Geology and Ground-Water Resources of Southeastern New Hampshire

By EDWARD BRADLEY

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Prepared in cooperation with the New Hampshire Water Resources Board

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GEOLOGY AND GROUND-WATER RESOURCES OF SOUTHEASTERN NEW HAMPSHIRE

By Edward Bradley

ABSTRACT

The continued growth and development of southeastern New Hampshire, an area of about 390 square miles adjacent to the Atlantic Ocean, will depend partly on effectively satisfying the demand for water, which has increased rapidly since World War II.

The report identifies and describes the principal geologic units with respect to the occurrence of ground water. These units include bedrock and the various unconsolidated deposits that mantle the bedrock surface discontinuously throughout the area.

The bedrock formations, consisting of igneous and metamorphic rocks, chiefly of Paleozoic age, form a single water-bearing unit. Ground water is in joints and fractures. The fractures are small and scattered and therefore impart only a low permeability to the rocks. Wells in the bedrock commonly produce small but reliable supplies of ground water at depths of less than 150 feet. The yields of about 80 wells inventoried for this report ranged from 1½ to 100 gpm (gallons per minute) and the median was 9½ gpm. Depths ranged from 45 to 600 feet.

The unconsolidated deposits consist of glacial drift of Pleistocene age; swamp deposits, alluvium, and beach deposits of Recent age; and eolian deposits of Pleistocene and Recent age. For this report the glacial drift is divided into till, ice-contact deposits, marine deposits, and outwash and shore deposits.

Glacial till forms a discontinuous blanket, commonly less than 15 but in some hills (drumlins) as much as about 200 feet thick. It has a low permeability but, because of its widespread outcrop area, it has been utilized as a source of water for numerous domestic supplies. Because most wells in till are shallow, many fail to meet modern demands during dry summers.

Ice-contact deposits locally form kames, kame terraces, kame plains, and ice-channel fillings throughout the area. They overlie bedrock and till and range in thickness from less than 1 foot to as much as 190 feet. In general, the ice-contact deposits are coarse textured and permeable, but variations in the physical and hydrologic properties of a single deposit and from deposit to deposit are common. Ice-contact deposits are the source of the larger ground-water supplies in southeastern New Hampshire.

Marine deposits underlie lowlands and valleys to a distance of about 20 miles inland from the present coastline. They commonly overlie bedrock and till and at places overlie or are interbedded with ice-contact deposits. Marine deposits range in thickness from less than 1 foot to possibly 75 feet. They are fine textured and impermeable; they do not yield water to wells in southeastern New Hampshire but generally act as a barrier to ground-water movement.

Outwash and shore deposits form broad sand plains or gently sloping terraces of small extent. At most places the outwash and shore deposits, which range in thickness from less than 1 foot to about 50 feet, overlie marine deposits, but at some places they overlie bedrock, till, or ice-contact deposits. The outwash and shore deposits are fine textured and moderately permeable. They commonly yield enough ground water to meet the needs of farms, homes, and small industries.

Alluvium underlies the flood plains and channels of the principal streams and overlies bedrock and older unconsolidated deposits wherever streams cross the older units. The alluvium generally is not tapped by wells.

Beach deposits occupy areas along the Atlantic Ocean between promontories of bedrock or till. In general beach deposits are permeable and are a source of water supplies for domestic use. Yields of wells are limited, however, by the danger of drawing in salty water.

Recharge in southeastern New Hampshire is derived principally from precipitation on outcrop areas of ice-contact deposits and outwash and shore deposits during the nongrowing season. Ground water is discharged naturally by springs, by effluent seepage to streams and other bodies of surface water, and by evapotranspiration. It also is discharged artificially, largely by municipal wells of the cities of Dover and Portsmouth and the towns of Exeter, Hampton, Newfields, Farmington, Salmon Falls, and Somersworth. In 1956 the average daily consumption for these communities was about 6.5 million gallons.

The chemical quality of the ground water is generally satisfactory for most uses. The water is soft and has a low dissolved solids content, but locally it is corrosive; an excessive iron content is fairly common.

The individual bodies of ice-contact deposits form numerous aquifers whose potentialities differ greatly; therefore each aquifer requires individual study. Some of the aquifers are recharged solely by direct precipitation, and the availability of ground water is limited thereby. Others are situated favorably with respect to inducing recharge from nearby streams, ponds, or lakes, and the availability of ground water commonly is determined partly by the flow of the stream or the size of the pond or lake.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

Since World War II the use of water in southeastern New Hampshire has increased rapidly owing to industrial expansion in the larger cities and towns, installation of the Pease Air Force Base in Portsmouth and Newington, and rapid growth of the coastal communities and the towns near the Massachusetts-New Hampshire border. The continued growth and development of the area will depend in part on effectively satisfying the resulting demand for additional water. As a basis for so doing, knowledge of the water resources of the area is essential.

This report presents the results of an investigation of the groundwater resources of southeastern New Hampshire by the U.S. Geological Survey in cooperation with the State of New Hampshire. Work was begun in 1953 with the New Hampshire State Planning and Development Commission as the cooperating State agency. In

1955, cooperation was transferred by the New Hampshire General Court from the State Planning and Development Commission to the New Hampshire Water Resources Board. The ground-water resources of the northern part of the area were described in a preliminary open-file report (Bradley, 1955).

The purpose of the investigation was to collect and interpret information on the occurrence of ground water and to evaluate the ground-water resources of southeastern New Hampshire. Particular attention was given to the occurrence of ground water in the unconsolidated deposits that form the principal aquifers in the area.

The report is based upon data collected during the period September 1953 to January 1958. The occurrence, availability, and quality of ground water are discussed in general terms; the aquifers that are promising with respect to the further development of ground water are identified and described in relation to the several towns and cities of the area. The report includes maps showing the glacial and other unconsolidated deposits in the area. Detailed maps and geologic sections for areas of special interest and the locations of selected wells, test holes, and springs are also in this report.

A separate basic-data report (Bradley and Petersen, 1962) contains descriptive records of wells, test holes, and springs, logs of wells and test holes, and records of water-level fluctuations compiled for this investigation.

The work was directed from 1953 to 1956 by J. E. Upson and from 1956 to 1958 by O. M. Hackett. Charles W. Poth assisted with geologic mapping during the summer of 1954. Analyses of samples of ground water were made by the Quality of Water Branch of the Geological Survey and by the Division of Sanitary Engineering of the New Hampshire Department of Health. Analyses of rock materials for particle size and hydrologic properties were made by the Denver Hydrologic Laboratory of the Geological Survey.

LOCATION AND EXTENT OF THE AREA

Southeastern New Hampshire, as defined for this report, is an area of about 390 square miles adjacent to the Atlantic Ocean (fig. 1). It includes a large part of the area designated as the "Seacoast Region" by the New Hampshire State Planning and Development Commission. It lies between Massachusetts on the south and Maine on the north and northeast. It is bounded on the east by the Atlantic Ocean and on the west by a line drawn approximately northward from Atkinson at the Massachusetts border to Farmington near the Maine border. Towns and cities all or partly included in the area are: Atkinson, Barrington, Brentwood, Dover, Durham, East Kingston, Epping, Exeter, Farmington, Greenland, Hampton, Hampton Falls, Kensing-

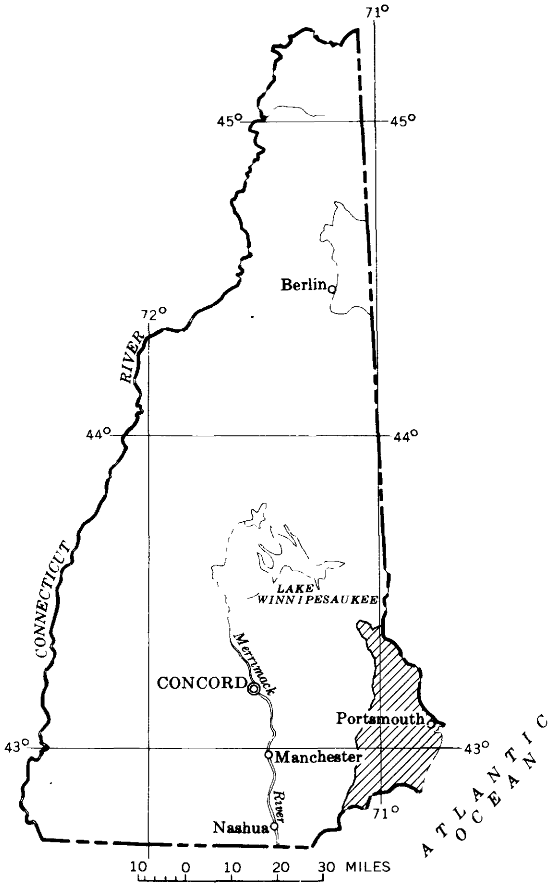

FIGURE 1.—Index map of New Hampshire.

ton, Kingston, Lee, Madbury, Newcastle, Newfields, Newington, Newmarket, Newton, North Hampton, Plaistow, Portsmouth, Rochester, Rollinsford, Rye, Seabrook, Somersworth, South Hampton, and Stratham. The entire area is within Rockingham and Strafford Counties.

METHODS OF INVESTIGATION

Field methods of investigation included inventorying wells and springs, mapping the surficial geology of the area, collecting samples of water for chemical analysis, collecting samples of rock materials for analyses of physical properties, and measuring water levels systematically in a network of observation wells.

The geologic mapping (pls. 1 and 2) for this report was supplemented by the use of existing geologic and soils maps. The geology of the southeastern part of the region was adapted from a map by S. D. Tuttle in an unpublished Ph. D. thesis (The Quaternary geology of the coastal region of New Hampshire, Harvard Univ., 1952). Tuttle's units were modified to suit the purpose of this report, and his locations of the contacts between some geologic units were altered on the basis of more recent information. A soils map of Strafford County (Shearin and others, 1949) and an unpublished soils map of Rockingham County by VanderVoet and others (written communication, 1957, Dirk VanderVoet, Soil Conservation Service, U.S. Dept. of Agriculture) were used in completing the mapping of contacts between geologic units in inaccessible areas.

In this report and in the basic-data report (Bradley and Petersen, 1962), wells and test holes are numbered consecutively in each town or city. Springs are numbered similarly, but the letters "sp" precede the numbers in order to distinguish them from well numbers. In the text and in other parts of the report where the number otherwise would not be clearly identified with a given town or city, the name of the town or city accompanies the number.

For ease in locating wells, test holes, and springs on the maps, a well-location system based on the 7½-minute quadrangles in New England has been adopted. In this system each 7½-minute quadrangle is designated by a capital letter and a number, beginning with A1 for the Glenville quadrangle, Connecticut. From there, letters extend from west to east and numbers from south to north. Each 7½-minute quadrangle is divided into nine 2½-minute rectangles that are numbered consecutively, as shown in figure 2. The location designation of each well is listed in tables 2 and 4 of the basic-data report (Bradley and Petersen, 1962).

The well-location system described above is also used in this report for ease in locating geologic and hydrologic units.

ACKNOWLEDGMENTS

The writer appreciates the information and assistance received from State and municipal officials, residents of the area, well drillers, and consulting engineers. T. R. Meyers, State Geologist, advised the writer on many aspects of the investigation and supplied data from the files of the State Geologist and the University of New Hampshire. Paul Otis and Donald Roach of the New Hampshire Public Works and Highways Department supplied logs of test borings and gave the writer access to State maps of sand and gravel deposits. W. A. Healy of the New Hampshire Department of Health furnished chemical analyses. Many of the logs of test holes were furnished by the New England Division, Corps of Engineers, U.S. Army.

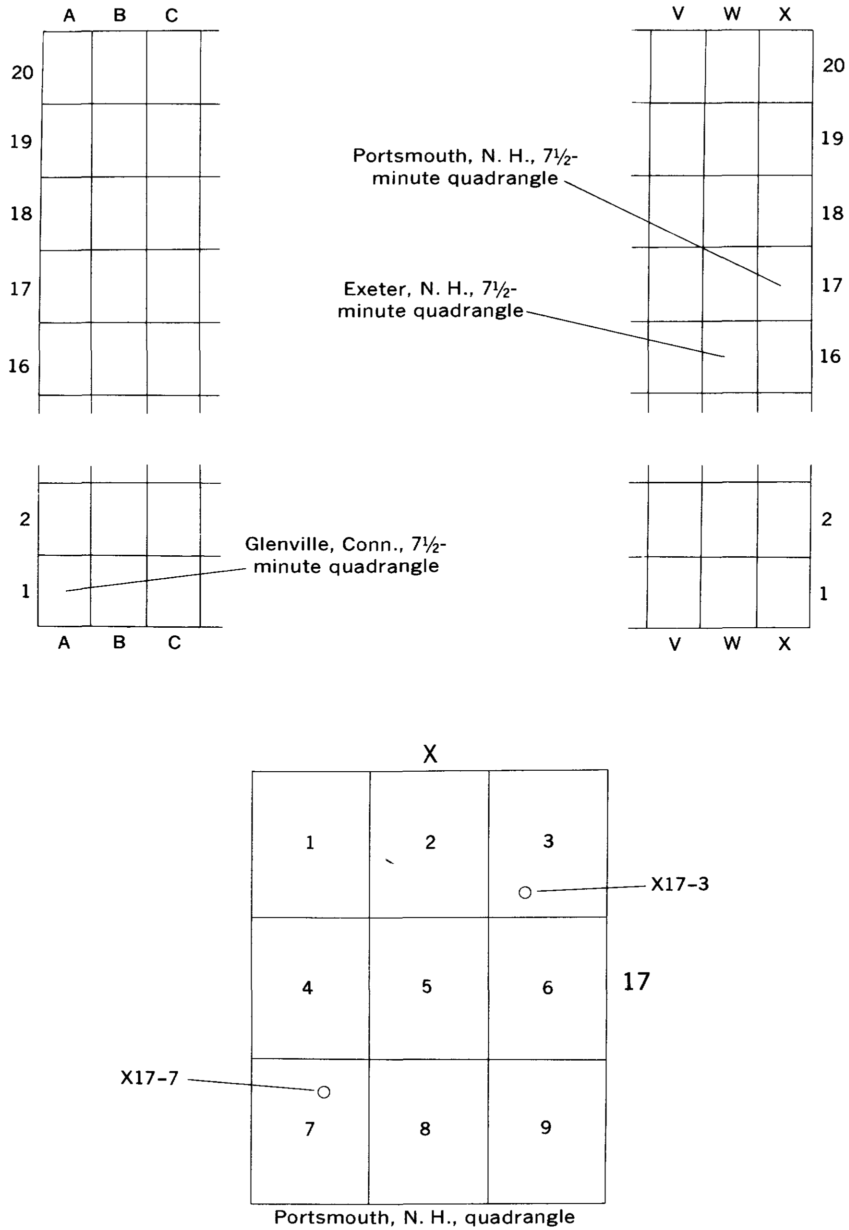

FIGURE 2.—Sketch showing well-location system.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Southeastern New Hampshire lies within the Seaboard Lowland section of the New England physiographic province. To the east is the Atlantic Ocean, to the west is the New England Upland section, which Fenneman (1938, p. 358) described as "* * * an upraised peneplain bearing occasional monadnocks and dissected by narrow valleys." The Seaboard Lowland he described (p. 370) as "* * * merely the sloping margin of the upland."

In broad form the eastern part of the report area differs somewhat from the western part. The eastern part is a coastal plain from 5 to 10 miles wide, which owes its form principally to unconsolidated deposits of glacial and marine origin. In contrast, the topography of the western part of the area mildly expresses the shape of the bedrock surface. Here unconsolidated deposits are widespread but hills and ridges of bedrock are much more prominent than on the coastal plain.

The relief of the area is low and the topography is irregular. Most of the area is less than 200 feet above sea level. Broad flat or undulating lowlands, commonly poorly drained and at many places swampy, are flanked by terraces and outwash plains. In general these slope gently southeast at levels ranging from about 30 to about 80 feet above the adjacent lowlands. Here and there are rounded hills and ridges, which in the western or inland part of the region commonly are sonewhat higher than the plains and terraces. Near the coast, however, they surmount the plains and terraces at only a few places.

The coastline of New Hampshire is relatively smooth and unbroken except near Portsmouth where it is indented by the estuary of the Piscataqua River and by Great and Little Bays. Much of the coastline is formed by off-shore bars. These are backed by extensive tidal flats.

Most of the report area is drained by tributaries of the Piscataqua River. The Salmon Falls River together with the Cocheco River and its main tributary the Isinglass drain the northern part of the area. These streams flow generally southward and join east of Dover to form the Piscataqua. The Bellamy, Oyster, Lamprey, Squamscott, and Exeter Rivers drain the western and central parts of the area. They flow generally eastward and enter the Piscataqua by way of Great Bay and Little Bay.

The rest of the area is drained by tributaries of the Merrimack River and by several coastal streams. Powow and Little Rivers, which flow southward to join the Merrimack in Massachusetts, drain a very small area in the southwestern corner of the area. Several short streams, which flow eastward directly to the Atlantic Ocean, drain most of the coastal plain. Of these, the Taylor River is the largest.

In general the streams of the region are consequent and follow courses determined by the configuration and slope of the postglacial topography. However, in a few places some of the streams fit a preglacial subsequent drainage pattern following the north-northeasterly strike of the metasedimentary rocks. For example, the course of the Lamprey River in the first few miles upstream from its mouth is controlled by the structure of the bedrock; the river flows between bedrock ridges parallel to the regional strike.

The coastal streams and the rivers that drain directly to Great and Little Bays and the Piscataqua are tidal for some distance from their mouths. Tidewater extends upstream to the towns of Salmon Falls on the Salmon Falls River, Dover on the Cocheco and Bellamy Rivers, Durham on the Oyster River, Newmarket on the Lamprey River, and Exeter on the Squamscott River. The Cocheco and Salmon Falls Rivers are polluted by industrial wastes and sewage both above and below tidewater.

In comparison with the rest of New Hampshire the report area has few lakes and ponds. There are several small lakes near the western margin of the area; elsewhere there are only a few small isolated ponds.

CLIMATE

Southeastern New Hampshire has a modified humid continental climate characterized by cold, long winters and moderate summers.

Precipitation at Durham is representative of that for the area in general. Data compiled from records collected at Durham by the U.S. Weather Bureau are summarized graphically in figures 3 and 4. The average annual precipitation is about 40 inches. The least annual precipitation, recorded in 1941, was 23.95 inches and the greatest, recorded in 1954, was 60.18 inches. Precipitation usually is distributed fairly evenly from month to month. Annual snowfall averages about 50 inches.

At Durham, which is in the inland part of the region, the average annual temperature is about 46° F. January is the coldest month; the average temperature is about 24° F. July, which is the warmest month, has an average temperature of about 70° F. During warm weather, a coastal belt several miles wide is affected by land-sea breezes and temperatures usually are a few degrees lower than in adjacent areas inland.

The growing season averages about 140 days. The average date of last killing frost in the spring is May 20 and that of the first killing

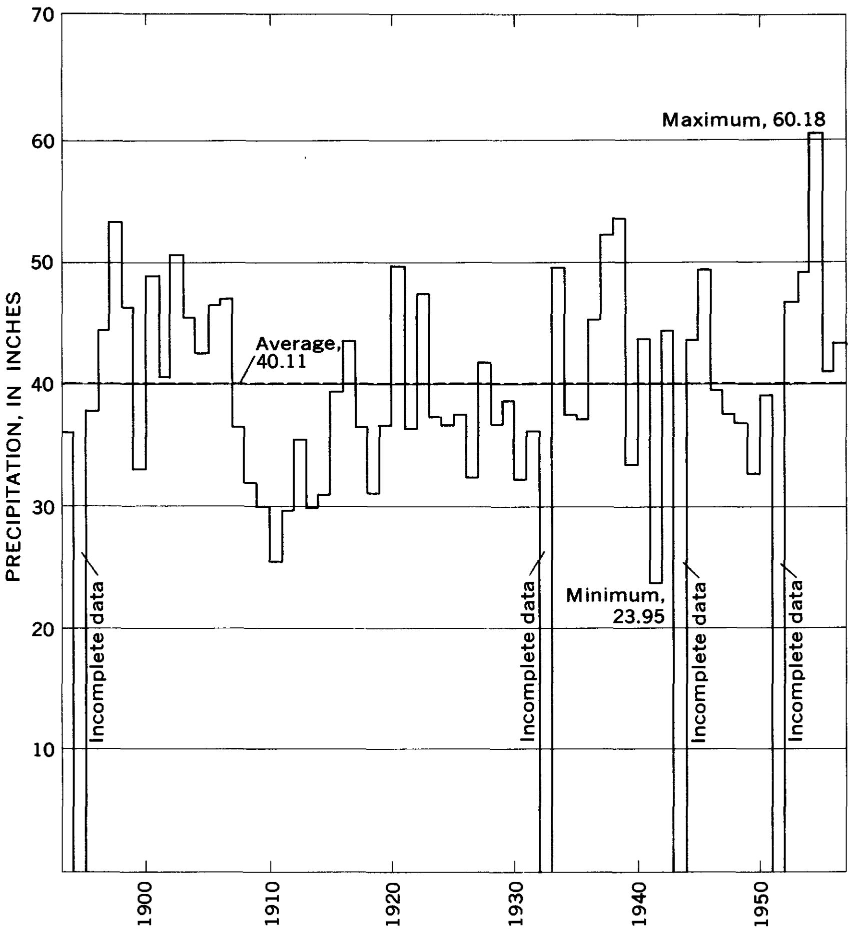

FIGURE 3.—Annual precipitation at Durham, N.H.

frost in the fall is September 30 (Garland and others, 1956, p. 12–14).

