GROUND-WATER RESOURCES IN NEW HAMPSHIRE: STRATIFIED-DRIFT AQUIFERS

U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS REPORT 95-4100

Prepared in cooperation with
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES,
WATER RESOURCES DIVISION

Moat Mountain viewed from North Conway, New Hampshire. Foreground of painting shows sand deposit and flat stratified-drift outwash deposit of the Saco River Valley, now known to be underlain by up to 100 feet of layered sand and gravel. Albert Bierstadt painting reprinted with permission from the Currier Gallery of Art, Manchester, New Hampshire: Currier Funds, 1947.3.

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By Laura Medalie and Richard Bridge Moore

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Bow, New Hampshire
1995

U.S. DEPARTMENT OF THE INTERIOR
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Foreword

New Hampshire's scenic landscape, from the peaks of the White Mountains to the sands of its beaches, was formed as a result of geologic processes over hundreds of millions of years. In relatively recent geologic history, advancing glaciers rounded the domes of the mountain summits, carved deep ravines, such as the famous Tuckerman Ravine on Mount Washington, and scoured the broad valleys common in the southern sections of the "Notches"—Crawford, Franconia, Evans, Pinkham, and Zealand. A testament to the tremendous scouring power of the glaciers is the widespread sand and gravel deposits in the valleys, where fragments of bedrock were transported and dropped by glacial meltwater. Today, these deposits, known as stratified drift, form major aquifer systems, holding one of New Hampshire's most valuable resources—ground water.

Assisting States in evaluating their water resources is a major part of the mission of the U.S. Geological Survey (USGS). A program of cooperative water-resources data collection between the State of New Hampshire and the USGS was instituted in 1903 to measure streamflows in the White Mountains. Today, the cooperative program encompasses a broad range of data collection and investigative studies involving the State's surface- and ground-water resources.

In 1983, the New Hampshire Legislature enacted Chapters 361 and 402 of the State Statutes, which authorized development of the New Hampshire Water Resources Management Plan and an intensive assessment of the State's ground-water resources. Following development of the Plan, in 1985 Governor John Sununu signed Chapter 77, which provided $2 million to fund the State's share of a 10-year-long ground-water-assessment program to be performed by the USGS in cooperation with the New Hampshire Department of Environmental Services (NHDES). The goals of this program were to (1) determine the extent and hydrologic characteristics of stratified-drift aquifers, (2) assess potential water-yielding capabilities of selected aquifers, and (3) define general quality of water in the major aquifers. After extensive data collection and analysis, results of these investigations are being published in a series of technical reports for the 13 study areas that cover the entire State. Each report includes a set of map plates showing aquifer locations and important aquifer characteristics in addition to written text. These technical reports are directed primarily toward planners, engineers, and scientists who are engaged in ground-water-resources development and management.

Reliable and comprehensive information about aquifers benefits all citizens by contributing towards informed decisions concerning water resources. By increasing knowledge and awareness about New Hampshire's ground-water resources, we seek to encourage and support their responsible use and management.

Robert M. Hirsch, Chief Hydrologist
United States Geological Survey

Robert W. Varney, Commissioner
New Hampshire Department of Environmental Services

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CONVERSION FACTORS AND ABBREVIATIONS

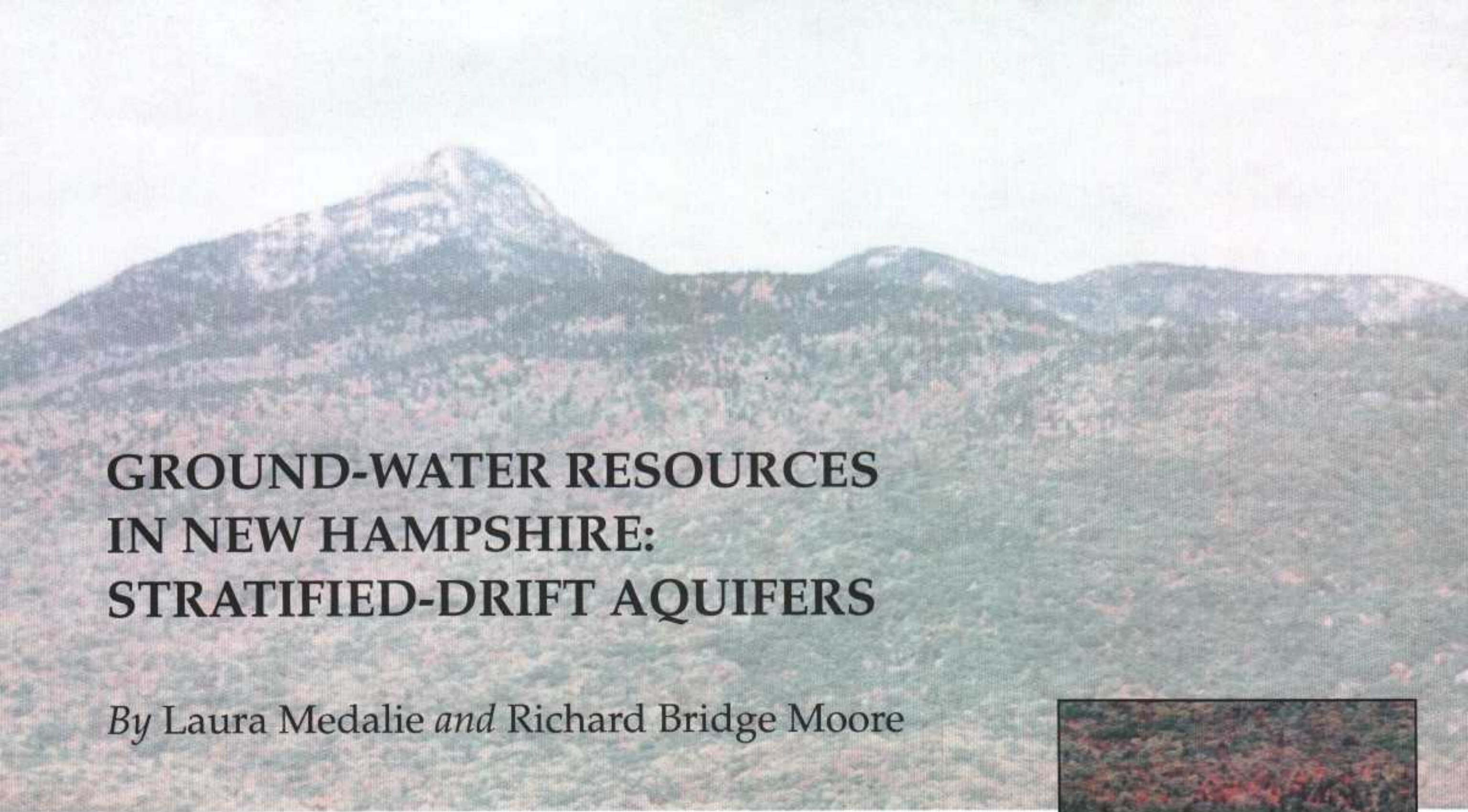
Multiply	By	To Obtain
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per second (ft/s)	0.3048	meter per second
foot squared per day (ft^2/d)	0.0929	square meter per day
gallon per day (gal/d)	0.003785	cubic meter per day
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second

ABBREVIATED WATER-QUALITY UNITS USED IN REPORT

In this report, the concentration of a chemical in water is expressed in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; 1,000 µg/L is equivalent to 1 mg/L.

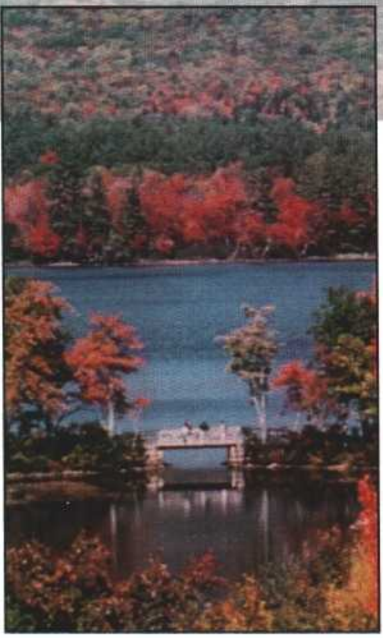
ABBREVIATIONS

NHDES	New Hampshire Department of Environmental Services
NRCS	U.S. Department of Agriculture, Natural Resources Conservation Service
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey



GROUND-WATER RESOURCES IN NEW HAMPSHIRE: STRATIFIED-DRIFT AQUIFERS

By Laura Medalie *and* Richard Bridge Moore



INTRODUCTION

Stratified-drift aquifers underlie about 14 percent of the land surface in New Hampshire and are an important source of ground water for commercial, industrial, domestic, and public-water supplies in the State.

This report introduces terms and concepts relevant to ground-water resources, summarizes some of the important information derived from a statewide stratified-drift-aquifer investigation, and provides examples of how the findings are used. The purpose of this report is to provide an overview of the stratified-drift aquifer assessment program, thus making summary information accessible to a broad audience, including legislators, State and local officials, and the public.

Different audiences will use the report in different ways. To accommodate the varied audiences, some data are summarized statewide, some are presented by major river basin, and some are provided by town. During data collection, care was taken to use consistent methods for each of the 13 study areas (fig. 1) so that results would be comparable throughout the State. If more specific or detailed information about a particular area of interest is needed, the reader is directed to one or more of the technical reports listed in the Selected References section of this report.

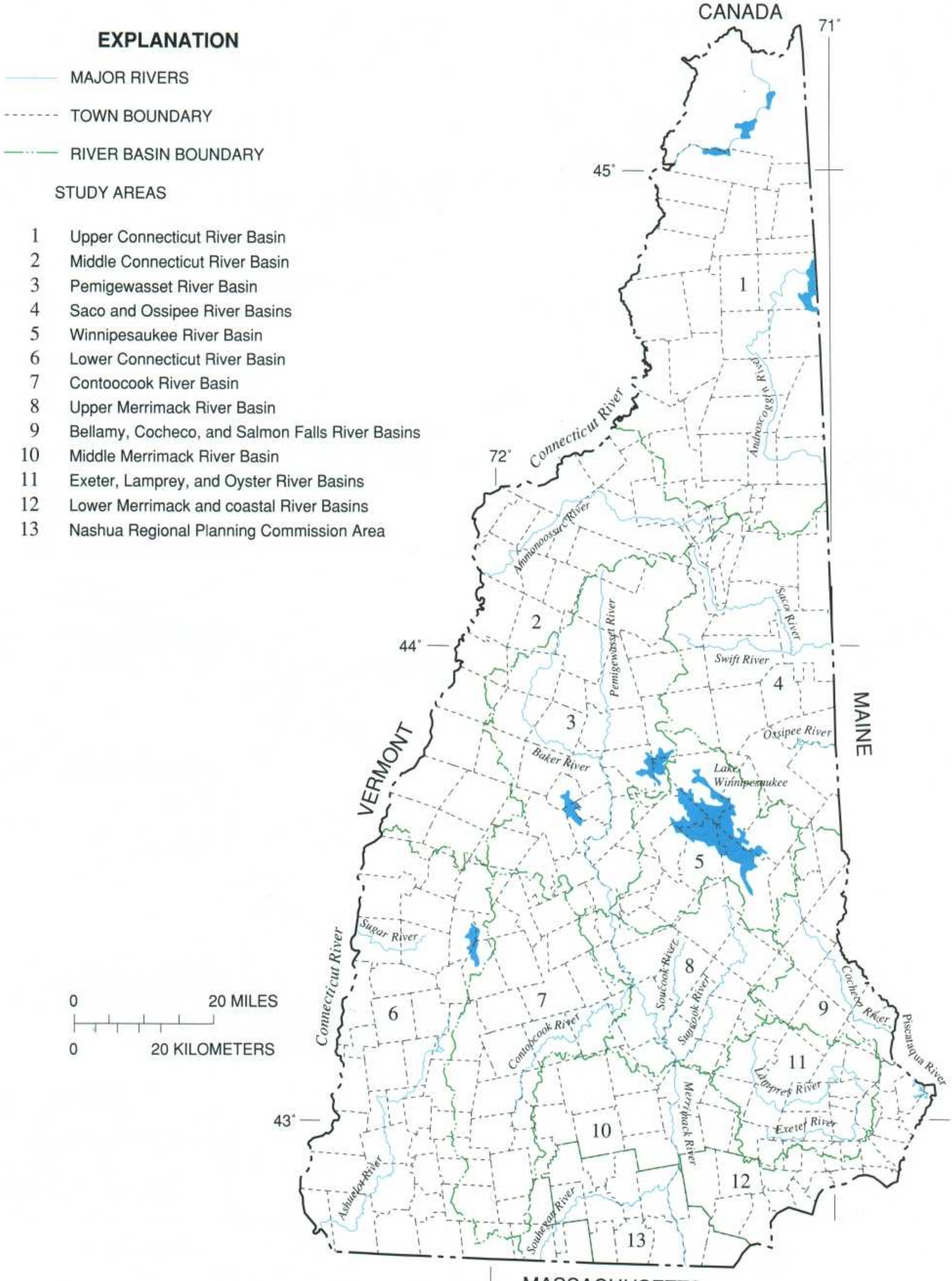


Figure 1. Study areas, major rivers, and town boundaries for U.S. Geological Survey stratified-drift-aquifer investigations in New Hampshire.

GROUND WATER IN THE HYDROLOGIC CYCLE

An illustration of the hydrologic cycle (fig. 2) shows how ground water relates to other components and processes in the natural environment. Discussion of the hydrologic cycle usually begins with precipitation, which occurs primarily as rain and snow. Some precipitation evaporates from leaf, soil, or other intercepting surfaces before even reaching the ground. Depending on soil characteristics, such as **porosity**[1], **permeability**, and degree of **saturation**, precipitation either infiltrates the ground or flows along the top of the ground as surface **runoff** before reaching streams or lakes. Some of the precipitation that infiltrates the ground is retained in the root zone, where it is used by plants and subsequently lost from leaf surfaces through transpiration. The rest of the infiltrating water continues to flow downwards under the force of gravity and **recharges** ground water.

