purpose, then regulates the motor-operated valves in each reclaimed-water supply line to maintain the same flow rate to each basin.

MONITORING-WELL NETWORK

The East Meadow recharge facility is surrounded by an observation-well network designed to monitor aquifer response to recharge. Data from these wells will aid in evaluating local changes in both pressure head and water quality. All observation-well clusters are within a 1-mi^2 area. Forty-seven 6-in diameter wells were installed at 23 sites (locations are shown in fig. 16); 23 are screened at 45 to 50 ft, 16 at 95 to 100 ft, and 8 at 195 to 200 ft below land surface. A 2-in diameter observation well was installed at each of 19 sites (locations are shown in fig. 17), with screened intervals ranging between 9.3 and 64.10 ft below land surface.

Six-Inch Observation Wells

All 6-in observation wells consist of fiberglass casing and a 5-ft section of 6-in stainless-steel screen. Water levels are recorded continuously by battery-powered, digital water-level recorders. Monthly hydrographs are produced for each well to depict water-level changes during and after recharge. A list of all 6-inch observation wells in the network is given in



Base from U.S. Geological Survey
Freeport, NY, 1:24,000, 1979

Figure 16.--Location of 6-inch observation wells near recharge facility. (Well data are summarized in table 3.)

table 3 with the screen depth and distance from closest point of recharge. The example in figure 18, from well N9198, 60 ft from basin 6 before recharge began, is a sample of the hydrographs that can be generated with data collected by the recorders.

Water samples are obtained periodically by submersible pump and are sent to the U.S. Geological Survey laboratory in Doraville, Ga., for full chemical analysis, including volatile organic compounds, base/neutral- and acid-extractable organic compounds, and chlorinated organic compounds. The Nassau County laboratory at the wastewater-treatment plant analyzes samples from the wells monthly and the storage reservoir daily for volatile organic compounds.

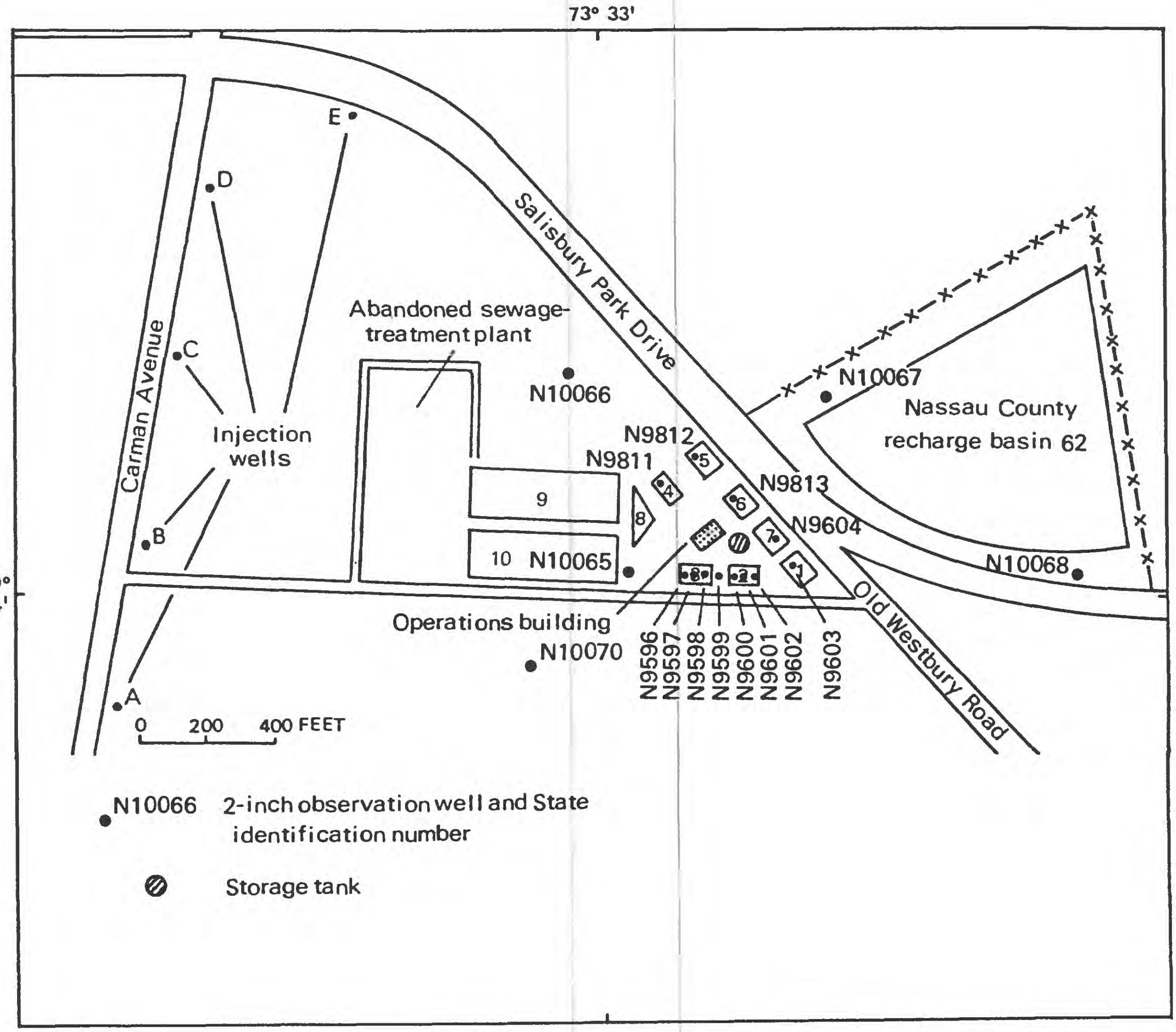


Figure 17.--Locations of 2-inch observation wells within and adjacent to recharge facility. (Well data are given in table 4.)

Table 3.--Statistics on 6-inch observation wells.

[Locations are shown in fig. 15.]

Well number State	Well number Local	Depth of screen bottom below land surface (ft)	Screened interval (ft below land surface)	Closest recharge point: Distance from source (ft)	Closest recharge point: Name
N9234	(1A)	205	200 - 205	1,650	Injection well E
N9235	(1B)	105	100 - 105	1,650	Injection well E
N9236	(1C)	50	45 - 50	1,650	Injection well E
N9217	(2)	50	45 - 50	2,250	Recharge basin 5
N9360	(3A)	205	200 - 205	100	Injection well D
N9361	(3B)	98	93 - 98	100	Injection well D
N9362	(3C)	45	40 - 45	100	Injection well D
N9363	(4A)	105	100 - 105	30	Injection well D
N9364	(4B)	45	40 - 45	30	Injection well D
N9449	(5A)	198	193 - 198	1,100	Center of site
N9450	(5B)	104	99 - 104	1,100	Center of site
N9451	(5C)	41	36 - 41	1,100	Center of site
N9218	(6)	44	39 - 44	1,500	Center of site
N9239	(7A)	205	200 - 205	1,500	Injection wells C and D
N9240	(7B)	105	100 - 105	1,500	Injection wells C and D
N9241	(7C)	45	40 - 45	1,500	Injection wells C and D
N9199	(8A)	105	100 - 105	125	Injection well C
N9200	(8B)	45	40 - 45	125	Injection well C
N9182	(9A)	196	191 - 196	25	Injection well C
N9183	(9B)	106	101 - 106	25	Injection well C
N9184	(9C)	45	40 - 45	25	Injection well C
N9193	(10A)	195	190 - 195	750	Center of site
N9194	(10B)	95	90 - 95	750	Center of site
N9195	(10C)	46	41 - 46	750	Center of site
N9196	(11A)	206	201 - 206	60	Basins 4, 5, and 6
N9197	(11B)	95	90 - 95	60	Basins 4, 5, and 6
N9198	(11C)	46	41 - 46	60	Basins 4, 5, and 6
N9367	(12A)	105	100 - 105	65	Basin 1
N9368	(12B)	45	40 - 45	65	Basin 1
N9219	(14A)	95	90 - 95	500	Injection well A
N9220	(14B)	45	40 - 45	500	Injection well A
N9247	(15A)	95	90 - 95	2,000	Center of site
N9248	(15B)	45	40 - 45	2,000	Center of site
N9221	(16A)	95	90 - 95	1,000	Injection well A
N9222	(16B)	45	40 - 45	1,000	Injection well A
N9223	(17A)	108	103 - 108	1,250	Injection well A
N9224	(17B)	45	40 - 45	1,250	Injection well A
N9201	(18)	45	40 - 45	4,500	Injection well A
N9365	(19A)	95	90 - 95	600	Injection well A
N9366	(19B)	45	40 - 45	600	Injection well A

(continued)

Table 3.--Statistics on 6-inch observation wells. (continued)
[Locations are shown in fig. 15.]

