Reprinted from
Economic Geology
Vol. 55, 1960, pp. 1739–1750

POSITION OF THE SALT-WATER BODY IN THE MAGOTHY(?) FORMATION IN THE CEDARHURST-WOODMERE AREA OF SOUTHWESTERN NASSAU COUNTY, LONG ISLAND, N. Y.[1]

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ABSTRACT

The position and chloride concentration of a sizable body of salt water, moving slowly landward from the south-shore bays of Long Island and the Atlantic Ocean were defined by recent test drilling in the Cedarhurst-Woodmere area of southwestern Nassau County, Long Island, N. Y. Most of the salt-water body is in the lower part of a permeable artesian aquifer; the lowermost part of the salt-water body is in clay deposits underlying the permeable aquifer.

The upper limit of the salt-water body in this area was found at depths increasing progressively in a landward direction. It was 318 feet below sea level at a well in Cedarhurst and 541 feet below sea level at a well in Woodmere. The lower limit of the salt-water body was determined at depths between 578 and 630 feet below sea level in the Cedarhurst-Woodmere area. The salt-water body is more than 300 feet thick at a well in Cedarhurst, and it thins out to zero in the vicinity of a pumping center about 1¾ miles northeast of the Cedarhurst well.

Chloride concentration in the salt-water body in the Cedarhurst-Woodmere area ranged from about 40 to 16,000 ppm (parts per million). Isochlors define a zone of diffusion about a mile wide in the Cedarhurst-Woodmere area. They indicate a thickness of diffused water ranging from a few tens to more than 150 feet vertically.

Electrical-log data show that the upper boundary of the salt-water body moved upward 21 feet between 1952 and 1958 at a site in Woodmere about half a mile southwest of the pumping center. From this information it is inferred that between 1952 and 1958 the leading edge of the salt-water front moved landward about 2,000 feet toward the pumping center.

[1] Publication authorized by the Director, U. S. Geological Survey.
Prepared in cooperation with the Nassau County Department of Public Works and the New York State Water Power and Control Commission.

INTRODUCTION

An extensive salt-water body occurs in deposits of Pleistocene and Cretaceous age in southeastern Queens and southwestern Nassau Counties, Long Island, N. Y. The salt-water body extends landward into the Magothy(?) formation from surface and underground salt-water bodies in the south-shore bays of Long Island and the Atlantic Ocean.

The approximate extent of this salt-water body in southeastern Queens and southwestern Nassau Counties is described in a paper by N. M. Perlmutter and others (1). On the basis of test drilling in 1952 and appraisal of data available prior to 1958, Perlmutter and others (1, Fig. 4) estimated the leading edge of the salt-water body to be approximately half the distance of about $1\frac{1}{4}$ miles between well N3861 at Cedarhurst and well N3864 at

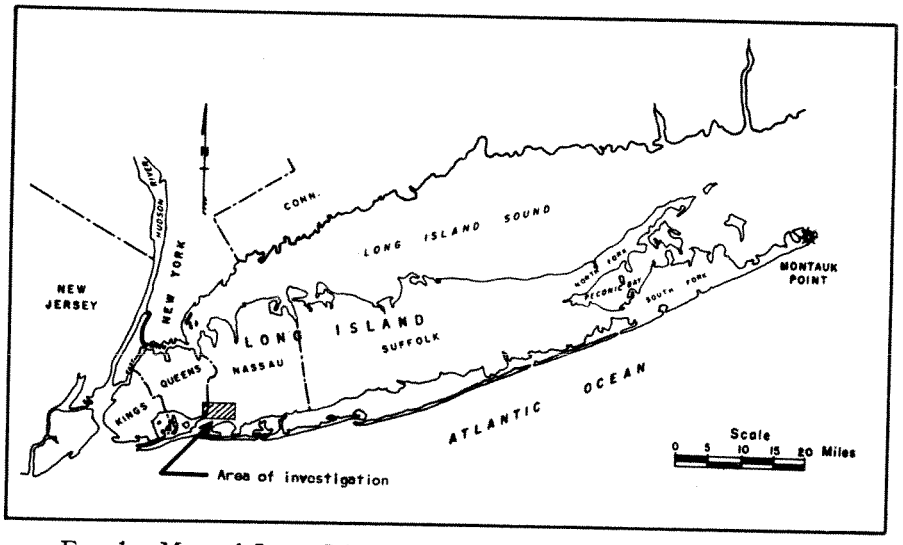

FIG. 1. Map of Long Island, N. Y., showing area of investigation.

