Availability of Fresh Ground Water Montauk Point Area Suffolk County Long Island, New York

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1613-B

Prepared in cooperation with the U.S. Air Force

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By NATHANIEL M. PERLMUTTER *and* FRANK A. DELUCA

RELATION OF SALT WATER TO FRESH GROUND WATER

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AVAILABILITY OF FRESH GROUND WATER, MONTAUK POINT AREA, SUFFOLK COUNTY, LONG ISLAND, NEW YORK

By NATHANIEL M. PERLMUTTER and FRANK A. DELUCA

ABSTRACT

Ground water is the only source of supply at the Montauk Air Force Station in eastern Suffolk County. The water is contained in the upper 200 feet of deposits of late Pleistocene age, which are broadly divided into an upper unit of undifferentiated till and stratified drift and a lower unit of stratified drift.

Fresh water in the principal aquifer, which is in the lower unit, is a lens-shaped body, which lies above salty water containing as much as 11,300 ppm of chloride. The fresh water is under artesian pressure and has a head ranging from about sea level to 3.5 feet above sea level. Pumping rates of 50 to 100 gpm cause salty water to move toward the supply wells from below.

The optimum pumping rate of most wells is about 30 gpm. New wells should be drilled as remote as possible from existing wells, and the well screens should be set as high above the zone of diffusion as the deposits permit.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

Ground water is the only source of supply for general use and air conditioning at the Montauk Air Force Station in eastern Suffolk County. Owing to proximity of Block Island Sound and the Atlantic Ocean, the fresh-water bearing beds are readily susceptible to salt-water encroachment. In the fall of 1960, the U.S. Air Force requested the U.S. Geological Survey to make an investigation of ground-water conditions at the Montauk Air Force Station where the water supply was being contaminated by encroaching salt water.

The investigation was limited to the Station and nearby hydrologically related areas. It included studies of (1) the areal extent, thickness, character, and hydraulic properties of the fresh-water bearing beds; (2) movement of the fresh water; (3) quality of the water; (4) delineation of the boundary between fresh water and salt water beneath the area; (5) the relation between pumping and salt-water encroachment; and (6) proposed sites of new supply wells at the Station.

LOCATION AND DEVELOPMENT OF THE AREA

The Montauk Point area is in the town of Easthampton, Suffolk County, at the extreme eastern point of Long Island (fig. 1).

The investigation, covering a total area of about 3.5 square miles, was concentrated chiefly in the Montauk Air Force Station (about 0.15 square mile) and in the unused part of the U.S. Military Reservation (about 0.55 square mile), which adjoins the station on the west and the east (pl. 1). As this report was nearing completion, the authors were informed by the U.S. Air Force (written communication, May 1961) that the Air Force Station would be enlarged to include a substantial part of the area now designated as Military Reservation on plate 1. The area is bounded on the north by Block Island Sound and on the east and the south by the Atlantic Ocean. The western boundary is arbitrary and is about 0.3 mile east of Montauk Harbor (fig. 1), which is another large body of salt water.

Prior to 1941, the Montauk Point area was occupied chiefly by a small number of summer homes, a resort hotel and restaurant, several dude ranches, Montauk State Park, and Montauk Lighthouse, which is maintained by the U.S. Coast Guard. All these places were supplied with water by individual wells. About 1941, much of the central and eastern part of the report area was acquired by the U.S. Army for the construction of Camp Hero. At least five wells (S3259, S3260, S3261, S19496, and S19498) were constructed for use by the Army; several former private wells included in the land purchase also may have been pumped from time to time. Wells on Long Island are numbered serially by counties generally in the order in which wells are drilled. The letter prefixing the number is the initial of the county. All numbers are assigned by the New York State Water Resources Commission. No records of the quality or quantity of ground water pumped at Camp Hero from 1941 to 1946 are available.

Shortly after the end of World War II, Camp Hero was shut down except for use as a reserve training center. About 1951, a rectangular strip of land in the western part of the former camp was taken over by the U.S. Air Force for construction of the Montauk Air Force Station. At first the original supply wells and pumps were used; later larger capacity pumps were installed. By 1959, all the original wells were abandoned. The chief supply in 1961 was from wells, S17231 and S17859 (replaced in 1962 by wells S20766 and S21077).

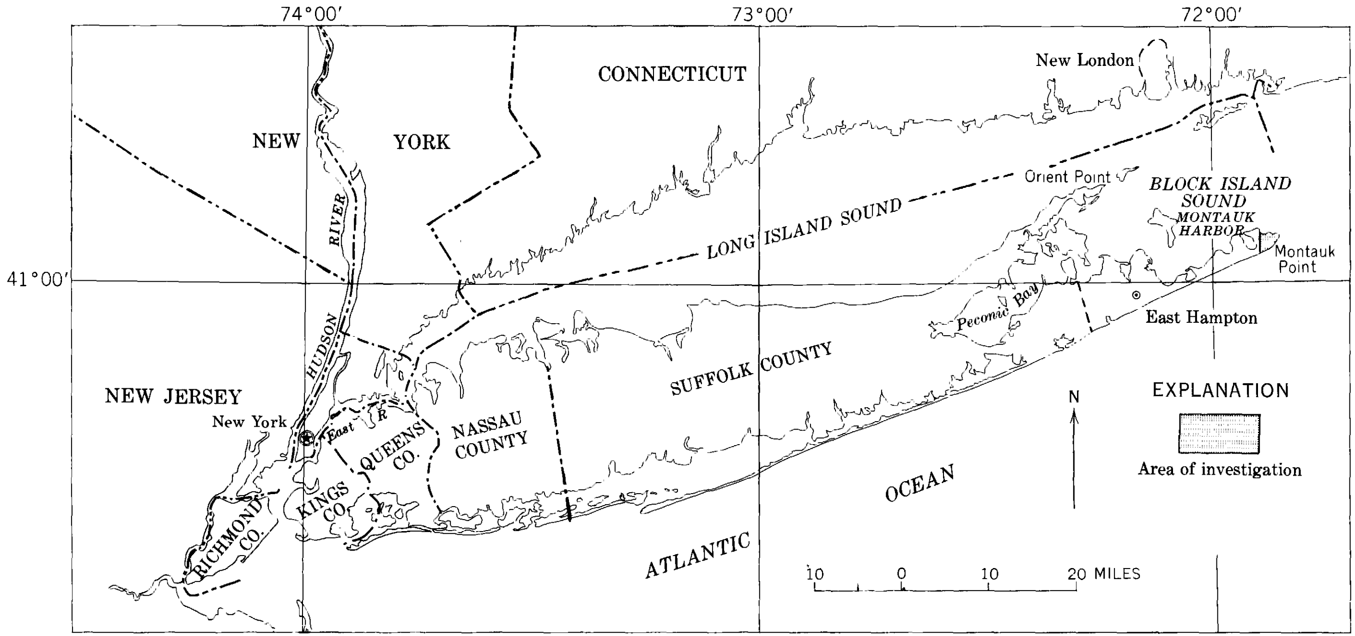

FIGURE 1.—Map of Long Island, New York, showing area of investigation.

TOPOGRAPHY AND DRAINAGE

Montauk Point is at the eastern extremity of the Ronkonkoma moraine. The moraine forms a ridge of coalescing hills traversing Long Island from west to east and marks the maximum advance of an ice sheet during late Pleistocene time.

The land surface, characterized by knob-and-kettle topography, ranges in altitude from sea level to about 100 feet above sea level. Steep wave-cut bluffs rise abruptly from 30 to 80 feet above narrow boulder-strewn beaches (figs. 2 and 4) along the eastern and southern shores. The land surface along the north shore declines gradually to sea level, and low wave-cut cliffs, where present, are less than 20 feet high. A few isolated low hills separated by marshy lowlands occur just north and west of the Montauk Lighthouse.

More than 50 kettle holes of various sizes and depths are occupied by swamps and ponds (pl. 1). Most of these are readily discernible in the field and on aerial photographs, but only a few of the larger ones are shown on plate 1. The kettle holes were occupied by detached masses of ice, which were partly or entirely covered by glacial deposits. Melting of the ice blocks and collapse of surrounding material left depressions, or kettle holes, in the land surface.

Most of the surface runoff is through four small unnamed streams (pl. 1). Three of the streams flow northwestward to Oyster Pond; the fourth flows southward to the Atlantic Ocean. Miscellaneous stream-discharge measurements made on March 31, 1961, are given in table 1. The measurements were made probably under low-flow conditions as no significant amount of rain had fallen since March 24, 1961. In much of the area precipitation runs off in temporary channels and in gullies to the Atlantic Ocean, to Block Island Sound, and into kettle holes.

TABLE 1.—*Miscellaneous stream-discharge measurements, Montauk Point area, Mar. 31, 1961*

[Measurements by Surface Water Branch, U.S. Geol. Survey; see pl. 1 for location of stations]

Station	Discharge		
	Cubic feet per second	Million gallons per day	Gallons per minute
1	0.65	0.42	292
2	.23	.15	103
3	.13	.09	60
4	.04	.03	20
5	.24	.15	106
Total	1.29	0.84	581

CLIMATE

The Montauk Point area has a temperate marine climate, which is influenced greatly by the Atlantic Ocean and Block Island Sound. Moderate temperatures prevail; the mean annual temperature at Bridgehampton, about 25 miles west of the Montauk Lighthouse, was 50.9°F (table 2) during the period 1931–60. The mean annual precipitation during the same period was 47.73 inches. Mean monthly precipitation ranges from a low of 2.9 inches in July to a high of 4.7 inches in November.

A nonrecording rain gage was operated at Montauk Air Force Station from October 1960 to April 1961. Its records were compared with records of the Bridgehampton station, and showed a general correspondence, although the total precipitation was 27.09 inches at Montauk Air Force Station and 30.12 inches at Bridgehampton during the period of record.

METHODS OF INVESTIGATION

After a brief reconnaissance of ground-water conditions at Montauk Air Force Station and vicinity by the writers in September 1960, the U.S. Air Force requested the U.S. Geological Survey to make a more detailed investigation of the ground-water resources. During November 1960, a power auger was used to drill 13 auger holes to depths of about 80 to 160 feet below land surface. Geologic samples were obtained at most of the holes, but owing to contamination from caving and contact of the augers with the wall of the hole, as they were raised and lowered, the samples were considered to be only approximately representative of the deposits.

