In cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA NEW ENGLAND), NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES, NEW HAMPSHIRE ESTUARIES PROJECT, and NEW HAMPSHIRE DEPARTMENT OF HEALTH AND HUMAN SERVICES

ARSENIC CONCENTRATIONS IN PRIVATE BEDROCK WELLS IN SOUTHEASTERN NEW HAMPSHIRE

MAJOR FINDINGS:

- ***Nearly one-fifth (19 percent) of randomly selected private bedrock wells tested in southeastern New Hampshire contain concentrations of arsenic that exceed 0.010 milligrams per liter, the U.S. Environmental Protection Agency's maximum contamination level for public water supplies.***

- ***An estimated 41,000 people in Hillsborough, Rockingham, and Strafford Counties may have private bedrock wells with concentrations of arsenic that exceed 0.010 milligrams per liter.***

- ***Arsenic concentrations are similar in all three counties; however, the spatial distribution of arsenic concentrations that exceed 0.010 milligrams per liter is variable and relates to geology.***

- ***Although most of the well owners (90 percent) reported that they use the water from their bedrock well for drinking, less than 14 percent had tested for arsenic prior to this study.***

INTRODUCTION

Southeastern New Hampshire is a rapidly growing region that has been identified as having moderate to high concentrations of arsenic in drinking water from ground-water sources (Ayotte and others, 2003; Ayotte and others, 1999; Peters and others, 1999). Southeastern New Hampshire, comprised of Hillsborough, Rockingham, and Strafford Counties (fig. 1), has grown in population by more than 84,500 or 12 percent over the past decade to more than 770,400 (U.S. Census Bureau, 2000). These counties contain 62 percent of the State's population, but encompass only about 22 percent of New Hampshire's land area. More than 37 percent of the population in New Hampshire uses private wells as a source for drinking water (U.S. Census Bureau, 1990).

Previous studies have indicated that arsenic in ground water from bedrock wells is more prevalent in southeastern New Hampshire than in other areas of the State (Ayotte and others, 2003; Ayotte and others, 1999; Peters and others, 1999). These studies also indicate that the arsenic in ground water probably has geologic origins, but acknowledge that in some areas, arsenic occurrence may be related to present or past land-use practices.

Arsenic concentration in public drinking-water supplies is regulated by the U.S. Environmental Protection Agency (USEPA) because of the associated health risks. In 1999, the National Academy of Sciences concluded that the standard of 0.050 milligrams per liter (mg/L, equivalent to parts per million) for arsenic in drinking water did not sufficiently protect the public from long-term exposure. In response to this conclusion, the USEPA revised the public drinking-water standard from 0.050 to 0.010 mg/L (U.S. Environmental Protection Agency, 2001). The revised standard of 0.010 mg/L will be fully enforceable for public drinking-water supplies by the year 2006.

The quality of drinking water obtained from private wells in New Hampshire is not regulated; consequently, private wells are often not sampled for arsenic unless individual well owners choose to do so. To provide private well owners and Federal and State environmental and health officials with accurate information on arsenic concentrations from private wells in this region, the U.S. Geological Survey (USGS) conducted an arsenic occurrence and distribution study, in cooperation with the U.S. Environmental Protection Agency (EPA New England), New Hampshire Department of Environmental Services (NHDES), New Hampshire Estuaries Project, and with

