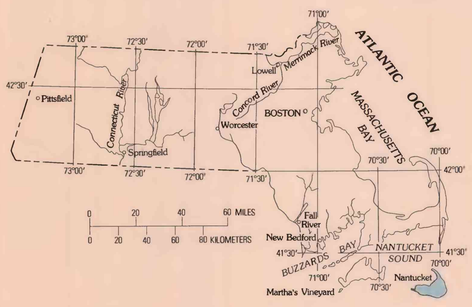
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with the
COMMONWEALTH OF MASSACHUSETTS WATER RESOURCES COMMISSION

HYDROLOGIC INVESTIGATIONS
ATLAS HA–615 (SHEET 1 OF 2)

INTRODUCTION



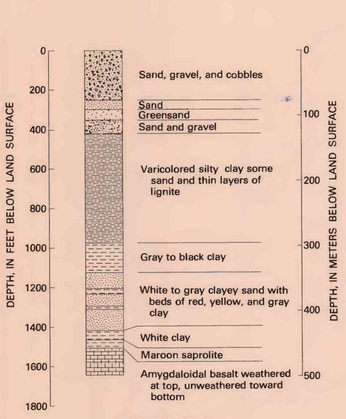
LOCATION OF NANTUCKET ISLAND MASSACHUSETTS—This report is one of a series prepared by the U.S. Geological Survey in cooperation with the Massachusetts Water Resources Commission. It provides hydrologic information for use in planning the development and management of the Commonwealth's water resources.

The island of Nantucket, the largest (49 mi²) of the group of islands that form the county and town of Nantucket, lies 25 miles south of Cape Cod and 15 miles east of Martha's Vineyard. Nantucket is about 12 miles long from east to west, and 4 miles wide from north to south. The islands to the west, Tuckernuck and Muskeget, have areas of 1.5 and 0.5 mi², respectively.

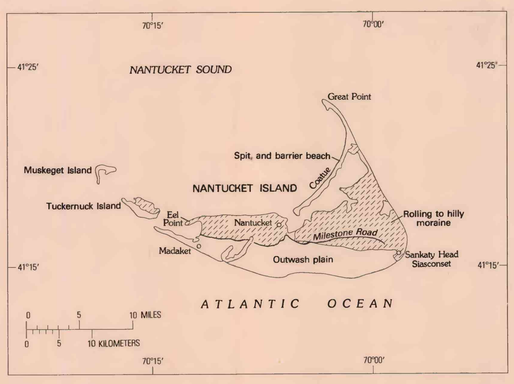
Nantucket was first settled by English colonists in 1659. Population rose to 10,000 in the 1840's during the height of the prosperity brought by the whaling industry. After petroleum replaced whale oil, the population declined to about 3,000 late in the 1800's. Development of Nantucket as a summer resort began in the 1870's and has continued ever since. The economy of the island is based largely on summer resort trade. In 1975, the year-round population was 5,500, but it is estimated that 27,000 people were on the island during the height of the summer season. A small amount of farming is carried on to produce vegetables and flowers, and a large cranberry bog is operated in the east-central part of the island.

The year-round population is concentrated in the village at Nantucket Harbor. Most of the residences elsewhere on the island are occupied only in summer. About 20 families live on Tuckernuck Island in summer, and Muskeget Island is uninhabited.

The Geological Survey received cooperation and assistance from officials of the town of Nantucket, from well contractors, and from numerous island residents. The Nantucket Conservation Foundation granted permission for drilling a deep test hole and several shallow water-level observation wells on its properties.



GEOLOGIC COLUMN



GEOGRAPHY AND SURFICIAL GEOLOGY—The two main topographic features of Nantucket are a belt of hilly terrain on the northern half of the island and a broad plain on the southern half of the island that slopes gently southward from the hills to the sea. Some of the hills in the eastern part reach altitudes of 100 feet and are the highest points on Nantucket.

The hilly terrain corresponds with an end moraine (Shaler, 1889; Woodworth and Wigglesworth, 1934), characterized by irregular hills and depressions with large boulders scattered upon the surface. The moraine is formed partly of sand and gravel that the glacier shoved forward and partly of sand, silt, and clay transported in the glacial ice. The morainal material may be as much as 100 feet thick in places, but toward its southern margins and through much of its eastern extent around Siasconset it is only a few feet thick and rests upon stratified sand and gravel outwash.