Eventually, a depth is reached below which all spaces between **unconsolidated** particles in sediment are filled, or saturated with water; this water is called **ground water**. The top of this saturated zone is known as the **water table**. If the saturated, subsurface zone is capable of yielding a significant volume of ground water through wells or springs, that zone is commonly referred to as an **aquifer**. Ground water in an aquifer continues to flow downward and laterally, until it reaches surface water and **discharges** into a swamp, stream, lake (fig. 3), or ocean. Water evaporates from the **surface water** body to form clouds, thus completing the hydrologic cycle.

[1] Words in bold type are defined in sidebars.

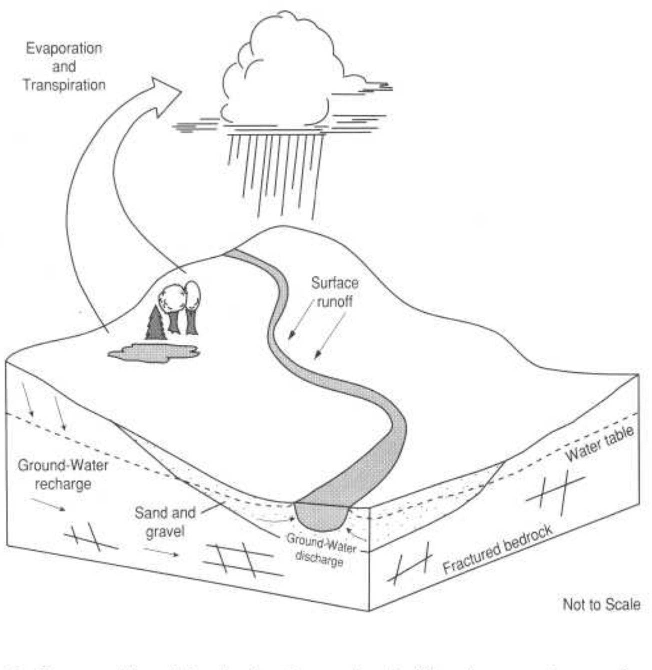


Figure 2. Generalized hydrologic cycle. Infiltrating water recharges ground water, which eventually discharges into streams and other surface-water bodies. Arrows show flow of water. (Modified from Waller, 1989.)

Withdrawal of ground water from wells interrupts this natural cycle and alters ground-water-flow patterns. The well becomes a discharge point, intercepting ground water that, if not pumped, would have discharged elsewhere. If pumping from a well causes surface water to infiltrate the ground and recharge the aquifer at a greater rate than if no water were being pumped, the aquifer is said to be recharged by **induced infiltration**.

The natural hydrologic cycle is also disrupted when large tracts of land are paved or otherwise made impervious, which can lead to a decrease in the quantity of ground-water recharge. In these areas, precipitation either runs off the land surface to nearby streams or evaporates directly from the paved ground, and, therefore, is diverted from the infiltration and ground-water recharge phase of the cycle.

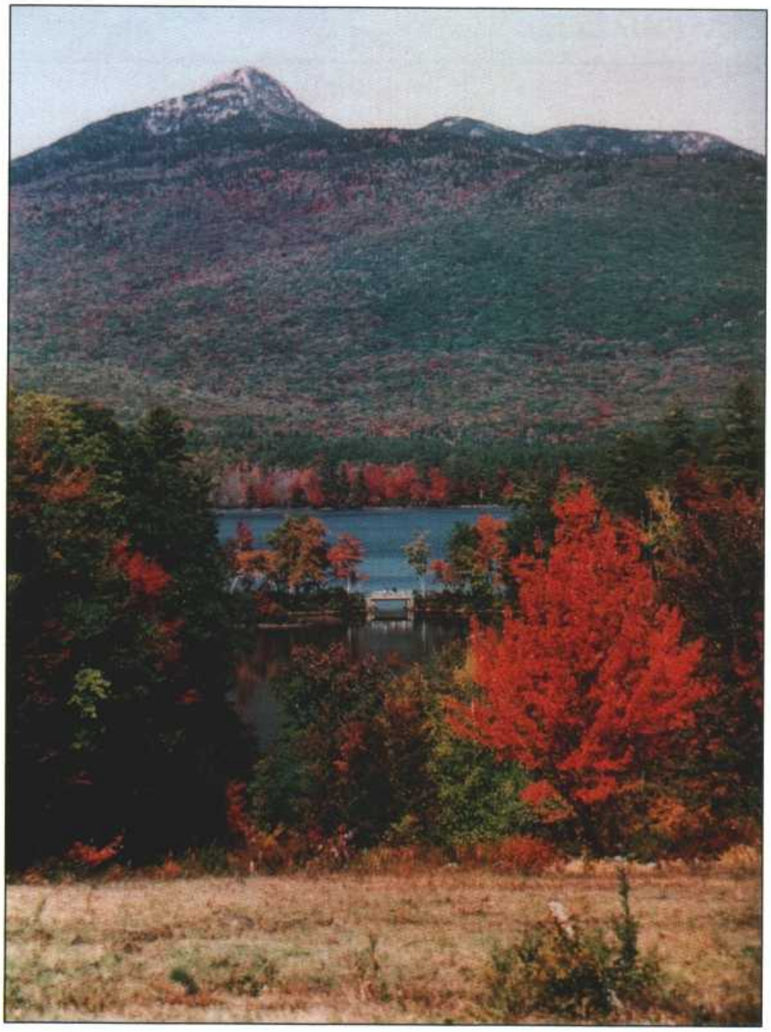


Figure 3. Chocorua Lake in Tamworth viewed from the south, east-central New Hampshire, a surface-water body fed primarily by ground-water discharge. (Photograph taken by B.R. Mrazik, U.S. Geological Survey.)

The ground-water discharge phase of the hydrologic cycle performs an important function by contributing to the maintenance of streamflow volumes. Streamflow is composed of **base flow** and **stormflow**. Compared to stormflow, base flow is less susceptible to large fluctuations over time. For selected segments of streams throughout the State, USGS hydrologists make measurements to determine the volumes contributed by base flow and stormflow. With this information, the minimum flow of the stream during periods of little or no precipitation (drought) can be calculated. Planners use this information to make assessments as to the availability of water for water supply, recreation, fish habitats, and other instream and off-stream uses of water.

Aquifer - *A geologic unit or formation that contains a usable supply of water*

Base flow - *the part of a stream's total flow that is sustained by ground-water discharge into the stream*

Ground water - *subsurface water below the water table in soils and geologic formations that are fully saturated*

Ground-water discharge - *ground water that emerges at the land surface, either into surface water or in the form of springs or seepage areas*

Ground-water recharge - *replenishment of water to aquifers, usually where a layer of permeable material is close to the land surface*

Induced infiltration - *the entry of water from a stream or lake into an adjacent aquifer as a consequence of pumping water from a well completed in the aquifer*

Permeability - *interconnectedness of pore spaces; permeability provides a measure of the relative ease of fluid flow*

Porosity - *the ratio of the total volume of pore space to the total volume of sediment*

Runoff - *water from precipitation that flows downhill along the top of the ground surface before it either infiltrates the soil or flows into a stream or lake*

Saturation - *wetness of the soil*

Stormflow - *that part of streamflow fed by precipitation and surface runoff*

Surface water - *water flowing or stored on the earth's surface, such as in streams, lakes, or swamps*

Unconsolidated - *refers to a deposit in which the particles are not firmly cemented together, such as sand in contrast to sandstone*

Water table - *the top of the zone in which all pore spaces or fractures are saturated with water*

GROUND-WATER USE IN NEW HAMPSHIRE

Ground water is a major source of water for households, industries, and commercial enterprises in New Hampshire. In 1990, ground-water withdrawals totalled about 63 Mgal/d and accounted for about 38 percent (surface water accounted for about 62 percent) of total water withdrawals, excluding water used for cooling at thermoelectric powerplants (Medalie and Horn, 1994). About 415,000 people (or 38 percent of the State's population) pump ground water from their own wells because their homes are not connected to a public-supply system. Throughout the State, ground water withdrawn by public suppliers is delivered to domestic customers; industries; and commercial enterprises including hotels, restaurants, office buildings, hospitals, and schools. Ground water is also withdrawn from private wells for many uses (fig. 4).

Approximately 3,000 individual wells or springs are registered with the NHDES Water Supply Engineering Bureau as active sources of ground water for public supply (Rene Pelletier, New Hampshire Department of Environmental Services, written commun., 1993). Of these sources, about 2,400 are wells drilled in bedrock and about 600 are in stratified-drift aquifers (fig. 5). Although there are fewer public-supply wells in stratified-drift aquifers than in bedrock, wells in stratified-drift aquifers are usually more productive and yield a higher quantity of water than wells in bedrock aquifers. The NHDES, Water Resources Division, maintains a data base of all registered water users that withdraw an average of more than 20,000 gal/d over any 7-day period (fig. 6). Of the registered public suppliers, the sum of withdrawals from bedrock wells averages less than 2 Mgal/d, whereas the sum of withdrawals from stratified-drift aquifers averages around 18 Mgal/d (Frederick H. Chormann, Jr., New Hampshire Department of Environmental Services, written commun., 1993).

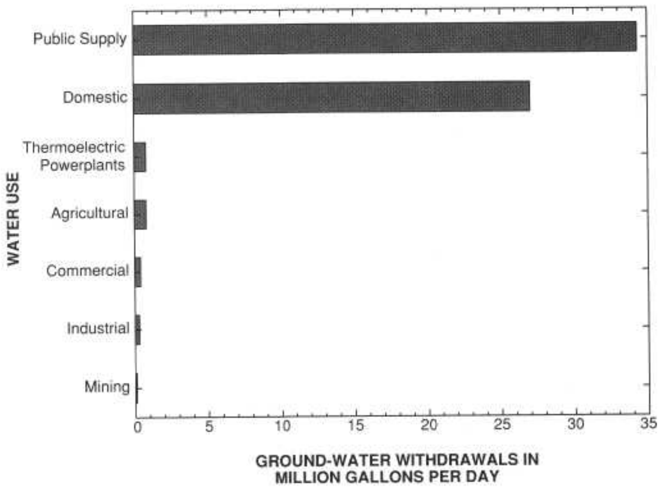


Figure 4. Ground-water withdrawals in New Hampshire by category in 1990. Bars shown above for domestic, thermoelectric powerplants, agricultural, commercial, industrial, and mining water uses represent the proportion for those categories that are self supplied—*not* from a public supplier.

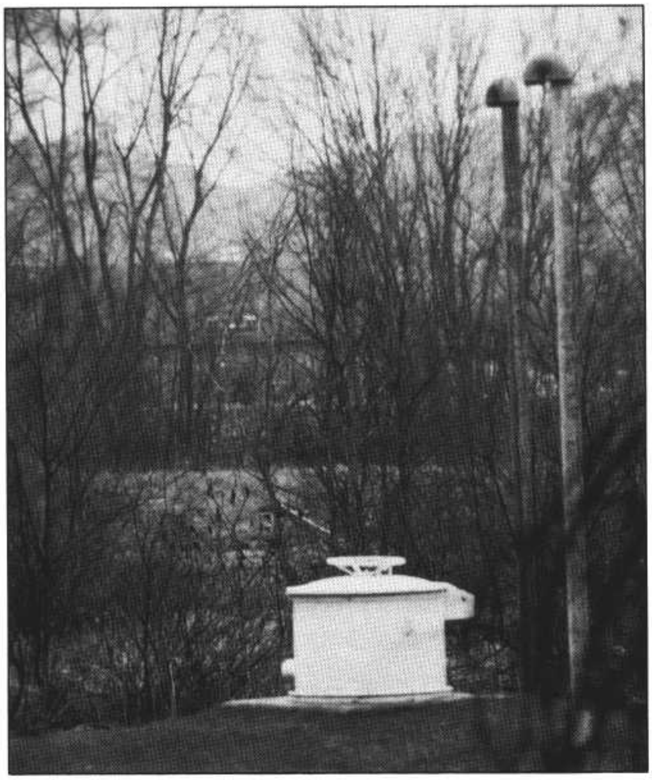


Figure 5. Gravel-packed public-supply well in stratified-drift aquifer in the town of Plymouth, central New Hampshire. (Photograph taken by B.R. Mrazik, U.S. Geological Survey.)

