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

Robert M. Hirsch, Chief Hydrologist
United States Geological Survey

Robert W. Varney

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

CONTENTS

FIGURES

CONTENTS—*Continued*

TABLES

CONVERSION FACTORS AND ABBREVIATIONS

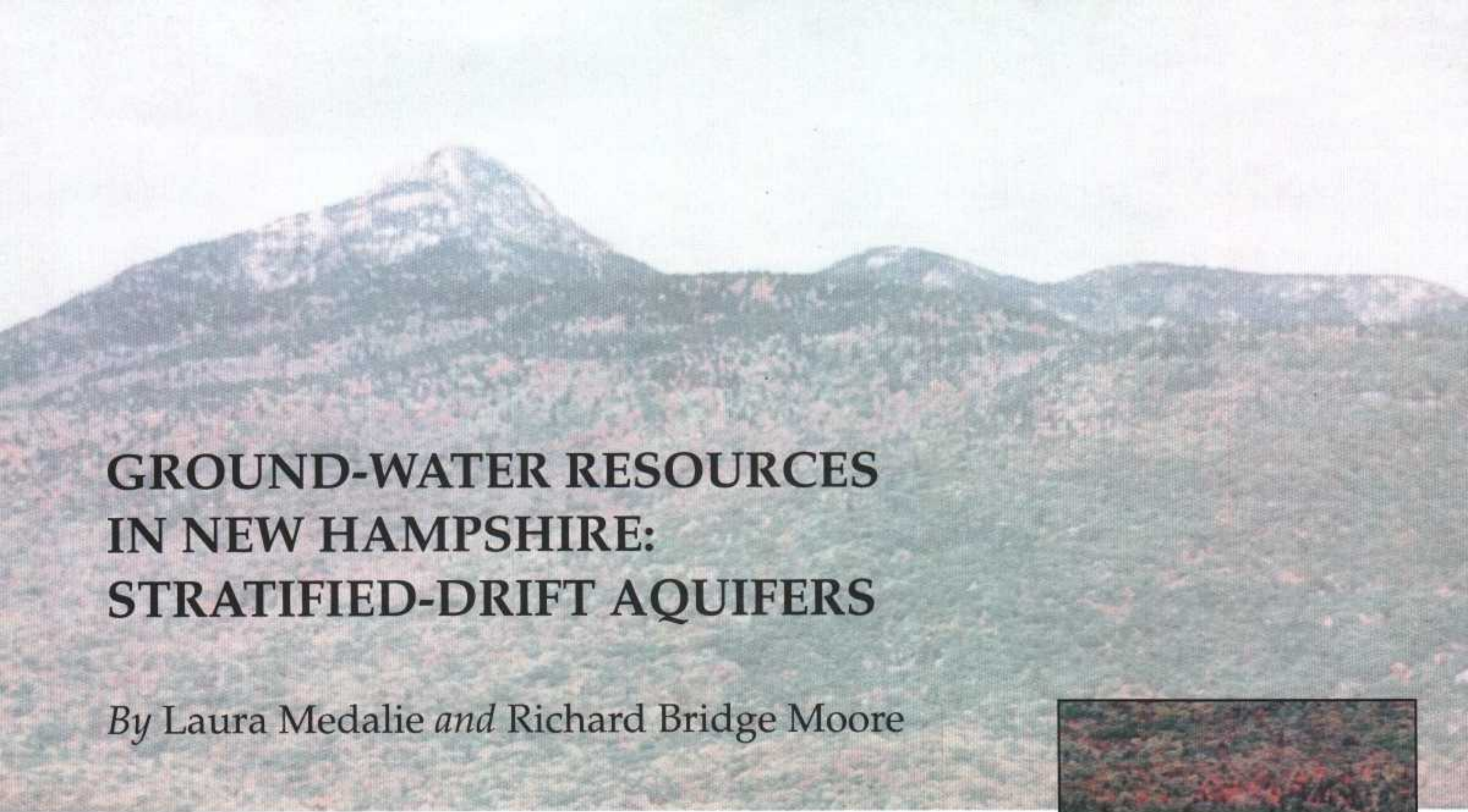
Multiply	By	To Obtain
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per second (ft/s)	0.3048	meter per second
foot squared per day (ft^2/d)	0.0929	square meter per day
gallon per day (gal/d)	0.003785	cubic meter per day
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square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