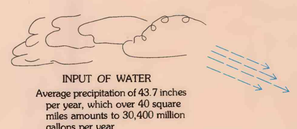
The broad plain that slopes southward from the moraine is underlain by sand and gravel outwash, which was spread by streams of meltwater that flowed southward from an ice front. Just south of Nantucket Harbor, these outwash deposits extend northward through a wide gap in the moraine.

During the close of the last glaciation sea level rose about 400 feet (Millimam and Emery, 1968), Nantucket became an island, and valleys on the south shore were drowned. Since that time, waves and currents have smoothed the coastline by eroding headlands and building sand bars such as the long compound barrier bar and spit of Coatue and Great Point. Bay-mouth bars were formed across drowned valleys on the south shore of the island, creating Miacomet, Hummock, and Long Ponds and other small ponds.

Geologic structure beneath Nantucket is known from two deep test holes. A hole 301 feet deep at Great Point penetrated glacial outwash composed of sand and gravel to a depth of 150 feet, below which beds of fine sand, silt, and clay of pre-glacial (Tertiary) age extended to a depth of 301 feet, the bottom of the hole. A test hole drilled to a depth of 1,686 feet near the center of the island penetrated Pleistocene outwash of sand and gravel from 0 to 250 feet, Tertiary sand and greensand from 250 to 330 feet, Cretaceous varicolored silty clay with some sand and several thin layers of lignite from 330 to 1145 feet, and Cretaceous white to gray clayey sand with three beds of clay between 1145 and 1500 feet deep. From 1500 to 1540 feet, a red-brown layer of weathered rock overlies hard igneous basalt of probable Triassic age, which extended to the bottom of the hole at 1686 feet (Folger and others, 1976; Kohout and others, 1977).

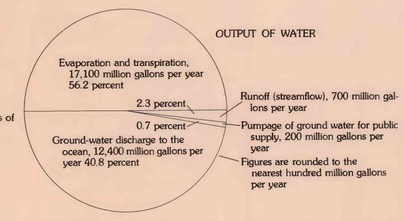
GENERAL HYDROLOGY

PRECIPITATION (measured) average annual 1941–1970 = EVAPOTRANSPIRATION (computed) by method of Thornthwaite and Mather, (1957) + RUNOFF (estimated) + AVERAGE RATE OF GROUND-WATER PUMPAGE FOR PUBLIC SUPPLY (measured) + GROUND-WATER DISCHARGE TO THE OCEAN (computed as a remainder)



INPUT OF WATER
Average precipitation of 43.7 inches per year, which over 40 square miles amounts to 30,400 million gallons per year

Total input of water is 43.7 inches of precipitation over 40 square miles, or 30,400 million gallons per year



THE HYDROLOGIC BUDGET.—The source of freshwater to Nantucket is precipitation as rain and snow. Average annual precipitation reported by the National Weather Service was 43.7 inches during 1941–70. This amount of water, if spread over the approximately 40 mi² of Nantucket that does not consist of salt marsh and sand bars equals 30,400 Mgal/yr (Million gallons per year).

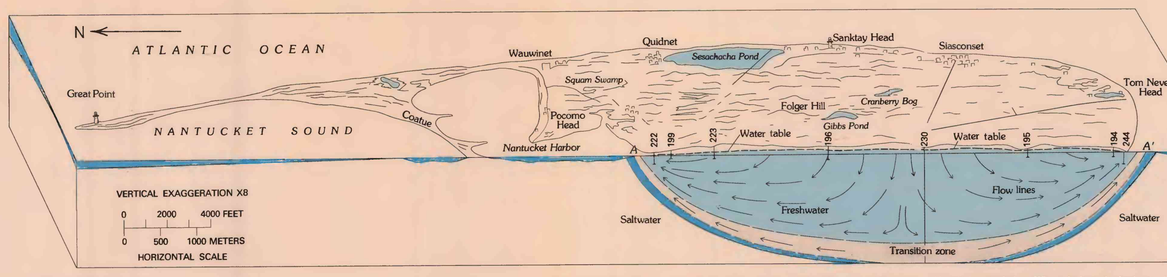
On the average, 24.6 inches or 17,100 Mgal/yr (calculated by Thornthwaite and Mather's method (1957) is returned to the atmosphere by evaporation and transpiration by plants.