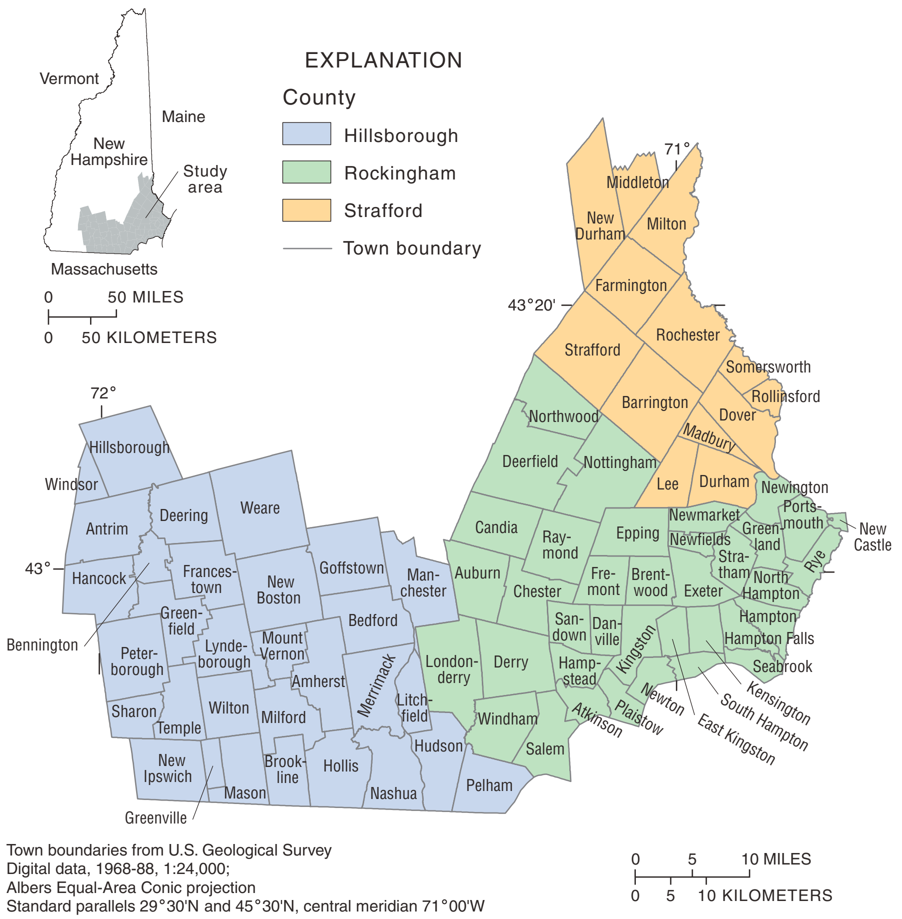

Figure 1. Locations of towns in Hillsborough, Rockingham, and Strafford Counties in the southeastern New Hampshire study area.

the New Hampshire Department of Health and Human Services (NHDHHS). This report describes the results of this study to determine the range of arsenic concentrations from ground water in the three counties of southeastern New Hampshire by analyzing water samples collected by a randomly selected group of well owners from this area.

Sampling Strategy

A database maintained by the NHDES containing information on private bedrock wells was used to randomly select wells from within the three-county study area. Sampling instructions and sample bottles were mailed to well owners. Samples were received from 353 participants—approximately 50 percent of all the well owners who received a sample packet. To obtain an unbiased representation of the ground-water quality in the study area, a computerized equal-area, random-well-selection approach was used (Scott, 1990). This random-well-selection approach ensured that the entire study area was represented, and that the number of samples received from each of the three counties was proportional to the size (area) of the county rather than its population. Study participants were asked to collect untreated water samples. Most of the water samples (56 percent) were collected from the kitchen faucet, 19.8 percent were collected from an outside spigot, and the remaining samples were collected at a spigot either before or after the pressure tank, or from the bathroom faucet. Samples were analyzed for total arsenic according to USEPA method 200.8 (U.S. Environmental Protection Agency, 1994) at either the NHDES Laboratory or the EPA New England Laboratory. The minimum reporting level for both laboratories was 0.001 mg/L. To assure the quality of the data obtained from this study, a quality-assurance project plan (QAPP) was developed. Quality-control samples represented 5 percent of the total samples collected for the study. The quality-control samples included duplicate, inter-laboratory split, and performance-evaluation samples. Results from the analysis of the quality-control samples indicated that there was no measurable bias or significant variability from either laboratory or between the two laboratories.

