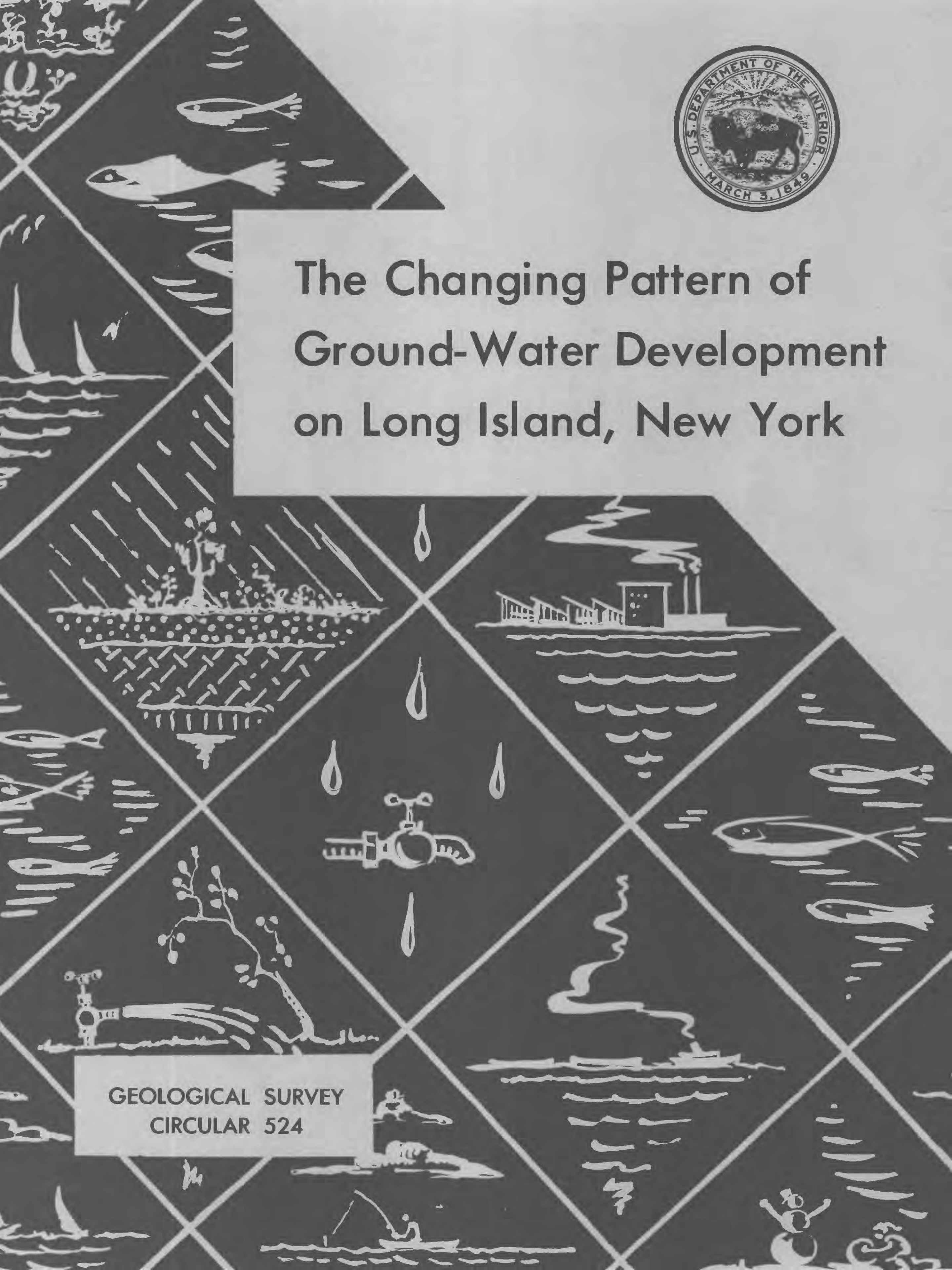
The Changing Pattern of Ground-Water Development on Long Island, New York



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The Changing Pattern of Ground-Water Development on Long Island, New York

By R. C. Heath, B. L. Foxworthy
and Philip Cohen

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ABSTRACT

Ground-water development on Long Island has followed a pattern that has reflected changing population trends, attendant changes in the use and disposal of water, and the response of the hydrologic system to these changes. The historic pattern of development has ranged from individually owned shallow wells tapping glacial deposits to large-capacity public-supply wells tapping deep artesian aquifers. Sewage disposal has ranged from privately owned cesspools to modern large-capacity sewage-treatment plants discharging more than 70 mgd of water to the sea.

At present (1965), different parts of Long Island are characterized by different stages of ground-water development. In parts of Suffolk County in eastern Long Island, development is similar to the earliest historical stages. Westward toward New York City, ground-water development becomes more intensive and complex, and the attendant problems become more acute. The alleviation of present problems and those that arise in the future will require management decisions based on the soundest possible knowledge of the hydrologic system, including an understanding of the factors involved in the changing pattern of ground-water development on the island.

INTRODUCTION

Even before the severe drought that is now (1965) affecting the Northeastern United States, Long Island was well known among water specialists for its underground-water resource, mainly as a result of both the magnitude of the ground-water resource and the unique aspects of man's utilization of that resource. The current drought has focused increased attention upon the vast amount of ground water in storage on Long Island and upon the large quantity of water being pumped from the system. In 1963, for example, an average of about 380 mgd (million gallons per day) was pumped from Long Island wells; these wells tap a fresh ground-water reservoir that has an estimated storage capacity of 10 to 20 trillion gallons. Nearly all the water pumped was for domestic and industrial use, and this pumpage probably represents one of the largest such uses of a single well-defined ground-water reservoir anywhere in the world.

The history of ground-water development on Long Island has been thoroughly documented, largely as a result of studies made by the U.S. Geological Survey in cooperation with the New York State Water Resources Commission and Nassau and Suffolk Counties. The water development has followed a general pattern which, although somewhat related to population density and local waste-disposal practices, has been controlled largely by the response of the hydrologic system to stresses that man has imposed upon the system. The purpose of this report is to summarize the highlights of the historical pattern of ground-water development on Long Island and to consider briefly the insight that the history of development affords regarding the future development and conservation of Long Island's most valuable natural resource.

