DELINEATION OF THE HYDROGEOLOGIC FRAMEWORK AND EXTENT OF SALTWATER INTRUSION WITHIN THE GREAT NECK PENINSULA, LONG ISLAND, NEW YORK, BY USE OF GEOLOGIC, HYDROLOGIC, AND GEOPHYSICAL METHODS

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ABSTRACT

Great Neck, a peninsula on the northern shore of Long Island, is underlain by unconsolidated deposits that form a sequence of aquifers and confining units. Several public-supply wells have been affected by the intrusion of saltwater from the surrounding saltwater embayments. Twelve wells were drilled for the collection of hydrogeologic, geochemical, and geophysical (gamma and induction logs) data in 1992-93 to delineate the peninsula's subsurface geology and the extent of saltwater intrusion. In 1993, a series of offshore continuous high-resolution seismic-reflection surveys were used to delineate the character and extent of the hydrogeologic deposits beneath Little Neck and Manhasset Bays, which bound the Great Neck peninsula on the west and east, respectively.

Water levels in wells screened within the confined Port Washington (?) and Lloyd aquifers respond to tidal fluctuations and pumping, but those in the overlying upper glacial (water-table) aquifer do not. Data from a tidal study indicates that the Port Washington and Lloyd aquifers are hydraulically connected.

The continuous seismic-reflection surveys identified two buried valleys beneath Little Neck and Manhasset Bays. Both valleys are filled with silt and clay. Hydrogeologic and geophysical data were used to delineate the landward extent of one of these valleys beneath the Great Neck peninsula.

Four wedge-shaped areas of saltwater intrusion in Great Neck were delineated by focused-induction logging. These saltwater wedges range from 20 to 125 ft in thickness have sharp interfaces (about 10 ft thick), and range in maximum chloride concentration from 141 to 15,300 milligrams per liter.

INTRODUCTION

Great Neck is a highly populated peninsula about 1.5 mi wide and 3.0 mi long on the northern shore of Nassau County, and is bounded on the west by Little Neck Bay and on the east by Manhasset Bay (fig. 1). The peninsula is underlain by unconsolidated deposits that form a sequence of aquifers and confining units. Ground water is the sole source of drinking water for the peninsula. Contamination of several public-supply wells by saltwater from the surrounding embayments has prompted concern over the potential for further saltwater intrusion.