The weather pattern is similar to that of New England in general; it is described by Nesmith (1941, p. 999–1,000) as follows: "New England, lying in the middle latitudes, comes within the influence of constant conflicts between cold, dry air masses flowing out of the great subpolar region to the northwest and the warmer, moisture-bearing, tropical marine air from the south." Frequently warm, moist air masses are forced aloft over wedges of relatively dry, continental air, and rain, snow, or cloudiness results. Under the influence of the prevailing westerlies, weather disturbances and storms in New England usually move northeastward, and are followed by several days of clear, fair weather characterized by warm south-

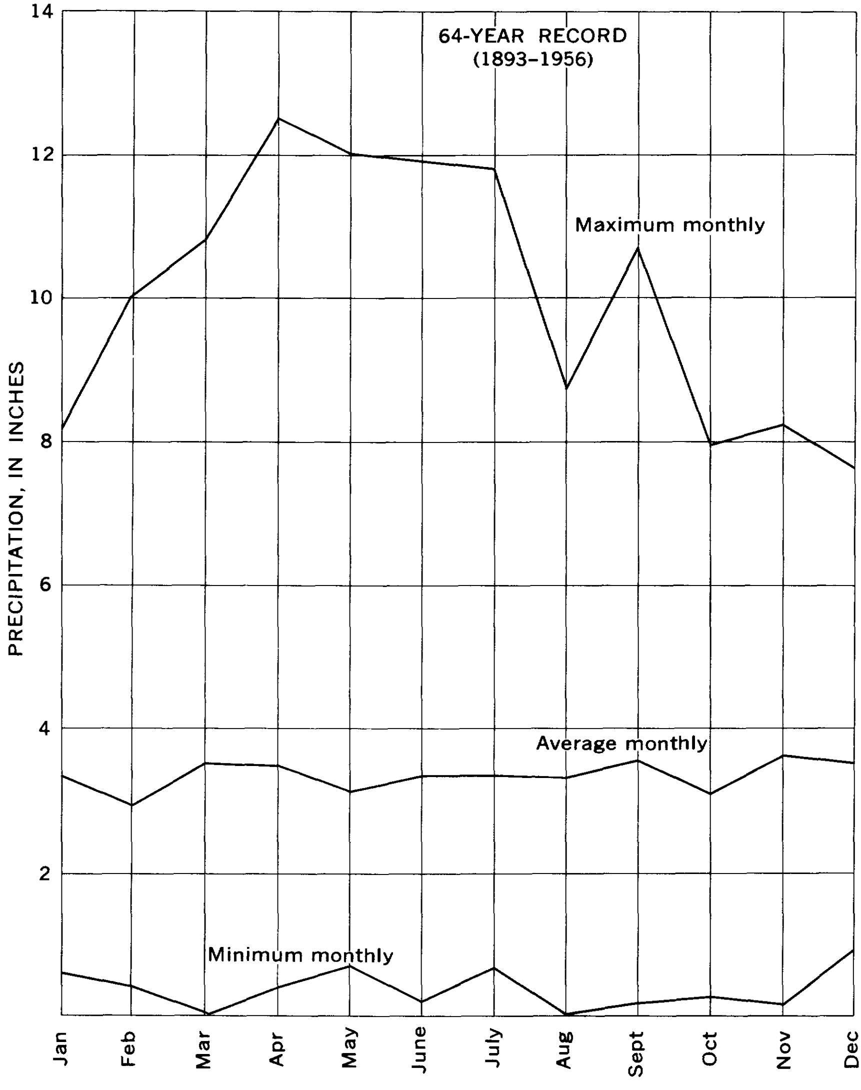

FIGURE 4.—Average, maximum, and minimum monthly precipitation at Durham, N.H.

westerly winds in the summer and cold northwesterly winds in the winter.

Hurricanes of tropical origin occasionally reach New England. In the past such storms in the northeastern part of the country occurred infrequently, perhaps about once every 100 or 125 years. However, since 1935, six hurricanes have swept across New England and adjacent states. A hurricane in September 1938 killed 661 persons in New England and severely injured 1,700 others. Other hurricanes occurred in September 1944, August and September 1954, and August 1955 (two). In southwestern New England the rainfall associated with the two storms in 1955 produced the worst floods known in that area.

DEVELOPMENT

POPULATION

The population of southeastern New Hampshire in 1950 was about 96,000, slightly less than one-fifth that of New Hampshire. About half the inhabitants lived in Portsmouth, Dover, and Rochester, the three largest cities.

The rate of increase of population during and after World War II is especially great. From 1940 to 1950 the population of Rockingham and Strafford Counties increased about 20 percent. The rate of increase was more than double that of New Hampshire as a whole and was substantially larger than that of other parts of the State. Estimates made since 1950 show the rapid growth of population to have continued. In particular the population of Portsmouth and nearby communities has grown rapidly since 1954 owing to the construction of the Pease Air Force Base. Each summer the populations of many of the coastal towns are increased temporarily by large numbers of summer residents and vacationers. Table 1 lists the population of towns and cities in 1950 and also gives the percent increase in population from 1940 to 1950. These data are from a report of the New Hampshire State Planning and Development Commission (1951, p. 6–7).

TABLE 1.—*Population of towns in southeastern New Hampshire*

Town or city	Population 1950	Percent increase 1940 to 1950	Town or city	Population 1950	Percent increase 1940 to 1950
Rockingham County			**Rockingham County—Continued**		
Atkinson [1]	492	13.4	Rye	1,982	59.1
Brentwood	819	13.8	Seabrook	1,788	0.3
East Kingston	449	5.9	South Hampton	314	6.8
Epping [1]	1,796	11.0	Stratham	759	19.7
Exeter	5,664	4.9			
Greenland	719	3.3			
Hampton	2,847	33.2	**Strafford County**		
Hampton Falls	629	27.6			
Kensington	542	18.3			
Kingston	1,283	28.0	Barrington [1]	1,052	34.9
New Castle	583	7.6	Dover	15,874	5.9
Newfields	469	12.5	Durham [2]	4,770	[2] 211.2
Newington	494	18.2	Farmington [1]	3,454	11.6
Newmarket	2,709	2.6	Lee [1]	575	19.5
Newton	1,173	30.3	Madbury	489	21.9
North Hampton	1,104	35.0	Rochester [1]	13,776	14.7
Plaistow	2,082	47.2	Rollingsford	1,652	12.9
Portsmouth	18,830	27.0	Somersworth	6,927	12.9

[1] Not all of the town or city is included in the area of this investigation.
[2] University of New Hampshire students were included in the 1950 census, but not in the 1940 census.

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ECONOMY

Industry is the greatest single factor in the economy of southeastern New Hampshire. In general the industry is similar to that of other parts of New Hampshire and is characterized by the manufacture of low-bulk high-value goods. Since World War II, the production of electronic, electrical goods, and light metals has increased in importance.

A few large industries that are distinct from others in the area occupy tidewater sites along the Piscataqua River in Portsmouth and Newington. They include fuel distributing, power producing, manufacturing of gypsum products, and manufacturing of submarine cables. A large mica-products plant is located at Newmarket.

Agriculture though less important than industry is nevertheless a significant factor in the economy of the area. The principal products, in order of income yielded, are poultry and poultry products; dairy products; crops such as vegetables and apples; livestock products; and forest products such as lumber, fence posts, fuel, and pulp.

Three types of mineral resources are being developed, mostly for use locally as construction materials. Sand and gravel are used as materials for roads and general construction. Quartzite is quarried from the bedrock and crushed for use as a road material also. Silt and clay are used for making bricks.

Recreational facilities bring an influx of vacationers, tourists, and summer residents to the area each year. The beaches along the coast are the greatest attraction, although some of the lakes and ponds in the western part of the report area are used for recreation also.

Transportation in southeastern New Hampshire is facilitated by several rail lines and by highways. The larger communities are served by main or branch lines of the Boston and Maine Railroad. Modern highways and many paved rural roads cross most parts of the report area.

Small vessels and barges formerly traveled up the Piscataqua River, Great and Little Bays, and the tidewater estuaries of the major streams to Exeter, Newmarket, Dover, and Salmon Falls, but in recent years rail and highway transportation have replaced water transportation to these communities.

Portsmouth has the only harbor for deep-draft vessels between Portland, Maine, and Gloucester, Mass. The harbor is open throughout the year and is a center for domestic trade and for occasional foreign trade. The Portsmouth Navy Yard in Kittery, Maine, opposite Portsmouth, is a large facility of the U.S. Navy.

The only major airfield in the region is Pease Air Force Base of the Strategic Air Command. There are several small private airstrips in the area.

WATER SUPPLY

Water supplies in southeastern New Hanpshire are obtained locally from ground-water or surface-water sources. The municipal supply for Rochester, the third largest city in the area, is obtained from ponds and streams. The municipal supply for Newmarket also is from a stream, although a drilled well is used as a standby and for emergencies. Durham and the University of New Hampshire obtain water from the Oyster River. The rest of the towns and cities that have municipal water supplies get all or most of their water from ground-water sources; these communities are Portsmouth, Dover, Somersworth, Exeter, Hampton, Seabrook, Newfields, Salmon Falls, and Farmington. In towns having no municipal water departments and in the rural parts of the towns and cities listed above, most water supplies are from privately owned wells or springs.

There is now little industrial use of fresh water from streams. During the early industrial development of the region, however, most of the major streams were dammed at one or more sites for utilization of water power.

GEOLOGY AND THE OCCURRENCE OF GROUND WATER

The principles of ground-water occurrence are discussed in detail by Meinzer (1923a, 1942). The following paragraphs summarize some of the basic concepts and define some of the terms used frequently in this report. Terms used less frequently are defined where they are first mentioned.

Within the earth is a zone in which the rocks are saturated with water under hydrostatic pressure. The water in the "zone of saturation" is termed "ground water," and the upper surface of the zone of saturation except where that surface is formed by an impermeable body is termed the "water table."

Ground water occurs in openings, called "pores" or "interstices," in the rock materials. The water-bearing properties of a rock depend on the number, size, shape, and arrangement of its interstices. The properties of particular interest are porosity, permeability, and specific yield.

The "porosity" of a rock, its property of containing interstices, determines its capacity to store water. Porosity may be expressed quantitatively as the percentage of the total volume of the rock that is occupied by interstices.

"Permeability," with respect to water, is the capacity of a rock to transmit water under pressure. The "coefficient of permeability" used by the Geological Survey is defined as the rate of flow of water in gallons per day through a cross-sectional area of 1 square foot under a hydraulic gradient of 100 percent at a temperature of 60°F (Meinzer, 1923b, p. 44). For convenience, a "field coefficient" often is used, in which the flow of water is measured at the prevailing temperature.

"Specific yield" is the capacity of a rock to yield water under the force of gravity. It is defined as the ratio, expressed as a percentage, of the volume of water that will drain by gravity to the total volume of the fully saturated rock. "Specific retention," the companion property of specific yield, is the ratio, also expressed as a percentage, of the volume of water retained in the rock by molecular attraction after it is drained by gravity to the total volume of the fully saturated rock. Together, specific yield and specific retention equal porosity.

The occurrence of ground water depends not only on the water-bearing properties of the rock materials, but on the thickness, structure, and distribution of units that are composed of rocks having more or less common properties among themselves but distinct from those of rocks of other units. A rock unit that yields enough water to be a source of supply is called a "water-bearing formation," "ground-water reservoir," or "aquifer."

Ground water is said to occur under either "water-table (unconfined)" or "artesian (confined)" conditions. Water-table conditions exist in an aquifer if the top of the ground-water body is at atmospheric pressure. Artesian conditions exist in an aquifer if it is fully saturated and if the water at the top of the aquifer is under hydrostatic pressure. The imaginary surface formed by connecting levels to which ground water would rise is an infinite number of tightly cased wells penetrating an artesian aquifer is called a "piezometric surface."

The conditions of occurrence have significant implications with respect to the development of an aquifer. Because the withdrawal of water from a water-table aquifer involves the actual dewatering of the aquifer, the effect is transmitted slowly to places remote from the point of withdrawal. In contrast, because an artesian aquifer ordinarily remains fully saturated, the change in hydrostatic pressure effected by a withdrawal is quickly transmitted a considerable distance.

The significant geoligic units with respect to the occurrence of ground water in southeastern New Hampshire are discussed below under two main headings, "Bedrock" and "Unconsolidated deposits." Bedrock, often called "ledge" in New Hampshire, is a general term for the consolidated or solid rocks of the earth's crust. The unconsolidated deposits are the loose granular rock materials that mantle the bedrock surface at most places. The distribution of the geologic units is shown in plates 1 and 2. A summary of these units and their water-bearing properties is given in table 2.

TABLE 2.—*Geologic units in southeastern New Hampshire*

Era	Series	Unit	Thickness	Character of material	Topographic situation	Water-bearing properties
Quaternary	Recent	Beach deposits	0–25±	Fine to medium sand; waterworn cobbles and stones.	Modern beaches along coastline.	Permeable but generally contain only a few feet of fresh water over salt or brackish water. May yield a few gallons per minute at places, but heavy pumping produces salt water.
		Alluvium	Unknown	Stratified sand and silt; contains a few cobbles and small boulders.	Stream channels and flood plains.	Probably moderately permeable and saturated with water at many places, but generally not tapped by wells.
	-----?------	Swamp deposits	0–20±	Silt, sand, some gravel and organic matter.	Poorly drained areas, depressions, and lowlands.	Not tapped by wells.
	Pleistocene	Outwash and shore deposits	0–50±	Stratified fine to coarse sand and fine gravel; contain pebbles and cobbles at places.	Extensive outwash plains in inland parts of the area; thin terraces and old shoreline deposits near coast.	Moderately permeable. Where saturated thickness is sufficient, supply water for domestic and farm wells and may yield as much as 100 gpm at places.
		Marine deposits	0–75±	Clay, silt, and some sand; commonly laminated, but massive in places.	Stream valleys and lowland areas.	Impermeable. Rarely yield water to wells, but overlie water-bearing deposits at places, and create artesian conditions.
		Ice-contact deposits	0–190±	Stratified sand, gravel, cobbles, and some boulders; contain silt and clay lenses in places; cross bedding and deltaic bedding common.	Generally flat, elongate plains, terraces along hillsides, and irregular hills and mounds.	Generally have high permeability but locally may have relatively low permeability. Furnish water for most of large public-supply systems in the area. Yields of about 700 gpm are available at many places where the saturated thickness is greater than about 50 ft.
		Till	0–225±	Unsorted clay, silt, sand, gravel, cobbles, and boulders, moderately to highly compact; largely silt and sand at most places.	Irregular rolling surface in ground moraine; rounded hills in drumlins.	Generally has low permeability. At some places, where thicker than 10 to 15 ft, yields sufficient water to dug wells for domestic use, but many wells go dry during long droughts.
Paleozoic	--------------	Bedrock	Unknown	Fractured igneous and metamorphic rocks; dense.	Irregular surface underlying unconsolidated deposits; outcrops on hills and ridges.	Contains water in cracks. Yields small to moderate quantities of water from drilled wells.

BEDROCK

Bedrock is discussed as a single unit with respect to the occurrence of ground water. Accordingly, only a brief summary of the bedrock geology is given. The source of this discussion is a report and geologic map by Billings (1956).

DESCRIPTION AND DISTRIBUTION

Metamorphic rocks of sedimentary and volcanic origin underlie most of southeastern New Hampshire. These rocks have been divided into the Rye formation of probable Ordovician and Silurian age; the Merrimack group, which includes the Kittery quartzite and the Berwick and Eliot formations, all of probable Ordovician and Silurian age; and the Littleton formation of Early Devonian age. The Rye formation, which consists of varieties of schist, gneiss, and amphibolite, crops out in a band less than 5 miles wide that extends along the coast from Portsmouth to Hampton Falls. The Littleton formation, consisting of gray micaceous quartzite and gray coarse-grained mica schist, underlies a small area extending from the Rochester vicinity up the valleys of the Cocheco and Salmon Falls Rivers. The Merrimack group underlies most of the rest of the area. Except for the Kittery quartzite, which consists of quartzite and slate, the rocks of this group are composed of varieties of slate, schist, siltstone, and phyllite.

All formations have been folded and faulted. In places they are intruded by plutonic rocks. The general structural trend is northeast.

Plutonic rocks underlie only small parts of the area. The Newburyport quartz diorite of Precambrian or Ordovician age occupies a few square miles in the extreme southeast corner of the area. The rest of the plutonic rocks, which are of Late Devonian age, consist of granite, diorite, granodiorite, quartz monzonite, and quartz diorite. They occur in generally lenticular bodies that trend northeast, parallel to the strike of the metamorphic rocks in which they were emplaced. A large body of diorite crops out in a belt as much as 4 miles wide extending south-southeastward from the vicinity of Salmon Falls to the Exeter River between Brentwood and Exeter. A large body of granite, quartz monzonite, and granodiorite, underlies an area of several square miles south of Rochester. Several small bodies of granite and diorite crop out near the coast in areas ranging in size from less than one to a few square miles.

As a result of erosion during most of the time since the Paleozoic era, the bedrock formations have been beveled, and now have a gently uneven surface of low relief. This surface is overlain discontinuously by unconsolidated deposits, and its precise configuration in the report area is effectively masked thereby. The greatest known local relief of the bedrock surface is about 200 feet.

There are numerous outcrops of bedrock on hills or ridges, but even there the bedrock is largely veneered by glacial till. Because most of these outcrops are small, they are not differentiated from till on the geologic maps (pls. 1, 2) accompanying this report. In the southeastern part of Durham (chiefly in W 17–3, pl. 2), bedrock is extensively exposed along ridges; it is covered between the ridges by a thin layer of unconsolidated deposits. In the western part of Exeter, knobs and ridges of bedrock protrude through marine deposits in one small area and through outwash and shore deposits in another. These areas are specially indicated on plate 1.

WATER IN THE BEDROCK

There seem to be no significant differences in the water-bearing properties of the several bedrock types despite their distinctive physical properties. Ground water occurs principally in joints or fractures—so called "secondary openings" that were formed after the rocks were consolidated. Water also may occur in openings between crystal grains, but these openings are so minute that they yield no water to wells. The following description by Cushman and others (1953, p. 54) of joints in the metamorphic and igneous rocks of southern New England also is applicable generally to joints in the bedrock of southeastern New Hampshire.

> The most common type of joint is that which dips at an angle greater than 45° from the surface, here called a vertical joint. These joints intersect each other at various angles and break the rock into irregular polygons. The width of opening varies with rock type and ranges from that which is scarcely visible to several inches. The spacing of vertical joints is usually 5 to 10 feet, but may range from a fraction of an inch to as much as 200 feet. The width of vertical joints and the number of joints decrease with depth, owing to increased pressure and the resulting decreased opportunity for lateral expansion. Thus, there is a greater circulation of water in the upper part of a given joint than in the lower part. This is an important consideration in the drilling of wells in consolidated rocks, as it is often thought that more water can always be obtained by deeper drilling. Actually, the deeper a well is drilled below a certain depth the less is the chance of striking fractures.
>
> A second type of joint is horizontal or nearly horizontal. Such joints are due to the process known as sheeting and are well developed in the more massive rocks, particularly granite. The joint surfaces are more or less conformable to the ground level, being convex upward on the hills and concave upward in the valleys. Those in the valleys thus form shallow basins which are ideal for the collection and storage of ground water. The spacing of horizontal joints is more regular than that of vertical joints but their number and width diminish rapidly with depth. It is probable that they do not exist at depths much below 300 feet. Above this depth there is a widespread intersection of vertical and horizontal joints, affording opportunity for the lateral transmission of water from one joint to another.

The above description shows that joints occupy only a small part of the total volume of the bedrock, and, furthermore, they vary in size and are distributed irregularly. As a result, the permeability and storage capacity of the bedrock not only are small but also differ greatly from place to place.

Ground water in the bedrock commonly occurs under artesian conditions, that is, it rises above the point where it first is reached when a well is drilled. At most places the water is confined by the walls of the joints, but where the bedrock is overlain by impermeable deposits, such as clay, these deposits may act as the confining layer.

Owing to its low permeability, bedrock generally yields only small amounts of water to wells, although commonly enough for domestic use and less commonly enough for use by small industrial or commercial establishments. The yields of about 100 wells inventoried for this study ranged from 1½ to 100 gpm (gallons per minute) and the median was 9½ gpm. For New Hampshire as a whole, R. P. Goldthwait (1949, p. 15) reported a median yield of 6½ gpm.

Despite the small storage capacity of bedrock, the yields of most wells are dependable. This apparently anomalous situation is attributed to the presence in much of the area of saturated unconsolidated deposits overlying the bedrock. At many places these deposits store enough water to assure a dependable source of recharge to the joints, which serve primarily as conduits and transmit water from storage in the overlying deposits to the wells at slow but generally sustained rates.

