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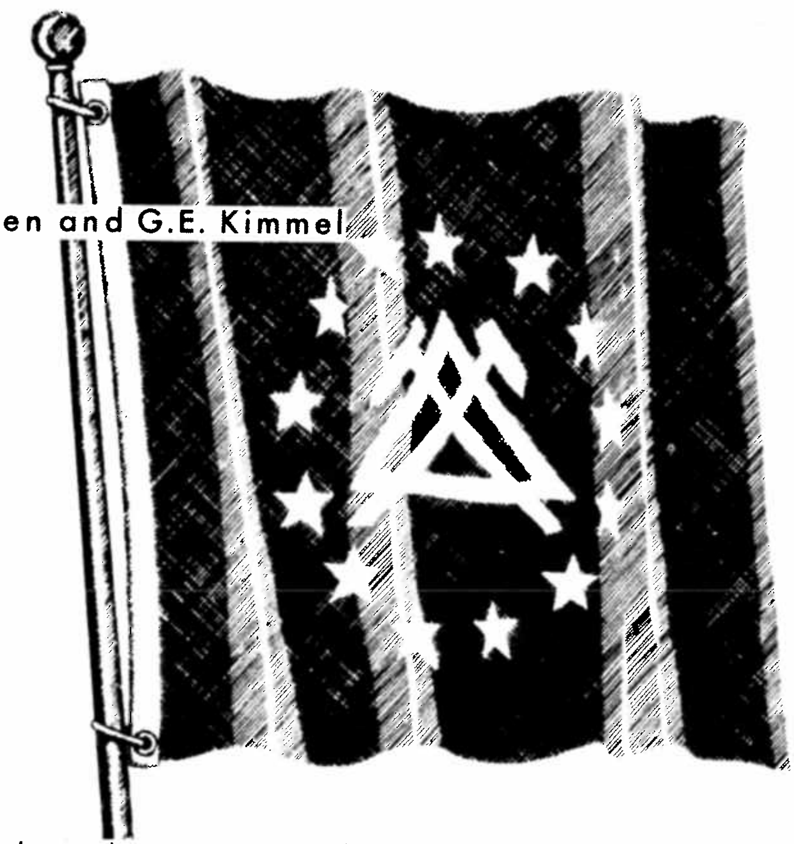

By Philip Cohen and G.E. Kimmel

Reprint from Geological Survey Research 1970
Geological Survey Professional Paper 700-D
p. 281–286

WORK DONE IN COOPERATION WITH THE NASSAU COUNTY DEPARTMENT OF PUBLIC WORKS AND THE NEW YORK STATE DEPARTMENT OF CONSERVATION, DIVISION OF WATER RESOURCES

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATUS OF SALT-WATER ENCROACHMENT IN 1969 IN SOUTHERN NASSAU AND SOUTHEASTERN QUEENS COUNTIES, LONG ISLAND, NEW YORK

By PHILIP COHEN and G. E. KIMMEL, Mineola, N.Y.

Work done in cooperation with the Nassau County Department of Public Works and the New York State Department of Conservation, Division of Water Resources

Abstract.—Chloride data obtained from "outpost" wells and other wells in southern Nassau and southeastern Queens Counties, Long Island, N.Y., indicate that landward movement of a deep wedge of salty ground water in the area has been minimal from 1960 to 1969. Significant changes in chloride content were noted in only 3 of 30 outpost wells. Chloride content of water from a well in southeastern Queens County increased from 34 mg/l in 1960 to 112 mg/l in 1969, as a result of intensive ground-water withdrawals in that county; chloride content in two wells in Nassau County increased from 8,520 to 11,000 mg/l and from 2,000 to 8,110 mg/l during the same period. These increases resulted from local heavy pumping near the zone of diffusion. No increase in chloride content was noted in water from the Lloyd aquifer, except where leaky casings permitted downward flow of salty water.

Salty ground water on Long Island, N.Y., especially in southeastern Queens and southern Nassau Counties (fig. 1), has been studied intensively for several decades. Among the more recent studies pertinent to the subject are those reported on by Lusczynski (1961a, b), Lusczynski and Swarzenski (1960, 1962, 1966), Perlmutter and Crandell (1959), Perlmutter and Geraghty (1963), Perlmutter, Geraghty, and Upson (1959), Soren (1970), and Swarzenski (1959). As a byproduct of much of this work, a network of so-called outpost wells was established to monitor the rate and extent of the landward movement of salty ground water (commonly referred to as salt-water encroachment) in the area.