TABLE 2.—*Precipitation and temperature at Bridgehampton, Long Island, N.Y., 1931–60*

[Annual precipitation: absolute minimum, 32.28 in. in 1957; absolute maximum, 66.87 in. in 1958; mean 1931–60, 47.73 in. Annual temperature (° F): mean maximum, 58.6; mean minimum, 43.3; mean annual 50.9. Compiled from U.S. Weather Bur. reports]

Month	Precipitation					Temperature		
	Minimum		Maximum		Mean monthly (inches)	Mean monthly maximum (° F)	Mean monthly minimum (° F)	Mean monthly (° F)
	Inches	Year	Inches	Year				
January	0.55	1955	9.25	1958	4.20	38.9	25.1	32.0
February	1.65	1941	6.76	1939	3.61	39.0	24.9	31.9
March	2.28	1947	9.99	1953	4.61	44.7	30.6	37.7
April	1.28	1942	6.24	1947	3.65	54.5	38.9	46.7
May	1.07	1939	7.09	1948	3.45	64.4	47.9	56.2
June	0.22	1957	6.90	1941	2.86	73.5	57.1	65.3
July	0.52	1944	6.85	1959	2.88	79.3	63.4	71.4
August	0.73	1935	13.19	1952	4.25	78.6	62.8	70.7
September	0.08	1941	10.28	1960	3.41	72.3	56.5	64.4
October	0.51	1946	5.87	1939	3.57	63.1	46.9	55.0
November	0.77	1931	10.22	1944	4.73	52.8	37.9	45.4
December	1.58	1943	9.81	1936	4.08	42.1	27.7	34.9

Thirteen observation wells, 2 inches in diameter and ranging in depth from about 70 to 150 feet, were installed at nine sites (test well symbols, pl. 1). At four of these sites, pairs of shallow and deep wells were installed to observe heads at different depths in fresh and salt water. The wells were developed and pumped by compressed air with a gasoline-driven jet pump.

Water from four of the observation wells was analyzed for chemical content. About 100 analyses were made of the chloride content of water from the observation wells and pumping wells in the report area. A water-level measurement program, begun immediately after the construction of the observation wells, was continued through September 1961. Water-stage recorders were installed on several wells for periods ranging from a few days to several weeks. The altitude of measuring points on observation wells were related to mean sea level by spirit leveling, and a water-level contour map (pl. 1) was prepared.

Thirty-four active and abandoned wells were inventoried (table 3), and a brief examination was made of the surficial geology, particularly of the exposures in cliffs along the south shore.

PREVIOUS INVESTIGATIONS

The surficial geology of the Montauk Point area has been described briefly by Fuller (1914) in a report, which contains a geologic map of Long Island and a few sketches of outcrops at Montauk Point. As part of another island-wide study of the ground-water resources, Suter, deLaguna, and Perlmutter (1949) prepared contour maps showing the depth to the Cretaceous deposits and bedrock beneath Long Island, including the Montauk area. A report by Perlmutter and Crandell (1959, p. 1064) presents generalized sections of the southshore beaches of Long Island, which suggest the presence of salt water in the deep aquifers beneath Montauk Point. However, no detailed study of the water resources of the area had been made prior to the present investigation.

ACKNOWLEDGMENTS

The writers acknowledge the cooperation of the U.S. Army Corps of Engineers, who supplied large-scale maps and other engineering data on former Camp Hero; the New York State Water Resources Commission, which provided records of existing wells; land owners who gave permission to enter their property to measure and install observation wells; and several well drilling firms which provided advice in planning the construction of the observation wells. The close cooperation of military and civilian personnel at both the Suffolk

County Air Force Base, Westhampton, N.Y., and the Montauk Air Force Station expedited the drilling of the test wells and the collection of hydrologic data.

GEOLOGY

The Montauk Point area is underlain by crystalline bedrock of Precambrian age upon which rest, in succession, unconsolidated deposits of Cretaceus, Pleistocene, and Recent age. As the bedrock and the Cretaceous formations are believed to contain salt water and are not penetrated by any wells in or near the project area, only a brief description of them, condensed from Suter, deLaguna, and Perlmutter (1949, p. 13–46 and pls. 10, 13), is given.

PRECAMBRIAN BEDROCK

The bedrock probably consists of gneiss and schist. Its surface is about 1,000 to 1,300 feet below sea level and slopes southeastward about 80 feet per mile. Very salty water is probably contained in openings along joints and other fractures in the rock. Because the bedrock has low permeability and contains only salty water, it is not considered an aquifer.

CRETACEOUS FORMATIONS

Immediately above the bedrock is the Raritan formation, which is about 300 to 400 feet thick. The Raritan is divided into a lower unit called the Lloyd Sand Member and an upper unit called the clay member. The Lloyd Sand Member is an artesian aquifer that contains fresh water in the western part of Long Island, but at Montauk Point it probably contains salty water only. The overlying clay member confines the water in the Lloyd.

The Raritan Formation is overlain by undifferentiated deposits of Cretaceous age that include the Magothy and probably several younger Cretaceous formations (Perlmutter and Crandall, 1959). These deposits contain permeable zones partly separated by lenticular beds of silt, sandy clay, and clay. The permeable zones probably could yield as much as 1,000 gpm to individual large wells, but the water is believed to be nearly as salty as the ocean. The Cretaceous surface in western Long Island is dissected by channels as deep as 300 to 500 feet below sea level. Similar deep channels probably exist beneath parts of the Montauk Point area, but the data are scanty as the deepest test well in the report area is terminated in glacial deposits at a depth of 130 feet below sea level.

TABLE 3.—*Records of wells, Montauk Point area*

[All wells screened in late Pleistocene deposits]

Depth of well: Reported depths given in feet; sounded depths given in feet and tenths. Top of well within 1 ft of land surface, unless indicated otherwise in Remarks column.
Use of water: A, abandoned; AFS, Air Force supply well; D, domestic; N, not used; O, observation; S, stock.
Measuring point: Ag, air gage; Hc, hole in cover; Ls, land surface; Pb, pump base; Ta, top of angle iron; Tc, top of casing; Tf, top of flange; Tn, top of nipple.
Water level: Reported depths given in feet; measured depths given in tenths and hundredths.
Remarks: gpm (gallons per minute).

Well	Owner or tenant	Depth of well (feet)	Diameter of well (inches)	Use of water	Measuring point		Water level		Temperature of water		Remarks
					Description	Altitude (feet above mean sea level)	Depth below measuring point (feet)	Date	(°F)	Date	
S1202	U.S. Coast Guard	35.6	6	A	Hc	32.80	27.63	Apr. 12, 1961			
S1245	Deep Hollow Ranch	113	6	D, S	Tn	55.93	52.58	Apr. 8, 1961			
S1473	Mr. Lewis Kayel	109	6	A		75					Yield, 10 gpm.
S2149	Montauk Water Supply Corp.	112	8	A		45					Driller reports indication of salting.
S2150	do	70	8	A	Tc	30	23.98	Apr. 7, 1961			Top of well 1.6 ft above land surface.
S2151	do	74	8	A	Ls	38	21	June 1927			Yield, 75 gpm.
S2440	Mr. Lewis Kayel	117	4	D	Tn	70					Yield, 5 gpm. Measuring point about 7 ft below land surface.
S3259	U.S. Air Force	106	6	A			58	May 1942			Formerly U.S.A.F. well 1. Yielded 40 gpm with drawdown of 6 ft after pumping 8 hr in 1941. Replaced by S17231.
S3260	do	112	6	A	Ta	65.03	60	June 1942			Formerly U.S.A.F. well 2. Yielded 40 gpm with drawdown of 5 ft after pumping 8 hr in 1941. Measuring point about 8 ft below land surface.
S3261	do	123	6	A	Pb	72.69	70.27	Apr. 12, 1961			Formerly U.S.A.F. well 3. Yielded 40 gpm with drawdown of 6 ft in 1941. Specific capacity 4.8 gpm per ft. Measuring point about 8 ft below land surface.
S3599	U.S. Coast Guard	69	6	A	Tn	27.14	25.85	do			
S7421	Long Island State Park Comm.	95	6	N	Tc	31.45	[1] 29.23	do			Specific capacity 10.7 gpm per ft. Measuring point about 5 ft below land surface.

S15812	do	95	10	D	Tc	31	29	Nov. 15, 1957			Specific capacity 11 gpm per ft. Measuring point about 5 ft below land surface. Yielded 150 gpm with drawdown of 14 ft in 1957.
S17231	U.S. Air Force	126	8	AFS	Pb	66.88	64.34	Oct. 13, 1960	52	Jan. 5, 1961	U.S.A.F. well 1A. Deepened 10 ft, October 1960. Screen length, 20 ft. Replaced by S20766(1B), 127 ft deep, in April 1962. Water contained 300 ppm of chloride in July 1962.
S17859	do	126	8	AFS	Ag	76.34	69	July 14, 1959	52	Sept. 9, 1960	U.S.A.F. well 3A. Yields 100 gpm with drawdown of 26 ft after pumping 8 hr. Replaced by nearby well S21077 in August 1962. Water is salty.
S19482	do	82.3	2	O	Tc	47.68	44.88	Apr. 12, 1961	52	Dec. 10, 1960	
S19483	do	82.0	2	O	Tc	16.69	13.45	do	[2] 52.5	Apr. 8, 1961	
S19484	do	70.4	2	O	Tc	50.85	47.33	do	[2] 52.5	do	
S19485	do	140.0	2	O	Tc	51.04	48.13	Apr. 19, 1961	[2] 53	do	
S19486	do	76.8	2	O	Tc	69.32	66.66	Apr. 12, 1961			
S19487	do	80.0	2	O	Tc	31.84	29.01	do			
S19488	do	87.3	2	O	Tc	49.17	46.59	do	[2] 52.3	Apr. 8, 1961	New supply well S21084, 118 ft deep, installed nearby in August 1962.
S19489	do	124.6	2	O	Tc	48.83	46.29	do	[2] 52.1	do	
S19490	do	103.5	2	O	Tc	31.91	[3] 30.01	do	[2] 52.4	do	
S19491	do	71.5	2	O	Tc	32.33	[3] 30.53	do	[2] 53	do	
S19492	do	150.5	2	O	Tc	44.95	44.22	do	51	Dec. 9, 1960	Temperature, 52.5°F,[2] Apr. 8, 1961.
S19493	do	70.9	2	O	Tc	44.86	[1] 42.42	do	50	Mar. 22, 1961	
S19494	do	87.4	2	O	Tc	58.60	56.05	do	[2] 51.9	Apr. 8, 1961	
S19495	American Telephone and Telegraph Co.	70–100(?)		D							Depth uncertain; submersible pump.
S19496	U.S. Air Force			N					52	Sept. 8, 1960	Used occasionally for emergency supply; yields 20 to 30 gpm. Chloride content of water increased to 150 ppm by July 1962 after several months of intermittent pumping.
S19497	do	100.4	4	A	Tf	65.45	[1] 63.60	Apr. 12, 1961			
S19498	do		4	A							Formerly U.S. Army well 4. Obstruction in well at 78 ft.
S19499	Indian Field Ranch	96	2	D, S	Tc	25.6	22	1950			
S19500	do	26	1¼	A	Tc	25.66	9.75	Apr. 19, 1961			

[1] Mean daily water level from recorder graph.
[2] Temperature measured by electronic thermometer.
[3] Water level estimated.

PLEISTOCENE DEPOSITS

GENERAL CHARACTER AND STRATIGRAPHY

The Pleistocene deposits of Long Island are end products of the advance and melting of several ice sheets during the Pleistocene Epoch. Because of the complex geologic history of these deposits, which are important sources of ground water, a summary of the general character of glacial deposits and of the sequence of glacial units in Long Island is given below, followed by a description of the strata in the Montauk Point area.

