

GEOHYDROLOGY AND GROUND-WATER QUALITY ON SHELTER ISLAND,
SUFFOLK COUNTY, NEW YORK, 1983-84

by Dale L. Simmons

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Conversion Factors and Abbreviations

For those who prefer to use metric (International System) units rather than the inch-pound units in this report, the following conversion factors may be used:

| <u>Multiply Inch-Pound Units</u> | <u>by</u> | <u>To Obtain Metric Units</u> |
|---|--------------------|---|
| | <u>Length</u> | |
| inch (in) | 25.40 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | <u>Area</u> | |
| square mile (mi ²) | 2.590 | square kilometer (km ²) |
| | <u>Volume</u> | |
| gallon (gal) | 3.785 | liter (L) |
| | <u>Flow</u> | |
| gallon per day (gal/d) | 3.785 | liter per day (L/d) |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second (m ³ /s) |
| million gallons per day per square mile [(Mgal/d)/mi ²] | 1,460 | cubic meter per day per square kilometer [(m ³ /d)/km ²] |
| | <u>Temperature</u> | |
| degree Fahrenheit (°F) | °C = 5/9 (°F-32) | degree Celsius (°C) |

Other Abbreviations

| | |
|-----------------------------|--|
| mo (month) | mg/L (milligrams per liter) |
| μg/L (micrograms per liter) | μS/cm (microsiemens per centimeter at 25°C) |

GEOHYDROLOGY AND GROUND-WATER QUALITY ON SHELTER

ISLAND, SUFFOLK COUNTY, NEW YORK, 1983-84

by Dale L. Simmons

Abstract

Shelter Island, with an area of about 11 mi², lies between the north and south forks of eastern Long Island in Suffolk County. The thin upper glacial (water-table) aquifer contains the lens-shaped freshwater body that is the sole source of freshwater for the Town's population of about 2,200 year-round and 10,000 summer residents. The aquifer consists of permeable sand and gravel deposits that readily permit intrusion of saline ground water in coastal areas. Underlying clay units that contain saline ground water form the lower boundary of the freshwater lens and limit its thickness.

Chloride concentrations in ground water above the freshwater/saltwater interface, defined as 40 mg/L (milligrams per liter) Cl⁻, are relatively constant with depth. Below the interface, however, chloride concentrations increase rapidly--as much as an order of magnitude within 10 feet--until they reach 19,000 mg/L, the chloride concentration of seawater.

Chloride concentrations in shallow ground water from wells screened in or near the zone of diffusion may range over two orders of magnitude in response to variations in recharge and ground-water withdrawal. After the summer season of relatively low recharge and peak water demand, the thickness of the freshwater lens is less than 20 ft in many nearshore areas.

A map showing the configuration of the water table in December 1983 indicates freshwater mounds in the center of the island, in the Mashomack Preserve, on the Dering Harbor-Hay Beach peninsula, and in the area between Shelter Island Heights and West Neck Bay. Areas in which the supply of fresh ground water is severely limited include all coastal areas, the southernmost part of the West Neck peninsula, and Little Ram Island. Water levels in most locations are less than 6 ft above sea level. During 1974-83, seasonal water-table fluctuations were greater than variations that occurred from year to year.

Ground-water quality on Shelter Island is generally good and usually meets Federal and State drinking-water standards. However, many wells contain water that has excessive concentrations of dissolved iron and manganese (up to 5.0 mg/L and 3.0 mg/L, respectively), and elevated chloride and dissolved-solids concentrations (up to 310 mg/L and 585 mg/L, respectively) have been found in some nearshore wells, especially during late summer and early fall.

Total pumpage on Shelter Island in 1983 was about 260 million gallons, which represents an increase of about 20 percent since 1974. Increased withdrawal of fresh ground water in nearshore areas will cause further landward movement of saline ground water; in other areas, excessive pumping may cause upconing. A system of widely spaced pumping wells that avoid nearshore areas would minimize these effects. Continued monitoring of observation wells would enable early detection of further landward movement of saline ground water.

INTRODUCTION

The Town of Shelter Island is a small island community between the north and south forks of eastern Long Island in Suffolk County (fig. 1). The upper glacial (water-table) aquifer is the sole source of freshwater for the year-round residents and summer tourist population. Increased development of the island in recent years has led to greater consumptive water use and increased discharge of sewage to the ground water through septic tanks and cesspools. The island depends entirely on this aquifer for public water supply; thus, the quantity and quality of fresh ground water is a matter of local concern.

A previous study of Shelter Island's freshwater supply was conducted in 1974 (Soren, 1978). Local interest in the current hydrologic situation led to a cooperative agreement between the U.S. Geological Survey and the Town of Shelter Island in June 1983 to update and supplement the information presented in that report. During 1983-84, the Geological Survey measured ground-water levels in wells throughout the island and collected water samples for chemical analysis.

Purpose and Scope

The purpose of the study was to (1) delineate the configuration of the water table, (2) define the quality of water in the upper glacial aquifer, and (3) approximate the position of the boundary between fresh and saline ground water at selected nearshore locations.

This report discusses the geology and hydrology of Shelter Island, presents a contour map of the water table in December 1983, summarizes the results of water-quality analyses, and discusses the nature of the freshwater/saltwater interface and the geologic controls on the distribution of fresh and saline ground water.

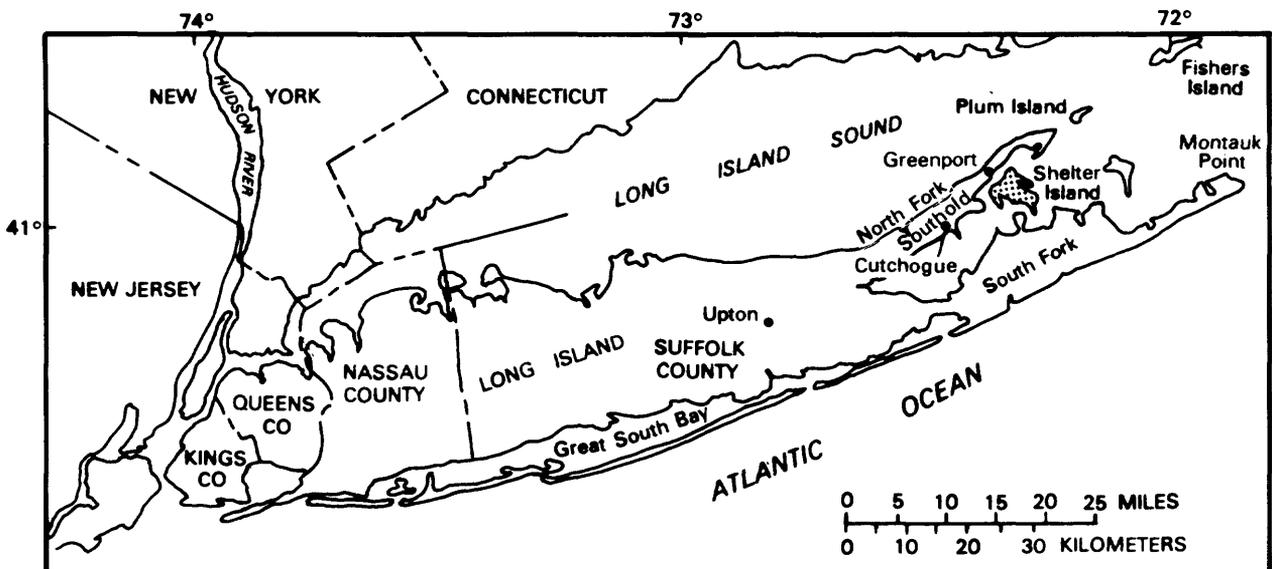


Figure 1.--Location of Shelter Island.

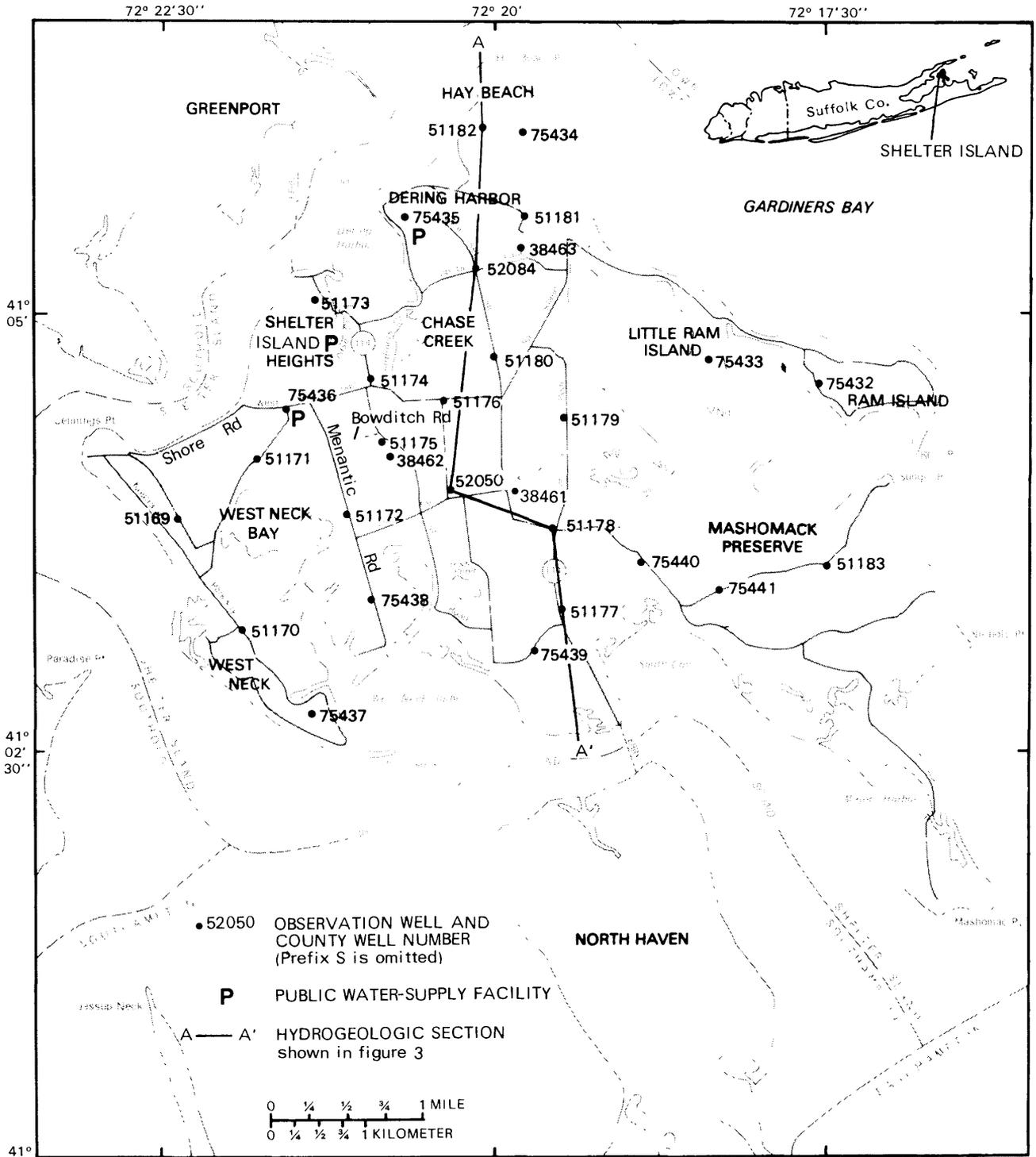


Figure 2.--Locations of observation wells.

Methods of Investigation

Ten observation wells (S75432 to S75441) were installed at locations shown in figure 2 to supplement the 17-well network. The locations were chosen to (1) improve the geographic coverage of the island with respect to water-level and water-quality data, (2) obtain information on the chloride concentration of ground water in nearshore areas, and (3) provide permanent facilities for monitoring saltwater movement.

The new wells have a 2-inch inside diameter. Four are cased with steel and finished with 2-ft-long screens, and six are cased with PVC (polyvinyl chloride) and finished with 5-ft-long screens. All screen tops were installed about 10 ft below the water table. (The screened interval and casing material of each well are given in appendix B.)

Wells were installed by auger to a depth of 85 ft. Each was then pumped with a suction pump until specific conductance values stabilized. Ground-water samples were collected for specific conductance and chloride analyses. The screen was subsequently raised 10 ft, the well was pumped again, and another sample was collected. This procedure was repeated at 10-ft intervals until the screen top was approximately 10 ft below the water table, where it was left for ground-water monitoring.

These 10 wells, in addition to the 17 observation wells installed during the previous study (Soren, 1978), were sampled either two or three times at 3-month intervals for a suite of water-quality characteristics, including temperature, pH, specific conductance, chloride, dissolved and total iron, dissolved and total manganese, and nitrate. (Complete water-quality analyses are given in appendix C.) Wells were sampled by suction pump or, if the water table was more than 20 ft below land surface, with a submersible pump. In each case, the well was pumped long enough for the volume of water in the casing to be evacuated three times to ensure that the ground water being sampled was from the formation. Temperature, pH, and specific conductance were measured in the field. Chloride analyses were made in the U.S. Geological Survey laboratory in Syosset, N.Y., with an Orion¹ combination chloride electrode; the remaining analyses were done by the U.S. Geological Survey Water-Quality Laboratory in Doraville, Ga.

Related Investigations

Jensen and Soren (1974) depicted the hydrogeology of Suffolk County in a series of geologic and hydrologic maps. Soren (1978) made a preliminary investigation of the geology and ground-water resources of Shelter Island, including a water-table map and selected water-quality data.

Several studies of nearby areas with hydrogeologic characteristics similar to Shelter Island's are available. Crandell (1962) discussed the geology and ground-water resources of Plum Island (fig. 1). Hoffman (1961) and Crandell (1963) described, respectively, the hydrologic and geologic

¹ Use of brand names is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

environment of the Town of Southold on the north fork (fig. 1). Perlmutter and DeLuca (1963) discussed the availability of fresh ground water in the Montauk Point area (fig. 1). Nieter and others (1975) gave information on the late Quaternary geology of the south fork; Nemickas and others (1977) presented ground-water, surface-water, and water-quality data compiled during an investigation of the same area. These data formed the basis for an exhaustive appraisal of the south fork's water resources (Nemickas and Koszalka, 1982). A recent assessment of the ground-water resources of the Montauk area is given in Prince (1986).

Acknowledgments

Observation wells were installed by Suffolk County Department of Health Services under the direction of Steven Cary and Richard Markel. Mr. Cary also assisted in the September 1983 water-quality sampling. J. Michael Laspia, director of the Nature Conservancy's Mashomack Preserve, allowed access to the property for well installation and sampling. Malvin Nevel, Town Supervisor of the Town of Shelter Island during the greater part of this study, helped in securing permission for the use of local road rights-of-way for well installation.

DESCRIPTION OF STUDY AREA

Shelter Island is bounded on the east and northeast by Gardiners Bay, and on the west, northwest, and south by Shelter Island Sound (fig. 2). The island is predominantly a residential and summer-resort community that, in 1983, had 2,200 year-round residents and a summer population of 10,000 (Dorothy Ogar, Town Clerk, oral commun., 1984). Access to the island is by ferry from Greenport on the north and from North Haven on the south.

Climate

Because of its latitude and proximity to Long Island Sound and the Atlantic Ocean, Shelter Island has a temperate marine climate characterized by moderate temperatures and abundant precipitation, especially during the fall, winter, and spring. Mean annual temperature at Cutchogue (fig. 1) was 51°F over a 54-year period, and mean annual precipitation at the same station was 45 inches over a 51-year period (Crandell, 1963). Miller and Frederick (1969) estimated mean annual precipitation on Shelter Island during 1951-65 to be between 43 and 45 inches. Measured precipitation at Greenport (fig. 1) averaged 47 inches during 1974-83.

Topography

Altitudes on Shelter Island range up to 180 ft. The highest altitudes are in the western part of the island--in Shelter Island Heights and north and west of West Neck Bay (fig. 2). A steep bluff about 100 ft high faces Shelter Island Sound. Most of the remainder of the island is lower than 70 ft. The

land surface gradually descends to the shore as a rolling plain characterized by small ponds and both dry and marshy depressions, which are especially common in the southeastern part of the island. Dry depressions range from 10 to 40 ft in depth, whereas ponds and marshes are mostly in shallow depressions that are less than 10 ft above sea level.

Surface Drainage

Shelter Island has no significant streams. A small part of the Village of Shelter Island Heights has a storm-sewer system that discharges to tidewater, but most precipitation either evaporates, transpires, or infiltrates through the soil to recharge the ground-water system. Overland runoff may occur during storms of high intensity or long duration, especially in the high areas in the northwestern part of the island and in areas where the surficial material is underlain by clayey or silty deposits. Runoff may discharge to surface-water bodies such as Shelter Island Sound or Chase Creek (fig. 2), or it may become ponded. Most of the ponded water eventually seeps into the ground; the remainder evaporates.