The most recent report on salt-water encroachment in southeastern Queens and southern Nassau

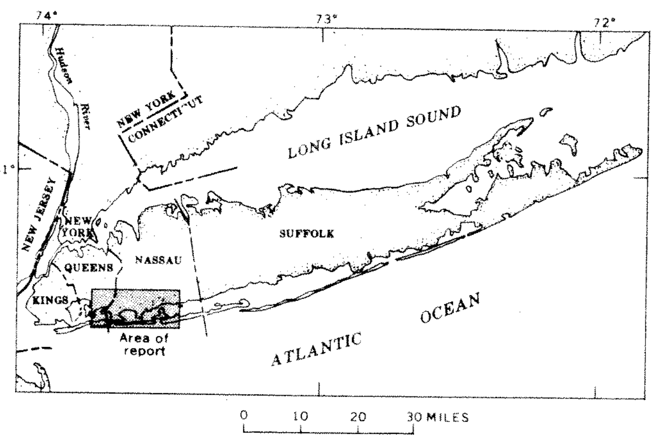

FIGURE 1.—Index map of Long Island, N.Y., showing area of report.

Counties (Lusczynski and Swarzenski, 1966) includes data from the outpost wells up to 1960–62. The major purpose of this paper is to review the chloride data obtained from 1960 to 1969 from the outpost wells and from other selected wells, and to consider the significance of these data, especially with regard to possible salt-water encroachment. Because salt-water encroachment into the deeper artesian aquifers is of primary concern to the Long Island water managers, the occurrence and movement of salty water in these aquifers are emphasized in this paper.

Acknowledgments.—Many individuals and agencies supplied much of the basic data given in this report. The authors are especially grateful to the

Nassau County Department of Health, the Nassau County Department of Public Works, and the New York State Department of Conservation, Division of Water Resources.

HYDROGEOLOGIC SETTING

The major hydrogeologic units beneath southeastern Queens and southern Nassau Counties and pertinent characteristics of these units are listed in table 1.

Under natural conditions, precipitation on Long Island was the source of all the fresh ground water beneath the study area (the shaded area in fig. 1). Ground water was discharged naturally by seepage to streams, which in turn flowed into the south-shore bays; by subsurface outflow to the bays and probably the Atlantic Ocean; and to a small extent by evapotranspiration near the shorelines.

At present (1969) ground-water recharge in the study area results mainly from (1) infiltration of precipitation through areas of bare soil, (2) subsurface inflow from upgradient areas, (3) infiltration of storm runoff through recharge basins, (4) injection of water used for industrial purposes into recharge wells, and (5) discharge of waste water into cesspools, septic tanks, and disposal basins (especially in the eastern part of the area). All the natural mechanisms of ground-water discharge are still operative in the area. In addition, a substantial quantity (several tens of millions of gallons per day) of ground water is artificially discharged by pumping and by the subsequent disposal of the pumped water to the sea by way of sewage-treatment plants.

TABLE 1.—*Major hydrogeologic units in southern Nassau and southeastern Queens Counties, Long Island, N.Y.*

Hydrogeologic unit [1]	Approximate maximum thickness in study area (feet)	Description
Upper glacial aquifer	100	Mainly sand and gravel of high hydraulic conductivity; some thin beds of clayey material of low hydraulic conductivity.
Gardiners Clay	100	Clay, silty clay, and a little fine sand of low to very low hydraulic conductivity.
Jameco aquifer	200	Mainly medium to coarse sand of moderate to high hydraulic conductivity.
Magothy aquifer	800	Mainly very fine sand, silt, and clay of low to very low hydraulic conductivity; some coarse to fine sand of moderate hydraulic conductivity; locally contains gravel of high hydraulic conductivity.
Raritan clay	200	Clay of very low hydraulic conductivity; some silt and fine sand of low hydraulic conductivity.
Lloyd aquifer	300	Sand and gravel of moderate hydraulic conductivity; some clayey material of low hydraulic conductivity.
Bedrock	---	Crystalline rock of very low interstitial hydraulic conductivity.

[1] Nomenclature after Cohen, Franke, and Foxworthy (1968).

Gross ground-water pumpage data for the period 1960–68 in selected subareas of Nassau and Queens Counties are listed in table 2.