Because of the random distribution and the variation in the size of the joints, neither the depths nor the yields of wells can be predicted accurately. Even where two wells are nearly side by side they may pass through different sets of joints. As a result, one well may yield an ample supply of water at a shallow depth whereas the other, even though drilled to a much greater depth than the first, may yield a comparatively small supply. Goldthwait (1949, p. 20), on the basis of data on 1,482 bedrock wells in New Hampshire, estimated the chances of obtaining 3 gpm or more as 77 in 100 and the chances of obtaining more than 12 gpm as 22 in 100. Wells inventoried for the current study ranged from 45 to 600 feet in depth, but most were less than 150 feet deep.

In most bedrock wells in southeastern New Hampshire, the static water level is within 20 feet of the land surface, and a few of the wells flow. The greatest reported depth to water is 54 feet.

In summary, the bedrock formations of the report area commonly produce small but reliable supplies of ground water from wells that at most places are less than 150 feet deep.

THE BEDROCK SURFACE

One of the principal factors controlling the occurrence of ground water in southeastern New Hampshire is the bedrock surface. The shape of this surface determines in part the thickness of the overlying unconsolidated deposits; that is, the lower the bedrock surface the thicker the overlying deposits. And because the bedrock is relatively impermeable, it, in effect, prevents the downward movement of ground water from the unconsolidated deposits. Greater understanding of ground-water conditions in the report area will be possible as more knowledge about the topography of the bedrock surface is obtained.

UNCONSOLIDATED DEPOSITS

The unconsolidated deposits in southeastern New Hampshire consist of glacial drift of Pleistocene age; swamp deposits, alluvium, and beach deposits of Recent age; and eolian deposits of Pleistocene and Recent age. For this report the glacial drift, which includes all deposits of glacial origin, is divided into till, ice-contact deposits, marine deposits, and outwash and shore deposits.

Ground water in the unconsolidated deposits occurs in the openings between the rock particles; hence, the hydrologic properties of these deposits differ according to the particle size and shape, sorting, and packing of the constituent materials. In general, the porosity, permeability, and specific yield of coarse-grained materials, such as sand and gravel, are fairly large, especially if these materials are well sorted. The porosity of fine-grained materials, such as silt and clay, commonly is large also, but because most of the water in the numerous small pores is retained there by molecular forces these materials are relatively impermeable and have a small specific yield. Poorly sorted materials, such as a mixture of clay, silt, sand, and gravel, commonly have a low porosity, permeability, and specific yield, especially if the materials are firmly packed.

The following summary of the Pleistocene and Recent geologic history of southeastern New Hampshire gives the classification, origin, and sequence of the units of unconsolidated deposits described in this report.

SUMMARY OF PLEISTOCENE AND RECENT HISTORY

The details of the Pleistocene and Recent history are complex, and the sequence has not been firmly established. Continental ice sheets may have advanced and retreated across New Hampshire several times, but it is believed that in the report area the observed deposits of glacial origin are related to a single major advance and retreat of the ice during the last (Wisconsin) stage of the Pleistocene epoch.

The ice sheet advanced across the area, scouring the underlying terrain and gathering up soil and rock debris. This debris, in turn, is spread over the bedrock surface to form a deposit known as glacial till, or simply till. In New Hampshire, including the report area two layers of till are recognized. Goldthwait (1948, p. 7), who studied these layers in some detail, concluded that both are related to a single major advance of the ice.

Subsequently the glacier melted away and its front retreated slowly from the area. Meanwhile, sediments freed from the melting ice, or perhaps derived in part from the till, were swept up by the melt water and transported, sorted, and deposited in streams, ponds, or the sea. Collectively these water-laid deposits of glacial origin are known as stratified glacial drift. They consist of ice-contact deposits, which were formed in contact with or adjacent to the ice; outwash,[1] which was deposited in ice-free valleys beyond the glacier terminus; glacial-marine shore deposits, which were formed along the shore line; and glacial-marine bottom deposits, which were formed along the bottom of the sea and in bays and estuaries. The glacial-marine shore deposits are referred to subsequently in this report simply as "shore deposits" and the glacial-marine bottom deposits are referred to as "marine deposits."

As the ice melted, hills and ridges were first exposed, while tongues of ice remained in the valleys. Gradually the ice broke into stagnating masses, then into isolated blocks. Ice-contact deposits were formed by streams flowing on, in, under, or about the ice, and marine deposits were formed in the sea beyond. Meanwhile, the melting of the ice was accompanied by a rise of sea level, and as the ice front retreated, the sea advanced across the area whose surface had been depressed by the weight of the ice. Ice-contact deposits thus formed progressively further inland, and present valleys and lowlands became island-studded bays and estuaries in which the underlying older deposits were gradually buried or partly buried by the transgressing marine deposits. Interbedded ice-contact and marine deposits suggest that at places in low areas and valleys, stagnating ice blocks were submerged by or at least were in contact with the transgressing sea.

Slowly the ice disappeared from the immediate area. Freed of the weight of the ice, the land surface rose and the present coastal region emerged from the sea. There was a regression of marine deposits as the sea receded. Melt-water streams were extended across the newly exposed land surface, and outwash and shore deposits were built progressively across the area. Finally, near the close of the Pleistocene epoch and probably continuing into Recent time, a thin discontinuous mantle of eolian (windblown) deposits was spread across the land surface.

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[1]As used here, the term "outwash" includes only stratified drift deposited beyond the glacier terminus under subaerial conditions. Many geologists use "outwash" to include all stratified drift; others restrict it to proglacial stratified drift, including marine deposits.

In Recent (postglacial) time the present drainage pattern, conforming in general to the topography of the glacial drift, was established. For a while the land surface continued to rise relative to sea level and streams channeled the earlier deposits; however, the erosion was slight and the landforms of glacial origin remain almost unchanged today. During the past 3,000 years at least, deposition apparently has been the dominant process in southeastern New Hampshire. Alluvium has been deposited along the streams, swamp deposits have accumulated in the low poorly drained parts of the area, and beach deposits have formed along the present shore line. Also during Recent time, wind action has formed sand dunes in parts of the area.

The geologic history summarized above conforms roughly to that of New Hampshire in general, as described by the Goldthwaits (1951). The field relationships observed during the current study and the other evidence supporting the postulated sequence of events in southeastern New Hampshire are given in the individual discussions of the several geologic units. These units are described below in the following order: till, ice-contact deposits, marine deposits, outwash and shore deposits, swamp deposits, alluvium, beach deposits, and eolian deposits. The extent and distribution of the principal units are shown on plates 1 and 2. The eolian deposits, which are superficial, thin, and present at only a few places, are not shown. The extent, distribution, and subsurface relationships of the principal units in special areas within southeastern New Hampshire are also shown on plates 3–7.

TILL

Description and distribution.—Till is distributed throughout the report area and crops out in about a quarter of the area (pls. 1, 2), chiefly on hills and ridges. At most places it forms ground moraine, a thin, generally continuous layer whose surface is gently irregular. This layer commonly is less than 15 feet thick but locally may be as much as a few tens of feet thick. Till also forms rounded, elliptically shaped hills called drumlins. Several of these are grouped in the towns of Kensington and Southampton, and isolated drumlins are scattered elsewhere. Many drumlins are composed almost entirely of till; others consist of bedrock covered by only a thin veneer of till. The thickness of the till in the drumlins ranges from less than 1 foot to as much as 200 feet. (See log of well Kensington 6, table 4, Bradley and Petersen, 1962.)

By definition "till" is an unsorted, mixture of rock particles of all sizes from clay to boulders that was deposited more or less directly by ice. It is compact and therefore often is referred to as "hardpan." In southeastern New Hampshire the till consists mostly of sand and silt, some gravel and larger rock fragments, and only a small proportion of clay. The particles are generally angular to subangular. The high proportion of silt and sand relative to clay reflects the resistant nature of the crystalline bedrock from which the till was derived. Particle-size analyses for 6 samples are given in table 3. Three of the analyses are compared in figure 5 by means of size-distribution curves.

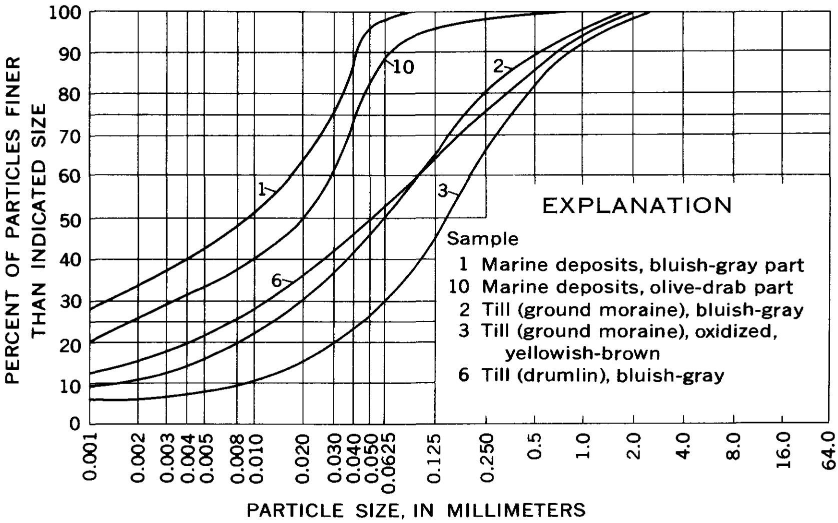

FIGURE 5.—Particle-size distribution curves for selected samples of unconsolidated deposits.

The upper part of the till commonly is yellowish brown or olive drab, the lower part grayish blue. Goldthwait (1948), who studied the till of New Hampshire in some detail, noted that the lower till also contains more silt and clay than the upper. He concluded that both tills originated from a single major ice advance. The color difference he attributed to the position of the water table. Below the water table the ground water protected the bluish-gray lower till from weathering and the attendant oxidation of the iron-rich minerals, by which the upper till gained its yellowish-brown color. The difference in clay and silt content he attributed to subglacial rather than englacial origin. He stated (1948, p. 8), "The subglacial debris would be expected to have more of the finer grains because the grinding effect would be greater in the lower dirtier ice and would remain with little change. As the surface of the ice melted downward, and the debris became concentrated on it, the clays and silts would tend to be carried off in suspension by drainage."

Till discontinuously overlies bedrock throughout the area and in turn is overlain by younger unconsolidated deposits in about three-fourths of the area. Layers or lenses of stratified sand and gravel are embodied in the till locally. In general the contact of

TABLE 3.—*Particle-size analyses of selected samples of unconsolidated deposits in southeastern New Hampshire.*

Sample	Percent of sample, of size indicated (millimeters)							
	Clay	Silt	Sand					Gravel
	<0.004	0.004–.0625	Very fine 0.0625–.125	Fine 0.125–.25	Medium 0.25–.5	Coarse 0.5–1.0	Very coarse 1.0–2.0	Very fine 2–4
1	40.2	57.6	2.0	0.2	0	0	0	0
10	30.5	59.0	8.3	1.4	0.4	0.0	0.4	0
2	13.7	37.0	14.0	16.1	9.0	6.0	4.2	0
3	7.4	22.2	16.2	20.8	14.9	10.3	8.0	0.2
6	20.0	33.2	11.8	12.4	9.2	8.8	4.6	0
7	20.5	32.5	11.0	11.6	8.2	9.2	5.2	1.8

Sample 1. Marine deposits, bluish-gray part, from highway cut, Dover.
10. Marine deposits, olive-drab part, from highway cut, Dover.
2. Till, grayish blue, from ground moraine in Portsmouth.
3. Till, "oxidized," yellowish brown, from ground moraine in Portsmouth.
6. Till, bluish gray, from drumlin at Great Boars Head, Hampton.
7. Till, olive drab, from drumlin at Great Boars Head, Hampton.

till and the younger unconsolidated deposits probably is sharp. At places, however, till and ice-contact deposits grade from one to the other or are so intimately associated that they cannot be classified precisely. No contact between till and ice-contact deposits was seen during the current investigation.

Owing to its poor sorting, compact nature, and predominance of fine-grained particles, till has a low permeability. For instance, a sample of till collected from a small drumlin near Portsmouth had a permeability of only 2 gpd (gallons per day) per sq ft. Other properties for this sample were: porosity, 33 percent; specific retention, 15 percent; and specific yield, 18 percent.

Water in the till.—Till is a source of water for numerous domestic wells in the report area. Because of its low permeability, the till transmits water slowly; consequently, most of the wells yield water at low rates—generally no more than a few gallons per minute. Most of the wells are shallow—from 10 to 30 feet deep; therefore, many fail to meet modern demands during dry summers when the seasonal decline of the water table is unusually great. As a result, there is a trend today toward the drilling of bedrock wells for domestic use, and new wells in till are uncommon.

At most places the water table in till is only a few feet below the land surface. In drumlins, however, the water table may be a few tens of feet below the surface. In general the ground water occurs under water-table conditions, but it may be confined at places where the till is overlain by impermeable marine deposits.

ICE-CONTACT DEPOSITS

Description and distribution.—Ice-contact deposits are bodies of stratified drift built in contact with the ice. They are classified primarily on the basis of distinctive landforms, which include kames, kame plains, kame terraces, crevasse fillings, and eskers. These landforms are characterized by ice-contact slopes, collapsed surfaces, and kettles. A kame is a small hill or mound and at places is grouped with others to form a kame field. A kame terrace is a flat-topped feature abutting a valley wall on one side and bordered on the other side by an ice-contact slope dipping toward the valley floor. A kame plain also is flat-topped, but it is isolated by ice-contact slopes. Crevasse fillings and eskers are sinuous elongate ridges bordered by ice-contact slopes on both sides and generally ranging from a few tens to a few hundreds of feet in width. The ice-contact features and their origin are discussed more completely by Jahns (1953) and by Flint (1947).

Ice-contact deposits are distributed from place to place throughout the report area. (See pls. 1, 2.) In the valleys of the Cocheco, Salmon Falls, and Bellamy Rivers, they form numerous kames, kame terraces, and kame plains, some of which are comparatively broad and thick. They also form broad, thick kame plains near the Atlantic coast. Altogether they underlie slightly less than a quarter of the report area and range in thickness from less than 1 foot to as much as 190 feet. The maximum known thickness, 190 feet, was penetrated by well Madbury 54 (table 4, Bradley and Petersen, 1962). There seems to be little correlation between the extent and the thickness of the individual features—some are extensive but thin, others are small but thick. The fact that most large ice-contact features in the northern part of the area are elongate or somewhat linear in a north-northwest direction suggests deposition between stagnating tongues of ice.

The ice-contact deposits consist mostly of sand and gravel but include particles ranging in size from clay to boulders. Because these deposits were laid down under a variety of conditions, the variation in their texture, sorting, and internal structure is great. Some deposits were formed in the channels of swiftly flowing streams. These deposits are cross bedded and are characterized by abrupt changes in texture; they contain almost no clay and silt. Other deposits, including those of the more extensive kame plains, were formed in ponds or pools. Some of these deposits contain a large proportion of fine and very fine sand. They may exhibit deltaic structure, typified by foreset beds that have pronounced differences in texture and by topset beds that are comparatively poorly sorted and coarse grained (fig. 6). Some of the kames which were formed by the melting of ice beneath the deposits are so poorly sorted and so lacking in structure that they resemble till. In most of the ice-contact deposits, the bedding is distorted locally by slumping that occurred as the supporting ice melted away.

FIGURE 6.—Ice-contact deposits in gravel pit in central part of Pudding Hill, Dover (pl. 6). This view faces north and shows deltaic bedding characteristic of many ice-contact deposits. Coarse-grained topset beds overlie finer grained foreset beds, which here dip steeply toward the south.

The particles composing the ice-contact deposits are derived from crystalline bedrock formations of the report area and of adjacent areas to the northwest. Most of these particles are probably farther from their original source than are those of the till. Some ice-contact deposits contain fragments derived mostly from bedrock of granitic origin; others have a large proportion of fragments derived from schistose rocks high in iron-bearing minerals. At places, certain beds are more highly iron-stained than adjacent beds. Most ice-contact deposits in the report area are light tan to buff, but locally they are reddish brown because of weathering of iron-bearing minerals. In general, individual grains are rounded or subrounded by abrasion in melt-water streams.

The ice-contact deposits overlie till or bedrock. From place to place they are overlain by younger unconsolidated deposits—principally by marine deposits (fig. 7) and by outwash and shore deposits.

FIGURE 7.—Unconsolidated deposits in gravel pit in the Johnson Creek area, Madbury (pl. 6). Section of massive marine deposits (light-colored layer) overlying coarse-grained ice-contact deposits (dark layer) at an angle of about 20°.

The local interbedding at the contact of the ice-contact deposits and the marine deposits suggests (1) that these units are in part contemporaneous and (2) that the sea was advancing across the coastal region while ice blocks were still present and before the main ice sheet had receded very far from the immediate area.

Because ice-contact deposits in the area are predominantly coarse textured, they generally have a large permeability and a large specific yield; however, abrupt changes in texture are characteristic of these deposits, and local variations in the hydrologic properties of a single deposit are therefore common. At places where fine-textured beds are thick or numerous, the permeability of a deposit may be relatively small. A sample of typical ice-contact material from a kame plain in Newington had the following properties: porosity, 39 percent; specific yield, 37 percent; specific retention, 2 percent. No measurement of permeability was made.

Water in the ice-contact deposits.—Ice-contact deposits are the source of the larger ground-water supplies in the report area. Because of their generally large permeability and specific yield, they are capable of yielding large amounts of water and of transmitting it rapidly. Properly constructed wells in these deposits produce several hundred gallons per minute. For example, wells Portsmouth 25 and Dover 5 were pumped continuously in 1956 and 1957 at rates of about 700 gpm. Other wells, including Dover 6, Hampton 7, Madbury 14, and Somersworth 1, reportedly have been pumped at rates greater than 600 gpm, although not continuously.

The water table in the ice-contact deposits ranges from less than 1 foot to about 60 feet below the land surface. The depth to water is greatest in ice-contact features that are topographically high with respect to adjacent landforms.

At most places in the ice-contact deposits the ground water is unconfined. However, where the margins of these deposits are overlain by marine deposits the ground water in the ice-contact deposits is under artesian pressure. At such places the piezometric surface of the confined water may be either above or below the land surface. At one place (well Madbury 9, table 2, Bradley and Petersen, 1962), the piezometric surface is about 10 feet above land surface. At several places water from test holes flows at the land surface.

Each body of ice-contact deposits forms a separate aquifer whose ground-water potential requires individual study. In general, the larger the extent and saturated thickness of a deposit, the more water it stores and the larger the total yield it can sustain. Some deposits are several square miles in area; others are a fraction of a square mile in area. Some deposits have a saturated thickness of as much as 140 feet; others have a saturated thickness of only a few feet. Some deposits are situated favorably with respect to replenishment from a stream or other surface-water body, and the flow of the stream rather than the storage capacity of the aquifer may limit the yield of these deposits.

MARINE DEPOSITS

Description and distribution.—In most of southeastern New Hampshire, marine deposits underlie lowlands and valleys to a distance of about 20 miles inland from the present coastline. They are absent from the southwestern part of the report area except at a few places along the Little River (pl. 1) in Plaistow, and they are absent from a highland area of drumlinlike hills in Kensington and South Hampton. In general they underlie rather flat lowland surfaces. These surfaces at places have been eroded by modern streams and terraces, which have a local relief of 15 to 20 feet, have been built. The marine deposits commonly range in thickness from less than 1 foot to about

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50 feet, but a few test holes have penetrated about 75 feet of fine-grained stratified materials thought to be part of the marine unit. Near the seacoast and the shorelines of Great and Little Bays, the deposits are relatively thin and their gently rolling surface reflects the configuration of the underlying surface of till and bedrock.

The marine deposits are divided into two zones: an upper zone of olive-drab to gray sand, silt, and clay, and a lower zone of bluish-gray silt and clay. The upper zone is laminated and has layers ranging in thickness from a fraction of an inch to about 2 feet. The thick layers consist mostly of silt and clay, and a little fine or very fine sand; the thin layers consist mostly of silt, moderate quantities of fine or very fine sand, and little or no clay. The lower zone is generally massive but has some bedding near the top, it consists almost entirely of clay and silt, materials which are more plastic than those of the upper zone. A particle-size analysis for one sample from each zone is given in table 3. The analyses are compared in figure 5 by means of particle-size distribution curves.

The contact between the two zones could be examined at only a few places. At a site in the northern part of Dover they are separated by a local disconformity; elsewhere they appear to grade from one to the other with no recognizable break.

At several localities in New Hampshire the fossil *Yoldia* (or *Portlandia*) *siliqua* has been found in the marine deposits. This fossil, which was described by Hitchcock (1878, p. 165–67) and by S. D. Tuttle on pages 99 to 106 of an unpublished Ph.D. theseis (The Quaternary geology of the coastal region of New Hampshire, Harvard University, 1952), is an arctic or cold-water clam dating from the Pleistocene to the present time; it is taken as evidence of the marine origin of the deposits. However, to the author's knowledge it has been found only in the bluish-gray lower zone and at altitudes lower than about 55 feet above present sea level. It is suggested that the sediments of the upper zone may have been deposited in estuaries where the environment was unfavorable to marine life, perhaps owing to the dilution of the sea water by fresh water from inflowing melt-water streams.