Woodmere (Figs. 1, 2). Observation wells N3861 and N3864, drilled in 1952, are about $1\frac{3}{4}$ miles and $\frac{1}{2}$ mile, respectively, southwest of a pumping station in Woodmere near Valley Stream, where ground-water withdrawals for public supply are made by a water company.

In 1958, three exploratory test holes and one observation well were drilled in Woodmere between well N3861 at Cedarhurst and well N3864 at Woodmere. The drilling in 1958 was the first phase of a program undertaken for the further investigation of salt-water encroachment in southwestern Nassau and southeastern Queens Counties, specifically for the definition of the position and the direction and rate of movement of the salt-water body. This program is being conducted by the U. S. Geological Survey in cooperation with the Nassau County Department of Public Works and the New York State Water Power and Control Commission.

Significant information on the position and chloride concentration of the salt-water body between Cedarhurst and Valley Stream at existing wells and at the test holes and well drilled in 1958 is given in this paper. Also, an estimate is made of the landward movement of the salt-water front along a section between Cedarhurst and Valley Stream. Not all the available geologic, electrical-logging, chloride-content, water-level, water-density, and pumping-test data obtained in 1958 are included in this paper. These data are to be studied together with information to be obtained in subsequent phases of the program.

The 1929 mean sea level at Sandy Hook, N. J., is the datum to which all altitudes and depths are referred in this paper. Measurements below mean

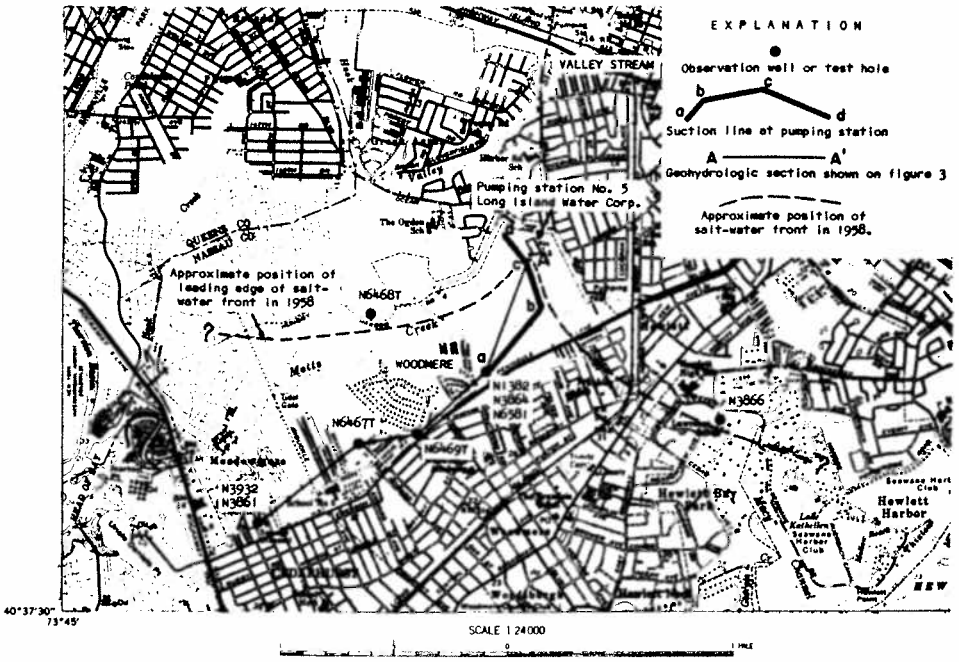

FIG. 2. Map showing the location of test holes and wells and the salt-water front in the Cedarhurst-Woodmere area.

sea level are shown by the minus (−) sign. Landsurface at test holes and wells described in this report is less than 20 feet above mean sea level.

ACKNOWLEDGMENTS AND SUPERVISION

The authors give thanks to Lee Associates and Mr. Phillip Lynne for permission to use sites on their respective properties for drilling of three exploratory test holes (N6467T-N6469T). They appreciate advice and

field supervision given by Mr. R. Sauvage, from the Research Section of the Schlumberger Well Surveying Corporation at Ridgefield, Conn., during the electrical logging of the test holes, and information furnished by the Long Island Water Corporation for well N6581. They also appreciate the support of and interest in this project of Mr. W. F. Welsch of the Nassau County Department of Public Works and Mr. A. H. Johnson of the New York State Water Power and Control Commission.