Well number		Depth of screen bottom below land surface (ft)	Screened interval (ft below land surface)	Closest recharge point	
State	Local			Distance from source (ft)	Name
N9225	(20)	44	39 - 44	2,600	Injection well A
N9252	(21A)	195	190 - 195	3,500	Center of site
N9253	(21B)	95	90 - 95	3,500	Center of site
N9254	(21C)	46	41 - 46	3,500	Center of site
N9226	(22)	45	40 - 45	4,000	Center of site
N9689	(Basin 2)	45	20 - 45	15	Basin 2
N9690	(Basin 3)	45	20 - 45	15	Basin 3

Table 4.--Statistics on 2-inch observation wells within and adjacent to recharge basins.

[Locations are shown in fig. 16; depths are in feet below land surface; screen bottom is total well depth]

State well no.	Location	Depth to screen bottom	Depth to top of screen
N9603	Center of basin 1	54.1	20.3
N9600	West side of basin 2	59.2	16.9
N9601	Center of basin 2	64.1	15.9
N9602	East side of basin 2	60.1	20.1
N9599	Between basins 2 and 3	61.4	16.0
N9596	West side of basin 3	50.2	9.3
N9597	Center of basin 3	54.8	13.8
N9598	East side of basin 3	57.4	15.5
N9811	Center of basin 4	44.5	24.5
N9812	Center of basin 5	44.2	24.2
N9813	South side of basin 6	50.7	30.7
N9604	Center of basin 7	52.9	21.1
N10065	South rim of basin 8	50.0	45.0
N10066	North of site	50.0	45.0
N10067	East of site	50.0	45.0
N10068	Southeast of site	50.0	45.0
N10069	South of site	50.0	45.0
N10070	Southwest of site	50.0	45.0
N10071	Southwest of site	50.0	45.0

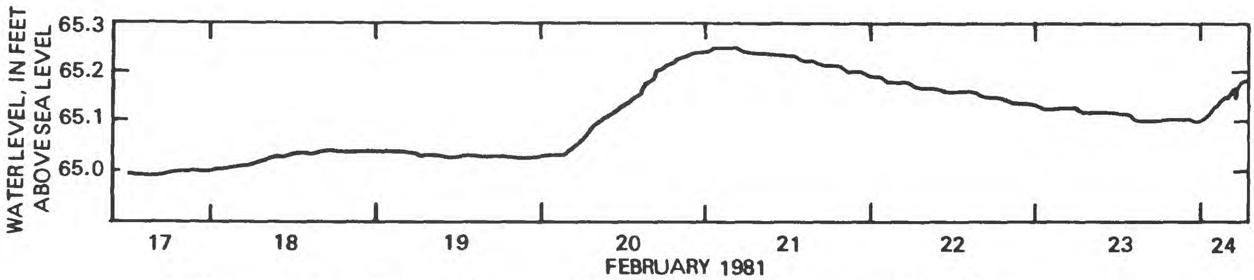


Figure 18.--Part of monthly hydrograph generated by digital float recorder before recharge began.

Two-Inch Observation Wells Within and Adjacent to Basins

Physical and chemical properties of reclaimed water directly beneath and adjacent to recharge basins are monitored by the 2-inch PVC observation wells mentioned previously (fig. 17). The proximity of these wells to points of recharge enables immediate detection of mounding directly beneath the basins and of changes in water quality. A small-diameter submersible pump and a compressed air-bladder pump are used to collect water samples from these wells.

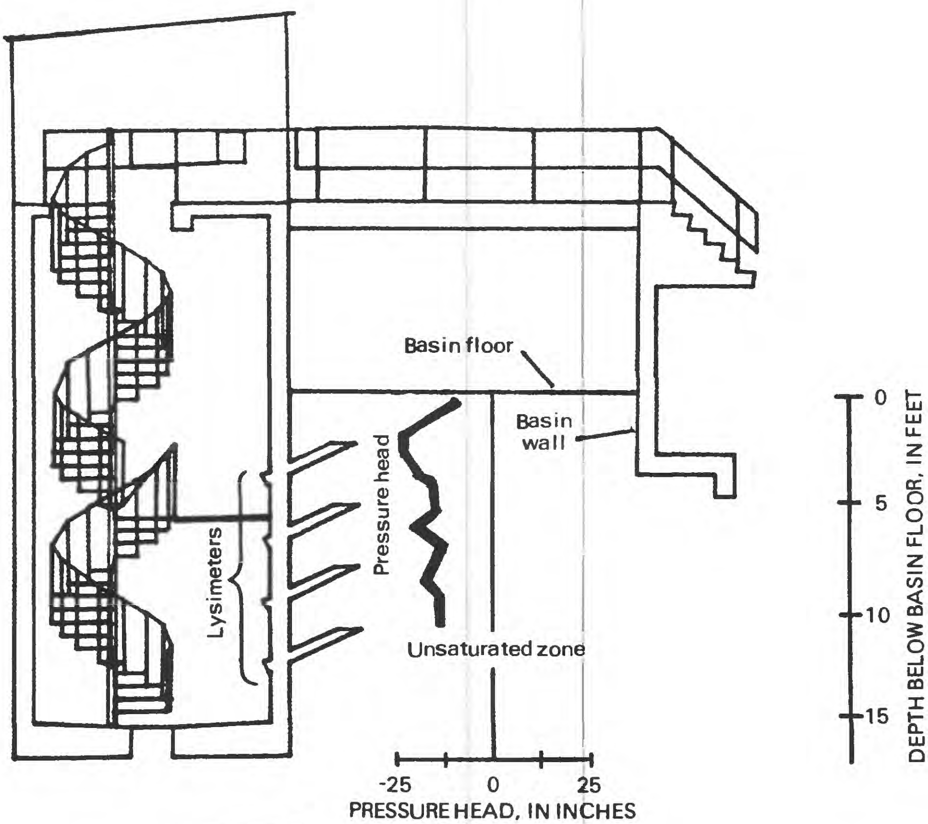
These wells range in depth from 44.2 to 64.1 ft. The holes were drilled to a depth of 80 ft to obtain geologic information. Screened intervals are between 5 and 50 ft long. A list of 2-inch observation wells with their total depths and screened intervals is given in table 4.

COLLECTION OF BACKGROUND DATA FROM THE UNSATURATED ZONE

Monitoring background conditions before recharge enables evaluation of the operating effectiveness of instruments within the manholes. During the summer of 1983, recharge experiments began in these two basins; preliminary results are discussed in Schneider and others (1984). Characterizing the unsaturated zone at each basin will aid in predicting what effects this zone will have on reclaimed water percolating down from the basin floor to the water table.

Data on soil moisture, temperature, hydraulic gradients, and water quality from precipitation have been collected on a continuous basis since 1980, when instrumentation to monitor physical and chemical properties of the unsaturated zone was installed. The percolation of precipitation through the unsaturated zone causes changes similar to those of artificial recharge, but on a much smaller scale and an intermittent basis.

An example of a computer-generated plot showing soil tension in the unsaturated zone (fig. 19A) depicts negative pressure heads in the unsaturated zone below basin 3 on a typical spring day after an 0.5-inch rainfall. This plot shows an increase in soil moisture just below basin floor in response to the rain that fell during the preceding 10 hours.