The marine deposits commonly rest on till and bedrock and are overlain at places by outwash and shore deposits or younger deposits. The marine deposits are interbedded locally with ice-contact deposits and with the outwash and shore deposits. The marine deposits also at places overlie the ice-contact deposits (fig. 7).

Because the marine deposits are fine grained, they are relatively impermeable and have a very small specific yield.

Water in the marine deposits.—The marine deposits are not an aquifer in southeastern New Hampshire, but they influence the behavior of ground water in the more permeable unconsolidated deposits They act as a barrier to the downward movement of water from the land surface in outcrop areas and from the more permeable unconsolidated deposits where such deposits overlie the marine deposits. The marine deposits, also act as a confining layer with respect to ground water in underlying, more permeable deposits. Near tidewater the marine deposits may, if situated between an aquifer and the sea or an estuary, prevent salt-water encroachment. For example, when a test of well Dover 16, which is only a few hundred yards from the estuaries of the Bellamy and Cocheco Rivers, produced a drawdown to about sea level, only fesh water was pumped, probably because the marine deposits kept out the nearby salty water.

OUTWASH AND SHORE DEPOSITS

Description and distribution.—Because outwash and shore deposits are intimately associated, contemporaneous, and similar in physical and hydrologic properties, they are treated as a single unit in this report.

Outwash and shore deposits are widely distributed near the western margin of the area and north of Rochester. They also occur in small patches near the coast. They form either broad sand plains, such as that between the Cocheco and Salmon Falls Rivers north of Rochester, or gently sloping terraces of small extent. They range in known thickness from less than 1 foot to about 50 feet.

Outwash and shore deposits in southeastern New Hamsphire consist chiefly of stratified buff to light-tan sand and gravel. They range in texture from silt to coarse gravel, but medium sand predominates; fine gravel occurs in a somewhat smaller proportion. In general the deposits in the western part of the area are coarser than those along the coast. In comparison with ice-contact deposits, outwash and shore deposits are finer textured and better sorted, and are composed of particles that have been transported farther and therefore are more rounded.

At most places outwash and shore deposits overlie marine deposits, but at some places, notably in the southeastern part of the area, they overlie till, bedrock, or ice-contact deposits. The relation of the outwash and shore deposits to these other units is complex; an example is provided by the deposits that form the extensive sand plains in Newton and Kingston. According to reports from local residents regarding dug and drilled wells, these deposits generally rest on till and bedrock or perhaps locally on older ice-contact deposits. To the west they appear to grade into ice-contact deposits, and the sand plains themselves are marked by relics of the ice in the form of kettles, such as those occupied by Greenwood, Great, and Country Ponds.

In the opposite direction, to the east of Greenwood Pond, the outwash and shore deposits interfinger with and overlap marine deposits, which pinch out a short distance west of the mapped contact (pl. 1). (See logs of wells Kingston 16 and 17, table 4, Bradley and Petersen, 1962.)

On the basis of composition and the yields of wells, the outwash and shore deposits are moderately permeable and probably have a fairly large specific yield.

Water in the outwash and shore deposits.—The outwash and shore deposits commonly yield enough ground water to meet the needs of small industries, farms, and homes. At most places they not only are thin, but also are partly drained by local streams. Consequently, in spite of their moderate permeability, these deposits do not yield large amounts of water to individual wells.

The depth to the water table in the outwash and shore deposits ranges from a few feet to about 30 feet belowl and surface. The ground water in these deposits is unconfined.

SWAMP DEPOSITS

Swamp deposits occupy poorly drained lowlands underlain by marine deposits, poorly drained or undrained depressions between knobs and ridges of bedrock or in ground moraine, and kettle holes or other depressions in ice-contact deposits. The swamp deposits consist of decomposed organic matter and peat mixed with silt, sand, or gravel. Although accurate data are lacking, these deposits probably range in thickness from less than 1 foot to about 20 feet. On the geologic maps (pls. 1, and 2) swamp deposits are shown only where they are relatively extensive or where it is impractical to determine by ordinary field methods, the character of the underlying material.

Swamp deposits are not a direct source of ground water in the report area. They may, however, contribute ground water to wells in adjacent or underlying deposits. Under natural conditions the water table in swamp deposits is at the land surface except during periods of drought, when it may range from several inches to a few feet below the land surface.

ALLUVIUM

Alluvium, which consists of detritus deposited by modern streams, underlies the flood plains and channels of the principal streams in the area. Alluvium is shown on the geologic maps (pls. 1, 2) only where it is relatively extensive. It consists of stratified sand and silt containing a few cobbles and small boulders. No data are available by which the precise thickness of the alluvium might be determined, but it is thought to be comparatively thin nearly everywhere. Alluvium overlies bedrock and older unconsolidated deposits wherever streams cross the older units.

At one place, near a small stream flowing into the tidewater section of Oyster River, fragments of wood were recovered from the base of the alluvium, which there is about 4½ feet thick. The Geochemistry and Petrology Branch of the Geological Survey, using the radiocarbon method, determined the age of the wood to be 2,880 years ±200. The age of the wood and its stratigraphic position suggest that alluvium in southeastern New Hampshire has been accumulating during the past 3,000 years at least—probably as a result of a rise in sea level relative to the land surface.

Ground water in alluvium ordinarily is interconnected with the water in adjacent streams and with ground water in adjacent geologic units. Owing to their location in flood plains, which are frequently inundated, the deposits are generally not tapped by wells. Data on their water-bearing properties are not available.

BEACH DEPOSITS

Modern beaches occur along the Atlantic Ocean between promontories of bedrock or till. The material composing the beaches ranges from very fine sand to cobbles and stones larger than 1 mm in diameter, but individual beaches commonly are made up of material of uniform size. Most of the long beaches are composed of fine to medium sand, whereas most of the short beaches adjacent to bedrock promontories are composed of rounded cobbles. In general, the beach deposits are relatively permeable.

At some places beach deposits are a source of water for domestic use. At most places a few feet of fresh water are underlain by salty water. Thus, only small quantities of water can be pumped without drawing in the salty water, and yields of wells are limited accordingly.

EOLIAN DEPOSITS

Deposits of windblown (eolian) sand and silt form a discontinous surficial mantle between the southwestern part of Exeter and the central part of Newton. These deposits, which are less than 2 feet in thickness, consist of very fine sand, some silt, and a few scattered wind-blasted pebbles. They overlie other unconsolidated deposits and are mixed with them by frost action. Along the Lamprey River, about 3½ miles directly south of the center of Lee, small sand dunes overlie outwash and shore deposits. These dunes are only slightly active at the present time (1962). Probably other windblown deposits, although not noted, are present elsewhere in the area.

The eolian deposits are not a source of ground water, nor do they appreciably influence the occurrence of ground water. They were not mapped for this investigation.

GROUND-WATER HYDROLOGY

Ground water is a major phase of the hydrologic cycle—the system by which water circulates continously between the earth and its atmosphere. Within this system the water-bearing formations both store and transmit water.

SOURCE AND MOVEMENT OF GROUND WATER

The source of nearly all the ground water in southeastern New Hampshire is precipitation. Of the precipitation that reaches the land surface, a part runs off overland and is carried away by streams, a part is returned to the atmosphere by evaporation or by transpiration from plants, and a part percolates downward through the zone of aeration to the zone of saturation, where it is stored temporarily as ground water. The process whereby water is added to the zone of saturation is termed "recharge."

Ground water moves from points of higher head to points of lower head, taking the path having the steepest hydraulic gradient. The water table, which reflects differences in head, conforms roughly to the topography. In southeastern New Hampshire, ground water generally moves from the interstream areas, where much of the recharge takes place, toward nearby streams or other bodies of surface water into which some of the ground water is discharged. During warm weather some ground water also is discharged directly to the atmosphere by evaporation and transpiration in areas such as swamps, where the water table is at or near the land surface.

During its passage through the rocks, ground water may move from one formation to another. For example, on hills and slopes some of the ground water moves from the unconsolidated deposits downward into the fractures in the bedrock. Then, in the valleys it may in turn pass from the bedrock into the overlying unconsolidated deposits.

In detail the movement of ground water is complex, owing principally to differences in the water-bearing properties of the rocks and changes in the ratio of recharge to discharge. The movement is three dimensional and has both vertical and horizontal components. Although ground water ordinarily moves toward the streams, the direction of movement at times is altered locally. For example, during times of flood, the direction of ground-water movement near streams may be reversed, and water may move from the streams into the adjacent deposits.

Under the hydraulic gradients that exist in nature the rate of ground-water movement is very slow. In the aquifers of the report area, ground water probably moves at rates that range from a few inches per year to a few feet per day.

RECHARGE

Under natural conditions nearly all recharge to aquifers in southeastern New Hampshire is accomplished by the infiltration of precipitation within the area. The principal recharge areas are the places immediately underlain by ice-contact deposits and by outwash and shore deposits. These deposits are sufficiently permeable to absorb water readily. They commonly form terraces and plains whose flat surfaces retard surface runoff and thereby afford ample opportunity for infiltration. They generally also provide sufficient storage space to accommodate the additional water.

Many places immediately underlain by till also serves as recharge areas, but here the rate of recharge is comparatively small. Not only is the till less permeable than the outwash and the ice-contact deposits, but it commonly forms hills whose slopes shed water rapidly. Furthermore, because till generally is thin, it may at some places become so fully staturated during prolonged periods of wet weather that potential recharge is rejected.

Recharge occurs intermittently and usually follows a seasonal pattern. During the growing season, most of the precipitation that enters the soil is retained there to satisfy soil-moisture requirements; recharge is therefore small. During the rest of the year, when plants are dormant, the soil-moisture requirement usually is small and recharge is great whenever there is much rain or snowmelt. At times during the winter, frost prevents or retards infiltration, but by far the largest proportion of the annual recharge is received during this part of the year, and the peak usually accompanies snowmelt during the spring season.

Where aquifers are situated favorably, natural recharge may be augmented by induced recharge or artificial recharge. Induced recharge is the process whereby water from a stream or other body of surface water flows into a nearby aquifer in response to the artificial withdrawal of water from the aquifer. This process helps sustain the yields of several wells in the report area, and it promises to be an important factor in the further development of the ground-water resources. Artificial recharge is the introduction of water into an aquifer either by spreading the water on the surface of the aquifer or by injecting the water into the aquifer through wells or spreading galleries. Artificial recharge is not practiced in southeastern New Hampshire at the present time (1962), but it may become important locally in the future.

DISCHARGE

Ground water is discharged naturally through springs, by effluent seepage to streams and to other bodies of surface water, and by evapotranspiration. It is discharged artificially through wells and artificial drains. Natural discharge is a continuing process. Discharge to streams, called ground-water runoff, usually is greatest soon after periods of dry weather and sustains the flow of the streams when there is little or no surface runoff. Discharge by evapotranspiration is greatest during the growing season.

Under natural conditions the principal discharge areas in the report area are stream channels, the swamps, and the coastline. Most of the ground water is discharged by effluent seepage directly to the streams. The water table normally slopes toward the streams, and ground water enters them wherever they flow on permeable material. Ground water is discharged in swamps and other low areas by effluent seepage whenever the water table is high enough to intersect the land surface and by evaporation and transpiration at times when the water table is only a short distance below the land surface. Along the coastline some of the ground water evaporates and some of it seeps directly into the ocean.

WATER-LEVEL FLUCTUATIONS AND CHANGES IN GROUND-WATER STORAGE

Changes in ground-water storage take place as a result of changes in the ratio between recharge and discharge. These changes are largely controlled by seasonal changes in temperature and by the quantity and time distribution of precipitation. In general, periods when recharge is greater than natural discharge occur in late fall, winter, and early spring while evapotranspiration is ineffective. During late spring, summer, and early fall, however, when most of the rainfall that infiltrates into the soil is evaporated or transpired by plants and does not reach the zone of saturation, natural discharge continues, though at a reduced rate, and the amount of ground water in storage declines.

Changes in ground-water storage are reflected by fluctuations in ground-water levels; these levels rise when recharge exceeds discharge and decline when discharge exceeds recharge. The pattern of water-level fluctuations, hence the pattern of changes in storage, in the report area, are illustrated (fig. 8) by the hydrographs of selected wells; for purposes of comparison, monthly precipitation at Durham, from Weather Bureau records, is shown also. Additional water-level fluctuation data are presented by Bradley and Petersen (1962, table 5). The hydrographs of wells Dover 11 and Madbury 9 reflect the piezometric surface of ground water that occurs under confined (artesian) conditions. The hydrographs of the rest of the wells reflect the position of the water table.

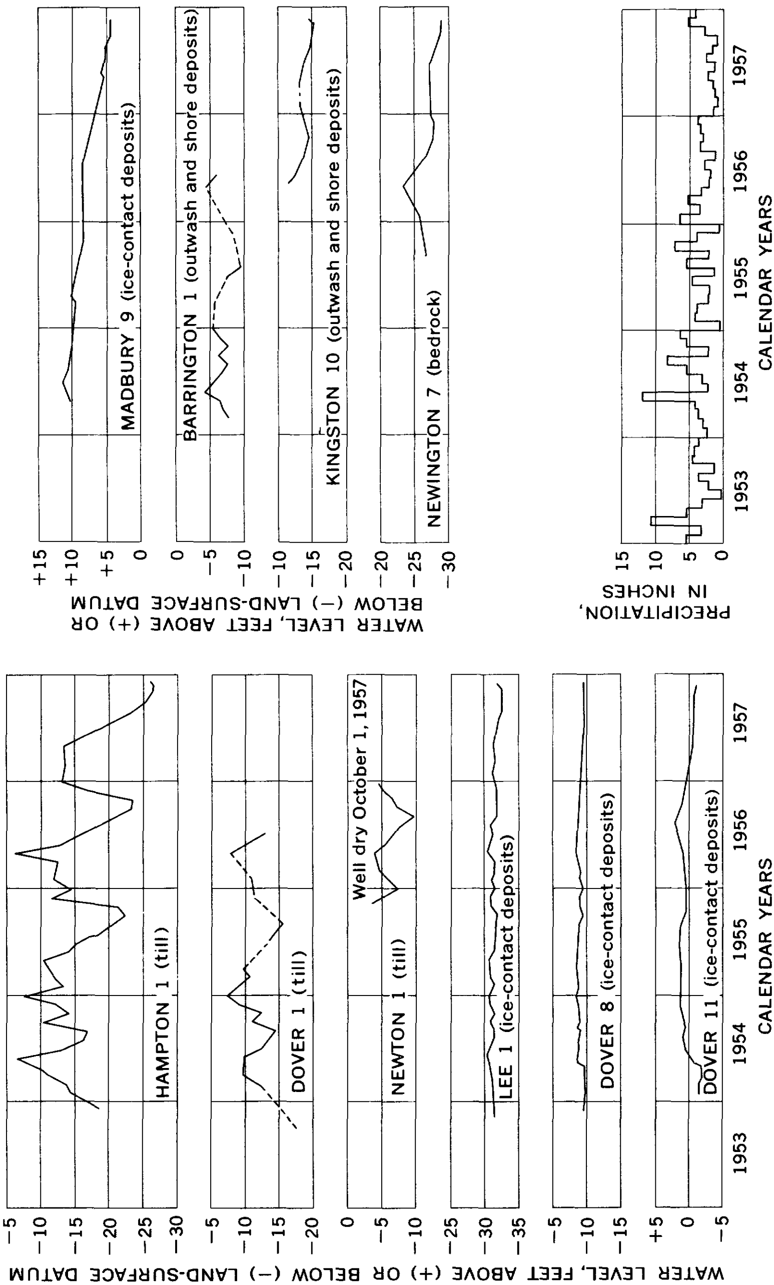

FIGURE 8.—Hydrographs of selected wells in southeastern New Hampshire and of monthly precipitation at Durham.

The hydrographs show seasonal trends that conform roughly to the seasonal pattern of recharge and discharge. The annual high stage of the water table usually accompanies precipitation or snowmelt in winter or early spring; the annual low stage usually occurs in late summer or fall, near the end of the growing season. The pattern of fluctuations of the piezometric surface at wells Dover 11 and Madbury 9 is similar to, but lags behind that of the water table. For example, a comparison of the hydrograph of Dover 11, which represents a piezometric surface, with that of Dover 8, which represents the water table suggests a time lag of about 2 months.

In detail the pattern of water-level fluctuations is irregular, reflecting variations in precipitation and temperature. For example, the peak stage of the water table in 1954 followed above-average rainfall—about 12 inches—during May. In 1954 also, an unseasonable rise of the water table occurred in September as an aftermath of rainfall from hurricanes Carol and Edna, which passed across or near New England on August 31 and September 11, respectively. Total rainfall from these storms, on the basis of Weather Bureau records for Durham, was more than 10 inches.

At most of the wells for which hydrographs are shown, withdrawals are not great and the water-level fluctuations therefore reflect natural conditions. At well Madbury 9, however, the steady decline of the water level suggests that substantial withdrawals are made from the aquifer, probably through well Dover 5, which is half a mile north of Madbury 9. Before 1954, Dover 5 was pumped at a rate of about 335 gpm, but beginning in 1954 it reportedly has been pumped at a rate of about 700 gpm. A progressive decline of the water level in a given aquifer over a period of years indicates that the average rate of withdrawal from the aquifer exceeded the average rate of recharge.

The range of water-level fluctuations under natural conditions depends principally upon the hydrologic properties of the water-bearing deposits and the topography. The hydrographs (fig. 8) show the magnitude of fluctuations that might be expected in till, ice-contact deposits, bedrock, and outwash and shore deposits. Plaistow 3, a well in marine deposits, showed a range of water-level fluctuations between 14.40 and 23.18 feet below land surface during a period from December 1955 to November 1957. In general, the greater the permeability of a deposit, the smaller the water-level fluctuations. In till, for example, fluctuations ranging from 10 to 20 feet are not unusual, especially in wells located on hills or slopes. During periods of recharge, the low permeability of the till prevents rapid lateral percolation of ground water to areas of discharge and the water level rises considerably. However, during periods of little recharge, the ground water continues to drain and discharge slowly; thus, the water level declines. In contrast, fluctuations of only a few feet are common in wells in ice-contact deposits. These deposits are sufficiently permeable to transmit ground water laterally at rates approximating those of recharge and large rises in water levels ordinarily do not occur.

Numerous short-term fluctuations of water level are not shown by the monthly hydrographs. For example, fluctuations probably occur in beach deposits and, perhaps, in other water-bearing units near the coast in response to ocean tides.

UTILIZATION OF GROUND WATER

The largest use of ground water in the report area is for municipal water supplies. Water-consumption figures for cities and towns that have municipal-supply systems using ground water are shown below.

Average daily withdrawal, in gallons, for Southeastern New Hampshire, as reported by municipal water departments

City or town	1954	1955	1956
Rockingham County			
Exeter	336,121	380,035	411,252
Hampton [1]	518,658	622,255	720,643
Hampton [2]	1,286,630	1,498,740	1,622,903
Hampton [3]	361,515	423,106	536,602
Newfields		1,856	4,359
Portsmouth [4]	2,208,557	2,524,713	3,081,736
Strafford County			
Dover	1,246,340	1,545,670	1,575,560
Farmington	161,470	162,796	147,720
Salmon Falls	58,000	26,340	28,569
Somersworth	519,572	530,045	550,528

[1] Includes part of North Hampton and Rye Beach.
[2] Figures for July and August.
[3] Figures for year excluding July and August.
[4] Includes part of Rye and Greenland.

Records of industrial use of water from municipal-supply systems are lacking or incomplete. The Dover and Portsmouth municipal water-supply systems furnish moderately large quantities of water for industrial and commercial use; in the other communities, industrial and commercial utilization of water is relatively small. The large water consumption in Hampton during July and August is due to a seasonal influx of summer residents and tourists attracted by the area's recreational facilities.

No data are available on farm, rural, and suburban consumption of ground water in the report area. Based on the 1950 census figures, a reasonable estimate of the population not served by municipal water-supply systems in the area is about 13,000. These people are served from privately developed ground-water sources. If a per capita consumption of 50 gpd (gallons per day) is used, 650,000 gpd would be the consumption by the rural dwellers and farmers of the area. Reliable figures on consumption of water for poultry, stock, and other farm purposes are not available; however, the water used for these purposes is probably not more than that used by the total rural human population.

Industrial use of ground water other than that supplied through municipal water-supply systems in the report area is small. Scattered small industrial enterprises use privately developed ground-water sources, but the quantities used by individual establishments are ordinarily no larger or only slightly larger than the amount normally used by a few rural dwellings.

QUALITY OF GROUND WATER

Most substances are at least partly soluble in water; consequently, natural water on and in the earth's crust contains dissolved minerals and gases in varying amounts. The quantity and the kind of these substances in ground water are controlled largely by (a) the chemical and physical characteristics of the soil and rocks through which the water moves, (b) the length of time the water is in contact with soil and rock materials, and (c) the minerals and gases already in solution in the water because of earlier contact with the atmosphere.