Glacial deposits may be divided into two principal types: (1) till and (2) stratified drift. Till is predominantly composed of unsorted or poorly sorted deposits of boulders, gravel, sand, silt, and clay, dropped directly from melting ice. Till deposited as an irregular surficial mantle is called ground moraine. A ridge composed chiefly of till and marking the former front of an ice sheet is called an end moraine. Stratified drift is deposited by meltwater streams as outwash deposits, in lakes as glaciolacustrine deposits, and in the sea as glaciomarine deposits. Stratified drift is generally distinctly bedded and well graded, owing to the sorting action of the water from which it is deposited. The beds may range in texture from gravel to clay size, depending on the velocity of the water and the size of the source material. A detailed account of the origin and nature of glacial deposits is given in Flint (1957).

The lowermost formation of Pleistocene age on Long Island is the Jameco Gravel, a coarse-grained outwash deposit. Above the Jameco is the Gardiners Clay, a fossiliferous marine interglacial formation composed chiefly of beds of silt and clay. The beds above the Gardiners Clay consist of several sequences of outwash and till. Fuller (1914, p. 114–157) divided these units into the Jacob Sand and the Manhasset Formation. He subdivided the Manhasset Formation into two outwash members separated by a till member called the Montauk Till, after the type area at Montauk Point. According to Fuller, erosion of the Manhasset Formation was followed by deposition of more outwash and till during the last, or Wisconsin Stage of glaciation. The uppermost deposits of till were laid down as part of the Ronkonkoma end moraine, which forms the surface of most of the Montauk Point area.

Because of the difficulty in recognizing discrete units of till and outwash in many well logs and outcrops, the Geological Survey generally uses the informal name upper Pleistocene deposits for glacial deposits of post-Gardiners age. Although Fuller believed that the post-Gardiners deposits were partly Illinoian and partly Wisconsin in age, later workers, including Wells (1934, p. 121–122), and Mac-

Clintock and Richards (1936, p. 332), have suggested that they were laid down entirely during the Wisconsin Stage.

PLEISTOCENE STRATIGRAPHY OF THE MONTAUK POINT AREA

Because the evidence from generalized well logs and well samples was scanty and because not enough time was available to make a detailed examination of the lithology and structural features of the outcrops along the south shore, the glacial deposits in the report area were not correlated specifically with known Pleistocene formations but have been broadly divided into (1) a lower unit of stratified drift and (2) an upper unit consisting of undifferentiated deposits of till and stratified drift (pl. 2).

LOWER UNIT OF STRATIFIED DRIFT

The lower unit of stratified drift is composed chiefly of nonmarine grayish-brown medium to coarse sand and gravel and some thin lenses of clay and silt. It does not crop out, hence is known entirely from well logs and a few samples. A sample from a depth of 120–126 feet below land surface at well S17231 (pl. 1) consists chiefly of angular to subangular clear and iron-stained quartz (about 80 percent) and miscellaneous grains (about 20 percent), which include granite, gneiss, schist, and the minerals garnet, biotite, chlorite, and hornblende, and other dark minerals. Because of their high permeability, thickness, and extensive distribution, the beds of the lower unit comprise the principal aquifer in the report area (see "Ground Water").

UNDIFFERENTIATED DEPOSITS OF TILL AND STRATIFIED DRIFT

Immediately above the lower unit of stratified drift is an undifferentiated unit of varied lithology composed of interbedded deposits of till and stratified drift about 30 to 100 feet thick (see diagonally ruled area on pl. 2). Although not clearly discernible in plate 2, a study of the well logs and outcrops suggests that, in general, the lower 20 to 40 feet of the undifferentiated deposits consists of interbedded gray and brown clay, laminated green and gray silt and clay, and some thin lenses of fine brown sand (figs. 2, 3, pl. 2). Samples of micaceous silt from depths of 55–75 feet below land surface, near S19849, consisted chiefly of quartz, biotite, and muscovite. No forams or diatoms were found in the material. The middle part of the undifferentiated deposits is probably composed largely of gray and brown compact clayey and gravelly till, which grades laterally into fine-grained stratified drift in some places. Immediately above the compact till is generally stratified drift, which ranges in thickness from a featheredge to about 30 feet and is composed chiefly of beds and lenses of brown and gray silt, fine to medium sand, and clayey

FIGURE 2.—Outcrop showing till above stratified drift composed chiefly of interbedded silt and clay, south side of Montauk Air Force Station. (Photograph by U.S. Geological Survey.)

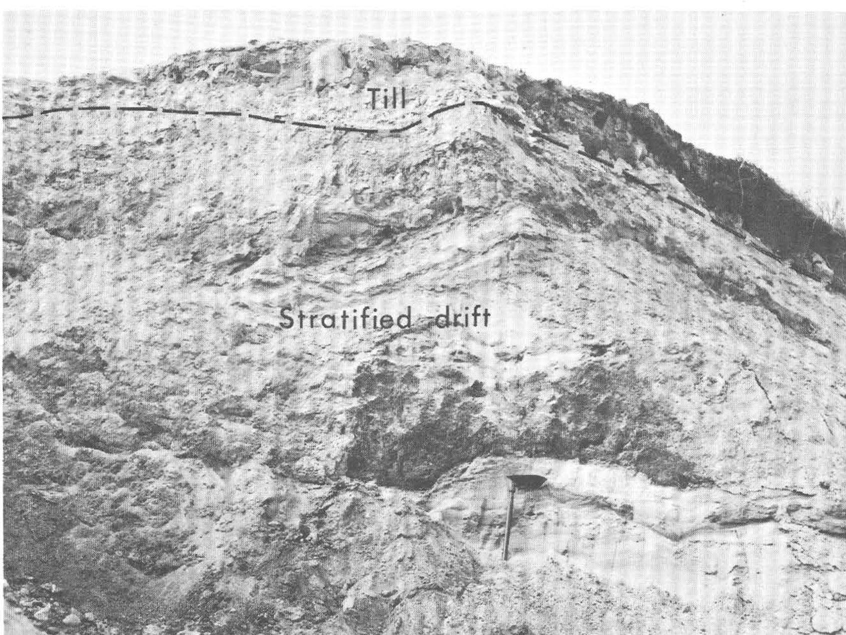

FIGURE 3.—Close-up view of till and underlying stratified drift composed chiefly of silt and clay, south side of Montauk Air Force Station. The trencher is lying against a lens of fine sand. (Photograph by U.S. Geological Survey.)

sand (fig. 4 and pl. 2). The uppermost part of the undifferentiated unit is generally a loose brown clayey till, about 5 to 20 feet thick, which contains some boulders. In some outcrops the intervening stratified drift is missing, and the upper till apparently rests directly on the lower till.

The till sheets and stratified drift, which crop out and are penetrated by wells in the report area, are probably correlative mostly with the upper Pleistocene deposits of western Long Island, but conceivably older Pleistocene units such as the Gardiners Clay and Jameco Gravel also may be present. Lohman (1939, p. 231–232) reports an assemblage of marine, brackish-water and fresh-water species of Pleistocene diatoms in a greenish-gray clay, reported to be the Gardiners, collected at an outcrop about half to three-quarters of a mile west of Montauk Lighthouse (pl. 1). The assemblage represents climatic conditions similar to or warmer than those of the present, which suggests an interglacial stage. As most of the species are living at present in the same region, Lohman concluded that the stage could not be named with the data on hand. It is not certain whether the clay examined by Lohman is correlative with the Gardiners Clay or "20-foot" clay found in western Long Island or neither. Additional field examination of the outcrops and more detailed laboratory study of samples are required before more specific correlations of the beds can be made.

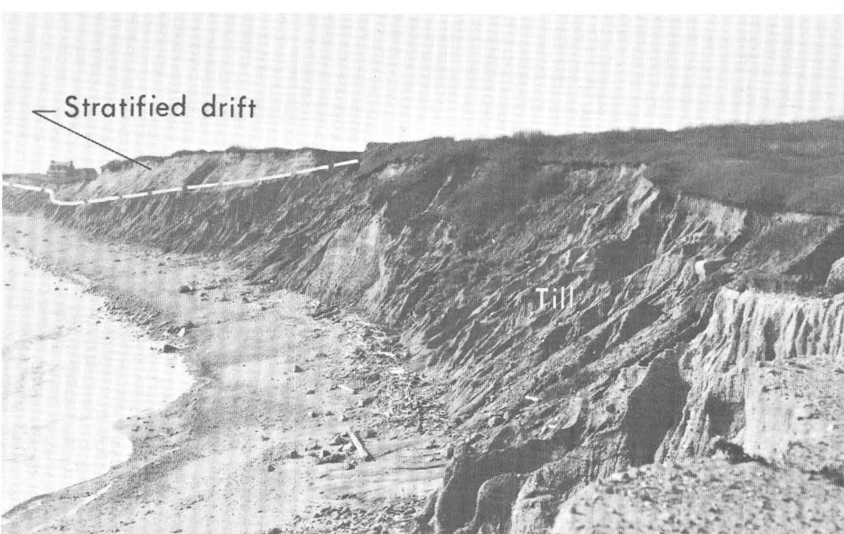

FIGURE 4.—Outcrop showing stratified drift above till, south side of Montauk Air Force Station. (Photograph by U.S. Geological Survey.)

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RECENT DEPOSITS

Thin deposits of sand, gravel, and boulders deposited in Recent time are distributed along the narrow beaches of Montauk Point. Large boulders and cobbles are most common on the southern and eastern shores (figs. 2 and 3). Sand and swamp deposits are more common along the low-lying north shore. Reddish lenses of garnet and ilmenite-rich sand can be seen in many places in beach deposits bordering the bluffs. The Recent deposits are uninmportant as aquifers because of their thinness, small intake area, and proximity to sea water.

GROUND WATER

SOURCE AND OCCURRENCE

The source of all fresh ground water in the report area is precipitation on the land surface, which averages about 48 inches annually. If all the precipitation were available for ground-water recharge, it would be equivalent to 2.3 million gallons per day per square mile. However, part is lost by direct evaporation from the soil and plants and from ponds and swamps that occupy numerous kettle holes; part is transpired by numerous trees and other forms of vegetation; part runs off to the sea in several small streams (pl. 1) whose discharge reaches a peak during and immediately after heavy precipitation; part is lost by seepage from cliffs along the south shore; and part percolates downward to replenish the ground-water reservoir.

Although no detailed studies have been made, general comparison of conditions at Montauk Point with those in western Long Island suggests that about 25 percent of the precipitation (12 inches, or about 570,000 gpd per sq mi) reaches the water table during a year of average precipitation. During years of above- or below-average precipitation, ground-water recharge is proportionately greater or lesser than average.

After seeping through the soil zone the water percolates downward through the pore spaces in the sand, gravel, silt, and clay to the main zone of saturation in the lower part of the undifferentiated deposits of till and stratified drift (pl. 2). The upper surface of the zone of saturation is called the water table. Scattered perched water bodies are found above the main water table, owing to lenses and beds of silt and clay, which retard downward movement of water. Some water in the upper part of the main zone of saturation moves to discharge areas at the shoreline, and some percolates slowly downward through confining beds of till, silt, and clay to the underlying principal aquifer. Water in the principal aquifer is under artesian pressure owing to the relatively low permeability of the overlying beds. The imaginary surface to which water in wells tapping the principal aquifier rises is called the piezometric surface (pl. 1). Except for withdrawals through wells, most water in the principal aquifer discharges to the sea by upward seepage at and near the shoreline.