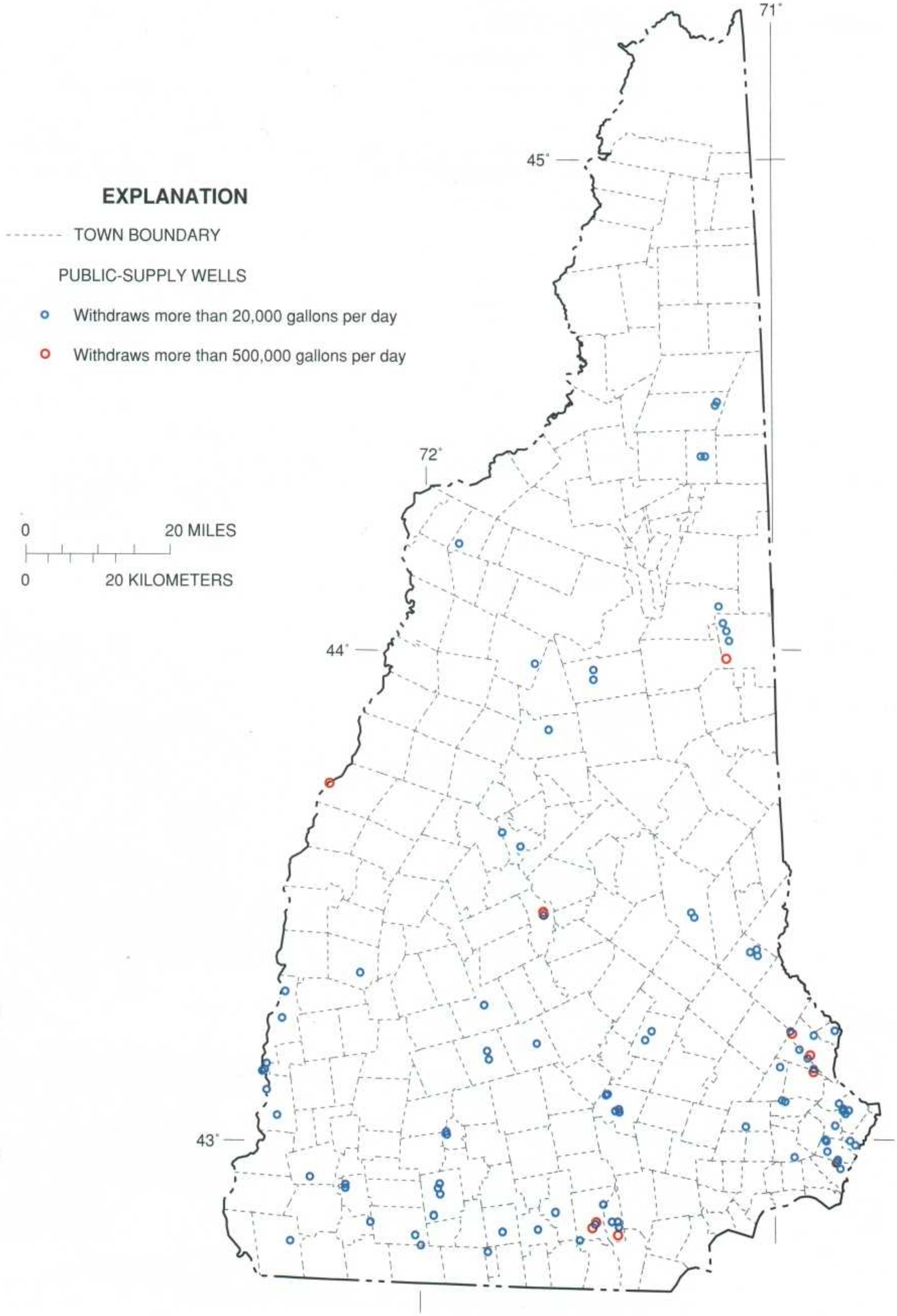


Figure 6. Locations of high-capacity public-supply wells from which more than 20,000 or more than 500,000 gallons of water per day are withdrawn from stratified-drift aquifers in New Hampshire.

GLACIERS AND STRATIFIED-DRIFT DEPOSITS IN THE NEW HAMPSHIRE LANDSCAPE

During The Great Ice Age or Pleistocene Epoch, the landscape of New Hampshire was significantly shaped and carved when thick glacial ice alternately advanced southward, covered the State, and retreated northward by melting. Before the Ice Age, the climate was warm, soils were deep, and the valleys were cut by stream erosion—conditions similar to those in the southern United States today. Starting about 2 million years ago, the climate cooled and continental glaciers formed. Over time, snow in northern Canada accumulated, was compacted by its own weight into glacial ice, advanced southward, and eventually covered New Hampshire with ice as much as a mile thick. As the glacier moved, it picked up loose rock and soil and plucked huge pieces of bedrock along its way. This ice and debris mixture scoured the landscape, streamlined hills, and transformed the stream-eroded valleys into glacially eroded "U"-shaped valleys with rounded valley walls (fig. 7).

Glaciers left two major types of deposits: till and stratified drift. Till consists of unsorted sediments deposited in place directly by melting ice. Sediment sizes generally range from very small to very large—from clays to boulders. Because glaciers covered New Hampshire, till was deposited throughout the State. In today's landscape, till is commonly seen at or near the ground surface in upland areas but it is also found buried beneath other unconsolidated deposits in valleys.

Figure 7. South-facing view of Crawford Notch from Mount Willard in Hart's Location, the heart of the White Mountains in north-central New Hampshire. Twenty-thousand years ago, the broad valley was filled with glacial ice and debris. Now, a glacially scoured U-shaped valley remains. [Sketch reproduced with permission from the New Hampshire Historical Society. (#F 128)]

The other major type of glacial deposit, stratified drift, began to form during late stages of the Great Ice Age, about 14,000 years ago. At that time, the southernmost extent of the most recent continental glacier had melted back, or retreated, from positions on Long Island, New York, to positions in New Hampshire. Throughout New Hampshire and the rest of New England, this glacial retreat is believed to have progressed in a stepwise fashion, with minor local readvances. How this melting occurred affected the location, size, and characteristics of the unconsolidated, stratified-drift deposits that are found today.

Many familiar landscape features composed of stratified-drift deposits were formed during the retreat of the glacier. Eskers, kame terraces, outwash plains, and deltas are good examples of this glacial deposition (fig. 8). Eskers are long sinuous ridges of sand and gravel deposited either in meltwater channels or streams within the glacier or at the ice margin, where the glacier retreated steadily in contact with a glacial lake. As they formed, esker deposits were surrounded by the glacier; when the surrounding ice melted, the esker deposit remained (fig. 9). Kame terraces are terrace-like ridges consisting of sand and gravel deposited by glacial meltwater that flowed between the melting glacial ice and a high valley wall. The kame terraces were left standing after the disappearance of the ice. Outwash plains are gently sloping plains composed chiefly of sand and gravel that was "washed out" from the glacier by meltwater streams. Deltas formed where meltwater streams flowed into a glacial lake or the ocean, in much the same way that present-day rivers form fan-shaped deltas at their mouths (fig. 10). Some glacial deltas formed where glacial ice extended into open water; other deltas formed at some distance from the retreating glacial ice where meltwater streams flowed

Carl Koteff, a geologist with the U.S. Geological Survey, in 1974 introduced the "dirt machine" concept to account for the enormous quantities of sand, gravel, silt, and clay found in valleys throughout New England. According to this analogy, moving ice is continually sheared up onto the stagnant end section of ice, depositing loose debris that the ice had carried which becomes available for transport by meltwater. This process of deposition keeps repeating itself, like a conveyor belt in a manufacturing plant that continually provides raw material to an assembly station.

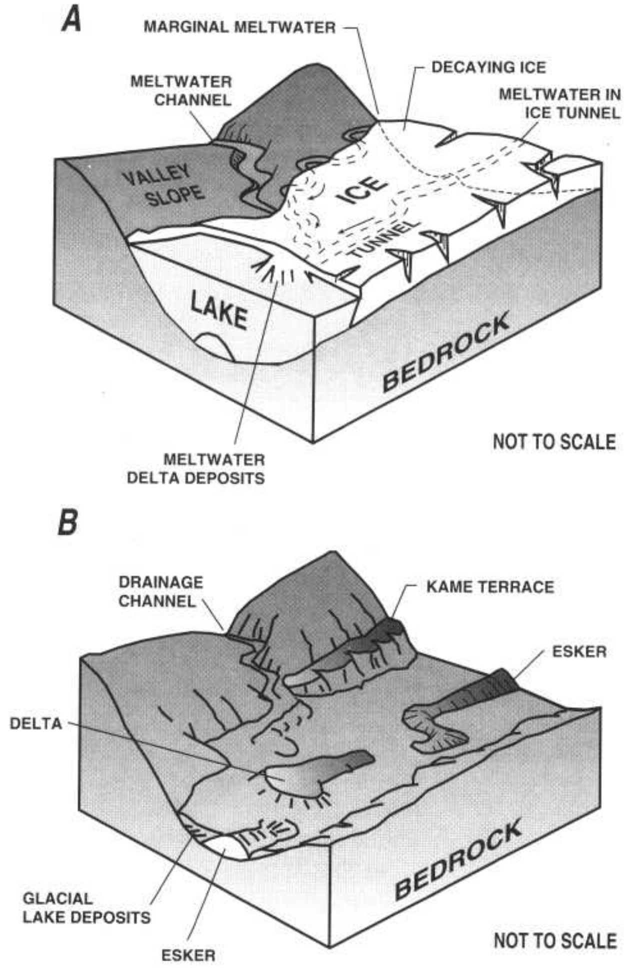


Figure 8. Depositional processes and features of typical stratified-drift deposits in New Hampshire. (*A*) Meltwater has formed a channel beneath the ice along the valley floor. A glacial lake has formed in low-lying areas fed by glacial streams. A delta has formed where the sediment-laden glacial stream flows into the still water of the lake. (*B*) Ice is completely melted, leaving various deposits of glacial origin: an esker, a kame terrace, a delta, and lake deposits. (Modified from Chapman, 1974, figs. 8 and 9.)

Figure 9. Aerial photograph taken in the 1940's of the Pine River Esker in Ossipee, east-central New Hampshire. Sand and gravel from this esker was used to build the road seen next to the esker in the photograph. Since the photograph was taken, much of the Pine River Esker has been mined for large construction projects. (From Goldthwait and others, 1951, fig. 20.)

into open water. Also, some deltas were formed soon after retreat of the glaciers by transport and redeposition of materials eroded from the initially barren land surface. In the modern-day landscape, stratified-drift deposits are found primarily in relatively flat or hummocky low-lying areas in stream valleys or near coastal lowlands.

Glacial lakes that ponded in front of the melting ice margin played an important role in the formation of stratified-drift aquifers in New Hampshire. These lakes, which were natural sediment traps, formed in many areas throughout the State during deglaciation, or glacial retreat. The formation of glacial lakes was enhanced where the underlying bedrock surface had been deeply scoured during multiple glaciations. Erosion of the bedrock by the glacier was extensive where the bedrock was already weak or fractured.

The largest of the glacial lakes, called glacial Lake Hitchcock, formed in the present-day Connecticut River Valley. Here, sediment carried by meltwater streams from the uplands accumulated in a long narrow lake that eventually extended 550 mi from central Connecticut to northern New Hampshire and Vermont. The deepest part of this lake was at least 560 ft deep before the deposition of more than 430 ft of layered sediments. A series of small glacial lakes formed along the Merrimack and Pemigewasset River Valley as the glacier retreated northward. Each lake was slightly higher in elevation than the lake to the south and was dammed by sediments that accumulated locally across the valley. Other glacial lakes formed in the Contoocook, Saco, Ossipee, Connecticut, and Androscoggin River Basins (fig. 1). Of these, the lake in the Ossipee area was the deepest; it was greater than 300 ft deep in the center and eventually was filled with more than 280 ft of stratified (layered) glacial deposits.

In the mid-1800s, bricks made from clay (that originated from a glacial lake) in Hooksett were floated down the Merrimack River to Manchester to build "the largest set of textile mills in the world." Similarly, bricks made from Bedford clay deposits were floated through the canal system down the Merrimack River to build mills in Lowell, Massachusetts. Brickmaking was also extensive in Dover, Rochester, Exeter, Epping, and in towns along the Connecticut River.

"Good fences make good neighbors", a line from Robert's Frost poem The Mending Wall (1981), symbolizes a practical use for ubiquitous stony soils, such as those found in New Hampshire. Cobbles and boulders, common in glacial till and ice-contact deposits, are a fact of life for New Hampshire residents.

Figure 10. Delta deposits in Newmarket, southeastern New Hampshire. Ice-marginal deltas, such as this one, formed where sediment carried by the meltwater streams was deposited into the ocean at the edge of the glacier. The flat and sandy land surface shown here is typical of deltaic deposits. The angled layers were deposited as the stream unloaded sediments in gradual increments over time. (Photograph taken by R.B. Moore, U.S. Geological Survey.)

Present-day stratified-drift lake deposits typically are distinguishable by their flat topography and fine-grained sand, silt, or clay composition. Glacial-lake deposits, such as those found in the Connecticut River Valley, can provide high-quality cropland because the fine-grained soils retain water for crops in contrast to sandy soils from which water drains more easily and is lost to plants.

A 1921 student at the Amos Tuck School of Administration and Finance recognized that most of New Hampshire's demographic and geographical development was related to glacial processes and the resulting landscape. The student's analysis related everything from the location of settlements, roads, railroads, and canals; the growth of forests and related industries; and the development of agriculture, water power, manufacturing, and tourism to the most recent glacial episode.

Some glacial lakes formed where the natural drainage to the north was obstructed by the margin of the melting glacier. As the glacier retreated northward, lower drainage outlets were exposed, causing a sudden draining of these ice-dammed glacial lakes and a redeposition of glacial-lake sediments (Moore, 1993). The large volumes of sediment-laden meltwaters that were released sometimes carved deep channels in till and bedrock that became exposed below the new outlets.

The erosive energy of meltwater was so great that in places the underlying rock was smoothed and sculptured into interesting and unusual forms. Evidence of former meltwater channels can be observed in such places as the Sculptured Rocks Natural Area in Hebron, the Lost River Gorge, Kinsman Notch in Woodstock, and Pulpit Rock in Bedford.

Construction sand and gravel deposited by glacial meltwater was valued at $20.7 million in New Hampshire in 1993. The sand and gravel industry employed an average of 252 workers in the State according to the U.S. Bureau of Mines.

Erosion and redistribution of glacial deposits by stream processes after the glacial age has significantly reshaped New Hampshire's landscape. Postglacial (after the glacial period) erosion by rivers and tributaries has formed erosional channels. Deposition of materials has formed alluvial fans at the base of mountains and has formed stream terraces, flood plains, and deltas in all the major valleys. Eolian deposits were formed by wind erosion of largely unvegetated glacial deposits and redeposition. Wind-borne materials were redeposited as either a layer of very fine sand and silt up to 2-feet thick over much of the stratified drift in New Hampshire or as thick dune deposits typically found on the eastern flanks of expansive glacial-lake deposits.

STRATIFIED-DRIFT AQUIFERS

Stratified-drift aquifers consist mainly of layers of sand and gravel, parts of which are saturated and can yield water to wells or springs. The distribution and hydraulic characteristics of stratified-drift aquifers are related to the original environment in which the sediments were deposited. A variety of "depositional environments" are represented by the stratified-drift deposits found statewide including eskers, kame terraces, deltas, and glacial-lake deposits.

Most sand and gravel found in New Hampshire was deposited by water from melting glaciers. Each distinct layer in sand and gravel deposits was caused by a distinct depositional environment and distinguished by different grain-size distributions (fig. 11). Characteristics of the meltwater flow, such as the speed and the turbulence of the current, determined the size of the particles that were transported and deposited. For example, swiftly moving sections of meltwater streams could carry coarse-grained materials. As the slope of the streambed decreased farther away from the source, streamflow velocity decreased and the coarse materials were dropped. These coarse-grained deposits have large pore spaces and, if saturated, generally form high-yielding aquifers. Fine-grained materials, including very fine sands, silts, and clays, were deposited by slow flowing sections of streams and in stagnant water bodies such as lakes and ponds. These deposits do not transmit water freely because pore spaces are minute and the interconnections between pore spaces are small.