The chemical quality of the ground water in southeastern New Hampshire is satisfactory for most uses. In general, the water has a low dissolved-solids content and is soft. At some places it contains objectionable quantities of iron or is unusually hard or corrosive. A few wells close to the sea or estuaries are subject to contamination by salt water.

For the current investigation, chemical analyses of ground water from selected wells and springs in the area were studied. These analyses (table 4) include 18 almost complete chemical analyses made by the Geological Survey and 23 partial chemical analyses—12 made by the Geological Survey and 11 made by the New Hampshire State Department of Health. Table 4 of this report is also contained in the report by Bradley and Petersen (1962, table 6). The analyses by the Geological Survey were made using the general methods discussed by Rainwater and Thatcher (1960).

A brief discussion of the constituents commonly found in ground water in the area follows. A more complete discussion of the occurrence and significance of the chemical and physical properties of water is presented by Lohr and Love (1954) and by Rainwater and Thatcher (1960).

TABLE 4.—*Chemical analyses of water samples from selected wells and springs in southeastern New Hampshire*

[Analyses by U.S. Geol. Survey unless indicated otherwise]

Well	Geologic unit	Date of collection	Temperature (° F)	Analyses in parts per million (ppm): Silica (SiO_2)	Dissolved iron (Fe)	Total iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Patassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	(Residue on evaporation at 180°C) Dissolved solids	Hardness as $CaCO_3$: Calcium and magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color [1]	Remarks [2]
U.S. Public Health Service drinking-water standards						0.3			125				250	250	1.5		500						
Rockingham County																							
Brentwood 1	Ice-contact deposits	10- 4-56	55	8.7	0.03	0.04	0.00	22	3.8	11	5.2	48	26	17	0.0	11	139	71	31	222	6.7	5	
Exeter 2	do	10- 5-56	52	12	.16	.24	.00	23	3.7	17	3.5	98	15	12	.0	.3	139	73	0	229	7.5	12	
Exeter sp 1	Outwash and shore deposits.	10- 4-56	50	10	.03	.03	.00	18	3.7	16	7.9	26	32	25	.0	16	149	60	40	244	6.1	3	
Greenland 1	Ice-contact deposits	5-13-54			<.1									12		.5					6.6		Analyzed by New Hampshire Dept. Health.
Hampton 3	do	9-28-54	52	12	.01	.08	.00	16	3.5	8.1	2.2	40	21	12	.0	4.2	102	55	22	164	7.8	2	Aluminum (Al), 0.1 ppm; lithium (Li), 0.1 ppm.
Kensington 7	do	10- 5-56			.02							80		6.0				79	13	169	8.2		
10	Till	10- 5-56	52		.03							12		5.9				16	6	60	6.5		
Kingston 11	Outwash and shore deposits.	10- 5-56			.07							48		87				84	45	432	6.6		
Newfields 4	Ice-contact deposits	10- 5-56	48		.01							36		25				53	24	196	6.8		
Newmarket sp 3	do	10- 3-56	50		.02							28		16				43	20	138	6.8		
Plaistow 1	do	10- 5-56	52		.02							23		6.7				45	26	133	6.6		
9	Outwash and shore deposits.	10- 5-56	55		.07							34		14				16	0	189	6.3		

See footnotes at end of table.

TABLE 4.—*Chemical analyses of water samples from selected wells and springs in southeastern New Hampshire*—Continued

[Analyses by U.S. Geol. Survey unless indicated otherwise]

Well	Geologic unit	Date of collection	Temperature (° F)	Analyses in parts per million (ppm): Silica (SiO_2)	Dissolved iron (Fe)	Total iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Patassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	(Cl) Chloride	Fluoride (F)	Nitrate (NO_3)	(Residue on evaporation at 180°C) Dissolved solids	Hardness as $CaCO_3$: Calcium and magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color [1]	Remarks [2]
Rockingham County—Continued																							
Portsmouth 1	Ice-contact deposits.	6- 5-51	---	13	------	0.01	----	26	12	5.2	1.7	73	54	7.0	0.0	1.4	156	114	54	206	7.1	3	From Lohr and Love (1954, p. 305). Finished water at Gosling Station.
2	do	6- 5-51	---	13	------	.01	----	26	11	5.2	1.5	72	54	6.0	.0	1.2	153	110	51	204	7.5	3	Do.
2	do	5-13-54	---	-----	<.1	----	----	-----	-----	-----	----	----	-----	7.6	---	.2	----	----	----	----	7.6	---	Analyzed by New Hampshire Dept. Health.
4	do	6- 5-51	---	13	------	.01	----	39	10	7.7	2.2	110	52	9.0	.0	3.6	191	139	49	321	7.4	4	From Lohr and Love (1954, p. 305). Finished water at Sherborne Station.
Rye 1	do	2-11-54	50	12	.01	.23	.00	8.9	2.5	14	8.2	18	20	14	.1	26	115	34	19	166	6.8	15	Aluminum (Al), 0.2 ppm; copper (Cu), 0.27 ppm; lithium (Li), 0.4 ppm.
Seabrook 1	do	10- 5-56	47	11	.03	.03	.00	8.6	1.4	4.0	1.3	25	5.6	7.2	.0	3.3	56	27	7	84	6.5	2	

Strafford County

Barrington 1	Outwash and shore deposits.	10- 3-56	50	---	0.03	---	---	---	---	---	---	20	---	96	---	---	---	63	47	388	6.3	---	
Dover sp 3	do	10- 3-56	50	---	.02	---	---	---	---	---	---	11	---	4.0	---	---	---	13	4	39	6.4	---	
Dover 5	Ice-contact deposits	9-24-52	---	---	.5	---	---	---	---	---	---	---	---	9.2	---	0.2	---	---	---	---	6.9	---	Analyzed by New Hampshire Dept. Health.
5	do	5-14-54	---	---	.2	---	---	---	---	---	---	---	---	7.6	---	.2	---	---	---	---	7.2	---	Do.
6	do	9-24-52	---	---	3.0	---	---	---	---	---	---	---	---	6.2	---	.0	---	---	---	---	6.4	---	Do.
6	do	5-14-54	---	---	3.0	---	---	---	---	---	---	---	---	8.2	---	.3	---	---	---	---	6.3	---	Do.
11	do	5-13-54	46	14	[3]<.1	---	0.01	3.5	0.8	3.2	---	14	1.6	4.0	0.0	.4	36	12	1	43	7.0	3	
24	do	5- 3-54	48	6.6	---	0.08	.03	3.9	.5	8.7	---	4	5.0	9.5	.0	11	52	9	6	72	6.0	5	
25	do	4-21-55	---	---	<.1	---	---	---	---	---	---	---	---	11	---	.2	---	---	---	---	6.1	---	Do
Farmington 1	do	5-22-53	44	---	<.1	---	---	---	---	---	---	---	---	4.4	---	.0	---	---	---	---	6.4	---	Do.
1	do	5-10-54	---	---	<.1	---	---	---	---	---	---	---	---	5.4	---	.2	---	---	---	---	6.3	---	Do.
4	do	10- 3-56	49	---	.03	---	---	---	---	---	---	19	---	27	---	---	---	48	32	253	6.0	---	
Lee 5	do	5-14-54	47	11	---	.60	.01	6.2	1.8	2.5	---	23	2.4	4.5	.0	.6	48	23	4	68	7.2	2	
6	Till	2-11-54	---	13	.00	.07	.00	21	2.8	14	4.2	62	15	19	.1	8.0	134	64	13	211	7.4	15	Zinc (Zn), 0.10 ppm; lithium (Li), 0.4 ppm; phosphate (PO_4), 0.7 ppm.
Madbury 4	Ice-contact deposits	5-13-54	48	13	[3]<.1	---	.00	16	3.6	7.9	---	54	15	8.0	.1	.6	102	55	10	163	7.5	2	
11-14	do	6-14-56	50	12	.06	.16	.00	8.1	2.3	5.4	---	27	7.7	6.3	.0	3.1	67	30	8	96	6.8	18	Turbidity, 0.5 ppm as SiO_2; free carbon dioxide (CO_2) (calc), 6.8 ppm; alkalinity as $CaCO_3$ (calc), 22 ppm.
Rochester 10	Outwash and shore deposits.	5-10-54	53	12	---	.37	.00	5.8	1.8	7.0	---	23	12	3.5	.2	.3	57	22	3	78	7.8	2	
18	Bedrock	10-20-55	54	10	.07	.24	.03	9.2	2.1	10	1.9	55	8.8	1.2	1.0	.1	72	32	0	113	8.2	3	Lithium (Li), 0.2 ppm; phosphate (PO_4), 0.10 ppm. Radiochemical analysis available.
Rollinsford 8	Ice-contact deposits	10- 3-56	49	---	.04	---	---	---	---	---	---	97	---	8.2	---	---	---	43	0	227	8.3	---	
Rollinsford sp 1	do	3- 3-55	49	---	.85	---	---	---	---	---	---	---	---	12.6	---	.8	---	---	---	---	6.6	25	Analyzed by New Hampshire Dept. Health.
Somersworth 1	do	5-14-51	---	12	---	.37	.04	6.2	1.2	3.3	.6	8	14	5.5	.1	.6	47	20	14	67	6.1	1	From Lohr and Love (1954, p. 306). Raw water from well.
1	do	5-12-54	44	---	<.1	---	---	---	---	---	---	---	---	4.8	---	.05	---	---	---	---	6.5	---	Analyzed by New Hampshire Dept. Health.
Somersworth sp 1	do	10- 3-56	50	---	.01	---	---	---	---	---	---	19	---	32	---	---	---	43	27	200	6.2	---	

[1] Color data were obtained by comparing color of water sample to the platinum-cobalt scale of Hazen (1892, p. 427–428).
[2] Data furnished by the New Hampshire State Department of Health has been rounded to agree with Survey style.
[3] From June 1952, analyses by New Hampshire State Department of Health.

MINERAL CONSTITUENTS IN SOLUTION

Silica, the most abundant mineral in rocks of the earth's crust, may be dissolved from nearly all rock materials. The dissolved-silica content of most natural water ranges from 1 to 30 ppm (parts per million). The range of silica content in the analyses reported in table 4 is from 6.6 to 14 ppm.

Ground water commonly contains iron dissolved from the iron-bearing minerals of various rocks. Water that is high in carbon dioxide and low in dissolved oxygen is particularly effective in dissolving iron oxides. The iron precipitate formed when water that contains more than about 0.3 ppm of iron is exposed to air is troublesome in many industrial processes. Excessive iron in water also stains enamelware, porcelain, and clothing. In table 4, figures for dissolved and total iron contents are given for analyses in which both were determined.

Examination of table 4 shows that the iron content exceeded 0.3 ppm in water from 3 wells and 1 spring: Dover 6, 3.0 ppm; Somersworth 1, 0.37 ppm; Rochester 10, 0.37 ppm; and Rollinsford sp 1, 0.85 ppm. Since the analysis for Dover 6 was made, the well was cleaned, and an analysis by the State Department of Health dated August 15, 1956, indicated that the iron content then was 0.55 ppm.

Reports of high iron content for samples of ground water in the report area suggest that objectionable amounts of iron in water is a fairly common problem. Iron can be removed from the water; for example, the city of Dover has a filtration plant for this purpose. However, the initial cost and maintenance cost of such water-processing plants make it desirable to seek sources of water that do not contain objectionable quantities of iron.

The available data for the area are not sufficient for attributing the iron in the ground water to specific causes. Basically, the high iron content of the water is related to the iron content of the deposits through which the water passes; therefore, water from deposits that contain iron-bearing minerals tends to be high in iron. However, other factors, such as the pH of the water, also are significant. It is of interest to note that the iron content of water from a single well may vary. For example, water taken from Dover 25 at depths ranging from 75 to 80 feet reportedly had an iron content of greater than 0.5 ppm, but water taken from the same well at depths ranging from 50 to 65 feet had an iron content of less than 0.1 ppm.

Manganese resembles iron in its occurrence in ground water and in its chemical behavior. The effects of manganese in water are similar to those of iron; it may be removed by the same filtering processes used for iron removal. Of 15 samples in the report area tested for manganese content, only 5 contained measurable amounts of manganese and these amounts were insignificant. (See table 4.)

Calcium may be dissolved from many rock types, but it is especially abundant in water from limestone, dolomite, or gypsum. Dolomite and gypsum do not occur in the report area. Calcium contributes to hardness of water and is a common constituent of boiler scale. The calcium content of ground-water samples collected during this investigation generally was low; it ranged from 3.5 to 39 ppm.

Magnesium in ground water ordinarily is derived from dolomite, dolomitic limestones, and basic igneous rocks; it contributes to the hardness of water. Where the rock types from which it is derived are absent, as in the report area, only a small amount of magnesium is ordinarily in the ground water. In the analyses shown in table 4, the magnesium content ranged from 0.5 to 12 ppm.

Sodium and potassium, which may be dissolved from nearly all rocks, comprise only a small part of the dissolved solids in most natural waters in humid and in subhumid regions. The analyses in table 4 suggest that ground water in southeastern New Hampshire contains small quantities of these constituents. In the samples analyzed, sodium ranged from 2.5 to 17 ppm and potassium ranged from 0.6 to 8.2 ppm.

Natural water ordinarily contains bicarbonate and carbonate. Carbon dioxide dissolved in water causes the solution of the carbonates of calcium and magnesium, which are in turn converted to bicarbonate. Large quantities (more than 150 to 200 ppm) of bicarbonate in water used in boilders or heating equipment contribute to scaling, because the soluble bicarbonates of calcium and magnesium become insoluble carbonates when heated. In the analyses shown in table 4 the bicarbonate content ranged from 4 to 110 ppm.

Sulfate in ground water is dissolved from calcium sulfate, from the more readily soluble sodium, potassium, and magnesium sulfates of evaporite beds, and from the products of the oxidation of sulfides of iron. The sulfate content of water may range from little or none in water containing barium to as much as about 200,000 ppm in certain types of brines. A maximum sulfate content of about 1,500 ppm can be expected in a water that acquires most of its sulfate from calcium sulfate (Hulett and Allen, 1902). The sulfate content in the samples analyzed for this investigation is small; it ranged from 1.6 to 54 ppm.

Chloride is dissolved in small quantities from many rock materials, and ground water contaiminated by sea water or sewage may contain excessive quantities of chloride.

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Water having a high chloride content is highly corrosive. In the samples for which data are shown in table 4 the chloride content ranged from 1.2 to 96 ppm.

Fluoride in ground water is less common than chloride. When more than 2 ppm occur in water, fluoride is associated with the dental defect known as mottled enamel. On the other hand, water containing between about 0.7 and 1.5 ppm of fluoride has been found to reduce greatly the incidence of dental cavities in the permanent teeth of children (Lohr and Love, 1954, p. 39–40). Of 18 samples of water tested for fluoride content, 12 had no fluoride; one, from Rochester 18, had 1.0 ppm of fluoride, which is within safe limits for drinking water based on the U.S. Public Health Service drinking-water standards (U.S. Public Health Service, 1946). It is noteworthy that the well from which this sample came draws water from bedrock.

Nitrate in water is considered to be part of the final oxidation product of nitrogenous organic matter. Studies have shown that nitrate as NO_3 in excess of about 44 ppm in drinking water may be a contributing factor or the cause of methemoglobinemia ("blue babies") in infants if the water is used in preparing babies' formulas (Waring, 1949). The nitrate content of the ground-water samples for which analyses are shown in table 4 ranged from less than 0.05 to 26 ppm.

Dissolved solids represent the approximate total quantity of dissolved mineral constituents in the water. In a given area, ground water generally contains more dissolved solids than surface water. Water with less than about 500 ppm of dissolved solids is considered satisfactory for domestic and most other uses unless it is unsuitable because of another undesirable feature, such as excessive iron, excessive hardness, or organic pollution. The dissolved-solids content in samples analyzed during this investigation ranged from 36 to 191 ppm (table 4).

PROPERTIES AND CHARACTERISTICS OF GROUND WATER

Hardness of water is the property attributable to the presence of alkaline earths. It has long been associated with the soap-consuming power of water. Calcium and magnesium are the chief constituents responsible for hardness. Other substances, such as aluminum, iron, manganese, strontium, zinc, and free acid also may contribute to hardness, but their effect generally is very small or negligible. The following statments on hardness are from Lohr and Love (1954, p. 12–13).

> The terms "carbonate" and "noncarbonate" hardness are roughly equivalent to or are used in the same sense as the older terms "temporary" and "permanent" hardness. Carbonate hardness refers to the hardness in equivalence with carbonate and bicarbonate; noncarbonate hardness to the remainder of the hardness.

A water has no noncarbonate hardness if the total hardness does not exceed in chemical equivalence the carbonate and bicarbonate (the alkalinity) present in the water. Waters of high noncarbonate hardness usually contain large quantities of calcium and magnesium sulfates, chlorides, or nitrates in solution. The character of scale formed in steam boilers is affected by the relation of carbonate to noncarbonate hardness. The selection of the proper methods for softening is based largely on the type and degree of hardness present in the waters.

Hardness of water limits vary from one industry or user to another. Water with a hardness of as much as 100 ppm is generally satisfactory for most domestic uses. Additional comments on hardness limits for particular uses are discussed by the California State Water Pollution Control Board (1952, p. 265–267).

The specific conductance of water is a measure of its capacity to transmit electric current. Within wide limits, specific conductance is an indication of the amount and kind of dissolved mineral matter in the water; it varies with the concentration and degree of ionization of the dissolved constituents.

The degree of acidity or alkalinity of a water is indicated by the hydrogen-ion concentration, which is expressed on the pH scale between 0 and 14. The numbers on the pH scale are the negative logarithms of the hydrogen-ion concentration in moles per liter of solution. A pH value of 7.0 represents neutrality, which means the water is neither alkaline nor acid. Progressively greater acidity is denoted by pH values that decrease from 7; progressively greater alkalinity is indicated by values that increase above 7. Although it is impossible to evaluate the corrosiveness of water by pH values alone, water with a pH of less than 7 is apt to be corrosive. Many public-water supplies with low pH values are treated with lime or soda ash to reduce the acidity. Twenty-six samples analyzed during this investigation (table 4) had pH values below 7; one had a pH value of 7.0; 14 had pH values greater than 7.

Color in natural water may be of animal, mineral, or vegetable origin. The color may be caused by decaying leaves, roots, or other organic material in the water or ground or by metallic substances. In a water analysis, color refers to the appearance of water that is free of suspended matter, and it is measured by comparing the color of the water sample to the platinum-cobalt scale of Hazen (1892, p. 427–428). In general, ground-water samples in southeastern New Hampshire are free from color in objectionable amounts.

The corrosiveness of a natural water refers to that property which causes it to attack metal surfaces. Corrosion results in deterioration of water pipes, steam boilers, and water-heating equipment. Hot-water lines usually are more subject to attack than are cold-water lines. Aside from the solvent action of water itself, the constituents in water that cause corrosion are acids, substances that upon hydrolysis and decomposition produce acid reactions, carbon dioxide, oxygen, and hydrogen sulfide. Speller (1951) made a comprehensive study of corrosion, its causes, and methods of treatment; practical considerations on this subject have been discussed also by Betz and Betz (1953).

In general, very soft water is apt to be more corrosive than hard water. The ground water used in several public-supply systems in southeastern New Hampshire is soft and corrosive. In these systems, soda ash or lime is introduced into the distribution mains at the source of the water in order to increase the pH and thereby to reduce corrosiveness.

The temperature of ground water that is more than a few feet below the land surface is almost constant throughout the year and approaches the mean annual air temperature. The stable, cool temperature of ground water makes it desirable for certain purposes, especially for cooling. The temperatures reported in table 4 ranged from 44° to 55°F; the average of these temperatures was 49.8°F. The mean annual air temperature at Durham is 46.2°F.

Examination of table 4 suggests that ground-water temperatures in outwash and shore deposits generally are slightly higher than those in ice-contact deposits. This difference may be due to the facts that the ground water in outwash and shore deposits is near the land surface; and that the temperatures were, for the most part, measured during periods when the air temperature was higher than the mean annual temperature.

QUALITY OF GROUND WATER IN RELATION TO ROCK TYPES

Because of the few available quality-of-water data, no definite conclusions were drawn regarding the relation of ground-water quality to the several types of aquifers. In general, variations in quality, which reflect differences in mineralogy, may be expected within a given aquifer. Water in an aquifer may have been derived from different environments and may vary in quality accordingly. For example, at different times and at different places within an aquifer, ground water may be derived directly from precipitation, from adjacent rocks or unconsolidated deposits, or from a nearby stream.

CONTAMINATION OF GROUND WATER

Near the sea or estuaries, salt water may contaminate fresh ground-water supplies and substantially increase the chloride content and the hardness of the water. Two wells, Newington 5 and 6, for which records are included in table 2 of Bradley and Peterson (1962), are reported to have been contaminated thus. These wells obtain their water from joints in the bedrock, and salty water from the Piscataqua

River, less than a quarter of a mile to the northeast, probably moves to the wells through joints that crop out below high-tide level along the river.