The Range of Arsenic Concentrations

Arsenic concentrations from the 353 ground-water samples received ranged from <0.001 to 0.215 mg/L. The median concentration (the value where 50 percent of the samples were higher and 50 percent were lower) of arsenic in each county is near the 3-county median of 0.002 mg/L (table 1). Over 30 percent of all the samples had at least

Table 1. Summary of arsenic concentrations and percent of wells with concentrations greater than 0.005, 0.01, and 0.05 milligrams per liter, by county

[No., number; <, less than]

County	No. of samples	Arsenic concentrations (milligrams per liter)			Percent of wells with arsenic greater than (milligrams per liter)		
		Minimum	Median	Maximum	0.005	0.01	0.05
Hillsborough	158	<0.001	0.002	0.075	32	21	3
Rockingham	125	<0.001	0.001	0.215	26	14	2
Strafford	70	<0.001	0.003	0.090	37	21	1
Overall	353	<0.001	0.002	0.215	31	19	2

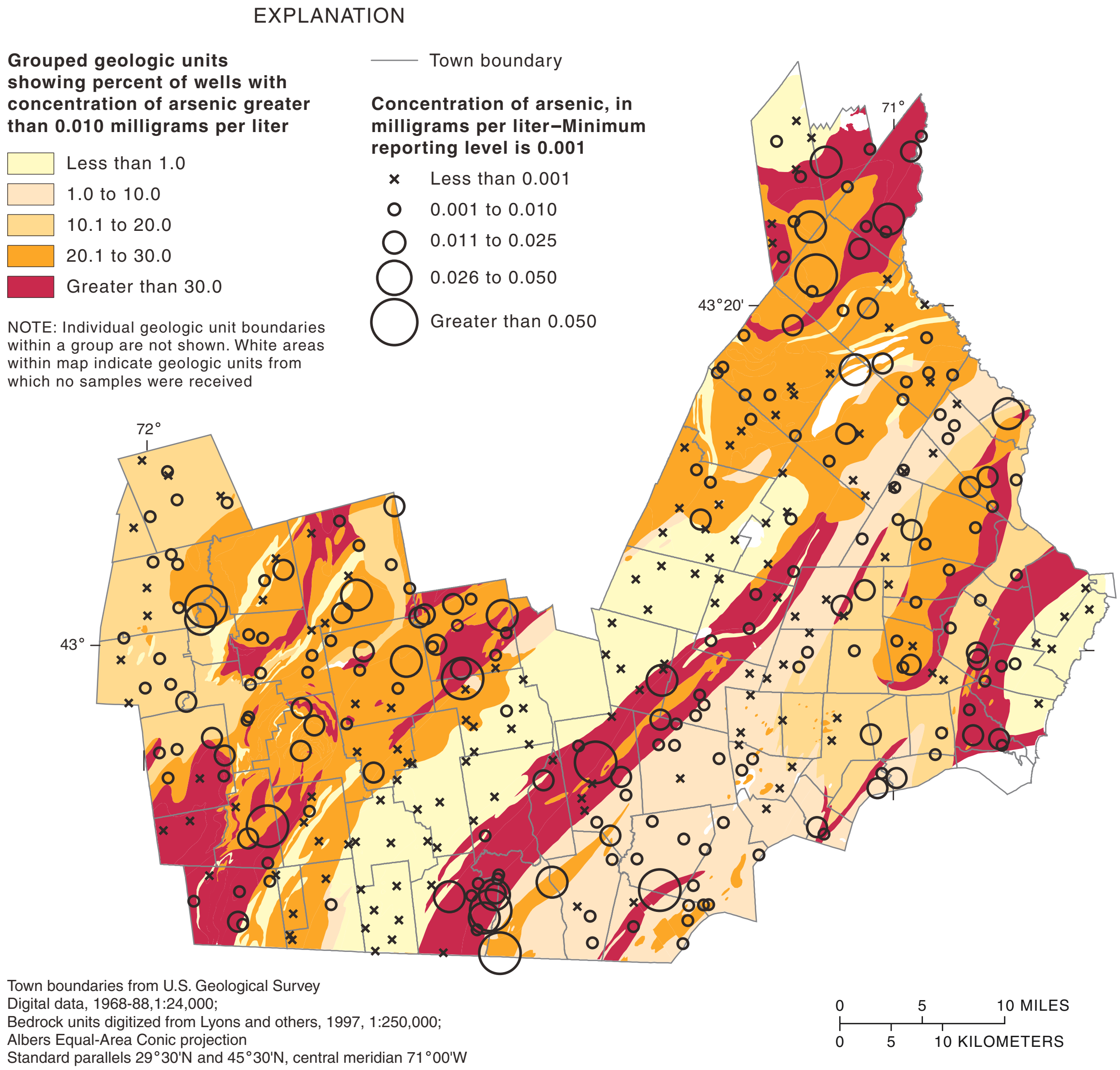

Figure 2. Concentrations of arsenic in private bedrock wells, and grouped geologic units showing percent of wells with concentrations of arsenic greater than 0.010 milligrams per liter. (For information on the individual geologic units in each group, see table 2.)

0.005 mg/L of arsenic in the water. The maximum concentration was 0.215 mg/L, but only eight samples (2 percent) were greater than 0.050 mg/L. Overall, 19 percent of the samples exceeded 0.010 mg/L. Twenty-one percent of the ground-water samples from Hillsborough and Strafford Counties had arsenic concentrations that exceeded 0.010 mg/L, whereas 14 percent of the samples from Rockingham County exceeded 0.010 mg/L. Although private bedrock wells are not required to meet Federal drinking-water standards, analytical results from the well samples are discussed for comparison purposes in terms of the recently approved public drinking-water standard of 0.010 mg/L.