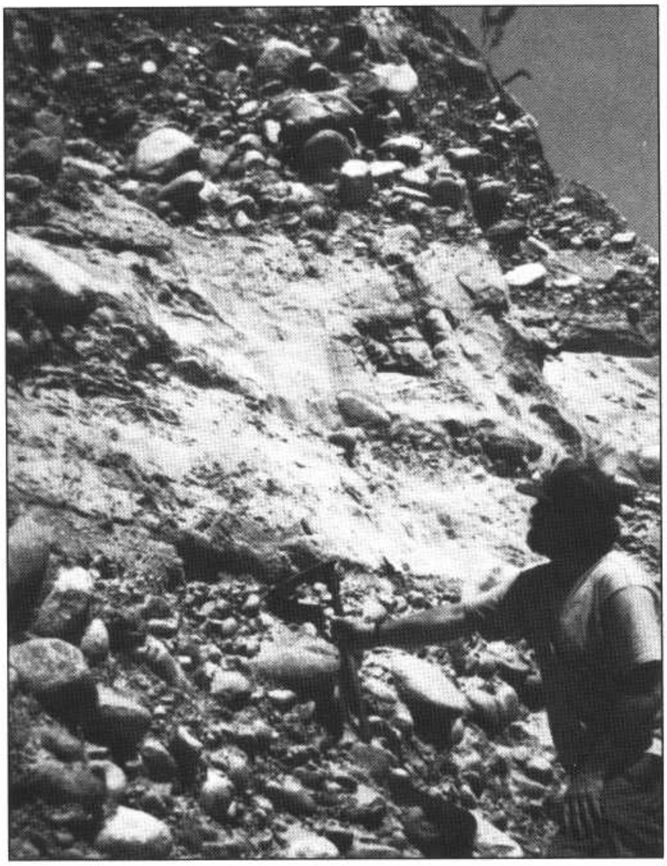


Figure 11. Well-sorted sand layers sandwiched between boulder and cobble layers at a site in Francestown, south-central New Hampshire. (Photograph taken by J.D. Ayotte, U.S. Geological Survey.)

Stratified drift *- sorted and layered unconsolidated material deposited in meltwater streams flowing from glaciers or settled from suspension in quiet-water bodies fed by meltwater streams*

Bedrock, which universally underlies the unconsolidated deposits at or near the land surface, contains water-filled fractures of varying size, number, and extent that constitute the bedrock aquifer. Because not all towns include areas of stratified-drift aquifer within their borders, the bedrock aquifer represents the only potentially significant source of ground water for some towns. The U.S. Geological Survey is presently (1995) involved in a cooperative program with the New Hampshire Department of Environmental Services to map high-yield zones in the bedrock aquifer throughout the State. When completed, this effort will complement the results of the stratified-drift-aquifer investigations presented here and enhance the statewide picture of ground-water availability.

Types of stratified-drift aquifers found in New Hampshire include: eskers, kame terraces, and deltas formed in contact with the glacial ice; outwash and deltas deposited by meltwater streams flowing in front of the glacier; alluvial fans and deltas formed from flooding after glacial dams were breached; as well as alluvial fans and deltas formed from erosion of the postglacial barren land surface. In some locations, exposed till and other glacial sediments were eroded after the glaciers receded and were redeposited as sand and gravel by streams. Deposits that settled out at or near the glacier margin ice tend to include large materials, such as boulders and cobbles. Deposits that were transported away from the ice by meltwater tend to consist of fine- or small-grained materials. Regardless of the circumstances of deposition, sand and gravel deposits commonly form high-yielding aquifers if there is a significant thickness of saturated material.

Characteristics of Aquifers

The size and arrangement of voids or pore spaces between sediment particles determine the ability of the aquifer material to store and transmit ground water. Porosity is a measure of the space available for ground-water storage. A more useful measure of the ground water available for use is **specific yield**. Porosity is always greater than specific yield for a given section of aquifer because some water remains on the grain surfaces as a result of surface tension and will not drain by gravity. The large, interconnected pore spaces of sand and gravel deposits provide a large volume of ground-water storage and also readily transmit ground water; these deposits are highly permeable. In contrast, silts and clays provide a large volume of ground-water storage but do not readily transmit ground water because surface-tension forces predominate in the small pore spaces. These types of deposits are relatively impermeable.

The ability of aquifer material to transmit water is described quantitatively by its **hydraulic conductivity**. Hydraulic conductivity can be illustrated by a comparative example: fine-grained sand can have hydraulic conductivities between 2 and 15 ft/d; whereas well-sorted, coarse-grained sand can have hydraulic conductivities that range from 50 to greater than 200 ft/d. The variation depends largely upon uniformity and shape of the grains (fig. 12).

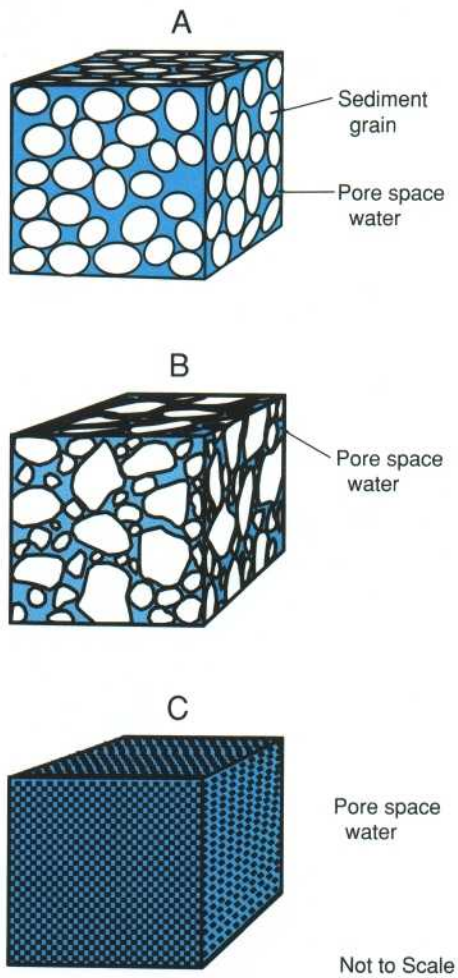


Figure 12. Shape, size, and sorting of sediments determine aquifer characteristics. (*A*) Rounded, coarse-grained, well-sorted material (uniform size) has high porosity and high hydraulic conductivity. (*B*) Angular, poorly sorted material (mixed sizes) has low porosity and low hydraulic conductivity. Small particles "plug up" pores between large particles, impeding flow. (*C*) Flat, fine-grained, well-sorted material has high porosity but low hydraulic conductivity. Because pore spaces are very small, water adheres to the grains by surface-tension force; in other words, by the same natural force of attraction that causes drops of water to cling to a downward- or sideways-facing object seemingly in defiance of gravity.

In the American water-well industry, hydraulic conductivity (k) is commonly expressed in units of gallons per day per foot squared (gal/day/ft²). This expression, perhaps more intuitive than the equivalent U.S. Geological Survey convention of expressing k in feet per day (ft/d), conveys that k is the rate at which water (gallons per day), or other fluid, moves through a cross-sectional area of aquifer (foot squared). Likewise, transmissivity, being the product of hydraulic conductivity times saturated thickness in feet, is expressed as gallons per day per foot (gal/day/ft) by the water-well industry.

Hydraulic conductivity *- a measure of the ability of a porous medium to transmit a fluid, expressed in unit length per unit time*

Saturated thickness (of stratified drift) *- thickness, in feet, of stratified-drift extending down from the water table to the till or bedrock surface*

Specific yield *- the ratio of the volume of water that can be drained by gravity to the total volume of sediment*

Transmissivity *- the rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient*

Conversions:
To convert hydraulic conductivity in gal/day/ft² to ft/d, multiply by 0.1137

To convert transmissivity in gal/day/ft to ft²/d, multiply by 0.1137.

Aquifer **transmissivity** quantifies the ability of the entire thickness of the aquifer to transmit water. The term is used often by hydrologists to describe the water-producing capability of an aquifer. Technically, the transmissivity of an aquifer is equal to the hydraulic conductivity of its materials multiplied by its **saturated thickness**, in feet. In this report, transmissivity is expressed in units of foot squared per day (ft²/d).

To summarize, the higher the value of hydraulic conductivity, the more readily water can flow through the aquifer material. Aquifers that have a large saturated thickness, and are composed of material with high hydraulic conductivity, will have a high transmissivity and can readily transmit water to wells.

Methods for Evaluating Stratified-Drift Aquifers

For the assessment of New Hampshire's stratified-drift aquifers, the State was subdivided into 13 study areas that generally corresponded to major watersheds. Many thousands of data records were compiled from existing sources, and additional thousands were added during the course of the study.

For each of the study areas, the evaluation of **stratified-drift aquifers** began with a compilation and assessment of all pertinent information from many sources. Existing data sources included hydrologic map reports from a USGS statewide reconnaissance study (Cotton, 1975a, b, c, and d, 1976a and b, 1977a, b, and c), county Natural Resources Conservation Service (NRCS) soils maps (Latimer and others, 1939; Winkley, 1965; Kelsey and Vieira, 1968; Vieira and Bond, 1973; Diers and Vieira, 1977; U.S. Soil Conservation Service, 1981, 1985a, 1985b), well records registered with the NHDES Water Resources Division, and bridge-boring records from the New Hampshire Department of Transportation. The NHDES, Water Resources Division and New Hampshire Department of Transportation provided more than 20,000 records of subsurface information at specific sites. Surficial-geology maps from the Cooperative Geologic Mapping Program (COGEOMAP—a cooperative program between various states and the USGS) were used when available. In addition, any available information from engineering firms, environmental consultants, and well drillers were compiled.

The first objective of the aquifer study was to determine the extent and hydrologic characteristics of stratified-drift aquifers. Field-data collection usually began with mapping the geographic location of sand and gravel deposits. Using information from USGS topographic and hydrologic-reconnaissance maps, county NRCS maps, and field investigations, the location of the contacts or boundary lines between areas of stratified drift and areas of till and bedrock

Stratified-drift aquifer*—A coarse-grained sand or sand and gravel deposit that contains a usable supply of water* were determined. For this aquifer study, the contact between sand and gravel and all other materials at the ground surface defined the mapped aquifer boundary. Thus, stratified-drift boundaries are the same as aquifer boundaries. Next, the thickness of the deposits and how much water they stored, were measured.

Depth to the water table and saturated thickness of the aquifer were determined in two ways: drilling (wells, test borings, and bridge borings) and surface-geophysical techniques. Drilling is used to determine certain aquifer parameters such as saturated thickness or depth to the water table and to collect samples of the aquifer materials for analysis. However, drilling is slow, expensive, and provides data at only one location on the ground. Seismic refraction, a surface-geophysical technique that depends on the generation and detection of sound waves below ground, generally yields results faster than drilling and provides a cross-sectional view of the aquifer. The major disadvantages of seismic refraction are that the technique is not usable under all conditions and the interpretation of the data can be variable.

USGS crews drilled wells or test holes at 674 sites to supplement existing data (fig. 13). As each hole was drilled, the depth to the water table was measured as the point where the drilling augers first reached saturated materials. Drilling continued until the augers reached bedrock or "refusal". Refusal marks the depth at which the drill auger could not penetrate the underlying bedrock, a large boulder, or till. The vertical distance between the water table and the bottom of the aquifer is the saturated thickness. Samples of the saturated aquifer sands and gravels were collected at 5- or 10-foot intervals for each drilled hole using a split-spoon sampler (fig. 14), which was inserted down through the hollow part of the augers to the bottom of the hole. Aquifer hydraulic conductivities for materials collected at these intervals were estimated from measurements of the proportion of grains that fell into specific size ranges when passed through a series of sieves of different sizes. Transmissivity

Figure 13. A hollow-stem auger drill rig and operator. This U.S. Geological Survey drill rig was used to drill 674 test holes statewide to collect data on aquifer characteristics and to install observation wells. (Photograph taken by J.R. Olimpio, U.S. Geological Survey.)

Regarding the theory of seismic-refraction, a simple analogy can help to illustrate the phenomenon that sound waves refract at boundaries of earth layers. Stick a pencil in a glass of water. The pencil will appear to bend at the boundary between the air and water layers. This happens because light waves, like sound waves, refract at the boundaries of distinct layers.

Figure 14. Split-spoon sampler and sediment from a drilled test hole. The sampler was used to retrieve aquifer material from drilled test holes and wells at 5- or 10-foot intervals. Once the sample is obtained, it is stored in the plastic bag for further analysis. (Photograph taken by J.D. Ayotte, U.S. Geological Survey.)

values for the entire saturated thickness of the aquifer were estimated by multiplying the hydraulic conductivity value for an interval by the saturated thickness of that interval and summing the results for each hole. Transmissivity values also were obtained from consultant reports when available.

Seismic refraction provides a shallow cross-sectional view, or slice, through the upper layers of the earth. Specifically, seismic refraction results can be used to determine depth to the water table and depth to bedrock from a line along the surface of the ground. This method utilizes the property that sound waves travel through layers of distinct earth materials at different and known velocities. For example, sound travels through dry sediments at 900 to 2,000 ft/s, through saturated sediments at about 5,000 ft/s, and through bedrock at 10,000 to 20,000 ft/s. In the seismic refraction method (fig. 15), a sound wave is created by detonating a small explosive buried just below the ground surface. The resulting waves are bent (refracted) at the boundaries between distinct layers. By measuring the time it takes for the refracted sound waves to travel to receivers called geophones, which are located at fixed intervals along a line at the ground surface, the rate at which the sound waves traveled can be calculated and matched to the material from which it was refracted. Geophones are so sensitive that they can detect the vibrations of passing traffic and even the motion of roots as trees sway in strong winds. The technique therefore works best under "quiet" conditions. Seismic refraction can be used to determine the thickness of the unconsolidated dry layer and the unconsolidated saturated layer, and the depth to the top of the bedrock layer. Seismic-refraction surveys were conducted at 651 sites for the aquifer studies.