TABLE 2.—*Gross pumpage in selected subareas of Long Island, N.Y., 1960–68*

[Data from the New York State Department of Conservation, Division of Water Resources]

Year	Pumpage (million gallons per day)				
	Nassau County	Queens County	Study area (fig. 1)	Mill Road well field	Long Beach
1960	146	67	35	4.9	5.6
1961	153	71	35	5.0	6.2
1962	172	74	40	5.1	7.1
1963	180	77	42	5.2	6.4
1964	194	78	46	5.6	6.8
1965	209	78	45	5.1	7.2
1966	215	75	47	5.0	7.6
1967	181	73	45	4.5	7.2
1968	208	78	50	5.0	8.0

Four bodies of salty ground water are found near and beneath parts of the study area—a shallow body in the upper glacial aquifer, an "intermediate wedge" that extends downward from the Gardiners Clay through the Jameco aquifer and into the upper part of the Magothy aquifer, a "deep wedge" that locally is in the Jameco aquifer but mainly is in the lower and middle parts of the Magothy aquifer, and a wedge in the Lloyd aquifer (Lusczynski and Swarzenski, 1966, p. F1 and pl. 3).

The shallow salty ground water is associated with, and is more or less freely connected with, the salty bays and estuaries and with the Atlantic Ocean. The intermediate and deep wedges thicken appreciably and ultimately merge in a seaward direction. Little is known about the wedge of salty ground water in the Lloyd aquifer except that it is believed to be seaward of the barrier beaches in the study area (see below). The three deepest wedges are moderately to highly confined (the salty ground water is under artesian pressure), and are, in one manner or another, hydraulically connected with the sea.

The landward extent of the intermediate and deep wedges of salty ground water, as mapped by Lusczynski and Swarzenski in 1961 (1966, fig. 5), is shown in figure 2. Sufficient data were not available in 1961 and are not presently available to map the landward limits of the other bodies of salty ground water accurately.

Mixtures of fresh and salty water form so-called zones of diffusion that separate the fresh and highly salty ground water in the study area. According to Perlmutter and Geraghty (1963, p. A92), the chloride content of the zones of diffusion on Long Island ranges from 10 to 40 mg/l (milligrams per liter) on the fresh-water sides to about 18,000 mg/l on the salt-water sides. Lusczynski and Swarzenski (1966, p. F19–F20) state that the chloride content of fresh ground water on Long Island is about 10 mg/l or less and that, "***a chloride concentration of more than 40 ppm [mg/l] in shoreline areas is assumed to indicate contamination by salty water."

CHLORIDE CONTENT OF WATER FROM WELLS

The chloride content of water from the outpost wells from 1960 through 1969 is listed in table 3. Significant trend-indicating changes in chloride content were noted in only 3 of the 30 wells—wells N6581, N6701, and Q1237.

Well N6581 is screened in the zone of diffusion near the leading edge of the deep wedge of salty ground water (fig. 2). The well is near the southern margin of the Mill Road well field, where pumpage during the past decade (table 2) has averaged about 5 mgd (million gallons per day). The moderately intensive local pumpage, a continual increase in regional pumpage, regional effects of a severe drought in 1962–66 (Cohen and others, 1969), decreased recharge resulting from urban development, and perhaps to some extent the effects of sewering in the area (Franke, 1968) have resulted in a decline in the water level in the well of about 2