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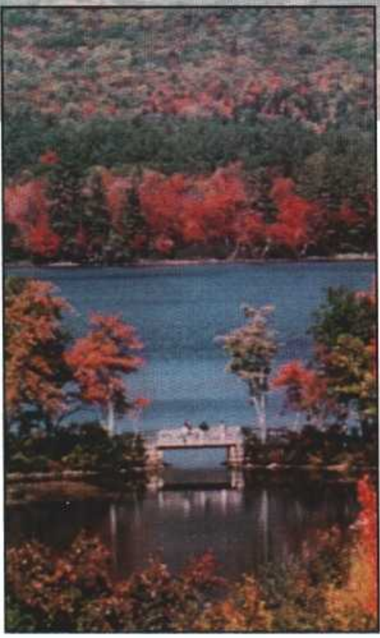

INTRODUCTION

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.

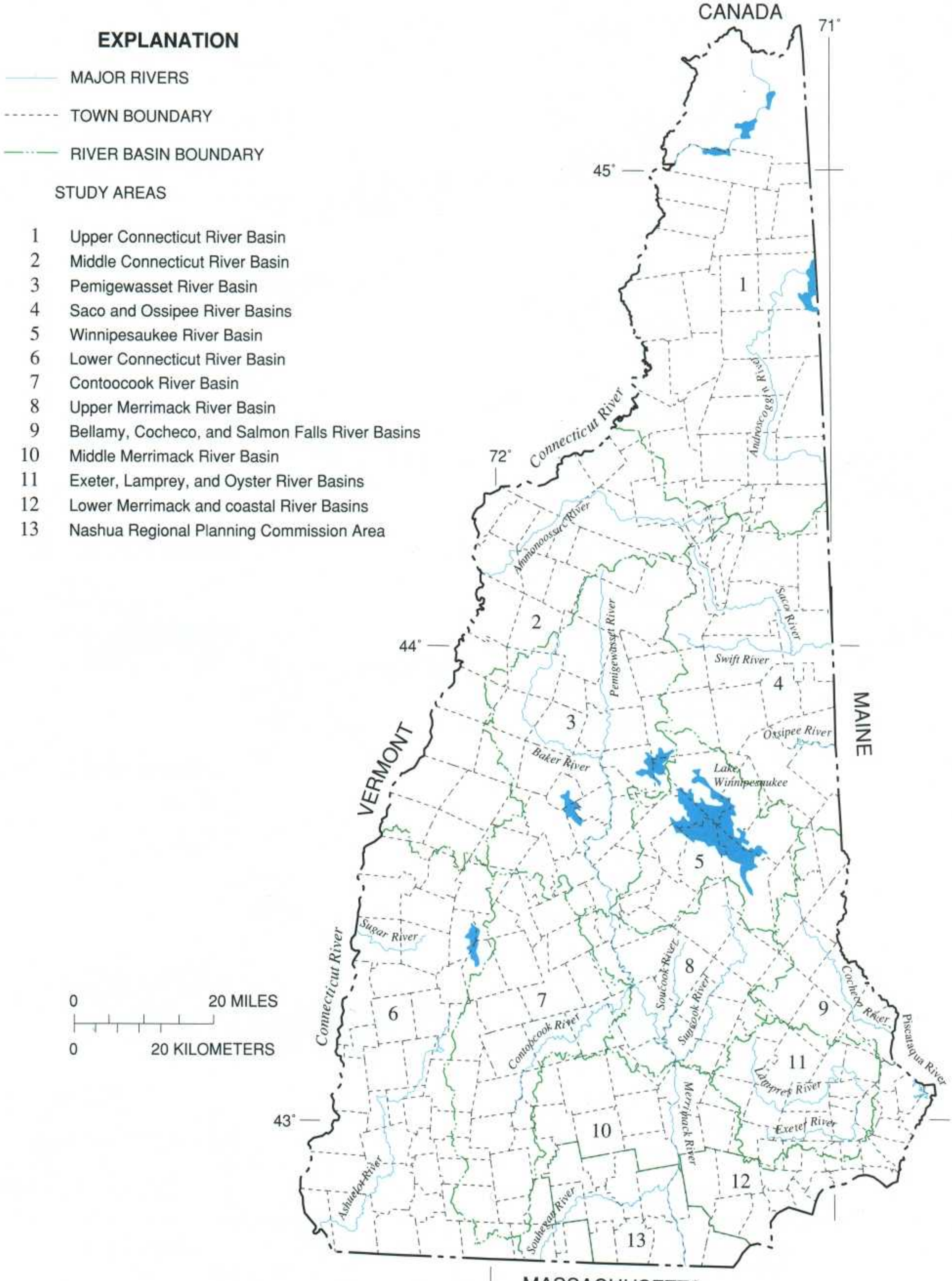

Figure 1. Study areas, major rivers, and town boundaries for U.S. Geological Survey stratified-drift-aquifer investigations in New Hampshire.