Seismic-reflection surveys, another geophysical method, were conducted in areas throughout the State where large rivers or lakes overlie sand and gravel deposits. This method, which is conducted from a boat traversing the water body, provided data on the thickness of the aquifer below the water body.

Data compiled from previously existing sources and collected from drilling, seismic refraction, and seismic reflection were analyzed and interpreted to produce a set of maps with hydrologic information for each of the study areas. The maps present hydrologic data superimposed on USGS topographic maps at scales of 1:24,000[1] and 1:48,000[2]. Maps of aquifer boundaries were produced from USGS topographic and hydrologic reconnaissance maps, NRCS maps, and field explorations. Maps showing contour lines of equal water-table altitudes were produced using data from drilling, seismic-refraction surveys, water-level measurements at wells drilled by the USGS for this project, altitudes of surface-water bodies and other well, test hole, or bridge-boring data when available. The water-table maps are presented as altitude contours in feet above sea level to make the data consistent with topographic contour lines on standard USGS topographic

[1]One inch on the map represents 2,000 feet on the ground.

[2]One inch on the map represents 4,000 feet on the ground.

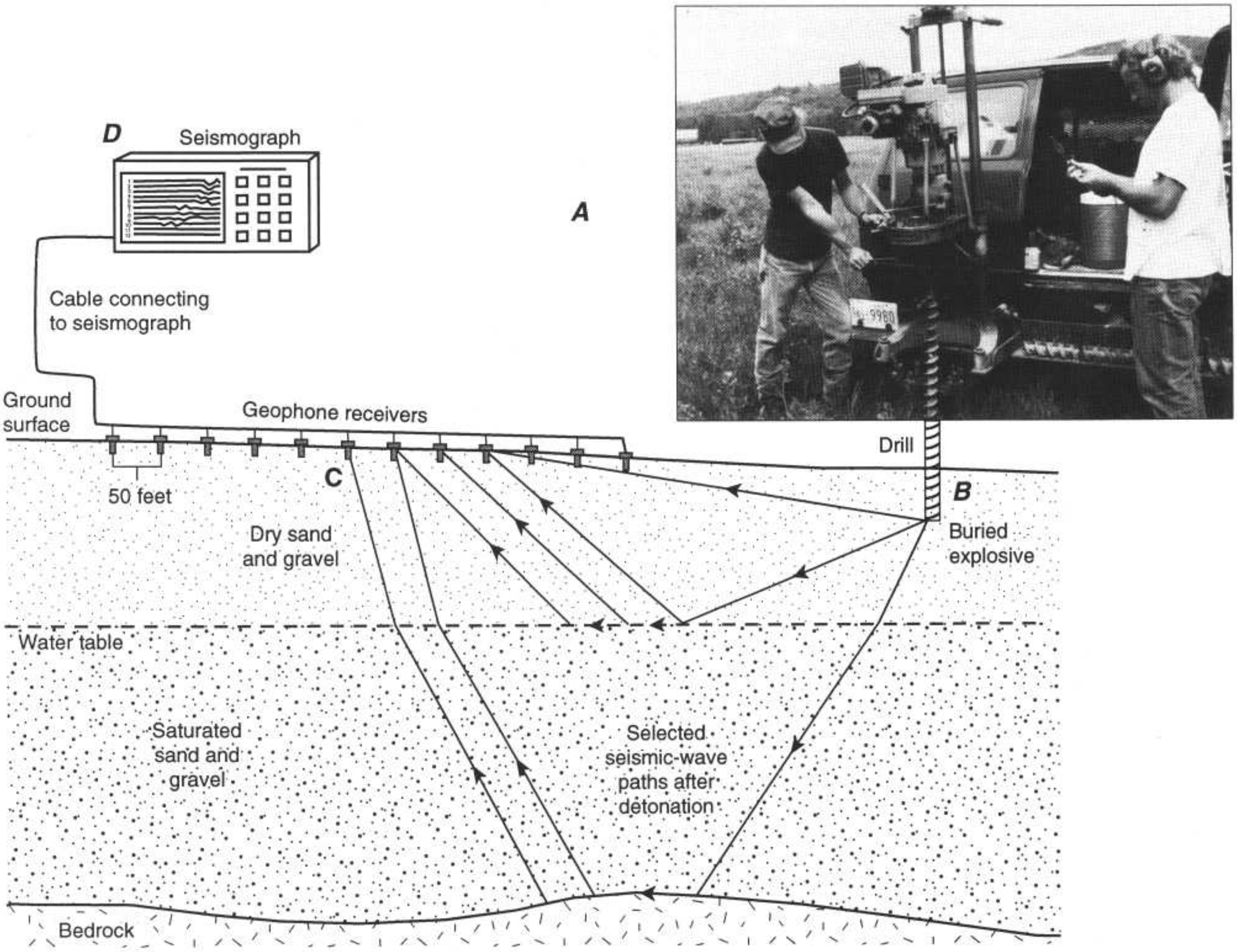


Figure 15. Seismic-refraction survey field work in Sugar Hill, northwestern New Hampshire. (*A*) Technician on the left side is drilling a "shot hole" for the explosive being prepared by the hydrologist on the right. (*B*) A carefully calculated amount of explosive material is used to generate enough sound energy to travel up to 1,100 feet underground and still register a signal. (*C*) Resulting seismic waves are detected by geophone receivers buried 2 inches in the ground. (*D*) A 12-channel seismograph, like an extremely accurate stopwatch, records the time of arrival in fractions of seconds of the first seismic wave detected by each geophone. (Photograph taken by S.M. Flanagan, U.S. Geological Survey).

maps. Maps showing contour lines of equal saturated thickness, in feet, and zones representing ranges of transmissivity values, in foot squared per day (ft^2/d), were produced using data from USGS drill holes, seismic refraction, and other well, test hole, or bridge-boring data if available.

The second objective of the aquifer study was to assess potential water-yielding capabilities for selected aquifers in each study area. These results provide planners with information on potential volumes of water that could be withdrawn from aquifers to supplement existing water supplies or to develop new ones. Aquifers were chosen for this evaluation to represent different types of local aquifer systems. Most of these analyses were done using computer-simulation models based on estimates of hydrologic and other aquifer properties and tested with data collected in the field. Forty-two aquifers were modeled to obtain potential-yield estimates. Potential-yield estimates are included in the section of this report titled "Major Aquifers in New Hampshire."

Figure 16. Typical setup for sampling water quality at a well in Concord, south-central New Hampshire.

- Transmissivity values range from 0 to 26,000 ft^2/d or greater.
- Depth to the water table ranges from 0 to 150 ft below the land surface. Depth to the water table for 50 percent of the wells inventoried is 9 ft or less.
- In general, the most transmissive aquifers are found in localized areas of the central and southern parts of the State.
- Aquifers along the main sections of major rivers tend to be continuous, while those elsewhere tend to be small and discontinuous.

The third objective of the aquifer study was to broadly define the ground-water quality of the major aquifers. The approach used for meeting this objective was to collect and analyze samples of ground water from springs and wells (fig. 16). This assessment of ground-water quality focused on natural or near-natural conditions in aquifers considered representative of the study area and did not attempt to identify or evaluate sites of possible ground-water contamination. Ground water was sampled in a variety of environments, including forested, agricultural, or residential areas. Samples of ground water from 240 wells and 20 springs were analyzed for a variety of substances including common inorganic, organic, and volatile organic constituents. The assessment of general ground-water quality is discussed in the section of this report titled "Quality of Water from Stratified-Drift Aquifers."

Major Stratified-Drift Aquifers in New Hampshire

General information about stratified-drift aquifers statewide is summarized in figure 17 and below:

- About 14 percent, or 1,299 of the 9,282 mi^2 of New Hampshire, is underlain by stratified-drift aquifers.
- The largest stratified-drift aquifer is in the Ossipee River Basin in the towns of Tamworth, Madison, Ossipee, Freedom, and Effingham.
- Saturated thicknesses range from 0 to more than 500 ft, the thickest being along the Connecticut River in Orford and Haverhill.

The following points should be kept in mind while reading this discussion of highlights from the individual study areas: (1) All study area boundaries are major watershed divides except for the Nashua Regional Planning Commission Area, whose boundary is defined by town boundaries, and parts of the two adjacent study areas, the Middle Merrimack and Lower Merrimack River Basins. (2) Because aquifers do not end at State boundaries, parts of some New Hampshire aquifers extend into Maine, Massachusetts, Vermont, or Canada. (3) Some towns, such as Dover, may be mentioned in more than one section of this report because separate aquifers are in different study areas. (4) As a general guideline for interpreting the discussion on transmissivities, a transmissivity value above 2,000 ft^2/d constitutes a major aquifer. (5) Thick stratified-drift deposits are not necessarily highly transmissive. For instance, the thick saturated deposits along the Connecticut River are primarily clays from the bottom deposits of glacial Lake Hitchcock that have low permeability and transmissivity.

Upper Connecticut and Androscoggin River Basins

The Upper Connecticut and Androscoggin River Basins in northern New Hampshire have a combined drainage area of 1,629 mi^2, of which 137 mi^2, or about 8 percent of the basin, are underlain by stratified-drift aquifers. Parts of stratified-drift aquifers in the towns of Colebrook, Shelburne, Stark, Stratford, and West Milan have saturated thicknesses greater than 200 ft and transmissivities greater than 4,000 ft^2/d. Stratified-drift aquifers in the towns of Berlin, Colebrook, and Gorham supplied a total of 4.5 Mgal/d of water for municipal public-supply wells in 1990. Results of computer model simulations indicate that stratified-drift aquifers in Colebrook and Shelburne can yield up to 7.7 and 23.2 Mgal/d, respectively (J.R. Olimpio, U.S. Geological Survey, written commun., 1995).

Middle Connecticut River Basin

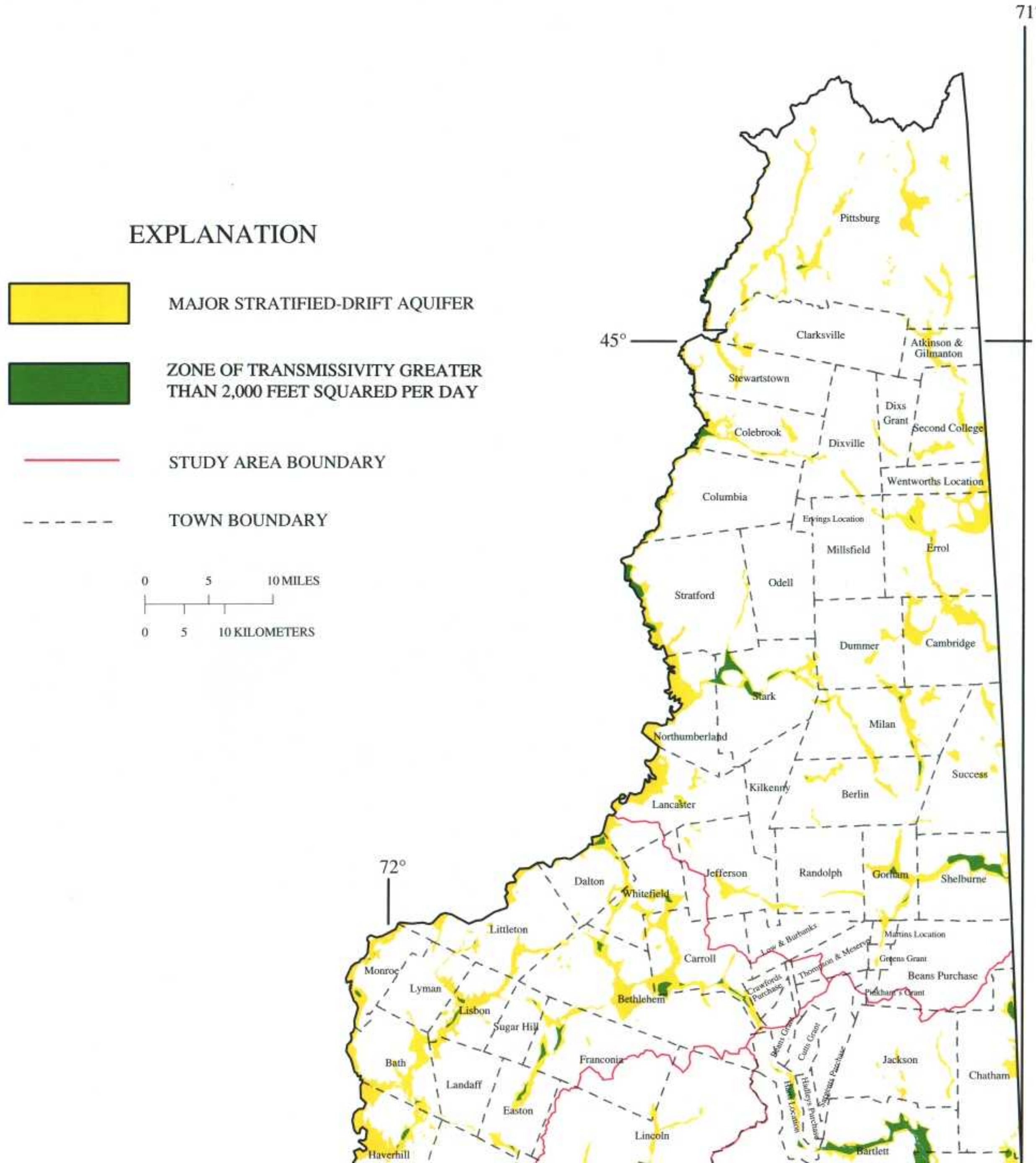
The Middle Connecticut River Basin in western New Hampshire has a drainage area of 987 mi^2, of which 123 mi^2, or about 12 percent of the basin, are underlain by stratified-drift aquifers. Although saturated thickness of stratified drift exceeds 500 ft in northwestern Orford and western Haverhill, saturated thickness generally is less than 100 ft. High transmissivity values (exceeding 4,000 ft^2/d) were measured in parts of stratified-drift aquifers in southwestern Carroll, northwestern Bethlehem, western Franconia, western Orford, eastern Haverhill, central Easton, and southwestern Lisbon. Transmissivity exceeds 1,000 ft^2/d in 17.5 mi^2 of the study area. In 1990, ground-water withdrawals from stratified-drift aquifers for municipal public-supply wells totalled about 1.5 Mgal/d in Carroll, Enfield, Hanover, Haverhill, Lisbon, Monroe, and Orford. A computer simulation of potential ground-water withdrawals indicated that additional yields of 1.4 to 2.9 Mgal/d could be pumped from aquifers in western Lisbon, central Haverhill, northern Easton, southern Franconia, and western Franconia. Parts of aquifers in Hanover, Haverhill, and Orford extend into Vermont (Flanagan, in press).