WATER IN THE UNDIFFERENTIATED DEPOSITS OF TILL AND STRATIFIED DRIFT

Undifferentiated deposits of till and stratified drift form the upper unit shown on plate 2. Owing to the poor sorting and clay content of the till and to the predominance of silt and sandy clay in the stratified part of the unit, the undifferentiated deposits probably cannot yield substantial amounts of water to individual wells in most parts of the area. Some water occurs in the undifferentiated deposits as perched water bodies above the main water table, and some is contained in minor permeable zones below the water table. The lower part of the undifferentiated unit consists chiefly of saturated deposits of till, silt, and clay, which serve mainly as confining beds for the underlying principal aquifer.

PERCHED WATER BODIES

Perched water bodies are generally small isolated bodies of water temporarily stored above the main water table in scattered lenses of permeable material underlain by clay and silt. During the drilling of most of the observation wells and during the foundation test borings for several structures at the Montauk Air Force Station, water was reported at depths ranging from about 5 to 25 feet below land surface, or about 35 to 100 feet above sea level. These altitudes, which are as much as 40 to 95 feet above the water level in the principal aquifer (pl. 1), are a strong indication of the existence of perched water bodies as they are too high to represent the main water table.

The fact that perched water is common was verified further by the history of test well S19486 in the northeast corner of the U.S. Military Reservation (pl. 1). Land surface at the well is about 70 feet above sea level. During the drilling of the auger hole for the well, the material from 0–8 feet was reported as dry; 8–16 feet as moist; and at 16 feet as a perched water zone of unknown thickness. A well driven in the auger hole to a depth of 65 feet below land surface remained dry for several months. To determine whether the well was plugged, it was filled with water, which seeped out through the screen in a few days. In March 1961 the well was driven about 12 feet deeper and penetrated the main zone of saturation between about 68 and 70 feet below land surface.

Perched water bodies may yield sufficient water for intermittent domestic use, but they generally are not dependable if large amounts are required for long periods. During months of low precipitation, wells tapping perched water-bearing zones may go dry, owing to the large declines in water level in short periods of time, which are characteristic of these zones. An example of the large fluctuations which may be expected in perched water tables is given by the record of a test boring for a building near well S19495 in the center of the Montauk Air Force Station. When the boring was completed at a depth of 30 feet on November 22, 1955, the water level was 10 feet below land surface (about 50 feet above sea level). The water level declined during the next several days and by November 26 it was 23 feet below the land surface, a decline of 13 feet.

MINOR WATER-BEARING ZONES

Scattered minor water-bearing zones occur below the main water table in lenses of sand and gravel in the undifferentiated deposits of till and stratified drift. The location, thickness, extent, and continuity of these zones in most of the area is not apparent from present data. The upper limit of these zones is the main water table; the lower limit is unknown. As nearly all the wells terminate in the underlying principal aquifer, the altitude and configuration of the water table can only be estimated. Scanty data from test holes, drilled with a power auger, suggest that it may be as high as 10 to 17 feet above sea level in the central part of the area, about 16 feet above sea level in the southwestern part (S19500, table 3), and about at sea level at the shoreline. The water table is mainly in beds of silt, clay, and till, which are not suitable for development of large supplies.

In some shallow minor water-bearing zones, the water is under watertable, or unconfined, conditions; but at greater depths where these zones are overlain by thick beds of silt and clay, the water may be confined. Indirect evidence of the low yield of the minor water-bearing zones is the fact that all the active wells, including those constructed for domestic use, were drilled through these zones and completed in the principal aquifer. Two wells, S19500 and S1202, originally completed in the shallow beds were abandoned and replaced by wells screened in the principal aquifer. However, as the data are scanty and to make the maximum use of all available supplies, all future wells should be logged carefully and samples should be taken at 5-foot intervals to evaluate further the possible existence of productive zones at shallow depths.

CONFINING BEDS

The data shown on plate 2, and records of other wells not on the line of these sections, indicate that the lower part of the undifferentiated deposits consists chiefly of beds of silt, clay, sandy clay, and possibly some deposits of till. At several wells (for example, S17231, pl. 2) the confining beds are at least 20 to 30 feet thick, and at one place they are about 65 feet thick (S1245, pl. 2). The effectiveness of these confining beds is confirmed hydraulically by the differences in head between the water table and the piezometric surface of the principal aquifer, which are estimated to be as much as 8 to 12 feet in the central part of the area. At well S19500 (26 feet deep) in the southwestern part of the area, the water table is about 16 feet above sea level, or about 13 feet above the piezometric surface (pl. 1). The barometric effects and the distinct tidal effects shown by the hydrographs (figs. 5 and 6) of wells which are as much as 0.4 mile from the shore and screened in the principal aquifer, is additional evidence of the wide extent and low permeability of the confining beds.

WATER IN THE LOWER UNIT OF STRATIFIED DRIFT

PRINCIPAL AQUIFER

The principal aquifer is in the lower unit of stratified drift shown in plate 2. The upper limit of the aquifer, which is the bottom of the overlying confining beds, ranges in altitude from about sea level to 40 feet below sea level. The lower limit, for purposes of this report, is set at the top of the zone of diffusion between fresh and salty water, which ranges in altitude from about sea level to 130 feet below sea level. The principal aquifer consists chiefly of beds of medium to very coarse sand and gravel, about 10 to 80 feet thick. Scattered thin lenses of silt and silty clay are interbedded in some places with the more permeable beds.

Water in the principal aquifer is replenished by slow downward leakage from the overlying confining beds. The amount and rate of leakage per unit area of confining beds probably is small owing to their low permeability; however, the leakage over a large area may be substantial. Water in the principal aquifer is under artesian pressure, but the head is not sufficient to cause wells to flow. The depth to the static water level in existing wells ranges from about 13 to 70 feet below land surface (table 3). The depth to water is greatest in the center of the area where the altitude of the land surface is highest, and is least at the shoreline.

The principal aquifer is the only source of fresh water tapped by active wells. Wells 8 to 10 inches in diameter and finished with screens 10 to 20 feet long yield as much as 150 gpm. Reported specific capacities of wells range from 4 to 11 gpm per foot of drawdown. The history of pumping at Montauk Air Force Station suggests that sustained pumping at rates of 50 gpm or more will probably induce salt-water encroachment laterally or from below in most of the area.

PIEZOMETRIC SURFACE

The imaginary surface to which water in wells tapping the principal aquifer will rise is called the piezometric surface. The piezometric surface responds to changes in pressure in the aquifer caused by tidal and barometric fluctuations and by variations in natural recharge and discharge, and pumping. Plate 1 shows contours on the piezometric surface for April 12, 1961. The surface generally mirrors the shape and, in a very subdued manner, the topographic profile of the Montauk peninsula, except for the cone of depression formed around the pumping wells at the Montauk Air Force Station. The cone was roughly circular and had a diameter of about 0.5 mile in 1961. Its diameter and depth varies with the duration and rate of pumping, as well as with changes in natural recharge and discharge. The maximum depth of the cone is unknown as no readings were obtained in the main supply well S17231.

The contours shown on plate 1 are based on the measurements of water levels made chiefly on April 12, 1961. The measurements were adjusted to a common tidal stage. A few, made on April 7 and 8, were adjusted by comparison of regional water-level trends, to conform with the April 12 measurements. The highest known points on the piezometric surface of April 12 were about 3.5 feet above sea level at well S19484 at the north side of the Montauk Air Force Station and at well S2150 in the western part of the project area. The lowest measured altitude was about 1.3 feet above sea level in well S3599 near Montauk Lighthouse. The altitude in the center of the cone of depression was not determined but probably was as low as several feet below sea level.

MOVEMENT OF FRESH WATER

The following description of movement of water applies chiefly to water in the principal aquifer as few or no data were collected on flow in the shallow minor water-bearing zones in the upper part of the main zone of saturation.

In general, ground water moves from points of high head to points of low head (that is, from areas of recharge to areas of discharge). Before the start of pumping at the Montauk Air Force Station, ground water in the principal aquifer probably moved radially away from a mound on the piezometric surface near the center of the Montauk Air Force Station. The mound may have been as much as 7 feet above sea level, according to estimates from drillers' records. As a result of relatively heavy intermittent pumping, a cone of depression has formed around supply well S17231 (pl. 1) at the Air Force Station. The arrows oriented perpendicular to the piezometric contours show the horizontal component of movement of the water and indicate that a part of the flow which formerly discharged to the sea now moves inland toward the center of the cone of depression.

Plate 2 illustrates the pattern of movement in the vertical section. The arrows show that during pumping some fresh water and salt water move radially toward the screen of supply well S17231. The remainder of the fresh water moves toward discharge areas at and near the shoreline. Some mixes with salt water to form the zone of diffusion and ultimately discharges to the sea. (See "Salt-water encroachment.") The hydraulic gradient under which the fresh water is moving probably ranges from about 2 to 10 feet per mile in most of the area, but near pumping wells it is higher.

Measurements in the observation wells and continuous records from waterstage recorders show that the artesian heads in the principal aquifer are constantly changing, owing to tidal, barometric, and pumping effects. Although the altitude of the piezometric surface fluctuated a foot or two during the period of record, the shape remained about the same, and consequently the general pattern of movement of fresh water was approximately as shown on plates 1 and 2.

FLUCTUATIONS OF WATER LEVELS

Fluctuations of water levels in wells are the result of changes in the balance between recharge and discharge in aquifers. Analysis of both short- and long-term fluctuations provides important data on the hydraulic characteristics of an aquifer. For example, the altitude and character of the fluctuations of water levels in wells screened at different depths give evidence of hydraulic interconnection or of separation between aquifers and indicate whether the water in the aquifer is confined or unconfined.

SHORT-TERM FLUCTUATIONS

Minor and recurring fluctuations of water levels in the principal aquifer in the report area, are caused by transient influences such as changes in barometric pressure and oceanic tides. A rise in barometric pressure causes water levels in wells to decline; a decline in pressure causes water levels to rise. Tidal effects produced by the pull of the moon and the sun on the oceans cause pressure changes in both the fresh and salty ground-water bodies as illustrated by the water-level fluctuations shown on the hydrographs in figures 5 and 6. The magnitude of the fluctuations is due partly to the tidal efficiency and partly to the barometric efficiency of the well, which are related to the degree of confinement of the aquifer. Tidal effects diminish with increased distance from the shoreline. The hydrographs show typical pairs of high and low water levels in fresh-water wells produced chiefly by daily tidal changes in the Atlantic Ocean and Block Island

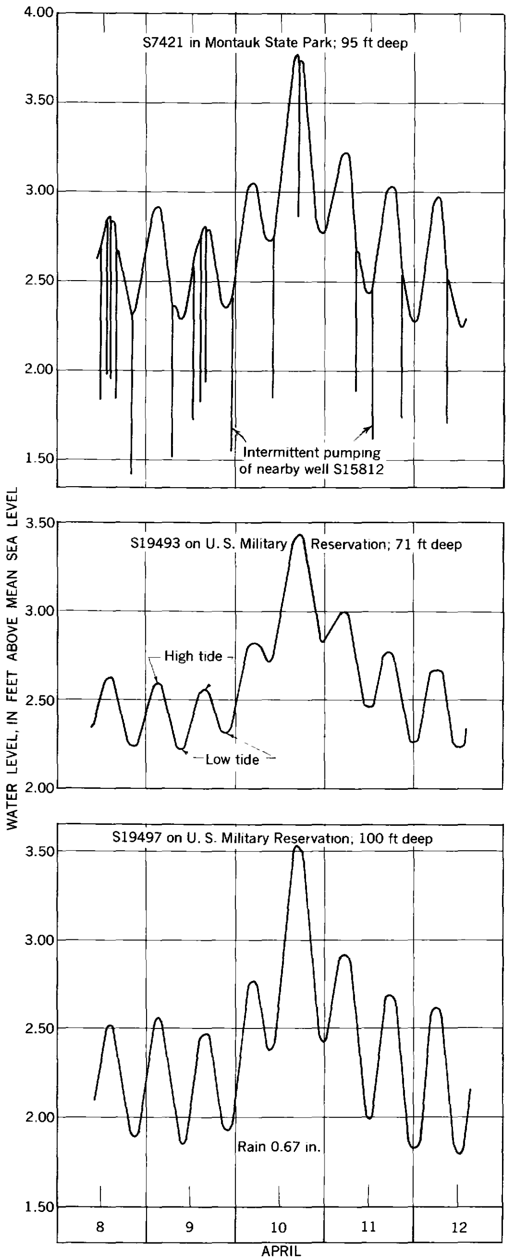

FIGURE 5.—Fluctuations of water level in three wells screened in fresh water in stratified drift, April 8–12, 1961.