Arsenic Occurrence in Relation to Geology

Although median concentrations of arsenic in water from private bedrock wells in each of the three counties are similar, there are distinct spatial patterns of arsenic concentrations greater than 0.010 mg/L within the study area (fig. 2). Data were analyzed in relation to mapped bedrock geologic units (referred to hereafter as geologic units in this report) identified on the State geologic map of New Hampshire (Lyons and others, 1997). Geologic units (also commonly referred to as formations, members, and groups) are rock types that have unique characteristics and thus, are defined based on factors such as processes of rock formation, mineral composition, and age. Arsenic data from the ground-water samples were grouped according to the geologic unit in which the well was located. This information was determined with geographic information system (GIS) analysis, using a digital version of the State geologic map of New Hampshire and the location of the wells. The GIS analysis identified 25 geologic units that were represented by these ground-water samples. The number of samples per geologic unit ranged from 1 to 54 and is related to the size (aerial extent) of the geologic unit in the study area (table 2). The percent of wells in each geologic

Table 2. Summary of the geologic units grouped by percent of samples with concentrations of arsenic greater than 0.010 milligrams per liter in ground water from private bedrock wells in southeastern New Hampshire

[fig., figure; No., number; mg/L, milligrams per liter; <, less than; geologic units from Lyons and others (1997). Color shading identifies the geologic units that compose the groups shown in figure 2]