Messrs. John Isbister and Warren Teasdale of the Geological Survey assisted the authors in the collection of basic data at the exploratory test holes, in making chloride determinations, and in preliminary appraisal of the geologic information.

The paper was written under the supervision of George C. Taylor, Jr., district geologist of the Geological Survey, Mineola, N. Y.

DRILLING PROGRAM IN 1958

In 1958 the U. S. Geological Survey, the Nassau County Department of Public Works, and the New York State Water Power and Control Commission furnished funds for the drilling of three exploratory holes between existing wells N3861 and N3864 at Cedarhurst and Woodmere, respectively, and west of existing well N3866 in Hewlett Bay Park (Fig. 2). Well N3861 is about 3 miles north of the Atlantic coastline and well N3864 is 1¼ miles northeast of well N3861. The exploratory holes (N6467T, N6468T, and N6469T) were drilled during April and June 1958 by Foundation Services, Inc., of New Jersey, by the standard rotary method to depths of − 694 feet, − 699 feet, and − 698 feet, respectively. At each site, core samples were taken in a 4-inch hole, after which the hole was reamed to 6 inches for electrical logging by the Schlumberger Well Surveying Corporation.

At hole N6467T a standard Schlumberger electrical log was obtained. At hole N6468T a microlog was run in addition to the standard Schlumberger electrical log, and at hole N6469T a microlateral log was run in addition to the standard Schlumberger electrical log. Also at hole N6469T a Widco log was run to a depth of about − 555 feet by U. S. Geological Survey personnel from the Trenton, N. J., office. After the desired geologic, water-salinity, and electrical-log information was obtained, the three exploratory holes were filled with a mixture of clay and cement.

In September 1958, observation well N6581 was drilled in Woodmere by Layne-New York Co., Inc., for the Long Island Water Corporation. It was constructed near two existing observation wells, 12 feet from well N3864 and 21 feet from well N1382. The test hole for well N6581 was drilled to − 611 feet but the completed observation well was screened between − 565 and − 575 feet. Well N6581 is thus screened at the deepest level of the three wells at the site, as well N3864 is screened from − 455 to − 466 feet and well N1382 from − 167 to − 188 feet. A Widco electrical log was run by Layne-New York Co., Inc., before the hole was cased and screened. The well was test-pumped and sampled after it was completed and developed.

GEOLOGIC ENVIRONMENT

The geologic environment in the general area of southern Nassau and southeastern Queens Counties is described in detail by Perlmutter and others (1).

The geologic units in the area of the 1958 test drilling consist of a basement of Precambrian (?) crystalline bedrock sloping to the southeast, overlain by the following unconsolidated deposits in ascending order: Lloyd sand member and clay member of the Raritan formation and the Magothy(?) formation of Late Cretaceous age, Jameco gravel and Gardiners clay of Pleistocene age, and upper Pleistocene and Recent deposits. All these