Development

The southeastern third of Shelter Island consists of the Mashomack Preserve (fig. 2)--an undeveloped, virtually uninhabited area owned and maintained by the Nature Conservancy. The remainder of the island is characterized by single-family houses, large open areas, a few public buildings, stores, restaurants, motels, yacht and country clubs, and boat marinas. The Town has a waste-disposal site east of Menantic Road and south of Bowditch Road (fig. 2).

Population

The year-round population of Shelter Island has been increasing at a slow but steady rate; the part-time population (primarily summer tourists) has been rising much more rapidly. Table 1 shows year-round and summer population estimates at irregular intervals during 1938-84.

An increase in population has several significant implications for the hydrologic system, among which are (1) increased housing and services (stores, etc.), which causes an increase in paved and impervious surfaces and a decrease in pervious areas that allow precipitation to infiltrate and recharge the ground-water system; (2) increased demand for water (which is highest during the summer, when recharge is lowest), which increases the stress on the system and in turn may result in upconing and intrusion of saline ground water; and (3) increased volume of sewage, which is discharged to the ground-water system through cesspools and septic tanks and may eventually have detrimental effects on the quality of the ground-water supply.

Water Use

Shelter Island has three local public water-supply facilities that serve the Villages of Shelter Island Heights, Dering Harbor, and West Neck (fig. 2).

These facilities supply water to a population of 535, or 25 percent of the year-round residents on the island. The remaining homes have private wells that supply water for domestic use, lawn sprinkling, and swimming pools.

Only the Shelter Island Heights Association and Dering Harbor Water District reported their actual 1983 pumpage to the New York State Department of Environmental Conservation in Stony Brook, Long Island. Pumpage by West Neck Water Supply was estimated by Suffolk County Department of Health Services; these values, shown in table 2, indicate that total daily public-supply pumpage on Shelter Island during 1983 was about 0.094 Mgal/d. Assuming this to be an average daily pumpage adequate to supply the water needs of a population of 535, annual pumpage for the island may be calculated as follows:

$$\begin{aligned} \text{Summer only:} & \quad (0.094 \text{ Mgal/d}) (10,000 \text{ persons}/535 \text{ persons}) (3 \text{ mo}) (30 \text{ d/mo}) \\ & = 158 \text{ Mgal} \end{aligned}$$

$$\begin{aligned} \text{Rest of year:} & \quad (0.094 \text{ Mgal/d}) (2,200 \text{ persons}/535 \text{ persons}) (9 \text{ mo}) (30 \text{ d/mo}) \\ & = 104 \text{ Mgal} \end{aligned}$$

for a total annual pumpage of 262 Mgal.

Soren (1978) estimated a per-capita water use of 200 gal/d during the summer and 100 gal/d during the rest of the year. From these estimates, the following pumpage calculations may be made:

$$\begin{aligned} \text{Summer only:} & \quad ([200 \text{ gal/d}]/\text{person}) (3 \text{ mo}) (30 \text{ d/mo}) (10,000 \text{ persons}) \\ & = 180 \text{ Mgal} \end{aligned}$$

$$\begin{aligned} \text{Rest of year:} & \quad (100 \text{ gal/d/person}) (9 \text{ mo}) (30 \text{ d/mo}) (2,200 \text{ persons}) \\ & = 59 \text{ Mgal} \end{aligned}$$

for a total annual pumpage of 239 Mgal.

Table 1.--Year-round and summer population,
Town of Shelter Island, 1938-84.

[Dashes indicate data are unavailable]

| Year | Approximate population | |
|------|------------------------|---------------------|
| | Year-round residents | Summer residents |
| 1938 | 500 ^a | -- |
| 1968 | 1,600 ^a | -- |
| 1969 | 1,700 ^a | 6,500 ^a |
| 1974 | 2,000 ^a | 8,000 ^a |
| 1984 | 2,200 ^b | 10,000 ^b |

^a Data from Soren (1978).

^b Oral commun., Dorothy Ogar, Town Clerk, April 30, 1984.

These estimates of total annual pumpage are in close agreement (within 10 percent); the first is preferred because it is derived from actual pumpage data. Therefore, 262 Mgal may be considered to approximate total annual pumpage on Shelter Island, and Soren's estimates of per-capita daily water use may be considered reasonable.

The value derived by Soren (1978) for total annual pumpage in 1974 was 198 Mgal; the value derived above for total annual pumpage in 1983, by the same method of calculation, was 239 Mgal. Therefore, total annual pumpage increased approximately 21 percent during 1974-83.

Table 2.--Public water-supply pumpage, Town of Shelter Island, 1983.

| Water-supply facility | Number of wells ^a | Number of services ^a | Population served ^a | Pumpage | |
|------------------------------------|------------------------------|---------------------------------|--------------------------------|-------------------|-------------------|
| | | | | Total (Mgal) | Mgal/d |
| Shelter Island Heights Association | 4 | 125 | 310 | ^b 27.1 | 0.074 |
| Dering Harbor Water District | 2 | 35 | 130 | ^b 2.99 | .008 |
| West Neck Water Supply | 2 | 27 | 95 | 4.38 | ^a .012 |
| Total | 8 | 187 | 535 | 34.5 | .094 |

^a Data from Suffolk County Department of Health Services estimate

^b Data from New York State Department of Environmental Conservation

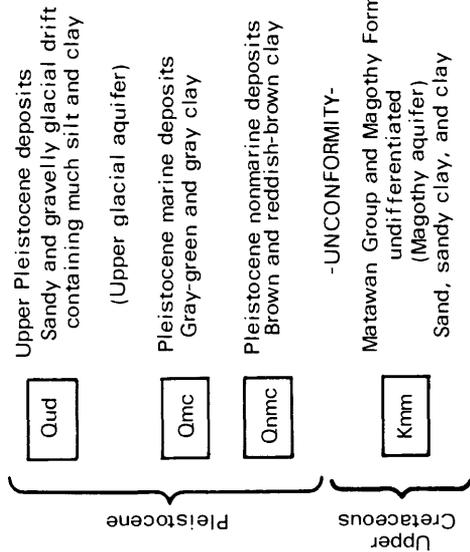
GEOLOGY

Shelter Island consists of Pleistocene deposits of mostly stratified, poorly to moderately sorted glacial drift that are underlain by two Pleistocene clay units. The clays are in turn underlain by an Upper Cretaceous sand unit informally known as the Magothy aquifer.

The stratified drift constitutes the upper glacial (water-table) aquifer. Particle size ranges from clay to boulders; the most common constituent is fine to coarse, light- to dark-brown sand. Clay and silt are found mostly in the northwestern part of the island, especially along the coast, where they form topographic highs. Abundant silty and clayey material was also found at the site of well S75436 on Shore Road (fig. 2), from 28 to 88 ft below land surface. Cobbles and boulders were common at the site of well S75434, on the Hay Beach peninsula.

Three exploratory wells penetrated the geologic units that underlie the stratified drift on Shelter Island; these units are described in detail by Soren (1978). A hydrogeologic section constructed from geologic and gamma-ray logs of these wells is shown in figure 3.

EXPLANATION



OBSERVATION WELL

Well number is at top; lower numbers are chloride concentrations, in mg/L, at depths indicated by arrow. Horizontal lines indicate screen setting of observation well. Dashed vertical line indicates drilled exploratory hole below screen setting. Line of section is shown in figure 2.

.....
 Approximate location of 40 mg/L chloride boundary. Chloride concentration of water increases significantly with depth below boundary.

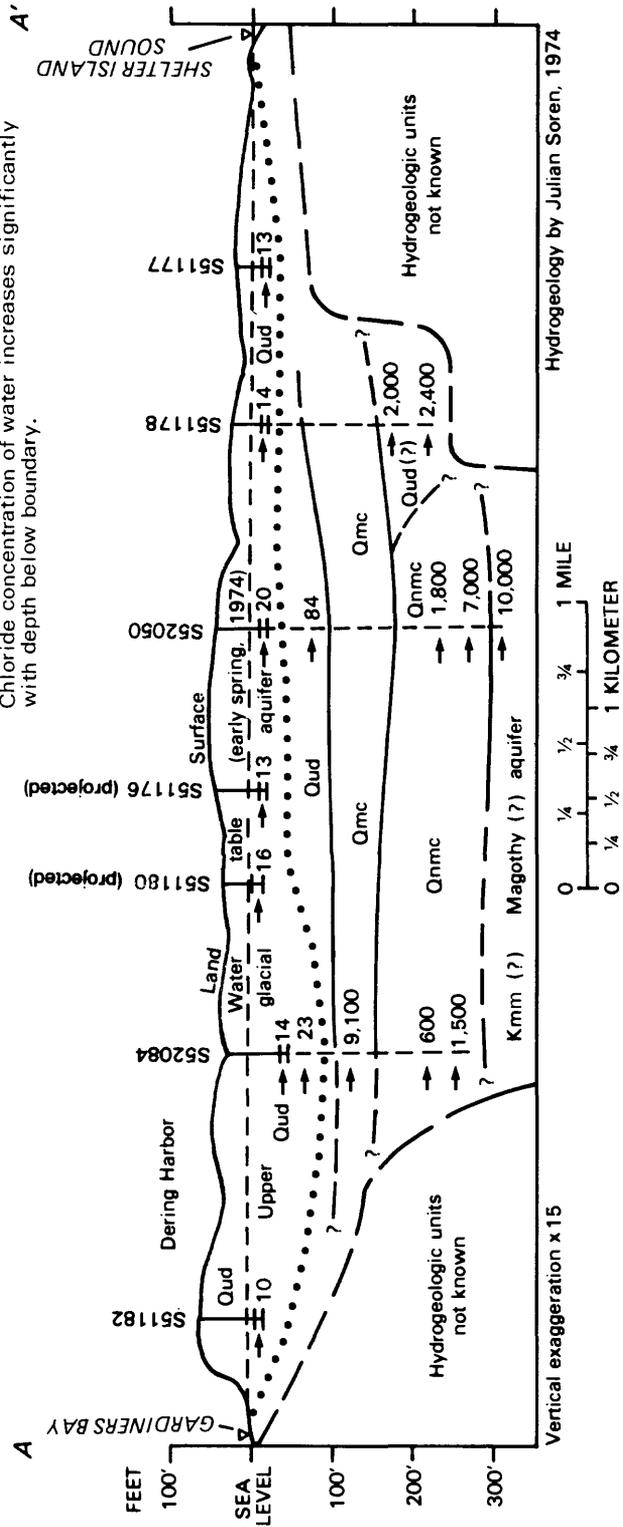


Figure 3.--Hydrogeologic section through Shelter Island. (Location of section is shown in fig. 2. Modified from Soren, 1978.)

Directly beneath the stratified drift is a gray-green to dark-gray marine clay; its thickness ranges from 50 to 95 ft at the three exploratory sites and increases southward. This unit was first encountered at depths of 130 ft, 139 ft, and 85 ft at wells S52084, S52050, and S51178, respectively (figs. 2 and 3).

The lower clay unit is a red-brown to brown nonmarine deposit; it is 123 ft thick at well S52050 and thicker at well S52084, where it was not fully penetrated. This unit was absent at well S51178, where the marine clay is directly underlain by glacial sand and gravel. The top of the nonmarine clay is 180 ft and 218 ft below land surface at wells S52084 and S52050, respectively (figs. 2 and 3).

Only one well (S52050) penetrated the Upper Cretaceous Matawan Group and Magothy Formation, undifferentiated (Magothy aquifer), which consists of gray to white, fine to coarse sand with interstitial clay, silt, and lignite (Jensen and Soren, 1974). The upper surface of this unit is about 300 ft below sea level (Soren, 1978). Below the Magothy are, in descending order, the clay member and Lloyd Sand Member (Lloyd aquifer) of the Raritan Formation, and crystalline bedrock. Additional information on these deep strata is given in Jensen and Soren (1974).

HYDROLOGY

The Hydrologic Cycle

Water circulates continually between the ocean and the atmosphere in a process known as the hydrologic cycle (fig. 4). Solar radiation causes sea water to evaporate and become part of the atmosphere. Precipitation returns the water to the land surface, where it may re-evaporate, be transpired back to the atmosphere by vegetation, run off impermeable surfaces or steep slopes to ponds, marshes, or bays, or infiltrate through the soil to become part of the ground-water flow system.

Pond or marsh water may evaporate, be transpired, or infiltrate to the aquifer. Most ground water on Shelter Island discharges directly to the ocean as subsurface outflow; from there it is evaporated back to the atmosphere.

A more generalized description of the hydrologic cycle would also include overland runoff to streams, ground-water discharge to streams, and streamflow to bays and the ocean as major components. However, Shelter Island has no significant streams.

Recharge and Discharge of Ground Water

Precipitation is the sole source of fresh ground water on Shelter Island. Because less than 1 percent becomes overland runoff (Nemickas and Koszalka, 1982), virtually all precipitation on the island ultimately takes one of two routes--evapotranspiration (evaporation plus transpiration) or recharge to the ground-water system.

Average annual precipitation at Greenport (fig. 1) during 1974-83 was 47 inches. If evapotranspiration and overland runoff are assumed to be about 50 percent and 1 percent of precipitation, respectively (Nemickas and Koszalka, 1982), then average annual ground-water recharge during this 10-year period is calculated as follows:

$$\begin{aligned} \text{Recharge} &= \text{Precipitation} - (\text{Evapotranspiration} + \text{Overland Runoff}) \\ &= 47 \text{ inches} - (23.5 \text{ inches} + 0.5 \text{ inches}) \\ &= 23 \text{ inches} \end{aligned}$$

or about 4.4 billion gallons annually. This represents an average recharge rate of about 12 Mgal/d islandwide, or slightly more than 1 (Mgal/d)/mi².

Fresh ground water on Shelter Island continually flows from the high areas of the water table toward the perimeter of the island and discharges into the surrounding saline water (fig. 4). The interface between fresh and saline water is not a sharp boundary, but a zone of diffusion in which the chloride concentration of the freshwater gradually increases with distance from the island until it equals the salinity of the surrounding bays.

Under natural conditions, recharge and discharge are in equilibrium, so that the freshwater/saltwater interface is maintained in a relatively constant position. When water is pumped from the aquifer, however, the flow of fresh ground water toward the zone of diffusion is decreased, which allows landward movement of the interface and reduces the volume of fresh ground water in storage.

Where most of the pumped water is returned to the aquifer through cesspools and septic tanks, this imbalance is minimized. However, some of the pumped water is directed to consumptive uses--that is, it is not returned

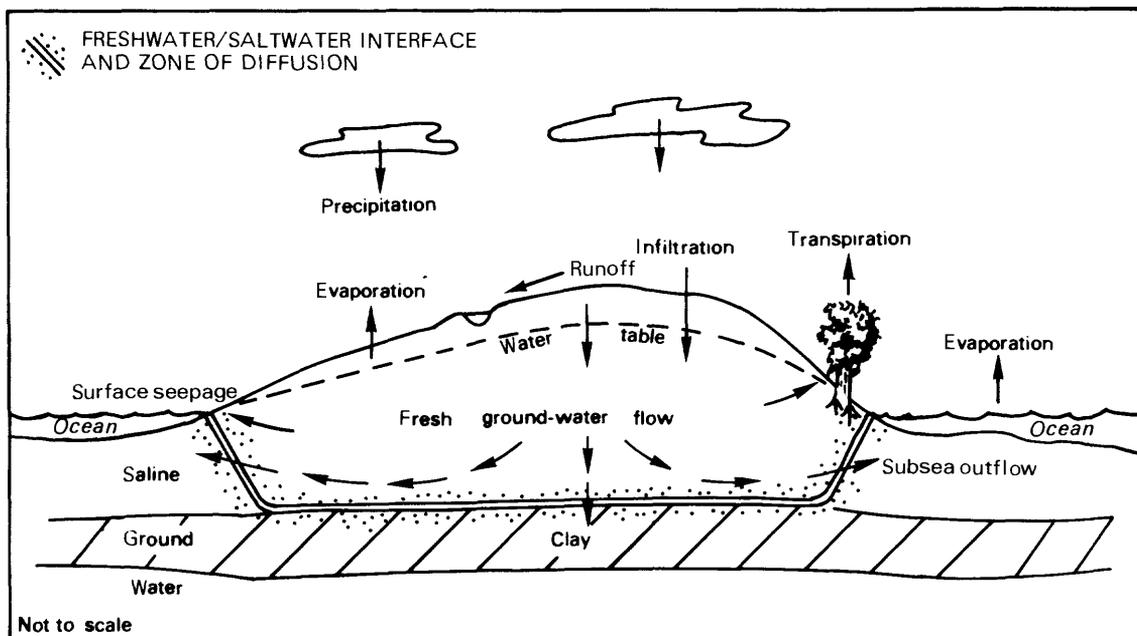


Figure 4.--Hydrologic cycle and pattern of ground-water movement on Shelter Island.

directly to the aquifer system. Examples of consumptive use on Shelter Island are evaporation from lawn sprinkling, irrigation, and swimming pools, and transpiration by plants, whereby water is returned to the atmosphere and is thus lost from the ground-water system.