GEOLOGIC ENVIRONMENT

Long Island (fig. 1) has a land area of about 1,400 square miles and is geographically a large detached segment of the Atlantic Coastal Plain. The island is underlain by crystalline bedrock, the uppermost surface of which ranges in altitude from about sea level at the northwest corner of the island to about 2,000 feet below sea level in the southeastern part of Suffolk County (fig. 2).

The bedrock is overlain by a wedge-shaped mass of unconsolidated sedimentary deposits

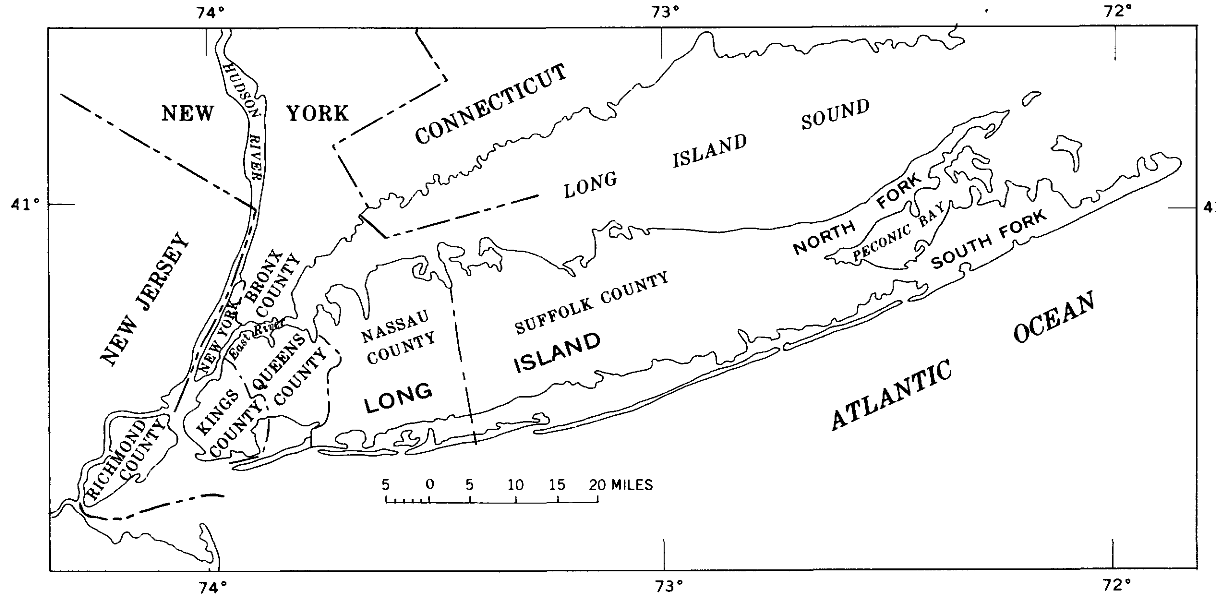


Figure 1.—Long Island and vicinity.

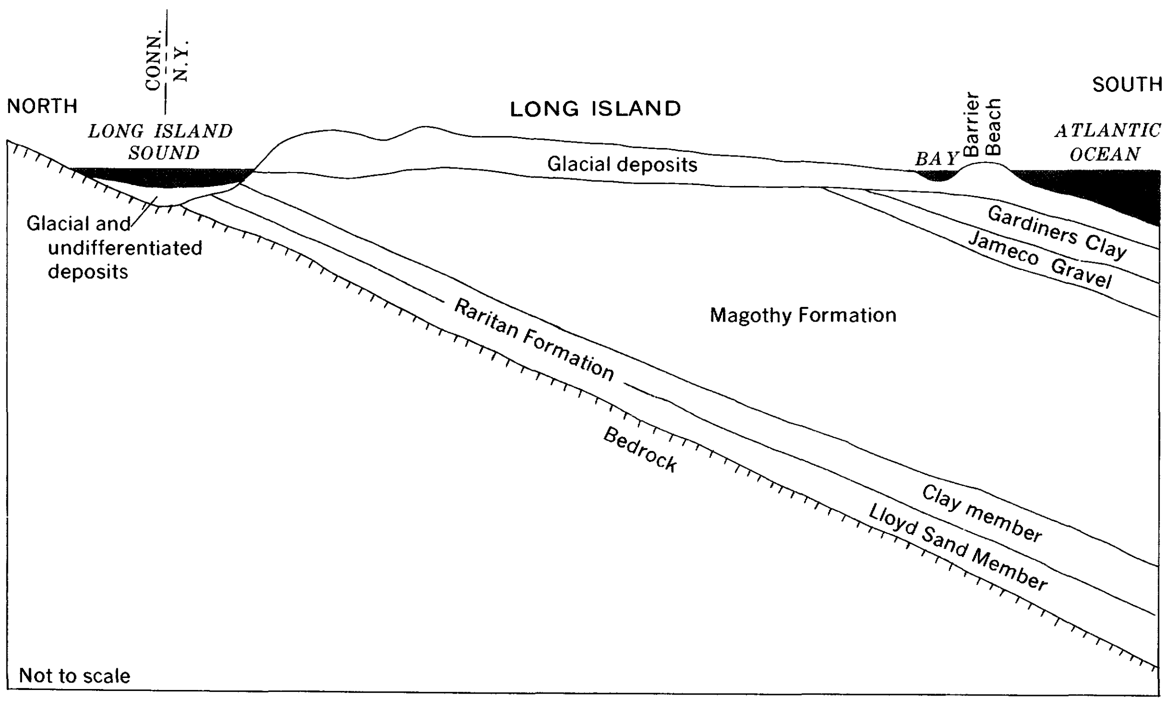


Figure 2.—Diagrammatic section showing general relationships of the major rock units of the ground-water reservoir in Nassau County.

that attain a maximum thickness of about 2,000 feet. These deposits constitute the ground-water reservoir of Long Island and can be divided into six major stratigraphic units, which differ in their geologic ages, mineral composition, and hydraulic properties. These units are, from oldest to youngest, (1) Lloyd Sand Member of the Raritan Formation, (2) clay member of the Raritan Formation, (3) Magothy Formation, (4) Jameco Gravel, (5) Gardiners Clay, and (6) glacial deposits. (Suter and others, 1949). The first three units listed are of Cretaceous age, and the last three are of Pleistocene age.