Brackish water reportedly also has been pumped from shallow domestic wells driven in beach deposits along the seacoast. Until recently, these wells, which were equipped with hand pumps, produced small amounts of fresh potable water from shallow depths. When hand pumps were replaced by modern electrically powered pumps, larger quantities of water were withdrawn and brackish water was drawn into the wells. At present, most dwellings along the coastline are supplied by municipal water-supply systems that obtain their water from inland sources.

Some wells in southeastern New Hampshire are contaminated from surface sources. Common sources of contamination are cesspool effluents, heavy applications of salt to snow-covered or ice-covered highways, seepage from farm manure, and heavy or concentrated applications of fertilizer. Poorly constructed wells in outwash and shore deposits are especially prone to contamination from surface sources, because the water table in those deposits generally is close to the land surface and because the material above the water table is permeable and transmits water readily.

RECOVERY OF GROUND WATER

WELLS

Wells in southeastern New Hampshire may be classified into four principal types: (1) hand-dug or power-excavated, large-diameter, wells, (2) driven wells, (3) drilled wells, including (4) gravel-packed wells. These types of wells are described below, following a brief discussion of the principles of recovery.

When a well is pumped under water-table conditions, the ground-water level in the immediate vicinity is lowered and the water table assumes the shape of an inverted cone whose apex is at the well. This cone is referred to as the "cone of depression" or "cone of influence." The water level under natural conditions—that is, before the well was pumped—is termed the "static water level." The difference between the static water level and the water level measured at any point on the cone of depression is termed the "drawdown."

For a short time after pumping begins, most of the water is derived from the dewatering of the materials in the immediate vicinity of the well. With continued pumping, the cone of depression deepens and expands, and water is derived from increasing distances. Unless recharge occurs, and if the aquifer is areally extensive, the cone of depression continues to enlarge, but at a decreasing rate. When recharge occurs, however, the development of the cone may be halted or even reversed. Thus, in southeastern New Hampshire where recharge from precipitation is strongly seasonal, cones of depression commonly enlarge during the summer and shrink during the winter and spring. If a cone of depression intercepts a stream or other source of continuous recharge, the development of the cone is halted as long as infiltration from the stream is sufficient to balance the withdrawal from the well. After pumping is stopped, water continues to move toward the well and the water level recovers at a decreasing rate until it again reaches a static position.

If an aquifer is not areally extensive and if its boundary is intercepted by a cone of depression, the cone deepens at an increased rate and drawdowns increase accordingly. This condition explains why in some wells drawdowns that apparently have been nearly stable for prolonged periods of time increase suddenly—and thus force reduction in the rates of pumping. Interference between cones of depression of adjacent wells has a similar effect.

The shape of a cone of depression is largely controlled by the ease with which the aquifer transmits water and by its storage properties. The factors involved are discussed in detail by Theis (1940, p. 278–280).

The specific capacity (yield per unit of drawdown) of a well often is used as a measure of potential production of the well and sometimes is used as a basis for predicting the yield of a well at different drawdowns. In the latter regard, it is important that the conditions of ground-water occurrence—artesian or water table—be recognized. For a well pumping water from an artesian aquifer, the drawdown is roughly proportional to the rate of pumping, that is, the specific capacity is constant. In contrast, for a well pumping water from a water-table aquifer, uniform increases of the pumping rate are accompanied by progressively larger increments of drawdown.

Much of the description of types of wells that follows was presented in an earlier report by Meyers and Bradley (1960).

Dug wells.—Since the time of the early settlers, rural New England has obtained water for home and farm use from wells dug by hand. Most of the dug wells in southeastern New Hampshire are old, many having been dug before 1900 and some even before 1800. Numerous dug wells tap till, ice-contact deposits, and outwash and shore deposits. The older dug wells are usually lined with rocks or bricks. Although most of the wells have inside diameters of from 2 to 4 feet, a few have diameters as great as 20 feet. The more recent dug or power-excavated wells are generally lined with tile or concrete.

Wells in till are commonly between 10 and 30 feet deep, but a few are deeper. Many wells in till become dry during droughts. Some may be deepened and the flow of water thus restored, but others have been dug to bedrock and cannot be deepened by digging. At the present time (1962), fewer wells are dug in till because more dependable water supplies are available from wells drilled into the bedrock.

Generally speaking, moderately large quantities of ground water can be pumped from wells dug in ice-contact deposits. Such wells range from about 10 to 45 feet in depth. In these materials, wells need not be dug much below the top of the zone of saturation, because the water table fluctuates only a few feet under natural conditions and from most of these wells ample supplies of water are available even during droughts. There is danger of losing such a supply, however, if continued heavy pumping is begun in a nearby gravel-walled or gravel-packed drilled well.

In outwash and shore deposits, dug wells should penetrate deeply into the saturated zone because seasonal fluctuations in precipitation and evaporation may change the level of the water table by several feet.

Driven wells.—A driven well consists of a well point or strainer attached to the end of a small-diameter casing that is driven into the water-bearing material. Driven wells are best adapted for use in loose medium to coarse sand in localities where the water-bearing beds are not far below the surface. They range from about 10 to 60 feet in depth and from 1 to 4 inches in diameter. They may be driven by hand or by a mechanically lifted weight.

Driven wells are used for obtaining small quantities of water, usually for domestic or farm supplies. They are used also for testing water-bearing formations and for observing variations in the water table. Wells of this type are easy and inexpensive to install; however, they have not been used widely in southeastern New Hampshire. Driven wells can be used in outwash and shore deposits or in fine-grained ice-contact deposits. The city of Portsmouth has made use of batteries of 2½-inch driven wells for public supply; these have been used successfully in ice-contact deposits at two separate places.

Drilled wells.—Drilled wells in southeastern New Hampshire may be grouped into two classes: (1) wells finished in unconsolidated deposits, and (2) wells finished in bedrock. The latter, often locally called artesian wells, are discussed in more detail by Goldthwait (1949) and by Cushman, Allen, and Pree (1953). In the report area these wells range from about 45 to 600 feet deep, are usually from 6 to 8 inches in diameter, and derive water from cracks in the bedrock. A steel casing is ordinarily lowered to the bedrock surface and cemented to it.

Drilled wells in unconsolidated deposits are not numerous in southeastern New Hampshire, but, where present, they usually yield substantial amounts of ground water. Those inventoried during this investigation are in ice-contact deposits. They range from about 30 to 70 feet in depth and have steel casings 6 to 8 inches in diameter; a few are equipped with well screens, but most are left with open-end casings. Wells of this type in the report area are used to supply rural or suburban homes or schools. In most cases, the available ground-water supply greatly exceeds the present demand for water.

Gravel-packed wells.—Another type of drilled well, the gravel-packed well, yields large quantities of water from permeable ice-contact deposits. In southeastern New Hampshire, gravel-packed wells are used primarily to satisfy the demands of municipal water-supply systems.

Gravel-packed wells are drilled by using two casings, a large-diameter outer temporary casing and an inner permanent casing to which a well screen is attached at the bottom. After the well has been drilled and all the material removed from the inside of the outer casing, the well screen and permanent casing are lowered to the desired depth, and uniform-sized gravel is poured between the two casings. Finally the outer casing is removed or raised above the water-bearing zone. The gravel envelope around the well screen permits use of large screen openings and thereby increases the efficiency and yield of the well. In addition, the gravel envelope reduces the amount of sand and silt that might be drawn into the well at high discharge rates. Gravel-packed wells in the report area commonly have screens and permanent casings ranging in diameter from 1 to 2 feet; they range in depth from about 40 to 95 feet.

The efficiency and yield of screened and gravel-packed wells may be increased by treatment after drilling, referred to as "well development." Common well-development procedures are surging, intermittent pumping, and backwashing; these processes help build a natural gravel envelope around the well screen and remove loose sand and silt particles from the screen area.

All the gravel-packed wells in the report area are drilled in ice-contact deposits because other units do not have sufficient water-yielding capacities to support high yields.

SPRINGS

Meinzer (1923b, p. 48) defines a spring as "* * * a place where, without the agency of man, water flows from a rock or soil upon the land or into a body of surface water." The water from springs flows from openings in the rocks or soil at the land surface. The size and number of openings, the geologic environment, and the amount of water which flows out may all vary from one spring to another.

In southeastern New Hampshire, springs are numerous and many are used for domestic or farm water supplies. In the unconsolidated deposits of that part of New Hampshire, two types of springs are common: contact springs and artesian springs. Springs also issue from the bedrock but these are less common than springs in the unconsolidated deposits. Records of selected springs in the area are given by Bradley and Petersen (1962, table 5).

Artesian springs may occur wherever an impermeable layer overlies a water-bearing bed in which ground water is under artesian pressure. Such springs require natural openings through the impermeable beds to permit the ground water to escape. In southeastern New Hampshire, water flows through openings in thin marine deposits that overlie ice-contact deposits and issues at the surface as artesian springs. The openings may have been made when tree roots that penetrated the impermeable layer decayed, or perhaps when ground water under pressure worked its way to the surface through the upper bed. Probably the flow of some of the developed springs has been increased by the activities of man.

Contact springs are formed where permeable deposits overlie impermeable deposits and the contact between the two intersects the land surface. Because the impermeable formation retards or prevents the downward movement of water, ground water in the permeable deposit escapes along the contact. In the report area such springs are common in valleys where outwash and shore deposits and underlying marine deposits intersect the land surface. The flow of these springs is concentrated in low places at the top of the marine deposits.

The flow from springs fluctuates with seasonal water-table changes in associated water-bearing rock materials. Occasionally, springs may stop flowing or diminish in yield as a result of sediment that clogs the openings and causes the water to discharge elsewhere or which diffuses the flow so that the water is discharged mostly by evaporation and transpiration.

Springs in the bedrock issue from joints and are classified as fissure springs. Only a few of these, Exeter sp 1 and Dover sp 2 for example, are used for water supply.

AQUIFERS IN SOUTHEASTERN NEW HAMPSHIRE

As an aid to the users of this report the principal aquifers or potential aquifers in southeastern New Hampshire are identified and some are described in a series of statements that follow. The scope of each statement is determined by the availability of data; thus, some statements merely identify the aquifer with reference to place names shown on the geologic maps (pls. 1, 2), others summarize pertinent elements of information, and a few include interpretations of ground-water conditions or offer qualitative appraisals of aquifer potentialities.

Where appraisal statements of yields of wells or aquifers are given, these appraisals, for lack of quantitative data, are necessarily expressed in general terms; they simply imply the potential relative to that of other wells or aquifers in southeastern New Hampshire. Their purpose is to call attention to the aquifers that appear to be most promising with respect to future development.

The aquifers are grouped by towns, which are listed alphabetically by counties. To avoid repeating statements for aquifers that extend into more than one town, the statements are numbered serially and aquifers are cross-referenced by way of these numbers.

As a guide to the availability of data for specific locations the reader is referred to the geologic maps and sections (pls. 1–7) and to records given by Bradley and Petersen (1962, tables 2 and 3).

Statement 1.—Numerous small bodies of ice-contact deposits are scattered throughout southeastern New Hampshire. Some of these underlie small kame terraces, which abut hills of till and bedrock; others form small isolated kames. In general these deposits are too small to store much water, and in many the bulk of the materials is above the water table. However, a few extend beneath adjacent marine deposits and are larger than they appear at the surface. Thus, where marine deposits adjoin ice-contact deposits, it may be worthwhile to drill test holes through the marine deposits on the chance that saturated ice-contact deposits will be reached beneath the marine deposits.

No attempt is made in this report to describe individually most of the small bodies of ice-contact deposits that are discussed in general above. For many of them no specific information exists. These deposits can be located within each town by reference to the geologic maps (pls. 1 and 2). Where wells are shown on the maps, some subsurface data are available from Bradley and Petersen (1962, tables 2 or 4).

ROCKINGHAM COUNTY

ATKINSON

Statement 2.—Ice-contact deposits underlie a small area in the eastern part of Atkinson. These deposits have not been explored.

Statement 3.—Sandy plains underlain by outwash and shore deposits extend from Atkinson into Plaistow. The deposits are described in statement 40.

BRENTWOOD

Statement 4.—Near the eastern margin of Brentwood are two fairly large bodies of ice-contact deposits (pl. 1). The northern or larger of these underlies an area of about 1 square mile. It is unexplored. The southern or smaller body of deposits is at least 66 feet thick according to the log of Brentwood 10 (Bradley and Petersen, 1962, table 4). This body of deposits extends southward to the Exeter River and may be continuous beneath the river with similar deposits in the town of Exeter. The deposits at Brentwood appear to be favorably situated to induce recharge from the river.

Statement 5.—Outwash and shore deposits underlie extensive areas in Brentwood and Epping. In most parts of these areas small but dependable supplies of ground water can be obtained. The deposits are as much as 40 feet thick but probably are less than 25 feet thick at most places. They commonly become finer grained and less permeable with depth and grade into underlying marine deposits.

Statement 6.—At a few places in Epping and Brentwood, permeable ice-contact deposits underlie and are concealed by marine deposits or by outwash and shore deposits. Probably the tops of these islands of ice-contact deposits were removed by erosion, and subsequently the remnants were covered by the marine deposits or by the outwash and shore deposits. The buried ice-contact deposits are a potential source of ground water; their potential as aquifers depends partly upon their connection to areas of recharge. Ordinarily there is no surficial evidence of the buried deposits, which must therefore be located by test drilling or by geophysical methods. For example, at Epping 2 (pl. 1), where marine deposits overlie 5 feet of stratified sand and gravel, no ice-contact deposits are exposed nearby. Near Brentwood 2 (pl. 1), where similar conditions exist, there is a small outcrop of ice-contact deposits (too small to be shown at the scale of the map) a few hundred yards from the well.

EAST KINGSTON

Statement 7.—A north-trending irregular body of ice-contact deposits underlies an area in southwestern East Kingston. (See pl. 1.) This body of deposits is crossed by the Powwow River, and conditions may be favorable for inducing recharge from the stream. Irregular topography and angular bedrock fragments suggest that the deposits are thin.

Statement 8.—In the northeastern part of East Kingston near the Kensington line are two small bodies of ice-contact deposits. (See statement 1.)

Statement 9.—Broad plains formed by outwash and shore deposits underlie most of Kingston and extend into East Kingston. The deposits are described in statement 23.

EPPING

Statement 10.—A few small scattered bodies of ice-contact deposits are in the part of Epping mapped for this report. (See pl. 1.) Most of the deposits are too small to be significant as sources of ground water. (See statement 1.) The largest, which forms a kame terrace at the west edge of the mapped area (V17–5, pl. 1) is as much as 44 feet thick at test hole Epping 4 (Bradley and Petersen, 1962, table 4). Probably most of this body of deposits is above the water table but where it adjoins the Lamprey River, conditions may be favorable for inducing recharge from the river.

Statement 11.—Outwash and shore deposits in Epping are described in statement 5.

Statement 12.—Buried ice-contact deposits in Epping are described in statement 6.

EXETER

Statement 13.—A fairly large kame terrace borders a large drumlin in Stratham and extends into Exeter. At test hole Stratham 18 the terrace deposits were 27 feet thick, but most of the saturated materials consisted of fine sand. The deposits may thicken from the flank of the drumlin toward the ice-contact margin of the terrace. The town of Exeter obtains a small supply of ground water for auxiliary use from a well (Stratham 10, pl. 1) in these deposits.

Statement 14.—Buried ice-contact deposits, which are overlain by marine deposits, are distributed fairly widely in the valley of the Exeter River. Wells Exeter 2, 13, 15, 18, 23, 24, 25, and 26 (pl. 1) all penetrated such deposits. The ice-contact deposits at these wells range in thickness from a few feet, as at Exeter 25 where they are 5 feet, to 40 feet, as at Exeter 15 (Bradley and Petersen, 1962, table 4). The large variation in thickness, and the wide distribution of the deposits suggest that they are discontinuous.

Well Exeter 2 (pl. 1), which penetrated 8 feet of ice-contact deposits beneath 48 feet of marine deposits, has yielded water at a rate of about 500 gpm. The water from this well is reported to have characteristics similar to water from the streams nearby. This report and the large yield of the well suggest that infiltration is induced from the Exeter or Little Rivers by leakage through the marine deposits. An analysis of a sample from Exeter 2 (table 4) shows the ground water to be satisfactory for most uses. The iron content, 0.24 ppm, is slightly higher than in water at most places in southeastern New Hampshire, but it is not high enough to require treatment. The color of the water is relatively dark also, probably because some of it is derived by infiltration from the streams.

Statement 15.—South of the Exeter River in the southwestern part of Exeter is a fairly broad kame terrace. (See pl. 1.) The ice-contact deposits, which consist of gravel and fine sand, are 90 feet thick at Exeter 11 (Bradley and Petersen, 1962, table 4). The Exeter River flows between the kame terrace and a kame plain to the north in Brentwood. (See statement 4.) The kame-plain deposits appear to be situated favorably with respect to inducing recharge from the river.

Statement 16.—A small body of ice-contact deposits is near the Hampton Falls-Exeter town line in the southeastern part of Exeter. Another small body of deposits is in the northwestern part of Exeter (W17–7 (pl. 1)), where it underlies a kame terrace along a small drumlin. Probably neither body of deposits is large enough to be a significant source of ground water. (See statement 1.)

GREENLAND

Statement 17.—An extensive kame plain occupies the central part of Greenland. (See pl. 3.) A small valley, containing marine deposits at the surface, bisects the kame plain, but the ice-contact deposits are continuous beneath the marine deposits. The subsurface relations are shown by section *N–N′*, plate 3. The total area of the kame plain is more than 1 square mile.

A city of Portsmouth municipal well, Greenland 1 (pl. 3), draws about 675,000 gpd from this body of deposits. The area of influence of the well extends to the northern edge of the kame plain, and pumping of the well has reduced the natural flow of Greenland sp 2 (pl. 3). The aquifer can probably sustain a moderate increase in yield, but wells should be located in the western, southern, or southeastern parts of the kame plain in order to avoid or minimize interference with Greenland 1.

Partial analysis of a ground-water sample from Greenland 1 (table 4) suggests that the quality of water in the Greenland kame plain is probably satisfactory for most purposes. Although the bedrock surface near Greenland 1 is below sea level, salt-water encroachment from the mouth of the Winnicut River—about a mile to the northwest—is prevented by a low bedrock barrier (Greenland 9, section *N–N′* pl. 3) and by the relatively impermeable marine deposits near the mouth of the river and along the southern shore of Great Bay. (See pl. 1.)

Statement 18.—A large kame plain is located mostly in Rye but extends into North Hampton and the southeastern corner of Greenland. The deposits forming this kame plain are described in statement 44.

HAMPTON

Statement 19.—A large kame plain occupies the central part of Hampton and extends northward into North Hampton. (See pl. 1.) The Hampton Water Works, which supplies water for the town of Hampton, has four wells in the deposits of this kame plain: two in North Hampton and two in Hampton. From these (Hampton 3 and 7 and North Hampton 7 and 8, pl. 1) water was withdrawn at a rate of 1,622,900 gpd during July and August 1956. An analysis of a sample from Hampton 3 (table 4) shows the water, which is soft and low in iron, to be suitable for most purposes.

Much of the Hampton kame plain is hydrologically unexplored. The recharge area, which coincides with the exposed part of the kame plain, is large, and the success of the wells of the Hampton Water Works attests to the high permeability of the deposits. If thick saturated deposits are distributed widely enough to permit some dispersal of wells, it should be possible to increase considerably the withdrawal of ground water from the Hampton kame-plain area.

HAMPTON FALLS

Statement 20.—Small bodies of ice-contact deposits are scatterad about Hampton Falls. (See statement 1.)

KENSINGTON

Statement 21.—Ice-contact deposits form an elongate, irregular-shaped kame plain that extends from north-central Kensington southeastward across the town and into the western part of Seabrook. Small parts of this body of deposits also extend into Hampton Falls and South Hampton. (See pl. 1.) The saturated thickness of the deposits is reported to be about 45 feet at Seabrook 1 and at least 33 feet at Kensington 7 (pl. 1).

Near the southern end of the kame plain, the town of Seabrook has two municipal supply wells. These wells, Seabrook 1 and 2, when tested individually, yielded 450 and 350 gpm respectively. Because the wells are only a few hundred feet apart, interference, if both were pumped simultaneously for any length of time, probably would reduce their combined yield to a value less than the total of the individual test yields. The water from these wells is of excellent quality. (See analysis for Seabrook 1, table 4.) Some of the Kensington kame plain remains to be explored. The outlook for further ground-water development appears good.

KINGSTON

Statement 22.—A few small bodies of ice-contact deposits occur in various parts of Kingston. (See statement 1.) They are relatively unexplored. Some of the bodies adjoin Country Pond, which lies along the Kingston-Newton border. It may be possible for wells in deposits near the pond to induce recharge fom the pond.

Statement 23.—Plains formed of outwash and shore deposits underlie large areas in Kingston and extend into East Kingston. (See pl. 1.) In most of these areas small but dependable supplies of ground water can be obtained, and from the parts of deposits where a few tens of feet are probably saturated supplies of moderate size can be obtained. In the western and southern parts of Kingston, marine deposits are absent and the outwash and shore deposits rest directly on till, bed-rock, or ice-contact deposits. In general the outwash and shore deposits are thicker in Kingston than elsewhere in southeastern New

Hampshire. Consequently, the Kingston deposits may have a somewhat greater potential as an aquifer than the outwash and shore deposits elsewhere in the area.