To maintain an adequate ground-water supply over the long term, recharge must balance both consumptive use and the natural outflow of fresh ground water to surrounding saltwater bodies. Total annual pumpage and total annual recharge on Shelter Island have been estimated to be 260 Mgal and 4,380 Mgal, respectively. Thus, 6 percent of annual recharge is "used" (not all of it consumptively), leaving more than 94 percent available to maintain the position of the interface. From an islandwide perspective, significant landward movement of saline ground water would be unlikely under these conditions. However, the geographic distribution of pumping wells is a critical factor. Excessive withdrawal of fresh ground water in nearshore areas will undoubtedly cause a local disturbance of the freshwater-saltwater equilibrium that will result in locally increased chloride concentrations in water near the pumping well. The degree of saltwater encroachment is dependent on the distance of the well from the shore, the amount of pumping, and the local characteristics of the aquifer. In other areas, excessive ground-water withdrawals may result in upconing of the saline ground water into the freshwater lens.

Boundary Between Fresh and Saline Ground Water

The thickness and position of the freshwater/saltwater interface depend on several factors, which are discussed below with respect to Shelter Island.

Ghyben-Herzberg Relationship

The simplest analysis of the relationship between fresh and saline ground water in a coastal aquifer assumes that the aquifer is homogeneous (of uniform composition), that the ground water is under unconfined (water-table) conditions, and that the interface is under hydrostatic conditions (no recharge or discharge).

Under these conditions, the interface between saltwater of density ρ_s and freshwater of density ρ_f projects into the aquifer as shown in figure 5A. The interface will remain stationary if the weight of a unit column of freshwater that extends from the water table to the interface is balanced by the weight of a unit column of saltwater that extends from sea level to the same depth as the point on the interface.

This relationship can be expressed mathematically as follows:

$$\rho_s g z_s = \rho_f g (z_s + z_w) \quad \text{or} \quad z_s = \frac{\rho_f}{\rho_s - \rho_f} z_w$$

where: ρ_s = density of saltwater;
 ρ_f = density of freshwater;
 g = acceleration due to gravity;
 z_s = depth of interface below sea level; and
 z_w = altitude of water table above sea level.

Taking the densities of fresh and saltwater to be 1.0 and 1.025, respectively,

$$z_s = 40 z_w$$

This equation is the Ghyben-Herzberg relationship. It states that, at any particular location, for every foot of water-table altitude above sea level, fresh ground water will extend 40 ft below sea level. For example, if the water table at a given site is 2.5 ft above sea level, the interface at that site is 100 ft below sea level; the thickness of the fresh ground-water body is, therefore, 102.5 ft at that spot. This principle also implies that, if the water table in a homogeneous, unconfined coastal aquifer is lowered 1 ft, the interface will rise 40 ft, and that the total thickness of saturated aquifer will be reduced by 41 ft (fig. 5B).

The following factors limit the usefulness of the Ghyben-Herzberg relationship for Shelter Island:

1. The Ghyben-Herzberg relationship generally underestimates the depth to the freshwater/saltwater interface because ideal (hydrostatic) conditions do not occur in most real settings. Intermittent freshwater recharge from precipitation and continuous discharge of fresh ground water to the surrounding saline water as subsurface outflow (fig. 5B) push the interface to a greater depth than predicted by the Ghyben-Herzberg relationship.
2. As stated earlier, the interface separating freshwater from saline water in a coastal aquifer is not a sharp boundary but a zone of diffusion in which mixing occurs. The width of this zone depends on the characteristics of the aquifer material. Where the zone of diffusion is wide, the flow pattern may be altered sufficiently to cause the position of the interface to depart considerably from the Ghyben-Herzberg prediction.

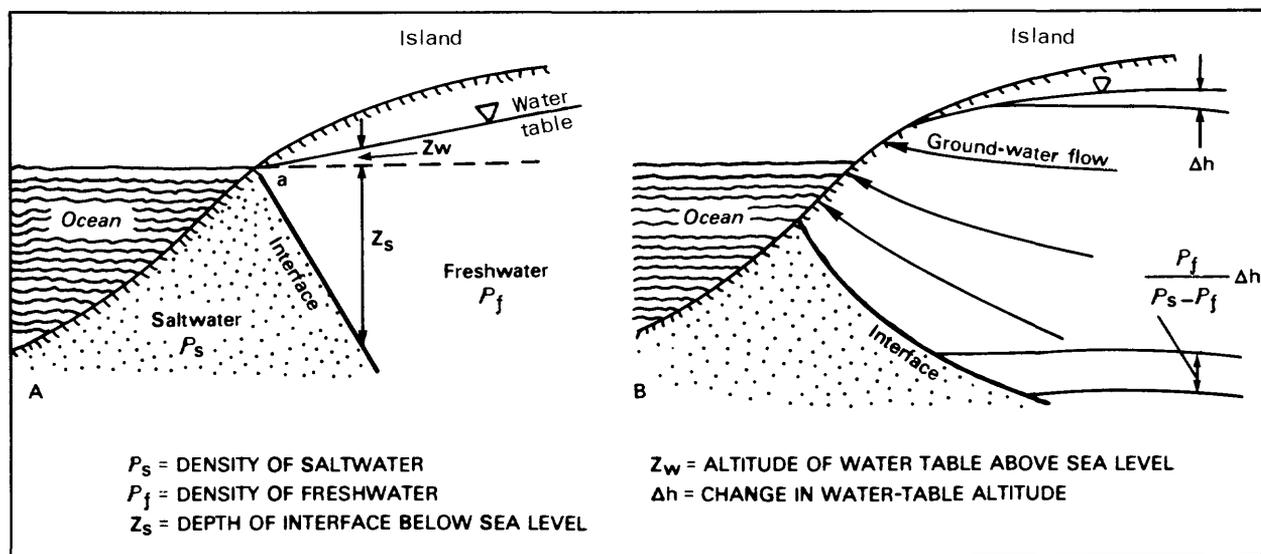


Figure 5.--Theoretical relationship between fresh and saline ground water: A. Under hydrostatic conditions. B. With seaward discharge of fresh ground water. (Modified from Freeze and Cherry, 1979.)

3. The geologic units underlying Shelter island are anisotropic. Geologic variations both laterally and with depth contradict the assumption of homogeneity (uniform composition).

Geologic Controls on the Distribution of Fresh and Saline Ground Water

On Shelter Island, the clay units beneath the upper glacial aquifer tend to confine saline ground water beneath them and prevent the water from mixing with the freshwater above. The nearly horizontal arrangement of the geologic units, however, enhances the lateral movement of saline ground water from shore areas toward pumping wells in the aquifer above the clay units. Thus, Shelter Island's geologic framework permits lateral infiltration of saline water into the aquifer and also limits the thickness of the freshwater lens.

As shown in figure 3, all fresh ground water in storage on Shelter Island lies between the water table and the top of the marine clay unit, which ranges from 65 to 100 ft below sea level (Soren, 1978). The lower boundary of the freshwater lens rises seaward near the shores.

The saline water in the clay strata is probably residual from the period when the marine (upper) clay was deposited. The chloride in this water has probably been diluted over time, and additional freshening is possible if the water table remains at present levels or rises. The clays cannot be relied upon for future water supply, however, because (1) the freshening process would require thousands to tens of thousands of years owing to the clays' thickness and low hydraulic conductivity; (2) potentiometric heads in the overlying fresh ground water are relatively low, which limits its rate of downward movement; and (3) even if the clays contained freshwater, the yield would almost certainly be insufficient to warrant the installation of wells.

The presence of fresh ground water beneath the clay units is highly improbable. Extrapolation of potentiometric heads in both the Magothy and the underlying Lloyd aquifers from nearby parts of Suffolk County to Shelter Island indicates that the heads are approximately at sea level (Jensen and Soren, 1974). This evidence, in conjunction with the high chloride concentration (10,000 mg/L) in the Magothy aquifer at well S52050 (fig. 3), indicates that both these aquifers beneath Shelter Island contain saline ground water. Thus, the freshwater supply of Shelter Island is limited to the thin freshwater lens in the upper glacial aquifer between the top of the marine clay unit and the water table.

Depth of Freshwater/Saltwater Interface at Selected Locations

The leading edge of the zone of diffusion can be represented by a plane of equal chloride concentration beyond which chloride levels increase seaward. In this report, a chloride concentration of 40 mg/L is interpreted as the beginning of the freshwater/saltwater boundary. Although this concentration is low compared with the Federal and State drinking-water standard of 250 mg/L, it is greater than background chloride levels in native ground water (<10 mg/L) and indicates the mixing of freshwater with seawater (Luszczynski and Swarzenski, 1960).

The position of the freshwater/saltwater interface is not fixed; rather, it continuously shifts in response to fluctuations in recharge and ground-water withdrawal. It moves seaward with increased recharge and landward with increased withdrawal. Any attempt to define its location is therefore valid only within a relatively short time span.

Chloride concentrations in shallow ground water in the 10 new observation wells were measured during well installation and twice subsequently. The concentrations, shown in table 3, illustrate the extreme variability of chloride in water in or near the zone of diffusion and reflect its changing position with time. At nine wells, the chloride concentration was highest during September-October, immediately after the summer period of little recharge and high ground-water use. At seven wells, the chloride concentration was lowest in early spring, a period of high recharge and relatively low ground-water use.

Table 3.--Chloride concentrations in shallow ground water on Shelter Island, 1983-84.

[Well locations are shown in fig. 2;
values are in mg/L; a dash indicates
no sample was collected]

| Well number | September - October 1983 | December 1983 | March - April 1984 |
|-------------|--------------------------|---------------|--------------------|
| S75432 | 150 | 25 | 22 |
| S75433 | 220 | 23 | 110 |
| S75434 | 36 | 21 | 19 |
| S75435 | 125 | 64 | 14 |
| S75436 | 38 | 28 | -- |
| S75437 | 2,400 | 310 | 18 |
| S75438 | 152 | 180 | 20 |
| S75439 | 27 | 20 | 20 |
| S75440 | 15 | 7.8 | 11 |
| S75441 | 20 | 18 | 11 |

During the installation of the 10 new wells, additional ground-water samples were collected from various depths below the water table and analyzed for both specific conductance and chloride concentration. Results, shown in table 4, indicate that the chloride concentration above the interface generally remains relatively constant or increases only slightly with depth. Below the beginning of the zone of diffusion (40 mg/L), however, the chloride concentration increases rapidly--as much as an order of magnitude within 10 ft--until it approaches or exceeds 19,000 mg/L, the chloride concentration of sea water.

The chloride concentrations in table 4 were used to estimate the altitude of the interface at each well. These values are included in table 4 for comparison with those predicted by the Ghyben-Herzberg (1:40) relationship. At each well, the probable depth of the interface based on chloride data is

Table 4.--Chloride concentration and specific conductance of ground water at various depths and approximate altitude of freshwater/saltwater interface in 10 observation wells on Shelter Island, September through October 1983.

[Well locations are shown in fig. 2]

| Well number | Sampling altitude ¹ (ft below sea level) | Chloride concentration (mg/L) | Specific conductance (μ S/cm) | Approximate altitude of interface ² (ft below sea level) |
|-------------|---|-------------------------------|------------------------------------|---|
| S75432 | 8 | 150 | 316 | <8 |
| | 22 | 325 | 729 | (65) |
| | 33 | 2,750 | 6,638 | |
| | 42 | 22,000 | 39,780 | |
| | 54 | 22,000 | 42,020 | |
| | 64 | 22,100 | 37,718 | |
| S75433 | 14 | 220 | 475 | <14 |
| | 23 | 1,430 | 3,588 | (71) |
| | 33 | 21,300 | 39,000 | |
| | 44 | 20,000 | 40,625 | |
| | 54 | 21,400 | 39,618 | |
| S75434 | 8 | 36 | 168 | >8 (82) |
| S75435 | 16 | 125 | 345 | <16 |
| | 22 | 94 | 271 | (77) |
| | 33 | 280 | 557 | |
| | 54 | 18,200 | 35,113 | |
| | 64 | 23,600 | 44,918 | |
| S75436 | 5 | 38 | 234 | >33 |
| | 33 | 38 | 238 | (510) |
| S75437 | 13 | 2,400 | 6,311 | <13 |
| | 21 | 415 | 839 | (56) |
| | 31 | 20,600 | 35,569 | |
| | 42 | 22,500 | 43,350 | |
| | 52 | 22,500 | 40,230 | |
| | 73 | 23,400 | 41,210 | |
| S75438 | 12 | 152 | 423 | <12 |
| | 17 | 63 | 223 | (83) |
| | 22 | 66 | 300 | |
| | 32 | 570 | 1,454 | |
| | 53 | 17,800 | 34,840 | |
| | 74 | 20,000 | 37,868 | |
| S75439 | 15 | 27 | 153 | >70 |
| | 19 | 22 | 144 | (130) |
| | 30 | 14 | 97 | |
| | 50 | 15 | 70 | |
| | 61 | 25 | 111 | |
| | 70 | 24 | 116 | |
| S75440 | 8 | 15 | 93 | >39 |
| | 18 | 15 | 91 | (130) |
| | 39 | 20 | 111 | |
| S75441 | 44 | 20 | 178 | >54 |
| | 54 | 18 | 103 | (100) |

¹ Rounded to nearest foot.

² Upper number represents estimate based on chloride data; lower number (in parentheses) represents prediction from Ghyben-Herzberg relationship (1:40).

significantly less than that predicted by the Ghyben-Herzberg formula, principally because of the geologic controls on the distribution of fresh and saline ground water discussed earlier. These data, in conjunction with the water-table-contour map discussed in the following section (fig. 7, p. 20), show that by the end of the summer, the thickness of the freshwater body (depth of interface plus height of water table) had decreased to less than 20 ft at many of the nearshore wells (S75432, S75433, S75435, S75437, S75438).

Where chloride analyses are unavailable, concentrations can be roughly estimated from measurements of specific conductance. Figure 6 is a log-log plot that illustrates the approximate straight-line relationship between chloride concentration and specific conductance in the 42 ground-water samples listed in table 4.

Specific conductance is a measure of the ability of a water sample to conduct an electric current. The conductance is due to the presence of dissociated ions in solution. In a simple dilute solution of a single salt (such as NaCl), the relationship between the concentration of dissolved solids and specific conductance is linear. As the concentration increases, the slope of the line steepens. In natural waters, which commonly contain a mixture of salts, the other ions cause aberrations in the relationship (Hem, 1959, p. 38-39).

Because the concentration of dissolved solids other than chloride in ground water on Shelter Island is generally low, and because the island is surrounded by saline ground water, chloride is the major contributor to the water's conductance, especially near the freshwater/saltwater interface. The relationship between chloride concentration and specific conductance therefore tends toward a straight line, although the slope generally increases with increasing chloride concentration. Thus, chloride concentrations on Shelter Island can be roughly estimated from specific conductance values in the graph in figure 6, but only within the range of conductance values shown.

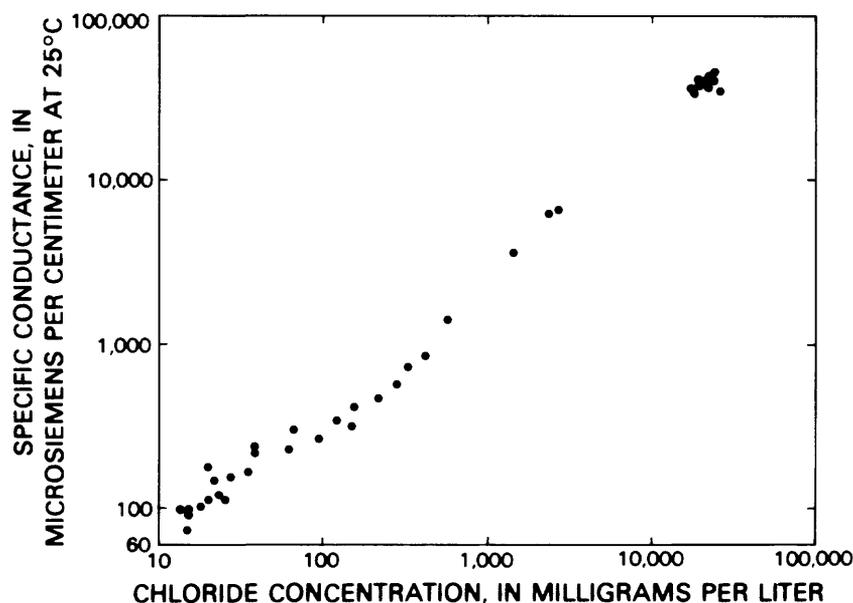


Figure 6.

Relationship between specific conductance and chloride concentration of ground water in observation wells on Shelter Island.

Water Table

The configuration of the water table is controlled by (1) the thickness and hydraulic conductivity (water-transmitting properties) of the aquifer and underlying units; (2) the quantity and location of recharge; (3) the location and type of natural discharge points (streams, springs, etc.), and (4) the quantity and location of man-induced discharge (wells). Its altitude on Shelter Island during this study and its fluctuations during the preceding 10-year period are described below.

Altitude in December 1983

A contour map of the water table on Shelter Island (fig. 7) was drawn from water levels measured in 26 of the 27 observation wells in December 1983. (Well S51181, which supplies water to the country club, was excluded because it has a submersible pump that cannot be turned off long enough to obtain a static water-level measurement.)