The Lloyd Sand Member of the Raritan Formation has a maximum thickness of about 300 feet and consists mainly of fine to coarse sand and some gravel and interbedded clay. It forms the basal water-bearing unit of the ground-water reservoir. The clay member of the Raritan Formation is composed mainly of clay but locally contains considerable sand; it also has a maximum thickness of about 300 feet. Hydraulically, the clay member is a leaky confining layer for the Lloyd Sand Member—retarding, but not preventing, vertical leakage of water to and from the Lloyd.

The Magothy Formation on Long Island is partly correlative with the Magothy Formation in New Jersey. It consists of complexly interbedded layers of sand, silt, and clay and some gravel in the lower part. The complexity of the interbedding and the character of fossils it contains suggest that the formation was mainly laid down under continental (flood-plain) conditions. The Magothy Formation is the thickest unit of the ground-water reservoir on Long Island, attaining a maximum thickness of about 1,000 feet. Its horizontal permeability differs widely from place to place and is considerably higher than its vertical permeability. It commonly yields more than 1,000 gpm (gallons per minute) per well. Water in the formation is largely under artesian conditions.

Near the north and south shores of the island, the Magothy Formation locally is overlain by the Jameco Gravel. The maximum thickness of the Jameco is about 200 feet. It consists mainly of medium to coarse sand, but locally contains abundant gravel and some silt and clay. The Jameco Gravel is moderately too highly permeable and yields as much as 1,500 gpm per well. Water in the formation occurs under artesian conditions.

The Gardiners Clay is mainly restricted in extent to two moderately narrow bands that parallel the north and south shores, and it is commonly underlain by either the Jameco Gravel or the Magothy Formation.

The surface of Long Island is composed mostly of material deposited either directly by Pleistocene continental ice sheets or by melt water derived from the ice sheets. These glacial deposits consist mainly of sand and gravel outwash in the central and southern parts of the island, and mixed till and outwash atop and between the hills in the northern part of the island. The glacial outwash deposits are highly permeable and therefore permit moderately rapid infiltration of precipitation.

HYDROLOGIC SYSTEM

The four major water-bearing units of the ground-water reservoir of Long Island are the glacial deposits, Jameco Gravel, Magothy Formation, and Lloyd Sand Member of the Raritan Formation (fig. 2). These four units contain mostly fresh ground water; however, locally they contain salty ground water or they are hydraulically connected with salty water of the ocean, sound, or bays. Under natural conditions recharge to the ground-water reservoir resulted entirely from the infiltration of precipitation, which is estimated to have averaged roughly 1 mgd per square mile (Swarzenski, 1963, p. 35). Most of the ground water moved laterally through the glacial deposits and discharged into streams or into bodies of salt water bordering the island without first reaching deeper water-bearing zones. Most of the remainder of the ground water moved downward through the glacial deposits into the Jameco Gravel or Magothy Formation, and from there part flowed laterally to the ocean and the remainder flowed downward through the clay member of the Raritan Formation into the Lloyd Sand Member. (See fig. 4.)

Estimates of ground-water discharge under natural conditions can be developed by extrapolation of data listed by Pluhowski and Kantrowitz (1964, p. 38–55) for the Babylon-Islip area, a large and reasonably representative part of Long Island. Those data suggest

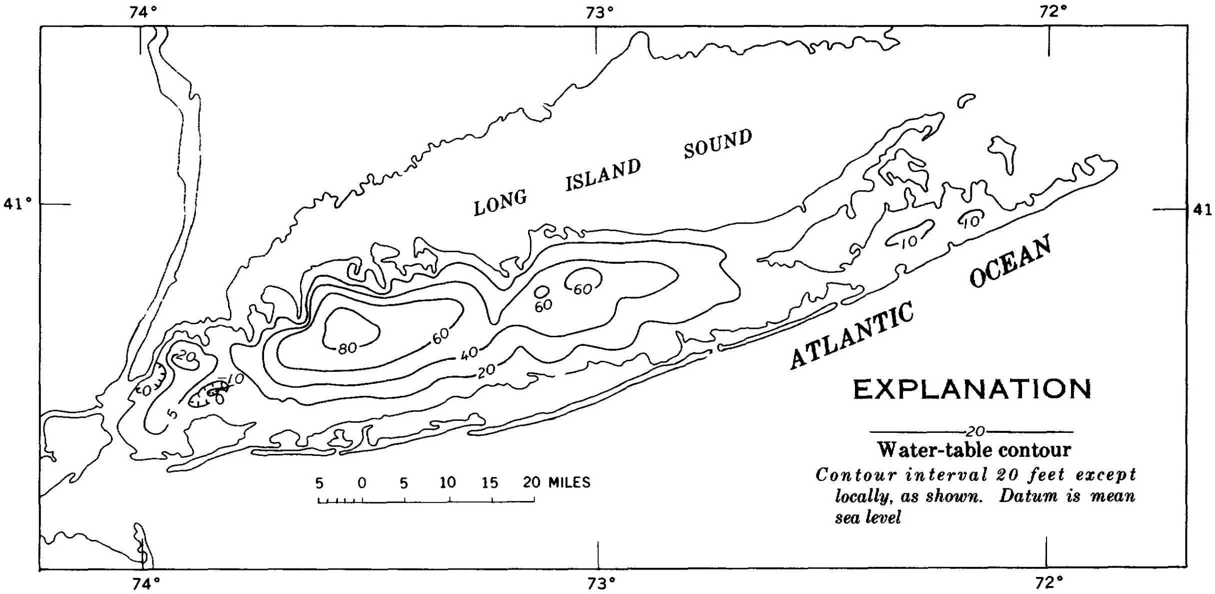


Figure 3.—Generalized contours on the water table (the upper surface of the ground-water reservoir) in 1961.

that about 90 percent of the total recharge ultimately discharged from the glacial deposits (mainly by seepage to streams), and about 10 percent discharged by subsurface outflow from the Magothy Formation, the Jameco Gravel, and the Lloyd Sand.