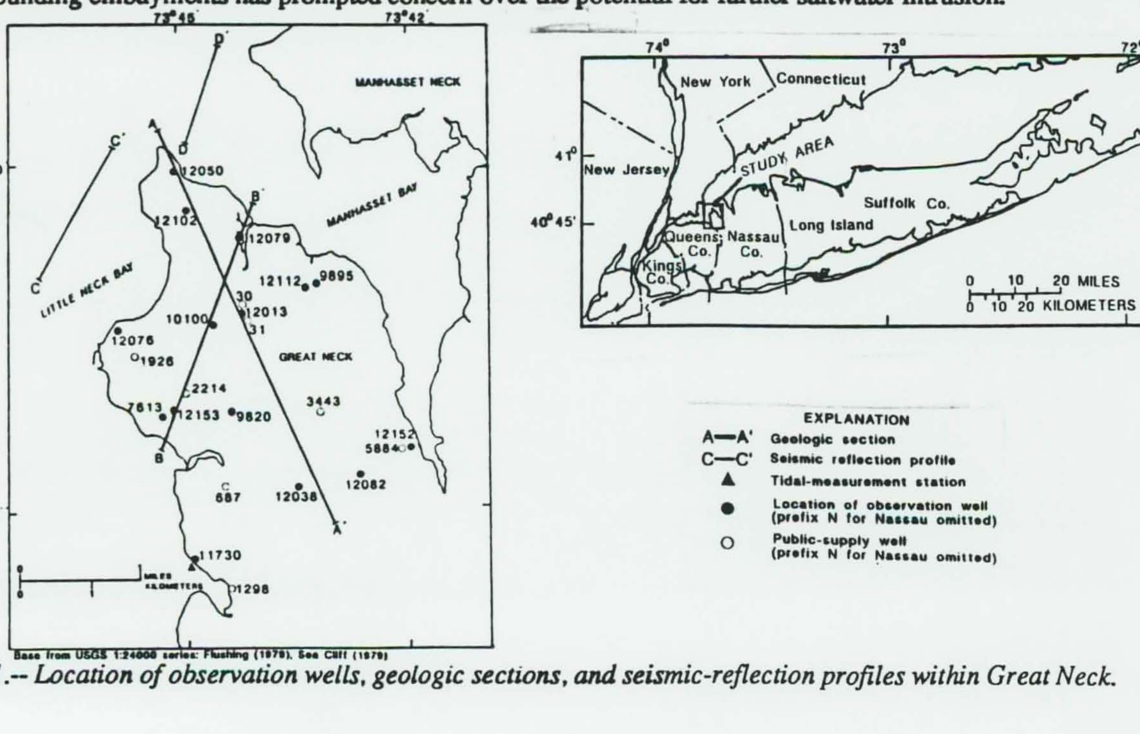


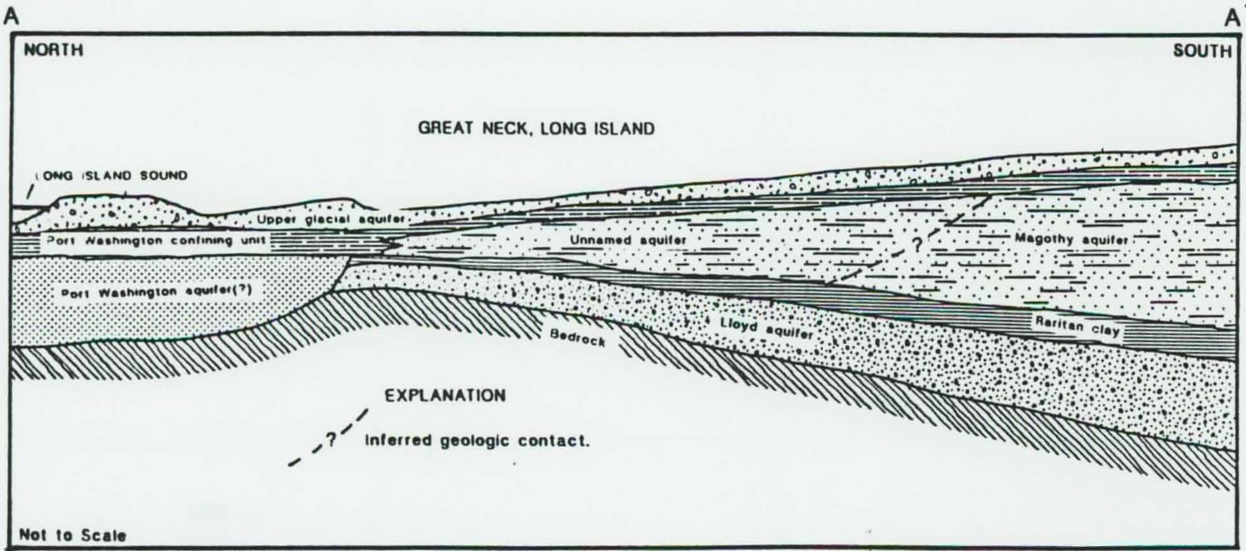
Figure 1.-- Location of observation wells, geologic sections, and seismic-reflection profiles within Great Neck.

Twelve observation wells were drilled in the study area in 1992-93 as part of a cooperative study with the Nassau County Department of Public Works to investigate the subsurface hydrogeology and the extent of saltwater intrusion on the Great Neck Peninsula. Geologic cores and ground-water samples were correlated with borehole geophysical (gamma and induction) logs, and the effect of tidal fluctuations on aquifers within Great Neck was studied to determine which observation wells were affected by tides and (or) by pumping. In 1993, a series of offshore, high-resolution, continuous seismic-reflection surveys were conducted in Manhasset and Little Neck Bays to investigate and characterize the unconsolidated deposits beneath the bay floors. Anomalous water levels at several observation wells on the peninsula indicated local changes in the hydrogeologic framework of the peninsula. Induction logging was used to delineate areas of saltwater intrusion within the peninsula.

This paper describes (1) the hydrogeology of the peninsula, (2) the effect of tidal fluctuations on water levels in the three major aquifers underlying the peninsula, (3) two buried valleys delineated by seismic-reflection surveys, and (4) four wedge-shaped areas of saltwater intrusion that were delineated by focused induction logs and filter-press data.

