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

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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.

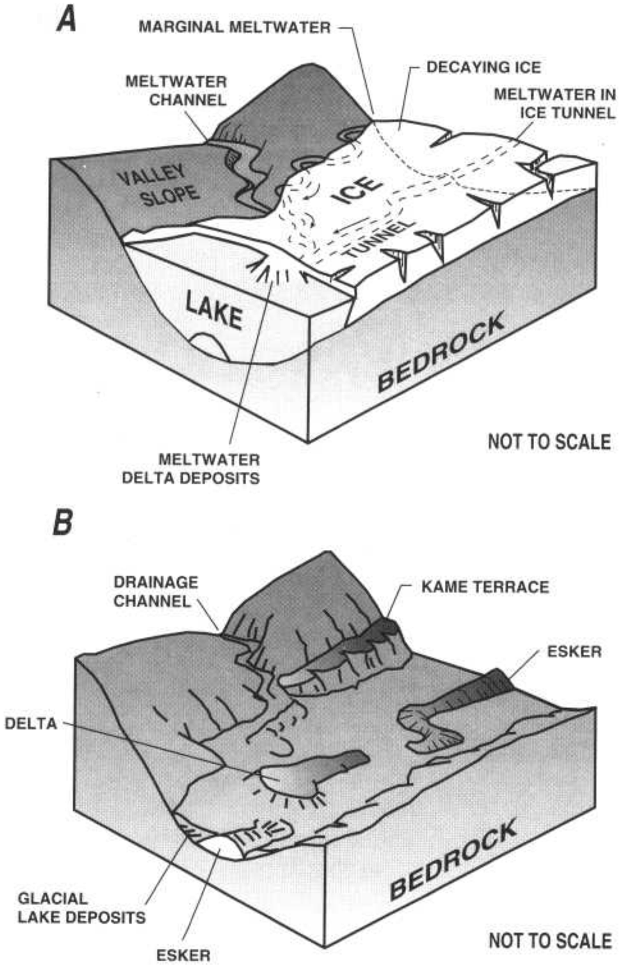

Figure 8. Depositional processes and features of typical stratified-drift deposits in New Hampshire. (*A*) Meltwater has formed a channel beneath the ice along the valley floor. A glacial lake has formed in low-lying areas fed by glacial streams. A delta has formed where the sediment-laden glacial stream 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.

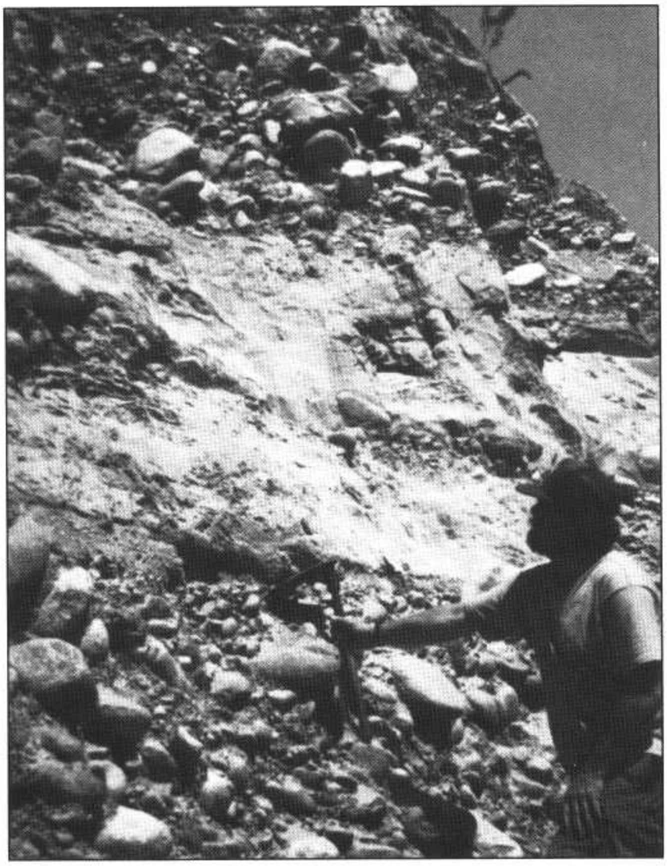

Figure 11. Well-sorted sand layers sandwiched between boulder and cobble layers at a site in Francestown, south-central New Hampshire. (Photograph taken by J.D. Ayotte, U.S. Geological Survey.)

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).