Pemigewasset River Basin

The Pemigewasset River Basin in central New Hampshire has a drainage area of 1,022 mi^2, of which 91 mi^2, or about 9 percent of the basin, are underlain by stratified-drift aquifers. Parts of aquifers in Campton, Alexandria, Hebron, and Rumney have saturated thicknesses greater than 100 ft and transmissivity greater than 8,000 ft^2/d. Stratified-drift aquifers in Bristol, Hill, Franklin, Sanbornton (for Franklin), Plymouth, Campton, Woodstock, Lincoln, and Waterville Valley supply ground water for municipal public-supply wells. Many other areas in the basin are potential sites for public-supply wells (Cotton and Olimpio, in press).

Saco and Ossipee River Basins

The Saco and Ossipee River Basins in east-central New Hampshire have a drainage area of 869 mi^2, of which 153 mi^2, or about 18 percent of the basin, are underlain by stratified-drift aquifers. The area contains several large, productive, and potentially productive aquifers. About 11 percent of the area has transmissivity values greater than 1,000 ft^2/d. Transmissivity values equal to or greater than 8,000 ft^2/d have been calculated for aquifers along the Saco River in Carroll, Hart's Location, Bartlett and Conway, and in tributary valleys in Chatham, northeastern Conway, central Madison, eastern Sandwich, western Tamworth, and in sections of Ossipee, Effingham, and Wakefield. The central part of the largest stratified-drift aquifer in New Hampshire underlies the Ossipee River Valley in Tamworth, Madison, Ossipee, Freedom, and Effingham. Saturated thickness in one section of the Ossipee River Valley stratified drift exceeds 280 ft. Sections of aquifers in Chatham, Conway, Effingham, and Wakefield extend into Maine. Water is pumped from municipal public-supply wells in stratified-drift aquifers in Bartlett, Conway, Freedom, Gorham, Jackson, and Madison. Results of model-simulated ground-water flow for the Ossipee River Valley aquifer indicate that more than 7 Mgal/d of water could be pumped from four wells with minimal impact on flows in the Ossipee River (Moore and Medalie, in press).


EXPLANATION
MAJOR STRATIFIED-DRIFT AQUIFER
ZONE OF TRANSMISSIVITY GREATER THAN 2,000 FEET SQUARED PER DAY
STUDY AREA BOUNDARY
TOWN BOUNDARY
0 5 10 MILES
0 5 10 KILOMETERS
71°
45°
72°
Pittsburg
Clarksville
Atkinson & Gilmanton
Stewartstown
Dixs Grant
Colebrook
Dixville
Second College
Wentworths Location
Columbia
Ervings Location
Millsfield
Errol
Odell
Stratford
Dummer
Cambridge
Stark
Milan
Northumberland
Success
Kilkenny
Berlin
Lancaster
Jefferson
Randolph
Gorham
Shelburne
Dalton
Whitefield
Littleton
Carroll
Low & Burbanks
Martins Location
Thompson & Meserve
Greens Grant
Crawfords Purchase
Beans Purchase
Pinkhams Grant
Monroe
Lyman
Bethlehem
Lisbon
Sugar Hill
Cutts Grant
Jackson
Bath
Franconia
Chatham
Landaff
Hadleys Purchase
Easton
Lincoln
Bartlett
Haverhill

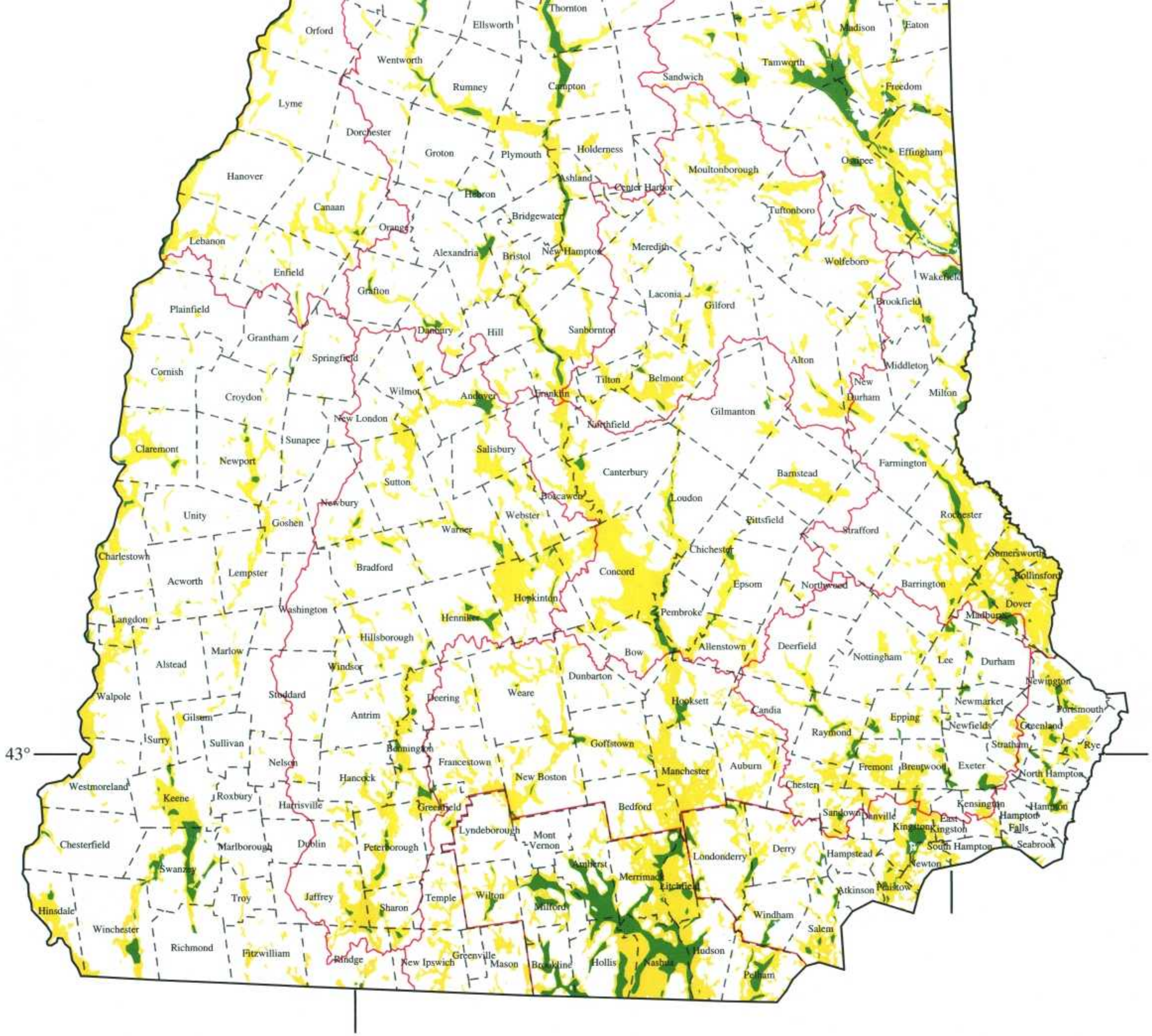


Figure 17. Major stratified-drift aquifers and zones of transmissivity greater than 2,000 square feet per day in New Hampshire.

Winnipesaukee River Basin

The Winnipesaukee River Basin in central New Hampshire has a drainage area of 484 mi^2, of which 66 mi^2, or 14 percent of the basin, are underlain by stratified-drift aquifers. Saturated thickness of parts of an aquifer in Belmont exceeds 100 ft, although generally it is less than 50 ft. Transmissivity, generally less than 1,000 ft^2/d, exceeds 6,000 ft^2/d in areas of Belmont, Alton, and New Durham. Belmont and Alton withdraw ground water from stratified-drift aquifers for municipal public-supply wells. Induced infiltration from nearby rivers could provide additional water for municipal public supplies in Tilton, Belmont, Gilford, Alton, and Meredith. Results of computer model simulations indicate that aquifers in Alton and Belmont can yield up to 1.1 and 1.8 Mgal/d of water, respectively (Ayotte, in press).

Lower Connecticut River Basin

The Lower Connecticut River Basin in southwestern New Hampshire has a drainage area of 1,163 mi^2, of which 116 mi^2, or 10 percent of the basin, are underlain by stratified-drift aquifers. Saturated thickness is greater than 400 ft in parts of Charlestown and Westmoreland. Transmissivity exceeds 4,000 ft^2/d in some aquifers in Newport, Walpole, Charlestown, Grantham, Keene, Hinsdale, and Chesterfield but is less than 1,000 ft^2/d in 80 percent of the aquifers in the area. Municipal public-supply wells withdraw water from stratified-drift aquifers to supply parts of Charlestown, Hinsdale, Keene, Marlborough, Newport, Plainfield, Chesterfield, Troy, Walpole, and Winchester. Additional water is potentially available from stratified-drift aquifers in many towns in the study area (Moore and others, 1994).

Contoocook River Basin

The Contoocook River Basin in southwestern New Hampshire has a drainage area of 766 mi^2, of which 123 mi^2, or 16 percent of the basin, are underlain by stratified-drift aquifers. Saturated thickness exceeds 200 ft in Hancock next to Norway Pond, and in central Andover, but generally is less than 80 ft. Estimated transmissivity was at least 22,000 ft^2/d along the Contoocook River in Bennington. Transmissivity is greater than 8,000 ft^2/d in the Contoocook River valley in part of Peterborough and in New Ipswich, in Antrim, Bennington, Greenfield and Hillsborough, northwestern Henniker, Warner, central Andover, and central Hopkinton, although it generally is less than 2,000 ft^2/d. Public-supply wells in stratified-drift aquifers provide municipal water to Bennington (for Antrim), Henniker, Hillsborough, Hopkinton, Jaffrey, Peterborough, and Warner. Induced infiltration from rivers could provide a source of additional ground water in several towns, including Harrisville, Hillsborough, and Antrim. Results from this study indicate that Peterborough, Hancock, Henniker, Hopkinton, Warner, Bradford, Andover, and Salisbury could potentially derive additional supplies of ground water from stratified-drift aquifers if needed (Harte and Johnson, 1995).

Upper Merrimack River Basin

The Upper Merrimack River Basin in south-central New Hampshire has a drainage area of 519 mi^2, of which 80 mi^2, or 15 percent of the basin, are underlain by stratified-drift aquifers. Parts of aquifers in Canterbury, Concord, and Loudon have transmissivities of at least 5,000 ft^2/d. Saturated thicknesses of aquifers in this river basin are generally less than 80 ft. Additional water is potentially available from stratified-drift aquifers in Bow, Pembroke, Chichester, Loudon, Northfield, Franklin, Allenstown, Epsom, and Concord. Induced infiltration from the Merrimack, Soucook, and Suncook Rivers may provide additional water to aquifers. Municipal public-supply wells currently (1995) provide water from stratified-drift aquifers to Barnstead, Concord, Epsom, and Pembroke (P.J. Stekl, U.S. Geological Survey, written commun., 1994).

Bellamy, Cocheco, and Salmon Falls River Basins

The Bellamy, Cocheco, and Salmon Falls River Basins in southeastern New Hampshire have a drainage area of 330 mi^2, of which 50 mi^2, or 15 percent of the basin, are underlain by stratified-drift aquifers. Aquifers scattered throughout Dover, Farmington, Rochester, and Somersworth have transmissivities that range from 2,400 to 26,700 ft^2/d, and saturated thicknesses greater than 100 ft. Municipal public-supply wells in Dover, Farmington, Rollinsford, Somersworth, Milton, and Wakefield withdraw water from stratified-drift aquifers. Stratified-drift aquifers in Milton, Union, Rochester, Farmington, and New Durham can potentially yield significant quantities of water through induced infiltration from nearby rivers and ponds. Parts of aquifers in Milton, Rochester and Somersworth extend into Maine (Mack and Lawlor, 1992).

Middle Merrimack River Basin

The Middle Merrimack River Basin in south-central New Hampshire has a drainage area of 469 mi^2, of which 98 mi^2, or 21 percent of the basin, are underlain by stratified-drift aquifers. The southern and eastern boundaries of this study area are formed by political divisions rather than by drainage basins. Saturated thickness exceeds 100 ft in Hooksett, and transmissivities exceed 4,000 ft^2/d in parts of Bow and Goffstown but are generally less than 2,000 ft^2/d. Water from municipal public-supply wells is pumped from stratified-drift aquifers in Goffstown and Hooksett. Stratified-drift aquifers in New Ipswich, Greenfield, and New Boston potentially could yield water to small municipal systems. The aquifer in Goffstown could supply significantly larger volumes of water than are currently (1995) being pumped (Ayotte and Toppin, 1995).

Exeter, Lamprey, and Oyster River Basins

The Exeter, Lamprey, and Oyster River Basins in southeastern New Hampshire have a drainage area of 351 mi^2, of which 56 mi^2, or 16 percent of the basin, are underlain by stratified-drift aquifers. Transmissivities greater than 3,000 ft^2/d have been measured in the Madbury-Dover area, the Durham-Lee area, and the Newmarket-Durham area. Water from municipal public-supply wells in Dover, Durham, Epping, Lee, Madbury, Newmarket, and Raymond is pumped from aquifers with transmissivities that exceed 1,000 ft^2/d. Water from municipal public-supply wells in Exeter, Madbury (for Portsmouth), Newfields, and Stratham is pumped from stratified-drift aquifers that are less transmissive than 1,000 ft^2/d. A computer model of ground-water flow indicated that four wells in an aquifer in Epping could yield 2 Mgal/d, and that two wells in an aquifer in Newmarket could yield 0.26 Mgal/d (Moore, 1990).