The soils of Nantucket are prevailingly sandy, and water from rain and snowmelt sinks into the ground readily; therefore, overland runoff component is relatively small. On the basis of hydrologic study on Long Island, New York (Pluhowski, and Kantrowitz, 1964), runoff in streams is estimated 1 in/yr, or 700 Mgal/yr from 40 mi².

Water pumped for public supply, around 220 Mgal/yr, is for practical purposes, diverted from the ground-water system because it is drained to sewage-treatment lagoons on the island's south shore, from which the water infiltrates through sand and gravel beneath the lagoons and discharges to the nearby sea. Water pumped from private wells is not considered in the water budget because it is almost all returned to the ground through septic systems.

A ground-water recharge of 18.1 in/yr or about 1,400 Mgal/yr is estimated by subtracting from precipitation the sum of discharge by evapotranspiration and streamflow. The ground water is discharged to the ocean, to marshes, and to streams and by pumpage for public water supply. By far the largest part of it is discharged into the ocean near the shore.

The mass balance water budget assumes a steady-state equilibrium in which ground-water inflow and outflow are nearly equal, and the change in ground-water storage, if any, is, by comparison, negligible. Although the amount of water in storage does change from year to year and during groups of years wetter or drier than normal, over the 30-year record period the changes in storage balance.



THE FRESH GROUND-WATER BODY.—The fresh ground water in the porous deposits of Nantucket forms a lens-shaped body that is about 500 feet thick at the center of the island and thins toward the shores to wedge out a short distance offshore. This lens of freshwater floats upon underlying saltwater because freshwater is about one-fortieth less dense than seawater.

A similar, but much thinner, lens of freshwater underlies Tuckernuck Island, but its thickness has not been measured. Beneath peninsular areas of Nantucket Island the freshwater lens may be very thin. For example, the Madaket area is bounded on the west by Madaket Harbor and saltwater and on the east by Long Pond, usually brackish, and the average thickness of the freshwater lens (to a depth where water contains 250 mg/L of chloride) has been reported to be 18 feet (Whitman and Howard, 1973a).

The freshwater lens is bounded by the water table on top and brackish water below. Where thickest, the freshwater lens extends down into the sandy beds of Tertiary and Cretaceous age beneath the glacial deposits of Pleistocene age. The salinity increases irregularly from less than 1 ppt (part per thousand) at a depth of 520 feet to more than 25 ppt at a depth of 650 feet, indicating the zone of transition from freshwater to saltwater to be about 130 feet thick. Using a static density model for describing the position of the freshwater to saltwater interface (Hubbert, 1940) and a measured hydraulic head of 11.9 feet from a piezometer open at 480 feet deep, the center of the transition zone was calculated to lie at a depth of 520 feet, or 485 feet below National Geodetic Vertical Datum of 1929. The observed depth of the center of the zone of transition (585 ft) is somewhat greater than the calculated depth (520 ft).

GROUND WATER

OCCURRENCE OF WATER

Diagram—No scale

PERCHED GROUND WATER.—At places on Nantucket, bodies of ground water occur above the main water table, perched upon thin beds of silty to clayey material. Water percolating down from the surface accumulates above such beds of low permeability and, where they end, spills off to the main water table below. In the illustration, the water level is higher in well A, which taps water perched above the bed of clay, than in wells B and C, which penetrate to depth below the bed of clay. In some places, these bodies of perched water intersect the land surface and give rise to seeps or springs. Sachems Spring, a small seep along the Nantucket Cliffs west of Jetties Beach, has this origin.

Some of the small swamps and wet weather ponds and even some ponds that do not dry up, such as Gibbs Pond, represent bodies of surface water perched above the main water table.