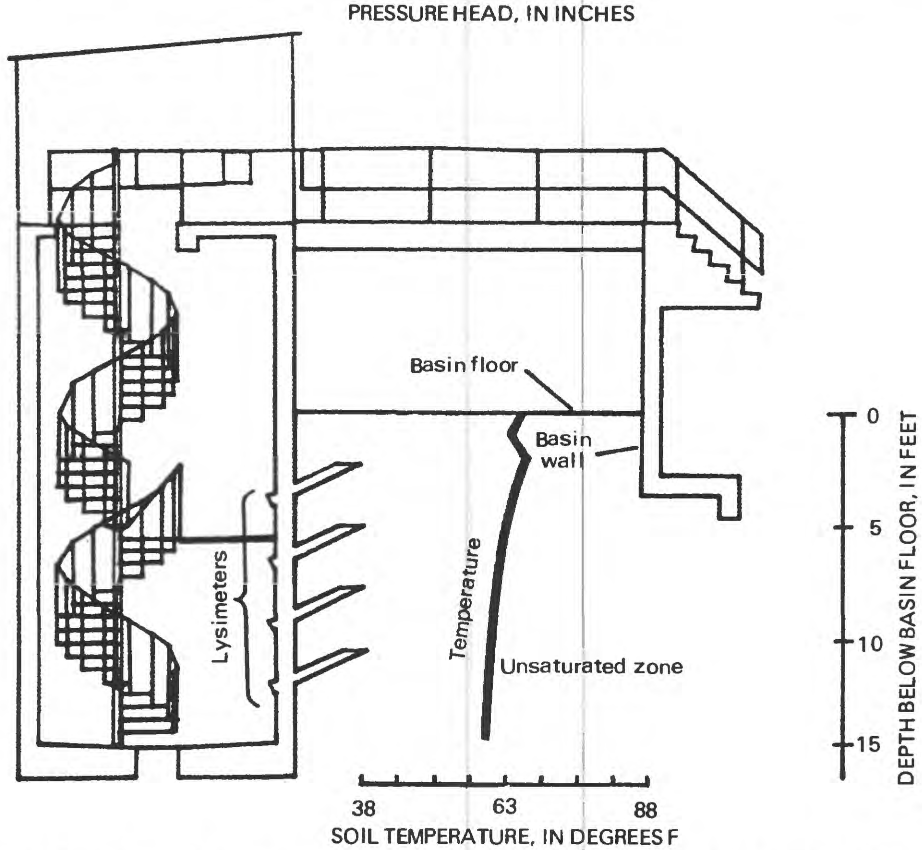


Figure 19.--Computer-generated plots of unsaturated-zone characteristics at basin 3. A. Pressure-head change with depth. B. Temperature change with depth.

An example of the soil temperature with depth is depicted in figure 19B; a plot of the temperature at 1-ft depth over a 24-hour period is shown in figure 20.

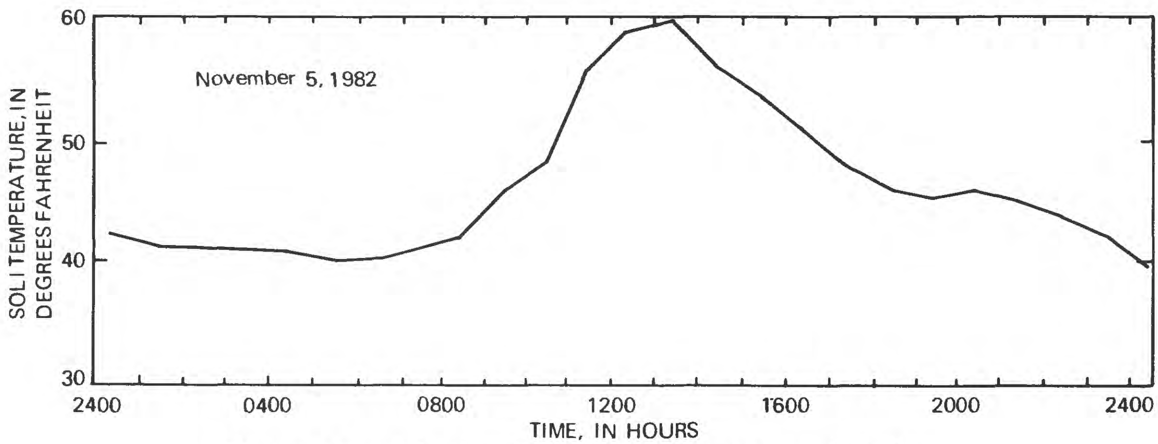


Figure 20.--Plot of soil-temperature at 1-ft depth over 24-hour period.

Soil-moisture logs obtained by neutron-logging equipment are periodically collected to record the moisture content of the soil column during nonrecharge conditions. An example of a soil-moisture log obtained by logging a neutron-access hole (fig. 21) shows the soil-moisture distribution beneath the center of basin 2 a day after the end of a 1.1-inch rainfall. The deflection near 30 ft indicates the approximate position of the water table.

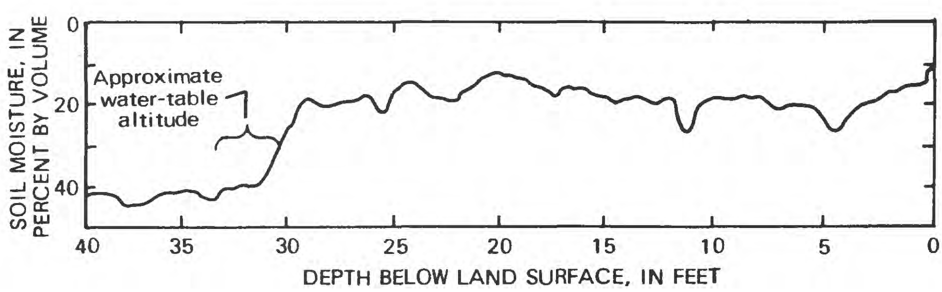


Figure 21.--Example of soil-moisture log showing soil-moisture content in the unsaturated zone 1 day after a storm.

PRELIMINARY ANALYSIS OF RECHARGE EFFECTS

Recharge experiments began on October 6, 1982, when reclaimed water from the treatment plant at Wantagh was pumped into four of the seven ponding basins at a rate of 350 gal/min per basin. Dates of water applications, basins used, duration of recharge tests, and quantities used are given in table 5.

Table 5.--Water-application schedule, October 6, 1982 through January 29, 1983.

[Quantities are in gallons, rounded to nearest hundred; basin locations are shown in fig. 4]

Water-application dates		Duration	Quantity of water applied				
From	Through	(days)	Basin 1	Basin 4	Basin 5	Basin 6	Basin 7
10- 6-82	10- 8-82	2	1,100,800	0	0	0	0
10- 6-82	10-12-82	6	0	0	3,026,300	3,181,100	3,244,800
10-15-82	10-29-82	14	7,409,500	0	6,417,600	6,248,700	7,475,900
12-15-82	12-18-82	3	1,732,400	1,537,800	0	1,580,500	1,608,200
12-22-82	12-24-82	2	1,076,200	989,800	0	974,800	1,005,200
12-30-82	1- 8-83	9	5,004,000	4,563,500	0	4,525,200	4,645,400
1-14-83	1-19-83	5	0	0	0	0	2,848,400
1-17-83	1-29-83	12	6,490,300	0	0	0	0
1-14-83	1-29-83	14	0	0	0	6,954,100	0
1-19-83	1-29-83	10	0	4,844,000	0	0	0
	Total[1]	[2] 48	22,813,200	11,935,100	9,443,900	23,464,400	20,827,900

[1] Total for 48 days = 88,484,500 Mgal; average about 1,800,000 gal/d.
[2] Several basins used at different times, therefore, common application dates are not reflected in total duration value.

Ground-Water Mounding and Movement

The longest continuous recharge period was just over 14 days. The water table directly beneath the basins rose 4.29 ft. The greatest rate of accretion was within the first 3 days and caused a water-table rise of 3.71 ft. The mound continued to rise during the remainder of the test but at a decreasing rate (fig. 22).

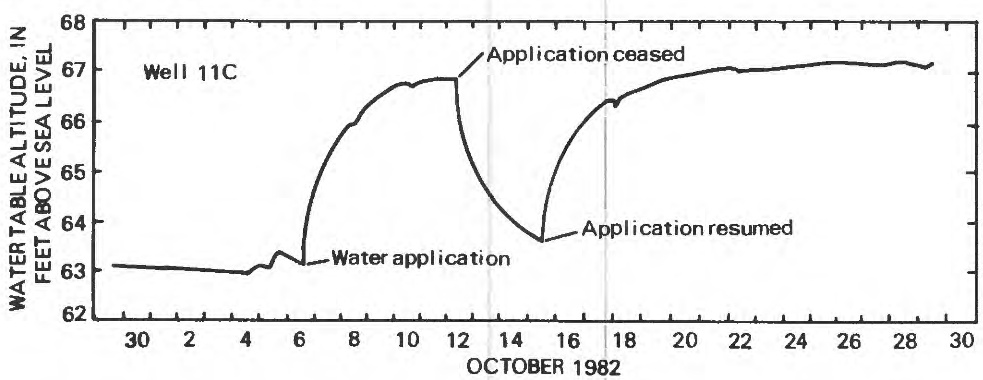


Figure 22.--Example of hydrograph from well N9198 (11C) showing effects of artificial recharge on water-table altitude during 2-week test.