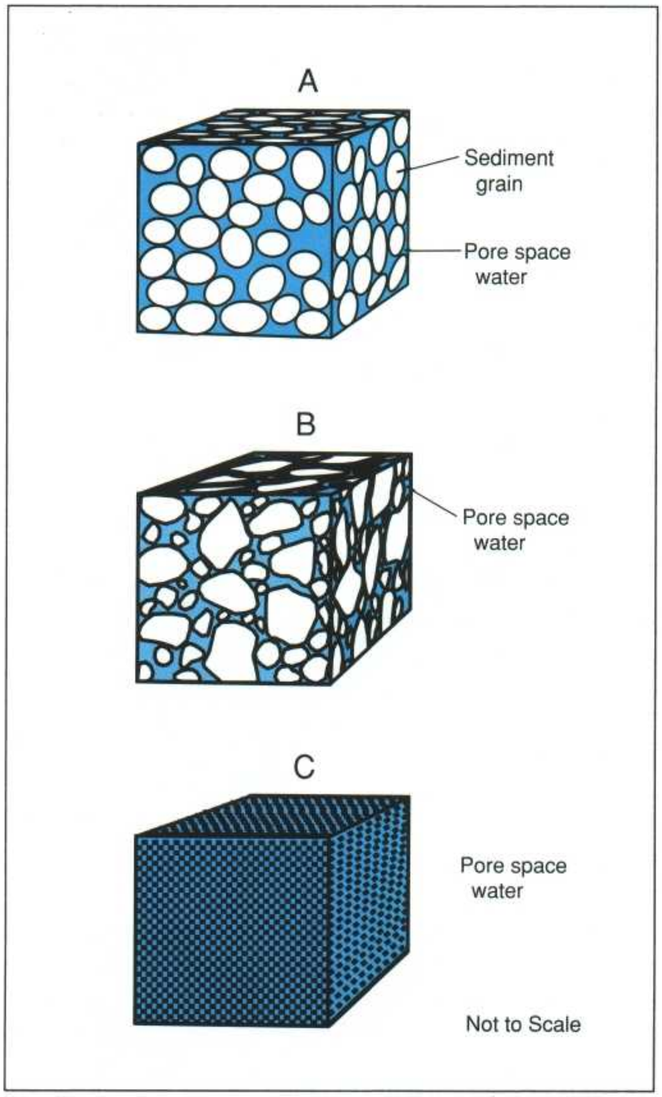

Figure 12. Shape, size, and sorting of sediments determine aquifer characteristics. (*A*) Rounded, coarse-grained, well-sorted material (uniform size) has high porosity and high hydraulic conductivity. (*B*) Angular, poorly sorted material (mixed sizes) has low porosity and low hydraulic conductivity. 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/ft^2). 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/ft^2 to ft/d, multiply by 0.1137

To convert transmissivity in gal/day/ft to ft^2/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 (ft^2/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.

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.)

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

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

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[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.

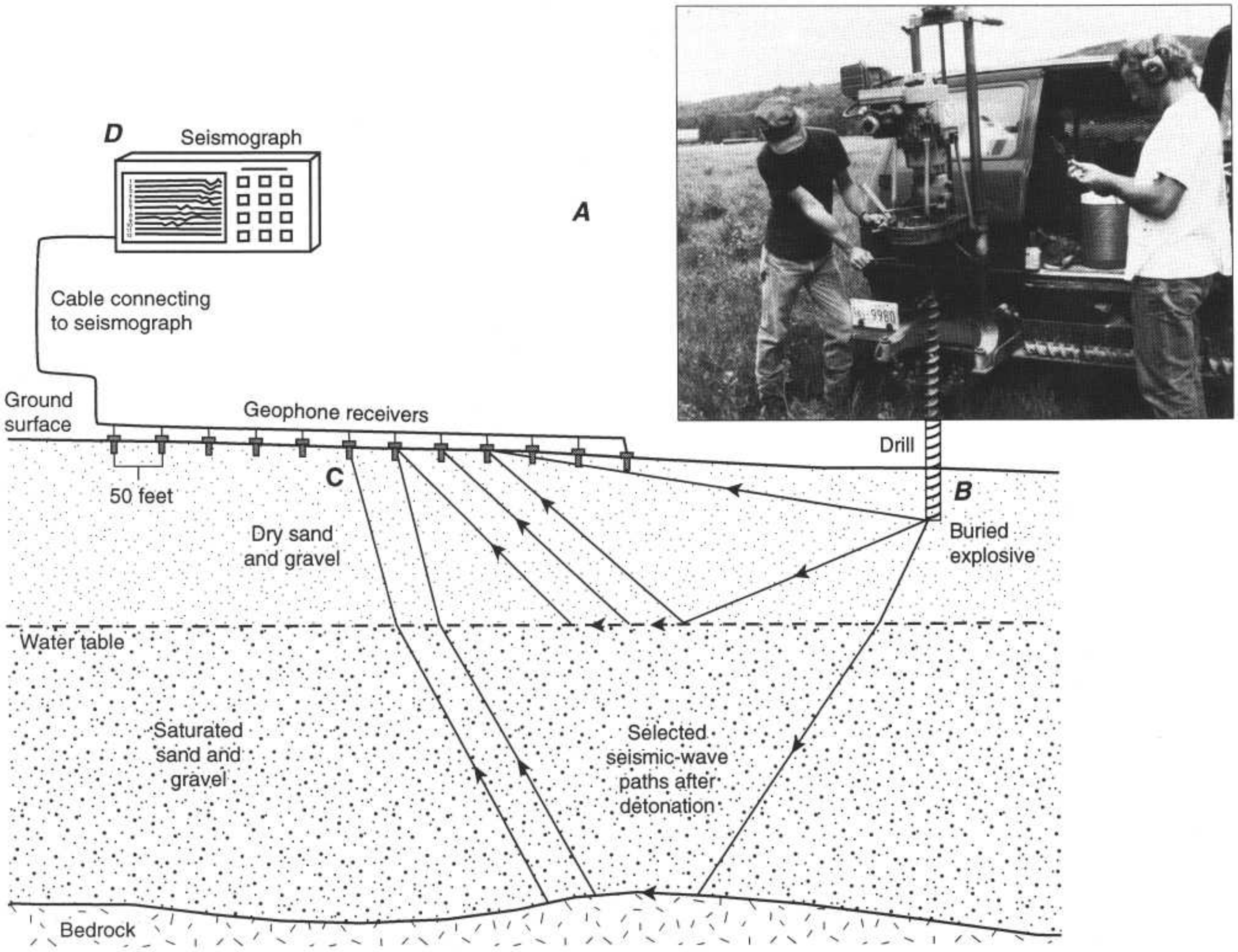

Figure 15. Seismic-refraction survey field work in Sugar Hill, northwestern New Hampshire. (*A*) Technician on the left side is drilling a "shot hole" for the explosive being prepared by the hydrologist on the right. (*B*) A carefully calculated amount of explosive material is used to generate enough 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.

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.
- 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 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).