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.

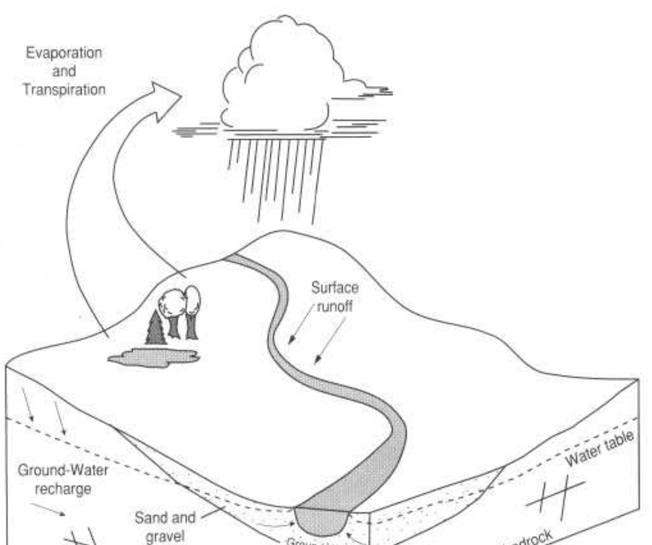

Figure 2. Generalized hydrologic cycle. Infiltrating water recharges ground water, which eventually discharges into streams and other surface-water bodies. Arrows show flow of water. (Modified from Waller, 1989.)

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.