Areas of greatest fresh ground-water availability may be discerned from the water-table map. Several major water-table mounds are evident; the largest of these is centered in the middle of the island. Two other ground-water highs are in the Mashomack Preserve and on the Dering Harbor-Hay Beach peninsula. Smaller freshwater mounds are indicated on the south-shore necks, on Ram Island, and in the western part of the Mashomack Preserve.

An additional mound, between Shelter Island Heights and West Neck Bay, is probably caused by fine-grained (silty and clayey) deposits within the aquifer. These deposits retard the downward movement of water and allow the buildup of a mound. Areas in which fresh ground water is severely limited include all coastal areas, the southernmost part of West Neck, and Little Ram Island.

Fluctuations

The water table, like the freshwater/saltwater interface, fluctuates in response to changes in inflow (recharge) and outflow (evapotranspiration, discharge to streams, and ground-water withdrawal) to and from the ground-water system. Precipitation acts in combination with other climatic variations, mainly increased evaporation during the summer and increased transpiration during the growing season, to produce annual water-table fluctuations that range from a high in early to mid-spring to a low in late fall. On Shelter Island, the effect of increased pumping during the summer is superimposed on these climatic variations.

Water-table fluctuations in two wells on Shelter Island over a 10-year period, and in a third well over a 4-year period, are shown in figure 8 with corresponding monthly precipitation data. The water table generally tends to rise during the early part of the year and declines from the beginning of summer through late fall. Thus, monthly variations in precipitation are a better predictor of water-table fluctuations than climatic generalizations. For example, the water table rose in response to unusually high precipitation in January 1979 and June 1982.

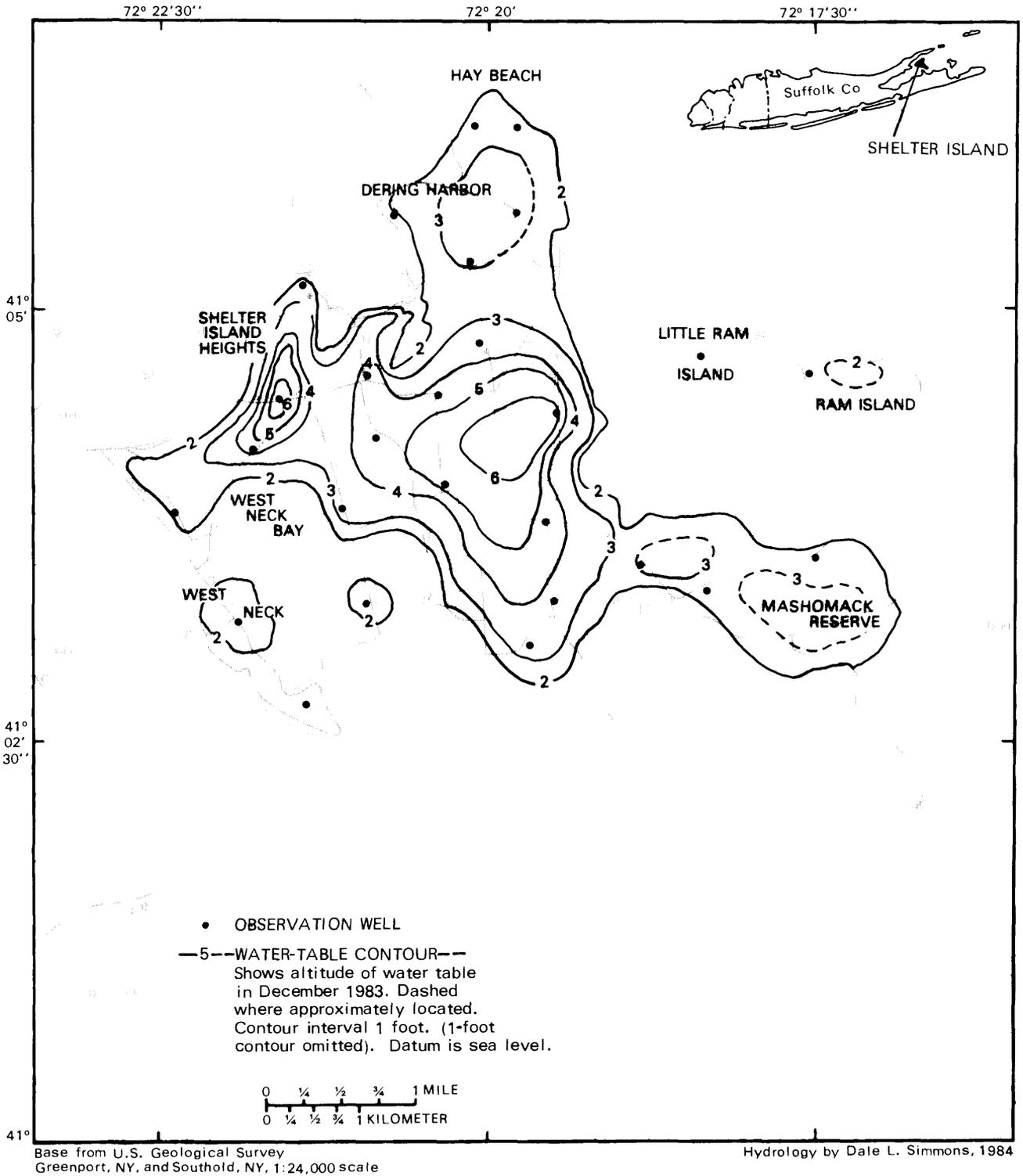


Figure 7.--Water-table altitude on Shelter Island in December 1983.

The 10-year period illustrated in figure 8 shows no discernible trend in water levels. On Shelter Island, water-table fluctuations within a single year (as much as 4 ft in well S38461 in 1979) are greater than those observed over a period of several years.

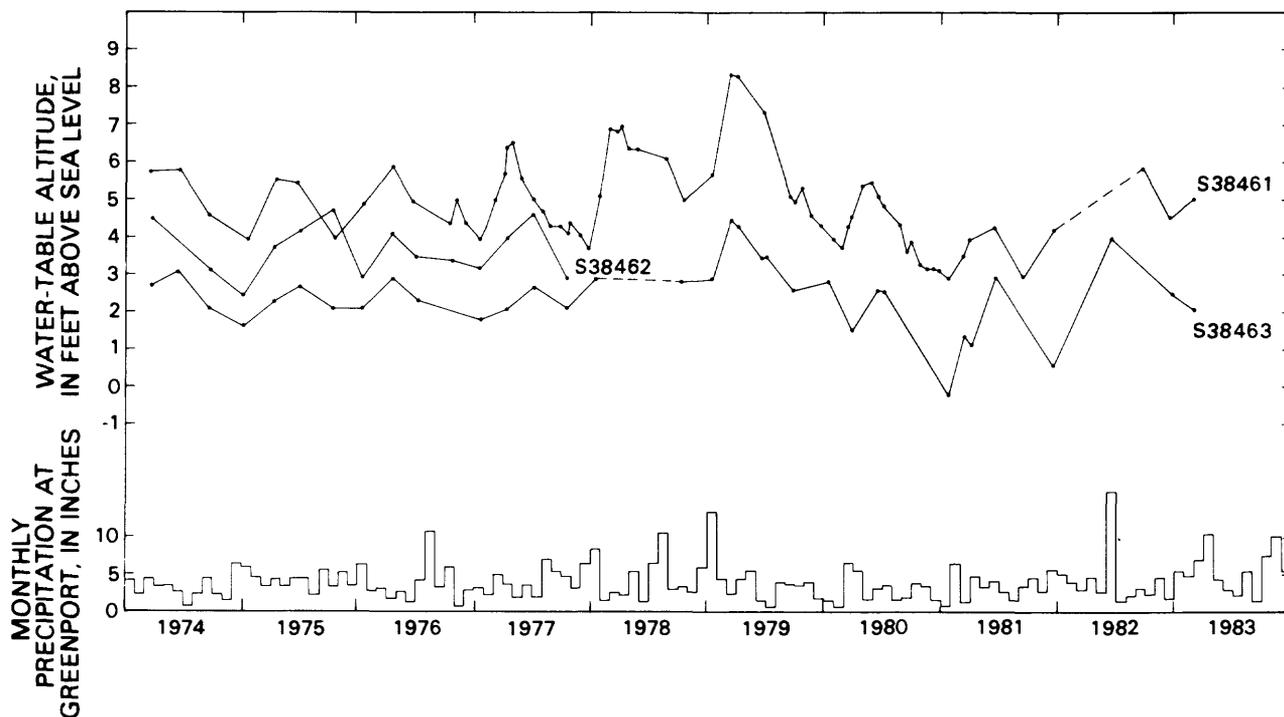


Figure 8.--Water-level fluctuations in three water-table wells and monthly precipitation, 1974-83.

CHEMICAL QUALITY OF GROUND WATER

The chemical analysis of a sample from a well in Upton, N.Y. (fig. 1) is shown in table 5. This sample is considered to be representative of ground water in the upper glacial aquifer on Long Island before alteration by human activity. Concentrations of constituents are much less than Federal and State maximum recommended limits for drinking water (listed in appendix A) and indicate the approximate background levels of these constituents. Table 5 shows approximate background concentrations of iron to be 0.01 mg/L; chloride, 5 mg/L; nitrate, 0.1 mg/L; and dissolved solids, 36 mg/L.

The chemical quality of ground water on Shelter Island is generally good--suitable for human consumption and most other uses--and most samples were well within Federal and State drinking-water standards (appendix A) for the constituents selected for analysis. Exceptions include excessive concentrations of dissolved iron and manganese at many wells and occasionally excessive concentrations of chloride in some nearshore wells.

Selected results of chemical analyses of ground-water samples collected during the study are given in appendix B; a complete list of chemical analyses is given in appendix C.

Table 5.--Concentration of selected constituents of native ground water in the upper glacial aquifer.

| Constituent | Concentration (mg/L) |
|---------------------------------|-------------------------|
| Iron (Fe) | 0.01 |
| Calcium (Ca) | 1.5 |
| Magnesium (Mg) | 1.3 |
| Sodium and Potassium (Na + K) | 3.8 |
| Bicarbonate (HCO ₃) | 4 |
| Sulfate (SO ₄) | 6 |
| Chloride (Cl) | 5 |
| Nitrate (NO ₃) | 0.1 |
| Total dissolved solids | 36 |

Data from Cohen, Franke, and Foxworthy (1968, p. 50)

Chloride

Chloride concentrations in shallow ground water from the 27 observation wells were generally less than 40 mg/L and ranged from 7.8 mg/L in the Hay Beach and Mashomack areas (wells S51182 and S75440) in December 1983 to 310 mg/L at the southern end of the West Neck peninsula (well S75437) in December 1983. Although the drinking-water standard for chloride (250 mg/L) was exceeded only in the latter sample, three other samples showed elevated concentrations--64 mg/L in Dering Harbor (well S75435) in December 1983, 110 mg/L at Little Ram Island (well S75433) in March 1984, and 180 mg/L near the south end of Menantic Road (well S75438) in December 1983. Concentrations in previous or subsequent samples from these three nearshore wells were near 20 mg/L, which illustrates that chloride concentrations in wells near the zone of diffusion are subject to large and rapid fluctuations in response to such factors as short-term or seasonal increases in pumpage and reduced recharge during periods of below-average precipitation.

Areas of present or potential chloride contamination from seawater intrusion include, in order of increasing severity, the nearshore part of Dering Harbor, Little Ram Island, the peninsula at the south end of Menantic Road, and the extreme south end of the West Neck peninsula.

Although chloride in moderately excessive concentrations is not harmful, it gives a salty taste to foods and beverages. In addition, the sodium usually found in association with chloride may contribute to hypertension and other health problems in some individuals, and to pregnancy-related toxemia (U.S. Environmental Protection Agency, 1976b).

Iron and Manganese

Drinking-water standards are written in terms of total iron and total manganese; however, much of the suspended material included in the analyses for total metals listed in appendix B is derived from particulate matter that results from inadequate development of the observation wells. Consequently,

dissolved, rather than total, iron and manganese concentrations are used in this discussion because they are more representative of those in water from sufficiently developed domestic or public-supply wells.

Concentrations of dissolved iron in shallow ground water ranged from the detection limit (<0.001 mg/L) to 5 mg/L. Although they were generally less than the recommended limit for iron in drinking water (0.3 mg/L; see appendix A), they exceeded this standard in approximately 20 percent of the samples. Dissolved iron concentrations in the Mashomack area ranged from 0.20 to 0.39 mg/L, indicating that the natural formation water is relatively high in dissolved iron, which is probably derived from iron hydroxide coatings on the sediment grains.

Elevated iron concentrations in water used for domestic or industrial supply are objectionable because they adversely affect the taste of foods and beverages and can stain laundry and build up deposits in plumbing fixtures. For these reasons the iron criterion for drinking water is set at 0.3 mg/L; however, this amount constitutes only a small fraction of the iron normally consumed and is of esthetic rather than toxicological significance (U.S. Environmental Protection Agency, 1976b).

Concentrations of dissolved manganese in ground water ranged from <0.001 mg/L to 3.00 mg/L. Approximately 33 percent of the samples exceeded the recommended limit of 0.05 mg/L. In the relatively undisturbed Mashomack area, dissolved manganese concentrations ranged from 0.01 to 0.22 mg/L.

Manganese is commonly found in association with iron; it causes laundry stains and has an objectionable taste. Although manganese dust can be toxic if inhaled, only extremely large doses of ingested manganese cause disease in humans (U.S. Environmental Protection Agency, 1976b). Therefore, the drinking-water recommendation is based largely on esthetic rather than health considerations.

pH

The pH of water from the observation wells ranged from 5.1 to 7.2, and about 85 percent of the values were less than or equal to 6.0. The pH of seven ground-water samples from the Mashomack Preserve ranged from 5.3 to 6.1, indicating that the natural ground water on Shelter Island is acidic. Water with pH values in this range is sufficiently acidic to corrode pipes and plumbing fixtures and to mobilize some metal ions occurring in sediments or as suspended material. A pH range of 5.0 to 9.0 is acceptable for water serving as a source of public water supply (U.S. Environmental Protection Agency, 1976b).

Dissolved Solids

Concentrations of dissolved solids ranged from 40 to 585 mg/L; more than 95 percent of the samples had values less than 250 mg/L. Only two samples had dissolved solids concentrations greater than 250 mg/L--they were 372 mg/L at the south end of Menantic Road (well S75438) and 585 mg/L at the south end of the West Neck peninsula (well S75437). In both samples the dissolved solids were a direct result of proximity to the freshwater/saltwater interface and of the high concentrations of chloride and other ions associated with seawater.

The recommended maximum allowable concentration of dissolved solids in drinking water is 500 mg/L (U.S. Public Health Service, 1962). Excessive dissolved solids are objectionable because of possible physiological reactions including laxative effects and other problems related to sodium (as described in the Chloride section), as well as unpalatable mineral tastes and the potential for pipe and fixture corrosion.

Nitrate

Nitrate concentrations (measured as nitrogen) in shallow ground water from the observation wells ranged from <0.1 to 9.1 mg/L. (One sample from well S75436, which had a nitrate concentration of 14 mg/L, was excluded because the well had been vandalized.) All but four analyses showed nitrate concentrations less than 5.0 mg/L. The exceptions are 5.5 and 5.6 mg/L between West Neck Bay and Menantic Road (well S51172), and 8.7 and 9.1 mg/L just south of the school (well S52050). These concentrations are all lower than the recommended drinking-water limit of 10 mg/L (U.S. Environmental Protection Agency, 1976).

Nitrogen concentrations in water from the Mashomack Preserve were all 0.1 mg/L or less, indicating that the amount of nitrate present in natural ground water on Shelter Island is negligible. Nitrate in the ground water of Shelter Island originates mostly from cesspool and septic-tank effluent in developed areas and from fertilizers in farmed and cultivated areas. The highest nitrate concentrations, which were found at well S52050 near the school, are attributed to cesspool effluent.

Excessive nitrate in drinking water can cause methemoglobinemia ("blue-baby disease"), a potentially fatal disease in infants less than 3 months of age. For adults and older children, the U.S. Public Health Service indicates the possibility of a wide latitude in the 10-mg/L limit (Soren, 1978).

SUMMARY AND CONCLUSIONS

Shelter Island, which lies between the north and south forks of eastern Long Island, contains 11 mi². The thin upper glacial aquifer, which consists mostly of permeable sand and gravel deposits that readily permit infiltration of saline ground water in coastal areas, is the sole source of freshwater for the Town's population (1982) of about 2,200 year-round and 10,000 summer residents. The thickness of the freshwater lens is limited by underlying clay units, which contain saline ground water. Increased development of the island in recent years has led to both greater consumptive water use and increased discharge of sewage to the ground water through private septic tanks and cesspools.

The purpose of this study was to (1) delineate the configuration of the water table; (2) investigate the chemical quality of water in the upper glacial aquifer; and (3) approximate the position of the boundary between fresh and saline ground water at selected nearshore locations.