Specific conductance was measured from observation wells within and adjacent to the facility to follow the path of reclaimed water after it entered the ground-water reservoir. (Specific conductance of reclaimed water ranges from 700 to 1,200 µmho/cm, whereas that of water in the upper glacial aquifer ranges from 100 to 400 µmho/cm.) From October 6 through December 31, 1982, reclaimed water was detected in observation wells as far as 400 ft downgradient (southwest) of the points of recharge. Rates of movement could not be measured in detail, however, because recharge was not constant during this period. Additional measurements are to be made in future studies, when longer continuous recharge periods can be maintained.

Water Quality

From 1978 to 1984, ground-water samples were collected from the observation-well network within and adjacent to the recharge facility to provide background data on water quality in the recharge area. After recharge began, samples were taken from wells that were affected by reclaimed water. These wells were readily identifiable by the sharp increase in specific conductance. Water samples are also collected from the storage tank (the distribution point to recharge basins and injection wells) to document the chemical composition of reclaimed water. Although data to date (January 1983) are insufficient for interpretation, the mechanisms of mixing, dilution, and dispersion are causing concentrations of some chemical constituents in the water-table aquifer to fluctuate. This fluctuation is directly related to the introduction of reclaimed water to the aquifer and its subsequent interaction with native ground water.

Values of selected physical properties and concentrations of selected inorganic constituents in the tertiary-treated effluent and in ground-water samples from well N9198 (fig. 16) during 1978-83 are listed in table 6 (at end of report) along with analyses of samples after reclaimed water had entered the screened zone. Well N9198 (11C) is only 60 ft downgradient from the recharge point; therefore the chemical composition of the samples is likely to resemble that of reclaimed water. The mean, median, and range of organic concentrations in excess of 1 µg/L in samples from the storage tank and of ground water are listed in table 7 (at end of report).

Organic Compounds

Data from table 7 indicate that concentrations of most low-molecular weight organic compounds undergo little or no change after passing through the unsaturated zone. Occasionally, however, high concentrations in background ground-water samples decreased when reclaimed water was added. For example, the median concentration of 1,1,1-trichloroethane at well N9198 decreased from 50 µg/L before recharge to <1 µg/L after recharge began (table 7).

Nitrogen

Because the recharge facility and several of the observation wells are close to a farm that uses fertilizers, nitrogen concentrations in the ground water are anomalously high. This, combined with residual waste from cesspools used in the surrounding area since the 1940's, has increased the concentration of nitrate as nitrogen in most observation wells to more than 13 mg/L.

Nitrogen concentrations in reclaimed water average less than 3 mg/L (table 6), and concentrations in samples from observation wells affected by reclaimed water also averaged less than 3 mg/L (table 6).

Pesticides

Insecticides have also been detected in ground water in the vicinity of the recharge facility. Specifically, dieldrin, aldrin, and heptachlor, all used to control termites, have been detected in concentrations higher than the 0.01 µg/L State limit (Katz and Mallard, 1981). Concentrations of these constituents in samples of reclaimed water from the facility are at or below that limit.

Anions and cations

A method of water-quality presentation developed by Stiff (1951) uses parallel horizontal axes extending to either side of a vertical axis (fig. 23). Concentrations of cations and anions are plotted on the individual horizontal lines, and the data points are connected to form an irregular polygon. The width of the pattern is an approximate indication of total ionic content.

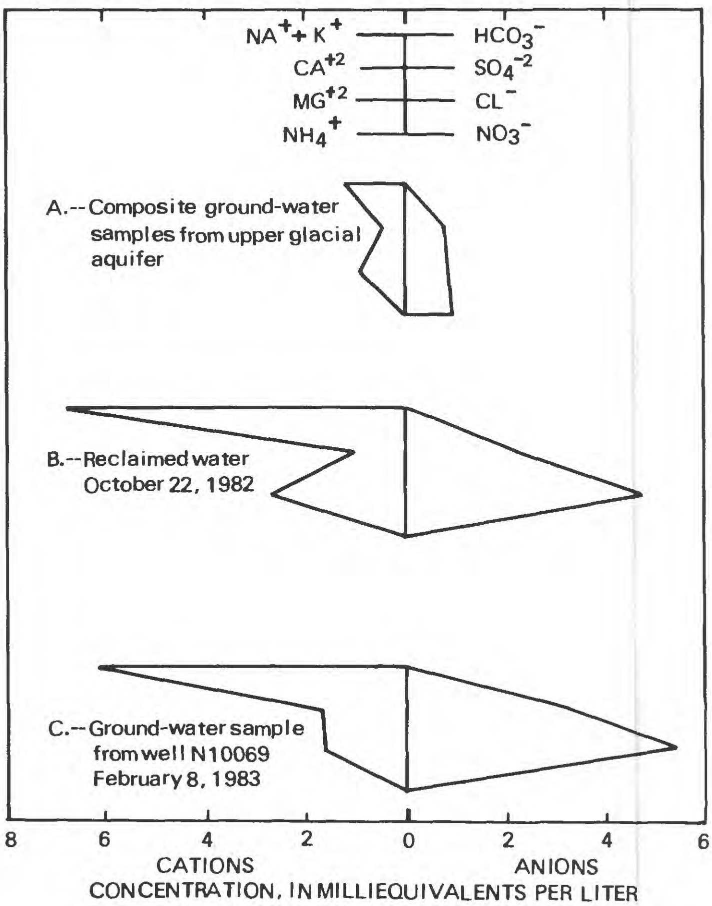


Figure 23.--Stiff diagrams showing concentrations of selected ions: A. In composite sample of native ground water from 12 wells tapping the upper glacial aquifer. B. In reclaimed water from the storage tank. C. In well N10069, a shallow well affected by reclaimed water.

FACTORS FOR CONVERTING MILLIEQUIVALENTS TO MILLIGRAMS

(Values from Hem, 1970)

CATIONS	
Potassium (K^+)	0.02557
Sodium (Na^+)	.04350
Calcium (Ca^{+2})	.04990
Ammonium (NH_4^+)	.05544
Magnesium (Mg^{+2})	.08226
ANIONS	
Bicarbonate (HCO_3^-)	0.01639
Sulfate (SO_4^{-2})	.02082
Chloride (Cl^-)	.02821
Nitrate (NO_3^-)	.01613

The character of native ground water in the upper glacial aquifer is represented by the Stiff diagram in part A of figure 23, which represents average concentrations of major ions in an average sample from 12 observation wells in and adjacent to the recharge facility. The corresponding data from reclaimed-water samples are depicted in part B. Most noticeable in this comparison are the elevated concentrations of sodium, magnesium, potassium, and chloride in the reclaimed water, and the decreased concentration of nitrate.

Ground-Water Levels

Ground-water levels in the East Meadow vicinity declined more than 7 ft from May 1980 through January 1983 as a result of below-normal precipitation and loss of recharge through expanded sewering in most of central and southern Nassau County. The net decline prior to recharge from May 1980 through October 1982 in the East Meadow vicinity is depicted in figure 25, and the hydrograph from well 11C (fig. 24), screened in the upper glacial aquifer near the center of the recharge facility, shows this trend with time. Biweekly values were used in this hydrograph to eliminate fluctuations due to precipitation.