DELINEATION OF THE HYDROGEOLOGIC FRAMEWORK

The Great Neck peninsula is underlain by unconsolidated deposits of Cretaceous and upper Pleistocene age (Kilburn, 1979; Swarzenski, 1963) that form three major aquifers and two confining units (fig. 2). The unconsolidated deposits rest unconformably upon the bedrock surface. Extensive glacial scouring and erosion of the Cretaceous deposits in the northern parts of Great Neck are indicated by the geologic data obtained during drilling.



(Modified from Stumm, 1993)

Figure 2.-- Generalized north-south geologic section of the Great Neck peninsula (location shown in fig. 1).

The upper glacial (water-table) aquifer, in deposits of Pleistocene age (Suter and others, 1949), consists of various till, sand, gravel, and clay layers underlain by a gray clay, equivalent to the Port Washington confining unit described by Kilburn (1979). An unnamed aquifer consisting of gray and brown silty sand in the northern part of Great Neck (Stumm, 1993), is confined by the Port Washington confining unit and is hydraulically connected to the Magothy aquifer of Cretaceous age (Suter and others, 1949) to the south.

Another aquifer that could be part of the Port Washington aquifer described by Kilburn (1979), was found in the northernmost part of the peninsula. The Port Washington (?) aquifer consists of gray sand in contact with the bedrock surface and is confined by the Port Washington confining unit. Hydraulic head values indicate that the aquifer is hydraulically connected to the Lloyd aquifer to the south.

Underlying the unnamed and Magothy aquifers is the Raritan clay of Cretaceous age (Suter and others, 1949), which consists of solid, multicolored clays. Glacial erosion has scoured and removed parts of the Raritan clay in the northern part of the peninsula.

The Lloyd aquifer in sediments of Cretaceous age, consists of discontinuous layers of gravel, sand, and clay (Suter and others, 1949), increases in thickness southward within the peninsula and is overlain and confined by the Raritan clay. Geologic data obtained during drilling indicate that the Lloyd aquifer underlies all but the northernmost part of Great Neck (wells N-12050 and N-12102, fig 2.), where it, along with the Raritan clay, was removed by glacial erosion.

The unconsolidated deposits beneath Great Neck are underlain by crystalline (metamorphic) bedrock. A 50 to 100 ft thick zone of highly weathered bedrock, or saprolite, was found at the bedrock surface, except in the northernmost part of the peninsula, where it was removed by extensive glacial scouring. The bedrock surface is considered to form an impermeable boundary for Long Island's ground-water system (Franke and McClymonds, 1972).

Effect of Tidal Fluctuations

In 1992 and 1993, two studies of the effect of tidal fluctuations on water levels in the upper glacial, Port Washington, and Lloyd aquifers were completed. Normally, all wells near the coast are assumed to be affected by tides and are measured during the high tide of the nearest embayment. The period of high tide is typically about 2 hours. Because the project network contained many wells, several days were needed for hydraulic head measurements. To decrease the number of wells requiring a high tide measurement, a study was done wherein several observation wells screened within three aquifers were measured simultaneously throughout an entire tidal cycle from high tide to low tide at 20- to 30-minute intervals. A tide-measurement station in Little Neck Bay was established at Harbor Hills Park on Great Neck (fig. 1).

Water levels within the upper glacial aquifer of Great Neck normally range from over 70 ft above mean sea level in the north-central part to less than 10 ft near the shore. Water levels in the upper glacial aquifer were found to be unaffected by tidal fluctuations in the surrounding embayments (fig. 3), therefore, wells screened within the upper glacial aquifer no longer need to be measured exclusively during periods of high tide.