Lower Merrimack and Coastal River Basins

The Lower Merrimack and Coastal River Basins in southeastern New Hampshire have a drainage area of 327 mi^2, of which 78 mi^2, or 24 percent of the basin, are underlain by stratified-drift aquifers. The western and southern edges of this study area are formed by political rather than drainage-basin boundaries. Although saturated thickness is 100 ft in one section of Kingston, it is generally 20 to 40 ft throughout the rest of the basin. Transmissivity exceeds 4,000 ft^2/d in parts of aquifers in Kingston, North Hampton, Rye, Greenland, and Portsmouth. Municipal public-supply wells provide water from stratified-drift aquifers to customers in Hampton, Portsmouth, Rye, Salem, and Seabrook. Stratified-drift aquifers in the study area can potentially yield additional water for public water supplies in Derry, Greenland, Kingston, North Hampton, and Windham. Some aquifers in the southern part of this study area extend into Massachusetts (Stekl and Flanagan, 1992).

Nashua Regional Planning Commission Area

The Nashua Regional Planning Commission area in south-central New Hampshire has a drainage area of 322 mi^2, of which 129 mi^2, or 40 percent of the basin, are underlain by stratified-drift aquifers. This study area is entirely defined by political boundaries. Saturated thickness of stratified drift is greater than 100 ft in areas of Amherst, Litchfield, Merrimack, and Pelham. Transmissivities exceed 8,000 ft^2/d in parts of aquifers in Amherst, Brookline, Hollis, Hudson, Litchfield, Merrimack, Milford, Nashua, and Pelham. More than 30 municipal public-supply wells in stratified-drift aquifers in Amherst, Hollis, Hudson, Litchfield, Merrimack, Milford, Nashua, Pelham, and Wilton withdraw at least 100 gallons of water per minute (0.14 Mgal/d); many of these pump at a rate of more than 500 gallons per minute (0.72 Mgal/d). Several stratified-drift aquifers, particularly in Amherst, Litchfield, Merrimack, Milford, and Pelham, could supplement municipal public-supply wells (Toppin, 1987).

Quality of Water from Stratified-Drift Aquifers

For water-resources planners, it is not enough to know where the productive aquifers are located or how much water they might yield. The quality of water and its suitability for various uses such as drinking, irrigation, or industry, is equally important.

Ground-water quality is influenced partly by natural processes and partly by human activity. Water quality between aquifers or even within a single aquifer can differ because of influences from the biological communities, aquifer materials, and underlying bedrock that are in contact with the ground water. Natural weathering of rocks and minerals contributes most of the dissolved substances found in uncontaminated ground water and can produce high concentrations of dissolved iron (fig. 18) and manganese, especially in acidic environments. Stratified-drift aquifers near coastal areas can contain higher levels of chloride than the levels found in inland areas. Arsenic, an element derived from earth materials, is sometimes identified in ground water. Radon in ground water from bedrock wells is caused by natural weathering of uranium minerals in a type of granite commonly found in New Hampshire.

The more persistent threats to ground-water quality in New Hampshire are caused by human activity, such as road salting, fertilizing, industrial waste discharge, and detergent discharge. For instance, sodium and chloride are not abundant elements in the types of rocks found in New Hampshire, yet tests on water samples from throughout the State indicate their presence. Sodium chloride is a compound commonly used for winter road salting. Excess nitrate in ground water can be the result of poorly designed or faulty septic systems or other waste-disposal sites, or inappropriate fertilization rates. Infiltration of solvents from industrial wastes can result in ground-water contamination (Morrissey and Regan, 1987). Arsenic also has been found in ground water associated with detergents in septic wastes (Boudette and others, 1985).

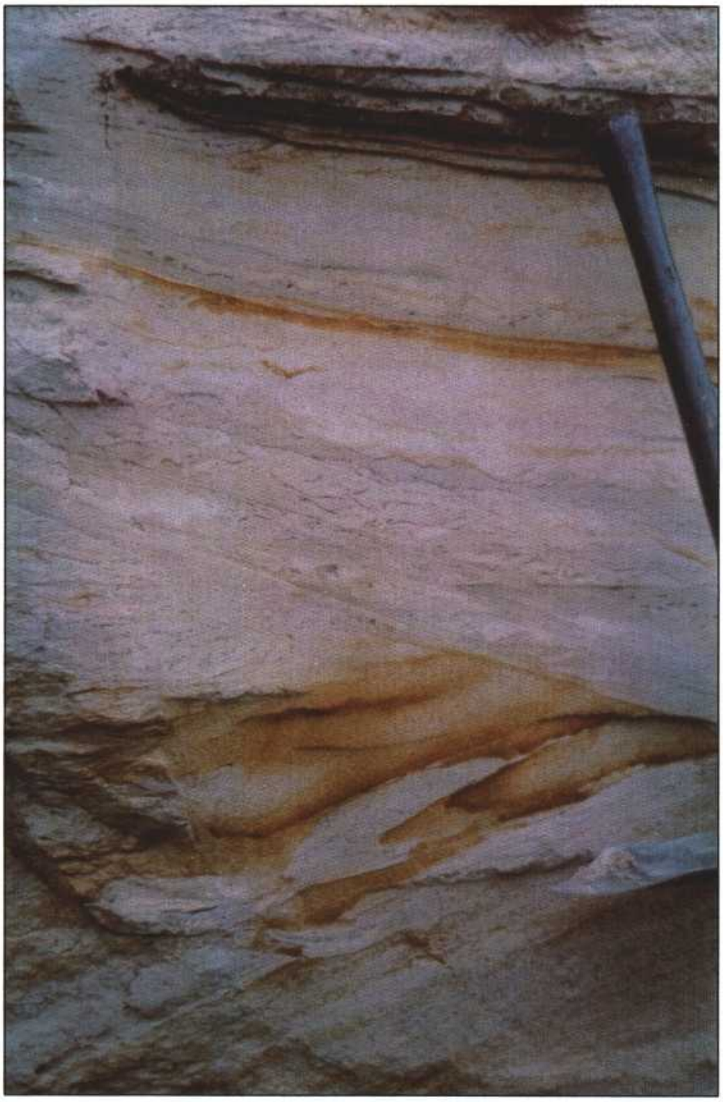


Figure 18. Sand deposits from a former river channel stained red from iron in ground-water seepage. High concentrations of iron are common in New Hampshire ground water. Stick in the upper right corner of the photograph is approximately 1.5 feet long. (Photograph taken by J.D. Ayotte, U.S. Geological Survey.)

Commonly, the potential for ground-water contamination is assessed by analyzing land use for the area that contributes ground-water recharge to an aquifer. Certain land uses can adversely affect the quality of ground water by contributing to **nonpoint source pollution.** In an attempt to account for sources of ground-water pollution in the State, the NHDES maintains a statewide Groundwater Hazards Inventory, which in

November 1991, documented more than 2,000 sites of ground-water contamination. According to this inventory, the most common and serious threats to ground-water quality in New Hampshire include hazardous waste sites, unlined landfills, leaking underground storage tanks, oil spills or releases, and septage or sludge lagoons (Flanders, 1992, p. IV-1).

Maximum levels for contaminants in public-water supplies were established by the U.S. Environmental Protection Agency (USEPA) under the Safe Drinking Water Act of 1986. Two general categories of regulations were created: National Primary Drinking-Water Regulations for contaminants that could adversely affect human health; and National Secondary Drinking-Water Regulations primarily for contaminants that can adversely affect the odor, taste, or appearance of water. Under the National Primary Drinking-Water Regulations, *enforceable* Maximum Contaminant Levels (MCL, U.S. Environmental Protection Agency, 1992) are established for contaminants such as arsenic, cadmium, lead, atrazine, and toluene. Under the National Secondary Drinking-Water Regulations, *advisory* Secondary Maximum Contaminant Levels (SMCL, U.S. Environmental Protection Agency, 1992) are established for contaminants such as chloride, iron, and manganese. Similarly, the NHDES Water Supply Engineering Bureau has established MCLs and SMCLs for certain contaminants such as sodium, cadmium, and lead (New Hampshire Department of Environmental Services, Water Supply Engineering Bureau, written commun., 1987).

On the basis of the results of this statewide assessment, the quality of ground water from stratified-drift aquifers in New Hampshire generally meets all drinking-water regulations (fig. 19). Analyses of water samples from wells and springs reveal that the most common water-quality problems are the high concentrations of iron or manganese. Although neither of these elements poses a threat to human health, excessive amounts of either in water will stain laundry or plumbing fixtures. Of the 257 samples analyzed (table 1), 51 samples (20 percent) had higher dissolved iron levels than the SMCL of 300

Nonpoint source pollution *is caused by rainfall or snowmelt runoff that carries unnatural and natural pollutants into lakes, rivers, wetlands, and aquifers. Certain land uses have been targeted by the Nonpoint Source Program administered by the New Hampshire Department of Environmental Services and listed as existing and potential sources of ground- or surface-water contamination (Flanders, 1992). Targeted land uses include landfills, septic systems, junkyards, urban areas, agricultural and silvicultural areas, and roads that are salted in the winter.*

Figure 19. A boy collects drinking water from a spring that flows from a stratified-drift aquifer in Sanbornton, central New Hampshire. (Photograph taken by B.R. Mrazik, U.S. Geological Survey.)

Table 1. Summary of selected analyses of ground water from stratified-drift aquifers in New Hampshire

[MCL, Maximum Contaminant Levels are enforceable U.S. Environmental Protection Agency (USEPA) primary drinking-water regulations (U.S. Environmental Protection Agency, 1992). SMCL, Secondary Maximum Contaminant Levels are established by the USEPA to provide advisory levels for certain contaminants in public water supplies. At higher concentrations, some of these constituents may be associated with adverse health effects (U.S. Environmental Protection Agency, 1992). <, actual value is less than value shown; --, not applicable; micrograms per liter is one in one billion parts; milligrams per liter is one thousand times that amount, or one in one million parts]

Chemical constituent and abbreviation	Number of samples analyzed	MCL	SMCL	Minimum value	Median value	Maximum value
		parts per million, milligrams per liter (mg/L)				
Dissolved oxygen, DO	144	--	--	0	6	13.1
pH, measured in the field	229	--	6.5-8.5	5.1	6.3	8.5
Alkalinity as calcium carbonate, as $CaCO_3$	139	--	--	1	22	158
Total hardness as $CaCO_3$	255	--	--	3	26	280
Total dissolved solids, TDS	252	--	500	17	77	612
Calcium, Ca	256	--	--	.04	7.6	87
Magnesium, Mg	256	--	--	.11	1.5	18
Chloride, Cl	256	--	250	.3	10	300
Sodium[1], Na	256	--	20	.3	6.4	220
Potassium, K	255	--	--	.2	1.6	17
Nitrite plus nitrate, NO_2+NO_3	155	10	--	<.05	.22	7.2
Sulfate, SO_4	255	--	250	<.1	7.8	79
Fluoride, F	255	4	2	<.1	.1	2.9
Silicate, SiO_2	256	--	--	<.01	12	40
		parts per billion, micrograms per liter (µg/L)				
Aluminum, Al	173	--	50	<10	<10	790
Cadmium[2], Cd	247	10	5	<1	<1	4
Copper, Cu	246	--	1,000	<1	<10	80
Iron, Fe	257	--	300	<3	10	19,000
Lead[3], Pb	246	50	--	<1	<10	110
Manganese, Mn	257	--	50	<1	63	3,500
Zinc, Zn	247	--	5,000	<3	4	300

[1]New Hampshire Department of Environmental Services (NHDES) MCL for sodium is 250 mg/L; SMCL is 100-250 mg/L.
[2]NHDES MCL for cadmium is 5 µg/L.
[3]NHDES SMCL for lead is 20 µg/L.

µg/L (micrograms per liter), and 136 samples (53 percent) had higher dissolved manganese concentrations than the SMCL of 50 µg/L. Chloride concentrations for 1 percent of the sampled wells and springs exceeded the SMCL of 250 mg/L (milligrams per liter); however, chloride concentrations in 94 percent of the samples of ground water were less than 100 mg/L. The SMCL for sodium is 20 mg/L and is established for people with cardiac or kidney problems or hypertension.

Because this SMCL has been established at such a low concentration, it was exceeded in 18 percent of the samples. Acidity levels, or pH, in 66 percent of the ground-water samples were less (more acidic) than the minimum limit (6.5) of the range recommended by the USEPA. Other New Hampshire studies also have found that ground water from stratified-drift deposits was slightly acidic, and could cause corrosion problems in metal pipes (Cotton, 1989, p.16). Nineteen of the 173 samples analyzed exceeded the SMCL (50 μg/L) for aluminum. These 19 samples with high aluminum may be associated with low pH because aluminum dissolves more readily as pH decreases.

Cleaning up contaminated ground water can be costly in terms of time and money. Ground-water contamination is commonly not detected until it becomes widespread. The source of pollution and the most effective method of clean up is not always obvious. Recognizing the economical benefits of maintaining high-quality water, in 1991, New Hampshire enacted legislation (RSA 485-C) to protect the State's ground waters.

How Stratified-Drift Aquifer Data are Used

The NHDES, the steward for water resources in the State, has several uses for maps and data pertaining to stratified-drift aquifers in New Hampshire. Most importantly, the Groundwater Protection Act (RSA 485-C) authorized local governments to implement ground-water-protection programs through classification of ground water. Under this Act, one of the four designated classes of ground water is GA2— "stratified-drift aquifers mapped by the USGS that are potentially valuable aquifers" (New Hampshire Department of Environmental Services, 1991, p.10). In addition, Phase 1 delineations of wellhead protection areas (WHPA) for public-supply wells are based on available data, such as the "hydrogeologic information from the USGS stratified-drift aquifer maps." Stratified-drift aquifer maps are commonly used in the administration of excavation regulations (RSA 155-E) by local governments.

A WHPA (wellhead protection area) delineation identifies the part of the mapped aquifer that actually supplies water to a particular public-supply well. This delineation defines the area through which contaminants are reasonably likely to move toward and potentially reach the public-supply well.