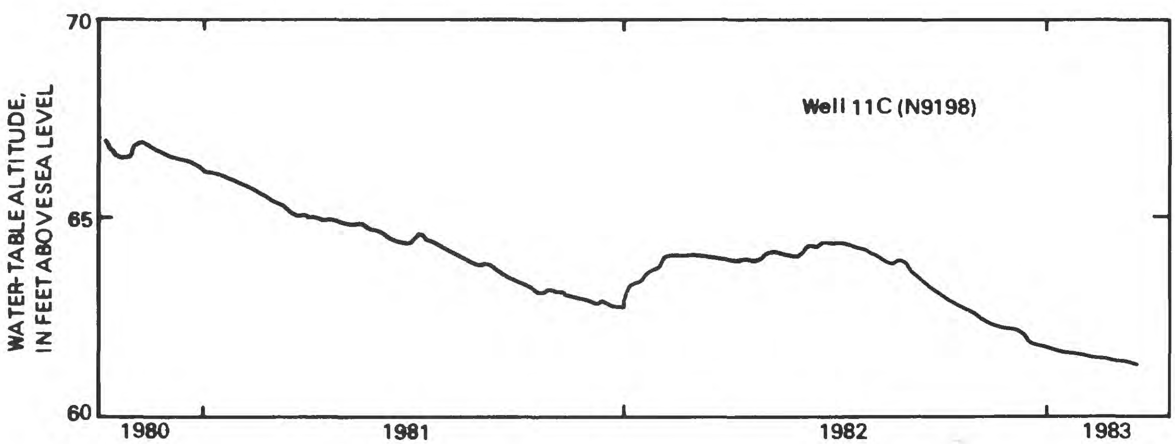
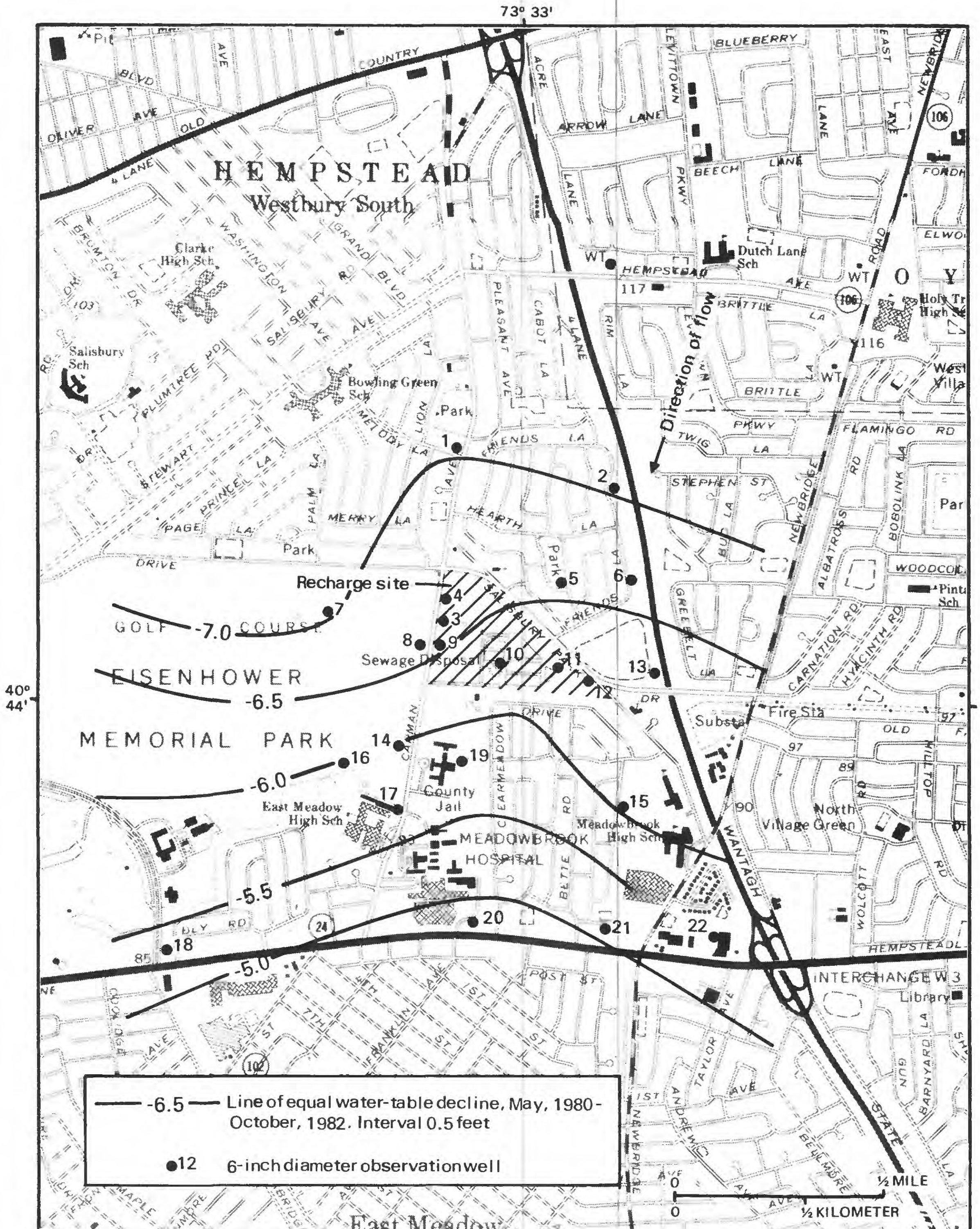


Figure 24.--30-month hydrograph from well 11C. (Location is shown in fig. 15.)

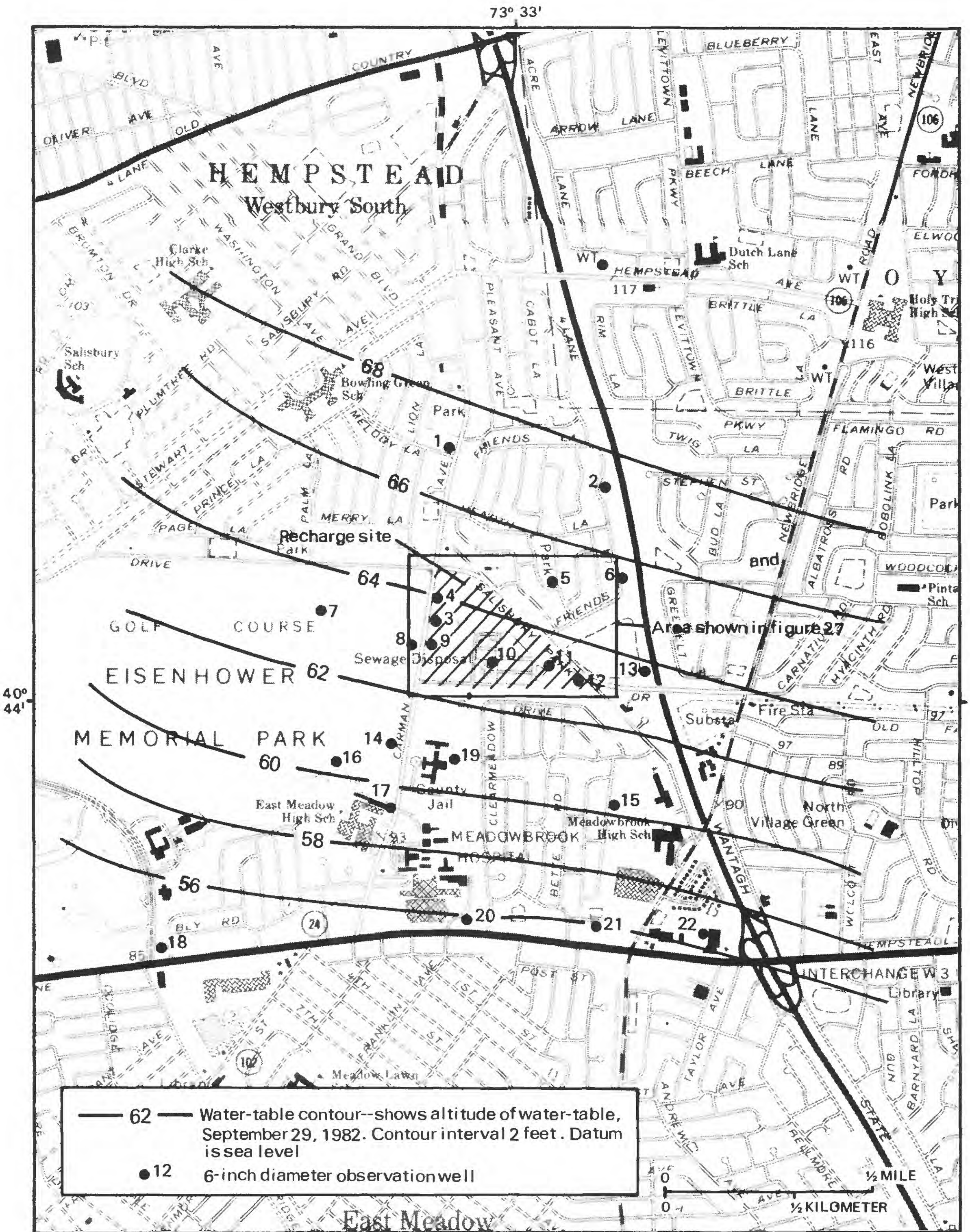
On September 29, 1982, just days before artificial recharge began, water-level measurements from the entire observation-well network were obtained to depict the regional water-table configuration (fig. 26). This map shows a regional southwest gradient of approximately 10 ft/mi (0.0018 ft/ft) within the area.