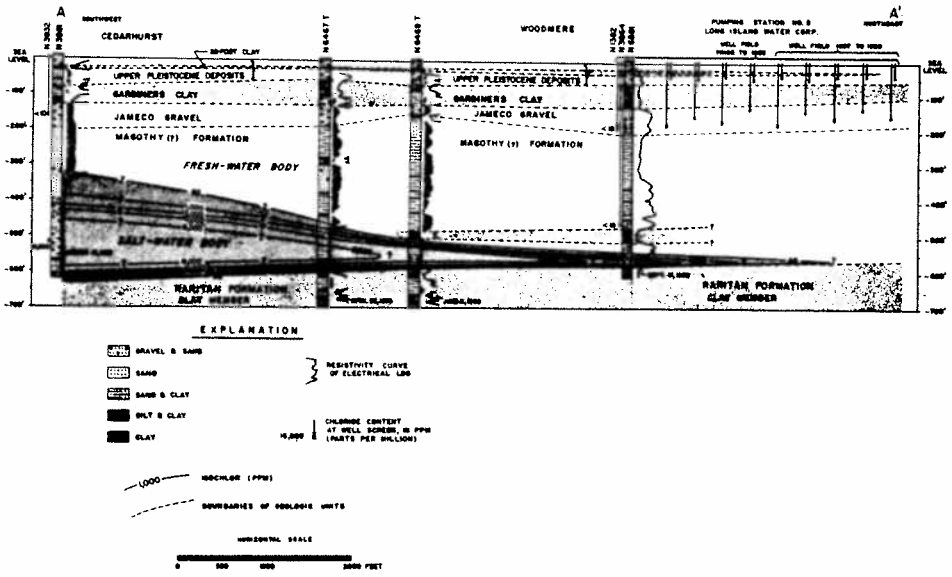

FIG. 3. Geohydrologic section A-A′ in Cedarhurst-Woodmere area of southwestern Nassau County, Long Island, N. Y.

geologic units except the Recent deposits are continuous in the Cedarhurst-Woodmere area (Fig. 3). Information obtained in 1958 and collected during the drilling of wells N3861 and N3864 in 1952 was used in part to define, more accurately than heretofore possible, the lithology and stratigraphy of the deposits from the land surface down to and including the upper part of the clay member of the Raritan formation in the area between Cedarhurst and Pumping Station No. 5 of the Long Island Water Corporation in Woodmere near Valley Stream (Figs.2, 3).

The character and lithology of the Magothy(?) formation and the underlying clay member of the Raritan formation are important to this study because the extensive salt-water body is found in these formations. The

Magothy(?) formation lies between about − 150 and − 600 feet in the Cedarhurst-Woodmere area. It consists of alternating layers and lenses of sand, gravel, silt, and clay, all of which appear to have limited lateral extent. The average permeability of the Magothy(?) formation at the three test holes appears to be intermediate between the rather high permeability at well N3861 and the rather low permeability at wells N3864 and N6581 (Fig. 3). At well N3861 in Cedarhurst, about 85 percent of the Magothy(?) formation consists of fine to coarse quartz sand and some gravel and a very small fraction of interstitial clay. However, at wells N3864 and N6581 in Woodmere the bulk of the Magothy(?) formation consists of very fine clayey sand and clay. The Magothy(?) at the site of wells N3864 and N6581, although containing more clay than is found commonly, corresponds closely to the Magothy(?) as it is known elsewhere in the area. The Magothy(?) deposits penetrated by test hole N6467T, which is closest to Cedarhurst, include considerable thickness of fine to coarse sand and only traces of clay. More clay content is noted in the northeasterly direction at wells N6469T, N3864, and N6581.

In general, the Magothy(?) formation contains thin lenses of solid clay, a few inches to several feet thick, but most of these apparently have short lateral extent. An exception may be a stratum of solid clay which occurs at wells N3864 and N6581 as a red and white clay in the lower part of the Magothy(?) (Fig. 3). This stratum, about 45 to 75 feet above the top of the clay member of the Raritan formation, seems to have some areal continuity. It apparently extends to the northwest and southwest for at least half a mile from wells N3864 and N6581. Its thickness is reduced in a northwesterly direction from about 40 feet at wells N3864 and N6581 to 22 feet at test hole N6468T. To the southwest, 19 feet of the material were found at test hole N6469T. However, this clay stratum was not recognized at the site of test hole N6467T southwest of test hole N6469T. The extent of this stratum in a northeasterly and easterly direction from wells N3864 and N6581 is not known, as the deepest wells at Pumping Station No. 5 are only about 200 feet deep, and as well N3866 was drilled only to − 452 feet.

The top of the clay member of the Raritan formation occurs at the following depths along section A-A′ and its vicinity: − 602 feet at N3861; − 578 feet at N3864 and N6581; − 583 feet at N6467T; − 565 feet at N6468T; − 580 feet at N6469T. From this information, the top of the clay member was estimated to be at about − 570 feet at the pumping center of the No. 5 station, which is about half a mile northeast of well N6581.

At the test holes drilled in 1958, the upper part of the clay member consists of about 38 feet of solid light-gray and dark-gray clay, with lignite and only traces of silt. Below is a zone of more permeable fine micaceous and silty gray sand, 38 to 60 feet thick, which, in turn, is underlain by more solid and silty clay.

Test holes at the sites of wells N3861 and N6581 penetrated 14 and 33 feet, respectively, of the clay member. At well N3861, solid light- and dark-gray, brown, and purple clay with layers of lignite was found between

− 602 and − 616 feet. At well N6581 solid gray clay with thin layers of silty clay was found between − 578 and − 611 feet.