The aquifer mapping and data collection by the USGS are valuable resources to local government and the private sector as well. For example, municipalities and their consultants use the information as the basis for exploring potentially new or expanded town water supplies and in siting waste disposal or storage sites to avoid ground-water contamination. In assessing plume migration from a contaminated site, all aquifers in the area need to be identified as to whether or not they are currently being tapped for a water supply. Conservation commissions evaluate wetlands and designate areas as Prime Wetlands (RSA 482-A:15) according to the standardized method of Ammann and Stone (1991). Part of this evaluation requires knowledge of the position of the wetland relative to the location of stratified-drift aquifers. Environmental educators use the aquifer maps to complement and enhance their lessons on watersheds.

Because many potential users of the stratified-drift-aquifer reports are town residents and local governments, table 2 provides an index of the USGS aquifer-assessment study areas that pertain to each town in New Hampshire. The geographic area covered by each report is shown on the map in figure 1, and complete citations for each report are included in the Selected References section.

Table 2. List of towns in New Hampshire, U.S. Geological Survey aquifer-assessment study areas, and areas of town and percentage of total town areas underlain by stratified-drift aquifers

[USGS, U.S. Geological Survey; UC, Upper Connecticut; MC, Middle Connecticut; PE, Pemigewasset; SA, Saco and Ossipee; WI, Winnipesaukee; LC, Lower Connecticut; CK, Contoocook; UM, Upper Merrimack; CO, Cocheco; MM, Middle Merrimack; LA, Lamprey; LM, Lower Merrimack and coastal; NS, Nashua Regional Planning Commission area]

Town	USGS aquifer-assessment study area(s)	Area of town underlain by stratified-drift aquifers	
		(square miles)	Percentage of total
ACWORTH	LC	1.5	4
ALBANY	SA	8.3	11
ALEXANDRIA	PE	4.2	10
ALLENSTOWN	UM, MM	5.4	27
ALSTEAD	LC	1.3	3
ALTON	WI, UM, CO	7.2	12
AMHERST	NS	13.1	39
ANDOVER	CK, UM, PE	6.9	17
ANTRIM	CK	3.5	10
ASHLAND	PE	2.9	27
ATKINSON	LM	.7	7
ATKINSON AND GILMANTON ACADEMY GRANT	UC	2.1	11
AUBURN	MM	7.4	30
BARNSTEAD	UM	5.7	14
BARRINGTON	CO, LA	10.7	23
BARTLETT	SA	8.6	11
BATH	MC	8.7	23
BEANS GRANT	SA	0	0
BEANS PURCHASE	UC	0	0
BEDFORD	MM	9.5	29
BELMONT	WI	12.0	39
BENNINGTON	CK	4.3	39
BENTON	MC	.9	2
BERLIN	UC	3.7	6
BETHLEHEM	MC	9.8	11
BOSCAWEN	UM, CK	6.3	25
BOW	UM, MM	6.0	22
BRADFORD	CK	4.0	11
BRENTWOOD	LA	5.6	33
BRIDGEWATER	PE	2.7	13
BRISTOL	PE	3.8	22
BROOKFIELD	CO, WI, SA	1.7	7
BROOKLINE	NS	6.5	33
CAMBRIDGE	UC	7.9	16
CAMPTON	PE	6.8	13
CANAAN	MC	8.4	16
CANDIA	MM, LA	3.0	10
CANTERBURY	UM	7.1	16
CARROLL	MC, UC, SA	10.6	21
CENTER HARBOR	WI, PE	.6	4
CHANDLERS PURCHASE	MC, SA	0	0
CHARLESTOWN	LC	9.5	26
CHATHAM	SA	4.1	7
CHESTER	LA, MM	4.8	18
CHESTERFIELD	LC	2.1	5
CHICHESTER	UM	1.2	6
CLAREMONT	LC	9.4	22
CLARKSVILLE	UC	1.7	3
COLEBROOK	UC	6.7	16
COLUMBIA	UC	2.4	4
CONCORD	UM, CK	34.8	54
CONWAY	SA	22.2	32
CORNISH	LC	2.7	6
CRAWFORDS PURCHASE	MC	.1	2
CROYDON	LC	.9	3
CUTTS GRANT	SA	0	0
DALTON	MC, UC	4.1	15
DANBURY	PE, CK	4.9	13
DANVILLE	LM, LA	2.2	19
DEERFIELD	LA, UM	5.2	10
DEERING	MM, CK	4.1	13
DERRY	LM, LA	5.2	15
DIXS GRANT	UC	0.5	2
DIXVILLE	UC	1.4	3
DORCHESTER	MC, PE	.8	2
DOVER	CO, LA	26.7	99
DUBLIN	CK, LC	1.4	5
DUMMER	UC	2.3	5
DUNBARTON	MM, UM	1.7	6
DURHAM	LA, CO	1.2	5
EAST KINGSTON	LM, LA	1.1	11
EASTON	MC	3.4	11
EATON	SA	2.1	9
EFFINGHAM	SA	15.8	41
ELLSWORTH	PE	0	0
ENFIELD	MC	3.3	8
EPPING	LA	4.0	15
EPSOM	UM	4.9	14
ERROL	UC	14.1	23
ERVINGS LOCATION	UC	0	0
EXETER	LA, LM	2.9	15
FARMINGTON	CO	4.2	12
FITZWILLIAM	LC	2.7	8
FRANCESTOWN	MM	4.4	15
FRANCONIA	MC, PE	4.6	7
FRANKLIN	UM, PE, WI	10.2	37
FREEDOM	SA	9.3	26
FREMONT	LA	6.7	39
GILFORD	WI	5.7	15
GILMANTON	UM, WI	2.5	4
GILSUM	LC	1.1	7
GOFFSTOWN	MM	5.6	15
GORHAM	UC	5.3	17
GOSHEN	LC	2.3	10

Table 2. List of towns in New Hampshire, U.S. Geological Survey aquifer-assessment study areas, and areas of town and percentage of total town areas underlain by stratified-drift aquifers--*Continued*

Town	USGS aquifer-assessment study area(s)	Area of town underlain by stratified-drift aquifers	
		(square miles)	Percentage of total
GRAFTON	PE, MC	2.9	7
GRANTHAM	LC, MC	.8	3
GREENFIELD	CK, MM	8.3	33
GREENLAND	LM	2.8	28
GREENS GRANT	UC	.3	8
GREENVILLE	MM	.3	4
GROTON	PE	1.0	2
HADLEY'S PURCHASE	SA	0	0
HALE'S LOCATION	SA	.5	27
HAMPSTEAD	LM, LA	2.4	19
HAMPTON	LM	2.5	19
HAMPTON FALLS	LM, LA	.3	3
HANCOCK	CK	3.9	13
HANOVER	MC	5.3	11
HARRISVILLE	CK, LC	1.3	7
HART'S LOCATION	SA	2.4	13
HAVERHILL	MC	14.6	29
HEBRON	PE	1.5	9
HENNIKER	CK, MM	6.2	14
HILL	PE, CK	1.9	7
HILLSBOROUGH	CK	6.1	14
HINSDALE	LC	7.3	35
HOLDERNESS	PE	4.0	14
HOLLIS	NS	11.4	36
HOOKSETT	MM	9.0	25
HOPKINTON	CK, UM	17.3	40
HUDSON	NS	11.1	40
JACKSON	SA, UC	1.8	3
JAFFREY	CK, LC	6.8	18
JEFFERSON	UC, MC	2.9	6
KEENE	LC	10.3	28
KENSINGTON	LM, LA	2.3	19
KILKENNY	UC	0	0
KINGSTON	LM, LA	11.3	57
LACONIA	WI	2.6	13
LANCASTER	UC, MC	8.1	16
LANDAFF	MC	1.2	4
LANGDON	LC	2.8	18
LEBANON	MC, LC	7.1	18
LEE	LA	4.3	22
LEMPSTER	LC	3.2	10
LINCOLN	PE	4.3	3
LISBON	MC	6.5	24
LITCHFIELD	NS	14.1	94
LITTLETON	MC	6.5	13
LIVERMORE	PE, SA	0	0
LONDONDERRY	LM	10.3	25
LOUDON	UM	6.0	13
LOW AND BURBANK'S GRANT	UC, MC	0	0
LYMAN	MC	1.6	6
LYME	MC	5.3	10
LYNDEBOROUGH	NS	2.4	8
MADBURY	CO, LA	5.5	46
MADISON	SA	9.0	23
MANCHESTER	MM	19.7	60
MARLBOROUGH	LC	.5	3
MARLOW	LC	1.6	6
MARTINS LOCATION	UC	.6	14
MASON	MM	3.5	15
MEREDITH	WI, PE	2.8	7
MERRIMACK	NS	18.8	59
MIDDLETON	CO, WI	.2	1
MILAN	UC	7.3	12
MILFORD	NS	9.3	37
MILLSFIELD	UC	.4	1
MILTON	CO	3.7	11
MONROE	MC	4.8	22
MONT VERNON	NS	.4	2
MOULTONBORO	WI, SA, PE	7.9	13
NASHUA	NS	22.1	71
NELSON	LC, CK	.7	3
NEW DURHAM	CO, WI	5.8	14
NEW HAMPTON	PE, WI	6.2	17
NEW IPSWICH	MM, CK, LC	6.1	19
NEW LONDON	CK, LC	1.3	6
NEWBURY	CK, LC	2.1	6
NEWFIELDS	LA	.8	11
NEWINGTON	LM	3.3	41
NEWMARKET	LA	1.1	9
NEWPORT	LC	6.1	14
NEWTON	LM	4.0	40
NORTH HAMPTON	LM	3.2	23
NORTHFIELD	WI, UM	4.4	15
NORTHUMBERLAND	UC	7.6	21
NORTHWOOD	UM, LA, CO	.4	2
NOTTINGHAM	LA	3.4	7
ODELL	UC	0	0
ORANGE	MC, PE	1.0	4
ORFORD	MC, PE	5.8	12
OSSIPEE	SA	24.5	35
PELHAM	NS	9.8	38
PEMBROKE	UM	5.7	25
PETERBOROUGH	CK	10.1	27
PIERMONT	MC	4.0	10
PINKHAM'S GRANT	UC, SA	0	0
PITTSBURG	UC	20.7	7
PITTSFIELD	UM	.4	2
PLAINFIELD	LC, MC	3.2	6
PLAISTOW	LM	5.1	47
PLYMOUTH	PE	6.5	23
PORTSMOUTH	LM	5.2	32
RANDOLPH	UC	1.2	3
RAYMOND	LA	6.2	22
RICHMOND	LC	1.1	3
RINDGE	LC, CK	5.5	15

Table 2. List of towns in New Hampshire, U.S. Geological Survey aquifer-assessment study areas, and areas of town and percentage of total town areas underlain by stratified-drift aquifers--*Continued*

Town	USGS aquifer-assessment study area(s)	Area of town underlain by stratified-drift aquifers	
		(square miles)	Percentage of total
ROCHESTER	CO	20.2	45
ROLLINSFORD	CO	7.2	99
ROXBURY	LC	.1	1
RUMNEY	PE	6.6	16
RYE	LM	2.7	20
SALEM	LM	8.3	33
SALISBURY	CK, UM	5.6	14
SANBORNTON	PE, WI	6.9	14
SANDOWN	LA, LM	3.9	28
SANDWICH	SA, PE, WI	7.6	8
SARGENT'S PURCHASE	SA, MC, UC	0	0
SEABROOK	LM	1.0	11
SECOND COLLEGE GRANT	UC	4.9	12
SHARON	CK	4.2	28
SHELBURNE	UC	6.8	14
SOMERSWORTH	CO	7.3	73
SOUTH HAMPTON	LM	.8	10
SPRINGFIELD	LC, CK, PE	.9	2
STARK	UC	6.9	12
STEWARTSTOWN	UC	3.4	7
STODDARD	CK, LC	.7	1
STRAFFORD	CO, UM	2.2	4
STRATFORD	UC	6.6	8
SUGAR HILL	MC	.5	3
SULLIVAN	LC	.1	1
SUNAPEE	LC	.6	3
SURRY	LC	2.2	14
SUTTON	CK	6.9	16
SWANZEY	LC	11.7	26
TAMWORTH	SA	15.3	26
TEMPLE	MM, CK	3.3	14
THOMPSON AND MESERVES PURCHASE	UC, MC	0	0
THORNTON	PE	9.0	18
TILTON	WI	3.7	33
TROY	LC	1.1	6
TUFTONBORO	WI, SA	8.7	21
UNITY	LC	1.1	3
WAKEFIELD	CO, SA	9.2	24
WALPOLE	LC	7.9	22
WARNER	CK	7.0	12
WARREN	PE, MC	2.6	5
WASHINGTON	CK, LC	.7	2
WATERVILLE VALLEY	PE, SA	2.6	4
WEARE	MM, CK	8.1	14
WEBSTER	CK	6.9	25
WENTWORTH	PE	4.2	10
WENTWORTH LOCATION	UC	2.2	11
WESTMORELAND	LC	3.3	9
WHITEFIELD	MC, UC	5.1	15
WILMOT	CK	3.0	10
WILTON	NS	5.3	20
WINCHESTER	LC	8.3	15
WINDHAM	LM	3.5	13
WINDSOR	CK	1.4	17
WOLFEBORO	WI, SA	6.4	13
WOODSTOCK	PE, MC	4.1	7

SUMMARY

New Hampshire is fortunate to have numerous stratified-drift aquifers that provide generally clean and plentiful ground water for a multitude of uses. These New Hampshire aquifers are products of glacial meltwater deposition from about 14,000 years ago and are scattered primarily in river valleys and other low-lying areas throughout the State. Aquifers composed of coarse sand and gravel materials, with large, interconnected pore spaces, are generally the most transmissive aquifers and yield the most water. These high-yielding aquifers were deposited as eskers, kame terraces, outwash plains, and deltas by meltwater during glacial retreat. Under natural or near-natural conditions, water quality from stratified-drift aquifers is generally good, although threats from natural and human-derived sources of contamination have been identified.

The public is encouraged to seek more information about any of the material presented in this report from the USGS office in Bow or the NHDES, Water Resources Division, in Concord.

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