Groups of geologic units (fig. 2)	Geologic unit	No. of samples	Percent of samples with concentrations of arsenic greater than 0.01 mg/L	Percent of study area underlain by geologic unit
Greater than 30 percent of samples				
	Ayer Granodiorite	2	50	<1
	Eliot Formation, Calef Member	2	50	<1
	Kittery Formation	11	46	3
	Rangeley Formation, lower part	16	31	4
	Rangeley Formation, upper part	16	31	5
	Berwick Formation, unnamed member	32	31	6
20.1 to 30 percent of samples				
	Spaulding Tonalite	40	28	10
	Exeter Diorite	11	27	3
	Littleton Formation	4	25	2
	Concord Granite	28	25	7
	Two-mica granite of northern and southeastern New Hampshire	4	24	2
	Perry Mountain Formation	21	24	6
10.1 to 20 percent of samples				
	Eliot Formation	20	20	8
	Kinsman Granodiorite	28	11	8
1 to 10 percent of samples				
	Berwick Formation	54	7	16
Less than 1 percent of samples				
	Smalls Falls Formation, undivided	3	0	1
	Massabesic Gneiss Complex	32	0	10
	Rangeley Formation, upper part, pink to green calc-silicate and purple biotite granofels	1	0	<1
	Madrid Formation, undivided	1	0	<1
	Rangeley Formation, undivided	3	0	<1
	Berwick Formation, Gove Member	3	0	<1
	Rye Complex	4	0	2
	Breakfast Hill Granite of Novotny (1964)	3	0	<1
	Mesoperthitic granite	3	0	1
	Gray biotite granite	11	0	3

unit with an arsenic concentration that exceeded 0.010 mg/L was computed. Geologic units with similar percents were then grouped together, as shown in figure 2 and table 2. The likelihood of having a well with arsenic at concentrations of concern for human health is shown in figure 2. Results of this analysis indicate that the number of ground-water samples with arsenic concentrations greater than 0.010 mg/L can vary between adjacent or nearby geologic units.

Specific geologic units stand out with respect to arsenic concentrations that exceeded 0.010 mg/L (table 2). Discussion in this section of the report is generally limited to geologic units that had at least 15 water samples. The Massabesic Gneiss Complex, for example, had no ground-water samples with concentrations of arsenic that exceeded 0.010 mg/L. In contrast, 25 and 28 percent of the ground-water samples from wells in the Concord Granite and the Spaulding Tonalite, respectively, had arsenic concentrations that exceeded 0.010 mg/L. Ten geologic units out of 25 had 25 percent or more of the wells with concentrations of arsenic greater than 0.010 mg/L.

Ground water from wells in different members or subdivisions of a geologic unit can have markedly different concentrations of arsenic greater than 0.010 mg/L. For example, the Berwick Formation consists of the main Berwick Formation and its two members—the Berwick Formation, Gove member; and the Berwick Formation, unnamed member (Lyons and others, 1997). Ground-

Table 3. Summary of reported problems with water quality and reported water-treatment methods used by private well owners in southeastern New Hampshire

[No., number; (34), number in parentheses is percent of problems or water-treatment methods; Note: more than one water-quality problem may have been reported per well]

No. of partici-pants	Type and number of reported water-quality problems						
	Staining: Iron/ manganese	Sediment	Taste/odor	pH	Radon		
353	120 (34)	88 (25)	43 (12)	6 (2)	2 (<1)		
No. of partici-pants	Type and number of reported water-treatment methods						
	Sediment filters	Ion exchange (Softeners)	Combinations: any two or three of the methods below: (Softeners/carbon filters/reverse osmosis/birm)	Oxidizing filters (Potassium permanganate/ birm/aeration)	Reverse osmosis	Carbon filter	Other
353	63 (18)	46 (13)	18 (5)	11 (3)	5 (1)	5 (1)	16 (5)

water samples from the main Berwick Formation had concentrations of arsenic greater than 0.010 mg/L in 7 percent of the samples, whereas, the Berwick Formation, unnamed member had concentrations that exceeded 0.010 mg/L in 31 percent of the samples. None of the three samples received from wells located in the Berwick Formation, Gove member had concentrations that exceeded 0.010 mg/L. Previous regional and local studies (Ayotte and other, 2003; Ayotte and others, 1999; Peters and others, 1999) also had identified frequent arsenic concentrations greater than 0.010 mg/L in several of these geologic units based on data from public and private wells.