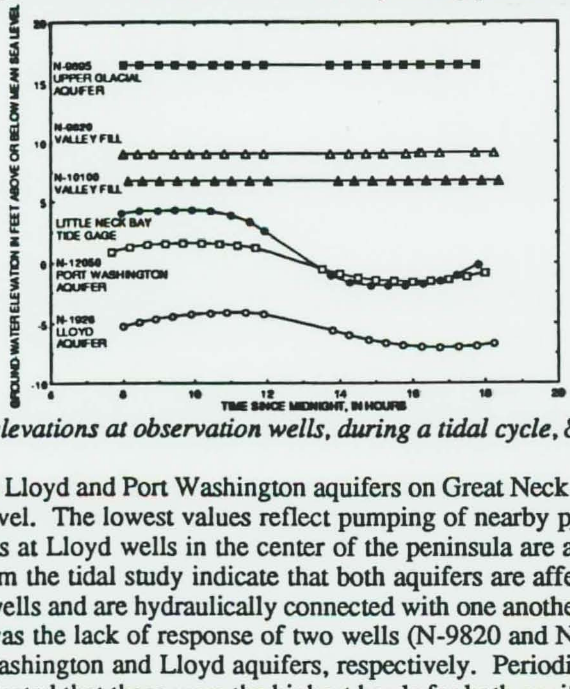


Figure 3.-- Ground-water elevations at observation wells, during a tidal cycle, 8/10/92 (locations shown in fig. 1).

Water levels within the Lloyd and Port Washington aquifers on Great Neck range from 19.5 ft below sea level to about 5.0 ft above sea level. The lowest values reflect pumping of nearby public-supply wells screened in the Lloyd aquifer. Water levels at Lloyd wells in the center of the peninsula are affected more by pumping than by tidal fluctuations. Data from the tidal study indicate that both aquifers are affected by tidal fluctuations and (or) pumping of public-supply wells and are hydraulically connected with one another (fig. 3).

Of particular interest was the lack of response of two wells (N-9820 and N-10100, fig. 1) originally listed as screened within the Port Washington and Lloyd aquifers, respectively. Periodic hydraulic head measurements at these wells consistently indicated that these were the highest heads for both aquifers within the peninsula, generally 7 to 10 ft above sea level. Data from the tidal study indicated that neither well is affected by tide fluctuations nor pumping from nearby public-supply wells (fig. 3). These data suggest that neither well is screened within the Lloyd or Port Washington aquifers, but both could instead be screened within a minor sand unit that is hydraulically isolated from the peninsula's ground-water system.

Continuous High-Resolution Seismic-Reflection Surveys

Offshore continuous high-resolution seismic-reflection surveys can be used to interpret the depth to individual reflectors, the continuity of a given reflector, and the lithology of individual geologic units (Haeni, 1986). Applications of this technique for hydrogeologic and water-resource studies have been described by Grim and others (1970); Zhody and others (1974); Haeni (1986); Reynolds and Williams (1988).

In August 1993, several continuous high-resolution seismic-reflection profiles along the coast of Great Neck were used to identify the unconsolidated deposits beneath Little Neck and Manhasset Bays. The seismic-reflection system consisted of a graphic recorder, an amplifier/filter, power generator, a catamaran-mounted sound source, a hydrophone array, digital tape recorder, and a shallow draft -21-ft boat. The sound source and hydrophone array were towed behind the slowly moving boat, where the seismic-reflection data were digitally recorded and filtered for graphic display.

The seismic signals generated by the sound source travel through the water column and penetrate the deposits underlying the sea floor. Part of the seismic signal is reflected back to the water surface from interfaces within the deposits at which a change in the acoustic impedance (the product of the density and acoustic velocity of each medium) is encountered (Haeni, 1986; Robinson and Couch, 1988). The reflected signals received by the hydrophone array produces an electrical signal which is then amplified, recorded on digital tape, filtered, and plotted. The resulting seismic section resembles a vertical geologic section, except that the vertical axis is a function of the time required for the seismic signal to travel from the source to the reflector and return (Haeni, 1986). The acoustic velocity of the medium involved is used to convert the two-way travel time to an approximate depth scale. Several seismic-reflection and refraction studies indicate that the average velocity of unconsolidated saturated glacial deposits is about 5,000 ft per second (Haeni, 1988; Reynolds and Williams, 1988), which was used as an average velocity in this study. The seismic results were correlated with geologic logs of nearshore observation wells.

Seismic-Reflection Survey

A major result of the tidal study and offshore seismic-reflection survey was the discovery of two buried valleys. The lack of tidal and pumping effects on water levels at nearshore wells N-10100 and N-9820 (screened more than 250 ft below sea level) indicated a major change in the underlying hydrogeology of the area surrounding these wells. The geologic log of well N-10100 indicates 120 ft of poorly sorted sand underlain by 180 ft of greenish-gray silty clay. Beneath the clay is a thin layer of sand about 15 ft thick resting upon bedrock. Comparison of geologic and gamma logs of well N-10100 with those of two nearby Lloyd observation wells, N-12013 and N-12153, indicates a buried glacial valley is located within the area occupied by these wells. Geologic section B-B' (fig. 4) indicates the position and depth of this buried valley in relation to the surrounding hydrogeologic units. The valley is about 1 mi wide, is filled with silt and clay, and extends to about 280 ft below sea level.