The water table on Long Island (fig. 3) and also the piezometric (pressure) surfaces of the underlying artesian aquifers (which have about the same general shape as the water table) form elongate mounds following roughly the configuration of the land surface. Two prominent highs characterize the water table—one centered in Nassau County and one centered in Suffolk County. Northwestern Queens County also has a small high in the water table. Other notable features are the cones of depression that extend below sea level in Kings and Queens Counties; these cones are in areas of past or current local overdevelopment of ground water.

CHANGES IN GROUND-WATER DEVELOPMENT WITH TIME

PHASE 1—PREDEVELOPMENT CONDITIONS

Ground-water development on Long Island has progressed and is progessing through several distinct phases. Under natural or predevelopment conditions (fig. 4), the hydrologic system was in overall equilibrium and long-term average ground-water recharge and discharge were equal. The general positions of the subsurface interfaces between fresh and salty water in each of the previously described geologic units were stable, reflecting the overall hydrologic balance. The interfaces were virtually at the coasts in the glacial deposits and were offshore in the underlying units.

PHASE 2

In the initial stage of development (fig. 5), which began with the arrival of the first European settlers, virtually every house had a shallow well drawing water from the glacial deposits and a cesspool returning waste water to the same deposits. As the population increased, individual wells were abandoned and public-supply wells were installed in the glacial deposits. The individual cesspools, however, were retained and little water was lost from the system during use. Although a considerable amount of ground water was being withdrawn, practically all of it was returned to the same aquifer from which it was removed. In general, therefore, the system remained in balance, and the positions of the interfaces between fresh and salt water remained practically unchanged. However, this cycle of ground-water development and waste-water disposal resulted in the pollution of the shallow ground water in the vicinity of the cesspools.

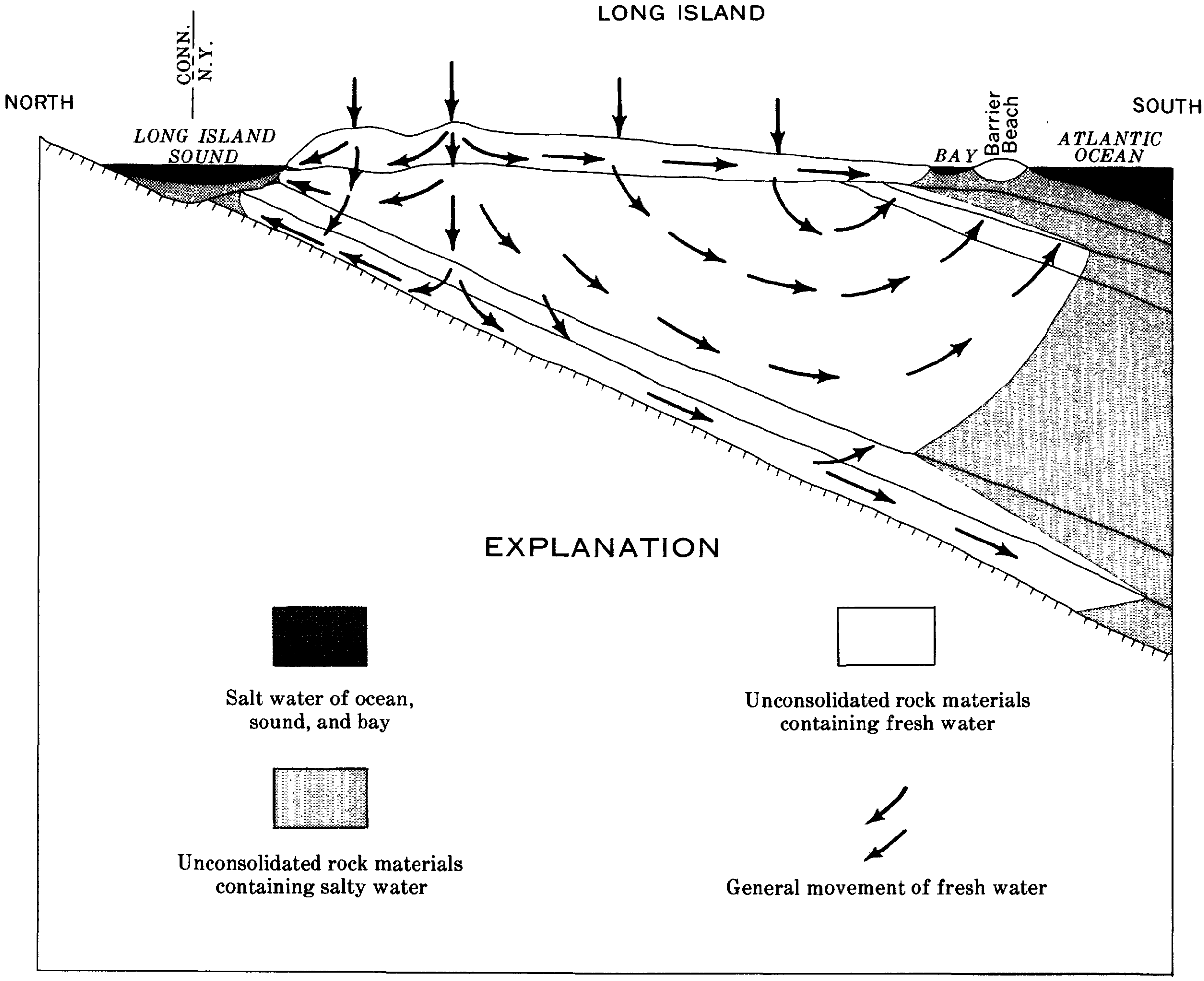


Figure 4.—Diagrammatic section showing predevelopment (phase 1) generalized ground-water conditions. Contacts between rock units are as shown in figure 2.