Water occurs in all the unconsolidated deposits in southwestern Nassau County. The zone of saturation extends to and into bedrock from depths of about 1 to 10 feet below the land surface. The land surface in the Cedarhurst-Woodmere area is in general less than 20 feet above mean sea level.

Water in the Magothy(?) formation and the Jameco gravel is confined between the Gardiners clay above and the clay member of the Raritan formation below. Water above the 20-foot clay unit in the upper Pleistocene deposits is unconfined; that below the 20-foot clay is confined, as the 20-foot clay is apparently continuous in the Cedarhurst-Woodmere area.

CHLORIDE CONCENTRATION AT TEST HOLES

Chloride concentration of water at the test holes was determined principally by analysis of the natural water content in core samples obtained during the test drilling. Most of the core samples were taken with a split-spoon core barrel 1½ inches in diameter and 18 inches long. A few samples 3 inches in diameter and as much as 5 feet long were obtained by a rotating double-walled coring device.

Fluorescein dye (400 ppm) added to the drilling fluid colored it green and identified core samples invaded by the drilling fluid. The formational water from uninvaded cores was analyzed for chloride content by two methods developed during drilling test holes N6467T-N6469T. These methods are described in detail by Swarzenski (2). A brief résumé of the methods is given below.

The first method, involving centrifugal extraction, is comparatively simple and apparently yields reliable results, if cores are obtained and preserved properly at the time of the drilling. The second method, termed the "dilution method," was devised for fine-textured samples—solid and silty clays, which did not yield sufficient water by centrifugal extraction. The laboratory procedure for the dilution method requires a determination of moisture content from the loss in weight of a core when it is dried in an oven, the restitution of original moisture content and further dilution with distilled water, resolution of the salts precipitated during drying, and filtration.

This technique must be considered experimental because of several unknown factors. However, results of the correct order of magnitude were obtained in the laboratory. Thus, the use of the dilution method seems justified, at least as a semiquantitative tool, in the determination of brackish and saline ground-water zones. In general, chloride values determined by the dilution method were in agreement with chloride concentrations determined by the centrifuge-extraction method and with known ground-water salinities in the area. It is considered that reasonably accurate data are obtained by the dilution method for formational water having a chloride concentration in excess of 200 parts per million.

Chloride concentrations determined by the centrifuge-extraction and/or

TABLE 1

CHLORIDE DETERMINATIONS OF WATER FROM CORE SAMPLES OBTAINED IN 1952 AND 1958

a—Depth, in feet below sea level.
b—Chloride content, in parts per million, by centrifuge-extraction method.
c—Chloride content, in parts per million, by dilution method.
d—Order of magnitude defined (see note below).

N3861		N3864		N6467T			N6468T			N6469T		
a	c	a	c	a	b	c	a	b	c	a	b	c
—	—	560	d_{30}	—	—	—	—	—	—	—	—	—
596	$d_{8,700}$	569	$d_{1,000}$	38	62	—	15	500	—	473	<20	—
605	$d_{6,200}$	579	d_{700}	457	<25	—	35	6,600	—	505	—	<50
615	$d_{1,900}$	—	—	477	1,300	—	55	7,500	—	511	<60	—
—	—	—	—	496	7,700	—	76	—	<10	527	>4,600	—
—	—	—	—	516	12,500	—	95	—	<20	536	12,700	—
—	—	—	—	537	16,000	—	95	Fresh water		560	10,800	10,200
—	—	—	—	576	—	10,800	699	(<40)		565	10,500	—
—	—	—	—	597	—	1,400	—	—	—	570	10,700	—
—	—	—	—	616	—	<15	—	—	—	573	—	8,700
—	—	—	—	—	—	—	—	—	—	575	—	7,900
—	—	—	—	—	—	—	—	—	—	580	—	1,020
—	—	—	—	—	—	—	—	—	—	597	—	<50

Note: Cores for wells N3861 and N3864 taken in 1952 and chloride determinations made in 1958. Original water content estimated, as cores had dried out. Determinations of chloride content approximate.

Chloride determinations at time cores were obtained: in April 1958 at test hole N6467T, in May 1958 at test hole N6468T, and in June 1958 at test hole N6469T.

dilution methods for test holes N6467T, N6768T, and N6469T are listed in Table 1.