The apparent relation of arsenic occurrence to geology provides a useful measure for predicting where arsenic concentrations in ground water are likely to exceed 0.010 mg/L. The data collected for this study, however, are of limited use in explaining why arsenic concentrations vary between and(or) within geologic units. Therefore, the concentration of arsenic in ground water for any given well cannot be accurately predicted; individual testing is necessary.

Water Use

Ninety percent of the study participants reported that they use the water from their private wells as drinking water. The remaining 10 percent (37) of the participants indicated that they do not drink the water from their well because of water-quality problems. The most frequently described problems were iron and(or) manganese staining (34 percent) and sediment (25 percent) (table 3). Only 13 percent of well owners reported that their well water had been previously tested for arsenic. Therefore, few private well owners were aware of the concentration of arsenic in their water. Of the 353 individuals who participated in the study, 46 percent (164) reported the use of some type of treatment or filtering system. Sediment filters were the most commonly reported system, followed by water softeners (18 and 13 percent, respectively). Only two participants specifically reported treating for arsenic. In general, water-treatment systems should be designed for the specific contaminant of interest, even though some systems may work for several contaminants. Treatment systems not specifically designed to remove arsenic, such as sediment filters or water softeners, may be ineffective and unreliable for removal of arsenic (Bernard Lucey, N.H. Department of Environmental Services, Water Division, oral commun., 2003).

Human Health Implications

The presence of arsenic in drinking water has been associated with adverse health outcomes, primarily cancers, and currently is regulated by Federal and State standards for public water supplies (U.S. Environmental Protection Agency, 2001). Although all public drinking-water supplies must meet the new arsenic standard by 2006, private drinking-water supplies are largely unregulated and are not required to meet this new standard. To show the effect on the population in southeastern New Hampshire, an estimate of the number of people with private wells with an arsenic concentration greater than 0.010 mg/L is presented.

Based on the population of the three-county region (U.S. Census Bureau, 2000) and water-use data from 1990 (U.S. Census Bureau, 1990), more than 285,000 people are estimated to use private water supplies. Water-use information tables for New Hampshire (U.S. Census Bureau, 1990) indicate that about 75 percent of people on private water supplies use bedrock wells rather then some other type of private source. Results from this study indicate that 19 percent of bedrock wells in the 3-county region have concentrations of arsenic greater than 0.010 mg/L; therefore, it can be estimated that approximately 41,000 people in the region have bedrock wells with arsenic at concentrations of concern for human health. This estimate may be conservative because recent well data from the State of New Hampshire indicate that from 1991 to 2000, approximately 95 percent of the wells constructed for private use in the three-county study area were bedrock wells (Rick Chormann, State of New Hampshire Geologic Survey, written commun., 2003).

Who to contact for more information:

The New Hampshire Consortium on Arsenic was formed in 2001 to better facilitate communication to the public of information related to all aspects of arsenic, and is a valuable source of arsenic information. The Consortium includes the USGS, USEPA, Dartmouth College, and agencies from the State of New Hampshire. The Consortium members can provide information to the public on treatment technologies, health effects, and occurrence of arsenic. Contact information is listed as the following:

Water testing and treatment guidelines:

New Hampshire Department of Environmental Services, Public Information Officer, Tim Drew (603) 271-3306, E-mail at tdrew@des.state.nh.us.

Health-related questions:

New Hampshire Department of Health and Human Services, Chief, Bureau of Environmental and Occupational Health, Neil Twitchell (603) 271-5870, E-mail at ntwitche@dhhs.state.nh.us.

Research on toxic effects of arsenic on ecosystems and human health:

Center for Environmental Health Sciences at Dartmouth, Associate Director for Outreach, Nancy Serrell (603) 650-1626, E-mail at nancy.serrell@dartmouth.edu.

Federal research on occurrence and sources of arsenic:

U.S. Geological Survey, Outreach Coordinator, Debra Foster (603) 226-7837, E-mail at dhfoster@usgs.gov.

Federal regulation guidelines:

U.S. Environmental Protection Agency, Toxicologist, Maureen McCelland (617) 918-1517, E-mail at mcclelland.maureen@epa.gov.