PHASE 3

In time, as the cesspool pollution spread, some shallow public-supply wells had to be abandoned and these were replaced with deeper public-supply wells, most of which tapped the Jameco Gravel and the Magothy Formation. Supply wells were also constructed in the deeper units at places where the glacial deposits contained water with objectionable amounts of dissolved iron or other troublesome natural constituents. Most of the water withdrawn from the deeper units was returned to the shallower glacial deposits by means of cesspools, and subsequently discharged to the sea by subsurface outflow or by seepage to streams (fig. 6).

As a result of the withdrawal of water from the Magothy Formation and the Jameco Gravel, and the concurrent decrease in hydraulic heads in these units, the downward movement of ground water from the overlying glacial deposits locally was increased. However, the increased downward movement only partially compensated for the withdrawals of water from the Magothy and Jameco deposits. Locally, a hydraulic imbalance developed in the Magothy and Jameco deposits and caused a decrease in the amount of fresh ground water in storage and a landward movement of salty water.

PHASE 4

The next major phase in the development of ground water on Long Island (fig. 7) was the introduction of large-scale sewer systems—notably in that portion of Long Island that is part of New York City (Kings and Queens Counties). Most of the pumped ground water that previously had been returned to

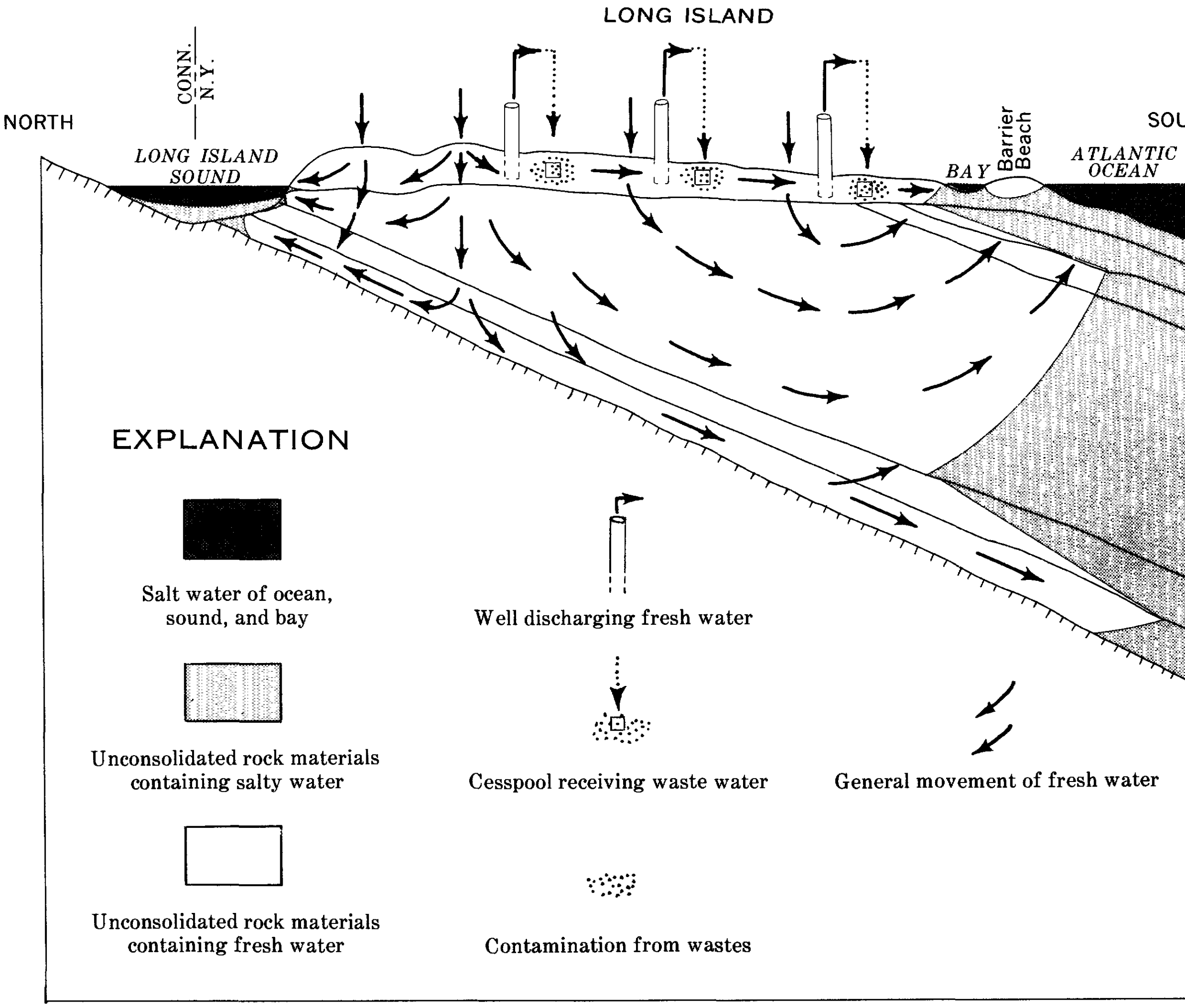


Figure 5.—Diagrammatic section showing generalized ground-water conditions during phase 2 of ground-water development (shallow supply wells and waste disposal through cesspools). Contacts between rock units are shown in figure 2.

the ground-water reservoir by means of cesspools was thereafter discharged to the sea through the sewers. Whereas the net draft on the ground-water system during the preceding phases of development was negligible, virtually all the ground water diverted to sewers during phase 4 represented a permanent loss from the system. The newly imposed stress on the ground-water system locally resulted in a rapid landward encroachment of salty water into the previously fresh ground-water reservoir. The most dramatic example occurred during the 1930's in Kings County (the Borough of Brooklyn), which by that time had been completely sewered for many years. In 1936, decreased natural recharge owing to urbanization and increased ground-water withdrawals, which during the previous few years averaged more than 75 mgd, caused ground-water levels in Brooklyn locally to decline to as much as 35 feet below sea level (Lusczynski, 1952, pls. 1 and 2). This local overdevelopment caused contamination of large parts of the ground-water reservoir in that area from sea-water encroachment.