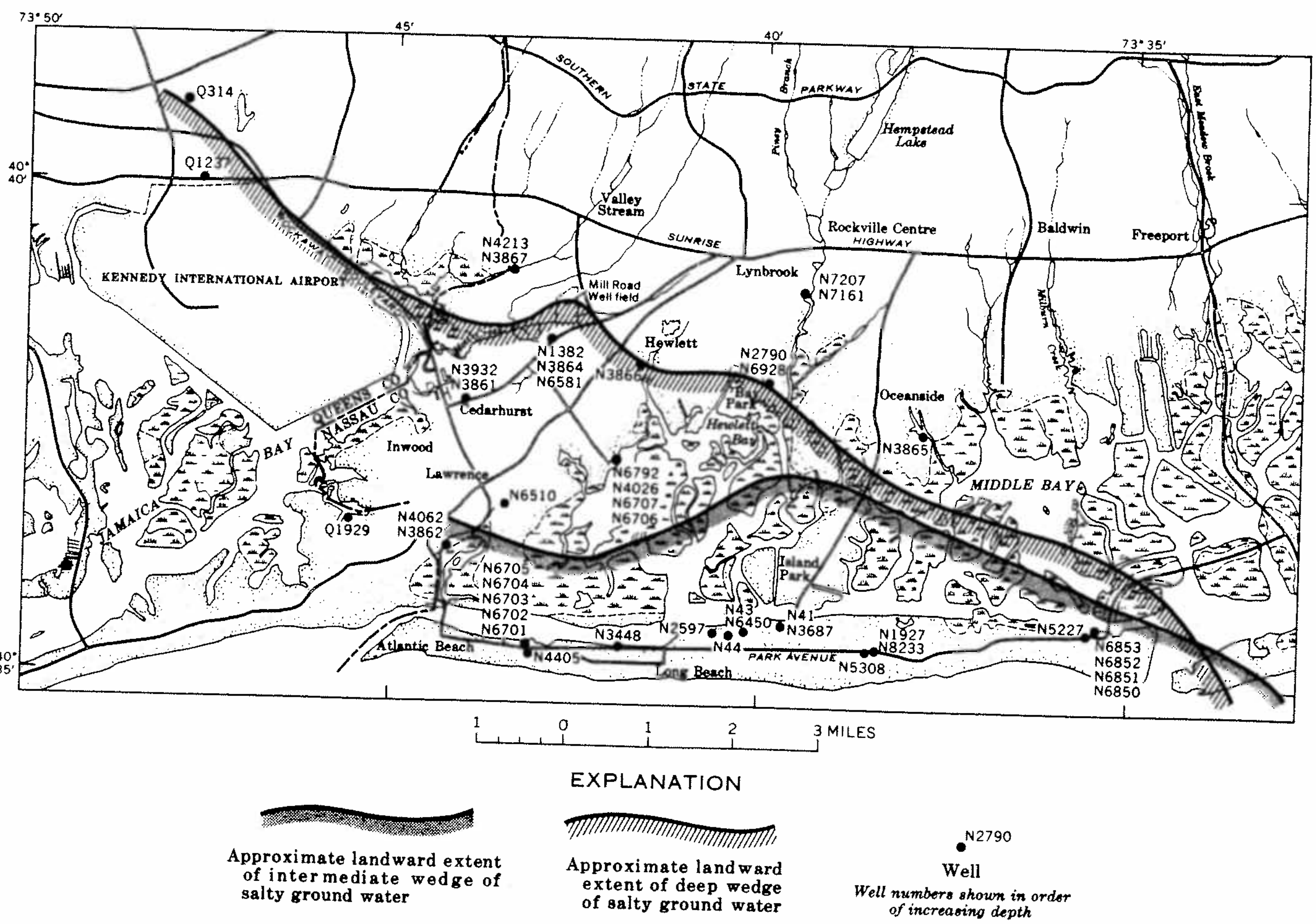

FIGURE 2.—Location of selected wells and the landward extent of the intermediate and deep wedges of salty ground water in southern Nassau and southeastern Queens Counties, Long Island, N.Y. Position of deep and intermediate wedges of salty ground water after Lusczynski and Swarzenski (1966, fig. 5).

TABLE 3.—*Chloride content of water from outpost wells in southern Nassau and southeastern Queens Counties, Long Island, N.Y.*

[Hydrogeologic units: Qug, upper glacial aquifer; Qg, Gardiners Clay; Qj, Jameco aquifer; Km, Magothy aquifer; Krc, Raritan clay. Analyses by several agencies. Rounding of data and use of decimals partly reflect the policy of the reporting agency]