YIELDS OF WELLS AND CHARACTERISTICS OF THE GROUND-WATER RESERVOIR

Supplies of water adequate for homes, for cooling, and for small business establishments are readily developed in most of Nantucket by wells 1½ to 2 inches in diameter, which are screened for 3 feet at about 10 feet below the water table. Average yields of wells tapping outwash sand and gravel are more than 10 gal/min. Wells within the area underlain by morainal deposits yield less water than those in outwash, and some wells have not encountered good water-bearing material until driven to as much as 100 feet.

Wells in the sand and gravel outwash that are 2 to 2½ inches in diameter and equipped with screens will commonly yield 50 gal/min or more. Large amounts of water can be pumped from fields of such wells. The Wannacomet Water Company pumps from about eighty 2½ inch wells with 7-ft screens, along two lines (wells 25 and 26) in a low valley 1½ miles south of Nantucket Harbor. Individual wells-yield 60 gal/min, and the well field has been pumped at 1,500 gal/min, or 2.2 Mgal/day. Water for the large cranberry bog 2 miles west of Siasconset is obtained from a field of forty 2-inch wells (well 9) with 5-ft screens that is reported to yield 2,000 gal/min.

High yields can be obtained from large-diameter screened wells. The 12-inch gravel-packed well (well 15) of the Siasconset water system yielded 520 gal/min with a specific capacity of 57.8 (gal/min)/ ft of drawdown when tested. Two 8-inch irrigation wells (wells 6 and 7) on the Sankaty Head Golf Club near Siasconset yielded 500 and 450 gal/min with specific capacities of 27.8 and 11.8 (gal/min)/ ft, respectively, when completed.

Records of 22 small-diameter wells show a range in specific capacity from 1.3 to 20 (gal/min)/ ft of drawdown and a median value of 9 gal/min per foot.

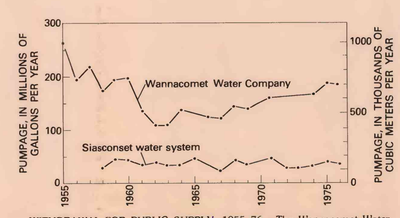
The amount of water that an aquifer will yield, provided that there is an adequate source of recharge, depends on its physical dimensions and its hydrologic characteristics, hydraulic conductivity is a measure of the aquifer's ability to conduct water, and the storage coefficient is a measure of the amount of water the aquifer will store or release during changes in water level.

Using the value for specific capacity of 58 (gal/min)/ ft of the gravel-packed Siasconset well, the hydraulic conductivity of the outwash aquifer is estimated to be 970 feet per day. This value is indicative of very permeable material. Hydraulic conductivity of the morainal deposit is considerably less than that of the outwash because it contains larger proportions of fine-grained material.

Hydraulic conductivity of the Tertiary and Cretaceous deposits beneath Nantucket will show a wide range because the texture of the deposits varies from coarse sand and gravel to clay. A 2-inch well with 5 feet of screen set at a depth of 480 feet in sandy strata of Cretaceous age yielded 15 gal/min, the capacity of the pump. The sandy beds become much finer grained and more silty at depth, and a 2-inch well (well 231) bottoming in fine, silty sand at 1,430 feet yielded only 2 gal/min with a drawdown of 13 feet.

The glacial outwash consists dominantly of medium through coarse sand (0.25 to 1 mm in diameter) and is well sorted. The specific yield of such material is about 30 percent (storage coefficient, 0.30) according to Eckis (1934) and Johnson (1967). Allowing for the presence of scattered beds of poorly sorted material, a conservative figure for storage coefficient would be 0.25. Expressed in other terms, the aquifer will store or release 3 inches of water when water level rises or falls 1 foot.