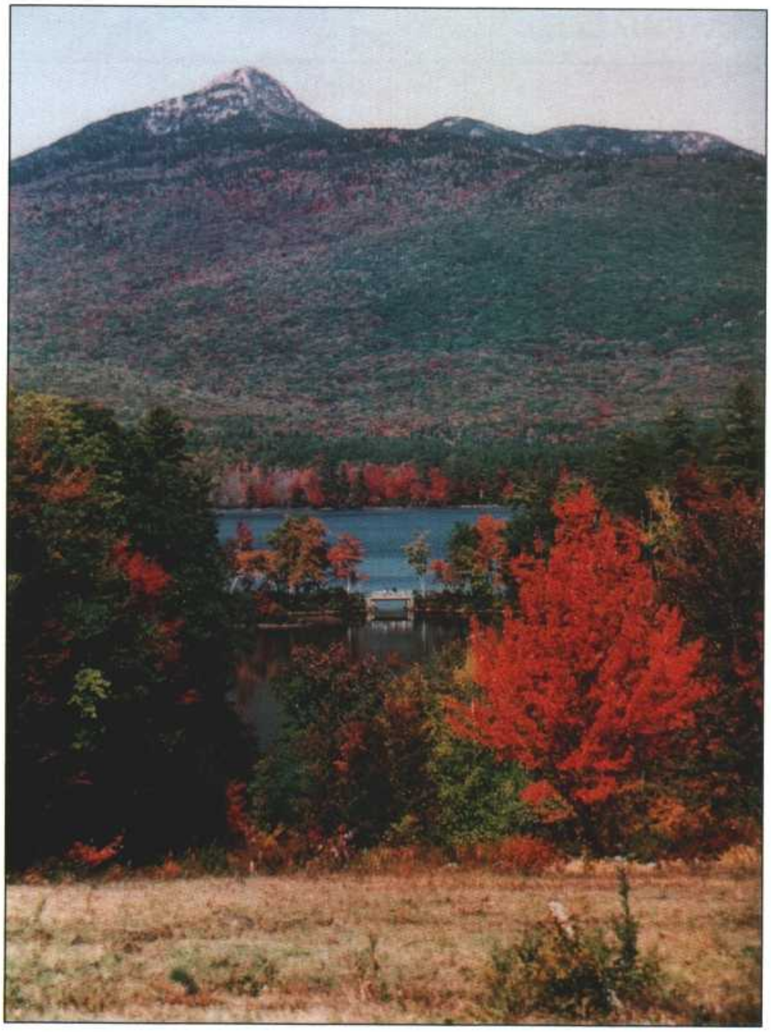

Figure 3. Chocorua Lake in Tamworth viewed from the south, east-central New Hampshire, a surface-water body fed primarily by ground-water discharge. (Photograph taken by B.R. Mrazik, U.S. Geological Survey.)

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).

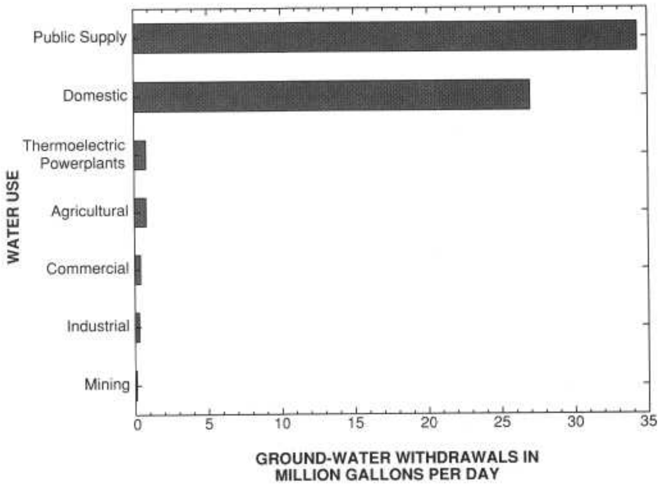

Figure 4. Ground-water withdrawals in New Hampshire by category in 1990. Bars shown above for domestic, thermoelectric powerplants, agricultural, commercial, industrial, and mining water uses represent the proportion for those categories that are self supplied—*not* from a public supplier.

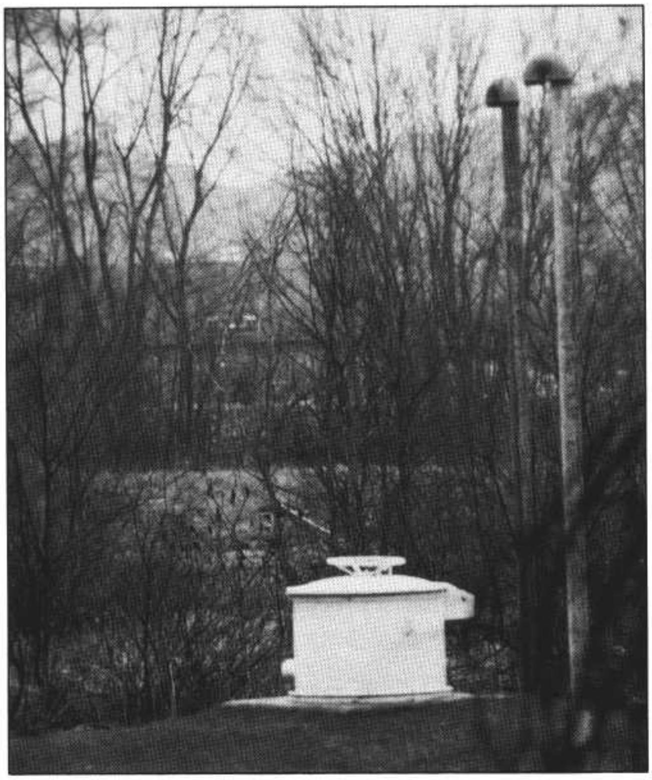

Figure 5. Gravel-packed public-supply well in stratified-drift aquifer in the town of Plymouth, central New Hampshire. (Photograph taken by B.R. Mrazik, U.S. Geological Survey.)