The immediate effects of artificial recharge on ground-water levels are evident in the hydrograph (fig. 22, p. 30) of well 11C (N9198). During the first 6 days of continuous recharge at basins 5, 6, and 7, the water level in this well rose 3.7 ft, from an initial height of 63.16 ft above sea level to 66.86 ft above sea level. Water levels directly beneath the ponding basins



Base from U.S. Geological Survey
Freeport, NY, 1:24,000, 1979

Figure 25.--Net decrease in water-table altitude, October 1980 through April 1983.



Base from U.S. Geological Survey
Freeport, NY, 1:24,000, 1979

Figure 26.--Water-table altitude on September 29, 1982, before start of recharge experiments.

increased as much as 4.29 ft, and increases were observed at wells as far as 1,000 ft from the points of recharge. Water-table contours within the recharge facility after 15 days of constant recharge are shown in figure 27; the mound covers 0.20 mi^2, with the highest point (4.29 ft) beneath basin 6. The extent of this mounding on a regional scale is shown in figure 28.

At the end of the 15-day test period (October 15 through October 29), a total of 28,850,000 gallons of reclaimed water had been added to the ground-water reservoir. The dispersion of reclaimed water was monitored through conductivity measurements and was detected as much as 200 ft from the points of recharge at the conclusion of this 15-day test period.

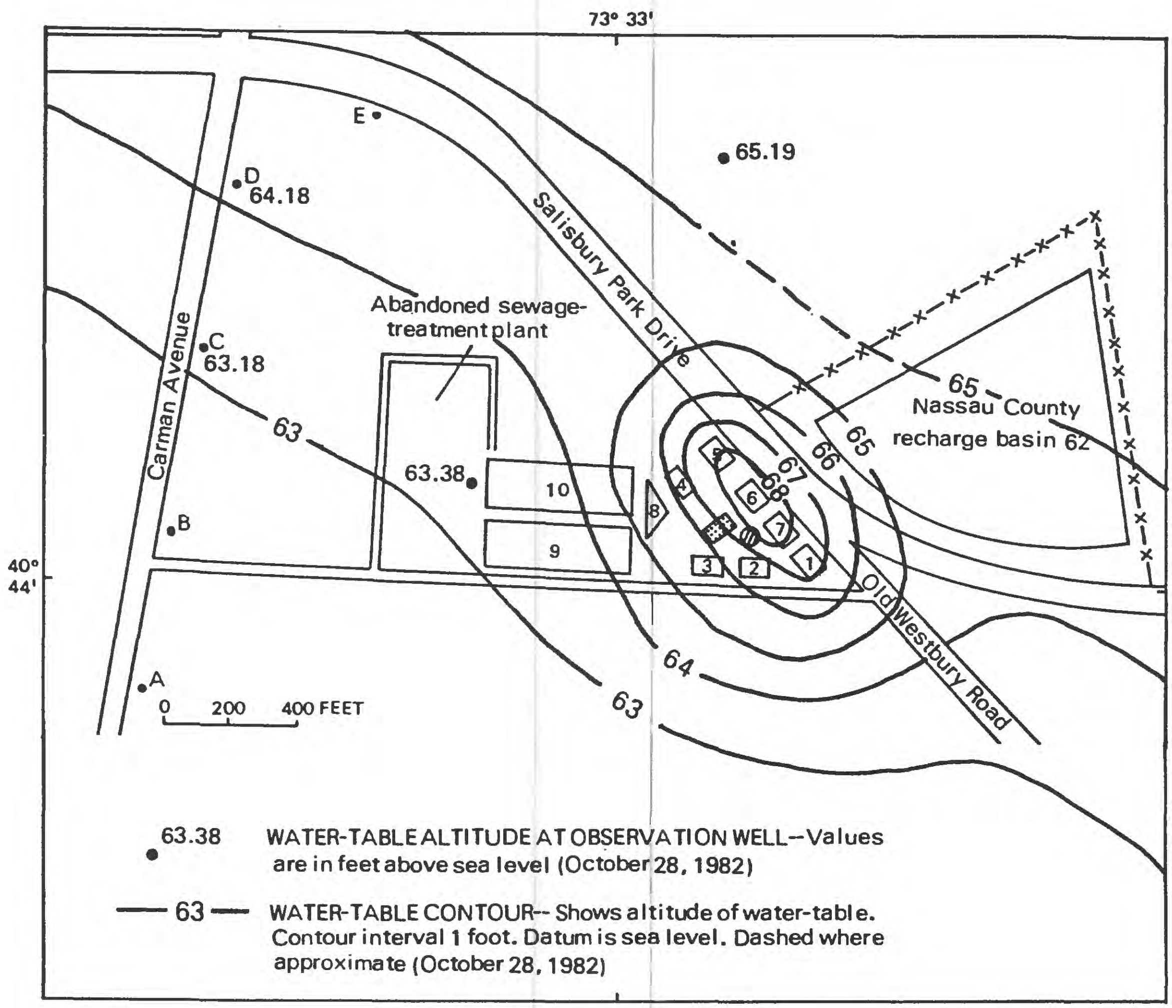
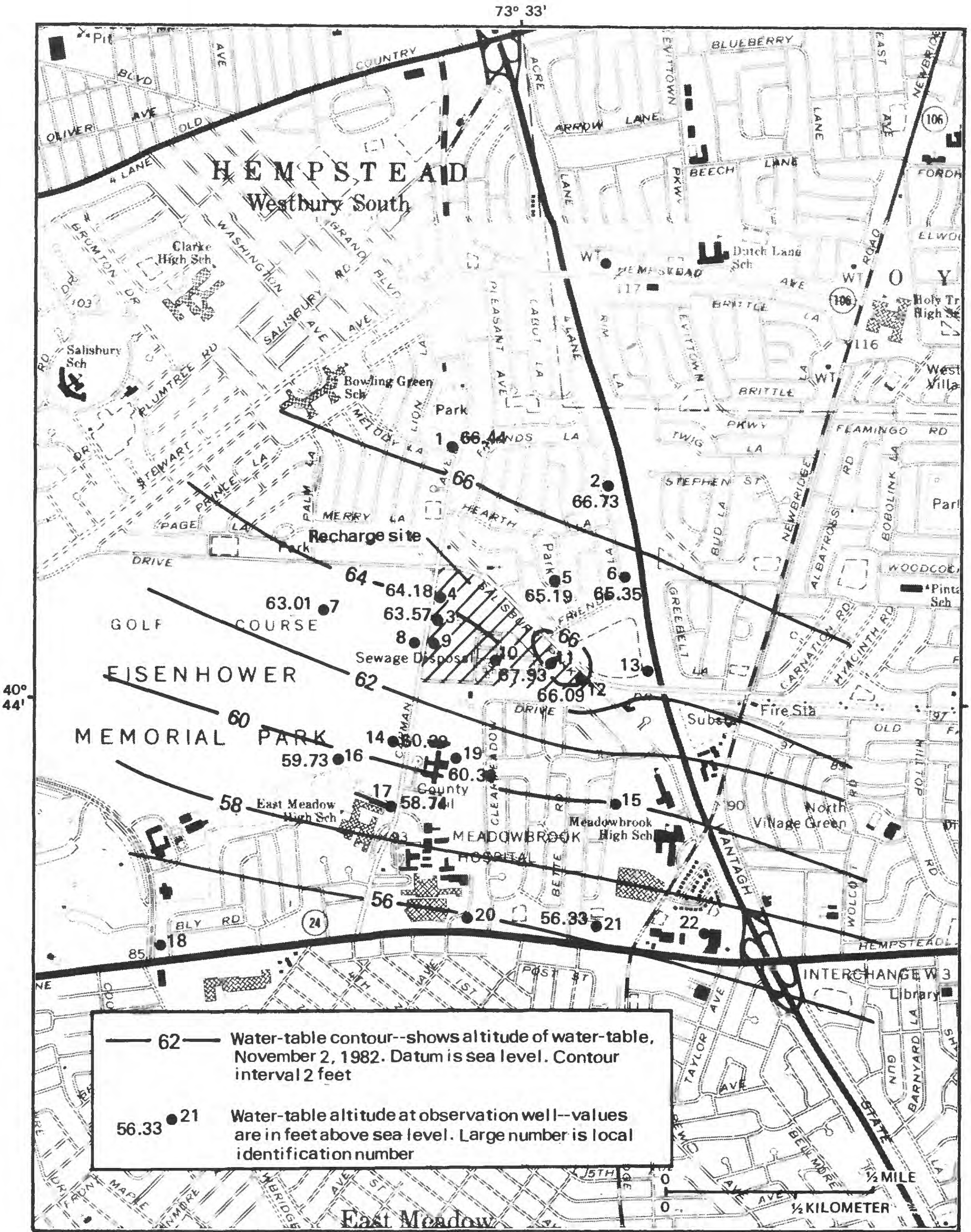