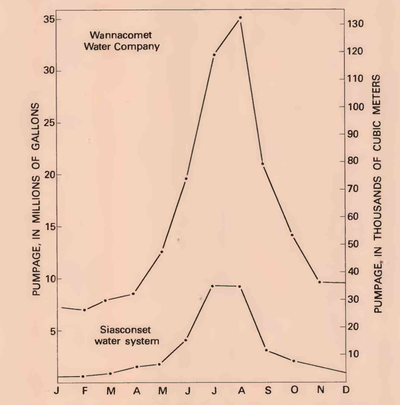
PUMPAGE



WITHDRAWAL FOR PUBLIC SUPPLY, 1955–76.—The Wannacomet Water Company supplies ground water to the village around Nantucket Harbor. Annual pumpage has ranged from 261 Mgal in 1955 to 107 Mgal in 1962. The decline in pumpage from 1955 to 1962 resulted from the installation of meters and increased water rates. The increase in annual pumpage after 1963 reflects the gradual increase in population of Nantucket and numbers of services supplied. Pumpage over the last 3 years (1975–77) has been about 185 Mgal/yr, supplying 2,300 services.

The Siasconset water system supplies ground water to this small summer colony on the east shore of Nantucket Island. Pumpage was 36 Mgal in 1976. Annual pumpage has not changed much over the last 20 years because few new residences have been built in the service area.

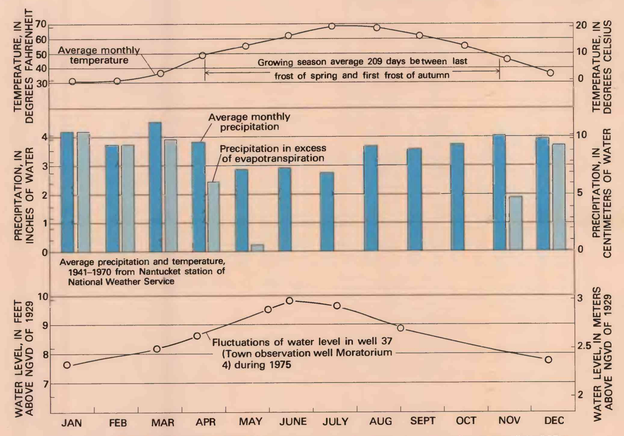
In "Massachusetts Water Supply Policy Study" (Wallace, Floyd, Ellenzweig, Moore, Inc., 1977) the yield of public-supply wells on Nantucket is reported to be 3.7 Mgal/d, about 6 times the estimated average daily consumption for 1990. Total pumpage for public supply, about 220 Mgal/yr, is less than 2 percent of the estimated amount of annual recharge.



SEASONAL PUMPING RATES BY PUBLIC SUPPLY SYSTEM IN 1975.—Monthly pumpage by the Wannacomet Water Company in 1975 ranged from 7.48 Mgal in February to 35 Mgal in August. The large range reflects the influx of visitors and summer residents, greatest in July and August. Peak daily use in 1975 was 1.4 Mgal on August 3d.

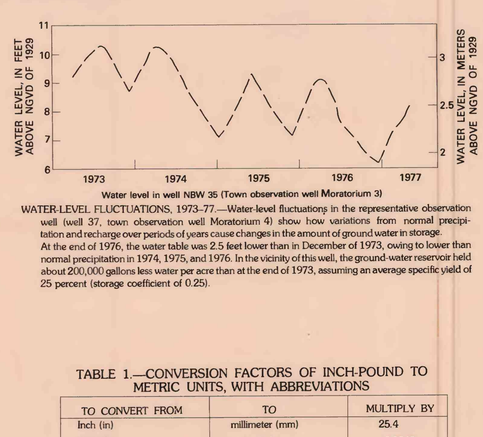
Monthly pumpage by the Siasconset water system in 1975 ranged from 0.73 Mgal in January to 9.8 Mgal or 13 times as much in July. The large range is due to the fact that very few people live in Siasconset in winter. Peak daily use was 0.5 Mgal on July 29th.

RECHARGE AND WATER-LEVEL FLUCTUATIONS



RECHARGE TO THE GROUND-WATER BODY.—The changes in water level in a representative observation well, (well 37, town observation well Moratorium 4) during 1975 shows that ground-water recharge exceeded discharge (the water level rose) from early January to early June, and discharge exceeded recharge (the water level declined) from June to late December. The period when discharge exceeds recharge coincides approximately with the growing season when the most precipitation is returned to the atmosphere through evapotranspiration.