SALT-WATER BODY IN THE CEDARHURST-WOODMERE AREA

In the Cedarhurst-Woodmere area, fresh water in the Magothy(?) and deeper formations under natural conditions has generally much less than 20 ppm of chloride content. Chloride concentrations in excess of 20 ppm in these formations thus indicate the presence of an additional source of chloride. The only known additional source of chloride, natural or otherwise, in the Magothy(?) and deeper formations in the Cedarhurst-Woodmere area is sea water. Chloride concentrations in excess of 20 ppm are then the first indications, and those in excess of 40 ppm are positive indications, of the mixing of fresh water with sea water. For this report, a "salt-water body" is defined as one having mixtures of fresh water and sea water, the chloride concentration in the salt-water body ranging between 20 to 40 ppm and 16,000 to 18,000 ppm. A salt-water body so defined includes the salty or diffused water between fresh water and sea water.

The position and chloride concentration of the salt-water body in the Magothy(?) formation and the clay member of the Raritan along section A-A' (Fig. 3) between well N3861 in Cedarhurst and the pumping center in Woodmere were defined by (1) the resistivity curves of electrical logs for

test holes and observation wells, (2) the chloride concentrations determined by the centrifuge-extraction and/or dilution methods, and (3) the chloride content of water sampled at observation wells. For this purpose, data obtained at wells N3861 and N3864 drilled in 1952 and at test holes N6467T-N6469T and well N6581 drilled in 1958 were used. In general the resistivity curves of electrical logs defined adequately the upper and lower limits of the salt-water body. The chloride concentrations in the salt-water body were determined principally by the centrifuge-extraction method, by the dilution method, and from water samples at finished wells.

The electrical log and the chloride concentrations determined by the dilution method at well N3861 show the salt-water body as lying between about − 318 and − 630 feet. The upper limit of the salt-water body was determined from the electrical log. The lower limit was based on the chloride concentration of approximately 1,900 ppm indicated in 1958 by an analysis made from a core sample taken at − 615 feet in 1952 (Table 1). The core had dried out between 1952 and 1958, and thus it was necessary to estimate the original water content in the sample. However, the determination suggests at least the proper order of magnitude of the chloride content, and the evidence is sufficient to show salt water at − 615 feet. From this, it is estimated that the lower limit of the salt-water body at the site of well N3861 is about 15 feet deeper than the bottom (− 615 feet) of the hole, or at about − 630 feet.

Water at the screen (− 515 to − 526 feet) of well N3861 had a chloride concentration of about 16,000 ppm between 1952 and 1958. In water at the screen (− 165 to − 169 feet) of observation well N3932, located at the site of well N3861, chloride concentrations of less than 10 ppm were observed between 1952 and 1958.

Electrical logs and chloride determinations by the centrifuge-extraction and dilution methods show the salt-water body to be between − 464 and − 600 feet in April 1958 at test hole N6467T, and between − 511 and − 583 feet in May 1958 at test hole N6469T. The observed maximum chloride concentration in the salt-water zone, as determined by the centrifuge-extraction method, was 16,000 ppm at test hole N6467T and 12,700 ppm at test hole N6469T. That at test hole N6469T may not be the maximum in the salt-water zone.

An electrical log run in September 1958 in well N6581 in Woodmere indicated a salt-water zone between − 541 and − 582 feet at and near the bottom of the Magothy(?) formation. Water at the well screen (− 565 to − 575 feet) had a chloride concentration of about 8,000 ppm in October 1958. The screen was set at a depth where the resistivity curve of the electrical log suggested the highest chloride concentration. Water at wells N3864 and N1382 had a chloride concentration of less than 10 ppm. These two wells, located at the site of well N6581, are screened from − 455 to − 466 feet and from − 167 to − 188 feet, respectively.