In 1947 virtually all pumping for public supply in Kings County was discontinued and the Borough was thereafter supplied with water from the New York City municipal-supply system, which utilizes surface-water reservoirs in upstate New York. A notable exception was ground-water withdrawal for air-conditioning use. Such usage was permitted, however, only under the condition that the water was returned to the ground-water reservoir by means of injection wells (locally referred to as "diffusion" wells).

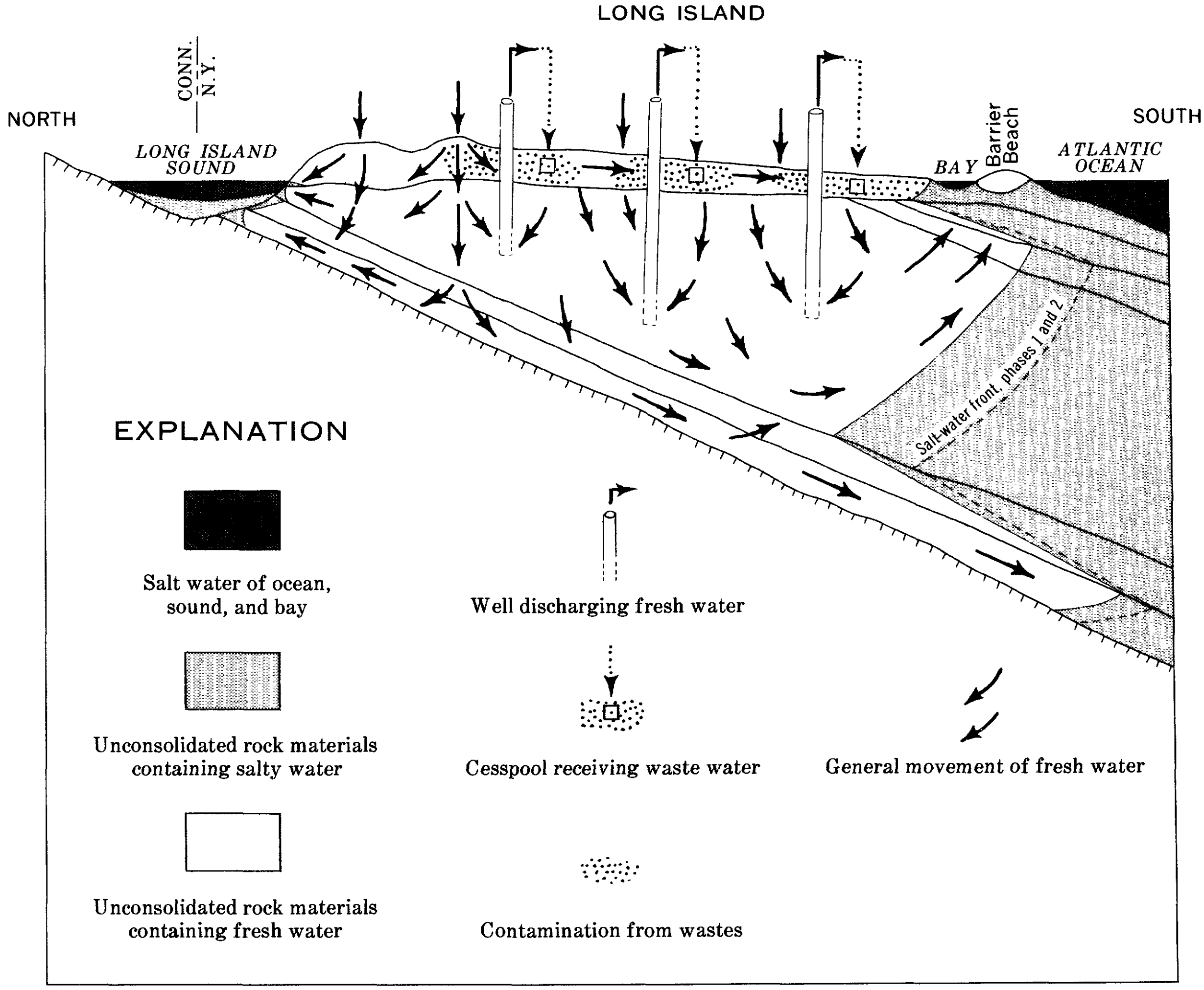


Figure 6.—Diagrammatic section showing generalized ground-water conditions during phase 3 of ground-water development (deep supply wells and waste disposal through cesspools). Contacts between rock units are as shown in figure 2.

PRESENT AREAL DIFFERENCES IN GROUND-WATER DEVELOPMENT

The present pattern of ground-water development on Long Island affords an excellent opportunity to observe and evaluate the historic trend of that development, because all the major phases of development described herein, except the predevelopment phase, can be observed now in different subareas of the island (fig. 8). Moreover, once the transitory status of present development in each subarea is recognized in relation to the pattern of historical trends, it becomes possible to predict and perhaps forestall some of the undesirable aspects of those trends.

Subarea A (fig. 8) includes roughly the eastern two-thirds of Suffolk County. Except for several small communities, the subarea is largely rural and has the lowest population density on Long Island. On the whole, the subarea can be characterized as being in phase 2 of ground-water development (fig. 5)—that is, most of the wells in the subarea tap the shallow glacial deposits and supply water to single-family dwellings. The bulk of this water is returned to the glacial deposits through individually owned cesspools, and in overall aspect the ground-water system is still in hydraulic balance.

Subarea B, in central Suffolk County, is experiencing the impact of the suburban expansion associated with the entire New York City metropolitan area. Farms and woodlands are giving way to housing developments, and most of the pumpage in the subarea is now from large-capacity public-supply wells that tap the glacial deposits.