The total average annual recharge of 18 in/yr amounts to about 490,000 gallons per acre, or about 313 (Mgal/yr)/mi². Recharge naturally varies considerably from year to year, depending upon the amount and distribution of precipitation and whether the year is warmer or cooler than average. Recharge was considerably above average in 1958, when a maximum precipitation of 60 inches occurred, and below average in the drought year of 1965, when precipitation was only 25 inches.



Water level in well NBW 35 (Town observation well Moratorium 3)

WATER-LEVEL FLUCTUATIONS, 1973–77.—Water-level fluctuations in the representative observation well (well 37, town observation well Moratorium 4) show how variations from normal precipitation and recharge over periods of years cause changes in the amount of ground water in storage.

At the end of 1976, the water table was 2.5 feet lower than in December of 1973, owing to lower than normal precipitation in 1974, 1975, and 1976. In the vicinity of this well, the ground-water reservoir held about 200,000 gallons less water per acre than at the end of 1973, assuming an average specific yield of 25 percent (storage coefficient of 0.25).

TABLE 1.—CONVERSION FACTORS OF INCH-POUND TO METRIC UNITS, WITH ABBREVIATIONS

TO CONVERT FROM	TO	MULTIPLY BY
Inch (in)	millimeter (mm)	25.4
Foot (ft)	meter (m)	0.3048
Mile (mi)	kilometer (km)	1.609
Square mile (mi²)	square kilometer (km²)	2.59
Gallon (gal)	liter (L)	3.785
Gallon per minute (gal/min)	liter per second (L/s)	0.0631
Million gallons per day (Mgal/d)	cubic meter per second (m³/s)	0.04381
	cubic meter per day (m³/d)	3785
Gallon per acre (gal/acre)	cubic meter per hectare (m³/ha)	0.09354
Gallon per minute per foot [(gal/min)/ft]	liter per second per meter [(L/s)/m]	0.207

Base from U.S. Geological Survey, 1:24,000, Great Point, 1972; Nantucket, 1972; Siasconset, 1972; Tuckernuck Island, 1972

SCALE 1:48 000
1 0 1 2 3 MILES
1 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 1.7 FEET ALONG THE ATLANTIC OCEAN AND 2.6 FEET IN NANTUCKET SOUND

EXPLANATION

—10— Water-table contour—Shows altitude of water table in Spring, 1976. Dashed where approximately located. Contour interval 5 feet. National Geodetic Vertical Datum of 1929

9.5 Observation well—Number is measured water level, Spring, 1976 National Geodetic Vertical Datum of 1929

8 Well—Number is water level in feet, National Geodetic Vertical Datum of 1929 Measurements made at miscellaneous dates

Shawkemo Spring Spring

Depth curves, in feet

WATER TABLE.—The water table under Nantucket forms several low domes, the largest of which reaches an altitude of 12 to 14 feet above sea level half way between Nantucket Harbor and Siasconset. Domes in the water table reaching more than 10 feet above sea level occur south and west of Nantucket Harbor beneath Burnt Swamp, Trots Hills, between Lovers Lane and Sewer Bed Road and east of Sheep Pond Road. Ground water in the upper part of the saturated zone generally moves downgradient, perpendicular to the water-table contours and toward the sea. Locally, movement may be toward ponds, such as Long, Hummock, and Miacomet Ponds, or toward swamps and stream channels. This information can be used to estimate the direction of movement of ground-water contaminants. For example, the effluent from the sewage-treatment lagoons on the southeastern and southern shores of Nantucket moves directly toward the nearby sea.

Depth to the water table at any point may be determined within a few feet by subtracting the altitude of the water table from the altitude of land surface, as determined from topographic contours.

The thickness of the freshwater body, and, thus, the depth to the zone of transition, may be estimated from the contours showing altitude of water level. The deep test hole in the east-central part of Nantucket showed the depth to the zone of transition to be nearly equal to 40 times the altitude of the water table, and this relation may be used to estimate the depth to the transition zone elsewhere beneath Nantucket. In other words, for each foot of freshwater head above sea level, there will be about 40 feet of freshwater below sea level.

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WATER RESOURCES OF NANTUCKET ISLAND, MASSACHUSETTS

By
Eugene H. Walker

1980

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