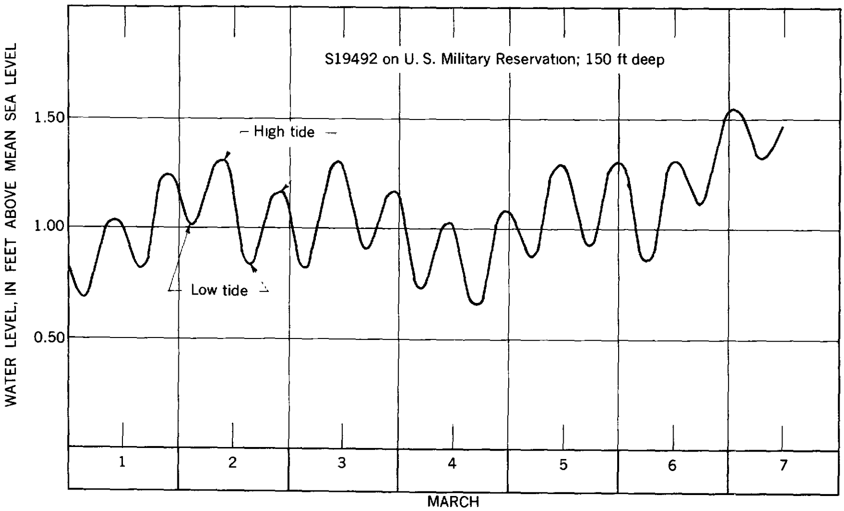

FIGURE 6.—Fluctuations of water level in a well screened in salt water in stratified drift, March 1–7, 1961.

Sound. In the examples shown, the daily fluctuations normally range from about 0.3 foot in the inland area (well S19493) to about 0.8 foot near the extreme eastern (well S7421) and southern (well S19497) shorelines. The combination of high tide and low barometric pressure accompanying the storm on April 10 resulted in an unusual peak in the water level; the fluctuation for the day in well S19497 was about 1.5 feet.

The hydrograph of well S19492 (fig. 6) screened in salty ground water also shows tidal and barometric effects similar to those illustrated in figure 5. The daily fluctuation in water level in well S19492 is normally about 0.4 foot, which is of about the same magnitude as that in nearby shallow well S19493, which is screened in the overlying fresh ground water. Comparison of the water-level records for the two wells shows that changes in levels in the fresh and salt water are simultaneous, as well as similar in magnitude, indicating that the fresh and salty ground waters are in hydraulic continuity.

Intermittent pumping of a well also causes fluctuations in water levels as illustrated by the hydrograph (fig. 5) of observation well S7421 at Montauk State Park. The well is about 10 feet from well S15812, which operates automatically in accordance with changes in pressure in a storage tank. On April 8 and 9, 1961, the pump was started and stopped five times as shown by the series of rapid drawdowns and recoveries, which appear as vertical lines on the hydrograph of well S7421.

LONG-TERM FLUCTUATIONS

Net changes in water levels over long periods of time, resulting from changes in climatic conditions or prolonged pumping at relatively high rates, are more significant than short-term fluctuations, because they indicate changes in the long-term balance between recharge and discharge. Such changes, as discussed in a later section, may shift the natural fresh-salt-water boundary (pl. 2), landward or seaward. The fluctuations of water levels described are of the piezometric surface, as data on fluctuations of the water table are too scanty for interpretation.

Periodic monitoring of the water levels in the Montauk Point area began about November 1960, after the construction of observation wells for this investigation. Comparison of a water level reported by a driller in 1941 for former supply well S3261, near the center of the Montauk Air Force Station, with its present (1961) level suggests a decline of about 5 feet in the static water level near the cone of depression shown on plate 1.

The period of record of water-level measurements in the observation wells is too short to detect any significant trends. The decline in water levels of about 1.5 feet in December 1960 and January 1961, shown by the hydrographs on figure 7, suggests a decrease in recharge during the winter months. The rise, which began about February 1961 and continued into March and April, shows the effect of increased precipitation and consequent increase in recharge during that period. These fluctuations correlate closely with natural seasonal fluctuations observed in artesian wells in western Long Island. Long-term records in observation wells 20 miles or more west of the report area indicate that piezometric levels in some parts of Montauk Point may decline several feet during the summer when evaporation, use of water by plants, and pumping are at a maximum. Conceivably, water levels in some wells tapping the principal aquifer at and near the Air Force station may decline to about sea level or possibly to below sea level. A permanent decline in piezometric levels will cause a rise in the fresh-salt-water boundary (pl. 2), which will be indicated by an increase in the chloride content of the water.

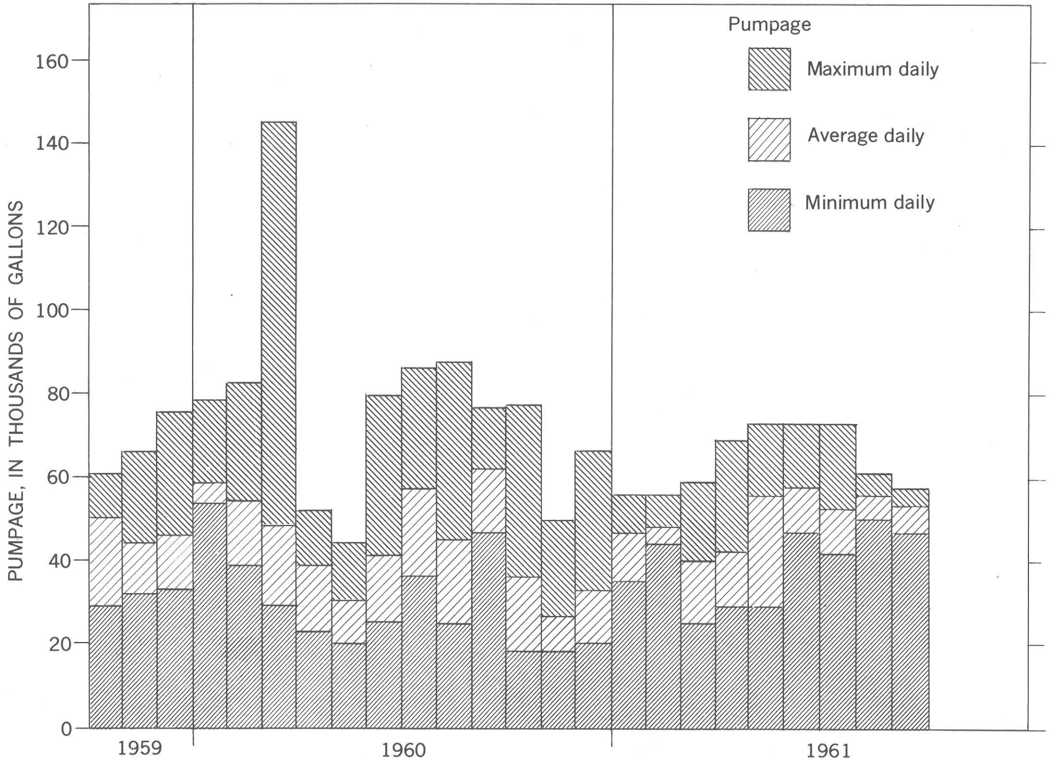

FIGURE 8.—Daily pumpage by months at Montauk Air Force Station, 1959–61.

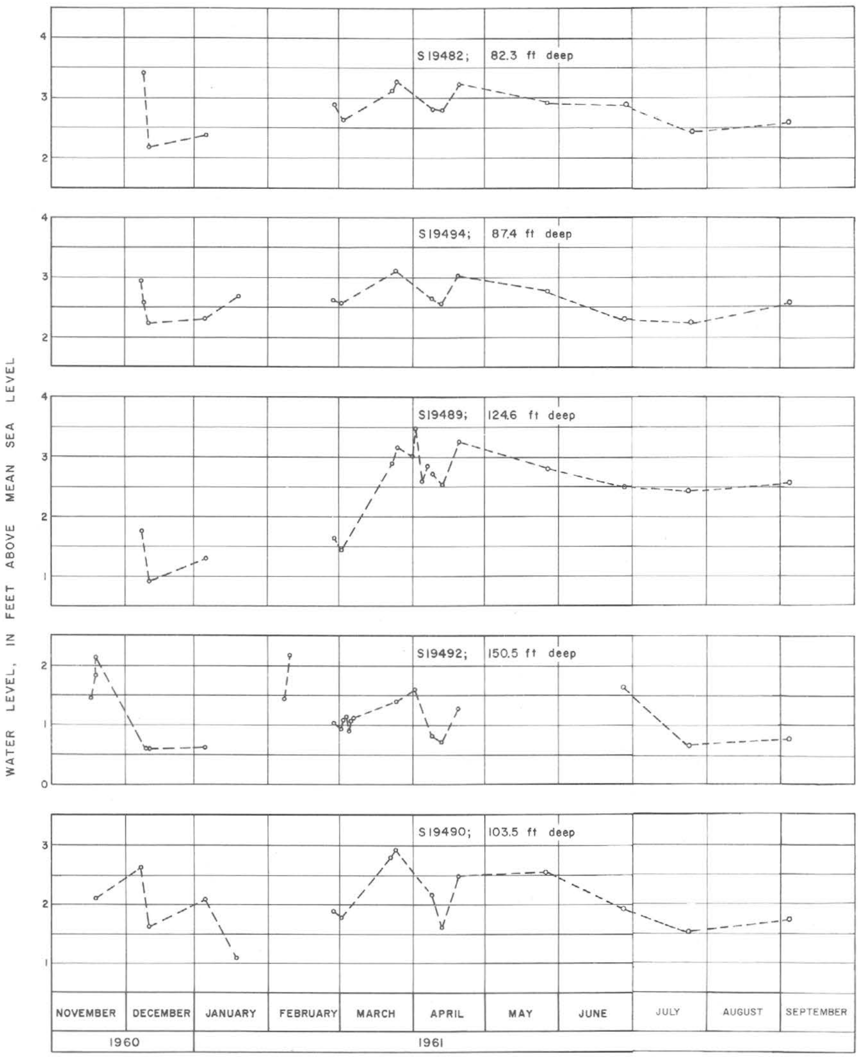

FIGURE 7.—Range in water-level fluctuations, November 1960 to September 1961.