The quality of the ground water from the outwash and shore deposits is generally suitable for most purposes. Analyses of water derived from these deposits show relatively low pH values; for example, water from Kingston 11 (pl. 1) had a pH of 6.6. (See table 4.) The low pH value suggests that the water may be corrosive. The water from Kingston 11 had a high chloride content, 87 ppm, possibly because Kingston 11 is near a state highway where salt is used for ice removal.

NEWCASTLE

Statement 24.—Neither ice-contact deposits nor outwash and shore deposits were mapped in Newcastle.

NEWFIELDS

Statement 25.—In the eastern part of Newfields are three bodies of ice-contact deposits. (See pl. 1.) There are few data concerning them, but these deposits are extensive enough to have some potential as aquifers. The southernmost deposit is 60 feet thick at Newfields 5 (Bradley and Petersen, 1962, table 4). From this body of deposits Newfields 1 produces about 45 gpm for the town of Newfields. A partial analysis of water from Newfields 4 (table 4) shows that the ground water is soft, low in iron, and has a nearly neutral pH.

NEWINGTON

Statement 26.—Ice-contact deposits form a large kame plain that extends from the central part of Newington into the northwestern part of Portsmouth. (See pl. 4.) This plain, which was called the Newington moraine by Keith and Katz (1917) and the Newington-Portsmouth kame plain by S. D. Tuttle in an unpublished Ph. D. thesis (The Quaternary geology of the coastal region of New Hampshire, Harvard University, 1952), is an irregular mass about 4 miles long and from about a quarter of a mile to a mile wide. Subsurface relationships for the southern part of the area are shown in cross-sections in plate 4.

At places the ice-contact deposits extend beneath adjacent outwash and shore deposits or beneath marine deposits, which may in turn be buried by outwash and shore deposits. Along the western edge of the kame plain, excavations show stratified sand, gravel, and cobbles in beds that dip gently westward. The ice-contact deposits are at least 70 feet thick at Portsmouth 25, at least 65 feet thick at Portsmouth 14, and at least 66½ feet thick at Newington 25 (Bradley and Petersen, 1962, table 4). Before 1955 the saturated thickness of deposits near Portsmouth 2 (pl. 4) was about 60 feet. Subsequently construction of drainage facilities for Pease Air Force Base lowered the water table about 15 feet, and continuous or nearly continuous pumping of Portsmouth 25 lowered the saturated thickness of deposits there to about 30 feet by the end of 1957.

Connected to the northwestern corner of the kame plain is a small mass of ice-contact deposits extending westward to Great Bay and southward about half a mile. Surface examination suggests that this body of deposits is thin, and it probably will not yield much ground water.

For many years the water supply for the city of Portsmouth was derived from wells on the Newington-Portsmouth kame plain. The municipal supply wells included Portsmouth 1–5. The yield of each well is not large, but the collective yield exceeded 2 mgd (million gallons per day) during part of the year. During construction of the Pease Air Force Base, wells Portsmouth 1 and 2 (pl. 4) were destroyed; subsequently the Air Force undertook to provide Portsmouth with a comparable water supply.

The yield from the deposits of the Newington-Portsmouth kame plain remains high despite changes caused by the construction of the Pease Air Force Base. The recharge area, which coincided with the exposed surface of the kame plain, was reduced somewhat by the construction of drained runways and parking aprons. However, the stripping of soil and trees has so reduced transpiration and soil-moisture retention in the present recharge area that recharge rates there probably are larger than before the construction of the base. The net effect of these opposing changes is unknown.

The quality of ground water in the Newington-Portsmouth kame plain is good. Analyses of water from the city of Portsmouth wells (Portsmouth 1, 2, and 4) and a later partial analysis of water from Portsmouth 2 are shown in table 4. Ground water from these wells is somewhat harder than most samples tested in the report area, but the hardness is not high enough to require treatment for most ordinary purposes.

Statement 27.—North of the Newington-Portsmouth kame plain along Great and Little Bays are three small bodies of ice-contact deposits (pl. 1), but they are not extensive enough to yield much ground water. There is no evidence of an impermeable barrier between the ice-contact deposits and the salt water in Great and Little Bays; heavy pumping of wells near the shore in these deposits might therefore cause salt-water encroachment and contamination of water supplies.

NEWMARKET

Statement 28.—In the northern part of Newmarket and extending into Durham and Lee is a fairly large kame plain. (See pl. 1.) Data for this body of deposits are few, but its extent and the coarse texture of the materials that are exposed in gravel pits in the central and western parts of Newmarket suggest that the deposits are a potential source of moderate to large supplies of ground water. Newmarket sp 3 (pl. 1), which derives water from the kame-plain deposits, flows at a rate of about 65,000 gpd. The water from this spring has a low iron content, a hardness of only 43 ppm, and a pH of 6.8.

Statement 29.—In the eastern part of Newmarket are two bodies of ice-contact deposits. (See pl. 1 and statement 1.) One body of deposits, near the northern edge of Newmarket, is traversed by the Piscassic River and appears to be situated favorably with respect to recharge from the river. The other body extends from the business district of Newmarket southward nearly to the Newmarket-Newfields town line. Subsurface data for the second body of deposits are lacking; the central part forms a narrow kame terrace around a large bedrock hill. Surface examination suggests that the terrace deposits are thin.

Statement 30.—Two small bodies of ice-contact deposits are located in the southwestern part of Newmarket. (See statement 1.)

NEWTON

Statement 31.—An irregular-shaped mass of ice-contact deposits underlies a fairly large area along the Newton-Plaistow line. (See pl. 1.) The deposits have not been explored, but the surface features suggest that they are generally thin.

Statement 32.—In the northwest and southeast corners of Newton are two fairly extensive, unexplored bodies of ice-contact deposits. (See pl. 1.) The body of deposits in the northwest corner adjoins Country Pond; there may be opportunity for inducing recharge from the pond at this locality.

Statement 33.—Outwash and shore deposits underlie an area along the western town boundary of Newton (statement 40) and a small area along the southern boundary. (See pl. 1.) Probably small but reliable supplies of ground water can be obtained from the deposits in these areas.

NORTH HAMPTON

Statement 34.—An extensive kame plain underlies parts of Rye, Greenland, and North Hampton. The deposits of this kame plain are described in statement 44.

Statement 35.—In the central part of North Hampton is another kame plain. (See pl. 1.) This kame plain is fairly extensive. According to data collected from well North Hampton 11, the saturated thickness of the ice-contact deposits is as much as 42 feet.

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Statement 36.—A large kame plain occupies the central part of Hampton and extends northward into the southern part of North Hampton. The deposits are described in statement 19.

Statement 37.—Elsewhere in North Hampton there are a few small bodies of ice-contact deposits. (See statement 1.)

PLAISTOW

Statement 38.—Along the Plaistow-Newton border is a fairly large, irregular-shaped mass of ice-contact deposits. (See statement 31.)

Statement 39.—Several small bodies of ice-contact deposits are scattered in various parts of Plaistow. (See statement 1.)

Statement 40.—Sandy plains underlain by outwash and shore deposits extend across the central part of Plaistow southward into Atkinson and northward into Kingston and Newton. The deposits are as much as 42 feet thick, but their saturated thickness probably is not more than a few feet in most places. Small but dependable supplies of ground water can be obtained from these deposits.

PORTSMOUTH

Statement 41.—The northwestern part of Portsmouth is underlain by part of the Newington-Portsmouth kame plain. The deposits of this kame plain are described in statement 26.

Statement 42.—Between Sagamore Creek and Berrys Brook in the southern part of Portsmouth is a large area underlain by ice-contact deposits. (See pl. 1.) From the northern end of the area, where they underlie a kame terrace surrounding a bedrock hill, the ice-contact deposits extend southward in the form of a flat, low plain marked by outcrops of bedrock. Examination of surficial features suggests that the deposits are thin, except possibly near the bedrock hill at the northern end of the area. Probably only small supplies of ground water, enough for domestic use or small-scale commercial use, can be obtained from these deposits.

Statement 43.—In the western part of Portsmouth are two small bodies of ice-contact deposits. (See pl. 1.) One is just north of Sagamore Creek, in the southwestern part of X17–6; the other is about 1¼ miles southwest of the first, in the southeastern part of X17–5. (See statement 1.)

RYE

Statement 44.—A large kame plain extends from the seacoast westward across Rye and into adjacent parts of Greenland and North Hampton. (See pl. 1.) Subsurface relations asross the central part of the kame plain (pl. 3) are shown by section *Q–Q′*, plate 3. Because the thickness and permeability of the kame-plain deposits differ considerably from place to place, the ultimate development of the aquifer probably will depend upon the extent to which the distribution of the thicker and more permeable deposits will permit the dispersal of wells across the area.

In the eastern part of the Rye kame plain, the Hampton Water Works has a municipal supply well, Rye 12 (pl. 1), which yields 135 gpm or about 195,000 gpd. Probably a larger yield could be obtained from this part of the aquifer. Also favorable for the development of a water supply are the deposits in part of the aquifer near Rye 20. (See section *Q–Q′*, pl. 3.)

The quality of the ground water from the Rye kame-plain deposits probably is satisfactory for most purposes. An analysis of a sample from Rye 1 (table 4) shows water of good quality. The water is soft and has a pH of 6.8. It has a slightly larger iron content, 0.23 ppm, than most of the ground water sampled for this report. The iron content is not large enough to require treatment, but it does indicate that attention should be given to the iron content of the ground water whenever new supplies are sought in the Rye kame-plain area.

Statement 45.—North of the Rye kame plain is another fairly large area of ice-contact deposits. (See pl. 1.) Here two bodies of ice-contact deposits are separated at the land surface by a small area underlain by marine deposits, but the ice-contact deposits may be continuous beneath the marine deposits. The northern body of ice-contact deposits is unexplored.

Statement 46.—A few small bodies of ice-contact deposits occur in Rye. (See statement 1.)

SEABROOK

Statement 47.—The Kensington kame plain extends into the western part of Seabrook from Kensington. The deposits forming this kame plain are described in statement 21.

Statement 48.—Ice-contact deposits form a kame plain in the southern part of Seabrook near the New Hampshire-Massachusetts border. (See pl. 1.) The distribution of bedrock outcrops suggests that the ice-contact deposits are generally thin. Moreover, where the deposits are relatively thick, as at Seabrook 23 (Bradley and Petersen, 1962, table 4), the materials are too fine grained to yield much water. Probably only small supplies of ground water can be obtained from this kame plain.

SOUTH HAMPTON

Statement 49.—A small part of the Kensington kame plain extends into the northwestern corner of South Hampton. The deposits of this kame plain are discussed in statement 21.

Statement 50.—In the southeastern part of Newton (see statement 32) and extending eastward just across the town line into South Hampton is body of ice-contact deposits. These depostits have not been explored. In the eastern part of South Hampton, west of the

Kensington kame plain is another unexplored, small irregular-shaped body of ice-contact deposits.

STRATHAM

Statement 51.—A more or less symmetrical, ridgelike kame plain trends northwest nearly across the central part of Stratham. (See pl. 1.) The deposits of this kame plain are 30 and 25 feet thick at Stratham 19 and 20 respectively (Bradley and Petersen, 1962, table 4); they are 62 feet thick at Stratham 13, which is a bedrock well. Pits near the center of the kame plain suggest that the deposits are thick there. The Stratham kame plain has not been extensively explored, but, because of its large extent and, locally at least, the fairly large thickness of deposits, it is a favorable area for prospecting.

Statement 52.—Bordering a drumlin and extending into Exeter is a large kame terrace. The deposits of this kame terrace are discussed in statement 13.

Statement 53.—In the northeastern part of Stratham, ice-contact deposits form a group of more or less continuous, irregular-shaped kame terraces along drumlins. These deposits are very poorly sorted at places, and there is some question as to whether parts of them are ice-contact deposits, till, or shore deposits derived by the reworking of till or ice-contact deposits. Field examination suggests that the deposits are thin and therefore will likely yield only small amounts of ground water.

STRAFFORD COUNTY

BARRINGTON

Statement 54.—A mass of ice-contact deposits underlies an area—called The Hoppers—of about three-fourths of a square mile at the intersection of Barrington, Dover, and Rochester, and extends into all three towns. (See pls. 2 and 5.) The deposits consist of sand and gravel. Their surface is marked by several steep-walled kettles, which are shaped like grain or coal hoppers and give the area its name. Each of the kettles, which are 60 to 80 feet deep, covers an area of several acres. The saturated thickness of the deposits is as much as 65 feet. The subsurface relations are shown by section *D–D′*, plate 5.

Because of their coarse texture and relatively large saturated thickness, the Hoppers deposits promise to yield large quantities of water to wells and the conditions for recharge by direct precipitation are especially favorable. The kettles, too, serve to collect surface runoff and funnel it to the ground-water body. Part of the saturated zone is below the level of the Cocheco River. In the part of the area near section *D–D′*, (pl. 5), a hydraulic connection between the river and the ice-contact deposits appears unlikely, but a connection may exist along the river northeast of Dover 83 and 43. Available data indicate that the quality of the ground water is generally good; the iron content of water sampled by the Corps of Engineers in 1952 was not excessive, but additional tests should be made.

Statement 55.—Elsewhere in the part of Barrington mapped for this report are three small bodies of ice-contact deposits. The largest of these is along the southeastern border of Barrington about a quarter of a mile south of Mallego Brook. (See pl. 2.) The other two, (one-tenth of a mile and 1 mile southwest of The Hoppers, respectively), form small kame terraces in the eastern corner of Barrington. All three are unexplored. Their location would allow recharge to occur by direct precipitation only and, because of their small surficial area, the quantity of recharge must be relatively small. These deposits are likely to yield only small quantities of water.

Statement 56.—A small part of a kame plain, which is located principally in Lee, extends into Barrington. The deposits in this kame plain are described in statement 73.

Statement 57.—A large body of outwash and shore deposits extends from the Isinglass River near the northeastern boundary of Barrington to the east-central part of Barrington near Mallego Brook. The deposits, which are continuous with similar deposits in Rochester (statement 90), are as much as 42 feet thick at Barrington 6 (Bradley and Petersen, 1962, table 4), but their saturated thickness probably is no more than 20 feet and may be considerably less at most places. They overlie marine deposits.

The outwash and shore deposits yield small to moderate amounts of water to shallow wells. Because the water table is near the land surface in much of the area, it is necessary to guard against contamination from local sources. An analysis of water from Barrington 1 (table 4), for example, shows a high chloride content suggestive of a nearby source of contamination.

DOVER

Statement 58.—Ice-contact deposits in the western part of Dover, part of The Hoppers area, are discussed in statement 54.

Statement 59.—A large kame plain underlies much of Somersworth and extends southward into Dover. The deposits underlying this feature are described in statement 96.

Statement 60.—In Dover and Rollinsford between the Cocheco and Salmon Falls Rivers is a body of outwash and shore deposits. No data are available for these deposits. (See statement 94.)

Statement 61.—Adjacent to the Cocheco River in Dover are two small bodies of ice-contact deposits. One, in the northeast corner of W18–6 (pl. 2), consists of coarse sand, gravel, and cobbles; it is exposed beneath marine deposits on both sides of the Cocheco River and probably is hydraulically connected to the river. Another is in the southeast corner of W18–2, about 2 miles northwest of the first. (See pl. 2.) Evidence of an interconnection between the second body of deposits and the river is lacking. The small outcrop area of both deposits suggests that they might support large withdrawals, but only if it were possible to induce recharge from the river. In this situation the quality and temperature of the ground water would be greatly influenced by the quality and temperature of the river water.

Statement 62.—Ice-contact deposits form a kame terrace along a small hill in the north-central part of Dover (east-central part of W18–2). (See pl. 2.) No subsurface data are available for these deposits.

Statement 63.—About half a mile south of the Dover business district, in the east-central part of W18–6 and extending into X18–4 (pl. 2), is a large body of ice-contact deposits. These deposits have not been explored.

Statement 64.—About 2 miles south of the Dover business district, at the intersection of W18–6 and 9, and X18–4 and 7 (pls. 2, 6), is another large body of ice-contact deposits. Test hole Dover 77 (Bradley and Petersen, 1962, table 4) penetrated 36 feet of sand and gravel in this body before reaching bedrock, but at that point the deposits were dry.

Statement 65.—A linear, north-trending body of ice-contact deposits occupies a strip of land between the Piscataqua and Bellamy Rivers in Dover. (See pl. 2.) The east and west edges of this deposit are buried beneath marine deposits. Logs of wells Dover 16, 78, and 79 and exposures in a gravel pit at the north end of this body of deposits show them to consist of sand and gravel, but outcrops of bedrock in the pit suggest that a large saturated thickness is unlikely in the area near the pit. Dover 16, in another gravel pit, near the southern end of the deposits, was drilled to bedrock at a depth of about 30 feet, or about 17 feet below sea level, and nearly all the materials penetrated were saturated. This well was tested for a few weeks at a rate of 125 gpm. The bedrock surface apparently slopes downward in a southerly direction, for Dover 78 and 79, just south of the exposed part of the deposits, reached bedrock at a depth of about 75 feet below sea level. Danger of saltwater encroachment exists if intensive development of ground-water supplies from these deposits is undertaken; however, the marine deposits may act as an impermeable barrier and prevent or retard such encroachment.

Statement 66.—A large mass of ice-contact deposits underlies the Barbadoes Pond area in Dover and Madbury. These deposits, which are a source of part of the Dover municipal water supply, are described in statement 81.

Statement 67.—A large body of ice-contact deposits underlies the Pudding Hill area in the southwest corner of W18–6. (See pls. 2, 6.) Pudding Hill is about 2 miles long and as much as three-fourths of a mile wide. Its top is about 90 feet above the surrounding area.

Subsurface relationships for the Pudding Hill deposits are shown in sections *G–G′* and *J–J′*. (See pl. 6.) The bedrock floor upon which the deposits rest is shallow at the east end (section *G–G′*, pl. 6) but slopes westward; about midway along the length of the hill it may be as much as 200 feet below the hill top. To the north the ice-contact deposits pinch out beneath thick marine deposits. To the south the ice-contact deposits are more extensive and may be hydraulically continuous as far south as Madbury 8 (sections *H–H′* and *J–J′*, pl. 6). The texture of the deposits in part of this area is relatively fine grained (Dover 84 and Madbury 30, pl. 6).

The ground water beneath the hill is probably unconfined, but where the ice-contact deposits extend beneath the marine deposits, the water is confined and in a few wells it flows or stands above the land surface in the well casings; examples of such wells are Dover 11 and 13 (Bradley and Petersen, 1962, table 4).

The Pudding Hill deposits are recharged by the infiltration of rain and snowmelt on the surface of the hill. Conditions for recharge from precipitation are especially favorable in several large gravel pits. Here soil-moisture retention and evapotranspiration are relatively ineffective because soil and vegetation are absent; consequently, the infiltration rate is greater than it would be under natural conditions.

On the north side of the hill the hydraulic continuity of the Bellamy River with the ice-contact deposits is broken by the generally thick and nearly continuous intervening body of marine deposits. Under existing conditions, therefore, wells in the ice-contact deposits cannot depend on the Bellamy River to any great extent for replenishment. However, artificial recharge might be possible if recharge wells were so located in the streambed as to pierce the marine deposits near production wells in the ice-contact deposits.

The quality of ground water in the Pudding Hill area is generally good. Water from Dover 54 contained 1 ppm of iron, according to an analysis made for the Corps of Engineers in 1952, but water from other test wells contained substantially less iron. An analysis of water from Dover 11 (table 4) shows this water to be soft, to have a pH of 7.0, and to contain less than 0.1 ppm iron.

In summary, the large areal extent and saturated thickness of the Pudding Hill deposits suggest that they can sustain a large withdrawal of ground water. Conditions are favorable for recharge from precipitation, and there appears to be some opportunity for artificial recharge by diverting water from the Bellamy River through recharge wells and into the ice-contact deposits. The quality of the ground water generally is good.

Statement 68.—About half a mile south of Pudding Hill along the Madbury-Dover town line is another body of ice-contact deposits. (See pl. 6). These deposits are described in statement 84.

DURHAM

Statement 69.—Ice-contact deposits form a small kame plain near the center of the town boundary between Durham and Lee. (See pl. 2.) Several wells and test holes (Durham 1, 9, 10, 11, and 12, and Lee 7, 13, 14, and 15) have been drilled in the deposits. The logs of wells and test holes show that the deposits beneath the kame plain are coarse textured and have a maximum thickness of at least 87 feet (Durham 10, Bradley and Petersen, 1962, table 4). In the vicinity of Durham 9 the ice-contact deposits extend beneath adjacent marine deposits. Outcrops of till and logs of wells near the kame plain suggest that elsewhere the boundaries of the aquifer nearly coincide with those of the kame plain.

Reliable verbal reports indicate that water from Durham 10 had an odor. This test hole was drilled on the west side of a kettle, which is about 200 yards in diameter and 50 feet deep, near the center of the kame plain. The odor was probably derived from stagnant swamp water in the kettle; if so, continuous moderate to heavy pumping might improve the quality of the ground water by increasing the circulation.