Available data indicate that the upper limit of the salt-water body is in the Magothy(?) formation, and that it is beneath the red and white clay between test hole N6469T and well N6581, as shown in section A-A′. The

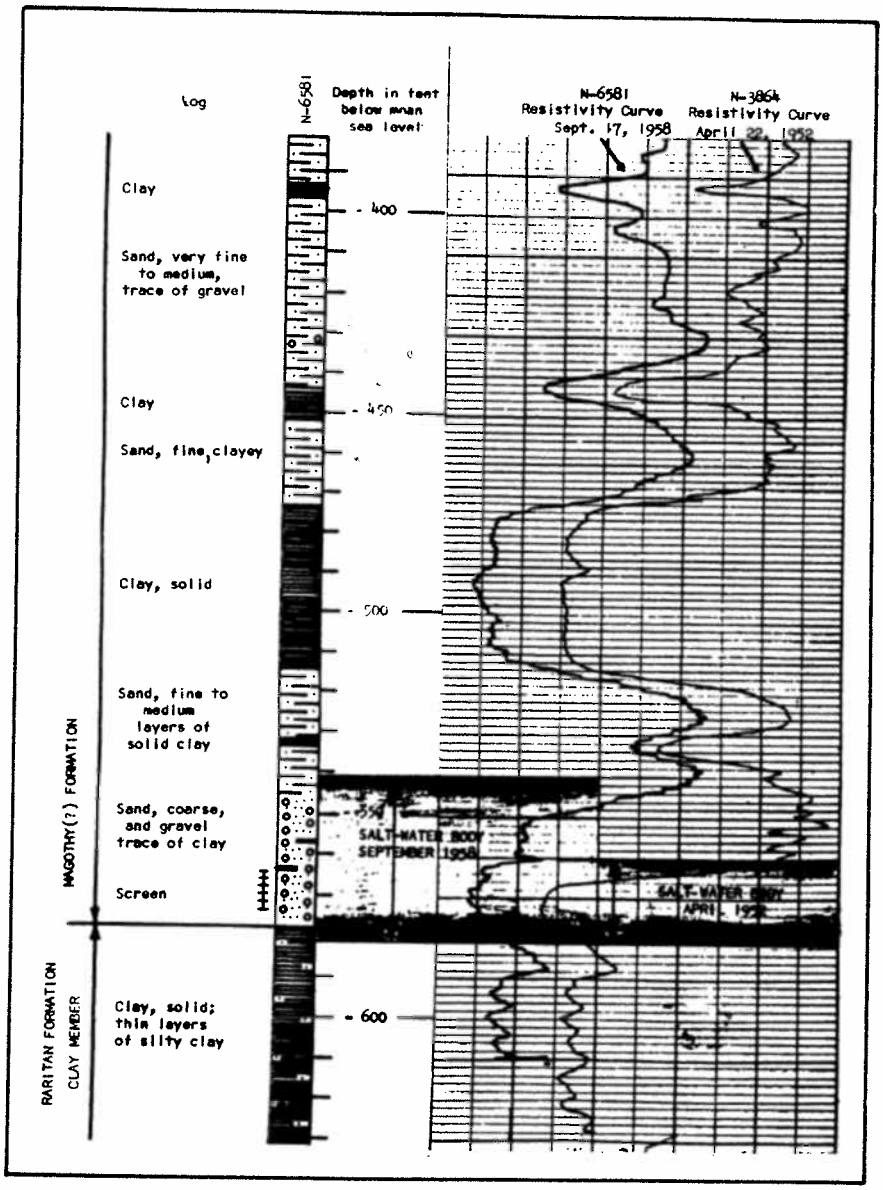

FIG. 4. Thickness of the salt-water body in April 1952 and September 1958 at site of wells N3864 and N6581 in Woodmere.

lower limit of the salt-water body penetrates the uppermost part of the underlying clay member of the Raritan formation, which contains salty water to a depth of about 28 feet below the top at well N3861, about 17 feet at test hole N6467T, about 3 feet at test hole N6469T, and about 4 feet at

well N6581 below the top of the clay member. The lowermost part of the salt-water body is believed to be in nearly solid clay along section A-A'

The isochlors shown in section A-A' (Fig. 3) are best defined at test holes N6467T and N6469T, where determinations of chloride content were made by the centrifuge-extraction and the dilution methods. Those at well N3861 and at wells N3864 and N6581 are based on the resistivity curve, chloride concentrations at the well screen, and determinations in 1958 by the dilution method from cores taken in 1952 near the bottom 20 feet of the hole (Table 1).