Ten observation wells were installed to supplement the 17 previously existing ones; their locations were chosen to (1) improve the geographic coverage of the island with respect to water-level and water-quality data, (2) obtain information on the chloride concentration of ground water in nearshore areas, and (3) provide permanent facilities for monitoring saltwater movement. In addition, all 27 wells were sampled two or three times during 1983-84 for such constituents as nitrate, dissolved and total iron, dissolved and total manganese, and dissolved solids.

Shelter Island's ground-water system is not in equilibrium. Total annual pumpage increased about 20 percent during 1974-83 to about 260 million gallons, or about 6 percent of total annual recharge. This implies that saline ground water has already moved landward, a conclusion corroborated by the elevated chloride concentrations (up to 310 mg/L) in shallow ground water in some nearshore wells.

Chloride concentrations in ground water above the zone of diffusion (less than 40 mg/L Cl^-) remain relatively constant or increase slightly with depth. Below the interface they increase rapidly, as much as an order of magnitude within 10 feet, until they reach 19,000 mg/L, the chloride concentration of seawater.

Chloride concentrations in wells screened in or near the zone of diffusion may range over two orders of magnitude in response to variations in recharge and ground-water withdrawal. After a summer season of relatively low recharge and peak water demand, the thickness of the freshwater body decreases to less than 20 ft in many nearshore areas.

A water-table-contour map prepared from ground-water levels measured in December 1983 shows freshwater mounds in the center of the island, in the Mashomack Preserve, on the Dering Harbor-Hay Beach peninsula, and in the area between Shelter Island Heights and West Neck Bay. Areas in which the supply of freshwater is severely limited include all coastal areas, the southernmost part of West Neck peninsula, and Little Ram Island.

Ground-water levels measured in December 1983 ranged from 1.62 ft above sea level at well S75432 (Ram Island) to 12.77 ft at well S75436 (West Neck Road and Shore Road). The latter water level is unusually high and is attributed to ground-water mounding above the silt and clay at this site. Water levels at most locations on Shelter Island are less than 6 ft above sea level.

No long-term trend in water levels was discernible during 1974-83. Seasonal water-table fluctuations are greater than variations that occur over a period of several years.

Ground-water quality on Shelter Island is good and generally meets Federal and State drinking-water standards. Exceptions are excessive concentrations of chloride and dissolved solids in one sample from a nearshore well, and excessive concentrations of iron and manganese in numerous samples. Moderately excessive concentrations of these ground-water constituents may be esthetically objectionable but do not constitute a health hazard.

Chloride concentrations in shallow ground water from the observation wells ranged from 7.8 mg/L to 310 mg/L. Although only one sample exceeded the recommended drinking-water limit of 250 mg/L, elevated chloride levels indicative of landward movement of the zone of diffusion were found in the nearshore part of Dering Harbor (64 mg/L at well S75435), Little Ram Island (110 mg/L at well S75433), the peninsula at the south end of Menantic Road (180 mg/L at well S75438), and the extreme south end of the West Neck peninsula (310 mg/L at well S75437).

Concentrations of dissolved iron ranged from below the detection limit to 5.0 mg/L. Although they were generally less than 0.3 mg/L, the recommended limit for iron in drinking water, they exceeded this standard in approximately 20 percent of the samples. Results of analyses for dissolved iron in the Mashomack area ranged from 0.20 to 0.39 mg/L, indicating that this constituent is present in relatively high concentrations in natural ground water. Much of this iron is probably derived from iron hydroxide coatings on the sediment grains.

Concentrations of dissolved manganese ranged from below the detection limit to 3.0 mg/L. Approximately 33 percent of the samples exceeded the recommended limit of 0.05 mg/L. In the Mashomack area, dissolved manganese concentrations ranged from 0.01 to 0.22 mg/L.

A ground-water sample from well S75437 had a dissolved-solids concentration of 585 mg/L; this was the only sample that exceeded the recommended limit of 500 mg/L. All nitrate concentrations were less than the recommended limit of 10 mg/L.

Chloride concentrations in shallow ground water beneath Shelter Island are likely to increase gradually as the demand for water increases with the population. Continued pumping of ground water near the shore will draw saline water landward into the upper glacial aquifer along the top of the underlying clay units. Subsequent pumping in nearshore areas, and excessive pumping in other areas, will cause upconing of saline water from the bottom of the upper glacial aquifer. Saline water is unlikely to be drawn upward from deeper units because of the low hydraulic conductivity of the intervening clays.

A system of widely spaced pumping wells distant from nearshore areas would minimize these undesirable effects. Continued, frequent monitoring of observation wells, especially during summer and early fall, would ensure early detection of further landward movement of saline ground water.

REFERENCES CITED

- Cohen, Philip, Franke, O. L., and Foxworthy, B. L., 1968, An atlas of Long Island's water resources: New York State Water Resources Commission Bulletin 62, 117 p.
- Crandell, H. C. Jr., 1962, Geology and ground-water resources of Plum Island, Suffolk County, New York: U.S. Geological Survey Water-Supply Paper 1539-X, 35 p.
- _____ 1963, Geology and ground-water resources of the Town of Southold, Suffolk County, New York: U.S. Geological Survey Water-Supply Paper 1619-GG, 36 p.
- Freeze, R. A., and Cherry, J. A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, 604 p.
- Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 1473, 269 p.
- Hoffman, J. F., 1961, Hydrology of the shallow ground-water reservoir of the Town of Southold, Suffolk County, Long Island, New York: New York State Water Resources Commission Bulletin GW-45, 49 p.
- Jensen, H. M., and Soren, Julian, 1974, Hydrogeology of Suffolk County, Long Island, New York: U.S. Geological Survey Hydrologic Investigation Atlas HA-501, 2 sheets.
- Luszczynski, N. J., and Swarzenski, W. V., 1960, Position of the saltwater body in the Magothy(?) Formation in the Cedarhurst-Woodmere area of southwestern Nassau County, Long Island, New York: Economic Geology, v. 55, p. 1739-1750.
- Miller, J. F., and Frederick, R. H., 1969, The precipitation regime of Long Island, New York: U.S. Geological Survey Professional Paper 627-A, 21 p.
- Nemickas, Bronius, and Koszalka, E. J., 1982, Geohydrologic appraisal of water resources of the South Fork, Long Island, New York: U.S. Geological Survey Water-Supply Paper 2073, 55 p.
- Nemickas, Bronius, Koszalka, E. J., and Vaupel, D. E., 1977, Hydrogeologic data from investigation of water resources of the South Fork, Suffolk County, New York: Suffolk County Water Authority, Long Island Water Resources Bulletin 7, 31 p.
- New York State Department of Environmental Conservation, 1977, Proposed ground water classifications, quality standards, and effluent standards and/or limitations--Title 6, Official compilation of codes, rules and regulations of the State of New York, part 703, 11 p.

REFERENCES CITED (CONTINUED)

- Nieter, William, Nemickas, Bronius, Koszalka, E. J., and Newman, W. S., 1975, The late quaternary geology of the Montauk peninsula--Montauk Point to Southampton, Long Island, New York, in New York State Geological Association, 47th annual meeting, Hofstra University, N.Y., Guidebook to Field Excursions: p. 129-156.
- Perlmutter, N. M., and DeLuca, F. A., 1963, Availability of fresh ground water, Montauk Point area, Suffolk County, Long Island, New York: U.S. Geological Survey Water-Supply Paper 1613-B, 39 p.
- Prince, K. R., 1985, Ground-water resource assessment of the Montauk area, Long Island, New York: U.S. Geological Survey Water-Resources Investigations 85-4013, 93 p.
- Soren, Julian, 1978, Hydrogeologic conditions in the Town of Shelter Island, Suffolk County, Long Island, New York: U.S. Geological Survey Water-Resources Investigations 77-77, 22 p.
- U.S. Environmental Protection Agency, 1976a, National Interim Primary Drinking Water Regulations: U.S. Environmental Protection Agency, EPA-570/9-76-003, 159 p.
- _____ 1976b, Quality criteria for water: U.S. Environmental Protection Agency, EPA-440/9-76-023, 501 p.
- U.S. Public Health Service, 1962, Public Health Service drinking-water standards, 1962: U.S. Public Health Service Publication 956, 61 p.
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Appendix A --New York State, U.S. Public Health Service, and U.S. Environmental Protection Agency drinking-water standards.

[Values of chemical constituents are in mg/L; dashes indicate no standard specified]

| Constituent | Proposed New York State drinking-water standards (1977) ^a | U.S. Public Health Service drinking-water standards (1962) ^b | U.S. EPA national interim primary drinking-water regulations (1977) ^c |
|----------------------------------|--|---|--|
| Arsenic (As) | 0.05 | 0.05 | 0.05 |
| Barium (Ba) | 1.0 | 1.0 | 1.0 |
| Cadmium (Cd) | .01 | .01 | .01 |
| Chloride (Cl) | 250 | ^d 250 | ^e 250 |
| Chromium (Cr ⁺⁶) | .05 | .05 | ^f .05 |
| Copper (Cu) | 1.0 | 1.0 | ^e 1.0 |
| Cyanide (CN) | .2 | .20 | -- |
| Fluoride (F) | 1.5 | ^g 1.7 | ^h 2.4 |
| Iron (Fe) | ⁱ .3 | .30 | ^e .3 |
| Lead (Pb) | .05 | .05 | .05 |
| Manganese (Mn) | ⁱ .3 | ^d .05 | ^e .05 |
| Mercury (Hg) | .002 | -- | .002 |
| Nitrate (NO ₃ , as N) | 10.0 | 10.0 | 10.0 |
| pH | 6.5 - 8.5 | | |
| Selenium (Se) | .01 | .01 | .01 |
| Silver (Ag) | .05 | .05 | .05 |
| Sodium (Na) | ^j 20;270 | -- | -- |
| Sulfate (SO ₄) | 250 | ^d 250 | ^e 250 |
| Total dissolved solids (TDS) | -- | ^d 500 | -- |
| Zinc (Zn) | 5.0 | 5.0 | -- |

^a From New York State Department of Environmental Conservation, 1977.

^b From U.S. Public Health Service, 1962.

^c From U.S. Environmental Protection Agency, 1976a, except as noted.

^d This value should not be exceeded if more suitable water supplies are available.

^e From U.S. Environmental Protection Agency, 1976b: a recommended criterion; not an enforceable regulation.

^f Total chromium.

^g Standard ranges from 0.8 to 1.7 mg/L, depending on annual average of maximum daily air temperature.

^h Standard ranges from 1.4 to 2.4 mg/L, depending on annual average of maximum daily air temperature.

ⁱ Combined concentration of iron and manganese shall not exceed 0.3 mg/L.

^j Applicable to drinking water for those on severely and moderately sodium-restricted diets, respectively.

Appendix B.--Analyses of selected chemical constituents of water from observation wells, 1983-84, and physical characteristics of wells

[Well locations are shown in fig. 2; concentrations in milligrams per liter; dashes indicate analysis not performed]

| Well number | Casing material | Depth of screen below land surface (ft) | Date sampled | Specific conductance ($\mu\text{S}/\text{cm}$ at 25°C) | pH (standard units) | Temperature (°C) | Chloride (Cl) | Dis-solved solids | Nitrate (NO_3 , as N) | Iron, total (Fe) | Iron, dis-solved (Fe) | Man-ganese, total (Mn) | Man-ganese, dis-solved (Mn) | Constituent or characteristic | |
|-------------|-----------------|---|--------------|---|---------------------|------------------|---------------|-------------------|---------------------------------|------------------|-----------------------|------------------------|-----------------------------|-------------------------------|--|
| | | | | | | | | | | | | | | | |
| S51169 | steel | 44-54 | 9-28-83 | 131 | 5.9 | 14.0 | 13 | 97 | 0.86 | 2.0 | -- | 0.03 | -- | | |
| | | | 11-29-83 | 127 | 5.9 | 11.5 | 12 | 93 | .90 | .43 | .14 | .14 | .02 | .02 | |
| | | | 4- 2-84 | 125 | 5.6 | 11.5 | 14 | 88 | 1.1 | .62 | .13 | .13 | .02 | .01 | |
| S51170 | steel | 21-31 | 9-28-83 | 129 | 5.8 | 14.0 | 28 | 99 | .40 | .11 | -- | .02 | -- | | |
| | | | 11-29-83 | 140 | 5.8 | 14.0 | 28 | 99 | .10 | 1.9 | 1.4 | .10 | .10 | .09 | |
| | | | 4- 2-84 | 122 | 5.7 | 12.0 | 27 | 86 | <.10 | 1.2 | .22 | .22 | .04 | .04 | |
| S51171 | steel | 43-53 | 9-28-83 | 208 | 5.8 | 12.0 | 19 | 143 | 4.9 | .50 | -- | .03 | -- | | |
| | | | 12- 1-83 | 216 | 5.7 | 11.0 | 19 | 138 | 4.4 | .34 | .22 | .22 | .04 | .02 | |
| | | | 4- 2-84 | 122 | 5.6 | 12.0 | 17 | 79 | 4.6 | 1.0 | .20 | .20 | .02 | .01 | |
| S51172 | steel | 25-35 | 9-27-83 | 326 | 5.7 | 12.0 | 40 | 205 | 5.5 | 1.2 | -- | .01 | -- | | |
| | | | 12- 1-83 | 194 | 5.4 | 12.0 | 37 | 216 | 5.6 | .56 | .22 | .22 | .01 | .01 | |
| | | | 4- 2-84 | 305 | 5.5 | 11.8 | 46 | 195 | 4.3 | 5.5 | .29 | .29 | .02 | .02 | |
| S51173 | steel | 39-49 | 9-27-83 | 137 | 6.0 | 14.5 | 16 | 98 | 1.1 | .80 | -- | .02 | -- | | |
| | | | 12- 5-83 | 122 | 6.0 | 13.0 | 15 | 83 | 1.0 | .95 | .14 | .14 | .01 | .01 | |
| | | | 4- 4-84 | 116 | 5.5 | 13.4 | 14 | 81 | 1.0 | 12.0 | .18 | .18 | .03 | .01 | |
| S51174 | steel | 51-61 | 9-27-83 | 168 | 5.7 | 13.0 | 18 | 115 | 2.2 | .48 | -- | .03 | -- | | |
| | | | 12- 7-83 | 161 | 6.0 | 12.0 | 19 | 106 | 2.2 | .25 | .10 | .10 | .02 | .02 | |
| | | | 4- 2-84 | 174 | 5.7 | 13.0 | 21 | 120 | 2.8 | .52 | .17 | .17 | .02 | .02 | |
| S51175 | steel | 48-58 | 9-27-83 | 161 | 5.9 | 13.0 | 17 | 119 | 1.5 | -- | -- | -- | -- | | |
| | | | 12- 5-83 | 160 | 6.0 | 11.0 | 16 | 108 | 1.4 | .30 | .25 | .25 | a.06 | .07 | |
| | | | 4- 2-84 | 164 | 5.7 | 11.5 | 18 | 108 | 1.8 | 1.0 | .28 | .28 | .04 | .04 | |
| S51176 | steel | 47-57 | 9-27-83 | 156 | 5.7 | 13.0 | 18 | 102 | 1.2 | 6.7 | -- | .04 | -- | | |
| | | | 12- 7-83 | 134 | 5.8 | 10.0 | 15 | 89 | 1.1 | 21.0 | 1.1 | 1.1 | .04 | .04 | |
| | | | 4- 4-84 | 135 | 5.4 | 11.9 | 17 | 90 | 1.5 | 10.0 | .58 | .58 | .04 | .04 | |
| S51177 | steel | 27-37 | 9-29-83 | 108 | 5.4 | 11.5 | 15 | 70 | <.10 | .51 | -- | <.01 | -- | | |
| | | | 12-14-83 | 126 | 5.5 | 12.0 | 23 | 71 | .90 | 1.3 | .81 | .81 | .03 | .03 | |
| | | | 4- 3-84 | 109 | 5.3 | 12.3 | 17 | 80 | <.10 | a4.8 | 5.0 | 5.0 | .05 | .05 | |

(continued)

Appendix B.--Analyses of selected chemical constituents of water from observation wells, 1983-84, and physical characteristics of wells
(Continued)