Well No.	Hydro-geologic unit tapped	Depth of screen below sea level (feet)	Chloride (milligrams per liter)						
			1960	1961	1962	1963	1965	1967	1969
N1382	Qj	168–188	---	---	---	5	7	3.5	---
N2790	Km	535–557	3	4	4.5	5	5	3.3	3.0
N3861	Km	515–526	15,500	---	16,500	---	15,600	15,000	15,500
N3862	Km	289–299	---	---	---	2,200	2,030	2,000	2,000
N3864	Km	455–466	---	---	---	5.0	---	2.8	3.5
N3865	Km	548–558	4	---	---	5	---	4.1	5.5
N3866	Km	395–405	4	---	---	---	---	---	4.6
N3867	Km	499–509	5	---	---	5	6	3.8	4.0
N3932	Qj	165–169	5	---	---	5	5	3.7	3.8
N4026	Km	144–148	5.8	---	---	5	5	2.4	4.1
N4062	Qg	130–135	40	---	33	26	24	24	25
N4213	Qj	125–129	4	---	---	5	---	6.8	5.7
N6510	Km	447–452	14,500	---	14,600	14,200	11,840	---	---
N6581	Km	565–575	8,520	8,710	9,100	9,100	9,640	9,720	11,000
N6701	Krc	811–821	2,000	3,800	4,600	4,500	5,320	7,800	8,110
N6702	Km	656–666	15,800	15,900	16,000	15,000	14,700	16,000	16,000
N6703	Km	457–467	4,830	6,000	6,100	6,300	5,280	5,600	5,870
N6704	Km	273–283	9	8	7	8	6.0	7.0	6.6
N6705	Qj	136–146	12,200	12,500	11,900	11,000	10,800	12,200	12,400
N6706	Km	618–623	15,000	15,000	15,100	15,200	14,200	15,500	---
N6707	Km	487–497	1,150	1,400	1,700	1,600	1,420	1,400	1,580
N6792	Qug	42–44	---	---	6	7	---	6.1	7.9
N6850	Km	891–902	106	111	109	102	121	110	111
N6851	Km	544–549	3.6	6	6	6	---	4.0	4.0
N6852	Km	251–256	8,900	9,200	8,600	8,300	8,000	8,700	8,600
N6853	Km	120–125	4	4	4.5	5	---	3.6	3.4
N6928	Krc	710–720	13	---	11	12	---	13	12
N7161	Km	654–659	---	5	---	5	8	4	3.8
N7207	Km	87–90	---	---	4.5	6	5	4.3	3.7
Q1237	Qj	178–202	34	---	---	54	68	---	112

feet [1] since 1960. Accompanying the decline in water level, the chloride content of water in the well increased from 8,520 mg/l in 1960 to 11,000 mg/l in 1969.

Well Q1237, which is screened in the Jameco aquifer, taps the zone of diffusion near the upper part of the deep wedge of salty ground water. The water level in the well declined about 3 feet since 1960, to a point about 3 feet below sea level in 1969. During the same period the chloride content increased from 34 mg/l to 112 mg/l (table 3).

The chloride content of water from well N6701, which also taps the zone of diffusion, increased from 2,000 mg/l in 1960 to 8,110 mg/l in 1969. The well is screened near the bottom of the Raritan clay, very close to the base of the deep wedge of salty ground water (Lusczynski and Swarzenski, 1966, pl. 2, sec. *A–A'*). Since 1960, the water level in this well declined about 4 feet, to a point about 8 feet above sea level in 1969. To some extent, all the regional factors that affected the water level in well N6581 probably also affected the water level in this well. However, local pumpage from the Lloyd aquifer, which is only about 10–20 feet beneath the screen of well N6701, probably was the major cause of the decline.

The chloride content of water from selected public-supply, industrial, and private wells is listed in table 4. The first group of 12 wells listed, wells N41–N8233, are public-supply or abandoned public-supply wells on Long Beach, the barrier beach along the south shore of western and central Nassau County, and all tap the Lloyd aquifer. Most of the water in the upper glacial and Magothy aquifers beneath Long Beach is salty. However, water in the underlying Lloyd aquifer is fresh and, therefore, that aquifer is the sole source of fresh water for the communities on Long Beach. Pump-

[1] All water levels and changes in water levels in wells described in this report are expressed in terms of equivalent fresh-water heads (Lusczynski and Swarzenski, 1966, p. F41).

age on Long Beach increased from 5.6 mgd in 1960 to 8.0 mgd in 1968 (table 2).

The chloride content of water from 10 of the 12 wells in the group has been less than 15 mg/l since 1960, and the chloride content of the water from the 10 wells showed no particular upward or downward trend during the period 1960–69. Prior to 1960, the chloride content of water from well N41 was as high as 80 mg/l, but since 1960 it has decreased steadily to 5.6 mg/l in 1968. The casing of the well reportedly had failed (presumably because of rusting), and salty water was entering the well from one of the shallower aquifers. The ruptured casing was repaired in 1962. Nonetheless, the well was abandoned that same year, and since then has been pumped infrequently only to obtain samples for chemical analyses.

Well N1927 also was abandoned because a ruptured casing allowed salty ground water from the shallower aquifers to enter. Well N8233, which is about 100 feet from abandoned well N1927, was constructed as a replacement well; the chloride content of water from this well is only 4.4 mg/l.