Figure 27.--Local water-table configuration after 15 days of recharge. (Location is shown in fig. 26.)



Base from U.S. Geological Survey
Freeport, NY, 1:24,000, 1979

Figure 28.--Regional water-table configuration at conclusion of 15-day artificial-recharge experiment.

SUMMARY AND CONCLUSIONS

Experiments conducted since 1982 at an artificial-recharge facility in East Meadow, N.Y., have been designed to test the physical and chemical effects of aquifer recharge with reclaimed wastewater and to study the injection and infiltration processes and their effect on the ground-water system. Volumes as large as 4 Mgal/d have been added to the water-table aquifer through 11 recharge basins. Reclaimed water is supplied by the Cedar Creek Wastewater Reclamation facility in Wantagh, 6.25 mi away, through a pipeline. Inflow to the basins is controlled on the basis of either flow rate or water depth; flow to the wells is controlled strictly on the basis of flow rate.

Two of the 11 recharge basins are designed to monitor the effect of the unsaturated zone on percolating reclaimed water, and vice versa. Both basins contain identically instrumented observation manholes that extend to 16 ft below the basin floor and permit observation of infiltration rates, clogging, soil moisture, and lateral water movement; they also permit water and soil sampling for chemical analysis. Background conditions in the unsaturated zone were documented before recharge to provide a data base for comparison in future tests.

Three types of injection-well design are used to permit a comparison of operating effectiveness. The principal difference pertains to the type of packing around the 30-ft length of stainless-steel well screen.

A total of 19 two-inch and 47 six-inch observation wells were installed within a 1-mi2 area surrounding the recharge site to monitor aquifer response to recharge in terms of head and water-quality changes.

In 48 days of total operation, nearly 88.5 Mgal of reclaimed water was added to the shallow aquifer. During one 15-day recharge period, water levels beneath the basins rose 4.29 ft, and increases were observed as far as 1,000 ft from the points of recharge. From October 6 through December 31, 1982, reclaimed water was detected in observation wells as far as 400 ft downgradient of the points of recharge.

Background data pertaining to water quality of the receiving aquifer were collected at the site during 1978-82. Preliminary water-quality data from wells affected by reclaimed water have also been collected. Concentrations of some chemical constituents in the water-table aquifer, specifically nitrogen and trichloroethane, seem to fluctuate, primarily as a result of the mixing of reclaimed water with native ground water.

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Table 6.--Selected chemical and physical data on ground water before injection, reclaimed water, and ground water after injection.

[Ground-water samples from well 11C]

	Nitrogen, dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as N)	Nitrogen, ammonia + organic dissolved (mg/L as N)	Nitrogen, NH_4 + organic suspended total (mg/L as N)
Ground water before injection								
Background								
Median	16.0	0.04	0.330	0.020	0.02	16.0	0.30	0.85
Mean	15.15	.20	.302	.038	.02	16.3	.43	.85
Minimum	2.6	.03	.010	.010	.01	14.0	.10	.20
Maximum	26.0	.85	.830	.150	.11	26.0	.80	1.50
No. of samples	4	5	23	21	22	19	5	2
Reclaimed water								
Median	1.53	.04	.020	--	.01	--	.95	.30
Mean	1.53	.04	.020	--	.01	--	.95	.30
Minimum	.95	.03	.020	--	.01	--	.50	.20
Maximum	2.10	.05	.020	--	.01	--	1.40	.40
No. of samples	2	2	2	0	2	0	2	2
Ground water after injection								
10-22-82	5.8	1.6	1.5	--	.02	--	3.60	.80
1-25-83	2.6	.85	.83	--	--	--	.80	.0

	Nitrogen, NO2 + NO3 dissolved (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, NO2 + NO3 total (mg/L as N)	Temperature (°C)	Turbidity (NTU)	Color (platinum-cobalt units)	Specific conductance (μmhos)	Oxygen, dissolved (mg/L)
Ground water before injection								
Background								
Madian	16.0	.430	16.0	14.0	4.00	1.00	350	3.70
Mean	15.4	.453	15.6	14.2	4.00	1.00	396	3.54
Minimum	1.8	.080	1.7	13.0	4.00	1.00	340	1.50
Maximum	26.0	2.20	28	16.0	4.00	1.00	1,175	5.60
No. of samples	23	23	23	23	1	1	22	8
Reclaimed water								
Median	.585	1.25	.60	17.0	1.00	5.50	990	5.75
Mean	.585	1.25	.60	17.0	1.00	5.50	990	5.75
Minimum	.450	.900	.50	15.0	1.00	5.00	940	4.90
Maximum	.720	1.60	.70	19.0	1.00	6.00	1,040	6.60
No. of samples	2	2	2	2	2	2	2	2
Ground water after injection								
10-22-82	2.2	2.9	2.2	20.0	2.5	5	1,160	6.1
1-25-83	1.8	.7	1.7	14.0	1.0	5	940	--

Table 6.--Selected chemical and physical data on ground water before injection, reclaimed water, and ground water after injection (continued)

[Ground-water samples from well 11C]

	pH field (units)	pH lab (units)	Solids, residue at 105°C, dissolved (mg/L)	Solids, residue at 105°C suspended (mg/L)	Oil and grease, total recov. gravimetric (mg/L)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P
Ground water before injection								
Background								
Median	4.70	5.00	251	7.0	1.00	0.015	0.020	0.010
Mean			262	10.1	1.00	.021	.026	.012
Minimum	4.30	4.80	239	5.0	1.00	.010	.010	.010
Maximum	11.2	5.30	420	42.0	1.00	.080	.060	.040
No. of samples	23	19	16	15	1	22	5	16
Reclaimed water								
Median	6.45	6.30	--	--	1.00	.460	.450	--
Mean			--	--	1.00	.460	.450	--
Minimum	6.30	5.20	--	--	1.00	.340	.330	--
Maximum	6.60	7.40	--	--	1.00	.580	.570	--
No. of samples	2	2	0	0	2	2	2	0
Ground water after injection								
10-22-82	4.6	5.9	--	--	<1.0	.04	.05	--
1-25-83	6.9	7.3	--	--	<1.0	.01	.03	--

	Carbon, organic total (mg/L as C)	Carbon, organic dissolved (mg/L as C)	Carbon, inorganic, total (mg/L as C)	Carbon, organic suspended total (mg/L as C)	Carbon, inorganic, dissolved (mg/L as C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
Ground water before injection								
Background								
Median	1.30	2.20	7.10	0.150	1.00	26.0	3.10	30.0
Mean	2.59	2.23	8.03	.167	7.80	42.6	2.98	29.4
Minimum	.80	1.00	2.00	.100	.50	21.0	.50	22.0
Maximum	12.0	5.10	15.0	.300	6.90	170.	4.10	36.0
No. of samples	17	7	3	6	3	9	9	9
Reclaimed water								
Median	2.75	--	--	--	--	54.5	12.5	155
Mean	2.75	--	--	--	--	54.5	12.5	155
Minimum	2.00	--	--	--	--	53.0	12.0	150
Maximum	3.50	--	--	--	--	56.0	13.0	160
No. of samples	2	0	0	0	0	2	2	2
Ground water after injection								
10-22-82	2.7	--	--	--	--	41	11	200
1-25-83	--	--	--	--	--	53	9.5	110