PUMPAGE AND UTILIZATION

GENERAL

Gross pumpage, all from deposits of Pleistocene age, averages about 50,000 gpd. At times, however, daily peak pumpage may be as much as 150,000 gallons, as in March 1960 (fig. 8). Public supply systems do not operate in the report area; the nearest one is the Montauk Water Co. which supplies the village of Montauk, about 3 miles west of the report area.

The largest individual withdrawals in 1961 were made from two supply wells (S17231 and S17859) at the Montauk Air Force Station. These wells, which were operated together or singly during 1960–61, pump an average of about 50,000 gpd, but, rarely, peak pumpage has been about 150,000 gpd. The water is used for general purposes and air conditioning. The next largest withdrawals are made at Montauk State Park (well S18512, pl. 1), where pumpage averages about 9,000 gpd during the summer months. About 86,000 gallons were pumped for use at the park in 1960. A small number of year-round homes, summer homes, and two dude ranches in the southwestern part of the area are supplied by individual wells; the total pumpage is small. Well S3599 supplies a small amount of water for maintenance and domestic use at Montauk Lighthouse in the extreme eastern part of the area.

Most of the production wells range from about 90 to 126 feet deep and are 2 to 8 inches in diameter. The depth to water is generally below suction limit; consequently, the most common types of pumps are deep-well turbine, submersible, and force.

HISTORY OF WITHDRAWALS

The number of privately-owned domestic wells and the amount of water pumped by them have changed little during the past 20 to 30 years. During World War II from 3 to 5 wells supplied former Camp Hero (U.S. Military Reservation, pl. 1). No records were obtained of the pumpage during that period.

When Montauk Air Force Station was established in part of Camp Hero in 1951, three former U.S. Army wells, S3259 (well 1), S3260

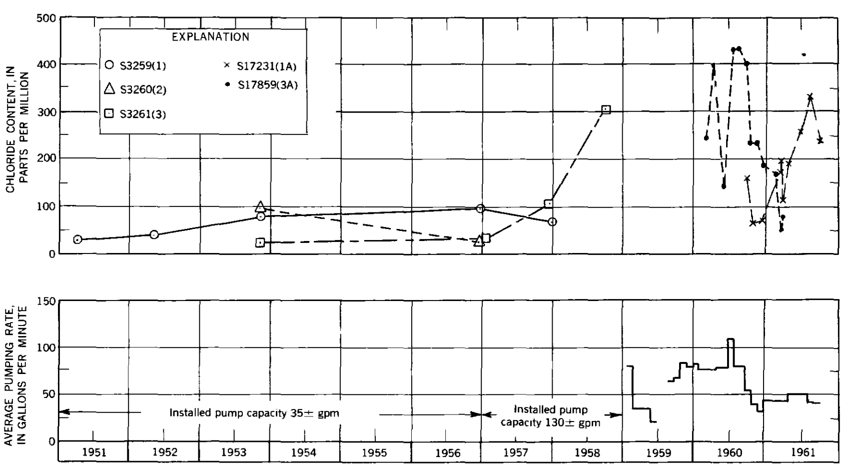

FIGURE 9.—Relation between chloride content of water and pumping rate. See text for well numbers.

(well 2), and S3261 (well 3), were put back into service, using the original low-capacity pumps (15 gpm or less). No data on pumpage were collected, but reportedly the combined installed pump capacity of the wells did not exceed about 35 gpm (fig. 9). In 1956 or 1957, deep-well turbine pumps rated at about 64 gpm were installed on wells S3259 and S3261. No records of pumpage were kept. In January 1959 well S17231 (well 1A) was drilled as a replacement for nearby well S3259 (well 1). In February 1959 wells S17231 and S3261 (3) were the only wells in operation. In June 1959 wells S17231 and S3261 were out of service frequently owing to well failure. In July 1959 well S17859 (3A) was installed as a replacement for nearby well S3261. The new well was equipped with a deep-well turbine pump rated at about 100-gpm capacity. From September 1959 to November 1960 well S17859 was the principal pumping unit. Pumping rates averaged about 80 gpm during much of this period, but at times were as high as 110 gpm (fig. 9). Average daily pumpage ranged from about 30,000 to about 60,000 gpd (fig. 8). In November 1960 well S17231, which had been out of service since February 1960, was deepened about 10 feet and was put back into use shortly thereafter. In January and February 1961 well S17231 was the chief source of water as the yield of well S17859 dropped so low that it was put out of service entirely in March 1961. In April 1961 S17231 was the only well in operation at Montauk Air Force Station and rehabilitation of well S17859 was being considered. In April 1962, S17231 was replaced by S20766(1B). In August 1962, S17859 was replaced by S121077, and a new supply well S21084 was being drilled near S19489 at the west side of the Air Force Station.

RELATION OF PUMPAGE TO RECHARGE

In the section dealing with the hydrologic cycle (p. 14), it was estimated that about 25 percent of the precipitation reaches the zone of saturation. On this basis, recharge at the Montauk Air Force Station (pl. 1) may be about 80,000 to 100,000 gpd. However, not all the recharge at the Air Force Station is available for withdrawal, as some must discharge to the sea in order to maintain the boundary between fresh and salt water close to its natural position. Recharge within the area of the cone of depression shown on plate 1 may be as low as 40,000 to 50,000 gpd. Comparison of these estimates with the average withdrawal of about 50,000 gpd shows that any surplus of recharge over present withdrawals may be small. Reduction in pumpage from the existing wells will reduce the size of the cone of depression, and constructon of new supply wells at the western and eastern limits of the station will distribute the pumping so as to improve the balance between recharge and pumpage.

QUALITY OF WATER

CHEMICAL QUALITY

Precipitation, which is the source of all fresh ground water in the Montauk area, is nearly pure; the chloride content of a sample of rainwater taken in December 1960 was only 5 ppm. Thus, it is apparent that nearly all the chemical constituents in the water shown by the analyses in table 4 were derived from interaction of the water with the minerals and organic constituents of the soil and underlying beds through which the water moved. Locally water may contain a high chloride and nitrate content where wastes from sanitary systems or fertilizer compounds have percolated down to the zone of saturation. Also, near the bottom of the principal aquifer, some fresh water moves into the zone of diffusion and mixes with salt water.

Most of the normal fresh water in the project area has about 25 to 30 ppm chloride, but in a few places the content may be about 45 ppm (tables 5 and 6). Concentration in excess of about 45 ppm indicates salt-water encroachment, unless attributable to other causes such as activities of man or residual salt-water contamination. The fresh ground water has less than 50 ppm of hardness as $CaCO_3$, less than 130 ppm of dissolved solids, and is neutral to slightly basic. The results of analyses of fresh ground water given in table 4 indicate that the iron plus manganese content of all but two samples exceeded 0.3 ppm, which is recommended by the U.S. Public Health Service (1946) as the maximum allowable limit for domestic use.

The streams and ponds in the Montauk area generally are fresh; most water from these sources contains less than 50 ppm chloride (table 6). The larger surrounding bodies of water are very salty. A chemical analysis of Atlantic Ocean water at Montauk Point is given in table 7.

TEMPERATURE

The temperature of water in 14 wells screened in the principal aquifer ranges from about 51° to 53°F (table 3). The average temperature of the water is about 52°F, which is 1° higher than the mean annual air temperature. The perennial low temperature of the ground water makes it highly suitable for air conditioning and cooling.

TABLE 4.—*Chemical analyses, in parts per million, of water from wells, Montauk Point area*

[Analyses by U.S. Geol. Survey except where indicated otherwise]

Well	Depth (feet)	Date sampled	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium[1] (Na)	Potassium[1] (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25° C)	pH	Remarks
																Calcium, magnesium	Noncarbonate			
S3259	106	Mar. 20, 1951	20	0.11	------	10	3.7	------	------	52	10	27	0.1	0.2	121	39	0	198	7.2	U.S.A.F. well 1
S3259	106	Apr. 10, 1952	23	3.1	------	11	6.3	------	------	51	14	36	.2	.3	139	53	12	139	7.0	
S3259	106	Oct. 1, 1953	20	16	------	15	6	49		53	14	78	.1	.5	215	63	19	369	6.8	
S3259	106	Nov. 27, 1956	24	3.7	1.1	16	7.4	60		58	13	99	.3	.2	258	72	24	460	6.8	
S3259	106	Dec. 13, 1956	25	7.6	1.0	16	7.4	62		57	13	103	.2	.1	265	71	24	472	6.7	
S3259	106	Dec. 3, 1957	28	5.9	.9	14	5.3	44		58	8.8	69	.3	.8	200	57	10	349	6.0	
S3260	112	Oct. 1, 1953	19	7.1	------	16	6.3	58		46	14	99	.2	.5	251	66	29	437	6.8	U.S.A.F. well 2
S3260	112	Nov. 27, 1956	24	1.0	.5	9	4.8	24		55	12	26	.2	.1	128	44	0	198	7.2	
S3260	112	Dec. 13, 1956	23	2	.6	9	4.9	22		55	10	26	.2	.2	124	44	0	196	7.0	
S3261	123	Oct. 1, 1953	21	2.5	------	10	4.6	21		53	13	26	.2	.3	124	48	5	192	6.9	U.S.A.F. well 3
S3261	123	Dec. 13, 1956	17	1.5	.6	10	4.2	24		54	9.7	29	.3	.1	127	43	0	203	7.0	
S3261	123	Dec. 3, 1957	25	5.9	.9	14	7.1	60		43	14	104	.2	.7	247	64	29	454	6.0	
S3261	123	Sept. 30, 1958	19	2.8	1.3	22	14	168		29	29	302	.3	.1	596	113	89	1,070	6.1	
S15812[2]	95	Aug. 5, 1957	------	.1	------	------	------	------	------	------	------	56	------	8.4	------	24	------	------	6.8	
S17231	126	Nov. 1, 1960	22	------	------	15	4.4	48		71	14	64	.2	.7	205	56	0	364	7.5	U.S.A.F. well 1A
S17859	126	Feb. 16, 1960	20	2.0	.9	24	16	146		42	61	245	.4	.4	536	126	92	917	6.8	U.S.A.F. well 3A
S17859	126	Nov. 1, 1960	21	------	------	22	14	139		43	27	250	.2	.6	533	113	78	969	6.8	Do.
S19491	71.5	Dec. 10, 1960	18	------	1.4	9	3.6	23	3.1	45	8.3	30	.3	.2	129	37	0	205	7.3	
S19492	150.5	Dec. 10, 1960	3.0	50	7.9	746	928	5,530	94	56	1,690	11,300	.5	46	21,300	5,680	5,640	30,200	5.8	
S19493	70.9	Mar. 22, 1961	27	3.2	.1	10	7.6	29	2.4	59	12	46	.2	1.7	167	57	8	276	7.1	
S19494	87	Dec. 10, 1960	16	------	7.9	13	8.1	37	3.8	97	11	44	.4	.6	183	66	0	356	7.1	

[1] Sodium, potassium calculated as sodium (Na).