Well Q314 is of particular interest because Perlmutter and Geraghty (1963, pl. 5) and Lusczynski and Swarzenski (1966, pl. 5) showed the leading edge of the deep wedge of salty ground water to be at or near the well in 1961. In 1940, the chloride content of water from the well was about 5 mg/l, and it increased at a fairly steady rate to about 20 mg/l in the late 1950's. Since 1960, it has fluctuated by about 1–3 mg/l, and in 1969 it reportedly was 2 mg/l greater than in 1960 (table 4). This slight increase in chloride content obviously cannot be considered to be indicative of significant landward movement of the wedge of salty ground water in the vicinity of the well since 1960.

A marked rise in chloride content, from 17 mg/l in 1961 to 1,300 mg/l in 1969, was noted in well Q1929 (table 4). The shallower aquifers in the vicinity of the well largely contain salty ground water. Down-hole photographic equipment was used to determine if a ruptured casing was allowing salty ground water to leak downward into the Lloyd aquifer. No break was found in the casing; however, a recent detailed chemical analysis indicates that the salty ground water pumped from the well apparently contains a small amount of detergent constituents (0.17 mg/l), which is probably characteristic of much of the shallow ground water in the area. Detergent constituents are not found in water from the Lloyd aquifer where that aquifer is more than several hundred feet below the water table, except in the vicinity of wells that are known or suspected to have ruptured casings. Accordingly, despite the negative evidence furnished by photographs, the increase in the chloride content of water from well Q1929 is believed to be related largely or entirely to leaks in the casing rather than more widespread salt-water encroachment into the Lloyd aquifer.

CONCLUSIONS

Increases in the chloride content of water from outpost wells Q1237 and N6581 from 1960 to 1969 are believed to have been caused by the landward movement of parts of the deep wedge of salty ground water beneath southern Nassau and southeastern Queens Counties. The heads in both wells

TABLE 4.—*Chloride content of water from selected production wells on Long Island, N.Y.*

[Hydrogeologic units: Qj, Jameco aquifer; Krl, Lloyd aquifer. Data largely from Nassau County Health Department. Rounding of data and use of decimals partly reflect the policy of the reporting agency]

Well	Hydrogeologic unit tapped	Depth of screen below sea level (feet)	Chloride (milligrams per liter)									
			1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
N41	Krl	1,190–1,250	24.8	19.2	16.8	---	12.0	7.4	8.0	6.2	5.6	---
N43	Krl	1,188–1,259	5.8	2.4	5.6	6.8	6.0	5.8	---	---	---	---
N44	Krl	1,184–1,254	9.8	6.2	8.0	8.8	8.4	7.5	6.2	7.2	7.2	8.2
N1927	Krl	1,149–1,209	2.0	---	---	12.4	11.8	41.0	---	---	---	---
N2597	Krl	1,169–2,129	6.0	3.8	7.2	6.4	7.4	7.6	7.4	6.6	6.0	6.2
N3448	Krl	1,187–1,227	9.0	---	9.0	7.8	8.6	9.0	8.2	10.4	8.6	8.4
N3687	Krl	1,190–1,240	4.8	3.6	5.4	4.8	---	5.0	6.2	5.0	4.6	5.2
N4405	Krl	991–1,061	10.2	---	11.4	9.4	11.8	11.0	10.4	12.8	11.0	12.6
N5227	Krl	1,190–1,250	2.0	2.6	---	3.2	2.6	3.6	3.6	2.2	2.0	3.2
N5308	Krl	1,150–1,210	3.4	---	4.8	2.8	3.2	2.9	3.0	3.0	4.2	6.8
N6450	Krl	1,210–1,270	5.0	---	6.2	5.8	5.6	6.4	5.6	6.0	4.8	5.8
N8233	Krl	1,170–1,220	---	---	---	---	---	---	---	---	---	4.4
Q314	Qj	209– 269	19	19	18	18	19	18	18	20	20	21
Q1929	Krl	961–1,012	---	17	16	18	---	65	180	---	215	1,300

declined from 1960 to 1969. In well Q1237, the decline in head is probably related to a widespread cone of depression, more than 10 square miles of which is below sea level, in southern Queens County. The landward encroachment of salty ground water in the area is thought to be fairly widespread (Soren, 1970). A much smaller cone of depression exists near well N6581, which partly reflects intensive pumping at the Mill Road well field. The salt-water encroachment seems to be limited to a small tongue of salty ground water in the immediate vicinity of the well field.