[Well locations are shown in fig. 2; concentrations in milligrams per liter; dashes indicate analysis not performed]

| Well number | Casing material | Depth of screen below land surface (ft) | Date sampled | Specific conductance (µS/cm at 25°C) | pH (standard units) | Temperature (°C) | Chloride (Cl) | Dis-solved solids | Nitrate (NO ₃ , as N) | Iron, total (Fe) | Iron, dis-solved (Fe) | Man-ganese, total (Mn) | Man-ganese, dis-solved (Mn) | Constituent or characteristic | |
|-------------|-----------------|---|--------------|--------------------------------------|---------------------|------------------|---------------|-------------------|----------------------------------|------------------|-----------------------|------------------------|-----------------------------|-------------------------------|--|
| | | | | | | | | | | | | | | | |
| S51178 | steel | 25-35 | 9-29-83 | 139 | 6.1 | 12.5 | 11 | 111 | 0.58 | 2.3 | -- | 0.03 | -- | | |
| | | | 12-16-83 | 142 | 6.0 | 12.0 | 11 | 92 | .70 | .25 | .17 | a.01 | .02 | | |
| | | | 4- 3-84 | 146 | 5.9 | 11.8 | 13 | 111 | .80 | .40 | .14 | .01 | .01 | | |
| S51179 | steel | 55-65 | 9-29-83 | 145 | 6.3 | 14.5 | 11 | 104 | .20 | 1.1 | -- | .02 | -- | | |
| | | | 12-14-83 | 132 | 6.3 | 12.5 | 11 | 88 | .20 | .46 | .20 | .01 | .01 | | |
| | | | 4- 3-84 | 125 | 6.2 | 13.2 | 10 | 94 | .20 | 4.1 | .18 | .03 | .01 | | |
| S51180 | steel | 39-49 | 9-29-83 | 153 | 5.9 | 12.5 | 21 | 114 | .98 | 1.5 | -- | .13 | -- | | |
| | | | 12- 7-83 | 57 | 5.9 | 11.0 | 8.5 | 40 | <.10 | 1.7 | .93 | .07 | .07 | | |
| | | | 4- 4-84 | 145 | 5.5 | -- | 23 | 97 | 1.8 | 6.5 | 4.9 | .20 | .20 | | |
| S51181 | steel | 62-72 | 9-28-83 | 211 | 6.1 | 14.0 | 17 | 138 | 4.0 | .21 | -- | <.01 | -- | | |
| | | | 12-16-83 | 203 | 5.9 | 13.0 | 16 | 118 | 4.0 | .16 | .03 | .01 | .01 | | |
| | | | 4- 4-84 | 191 | 5.8 | 9.8 | 16 | 120 | 4.5 | 1.1 | .03 | .01 | .01 | | |
| S51182 | steel | 64-74 | 9-28-83 | 72 | 5.9 | 14.5 | 9.1 | 53 | <.10 | 11.0 | -- | .06 | -- | | |
| | | | 12- 8-83 | 59 | 5.8 | 11.0 | 7.8 | 42 | 5.9 | 1.7 | .15 | a.01 | .02 | | |
| | | | 4- 4-84 | 58 | 5.6 | 11.4 | 8.2 | 49 | <.10 | 4.6 | .11 | .02 | .01 | | |
| S51183 | steel | 39-49 | 9-29-83 | 108 | 5.9 | 12.0 | 12 | 74 | .10 | -- | -- | -- | -- | | |
| | | | 12- 8-83 | 105 | 6.1 | 10.0 | 12 | 72 | .09 | .46 | .20 | .01 | .01 | | |
| | | | 4- 3-84 | 92 | 5.9 | 11.2 | 14 | 69 | .10 | .30 | .20 | .01 | .01 | | |
| S52050 | steel | 52-62 | 9-27-83 | 229 | 5.9 | 14.5 | 15 | 164 | 8.7 | 12.0 | -- | .08 | -- | | |
| | | | 12- 7-83 | 208 | 5.8 | 13.0 | 13 | 155 | 9.1 | .36 | .10 | .02 | .02 | | |
| | | | 4- 3-84 | 187 | 5.4 | 13.2 | 13 | 118 | 4.7 | .56 | .33 | .03 | .03 | | |
| S52084 | steel | 62-72 | 9-28-83 | 133 | 7.2 | 13.5 | 15 | 102 | 1.2 | .77 | -- | .02 | -- | | |
| | | | 12- 8-83 | 121 | 6.1 | 12.0 | 13 | 88 | 1.4 | .32 | .04 | .01 | <.01 | | |
| | | | 4- 3-84 | 123 | 6.0 | 12.3 | 14 | 94 | 1.5 | .19 | .03 | <.01 | <.01 | | |

(continued)

Appendix B.--Analyses of selected chemical constituents of water from observation wells, 1983-84, and physical characteristics of wells
(Continued)

[Well locations are shown in fig. 2; concentrations in milligrams per liter; dashes indicate analysis not performed]

Constituent or characteristic

| Well number | Casing material | Depth of screen below land surface (ft) | Date sampled | Specific conductance (µS/cm at 25°C) | pH (standard units) | Temperature (°C) | Chloride (Cl) | Dis-solved solids | Nitrate (NO ₃ , as N) | Iron, total (Fe) | Iron, dis-solved (Fe) | Man-ganese, total (Mn) | Man-ganese, dis-solved (Mn) |
|-------------|-----------------|---|---------------------|--------------------------------------|---------------------|------------------|---------------|-------------------|----------------------------------|------------------|-----------------------|------------------------|-----------------------------|
| S75432 | PVCb | 24-29 | 12-15-83 3-26-84 | 131 128 | 5.5 5.7 | 13.0 11.5 | 25 22 | 75 77 | <0.10 <.10 | 0.33 .61 | <0.01 <.01 | 0.14 .04 | <0.01 .02 |
| S75433 | PVC | 30-35 | 12-15-83 3-26-84 | 132 420 | 5.6 5.4 | 12.0 10.5 | 23 110 | 71 229 | <.10 <.10 | 3.3 .21 | .14 .10 | .23 .19 | .19 .19 |
| S75434 | steel | 60-62 | 12-15-83 3-26-84 | 175 156 | 5.8 5.8 | 11.5 11.0 | 21 19 | 96 93 | 4.8 2.8 | 13.0 2.6 | .48 .12 | .28 .03 | .19 .03 |
| S75435 | PVC | 32-37 | 12-14-83 4-5-84 | 347 161 | 6.0 6.0 | 12.0 11.9 | 64 14 | 177 93 | 1.4 1.5 | .66 .39 | <.01 .03 | .15 .04 | .11 .03 |
| S75436 | steel | 60-62 | c1-4-84 | 318 | 6.6 | 11.0 | 28 | 186 | 14.0 | 15.0 | .08 | .34 | .18 |
| S75437 | PVC | 20-25 | 12-15-83 4-6-84 | 1,410 104 | 6.7 5.8 | 13.0 12.2 | 310 18 | 585 57 | .38 <.10 | 2.5 .39 | <.01 .01 | .36 .11 | .30 .11 |
| S75438 | PVC | 18-23 | 12-19-83 4-6-84 | 694 148 | 5.5 5.3 | 13.0 11.5 | 180 20 | 372 87 | .40 .20 | .10 .18 | .01 -- | 1.7 .35 | 1.5 -- |
| S75439 | PVC | 24-29 | 12-16-83 4-6-84 | 174 155 | 5.5 5.1 | 12.0 12.3 | 20 20 | 104 99 | 2.0 3.6 | .63 .21 | .01 .01 | 3.1 12.8 | 2.9 3.0 |
| S75440 | PVC | 51-53 | 12-19-83 4-5-84 | 83 80 | 5.3 5.4 | 10.0 11.2 | 7.8 11 | 52 53 | <.10 <.10 | 9.5 1.6 | .27 .39 | .64 a.08 | .22 .10 |
| S75441 | PVC | 31-33 | 12-19-83 4-5-84 | 106 79 | 5.9 5.7 | 12.0 10.9 | 18 11 | 64 54 | <.10 <.10 | .69 .56 | .39 .21 | .15 .05 | .15 .05 |

a value for total constituent reported by lab is less than that for dissolved constituent.

b polyvinyl chloride

c well tampered with; sample contaminated.

APPENDIX C. ANALYSES OF CHEMICAL CONSTITUENTS OF GROUND WATER.

SHELTER ISLAND, 1983-84.

ANALYSES BY U. S. GEOLOGICAL SURVEY WATER-QUALITY LABORATORY, DORAVILLE, GA.
WELL LOCATIONS SHOWN IN FIG. 2. DASHES INDICATE ANALYSIS NOT PERFORMED.]

| WELL NUMBER | GEO-LOGIC UNIT 1 | DATE OF SAMPLE | DEPTH OF WELL, TOTAL (FEET) | CALCIUM DIS-SOLVED (mg/L AS Ca) | CHLO-RIDE, DIS-SOLVED (mg/L AS Cl) | DEPTH BELOW LAND SURFACE (WATER LEVEL) (FEET) | FLUO-RIDE, DIS-SOLVED (mg/L AS F) | | IRON, DIS-SOLVED (ug/L AS Fe) | | IRON, SUS-PENDED RECOV-ERABLE (ug/L AS Fe) | | IRON, TOTAL RECOV-ERABLE (ug/L AS Fe) |
|-------------|------------------|----------------|-----------------------------|---------------------------------|------------------------------------|---|-----------------------------------|-------|-------------------------------|-------|--|-------|---------------------------------------|
| | | | | | | | AS Ca | AS Cl | AS Fe | AS Fe | AS Fe | AS Fe | |
| S 51169 | 1126LCLU | 83-09-28 | 56.00 | -- | 13 | 28.89 | -- | -- | -- | -- | -- | 2000 | |
| | 1126LCLU | 83-11-29 | 56.00 | 8.6 | 12 | 28.52 | <.10 | 140 | 140 | 290 | 290 | 430 | |
| | 1126LCLU | 84-04-02 | 56.00 | 8.1 | 14 | 27.70 | <.10 | <130 | <130 | 490 | 490 | 620 | |
| S 51170 | 1126LCLU | 83-09-28 | 33.00 | -- | 28 | 5.99 | -- | -- | -- | -- | -- | 110 | |
| | 1126LCLU | 83-11-29 | 33.00 | 5.1 | 28 | 4.46 | <.10 | 510 | 510 | 1400 | 1400 | 1900 | |
| | 1126LCLU | 84-04-02 | 33.00 | 4.1 | 27 | 4.40 | <.10 | 220 | 220 | 980 | 980 | 1200 | |
| S 51171 | 1126LCLU | 83-09-28 | 55.00 | -- | 19 | 22.58 | -- | -- | -- | -- | -- | 500 | |
| | 1126LCLU | 83-12-01 | 55.00 | 15 | 19 | 21.90 | <.10 | 220 | 220 | 120 | 120 | 340 | |
| | 1126LCLU | 84-04-02 | 55.00 | 11 | 17 | 20.70 | <.10 | 200 | 200 | 800 | 800 | 1000 | |
| S 51172 | 1126LCLU | 83-09-27 | 37.00 | -- | 40 | 12.70 | -- | -- | -- | -- | -- | 1200 | |
| | 1126LCLU | 83-12-01 | 37.00 | 26 | 37 | 12.36 | <.10 | 220 | 220 | 340 | 340 | 560 | |
| | 1126LCLU | 84-04-02 | 37.00 | 20 | 46 | 11.40 | <.10 | 290 | 290 | 5200 | 5200 | 5500 | |
| S 51173 | 1126LCLU | 83-09-27 | 51.00 | -- | 16 | 29.02 | -- | -- | -- | -- | -- | 800 | |
| | 1126LCLU | 83-12-05 | 51.00 | 7.0 | 15 | 28.30 | <.10 | 140 | 140 | 810 | 810 | 950 | |
| | 1126LCLU | 84-04-04 | 51.00 | 6.6 | 14 | 28.10 | <.10 | 180 | 180 | 12000 | 12000 | 12000 | |
| S 51174 | 1126LCLU | 83-09-27 | 63.00 | -- | 18 | -- | -- | -- | -- | -- | -- | 480 | |
| | 1126LCLU | 83-12-07 | 63.00 | 8.1 | 19 | 39.30 | <.10 | 100 | 100 | 150 | 150 | 250 | |
| | 1126LCLU | 84-04-02 | 63.00 | 8.8 | 21 | 37.70 | <.10 | 170 | 170 | 350 | 350 | 520 | |
| S 51175 | 1126LCLU | 83-09-27 | 60.00 | -- | 17 | 33.05 | -- | -- | -- | -- | -- | -- | |
| | 1126LCLU | 83-12-05 | 60.00 | 9.6 | 16 | 33.20 | <.10 | 250 | 250 | 50 | 50 | 300 | |
| | 1126LCLU | 84-04-02 | 60.00 | 8.8 | 18 | 31.50 | <.10 | 280 | 280 | 720 | 720 | 1000 | |
| S 51176 | 1126LCLU | 83-09-27 | 59.00 | -- | 18 | 33.46 | -- | -- | -- | -- | -- | 6700 | |
| | 1126LCLU | 83-12-07 | 59.00 | 6.1 | 15 | 33.50 | <.10 | 1100 | 1100 | 20000 | 20000 | 21000 | |
| | 1126LCLU | 84-04-04 | 59.00 | 6.0 | 17 | 31.60 | <.10 | 580 | 580 | 9400 | 9400 | 10000 | |
| S 51177 | 1126LCLU | 83-09-29 | 39.00 | -- | 15 | 13.58 | -- | -- | -- | -- | -- | 510 | |
| | 1126LCLU | 83-12-14 | 39.00 | 7.8 | 23 | 11.90 | <.10 | 810 | 810 | 490 | 490 | 1300 | |
| | 1126LCLU | 84-04-03 | 39.00 | 6.1 | 17 | 11.20 | <.10 | 5000 | 5000 | 100 | 100 | 5100 | |
| S 51178 | 1126LCLU | 83-09-29 | 47.00 | -- | 11 | 23.67 | -- | -- | -- | -- | -- | 2300 | |
| | 1126LCLU | 83-12-16 | 47.00 | 10 | 11 | 21.70 | <.10 | 170 | 170 | 80 | 80 | 250 | |
| | 1126LCLU | 84-04-03 | 47.00 | 10 | 13 | 20.50 | <.10 | 140 | 140 | 260 | 260 | 400 | |
| S 51179 | 1126LCLU | 83-09-29 | 67.00 | -- | 11 | 11.79 | -- | -- | -- | -- | -- | 1100 | |
| | 1126LCLU | 83-12-14 | 67.00 | 9.0 | 11 | 9.00 | <.10 | 200 | 200 | 260 | 260 | 460 | |
| | 1126LCLU | 84-04-03 | 67.00 | 8.2 | 10 | 8.30 | <.10 | 180 | 180 | 3900 | 3900 | 4100 | |
| S 51180 | 1126LCLU | 83-09-29 | 51.00 | -- | 21 | 27.38 | -- | -- | -- | -- | -- | 1500 | |
| | 1126LCLU | 83-12-07 | 51.00 | 3.3 | 8.5 | 27.40 | <.10 | 930 | 930 | 770 | 770 | 1700 | |
| | 1126LCLU | 84-04-04 | 51.00 | 6.4 | 23 | 25.80 | <.10 | 4900 | 4900 | 1600 | 1600 | 6500 | |

APPENDIX C. ANALYSES OF CHEMICAL CONSTITUENTS OF GROUND WATER,
SHELTER ISLAND, 1983-84. --CONTINUED.