[2] Analysis by C. W. Lauman & Co., Inc.

TABLE 5.—*Chloride content of ground water, 1946–61*

[Analyses by U.S. Geol. Survey, unless otherwise indicated. See table 3 for other well data]

Well	Depth of well (feet)	Date sampled	Chloride (Cl) (ppm)	Remarks
S1202	37	Sept. 16, 1960	46	
S1245	113	Apr. 8, 1961	21	
S2150	70	Mar. 13, 1946	18	
S2240	117	Oct. 19, 1960	32	U.S.A.F. well 1.
S3259	106	Mar. 20, 1951	27	
		Apr. 10, 1952	36	
		Oct. 1, 1953	78	
		Nov. 27, 1956	99	
		Dec. 13, 1956	103	
		Dec. 3, 1957	69	
S3260	112	Oct. 1, 1953	99	U.S.A.F. well 2.
		Nov. 27, 1956	26	
		Dec. 13, 1956	26	
S3261	123	Oct. 1, 1953	26	U.S.A.F. well 3.
		Dec. 13, 1956	29	
		Dec. 13, 1957	104	
		Sept. 30, 1958	302	
S3599	69	Sept. 16, 1960	88	
		Mar. 31, 1961	95	
S7421	95	Aug. 7, 1952	[1] 46	
S15812	95	Sept. 12, 1960	46	
S17231	118	Sept. 9, 1960	160	U.S.A.F. well 1A.
	126	Dec. 9, 1960	70	U.S.A.F. well 1A; well deepened Oct. 1960. Replaced by well S20766 (1B) in April 1962. Chloride content of water in 1B was 300 ppm in July 1962.
		Mar. 1, 1961	175	
		Mar. 9, 1961	200	
		Mar. 27, 1961	200	
		Mar. 29, 1961	140	
		Mar. 30, 1961	110	
		Mar. 31, 1961	180	
		Apr. 1, 1961	195	
		Apr. 13, 1961	150	
		Apr. 25, 1961	180	
		Feb. 20, 1962	90	Well not being pumped due to low yield.
S17859	126	Feb. 16, 1960	245	U.S.A.F. well 3A.
		Feb. 25, 1960	250	
		Mar. 1960	400	Pumping rate reported to be 100 gpm.
		May 1960	145	Pumping rate reported to be 65 gpm.
		July 13, 1960	438	Pumping rate reported to be 100 gpm.
		Sept. 9, 1960	405	
		Sept. 12, 1960	405	
		Oct. 19, 1960	232	
		Nov. 11, 1960	250	
		Nov. 30, 1960	190	
		Dec. 10, 1960	180	
		Mar. 2, 1961	170	
		Mar. 23, 1961	50	Well out of service.
		Mar. 30, 1961	80	
		Apr. 1, 1961	50	

See footnotes at end of table.

TABLE 5.—*Chloride content of ground water, 1941–61*—Continued

[Analyses by U.S. Geol. Survey, unless otherwise indicated. See table 3 for other well data]

Well	Depth of well (feet)	Date sampled	Chloride (Cl) (ppm)	Remarks
S17859	126	Apr. 19, 1962	80	Well out of service due to low yield. Replaced by S21077 in August 1962.
S18512	95	Aug. 5, 1957	[2] 56	
		Sept. 12, 1960	46	
S19482	82	Dec. 8, 1960	25	
S19484	70	Dec. 9, 1960	95	
S19485	140	Dec. 2, 1960	2, 850	
S19487	80	Dec. 10, 1960	120	
S19488	82	Nov. 10, 1960	46	
S19489	125	Nov. 30, 1960	25	Supply well S21084, 120 ft. deep, installed nearby, August 1962.
S19490	103	Dec. 2, 1960	26	
S19491	71	Dec. 2, 1960	34	
S19492	151	Nov. 17, 1960	11, 500	
		Dec. 1960	11, 300	
S19493	71	Mar. 22, 1960	46	
S19494	87	Dec. 10, 1960	44	
		Apr. 19, 1961	37	
S19495	70–100(?)	Mar. 8, 1961	25	
S19496	---------	Sept. 12, 1960	30	
S19497	100	Apr. 1, 1961	45	Bailer sample.
S19499	96	Oct. 19, 1960	23	

[1] Analysis by Long Island State Park Commission.
[2] Analysis by C. W. Lauman & Co., Inc.

TABLE 6.—*Chemical quality of surface water*

]Analyses by U.S. Geol. Survey. See pl. 1 for location of sampling points]

Sampling point		Date sampled	Chloride (Cl) (ppm)	Nitrate (NO_3) (ppm)
No.	Location			
1	Block Island Sound	Dec. 2, 1960	17, 500	------
2	Atlantic Ocean	Nov. 30, 1960	18, 500	------
		Jan. 19, 1961	17, 100	0. 2
3	Stream, U.S. Military Reservation	Nov. 30, 1960	50	------
4	Swamp, U.S. Military Reservation near S19493	------------	--------	4. 2
5	Oyster Pond	Dec. 2, 1960	13, 500	------
		Apr. 12, 1961	10, 000	------
6	Stream near S19483	Nov. 30, 1960	40	------
7	Pond near S1245	Apr. 20, 1961	36	------
8	Montauk Harbor, about 0.3 mile west of report area	Dec. 2, 1960	16, 500	------

TABLE 7.—*Chemical analysis, in parts per million, of Atlantic Ocean water at Montauk Point*

[Date of Collection: Jan. 19, 1961. Analysis by U.S. Geol. Survey]

Silica (SiO_2)	1.1
Iron (Fe)	.03
Manganese (Mn)	.0
Calcium (Ca)	356
Magnesium (Mg)	1,160
Sodium (Na)	9,470
Potassium (K)	353
Bicarbonate (HCO_3)	132
Carbonate (CO_3)	0
Sulphate (SO_4)	2,390
Chloride (Cl)	17,100
Fluoride (F)	.8
Nitrate (NO_3)	.2
Dissolved solids:	
Residue on evaporation at 180° C	32,500
Hardness as $CaCO_2$ (calcium, magnesium)	5,660
Noncarbonate hardness as $CaCO_3$	5,560
Specific conductance micromhos at 25°C	43,500
ph	7.3
Density g per ml	1.0220

SALT-WATER ENCROACHMENT

Salt-water encroachment is the movement of salt water so as to displace fresh water in an aquifer. The movement may be landward from the sea or upward from an underlying body of salt water. Contamination occurs when the salt water reaches a pumping well.

BOUNDARY OF FRESH WATER AND SALT WATER

The boundary between fresh and salt water in the report area is not a sharp interface but is a transitional zone of mixed water, commonly termed the "zone of diffusion." The zone of diffusion extends beneath the entire project area (pl. 2), and, in turn, is underlain by water that is nearly as salty as the Atlantic Ocean. The top of the zone of diffusion is concave upward, except for the area of upconing beneath pumping wells. Water at the top of the zone of diffusion has a chloride content of about 25 to 45 ppm. The chloride content increases downward to about 17,000 ppm. Below the bottom of the zone of diffusion, the salt water has a uniform density and contains about 17,000 ppm of chloride.

Theoretically, if the contact between fresh ground water of density 1.000 g per l and salt water of density 1.025 g per ml were sharp and if the water were not in motion, the contact would be depressed to a depth directly proportional to the fresh-water head and inversely proportional to the difference in the density of the two waters. Stated another way, the contact between fresh water and water as salty as the ocean (density 1.025 g per ml) would be depressed 40 feet below sea level for each foot of fresh-water head above sea level. This 40:1 relation is usually termed the Ghyben-Herzberg ratio. Hubbert (1940, p. 924–926) has shown that the Ghyben-Herzberg relationship is based on the assumption of hydrostatic equilibrium and may not even be approximately correct where hydraulic gradients are high such as in the vicinity of pumping wells or near the shore. As both the fresh and salt water in the project area are in motion and a sharp interface does not exist, the theoretical 40:1 ratio is not strictly applicable to the report area.

MOVEMENT OF SALT WATER

Salt water has existed under natural conditions beneath the project area probably since Pleistocene time. Under natural conditions some water from the main salt-water body probably moves slowly and continuously into the zone of diffusion and from there to discharge zones at the shoreline (pl. 2).

Natural gradients in the salt water and the pattern of flow of the salt water have been modified by pumping of the supply wells at the Montauk Air Force Station so as to cause upward movement of salt water and contamination of the wells (see flow arrows, pl. 2). The velocity of the movement of the salt water toward the wells is directly proportional to the permeability of the deposits and the hydraulic gradient of the water and inversely proportional to the porosity of the deposits. Flow is radial toward the well screens from both the fresh water and salt water. This accounts for large variations in the chloride content of the water pumped at wells S17231 and S17859 (table 5), which reflect changes in the relative volume of fresh and salt water reaching the wells under different pumping rates.

DETERIORATION OF THE CHEMICAL QUALITY OF THE WATER

The quality of the water in the principal aquifer has varied widely since 1951 owing to salt-water encroachment. The original chloride content of the fresh water in the principal aquifer near the center of the Montauk Air Force Station was as low as 26 ppm in 1953 (table 5); in July 1960 it was 438 ppm, and in May 1961 it was 250 ppm.

Concentrations of other constituents also have varied widely during the same period. For example, comparison of the results of analyses of water from well S3261 (table 4) in 1953 and 1958 showed the following changes:

	1953	1958
Chloride (Cl) ppm	26	302
Dissolved solids (Residue at 180°C) do	124	596
Hardness as $CaCO_3$ do	48	113
pH	6.9	6.1

The analysis of salty water from well S19492 (table 4) shows that if salt-water encroachment were to proceed unchecked, water having as much as 11,300 ppm of chloride, 21,300 ppm of dissolved solids, 50 ppm of iron, a hardness of 5,680 ppm as $CaCO_3$, and a pH of 5.8 would ultimately reach the pumping wells. The relative concentration of the constituents in the salty ground water, except for iron, is virtually the same as that in water from the Atlantic Ocean (table 7).

An unusual characteristic of the water from well S19492 is the high content of nitrate (46 ppm of NO_3), the highest reported in the area. Because sea water has a negligible nitrate content (table 7) and because the minerals constituting the deposits are not known to contain nitrate in any form, it is suggested that the high nitrate may be due to local pollution. However, the origin is still uncertain as the nitrate content of a nearby shallow well, S19493, was only 1.7 ppm (table 4) and that of water in a nearby swamp was only 4.2 ppm (table 6).

RELATION OF PUMPAGE TO SALT-WATER ENCROACHMENT

Owing to the sequence and lithology of the beds and the relative thinness of the fresh-water zone in the principal aquifer, the screens of supply wells at Montauk Air Force Station generally have been set less than 100 feet above the top of the zone of diffusion. As thick beds of clay do not intervene between the salty ground water and the well screens, encroachment occurs relatively quickly when pumping exceeds a certain rate for prolonged periods.

The graphs in figure 9 show that so long as the combined pumping rate of wells at the Montauk Air Force Station did not exceed about 35 gpm the chloride content of the water did not rise above about 100 ppm.