Table 6.--Selected chemical and physical data on ground water before injection, reclaimed water, and ground water after injection (continued)

[Ground-water samples from well 11C]

	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SIO_2)	Arsenic, total (μg/L as As)	Barium, total recoverable (μg/L as Ba)
Ground water before injection							
Background							
Median	6.10	29.0	38.0	0.250	14.0	1.00	100
Mean	6.46	30.7	39.0	.262	14.0	1.40	162
Minimum	5.6	23.0	36.0	.100	8.70	1.00	10.0
Maximum	8.90	39.0	43.0	.500	16.0	3.00	500
No. of samples	9	9	9	8	9	5	5
Reclaimed water							
Median	12.5	170	87.0	.350	13.5	1.50	150
Mean	12.5	170	87.0	.350	13.5	1.50	150
Minimum	12.0	160	76.0	.200	13.0	1.00	100
Maximum	13.0	180	98.0	.500	14.0	2.00	200
No. of samples	2	2	2	2	2	2	2
Ground water after injection							
10-22-82	8.3	240	140	.2	3.6	1.0	300
1-25-83	12	170	80	.2	8.1	1.0	100

	Beryllium, total recoverable (μg/L as Be)	Cadmium total recoverable (μg/L as Cd)	Chromium, total recoverable (μg/L as Cr)	Cobalt, total recoverable (μg/L as Co)	Copper, total recoverable (μg/L as Cu)	Iron, suspended recoverable (μg/L as Fe	Iron, total recoverable (μg/L as Fe)
Ground water before injection							
Background							
Median	10.0	1.00	10.0	2.00	15.0	160	175
Mean	10.0	2.67	8.89	2.67	14.4	346	320
Minimum	10.0	1.00	2.00	1.00	3.00	10.0	20.0
Maximum	10.0	10.0	20.0	5.00	43.0	2,000	2,000
No. of samples	2	6	9	3	9	19	24
Reclaimed water							
Median	10.0	1.00	20.0	1.50	--	40.0	45
Mean	10.0	1.00	20.0	1.50	--	40.0	45
Minimum	10.0	1.00	10.0	1.00	--	40.0	40
Maximum	10.0	1.00	30.0	2.00	--	40.0	50
No. of samples	2	2	2	2	0	1	2
Ground water after injection							
10-22-82	<10	<1	10	2	--	120	130
1-25-83	<10	2	10	<1	--	60	70

Table 6.--Selected chemical and physical data on ground water before injection, reclaimed water, and ground water after injection (continued)

[Ground-water samples from well 11C]

	Iron, dissolved (µg/L as Fe)	Lead, total recov-erable (µg/L as Pb	Manganese, total recov-erable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Molybdenum, total recoverable (µg/L as Mo)	Nickel, total recov-erable (µg/L as Ni)	Silver, total recov-erable (µg/L as Ag)
Ground water before injection							
Background							
Median	20.0	4.50	815	900	1.00	7.00	1.00
Mean	18.0	53.2	783	886	1.00	9.40	1.00
Minimum	10.0	1.0	90	800	1.00	1.00	1.00
Maximum	40.0	300	1,200	940	1.00	22.0	1.00
No. of samples	23	6	24	15	3	5	4
Reclaimed water							
Median	4.00	2.50	10	--	--	9.00	2.50
Mean	4.00	2.50	10	--	--	9.00	2.50
Minimum	3.00	2.00	10	--	--	8.00	1.00
Maximum	5.00	3.00	10	--	--	10.0	4.00
No. of samples	2	2	2	0	0	2	2
Ground water after injection							
10-22-82	6	1	60	11	5	--	<1
1-25-83	11	3	10	915	7	--	<1

	Zinc, total recoverable (µg/L as Zn)	Aluminum, total recov-erable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Aluminum, suspended recov-erable (µg/L as Al)	Lithium total recov-erable (µg/L as Li)	Selenium, total (µg/L as Se)	Mercury, total recov-erable (µg/L as Hg)
Ground water before injection							
Background							
Median	50.0	1,300	100	1,200	10.0	1.00	.200
Mean	64.4	1,309	303	1,400	10.0	1.00	.200
Minimum	10.0	200	80	200	10.0	1.00	.100
Maximum	130.0	4,400	1,200	4,300	10.0	1.00	.300
No. of samples	9	23	15	14	3	4	2
Reclaimed water							
Median	80.0	--	--	--	--	1.00	.200
Mean	80.0	--	--	--	--	1.00	.200
Minimum	50.0	--	--	--	--	1.00	.100
Maximum	110.0	--	--	--	--	1.00	.300
No. of samples	2	0	0	0	0	2	2
Ground water after injection							
10-22-82	40	--	--	--	--	<1	.8
1-25-83	20	--	--	--	--	<1	.5

Table 7.--Mean, median, and range of organic compounds exceeding 1 μg/L in storage tank and ground water before and after injection.

	Di-chloro-bromo-methane total (μg/L)	1,2-Di-chloro-ethane total (μg/L)	Bromo-form total (μg/L)	Chloro-di-bromo-methane total (μg/L)	Chloro-form total (μg/L)	Toluene total (μg/L)	Benzene total (μg/L)	Bis-ether total (μg/L)	Ethyl-benzene total (μg/)
N 9198									
Background (pre-recharge)									
Median	<1	<1	<1	<1	<1	<1	<1	6	<1
Mean	2.92	<1	13.6	9.44	1.92	7.57	170	6	<1
Minimum	<1	<1	<1	<1	<1	<1	<1	6	<1
Maximum	7.4	<1	45.2	32.2	4.3	30.0	1,180	6	1
No. of Samples	5	3	5	5	5	7	7	1	5
Storage Tank									
Median	1.15	<1	39.5	16.6	.3	<1	<1	1	<1
Mean	8.13	<1	30.5	22.7	3.1	5.29	6.14	1	5.71
Minimum	<1	<1	<1	<1	< .3	<1	<1	1	<1
Maximum	39.3	2.1	87.0	62.8	12.4	>25	>30	1	>28
No. of Samples	7	7	7	7	7	7	7	1	7
Ground water (post-recharge)									
N 9198									
1-25-83	5	<1	19	20	<1	<1	<1	1	<1
N 9689									
1-25-83	<1	<1	14	13	<1	2	<1	--	<1
N 9690									
1-25-83	<1	<1	14	13	<1	3	<1	--	<1

	Methyl-ene chlo-ride total (μg/L)	Tetra-chloro-ethyl-ene total (μg/L)	1,1-Di-chloro-ethane total (μg/L)	1,1-1-tri-chloro-ethane total (μg/L)	Chloro-ethyl-ene total (μg/L)	Di-N-butyl-phthal-ate total (μg/L)	Tri-chloro-ethyl ene total (μg/L)	Dichloro-methane (μg/L)	1,2-dichloro-ethene (μg/L)
N 9198									
Background (pre-recharge)									
Median	1	2.5	1	50	1	2	3	.8	<1
Mean	480	4.68	14.6	51.4	6	2	4.35	.93	<1
Minimum	1	.4	<1	.8	<1	2	<1	<1	<1
Maximum	1,440	20	50.2	165	30	2	10	2.0	1
No. of Samples	3	14	5	27	7	1	14	3	3
Storage Tank									
Median	1	.9	<1	<1	<1	1	<1	1.1	<1
Mean	1	.61	.3	.54	<1	1	<1	8.98	<1
Minimum	1	<0.4	<1	<1	<1	1	<1	<1	<1
Maximum	1	1	1.2	1.8	1	1	<1	39.3	1.8
No. of Samples	1	7	7	7	7	2	7	6	6
Ground water (post-recharge)									
N 9198									
1-25-83	<1	<1	<1	<1	<1	8	<1	--	<1
N 9689									
1-25-83	<1	--	<1	<1	--	7	<1	--	<1
N 9690									
1-25-83	<1	<1	<1	<1	--	12	<1	--	<1

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