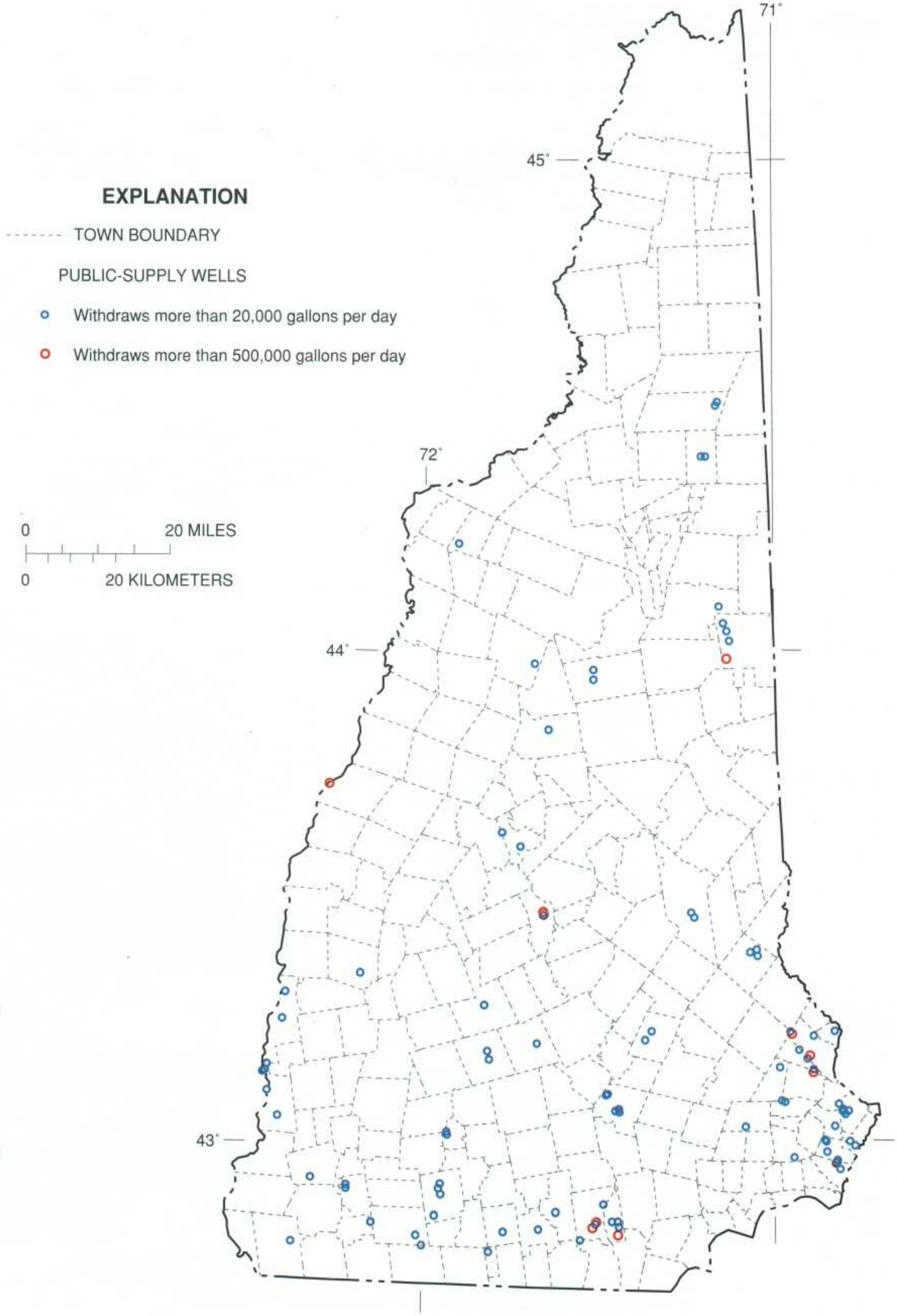

Figure 6. Locations of high-capacity public-supply wells from which more than 20,000 or more than 500,000 gallons of water per day are withdrawn from stratified-drift aquifers in New Hampshire.