After the installation of pumps rated at 64 gpm and with presumably higher rates of withdrawal than previously, the chloride content of the water in well S3261 (well 3) rose from 26 to 300 ppm. In 1960, when pumping rates occasionally reached 80 to 110 gpm and daily withdrawals ranged as high as 85,000 to 140,000 gpd, the chloride content of the water reached a peak of about 440 ppm. The chloride content dropped sharply in November and December 1960 when the pumping rate was reduced to about 40 gpm per well. At the end of April 1961, when well S17231 was the only unit in operation, the pumping rate was 40 to 50 gpm; daily withdrawals were about 40,000 gpd; and the chloride content of the water was about 180 ppm. On July 5, 1961, the chloride content of the water in well S17231 rose to 380 ppm as the use of water for air conditioning and other purposes increased. From August to October 1961, the chloride content of the water was about 250 ppm. The chloride content decreased to 50 ppm on November 17, after the well had been shut down for repairs, but the concentration increased to 100 to 150 ppm after the well was restored to service.

SUMMARY

Ground water is the only source of supply for general use and air conditioning at the Montauk Air Force Station in extreme eastern Suffolk County (pl. 1). Because of the proximity of the Atlantic Ocean and the presence of salty ground water beneath a relatively thin lens-shaped body of fresh ground water, the supply wells at the station have been contaminated intermittently through encroachment of salt water; at times the chloride content of the water has been as high as 440 ppm. As a result of this deterioration in the quality of the water, the U.S. Air Force requested the U.S. Geological Survey to make a study of the ground-water conditions at and near the station, to determine the availability of fresh water, and to suggest locations for new supply wells.

The availability of the fresh ground water at Montauk Air Force Station is directly related to the depth, distribution, thickness, lithology, and hydraulic characteristics of the various deposits constituting the ground-water reservoir, and to the depth to the contact and the hydraulic relation between fresh and salty ground water. Prior to the present investigation, information on most of these elements was scanty or unknown. The investigation therefore included the collection and the study of well logs and samples, the examination of outcrops in the bluffs at the south side of the station, the drilling of 13 small-diameter test wells to depths of about 80 to 160 feet below land surface, the collection of water samples for analysis of chloride content, and the periodic measurement of water levels in all available wells.

Crystalline bedrock lies about 1,000 to 1,300 feet beneath the area. The overlying unconsolidated deposits consist of sand, gravel, and clay of Cretaceous, Pleistocene, and Recent age. This report is concerned mainly with the water-bearing properties of the upper 100 to 200 feet of deposits of Pleistocene age as the underlying beds are believed to contain water nearly as salty as the ocean and as the Recent deposits are too thin and scattered to provide significant amounts of water.

The Pleistocene deposits were laid down by melting ice sheets as glacial till (poorly sorted mixture of boulders, gravel, sand, and clay) and by streams as stratified drift (beds of well sorted gravel, sand, silt, and clay). In this report the Pleistocene deposits have been divided broadly (pl. 2) into two geologic units: (1) a lower unit of stratified drift, which consists predominantly of beds of highly permeable medium to coarse sand and gravel, and (2) an overlying unit of undifferentiated deposits of till and stratified drift, which consists predominantly of material of relatively low permeability such as beds of sandy clay, clay, silt, and glacial till. Some scattered beds and lenses of permeable sand and gravel occur in parts of the upper unit. The boundary between the upper and lower units is irregular and cannot be sharply defined everywhere, but on the basis of present data, it is estimated to be about 30 to 40 feet below sea level in most of the area (pl. 2).

Precipitation is the source of all ground water in the Montauk Point area. It is estimated that about one-fourth of the total precipitation of 48 inches reaches the ground-water reservoir. The remainder is lost through evaporation, plant use, and runoff. After seeping through the soil zone, the water moves down through the pore spaces in the deposits of undifferentiated till and stratified drift. Below a certain depth, which varies from place to place, the deposits are completely saturated with water. The top of the zone of saturation is called the water table. Few data were collected on the altitude of the water table as it lies mainly in deposits of low permeability and as nearly all the wells in the report area are finished at greater depth in the principal aquifer in the lower unit of stratified drift. The few available data suggest that the water table may be as much as 10 to 17 feet above sea level near the center of the area; under normal conditions, the water table should slope radially from a central high point to sea level at the shoreline.

Ground water occurs in the upper unit in (1) perched water bodies above the water table and (2) in minor water-bearing zones below the water table. Perched water bodies are common at depths of 5 to 30 feet below the land surface in permeable lenses surrounded by silt and clay but are too thin and temporary to be considered as a source of supply. On the other hand, lenses and beds of sand and gravel a short distance below the water table are permanently saturated, but because most of these seem to be too thin and too discontinuous to yield substantial amounts of water they are considered minor water-bearing zones in this report (pl. 2). The lower 20 to 65 feet of the undifferentiated deposits consists predominantly of clay, silt, and perhaps some till and is of low permeability in most places. These beds also are saturated with water, but their low permeability makes them unsuitable as a source of supply. However, they are important hydrologically in helping to confine the water in the underlying principal aquifer under artesian pressure.

The beds of sand and gravel in the lower unit of stratified drift constitute the principal aquifer, which is the source of supply for all existing wells in the report area. Water reaches the principal aquifer by slow downward percolation through the overlying beds. Wells screened in the principal aquifer yield as much as 100 to 150 gpm, but sustained pumping at these rates causes encroachment of salt water and generally contamination of the wells. Because of the artesian character of the principal aquifer, water levels fluctuate from several tenths of a foot to nearly a foot per day in some wells owing to tidal and barometric changes. The pressure surface to which water in wells tapping the principal aquifer rises is called the piezometric surface. A contour map (pl. 1) shows that the piezometric surface has a maximum altitude of about 3 to 4 feet. A cone of depression, about 0.5 mile in diameter and of unknown depth, exists around the present supply wells at the Air Force station. Pumpage at the station averages generally about 50,000 gpd, but at times it has been as high as 140,000 gpd. Withdrawals at the higher rates have caused salt water to move toward the pumping wells.

The natural chloride content of the fresh water in most of the area is about 25 to 30 ppm. The concentration of other constituents is also low, except for iron, which may be excessive locally. Results of analyses of water from the test wells constructed during the investigation show that salt water, having a chloride content of a least 11,300 ppm and probably as high as about 17,000, underlies the report area.

A zone of mixed water, the zone of diffusion, lies between the fresh water and the highly salty water. The top of the zone of diffusion ranges from sea level at the shoreline to about 130 feet below sea level just west of the Air Force station. The boundary between fresh water and salt water is an equilibrium position related to the respective heads and densities of the fresh and salt water. The lowering of water levels in the principal aquifer due to pumping of the Air Force supply wells has caused salt water to move upward toward the well screens. When pumping rates are reduced the fresh-water head rises and the boundary between the fresh and the salt water begins to move down. This movement is reflected in the wide range in the chloride content of the water pumped from supply wells at the station. Results of water analyses made in 1951 show that when the combined pumping rate of the supply wells was about 35 gpm the chloride content of the water was generally less than 100 ppm, but when larger pumps were installed and pumping rates ranged from 50 to 100 gpm at individual wells, the chloride content of the water increased to about 450 ppm. The increase in chloride content was accompanied by large increases in the content of iron and dissolved solids and in the hardness of the water.

MEASURES FOR CONTROL OF WATER QUALITY AND PROPOSED SITES OF NEW SUPPLY WELLS

1. Ideally, about four widely separated wells each operating at low pumping rates (30 gpm or less) probably could supply fresh or nearly fresh water continuously at the Montauk Air Force Station, if the pumping load were distributed equally among the wells. By operating the wells together at low rates or alternately for short periods, the drawndown of water level and reduction of fresh-water head would be kept to a minimum, which would lessen the tendency of salt water to move up toward the well screens.
2. Under the present (1961) system, wells S17231 (1A) and S17859 (3A) are the only operating units at Montauk Air Force Station. The wells have been pumped individually from time to time at rates of 50 to 100 gpm, and both have yielded water of high chloride content intermittently. Reduction of the pumping rate to about 30 gpm at these wells should result in marked improvement in the quality of the water. Wells S17231 and S17859 were replaced by nearby wells S20766 and S21077 in April and August 1962, respectively.
3. To compensate for this suggested reduction in pumpage, a third well as remote as possible from the existing wells is needed to meet peak demands, especially during the summer months, in order to maintain low pumping rates and to act as a standby well in the event of a breakdown of one of the present installations. The results of this investigation suggest that the best site for a new supply well would be in the extreme west-central part of the Military Reservation near observation well S19489 (pl. 1). At this site the top of the principal aquifer is about 30 feet below sea level, and the bottom of the fresh-water lens is about 100 feet below sea level. A production well, drilled by either the cable-tool or rotary method, probably could be completed at about 80 to 120 feet below the land surface, depending on the depth and character of the deposits.

To set the well screen as high above the top of the zone of diffusion as possible and to select the most productive zone, a pilot hole should be drilled to a depth of about 150 feet. Bailer-type or core samples of the deposits should be collected at 10-foot intervals from land surface to 40 feet below land surface and at 5-foot intervals from a depth of 40 feet below land surface to the bottom of the hole. After drilling the pilot hole, a supply well, 6 to 8 inches in diameter and finished with 15 to 20 feet of screen, can be installed at a depth selected on the basis of the samples. If the pilot hole is constructed of suitable diameter, it can be converted to a supply well readily, regardless of the method of drilling. If the supply well is drilled by the rotary method, the area around the screen should be gravel packed. A pumping test of 8 hours duration at a rate of about 50 gpm should be made upon completion of the well. Frequent measurement of the pumping level and collection of samples of water for analysis should be required during the pumping test. If necessary, a fourth well similar in construction to the well described above could be drilled in the eastern part of the area near wells S19492, and S19493 (pl. 1). As this report was being prepared for publication in August 1962, a new supply well, S21084, was being installed at a depth of 120 feet near S19489.

4. Another supplementary source of water, which may be available, at least on a part-time basis, is abandoned well S19496 (pl. 1), about one-quarter of a mile south of supply well S17859. The well reportedly yields 20 to 30 gpm and was used for a short period during an emergency in 1960, but no records were made of the pumpage or of the chloride content of the water. A sample of water collected after 10 minutes of pumping in September 1960 had 30 ppm chloride, about normal for the area. As this well is closer to the shore than any other possible supply well, it is not known what effect continuous pumping may have on the chloride content of the water. If this well is tied into the existing system through temporary mains it can be pumped intermittently throughout the summer months. Samples of water should be collected periodically for chloride determination, which would provide a basis for determining whether it would be feasible to incorporate this well into the system permanently. After this report was submitted to the Air Force, well S19496 was operated intermittently during the fall of 1961 and the summer of 1962. The chloride content of the water was about 40 ppm when the well was shut down, but during periods of continuous heavy pumping, as in July 1962, the chloride content was as high as 150 ppm.

5. Continuation of the water-level measurement and chemical sampling program for about a year would determine the trend of water-level fluctuations and would indicate any changes in the chloride content of the water, especially during the period of low recharge in the summer and fall and under conditions resulting from the installation of one or more new supply wells.

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