The increased chloride content in outpost well N6701 is mainly related to intensive pumping on Long Beach, which in turn is causing salty ground water in the Raritan clay to move downward toward the underlying Lloyd aquifer. To date, no firm evidence is available to conclude that salty ground water has invaded the Lloyd aquifer beneath Long Beach (either laterally or by downward leakage from the Raritan clay), except locally by downward flow through several abandoned wells having ruptured casings.

The positions of the landward limits of the intermediate and deep wedges of salty ground water as shown in figure 2 are those given by Lusczynski and Swarzenski (1966, pl.5, and fig. 12), and none of the presently available data can be used as a basis for shifting these positions either landward or seaward. In other words, if the toes of the wedges have moved landward since 1960, as they probably have locally (for example, in the vicinities of wells Q1237 and N6581), the coarseness of the network of available sampling points presently precludes a more exact delineation of the positions of the toes of the wedges and a clear recognition of movement of the wedges since 1960.

Finally, the data obtained since 1960 do not contradict the conclusions of Lusczynski and Swarzenski (1966, p. F56 and F71–72) that: (1) "The present (1961) occurrence, position, alignment, and even the sizable thickness and width of the zone of diffusion of the deep wedge of salt water as well as the intermediate wedge, therefore, are phenomena attributable mainly to natural conditions that prevailed long before the start of ground-water development in the report area;" (2) regionally, the deep wedge of salty ground water, "***is apparently moving no faster than 10 feet a year;" and (3) the intermediate wedge of salty ground water, "***is apparently moving landward at less than 10 to 20 feet a year."

REFERENCES

Cohen, Philip, Franke, O. L., and Foxworthy, B. L., 1968, An atlas of Long Island's water resources: New York Water Resources Comm. Bull. 62, 117 p.

Cohen, Philip, Franke, O. L., and McClymonds, N. E., 1969, Hydrologic effects of the 1962–66 drought on Long Island, New York: U.S. Geol. Survey Water-Supply Paper 1879–F, 18 p.

Franke, O. L., 1968, Double-mass-curve analysis of the effects of sewering on ground-water levels on Long Island, New York *in* Geological Survey Research 1968: U.S. Geol. Survey Prof. Paper 600–B, p. B205–B209.

Lusczynski, N. J., 1961a, Filter-press method of extracting water samples for chloride analysis: U.S. Geol. Survey Water-Supply Paper 1544–A, 8 p.

——— 1961b, Head and flow of ground water of variable density: Jour. Geophys. Research, v. 66, no. 12, p. 4247–4256.

Lusczynski, N. J., and Swarzenski, W. V., 1960, Position of the salt-water body in the Magothy(?) Formation in the Cedarhurst-Woodmere area of southwestern Nassau County, Long Island, N.Y.: Econ. Geology, v. 55, no. 8, p. 1739–1750.

——— 1962, Fresh and salty ground water in Long Island, New York: Am. Soc. Civil Engineers Proc. v. 88, no. 3207, p. 173–194.

——— 1966, Salt-water encroachment in southern Nassau and southeastern Queens Counties, Long Island, New York: U.S. Geol. Survey Water-Supply Paper 1613–F, 76 p.

Perlmutter, N. M., and Crandell, H. C., 1959, Geology and ground-water supplies of the southshore beaches of Long Island, N.Y.: New York Acad. Sci. Annals. v. 80, art. 4, p. 1060–1076.

Perlmutter, N. M., and Geraghty, J. J., 1963, Geology and ground-water conditions in southern Nassau and southeastern Queens Counties, Long Island, N.Y.: U.S. Geol. Survey Water-Supply Paper 1613–A, 205 p.

Perlmutter, N. M., Geraghty, J. J., and Upson, J. E., 1959, The relation between fresh and salty ground water in southern Nassau and southeastern Queens Counties, Long Island, New York: Econ. Geology, v. 54, no. 3, p. 416–435.

Soren, Julian, 1970, Ground-water and geohydrologic conditions in Queens County, Long Island, New York: U.S. Geol. Survey Water-Supply Paper 2001–A. [In press]

Swarzenski, W. V., 1959, Determination of chloride in water from core samples: Am. Assoc. Petroleum Geologists Bull., v. 43, no. 8, p. 1995–1998.