| WELL NUMBER | DATE OF SAMPLE | MAGNESIUM, DIS-SOLVED (mg/L AS Mg) | | MANGANESE, DIS-SOLVED (ug/L AS Mn) | | MANGANESE, SUSPENDED (ug/L AS Mn) | | MANGANESE, RECOVERABLE (ug/L AS Mn) | | NITROGEN, NITRITE (mg/L AS N) | | NITROGEN, NO2+NO3 (mg/L AS N) | | NITROGEN, AMMONIA (mg/L AS N) | | NITROGEN, ORGANIC TOTAL (mg/L AS N) | | PH LAB (STANDARD UNITS) |
|-------------|----------------|------------------------------------|-----|------------------------------------|-----|-----------------------------------|-----|-------------------------------------|-----|-------------------------------|-------|-------------------------------|-------|-------------------------------|------|-------------------------------------|-----|-------------------------|
| | | | | | | | | | | | | | | | | | | |
| S 51169 | 83-09-28 | -- | -- | -- | -- | -- | 30 | 0 | 30 | .040 | .900 | .400 | <.010 | <.010 | .30 | | | 5.9 |
| | 83-11-29 | 5.0 | 20 | 0 | 0 | 20 | 20 | 0 | 20 | <.010 | .900 | .100 | <.010 | <.010 | .20 | | | 5.9 |
| | 84-04-02 | <4.8 | <13 | 7 | 7 | 20 | 20 | 20 | 20 | <.010 | 1.10 | <.100 | <.010 | <.010 | .30 | | | 5.6 |
| S 51170 | 83-09-28 | -- | -- | -- | -- | -- | 20 | 8 | 20 | <.010 | .400 | .400 | <.010 | .020 | .30 | | | 5.8 |
| | 83-11-29 | 2.7 | 92 | 8 | 100 | 100 | 40 | 40 | 40 | <.010 | .100 | .100 | <.010 | .170 | .40 | | | 5.8 |
| | 84-04-02 | 2.4 | 38 | 2 | 40 | 40 | 40 | 40 | 40 | <.010 | <.100 | <.100 | <.010 | .50 | | | 5.7 | |
| S 51171 | 83-09-28 | -- | -- | -- | -- | -- | 30 | 20 | 30 | <.010 | 4.90 | 4.90 | <.010 | .040 | .20 | | | 5.8 |
| | 83-12-01 | 5.5 | 24 | 20 | 40 | 40 | 40 | 40 | 40 | <.010 | 4.40 | 4.40 | <.010 | .070 | .40 | | | 5.7 |
| | 84-04-02 | 4.3 | 12 | 8 | 20 | 20 | 20 | 20 | 20 | <.010 | 4.60 | 4.60 | <.010 | .30 | | | 5.6 | |
| S 51172 | 83-09-27 | -- | -- | -- | -- | -- | 10 | 3 | 10 | .020 | 5.50 | 5.50 | <.010 | .040 | .50 | | | 5.7 |
| | 83-12-01 | 5.5 | 7 | 3 | 10 | 10 | 10 | 10 | 10 | <.010 | 5.60 | 5.60 | <.010 | .40 | .40 | | | 5.4 |
| | 84-04-02 | 4.7 | 16 | 4 | 20 | 20 | 20 | 20 | 20 | <.010 | 4.30 | 4.30 | <.010 | .40 | .40 | | | 5.5 |
| S 51173 | 83-09-27 | -- | -- | -- | -- | -- | 20 | 3 | 20 | .040 | 1.10 | 1.10 | <.010 | .090 | .40 | | | 6.0 |
| | 83-12-05 | 2.6 | 7 | 3 | 10 | 10 | 10 | 10 | 10 | <.010 | 1.00 | 1.00 | <.010 | .090 | <.10 | | | 6.0 |
| | 84-04-04 | 2.5 | 9 | 20 | 30 | 30 | 30 | 30 | 30 | <.010 | 1.00 | 1.00 | <.010 | .60 | .60 | | | 5.5 |
| S 51174 | 83-09-27 | -- | -- | -- | -- | -- | 30 | 0 | 30 | <.010 | 2.20 | 2.20 | <.010 | .040 | .40 | | | 5.7 |
| | 83-12-07 | 3.3 | 20 | 0 | 20 | 20 | 20 | 20 | 20 | <.010 | 2.20 | 2.20 | <.010 | .040 | <.10 | | | 6.0 |
| | 84-04-02 | 3.7 | 16 | 4 | 20 | 20 | 20 | 20 | 20 | <.010 | 2.80 | 2.80 | <.010 | .20 | .20 | | | 5.7 |
| S 51175 | 83-09-27 | -- | -- | -- | -- | -- | -- | 0 | -- | .030 | 1.50 | 1.50 | <.010 | .30 | .30 | | | 5.9 |
| | 83-12-05 | 4.5 | 71 | 0 | 60 | 60 | 40 | 40 | 40 | <.010 | 1.40 | 1.40 | <.010 | .100 | <.10 | | | 6.0 |
| | 84-04-02 | 4.4 | 35 | 5 | 40 | 40 | 40 | 40 | 40 | <.010 | 1.80 | 1.80 | <.010 | .50 | .50 | | | 5.7 |
| S 51176 | 83-09-27 | -- | -- | -- | -- | -- | 40 | 0 | 40 | .030 | 1.20 | 1.20 | <.010 | .20 | .20 | | | 5.7 |
| | 83-12-07 | 3.4 | 42 | 0 | 40 | 40 | 40 | 40 | 40 | <.010 | 1.10 | 1.10 | <.010 | .100 | <.10 | | | 5.8 |
| | 84-04-04 | 3.4 | 42 | 0 | 40 | 40 | 40 | 40 | 40 | <.010 | 1.50 | 1.50 | <.010 | .60 | .60 | | | 5.4 |
| S 51177 | 83-09-29 | -- | -- | -- | -- | -- | <10 | 2 | <10 | .030 | <.100 | <.100 | <.010 | .30 | .30 | | | 5.4 |
| | 83-12-14 | 2.5 | 28 | 4 | 30 | 30 | 10 | 10 | 10 | <.010 | .900 | .900 | <.010 | .090 | .20 | | | 5.5 |
| | 84-04-03 | 2.0 | 46 | 4 | 50 | 50 | 10 | 10 | 10 | <.010 | <.100 | <.100 | <.010 | .70 | .70 | | | 5.3 |
| S 51178 | 83-09-29 | -- | -- | -- | -- | -- | 30 | 0 | 30 | .020 | .600 | .600 | <.010 | .20 | .20 | | | 6.1 |
| | 83-12-16 | 4.4 | 16 | 5 | 10 | 10 | 10 | 10 | 10 | <.010 | .700 | .700 | <.010 | 1.7 | 1.7 | | | 6.0 |
| | 84-04-03 | 4.4 | 5 | 5 | 10 | 10 | 10 | 10 | 10 | <.010 | .800 | .800 | <.010 | .20 | .20 | | | 5.9 |
| S 51179 | 83-09-29 | -- | -- | -- | -- | -- | 20 | 0 | 20 | <.010 | .200 | .200 | <.010 | .030 | .50 | | | 6.3 |
| | 83-12-14 | 5.6 | 10 | 0 | 10 | 10 | 10 | 10 | 10 | <.010 | .200 | .200 | <.010 | .020 | .40 | | | 6.3 |
| | 84-04-03 | 5.1 | 6 | 20 | 30 | 30 | 30 | 30 | 30 | <.010 | .200 | .200 | <.010 | .30 | .30 | | | 6.2 |
| S 51180 | 83-09-29 | -- | -- | -- | -- | -- | 130 | 0 | 130 | .020 | 1.00 | 1.00 | <.010 | .40 | .40 | | | 5.9 |
| | 83-12-07 | 1.4 | 74 | 0 | 70 | 70 | 200 | 200 | 200 | <.010 | <.100 | <.100 | <.010 | <.10 | <.10 | | | 5.9 |
| | 84-04-04 | 2.8 | 200 | 0 | 200 | 200 | 200 | 200 | 200 | .020 | 1.60 | 1.60 | <.010 | .70 | .70 | | | 5.5 |

APPENDIX C. ANALYSES OF CHEMICAL CONSTITUENTS OF GROUND WATER,
SHELTER ISLAND, 1983-84. --CONTINUED.

| WELL NUMBER | DATE OF SAMPLE | PHOSPHORUS, TOTAL (mg/L AS P) | POTASSIUM, DIS-SOLVED (mg/L AS K) | SOLIDS, RESIDUE AT 180 DEG. C | | SODIUM, DIS-SOLVED (mg/L AS Na) | SPE- CIFIC CONDUCTANCE LAB (µS/cm) | SULFATE DIS-SOLVED (mg/L AS SO4) | TEMPERATURE (DEG C) |
|-------------|----------------|-------------------------------|-----------------------------------|-------------------------------|---------------|---------------------------------|------------------------------------|----------------------------------|---------------------|
| | | | | DIS-SOLVED (mg/L) | SOLVED (mg/L) | | | | |
| S 51169 | 83-09-28 | --- | --- | 97 | --- | --- | 131 | 18 | 14.0 |
| | 83-11-29 | <.010 | .70 | 93 | 7.7 | 7.7 | 127 | 16 | 11.5 |
| | 84-04-02 | <.010 | .70 | 88 | 7.3 | 7.3 | 125 | <5.0 | 11.5 |
| S 51170 | 83-09-28 | --- | --- | 99 | --- | --- | 129 | 6.2 | 14.0 |
| | 83-11-29 | <.010 | 1.0 | 99 | 15 | 15 | 140 | <5.0 | 14.0 |
| | 84-04-02 | <.010 | .80 | 86 | 15 | 15 | 122 | 7.5 | 12.0 |
| S 51171 | 83-09-28 | --- | --- | 143 | --- | --- | 208 | 26 | 12.0 |
| | 83-12-01 | .010 | 4.4 | 138 | 14 | 14 | 215 | 25 | 11.0 |
| | 84-04-02 | .010 | 4.0 | 79 | 12 | 12 | 122 | 19 | 12.0 |
| S 51172 | 83-09-27 | --- | --- | 205 | --- | --- | 326 | 33 | 12.0 |
| | 83-12-01 | <.010 | 8.7 | 216 | 17 | 17 | 194 | 31 | 12.0 |
| | 84-04-02 | <.010 | 8.2 | 195 | 25 | 25 | 305 | 40 | 12.0 |
| S 51173 | 83-09-27 | --- | --- | 98 | --- | --- | 137 | 14 | 14.5 |
| | 83-12-05 | .030 | 1.2 | 83 | 11 | 11 | 122 | 15 | 13.0 |
| | 84-04-04 | <.010 | 1.2 | 81 | 12 | 12 | 116 | 15 | 13.5 |
| S 51174 | 83-09-27 | --- | --- | 115 | --- | --- | 168 | 20 | 13.0 |
| | 83-12-07 | .070 | 1.1 | 106 | 16 | 16 | 161 | 18 | 12.0 |
| | 84-04-02 | <.010 | 1.2 | 120 | 18 | 18 | 174 | 22 | 13.0 |
| S 51175 | 83-09-27 | --- | --- | 119 | --- | --- | 161 | 24 | 13.0 |
| | 83-12-05 | .020 | 1.5 | 108 | 12 | 12 | 160 | 23 | 11.0 |
| | 84-04-02 | <.010 | 1.5 | 108 | 11 | 11 | 164 | 24 | 11.5 |
| S 51176 | 83-09-27 | --- | --- | 102 | --- | --- | 156 | 15 | 13.0 |
| | 83-12-07 | .030 | 1.8 | 89 | 13 | 13 | 134 | 13 | 10.0 |
| | 84-04-04 | <.010 | 1.9 | 90 | 13 | 13 | 135 | 10 | 12.0 |
| S 51177 | 83-09-29 | --- | --- | 70 | --- | --- | 100 | 10 | 11.5 |
| | 83-12-14 | .020 | .80 | 71 | 12 | 12 | 126 | 6.2 | 12.0 |
| | 84-04-03 | <.010 | .80 | 80 | 11 | 11 | 109 | 10 | 12.5 |
| S 51178 | 83-09-29 | --- | --- | 111 | --- | --- | 139 | 23 | 12.5 |
| | 83-12-16 | .010 | .90 | 92 | 9.1 | 9.1 | 142 | 26 | 12.0 |
| | 84-04-03 | 1.80 | 1.0 | 111 | 9.6 | 9.6 | 146 | 26 | 12.0 |
| S 51179 | 83-09-29 | --- | --- | 83 | --- | --- | 145 | 32 | 14.5 |
| | 83-12-14 | .020 | .80 | 88 | 6.8 | 6.8 | 132 | 25 | 12.5 |
| | 84-04-03 | .020 | .80 | 94 | 6.3 | 6.3 | 125 | 25 | 13.0 |
| S 51180 | 83-09-29 | --- | --- | 114 | --- | --- | 153 | 12 | 12.5 |
| | 83-12-07 | .040 | 1.0 | 40 | 4.3 | 4.3 | 57 | 6.7 | 11.0 |
| | 84-04-04 | <.010 | 1.2 | 97 | 15 | 15 | 145 | 11 | --- |

APPENDIX C. ANALYSES OF CHEMICAL CONSTITUENTS OF GROUND WATER,
SHELTER ISLAND, 1983-84. --CONTINUED.

| WELL NUMBER | GEO-LOGIC UNIT | DATE OF SAMPLE | DEPTH OF WELL, TOTAL (FEET) | CALCIUM DIS-SOLVED (mg/L AS Ca) | | CHLO-RIDE, DIS-SOLVED (mg/L AS Cl) | | DEPTH BELOW LAND SURFACE (WATER LEVEL) (FEET) | FLUO-RIDE, DIS-SOLVED (mg/L AS F) | IRON, DIS-SOLVED (ug/L AS Fe) | | IRON, SUS-PENDED (ug/L AS Fe) | | IRON, TOTAL RECOV-ERABLE (ug/L AS Fe) |
|-------------|----------------|----------------|-----------------------------|---------------------------------|-------|------------------------------------|-------|---|-----------------------------------|-------------------------------|-------|-------------------------------|-------|---------------------------------------|
| | | | | AS Ca | AS Ca | AS Cl | AS Cl | | | AS Fe | AS Fe | AS Fe | AS Fe | |
| S 51181 | 112GLCLU | 83-09-28 | 74.00 | -- | -- | 17 | -- | -- | -- | -- | -- | -- | -- | 210 |
| | 112GLCLU | 83-12-16 | 74.00 | 14 | -- | 16 | -- | -- | <10 | 28 | 130 | 160 | -- | 160 |
| | 112GLCLU | 83-12-21 | 74.00 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | 112GLCLU | 84-04-04 | 74.00 | 13 | -- | 16 | -- | -- | <10 | 30 | 80 | 110 | -- | 110 |
| S 51182 | 112GLCLU | 83-09-28 | 76.00 | -- | -- | 9.1 | 51.14 | -- | -- | -- | -- | -- | -- | 11000 |
| | 112GLCLU | 83-12-08 | 76.00 | 2.3 | -- | 7.8 | 33.20 | <10 | <10 | 150 | 1600 | 1700 | -- | 1700 |
| | 112GLCLU | 84-04-04 | 76.00 | 2.0 | -- | 8.2 | 49.90 | <10 | <10 | 110 | 4500 | 4600 | -- | 4600 |
| S 51183 | 112GLCLU | 83-09-29 | 51.00 | -- | -- | 12 | 31.08 | -- | -- | -- | -- | -- | -- | -- |
| | 112GLCLU | 83-12-08 | 51.00 | 5.9 | -- | 12 | 30.50 | <10 | <10 | 200 | 260 | 460 | -- | 460 |
| | 112GLCLU | 84-04-03 | 51.00 | 5.1 | -- | 14 | 29.10 | <10 | <10 | 200 | 100 | 300 | -- | 300 |
| S 52050 | 112GLCLU | 83-09-27 | 64.00 | -- | -- | 15 | 37.85 | -- | -- | -- | -- | -- | -- | 12000 |
| | 112GLCLU | 83-12-07 | 64.00 | 12 | -- | 13 | 37.80 | <10 | <10 | 98 | 260 | 360 | -- | 360 |
| | 112GLCLU | 84-04-03 | 64.00 | 13 | -- | 13 | 35.70 | <10 | <10 | 330 | 230 | 560 | -- | 560 |
| S 52084 | 112GLCLU | 83-09-28 | 74.00 | -- | -- | 15 | 24.03 | -- | -- | -- | -- | -- | -- | 770 |
| | 112GLCLU | 83-12-08 | 74.00 | 8.5 | -- | 13 | 23.90 | <10 | <10 | 44 | 280 | 320 | -- | 320 |
| | 112GLCLU | 84-04-03 | 74.00 | 9.1 | -- | 14 | 22.40 | <10 | <10 | 25 | 160 | 190 | -- | 190 |
| S 75432 | 112GLCLU | 83-12-15 | 29.00 | 3.02 | -- | 23 | 19.80 | <10 | <10 | 43 | 600 | 330 | -- | 330 |
| | 112GLCLU | 84-03-26 | 29.00 | 3.5 | -- | 22 | 19.20 | <10 | <10 | 6 | 600 | 610 | -- | 610 |
| S 75433 | 112GLCLU | 83-12-15 | 35.00 | 2.0 | -- | 23 | 19.00 | <10 | <10 | 140 | 3200 | 3300 | -- | 3300 |
| | 112GLCLU | 84-03-26 | 35.00 | 9.3 | -- | 110 | 19.80 | <10 | <10 | 98 | 110 | 210 | -- | 210 |
| S 75434 | 112GLCLU | 83-12-15 | 62.00 | 9.5 | -- | 21 | 51.90 | <10 | <10 | 480 | 13000 | 13000 | -- | 13000 |
| | 112GLCLU | 84-03-26 | 62.00 | 7.0 | -- | 19 | 52.00 | <10 | <10 | 120 | 2500 | 2600 | -- | 2600 |
| S 75435 | 112GLCLU | 83-12-14 | 37.00 | 6.6 | -- | 64 | 19.40 | <10 | <10 | 63 | -- | 660 | -- | 660 |
| | 112GLCLU | 84-04-05 | 37.00 | 12 | -- | 14 | 19.00 | <10 | <10 | 30 | 360 | 390 | -- | 390 |
| S 75436 | 112GLCLU | 84-01-04 | 62.00 | 19 | -- | 28 | 44.70 | <10 | <10 | 78 | 15000 | 15000 | -- | 15000 |
| S 75437 | 112GLCLU | 83-12-15 | 25.00 | 9.2 | -- | 310 | 10.70 | <10 | <10 | 7 | 2500 | 2500 | -- | 2500 |
| | 112GLCLU | 84-04-06 | 25.00 | 2.1 | -- | 18 | 10.40 | <10 | <10 | 7 | 380 | 390 | -- | 390 |
| S 75438 | 112GLCLU | 83-12-19 | 23.00 | 18 | -- | 180 | 9.00 | <10 | <10 | 12 | 90 | 100 | -- | 100 |
| | 112GLCLU | 84-04-06 | 23.00 | -- | -- | 20 | 8.40 | <10 | <10 | -- | -- | 180 | -- | 180 |
| S 75439 | 112GLCLU | 83-12-16 | 29.00 | 10 | -- | 20 | 10.60 | <10 | <10 | 12 | 620 | 630 | -- | 630 |
| | 112GLCLU | 84-04-06 | 29.00 | 9.3 | -- | 20 | 9.90 | <10 | <10 | 6 | 200 | 210 | -- | 210 |
| S 75440 | 112GLCLU | 83-12-19 | 53.00 | 3.1 | -- | 7.8 | 42.90 | <10 | <10 | 270 | 9200 | 9500 | -- | 9500 |
| | 112GLCLU | 83-12-21 | 53.00 | -- | -- | -- | 43.00 | <10 | <10 | -- | -- | -- | -- | -- |
| | 112GLCLU | 84-04-05 | 53.00 | -- | -- | 11 | 42.20 | <10 | <10 | 390 | 1200 | 1600 | -- | 1600 |