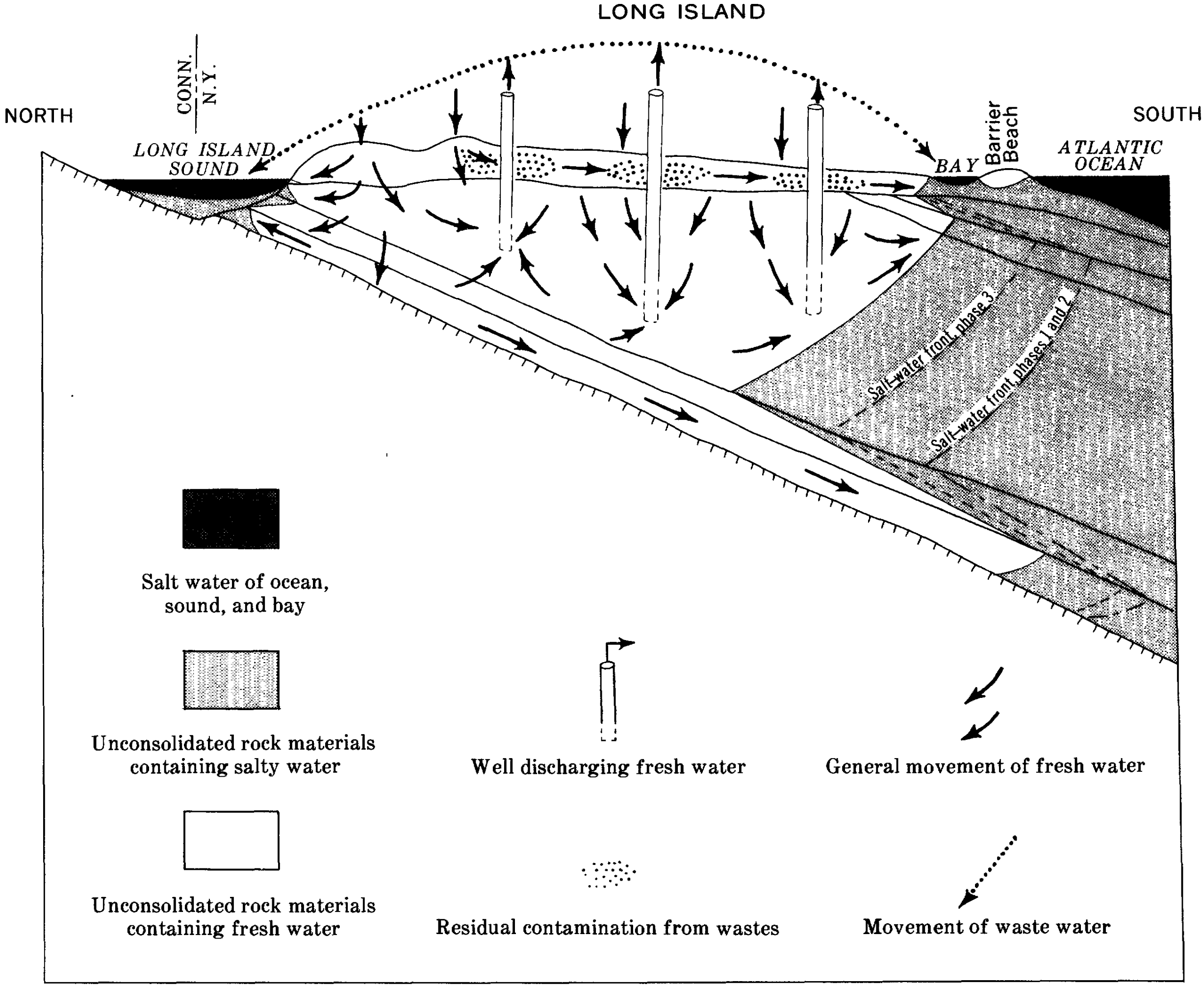


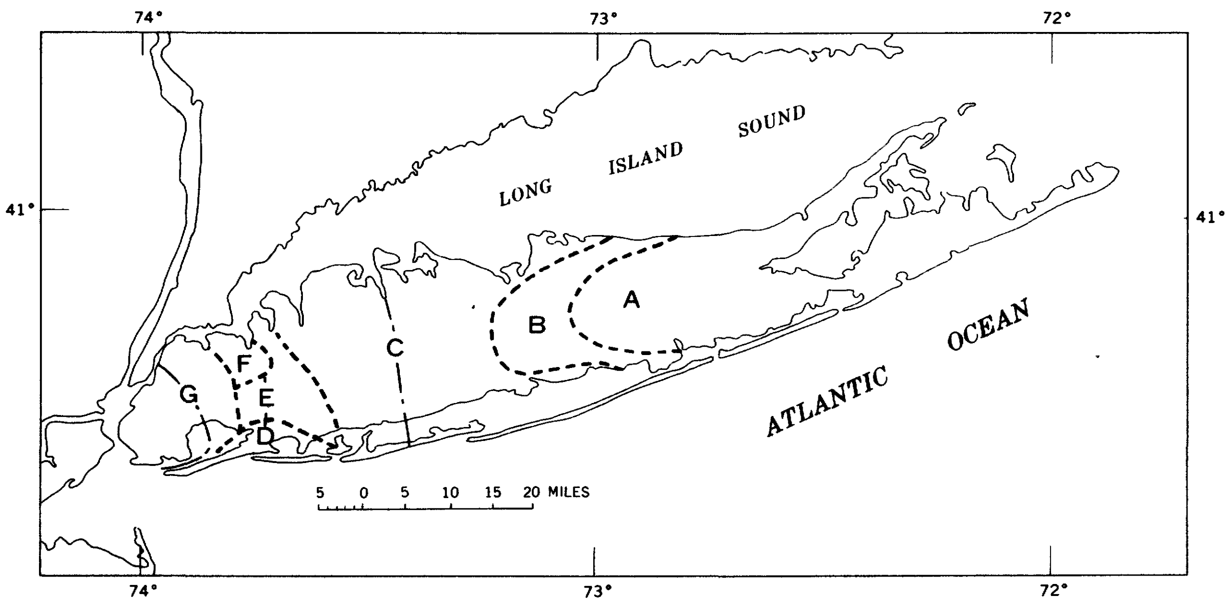
Figure 7.—Diagrammatic section showing generalized ground-water conditions during phase 4 of ground-water development (deep supply wells and waste disposal through sewers to adjacent salt-water bodies). Contacts between rock units are as shown in figure 2.