Statement 70.—An irregular-shaped body of ice-contact deposits extends from the Lamprey River southward to the Rockingham-Strafford County line in the southern part of Durham. (See pl. 2.) The deposits have not been explored. Outcrops on both sides of the Lamprey River suggest a hydraulic connection between these deposits and the river; accordingly, there may be opportunity for wells to induce recharge from the Lamprey.

Statement 71.—At the intersection of the Rockingham-Strafford County line and the Lee-Durham town line is a kame plain located mostly in Newmarket, and described in statement 28.

FARMINGTON

Statement 72.—Ice-contact deposits extend from the western border of the mapped area along the Cocheco River through Farmington and into Rochester. (See pl. 2.) These deposits form kame terraces on both sides of the river and apparently continue beneath the river from one side of the valley to the other. They underlie an area of a few square miles. The saturated thickness of the deposits, which consist predominantly of sand and gravel, is as much as 43 feet in Farmington (Farmington 5) and as much as 96 feet in Rochester (Rochester 9).

An interpretation of the geologic and hydrologic relations in this part of the Cocheco River valley is shown in figure 9.

Where wells penetrate the thicker, saturated part of these deposits, they are expected to yield moderate to large quantities of ground water; for example, the reported yield of Farmington 1 is 315 gpm. The aquifer is situated favorably with respect to inducing recharge from the Cocheco River.

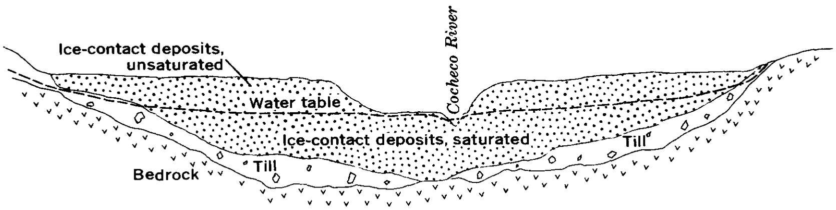

FIGURE 9.—Diagrammatic cross section showing geologic and hydrologic conditions in the Cocheco River valley, Farmington, N.H.

Analyses suggest that the quality of the water is generally satisfactory. The pH value of 6.0 of a sample of water from Farmington 4 has suggested that locally the water may be corrosive; also it may locally be high in iron. In the vicinity of Rochester 6, 9, and 22–24, ground water that is high in iron has been reported. If the wells are located so as to induce recharge from the Cocheco River, the influx of surface water, which is low in iron, may improve the quality of the ground water in this area. The yield that can be sustained from this aquifer by inducing recharge from the river is probably as much as several million gallons per day.

LEE

Statement 73.—In the northwestern corner of Lee, ice-contact deposits underlie a large kame plain extending from the Oyster River on the south to just across the Barrington-Lee town line on the northwest. (See pl. 2.) At some places these deposits consist principally of very fine sand (Lee 27); at others they consist of sand and gravel (Lee 5). (See Bradley and Petersen, 1962, table 4). Test well Lee 5 was drilled only about 10 feet from the Oyster River. This test well, which flowed, penetrated 48 feet of ice-contact deposits. The proximity to the river of so thick a section of permeable materials strongly suggests that a large withdrawal might be sustained from wells inducing recharge from the river.

Statement 74.—Continuous with the ice-contact deposits described in the preceding statement is a body of deposits that form a kame delta on the south side of the Oyster River. On the basis of tests of wells in these deposits (Lee 4, 23, 24, 25, and 26 Bradley and Petersen, 1962, table 2) it was concluded by the U.S. Army Corps of Engineers that a yield of 0.5 mgd could be sustained. Conditions are favorable for inducing recharge from the Oyster River.

Statement 75.—Just west of the north-central part of the Durham-Lee town boundary (W18–7, pl. 2), ice-contact deposits form a fairly large kame terrace. No wells have been drilled on the terrace. Several test holes (Lee 18, 19, 20, and 21) were drilled in the Oyster River valley near the base of the terrace, but the materials penetrated were predominantly fine textured and probably of low permeability.

Statement 76.—Near the center of the town boundary between Durham and Lee a small part of a kame plain extends from Durham into Lee. The deposits forming this kame plain are described in statement 69.

Statement 77.—Ice-contact deposits form a kame plain near the center of Lee at the western border of the mapped area. (See pl. 2.) The positions of nearby outcrops of till and bedrock indicate that the deposits do not extend much beyond the periphery of the kame plain. On the basis of the log of Lee 10 and the water level in an adjacent well, Lee 1, the thickness of permeable materials in these deposits is estimated to be as much as 45 feet. (See Bradley and Petersen, 1962, tables 2 and 4.) The principal source of recharge is precipitation on the outcrop area.

Statement 78.—A small body of ice-contact deposits adjoins the south side of the Lamprey River in north-central W17–1. (See pl. 2.) The deposits appear to be situated favorably with respect to inducing recharge from the river, but have not been explored.

Statement 79.—A few small, isolated bodies of ice-contact deposits, not discussed individually here, are scattered throughout Lee. (See pl. 2.) Some of these deposits may be potential sources of small supplies of ground water.

Statement 80.—At the intersection of the Rockingham-Strafford County line and the Lee-Durham town line is a kame plain, which is mostly in Newmarket; it is described in statement 28.

MADBURY

Statement 81.—A large body of ice-contact deposits underlies the Barbadoes Pond area. (See pls. 2, 6.) The main part of this body, which centers near the pond, forms a fairly large ground-water reservoir. According to the logs of Dover 5 and Madbury 54 (Bradley and Petersen, 1962, table 4), the materials forming the deposits range in texture from very fine sand to gravel. At Dover 5 the deposits are 102 feet thick, and at Madbury 54 they are 190 feet thick. The saturated thickness under natural conditions was probably about 85 feet at Dover 5 and about 130 feet at Madbury 54. Wells near Barbadoes

Pond may induce recharge from the pond; its storage capacity thus supplements that of the ground-water reservoir.

The City of Dover obtains part of its water supply from Dover 5. Water was withdrawn from this well at an average rate of slightly less than 0.5 mgd before 1954 and slightly more than 1 mgd from 1954 to 1956. Reports in the office of the city engineer of Dover suggest that the yield of this well might be increased further. The position of Dover 5 relative to Barbadoes Pond suggests that the well draws some water from the pond, though no trend of pond levels that could be definitely attributed to pumping of the well was observed during this investigation. On the other hand, there has been a more or less steady decline of the water level in Madbury 9 (fig. 8) since April 1955, and this decline may be due to the pumping of Dover 5.

Tabulated below are occasional measurements of the level of Barbadoes Pond during the period November 1954 to February 1958. The table lists approximate (hand-level) altitudes above mean sea level.

Level of Barbadoes Pond

[Altitudes approximate, taken by hand level]

Date	Altitude (feet)	Date	Altitude (feet)
1954		*1956*	
Nov. 10	131.5	Jan. 12	132.6
29	132.0	Apr. 27	133.0
Dec. 16	132.5	June 1	131.9
		29	130.8
1955		Aug. 1	130.5
Jan. 3	132.6	Oct. 8	130.2
Feb. 8	132.9	26	130.0
Apr. 6	132.9	Nov. 30	130.4
22	132.6	Dec. 27	130.9
May 23	131.8		
Aug. 2	131.4	*1957*	
30	131.5	May 7	130.4
Sept. 30	130.4	July 11	129.9
Oct. 31	130.9	Nov. 25	129.1
Nov. 30	131.7	Dec. 13	129.4
		1958	
		Feb. 3	129.1

A chemical analysis (table 4) of water collected from Dover 5 on September 24, 1952 shows 0.5 ppm of iron but later analyses (table 4) show a much lower iron content (0.2 ppm), and officials of the Dover Water Department have indicated no difficulties from excessive iron in the water.

Northwest of Madbury 10 is a small lobe of the Barbadoes Pond deposits. (See pls. 2, 6.) This lobe is separated hydrologically from the main body by a ridge of bedrock, which is exposed at a few places. The deposits of the lobe are 166 feet thick at Dover 36 (pl. 5) and probably have a saturated thickness there of about 145 feet. They extend beneath adjacent marine deposits (Section *E–E′* and *F–F′*, pl. 5) for an unknown distance, and it appears that these deposits form a ground-water reservoir sufficiently thick and extensive to warrant consideration for future development. An iron content of 2.0 ppm in sample of water from Dover 36 suggests that treatment of the ground water to reduce the iron content might be necessary.

Statement 82.—The Pudding Hill deposits, in Dover and Madbury, are described in statement 67.

Statement 83.—Ice-contact deposits form a small kame along Johnson Creek. (See pl. 6.) The exposed area of these deposits is only about one-tenth of a square mile, but they extend beneath marine deposits up the valley of Johnson Creek at least as far as Madbury 6 and 14. In all other directions the subsurface extent of the ice-contact deposits appears to be limited. (See section *J–J′*, pl. 6, and logs of Madbury 51 and 52, table 6.) In 1954 and 1955, four gravel-packed wells (Madbury 11, 12, 13, and 14) were constructed in these deposits to augment the water supply of the city of Portsmouth and the Pease Air Force Base. Between ½ and ¾ million gallons per day were being pumped from the area during the summer of 1957.

Where Johnson Creek flows across part of the kame deposits, the stream and the aquifer are hydraulically connected. Under natural conditions, ground water was discharged to the stream; however, in 1956 and 1957, pumping of the wells in this vicinity lowered ground-water levels sufficiently to reverse the movement of the water and induce infiltration form the stream. As a result, during the summers of 1956 and 1957, Johnson Creek was dry in the reach extending from Madbury 14 and 6 downstream to a point several hundred yards below Madbury 11 and 1.

Ground water in the ice-contact deposits along Johnson Creek is unconfined except where they underlie marine deposits. In Madbury 14 (and formerly in Madbury 6), ground water is under artesian pressure.

Recharge to the Johnson Creek kame deposits is by infiltration of rain and melted snow on the exposed surface of the deposits and by induced infiltration of streamflow from Johnson Creek. The recharge from rainfall and snow is very small because of the limited areal extent of the deposits; during the summer and early fall, therefore, when there is little recharge from precipitation, virtually all the recharge to the deposits is by induced infiltration from Johnson Creek. A few miscellaneous measurements indicate that except, for storm runoff, the flow of Johnson Creek probably is about 1 cfs (cubic feet per second) or slightly less during the summer and early fall. During the warm season, the yield of wells in the Johnson Creek area may be limited to about 660,000 gpd. Bradley (1955; 1957) has discussed ground-water conditions in Johnson Creek in more detail.

The quality of ground water in the Johnson Creek area is shown by an analysis of a sample from Madbury 4 (table 4); the untreated water is satisfactory for all ordinary purposes.

Statement 84.—A body of ice-contact deposits is exposed in a small area about half a mile south of Pudding Hill along the Madbury-Dover town line. To the south and east, these deposits pinch out against a bedrock ridge. To the west they extend for some distance beneath younger unconsolidated deposits which floor a shallow valley. To the north, along the town line, they may be connected by fine-grained materials to the Pudding Hill deposits. (See geologic map and sections *H–H'* and *J–J'*, pl. 6.)

In the shallow valley to the west of their outcrop area, the ice-contact deposits are overlain by about 40 to 75 feet of marine deposits. Here the water in the ice-contact deposits is confined and under greater head than the water in either the Pudding Hill or the Johnson Creek deposits. Replenishment to the buried deposits depends largely on infiltration of rain and snow on the outcrop area to the east. Because the outcrop area is small, recharge also is small.

ROCHESTER

Statement 85.—The Hoppers area at the intersection of Dover, Barrington, and Rochester is discussed in statement 54.

Statement 86.—Ice-contact deposits extending along the Cocheco River from Farmington into Rochester are described in statement 72.

Statement 87.—Along the Cocheco River, in W19–7 (pl. 2), a small body of ice-contact deposits crops out near the garage of the Rochester Department of Public Works, which is about 1 mile south of the Rochester business district. These deposits have an area of about one-tenth of a square mile. They may extend southward some distance beneath adjacent marine deposits. They are as much as 50 feet thick (Rochester 27, Bradley and Petersen, 1962, table 4).

The logs of Rochester 27 and 28 suggest that the aquifer is permeable and should yield water freely. It is situated favorably with respect to inducing recharge from the Cocheco River. Because the aquifer is small, its sustained yield probably will be determined by the low flow of the Cocheco River.

South of Rochester the Cocheco River carries industrial wastes and other contamination; the effect of this contamination on the quality of ground water from deposits adjacent to the river here and elsewhere should be considered prior to development of the aquifer.

Statement 88.—In the northeast corner of W18–1 (pl. 2), near the Cocheco River, ice-contact deposits underlie an area of about half a square mile; they are as much as 90 feet thick (Rochester 21). The log of Rochester 21 suggests that they consist of sand.

No information concerning yields of wells in these deposits or the quality of the ground water is available. The aquifer appears to be isolated from the Cocheco River by overlying marine deposits. The storage capacity of the aquifer is small, but if the aquifer extends beneath the river and if recharge wells were installed so as to pierce the marine deposits, recharge from the Cocheco might be induced. If recharge could be induced from the Cocheco, the sustained yield of the aquifer would then depend upon the low flow of the Cocheco.

Statement 89.—Two small bodies of ice-contact deposits border the Salmon Falls River in the eastern and northern parts of Rochester. One body, which is about half a square mile in area, underlies a kame terrace in the northeastern part of W19–5 (pl. 2); the other, which is about two-thirds of a square mile in area, forms a kame terrace in W19–1. Neither body of deposits has been explored, but they appear to be situated favorably with respect to inducing recharge from the Salmon Falls River.

Statement 90.—From the Salmon Falls River in the northern part of Rochester a large body of outwash and shore deposits extends southward to the Cocheco River valley, thence along both sides of the valley to the southeastern and southwestern boundaries of Rochester, and into Barrington. These deposits consist of fairly well sorted fine and medium sand. They are as much as 25 feet thick (Rochester 18), but their average saturated thickness is probably much less than 25 feet.

This aquifer is expected to yield small quantities of water, enough for domestic or small-scale industrial use, to shallow wells. At places the water is high in iron; for example, an analysis of water from Rochester 10 (table 4) shows 0.37 ppm of iron.

ROLLINSFORD

Statement 91.—A body of ice-contact deposits lies about 1 mile west of the village of Salmon Falls, in the central part of X18–1 (pl. 2). The few available data suggest that these deposits are as much as 40 feet thick and extend beneath adjacent marine deposits (Bradley and Petersen, 1962, tables 2 and 4). An analysis of water from Rollinsford 8 (table 4) shows 43 ppm total hardness and 0.04 ppm iron.

Statement 92.—Another small body of ice-contact deposits lies about six-tenths of a mile northeast of the deposits just described. (See pl. 2) The very small outcrop area in which recharge from precipitation can take place, limits the potential sustained yield of these deposits to small quantities, unless they are hydraulically connected to the

Salmon Falls River beneath adjacent finer grained deposits. The probability of such a connection is small.

Statement 93.—Outwash and shore deposits underlie two fairly large areas in Rollinsford (pl. 2). One of these areas extends from the central part of Rollinsford northward into Somersworth. It underlies the southern and western part of the village of Salmon Falls. At places the deposits are relatively thick; for example, in Rollinsford 9 there is 49 feet of sand of which more than 30 feet is saturated. In most of this area, satisfactory domestic water supplies can be obtained from dug or driven wells, and probably at some places enough water can be obtained for small-scale industrial use.

Statement 94.—The second area of outwash and shore deposits is located between the mouths of the Cocheco and Salmon Falls Rivers in Rollinsford and Dover. There are no data for this body of deposits. (See statement 60).

Statement 95.—The community of Salmon Falls, which is part of Rollinsford, obtains its public water supply from three bedrock wells (Rollinsford 2, 3, and 4, pl. 2). The yields of these wells are not large; in 1956 the average daily consumption for Salmon Falls was 28,569 gallons.

SOMERSWORTH

Statement 96.—A large kame plain underlies much of Somersworth and extends into Dover and Rollinsford on the south and Rochester on the north. (See pl. 7.) At the northern end of the kame plain the saturated thickness of the ice-contact deposits is 50 feet or more. (See sections *A–A′* and *B–B′*, pl. 7.) Well logs show that at the southern end the saturated thickness is as much as 75 feet. (See Dover 6, 25, and 80, Bradley and Petersen, 1962, table 4.) The deposits are thin in the east-central part of the kame plain (section *C–C′*, pl. 7), in the area northwest of Willand Pond (Somersworth 6 and 7), and possibly elsewhere. At places, as at Somersworth 13 (section *C–C′*, pl. 7), the ice-contact deposits extend beneath adjacent marine deposits.

The town of Somersworth has a well field at the northern end of the kame plain. Sections *A–A′* and *B–B′*, plate 7, show the subsurface relationships of the deposits there. In 1956 the average daily use of water for municipal supply in Somersworth was 550,528 gallons, all of which was pumped from Somersworth 1 and 2. The quality of the water is excellent. (See Somersworth 1, table 4.) The pH of the water, which was 6.1 on October 3, 1956, and 6.5 on May 12, 1954, is raised by the addition of lime.

The Somersworth wells may induce a small amount of recharge from the Salmon Falls River or from Lily Pond, but the surficial geology and the well data indicate that bedrock barriers or a combination of bedrock and marine deposits prevent a large-scale or effective interconnection. Probably the present withdrawal approaches the sustained yield of the well field as it now is constituted.

The city of Dover has three wells in the Willand Pond area, which is at the southern end of the Somersworth kame plain (pl. 5). Dover 6, which yields about 700,000 gpd, is pumped at a rate of about 650 gpm. Dover 31, which is used intermittently when Dover 6 is not used, is pumped at a rate of about 625 gpm, and Dover 25 is pumped continuously at about 235 gpm. Several decades ago Dover obtained most of its water from Hussey Springs (Rollinsford sp 1) about one-fourth of a mile southeast of Willand Pond. These springs flow at about 500 gpm. In the Willand Pond area, the ground water in the ice-contact deposits is hydraulically interconnected with the water in Willand Pond, and the storage capacity of the pond may, therefore, supplement that of the ground-water reservoir.

The quality of the ground water from the wells in the Willand Pond area is good, except for excessive quantities of iron reported in the water from heavily-pumped wells. (See Dover 6, table 4.) The high iron content of water from Hussey Springs probably was one of the principal causes for its abandonment as a public-supply source.

The ice-contact deposits of the Somersworth kame plain form a very large ground-water reservoir whose recharge area, which coincides with the area of the kame plain, is large also. The composition of the deposits, as shown by logs of wells and test holes, and the large yields of the Dover and Somersworth municipal wells suggest that the deposits are, in general, relatively permeable, but the well data show that the saturated thickness of the deposits differs greatly from place to place. The basic factor limiting the ultimate development of the reservoir is probably the extent to which the distribution of the thicker saturated materials will permit wells to be dispersed and the draft on storage to be thus spread across the area of the reservoir. As noted in the first paragraph of this statement, the deposits in part of the east-central section of the kame plain and northwest of Willand Pond are known to be thin; however, much of the kame plain remains to be explored.

Statement 97.—A small kame terrace borders the Salmon Falls River in the southeastern part of Somersworth (X19–7 and X18–1, pls. 2 and 7). Subsurface data are lacking, but the kame-terrace deposits which extend below stream level, probably are hydraulically connected to the river. Because this body of deposits is too small to store much ground water, the yield of wells would be limited by the flow of the river. It is likely that the quality and temperature of the river water would be reflected in the quality of ground water pumped from this area.

PRINCIPAL CONCLUSIONS

1. Ground water is generally available throughout southeastern New Hampshire. Small but usually reliable supplies of water, commonly enough for household and rural use, may be obtained from the bedrock at most places. Enough water for small-scale industrial use and perhaps for small public supplies is obtained at some places from outwash and shore deposits. Large supplies, enough for municipal use and large-scale industrial use, are obtained from the ice-contact deposits.

2. The ice-contact deposits form numerous aquifers whose potentialities differ greatly and therefore require individual study. Some of the aquifers are recharged solely by direct precipitation, and the availability of ground water from them is therefore limited. Others are situated favorably with respect to inducing recharge from nearby streams, ponds, or lakes, and the availability of ground water commonly is determined partly by the flow of the stream or the size of the pond or lake.

3. The substantial interdependence of ground water and surface water at many places in southeastern New Hampshire complicates development. Diversions of water upstream from a well field may reduce the supply of water available at the field; likewise, withdrawals at the field may so deplete the streamflow that water users downstream may be affected adversely. The quality of the ground water may be affected by the quality of the surface water; for example, where ground water is high in iron, induced recharge from a stream that is low in iron may improve the quality of the water pumped from the wells. On the other hand, where wells are situated near a polluted stream or the sea, care must be taken to avoid drawing in contaminated or salt water.

4. In general the ground water in southeastern New Hampshire is of good chemical quality and suitable for most uses. The hardness of the water sampled and analyzed ranges from 9 to 139 ppm and the dissolved solids content ranges from 36 to 191 ppm, but some of the water is corrosive and objectionable amounts of iron are fairly common.

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