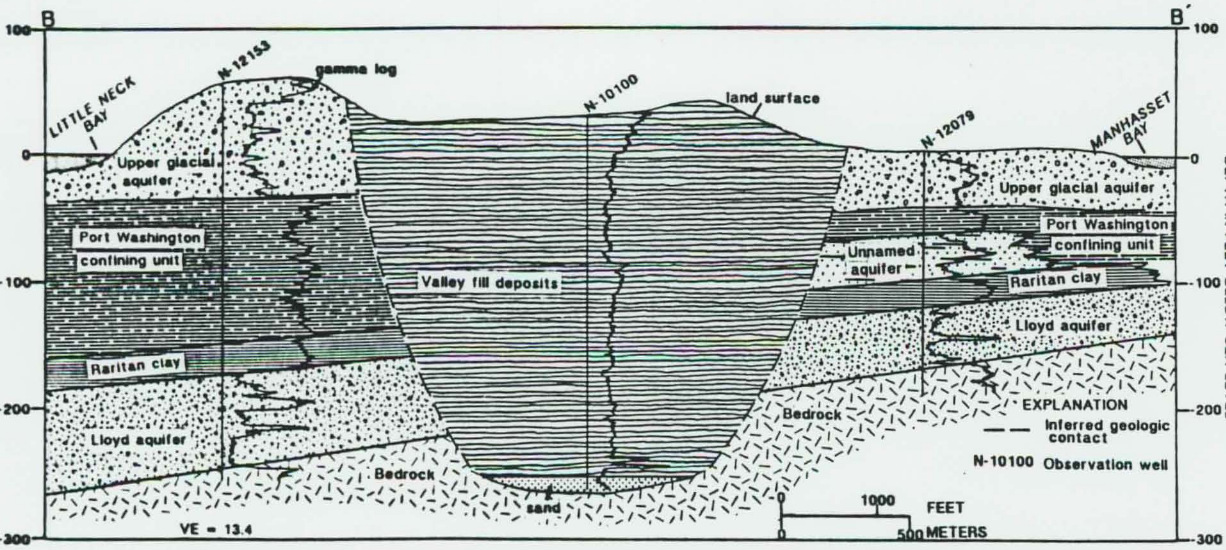


Figure 4.– Geologic section of B-B' (location shown in fig. 1).

Continuous high-resolution seismic-reflection profile C-C', located about 3,000 ft off the northwestern shore of Great Neck in Little Neck Bay and roughly parallel to section B-B', indicates the extent of the valley offshore (fig. 5A). Water depths in this area range from 10 to 50 ft . The first subsurface reflector marks the top of a complex, layered unit of fine-grained silt and sand 10 to 40 ft thick. Below this reflector, the sub-horizontal, parallel reflections indicative of draped bedding suggest deposits of silt and clay. These deposits fill a sharply defined valley that truncates the surrounding coarse-grained deposits. The valley is asymmetrical, trends northwest-southeast, is about 3 mi long, and 1 mi wide, reaches about 200 ft below sea level, and extends across only the western part of the peninsula.

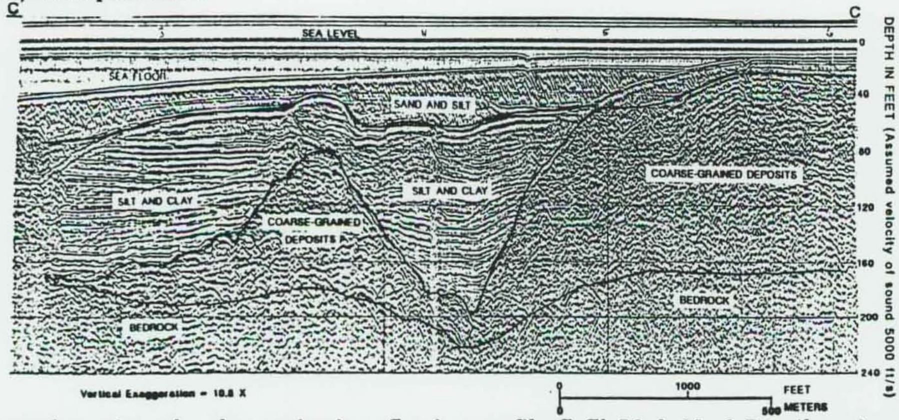


Figure 5A.-- Interpreted stratigraphy along seismic-reflection profile C-C', Little Neck Bay (location shown fig.1).