The chloride concentrations in the salt-water body along section A-A' are at a maximum as much as 50 feet, and perhaps more, above the top of the clay member. They decrease landward from about 16,000 ppm at well N3861 and N6469T to about 8,000 ppm at well N6581 and to less than 40 ppm near the pumping center. Along the top of the clay member, the chloride decreases from about 12,000 ppm at well N3861 to about 8,000 ppm at test hole N6467T to about 1,000 ppm at test hole N6469T, and to probably less than 1,000 ppm at well N6581 (Fig. 3). The zone of diffusion is at least a mile wide along section A-A'. The thickness of the zone of diffusion in a vertical direction ranges from a few tens of feet to more than 150 feet along this section.

In 1958 the salt-water body was observed to decrease in thickness from more than 300 feet at well N3861 to 72 feet at test hole N6469T and 41 feet at well N6581. The salt-water wedge apparently thins out to zero at or near the pumping center about half a mile landward from well N6581. Available information does not allow pinpointing the position of the leading edge of the salt-water front. However, apparently the leading edge is within at least a quarter mile of the pumping center at the No. 5 Pumping Station.

The leading edge of the salt-water front is at the bottom of the Magothy(?) formation and at or near the top of the clay member. It is apparently about 400 feet below the bottoms of the deeper supply wells screened in the Jameco gravel at the No. 5 Pumping Station. Thus, fresh-water supplies at the station are in little immediate danger under present (1959) conditions. A plan view of the estimated position in 1958 of the leading edge of the salt-water front in the vicinity of section A-A' is shown in Figure 2. The position is based in part on conditions shown in Figure 3, and on finding no salt water in the Magothy(?) formation and in the clay member at test hole N6468T drilled in 1958. It is also based on indirect evidence which suggests that the leading edge of the salt-water front may be in the vicinity of or at well N3866 at depths of about 200 feet below the screened zone at − 395 to − 405 feet at and above which only fresh water was found.

MOVEMENT OF THE SALT-WATER FRONT

The resistivity curve of the electrical log at well N6581 and the chloride content of the water sampled at the screen (− 565 to − 575 feet) of well N6581 defined the presence in October 1958 of a diffused-water zone 41 feet thick between − 541 and − 582 feet at and below the bottom of the Mag-

othy(?) formation. The presence of salt water in this zone at this site was first suggested by chloride determinations (Table 1) made in 1958 by means of the dilution method on cores taken in 1952 at well N3864. Wells N3864 and N6581 are about 12 feet apart at the same site. The presence of salt water was confirmed subsequently by the chloride content of 8,000 ppm in October 1958 in water at the screen of well N6581. Thus it was possible to interpret with assurance the resistivity curve of the electrical log for well N3864 as demonstrating a salt-water zone 20 feet thick between about − 562 and − 582 feet in April 1952.

As indicated by the side-by-side comparison of the resistivity curves for wells N3864 and N6581 given in Figure 4, the salt-water body thickened at the site of well N6581 between April 1952 and October 1958. The thickening produced an upward movement of about 21 feet in the upper limit of the salt-water body. The upward movement in all likelihood was accompanied by a landward advance of the leading edge of the salt-water front toward the pumping center. The landward advance is estimated to be on the order of 2,000 feet on the basis of the slope of the upper boundary of the salt-water front. The slope at well N6581 was approximately 20 feet in 2,000 feet (1%).

The upward and landward advance of the salt-water front was caused by the effects of continuous pumping from wells at the Mill Road Station near Valley Stream. Withdrawals at the Mill Road Station averaged about 7 mgd (million gallons per day) between 1945 and 1952 and about 5 mgd between 1953 and 1958. They were made from as many as 150 wells screened in the upper Pleistocene deposits and in the Jameco gravel along the common suction line at the No. 5 Station. Originally the dogleg suction line consisted of sections *ab*, *bc*, and *cd* (Fig. 2) and was 3,900 feet long. Its southeast end was at well N1382. However, in July 1957 section *ab* (1,900 feet long) was abandoned, and since then about 100 wells are pumped along sections *bc* and *cd*.

More than half the total withdrawal is made from the Jameco gravel, but the exact amount is not known. Nevertheless, the withdrawals create a sizable cone of depression in the piezometric surface not only in the Jameco gravel but also in the full thickness of the Magothy(?) formation. To the southwest the cone of depression extends beyond wells N3861 and N3932 at Cedarhurst. Thus the salt-water body between Cedarhurst and the pumping center also is within the cone of depression.

U. S. Geological Survey,
Mineola, New York,
April 4, 1960

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