However, most of the sewage disposal is still through individually owned cesspools. Thus, the area is in a transition between phase 2 and phase 3 of development. Cesspool pollution still is not widespread, but is substantial enough to be of concern to local government agencies. Accordingly, plans are currently (1965) being made to construct sewers in the area and to gradually replace the wells that tap the glacial deposits with wells that will tap the Magothy Formation.

Subarea C includes the westernmost part of Suffolk County and the eastern two-thirds of Nassau County. Mainly because it is closer to New York City, this subarea was subjected to intensive suburban development earlier than was subarea B. Therefore, the population density and, accordingly, the water requirements in subarea C are substantially greater than in subarea B. Virtually the entire water supply for subarea C is obtained from large-capacity public-supply wells. The part of the subarea that is in western suffolk County obtains most of its water supply from public-supply wells, of which about half tap the glacial deposits and most of the remainder tap the Magothy Formation. In the part of the subarea that is in Nassau County, most of the public-supply wells tap the Magothy Formation.

Except for a few communities along the coast, most of subarea C is not sewered; practically all the domestic sewage is disposed of through individually owned cesspools. Thus, on the whole the subarea is in phase 3 of development (fig. 6). The system locally is out of balance owing to this development; however, substantial widespread salt-water encroachment has not yet occurred. Plans are being made to install sewers throughout the subarea.

Subareas D and E, which include parts of western Nassau and southeastern Queens Counties, are moderately to highly urbanized and are almost completely sewered. Practically the entire water supply for these subareas is derived from wells tapping the Magothy Formation, Jameco Gravel, and the Lloyd Sand Member of the Raritan Formation. Thus, these subareas are mainly in phase 4 of development and are characterized by a



EXPLANATION

Subarea	*Characteristics*
A	Phase 2 of development. Pumpage mainly from shallow privately owned wells. Waste water returned to shallow glacial deposits through cesspools; local contamination of glacial deposits by cesspool effluent. System virtually in balance; positions of salt-water fronts unchanged.
B	Transition between phase 2 and 3. Pumpage from privately owned and public-supply wells. Waste water returned to shallow glacial deposits by way of cesspools; areas of cesspool-effluent contamination spreading. System virtually in balance.
C	Phase 3 of development. Pumpage mainly from deep public-supply wells; waste water returned to shallow glacial deposits by way of cesspools. System locally out of balance, causing local salt-water intrusion.
D	Phase 4 of development. Pumpage almost entirely from deep public-supply wells; waste water discharged to the sea by way of sewers. System out of balance; salty water actively moving landward.
E	Phase 4 of development. Pumpage almost entirely from deep public-supply wells; waste water discharged to the sea by way of sewers. System out of balance; may be subject to salt-water intrusion in the future.
F	Very little ground-water development. Water supply derived from New York City municipal-supply system; waste water discharged to the sea by way of sewers. System in balance.
G	Very little ground-water development. Water supply derived from New York City municipal-supply system; waste water discharged to the sea by way of sewers. Large areas contain salty ground water owing to former intensive ground-water development and related salt-water intrusion.

Figure 8.—Water-development subareas in 1965.

hydrologic imbalance (fig. 7). The imbalance, which is accentuated because more than 70 mgd of water derived from the ground-water reservoir of these subareas currently is being discharged to the sea by way of sewage-treatment plants, is mostly clearly manifested in subarea D, where salty water is moving landward (Lusczynski and Swarzenski, 1960; Perlmutter and Geraghty, 1963). If the present trend continues, subarea D (the area of active salt-water encroachment) probably will expand at the expense of subarea E.

Subarea F, in northeastern Queens County, receives nearly its entire water supply from the New York City municipal-supply system. The subarea is sewered; however, because ground-water pumpage is negligible, the ground-water system is largely in balance.

Subarea G is the most highly urbanized and receives virtually all its water from the New York City municipal system. The entire subarea is sewered. As previously noted, large areas in Kings County were invaded by salty water because of substantial overdevelopment and the resulting decline in ground-water levels. Similarly, salty water had invaded the ground-water reservoir in parts of western Queens County. Water levels in Kings County have recovered appreciably since the mid 1940's, when the consumptive ground-water uses were drastically reduced. Presumably, the salty water is retreating seaward and is being diluted by recharge derived from precipitation, but precise data regarding these changes are lacking.

CONCLUSION

Ground water probably will continue to be the major source of water for most of Long Island (except for Kings and Queens Counties) for at least the next several decades. Moreover, if the present trends continue, the ground-water resources of the island probably will continue to be depleted—perhaps at an accelerated rate. The historic trends of ground-water development and the present status of development strongly suggest that such depletion will in time cause salt-water contamination of larger and larger parts of the ground-water reservoir. Moreover, the areas in which such contamination occurs, in addition to extending inward from the coasts, probably will also extend farther and farther eastward as the population continues to expand in that direction.

Several alternative methods of conserving and augmenting the ground-water resources of Long Island are currently being considered. These include, among others, desalting of sea water with the use of atomic energy, artificial recharge, and the reclamation of water from sewage. The consequences of such possible measures are highly significant inasmuch as the future well-being of several million people is at stake. However, even with the most promising of conservation methods, wise management will be required to gain the fullest use from the available fresh-water supply while also preventing undue hardships resulting from local overdevelopment of the ground-water reservoir. Fully effective management requires:

1. Recognition of the unity of the hydrologic system of Long Island.

2. The best obtainable scientific information about the system and how it functions.

3. Sound evaluation of the various alternative methods of water development and conservation, guided by available scientific information—including the hydrologic consequences of the historic and present-day changing pattern of ground-water development on Long Island.

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