Seismic-reflection profile D-D', off the northernmost shore of Great Neck and across the opening of Manhasset Bay, indicates another buried valley (fig. 5B). The depth of water here is 20 to 60 ft. The first subsurface reflector represents the top of a complex layered unit of silt and sand about 35 ft thick, beneath which is a fine-grained deposit of draped, parallel reflections that suggest silt and clay. This extensive deposit fills an asymmetrical valley about 1 mi wide that extends to about 235 ft below sea level. Several seismic-reflection profiles within Manhasset Bay indicate the valley to be about 2.5 mi long. The valley truncates deposits of coarse-grained sand and gravel that rest upon the bedrock surface about 210 ft below sea level. The bedrock surface appears to undulate within the valley. Geologic data from nearby well N-12050 correlate with the seismic-reflection data.

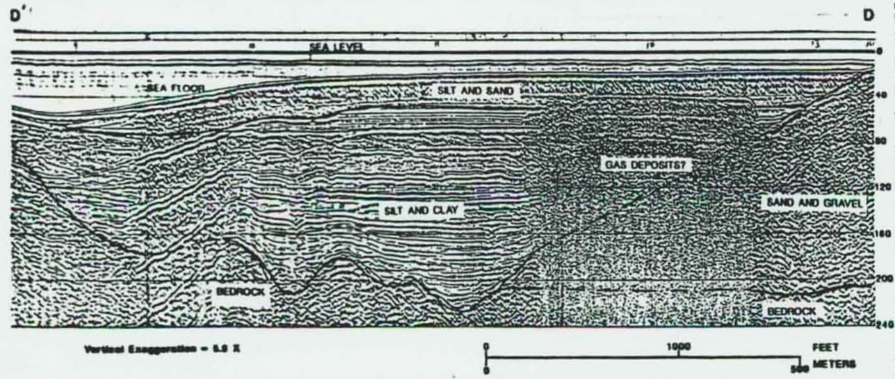


Figure 5B.-- Interpreted stratigraphy along seismic-reflection profile D-D', Manhasset Bay (location shown fig.1).

DELINEATION OF SALTWATER INTRUSION

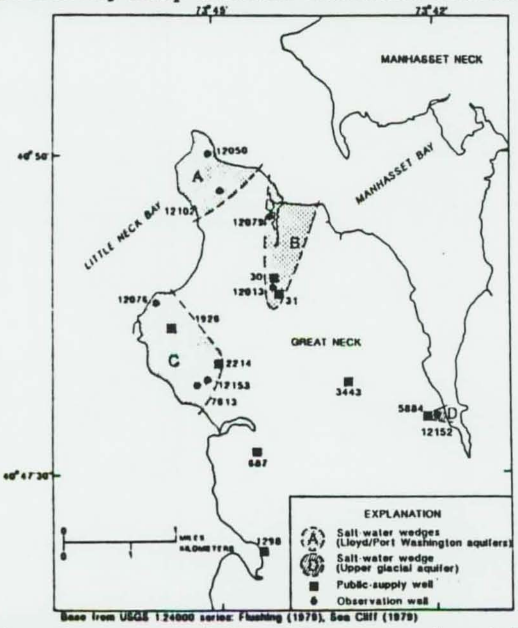
In 1992 and 1993, 12 observation wells were drilled in Great Neck for collection of geologic, geophysical, and geochemical data. Filter-press samples obtained by a nitrogen-gas-pressurized chamber to force interstitial water from uninvaded parts of a core sample (Lusczynski, 1961), obtained during drilling were analyzed for chloride concentration and correlated with well-screen samples, geologic logs, and geophysical (gamma and induction) logs to delineate the extent of saltwater intrusion.