APPENDIX C. ANALYSES OF CHEMICAL CONSTITUENTS OF GROUND WATER,
SHELTER ISLAND, 1983-84. --CONTINUED.

| WELL NUMBER | DATE OF SAMPLE | MAGNE- SIUM, DIS- SOLVED (mg/L AS Mg) | | MANGA- NESE, DIS- SOLVED (ug/L AS Mn) | | MANGA- NESE, SUS- PENDED RECOV. (ug/L AS Mn) | | MANGA- NESE, TOTAL RECOV- ERABLE (ug/L AS Mn) | | NITRO- GEN, NITRITE TOTAL (mg/L AS N) | | NITRO- GEN, NO2+NO3 TOTAL (mg/L AS N) | | NITRO- GEN, AMMONIA TOTAL (mg/L AS N) | | NITRO- GEN, AM- MONIA + ORGANIC TOTAL (mg/L AS N) | | PH LAB (STAND- ARD UNITS) |
|-------------|----------------|--|------|--|-----|--|------|---|-------|--|-------|--|-------|--|-------|---|-----|---------------------------------------|
| | | | | | | | | | | | | | | | | | | |
| S 51181 | 83-09-28 | -- | -- | -- | -- | -- | -- | <10 | .050 | 4.00 | <0.10 | 4.00 | <0.10 | 4.00 | <0.10 | 4.00 | 6.1 | |
| | 83-12-16 | 6.3 | 12 | 0 | 0 | 0 | 10 | <0.10 | <0.10 | 4.00 | 1.40 | 4.00 | 2.5 | 5.9 | -- | -- | 5.9 | |
| | 83-12-21 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | |
| | 84-04-04 | 5.9 | 9 | 1 | 1 | 1 | 10 | <0.10 | <0.10 | 4.50 | <0.10 | 4.50 | .30 | 5.8 | -- | -- | 5.8 | |
| S 51182 | 83-09-28 | -- | -- | -- | -- | -- | -- | 60 | .030 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | 5.9 | |
| | 83-12-08 | 2.3 | 19 | 0 | 0 | 0 | 10 | <0.10 | <0.10 | <0.10 | 3.00 | <0.10 | <1.0 | 5.8 | -- | -- | 5.8 | |
| | 84-04-04 | 2.0 | 13 | 7 | 7 | 7 | 20 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | .40 | 5.6 | -- | -- | 5.6 | |
| | 83-09-29 | -- | -- | -- | -- | -- | -- | -- | <0.10 | 1.00 | <0.10 | 1.00 | <0.10 | .80 | 5.9 | -- | -- | 5.9 |
| S 52050 | 83-12-08 | 2.9 | 7 | 3 | 3 | 3 | 10 | <0.10 | <0.10 | 1.00 | 1.00 | 1.00 | <0.10 | 6.1 | -- | -- | 6.1 | |
| | 84-04-03 | 2.5 | 6 | 4 | 4 | 4 | 10 | <0.10 | <0.10 | 1.00 | 1.00 | 1.00 | .50 | 5.9 | -- | -- | 5.9 | |
| | 83-09-27 | -- | -- | -- | -- | -- | -- | 80 | <0.10 | 8.70 | <0.10 | 8.70 | .050 | 5.9 | -- | -- | 5.9 | |
| | 83-12-07 | 3.6 | 22 | 0 | 0 | 0 | 20 | <0.10 | <0.10 | 7.10 | <0.10 | 7.10 | .060 | 5.8 | -- | -- | 5.8 | |
| S 52084 | 84-04-03 | 4.1 | 30 | 0 | 0 | 0 | 30 | <0.10 | <0.10 | 4.70 | <0.10 | 4.70 | .50 | 5.4 | -- | -- | 5.4 | |
| | 83-09-28 | -- | -- | -- | -- | -- | -- | 20 | .040 | 1.20 | <0.10 | 1.20 | .020 | 7.2 | -- | -- | 7.2 | |
| | 83-12-08 | 3.9 | 4 | 6 | 6 | 6 | 10 | <0.10 | <0.10 | 1.40 | <0.10 | 1.40 | .050 | 6.1 | -- | -- | 6.1 | |
| | 84-04-03 | 4.1 | 3 | -- | -- | -- | -- | <0.10 | <0.10 | 1.50 | <0.10 | 1.50 | <0.10 | 6.0 | -- | -- | 6.0 | |
| S 75432 | 83-12-15 | .07 | <1 | -- | -- | -- | -- | 140 | <0.10 | <0.10 | <0.10 | <0.10 | .080 | 5.5 | -- | -- | 5.5 | |
| | 84-03-26 | 2.9 | 19 | 20 | 20 | 20 | 40 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | 5.7 | -- | -- | 5.7 | |
| | 83-12-15 | 2.8 | 190 | 40 | 40 | 40 | 230 | <0.10 | <0.10 | <0.10 | <0.10 | .060 | 5.6 | -- | -- | 5.6 | | |
| | 84-03-26 | 13 | 190 | 0 | 0 | 0 | 190 | <0.10 | <0.10 | <0.10 | <0.10 | .060 | 5.4 | -- | -- | 5.4 | | |
| S 75434 | 83-12-15 | 5.4 | 190 | 90 | 90 | 90 | 280 | <0.10 | <0.10 | 4.80 | 3.00 | 4.80 | .50 | 5.8 | -- | -- | 5.8 | |
| | 84-03-26 | 5.0 | 26 | 4 | 4 | 4 | 30 | <0.10 | <0.10 | 2.80 | <0.10 | 2.80 | <0.10 | 5.8 | -- | -- | 5.8 | |
| | 83-12-14 | 5.9 | 110 | 40 | 40 | 40 | 150 | <0.10 | <0.10 | 1.40 | .080 | 1.40 | <0.10 | 6.0 | -- | -- | 6.0 | |
| | 84-04-05 | 4.7 | 33 | 7 | 7 | 7 | 40 | <0.10 | <0.10 | 1.50 | <0.10 | 1.50 | .60 | 6.0 | -- | -- | 6.0 | |
| S 75436 | 84-01-04 | 7.0 | 180 | 160 | 160 | 160 | 340 | <0.10 | <0.10 | 14.0 | .220 | 14.0 | .30 | 6.6 | -- | -- | 6.6 | |
| | 83-12-15 | 15 | 300 | 60 | 60 | 60 | 360 | <0.10 | <0.10 | .400 | .070 | .400 | .10 | 6.7 | -- | -- | 6.7 | |
| | 84-04-06 | 3.3 | 110 | 0 | 0 | 0 | 110 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | .50 | 5.8 | -- | -- | 5.8 | |
| | 83-12-19 | 11 | 1500 | 200 | 200 | 200 | 1700 | <0.10 | <0.10 | .400 | .020 | .400 | .80 | 5.5 | -- | -- | 5.5 | |
| S 75439 | 84-04-06 | -- | -- | -- | -- | -- | 350 | <0.10 | <0.10 | .200 | <0.10 | .200 | .50 | 5.3 | -- | -- | 5.3 | |
| | 83-12-16 | 5.8 | 2900 | 200 | 200 | 200 | 3100 | <0.10 | <0.10 | 2.00 | .080 | 2.00 | 1.4 | 5.5 | -- | -- | 5.5 | |
| | 84-04-06 | 5.5 | 3000 | 0 | 0 | 0 | 2800 | <0.10 | <0.10 | 3.60 | <0.10 | 3.60 | .80 | 5.1 | -- | -- | 5.1 | |
| | 83-12-19 | 1.9 | 220 | 420 | 420 | 420 | 640 | <0.10 | <0.10 | <0.10 | .080 | <0.10 | .80 | 5.3 | -- | -- | 5.3 | |
| S 75440 | 83-12-21 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | |
| | 84-04-05 | 2.2 | 97 | 0 | 0 | 0 | 80 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | .50 | 5.4 | -- | -- | 5.4 | |

APPENDIX C. ANALYSES OF CHEMICAL CONSTITUENTS OF GROUND WATER,
SHELTER ISLAND, 1983-84. --CONTINUED.

| WELL NUMBER | DATE OF SAMPLE | PHOS-PHORUS, TOTAL (mg/L AS P) | POTASSIUM, DIS-SOLVED (mg/L AS K) | SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (mg/L) | SODIUM, DIS-SOLVED (mg/L AS Na) | SPECIFIC CONDUCTANCE LAB (uS/cm) | SULFATE DIS-SOLVED (mg/L AS SO4) | TEMPERATURE (DEG C) |
|-------------|----------------|--------------------------------|-----------------------------------|---|---------------------------------|----------------------------------|----------------------------------|---------------------|
| | | | | | | | | |
| S 51181 | 83-09-28 | -- | -- | 138 | -- | 211 | 32 | 14.0 |
| | 83-12-16 | <.010 | 1.2 | 118 | 12 | 203 | 36 | 13.0 |
| | 83-12-21 | -- | -- | -- | -- | -- | 36 | -- |
| S 51182 | 84-04-04 | <.010 | 1.2 | 120 | 11 | 191 | 34 | 10.0 |
| | 83-09-28 | -- | -- | 53 | -- | 72 | 7.3 | 14.5 |
| | 83-12-08 | .270 | .70 | 42 | 4.7 | 59 | 14 | 11.0 |
| S 51183 | 84-04-04 | <.010 | .70 | 49 | 5.6 | 58 | 8.6 | 11.5 |
| | 83-09-29 | -- | -- | 74 | -- | 108 | 14 | 12.0 |
| | 83-12-08 | .030 | .70 | 72 | 8.8 | 105 | 15 | 10.0 |
| S 52050 | 84-04-03 | <.010 | .60 | 69 | 8.6 | 92 | 13 | 11.0 |
| | 83-09-27 | -- | -- | 164 | -- | 229 | 25 | 14.5 |
| | 83-12-07 | .020 | 6.0 | 155 | 16 | 208 | 28 | 13.0 |
| S 52084 | 84-04-03 | <.010 | 6.2 | 118 | 15 | 187 | 27 | 13.0 |
| | 83-09-28 | -- | -- | 102 | -- | 133 | 15 | 13.5 |
| | 83-12-08 | .020 | 1.1 | 88 | 6.8 | 121 | 14 | 12.0 |
| S 75432 | 84-04-03 | <.010 | 1.2 | 94 | 7.0 | 123 | 15 | 12.5 |
| | 83-12-15 | .020 | -- | 75 | <.20 | 131 | -- | 13.0 |
| | 84-03-26 | <.010 | .80 | 77 | 15 | 128 | 18 | 11.5 |
| S 75433 | 83-12-15 | .030 | 1.1 | 71 | 17 | 132 | 16 | 12.0 |
| | 84-03-26 | <.010 | 1.7 | 229 | 40 | 420 | 9.5 | 10.5 |
| | 83-12-15 | .020 | 1.4 | 96 | 13 | 175 | 18 | 11.5 |
| S 75434 | 84-03-26 | <.010 | .90 | 93 | 13 | 156 | 17 | 11.0 |
| | 83-12-14 | .020 | 1.9 | 185 | 46 | 347 | 28 | 12.0 |
| | 84-04-05 | <.010 | 1.5 | 93 | 11 | 161 | 15 | 12.0 |
| S 75436 | 84-01-04 | .320 | 3.7 | 186 | 29 | 318 | 16 | 11.0 |
| | 83-12-15 | .050 | 7.0 | 585 | 210 | 1410 | 60 | 13.0 |
| | 84-04-06 | <.010 | 2.9 | 57 | 10 | 104 | 5.8 | 12.0 |
| S 75438 | 83-12-19 | .010 | 4.0 | 372 | 91 | 694 | 25 | 13.0 |
| | 84-04-06 | <.010 | -- | 87 | -- | 148 | 19 | 11.5 |
| | 83-12-16 | .030 | 1.2 | 104 | 11 | 174 | 6.0 | 12.0 |
| S 75439 | 84-04-06 | <.010 | 1.2 | 99 | 9.1 | 155 | 4.9 | 12.5 |
| | 83-12-19 | .220 | .80 | 52 | 8.1 | 83 | 15 | 10.0 |
| | 83-12-21 | -- | -- | -- | -- | -- | 14 | -- |
| S 75440 | 84-04-05 | <.010 | .90 | 53 | 7.7 | 80 | 15 | 11.0 |

APPENDIX C. ANALYSES OF CHEMICAL CONSTITUENTS OF GROUND WATER, SHELTER ISLAND, 1983-84. --CONTINUED.

| WELL NUMBER | GEO-LOGIC UNIT | DATE OF SAMPLE | DEPTH OF WELL, TOTAL (FEET) | CALCIUM | | CHLD-RIDE, DIS-SOLVED (mg/L AS Ca) | DEPTH BELOW LAND SURFACE (WATER LEVEL) (FEET) | | FLUORIDE, DIS-SOLVED (mg/L AS F) | | IRON, SUS-PENDED RECOVERABLE (ug/L AS Fe) | | IRON, TOTAL RECOVERABLE (ug/L AS Fe) | |
|-------------|----------------|----------------|-----------------------------|-------------------------|---------------------|------------------------------------|---|--------------------|----------------------------------|---------------------|---|---------------------|--------------------------------------|--|
| | | | | DIS-SOLVED (mg/L AS Ca) | SOLVED (mg/L AS Ca) | | DIS-SOLVED (mg/L AS F) | SOLVED (mg/L AS F) | DIS-SOLVED (ug/L AS Fe) | SOLVED (ug/L AS Fe) | DIS-SOLVED (ug/L AS Fe) | SOLVED (ug/L AS Fe) | | |
| S 75441 | 112GLCLU | 83-12-19 | 33.00 | 4.3 | 18 | 18.80 | <.10 | 390 | 690 | | | | | |
| | 112GLCLU | 84-04-05 | 33.00 | 3.0 | 11 | 16.40 | <.10 | 210 | 350 | | | | | |

| WELL NUMBER | DATE OF SAMPLE | MANGANESE, DIS-SOLVED (ug/L AS Mn) | | MANGANESE, SUS-PENDED RECOVERABLE (ug/L AS Mn) | | NITROGEN, NITRITE TOTAL (mg/L AS N) | | NITROGEN, NITRATE NO2+NO3 TOTAL (mg/L AS N) | | NITROGEN, AMMONIA TOTAL (mg/L AS N) | | PH LAB (STANDARD ARD UNITS) |
|-------------|----------------|------------------------------------|-------|--|-------|-------------------------------------|-------|---|-------|-------------------------------------|------|-----------------------------|
| | | MANGANESE, DIS-SOLVED (ug/L AS Mn) | AS Mg | MANGANESE, SUS-PENDED RECOVERABLE (ug/L AS Mn) | AS Mn | NITROGEN, NITRITE TOTAL (mg/L AS N) | AS N | NITROGEN, NITRATE NO2+NO3 TOTAL (mg/L AS N) | AS N | NITROGEN, AMMONIA TOTAL (mg/L AS N) | AS N | |
| S 75441 | 83-12-19 | 150 | 2.3 | 150 | 0 | <.010 | <.100 | <.100 | <.070 | .20 | 5.9 | |
| | 84-04-05 | 47 | 1.8 | 50 | 3 | <.010 | <.100 | <.100 | <.010 | 1.1 | 3.7 | |

| WELL NUMBER | DATE OF SAMPLE | PHOSPHORUS, TOTAL (mg/L AS P) | | POTASSIUM, DIS-SOLVED (mg/L AS K) | | SODIUM, DIS-SOLVED (mg/L AS Na) | | SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (mg/L) | | SPE-CIFIC CONDUCTANCE LAB (uS/cm) | | SULFATE, DIS-SOLVED (mg/L AS SO4) | | TEMPERATURE (DEG C) |
|-------------|----------------|-------------------------------|------|-----------------------------------|------|---------------------------------|-------|---|-------|-----------------------------------|--------|-----------------------------------|------|---------------------|
| | | PHOSPHORUS, TOTAL (mg/L AS P) | AS P | POTASSIUM, DIS-SOLVED (mg/L AS K) | AS K | SODIUM, DIS-SOLVED (mg/L AS Na) | AS Na | SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (mg/L) | AS Na | SPE-CIFIC CONDUCTANCE LAB (uS/cm) | AS SO4 | AS SO4 | | |
| S 75441 | 83-12-19 | .020 | 1.5 | 64 | 11 | 106 | 12 | 12.0 | | | | | 12.0 | |
| | 84-04-05 | <.010 | 1.4 | 54 | 8.3 | 79 | 12 | 11.0 | | | | | 11.0 | |

112GLCLU = UPPER GLACIAL AQUIFER