Acknowledgments

The authors thank the citizens who participated in the study and the staff at New Hampshire Department of Environmental Services Laboratory for sample analysis. The authors also thank the staff at EPA New England for their assistance—Richard Willey for supporting this project, Rhonda Mason for sample tracking, and the laboratory staff for sample analysis.

References Cited

Ayotte, J.D., Montgomery, D.L., Flanagan, S.M., Robinson, K.W., 2003, Arsenic in ground water in eastern New England: Occurrence, controls, and human health implications: Environmental Science and Technology, v. 37, no. 10, p. 2075-2083.

Ayotte, J.D., Nielsen, M.G., Robinson, G.R., Jr., Moore, R.B., 1999, Relation of arsenic, iron, and manganese in ground water to aquifer type, bedrock lithogeochemistry, and land use in the New England Coastal Basins: U.S. Geological Survey Water-Resources Investigations Report 99-4162, 61 p.

Lyons, J.B., Bothner, W.A., Moench, R.H., and Thompson, J.B., Jr., 1997, Bedrock geologic map of New Hampshire: U.S. Geological Survey Special Map, 2 map sheets, scale 1:250,000.

National Research Council, 1999, Arsenic in drinking water: Washington, D.C., National Academy Press, 263 p.

Peters, S.C., Blum, J.D., Bjoern, Klaue, and Karagus, M.R., 1999, Arsenic occurrence in New Hampshire drinking water: Environmental Science and Technology, v. 33, no. 9, p. 1328-1333.

Scott, J.C., 1990, Computerized stratified random site-selection approaches for design of ground-water quality sampling network: U.S. Geological Survey Water-Resources Investigations Report 90-4101, 109 p.

U.S. Census Bureau, 2000, Municipal populations 1960-2000—Arranged by county: U.S. Census Bureau, accessed March 21, 2003, at http://www.state.nh.us/osp/sdc/Munipop60-00.doc

———1990, Historical census of housing tables—Sources of water: U.S. Census Bureau, accessed February 10, 2003, at http://www.census.gov/hhes/www/housing/census/historic/water.html

U.S. Environmental Protection Agency, 2001, National primary drinking water regulations; Arsenic and clarifications to compliance and new source contaminants monitoring; Final rule: Federal Register Part VIII, 40 CFR, Parts 9, 141 and 142, p. 6981.

———1994, Methods for the determination of metals in environmental samples, supplement I: U.S. Environmental Protection Agency/600/R-94/111, rev. 5.4.

NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES RECOMMENDS THAT ALL PRIVATE WELLS BE TESTED

Private wells in New Hampshire are not regulated as water supplies, and are often not tested for health-related contaminants such as arsenic, a common contaminant found in bedrock wells in New Hampshire. The State of New Hampshire recommends that all private wells be tested for arsenic and a number of other naturally occurring health-related contaminants.

Information on the State of New Hampshire's recommendations for testing and guidance on water treatment options of private wells is available at http://www.des.state.nh.us/ws.htm

Fact Sheet WD-WSEB-2-1: Suggested Water-Quality Testing for Private Wells

Fact Sheet WD-WSEB-3-2: Arsenic in Drinking Water

FOR ADDITIONAL INFORMATION:

The data for this study are available at:

U.S. Geological Survey
New Hampshire/Vermont District
361 Commerce Way
Pembroke, NH 03275
(603) 226-7800 Phone
(603) 226-7894 FAX

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver Federal Center
Denver, CO 80225-0286

Visit USGS Web sites at URL:
http://nh.water.usgs.gov
http://www.usgs.gov

NAWQA Program:
http://water.usgs.gov/nawqa

—By Denise L. Montgomery[1], Joseph D. Ayotte[1], Paul R. Carroll[2], and Patricia Hamlin[2]

[1]U.S. Geological Survey.
[2]U.S. Environmental Protection Agency (New England).