Focused-Induction Logging

Focused-induction logging of boreholes uses an electromagnetic emitter coil that induces current loops within the surrounding formation to generate a secondary electromagnetic field. The intensity of the secondary field received by the receiver coil is proportional to the formation conductivity (Keys, 1990; Serra, 1984; Keys and McCary, 1971). All observation wells drilled during this study were cased using polyvinylchloride, which is non-conductive. The normally low conductivities of Long Island's geologic deposits and ground water enhance the application of focused-induction logging in the delineation of highly conductive fluids such as saltwater.

Location and Extent of Saltwater Intrusion

Four distinct wedge-shaped areas of saltwater intrusion have been identified in Great Neck (fig. 6); three (A, B, C) have intruded the Port Washington and Lloyd aquifers, and the fourth (D) has intruded the upper glacial aquifer. The saltwater wedges typically form at the base of an aquifer resting on an impermeable layer (either bedrock or a confining unit) because their density is greater than that of freshwater. The wedges decrease in thickness landward and have relatively sharp saltwater-freshwater interfaces (transition zones) about 10 ft thick (Stumm, 1993).



Base from USGS 1:24000 series: Flushing (1979), Sea Cliff (1979)

Figure 6.-- Location of areas occupied by salt-water wedges A, B, C, and D in Great Neck.

Saltwater wedge A, in the northernmost part of Great Neck, is 125 to 50 ft thick at the base of the Port Washington aquifer and has a maximum chloride concentration of 15,300 mg/L. Saltwater wedge B, just southeast of wedge A (fig. 6), caused the abandonment of public-supply wells N-30 and N-31. This wedge is about 20 ft thick at the base of the Lloyd aquifer and has a maximum chloride concentration of 1,900 mg/L. Saltwater wedge C, along the western shore of Great Neck, has affected two public-supply wells (N-1926 and N-2214) and a private well (N-7613). This wedge is about 20 to 40 ft thick at the base of the Lloyd and has a maximum chloride concentration of about 5,000 mg/L (estimated from induction-log responses). Saltwater wedge D is on the eastern shore of the peninsula within the upper glacial aquifer, is about 30 ft thick, and has a maximum chloride concentration of 141 mg/L (filter-press), it has affected public-supply well N-5884.

CONCLUSIONS

The potential for continued intrusion of saltwater into aquifers underlying the Great Neck peninsula fostered an investigation of the area's hydrogeology. Twelve observation wells were installed in Great Neck in 1992 and 1993 for collection of hydrogeologic, geochemical, and geophysical data. Two studies of the effect of tidal fluctuations on ground-water levels were completed in 1992 and 1993, and a series of offshore high-resolution seismic-reflection surveys were used to identify the character and extent of the unconsolidated deposits beneath Little Neck and Manhasset Bays.

Results indicate that water levels from wells screened in the upper glacial aquifer do not respond to tidal fluctuations. Water levels from wells screened in the hydraulically connected Port Washington and Lloyd aquifers respond to tidal fluctuations and to pumping. Pumping from public-supply wells has lowered the hydraulic head within the Lloyd by as much as 19.5 ft below sea level.

Two buried valleys beneath Little Neck and Manhasset Bays were delineated by seismic-reflection surveys. Both valleys trend northwest-southeast, and are filled with silt and clay. Both of these valleys are about 1 mi wide, extend for several miles, and reach to more than 200 ft below sea level. Hydrogeologic data from observation wells indicates one of these valleys extends beneath the western part of the Great Neck peninsula, and truncates the aquifers and confining units locally. The silts and clays that fills these valleys are hydraulically isolated from the peninsula's ground-water system.

Focused-induction logs, filter-press and well-screen sample data indicate at least four wedge-shaped areas of saltwater intrusion in Great Neck. The northernmost wedge intrudes the Port Washington aquifer at the tip of the peninsula; at the base of the Port Washington aquifer; it ranges from 50 to 125 ft thick, and has a maximum chloride concentration of 15,300 mg/L. The wedge just to the southeast intrudes the Lloyd aquifer, is 20 to 40 ft thick, and has a maximum chloride concentration of 1,900 mg/L. A third wedge on the western shore, also intrudes the Lloyd, is about 20 to 40 ft thick, and has a maximum chloride concentration of about 5,000 mg/L. A fourth wedge on the eastern shore, intrudes the upper glacial aquifer, is about 30 ft thick, with a maximum chloride concentration of 141 mg/L.

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