NEW HAMPSHIRE
Ground-Water Quality

Ground water is a major source for public supply in New Hampshire; about 57 percent of the population (fig. 1) depends on ground water. Water from principal aquifers in the State (fig. 2) does not exceed the drinking-water standards developed by the New Hampshire Department of Environmental Services (1984) for dissolved solids, hardness, and nitrate, which are important indicators of water quality. Subsurface waste disposal (fig. 3) and urbanization have caused contamination in some areas, and highway deicing has affected ground-water quality along roads throughout the State. Upland areas away from highways have not been affected by road salting.

Fifty-four hazardous-waste sites require monitoring of ground-water quality under the Federal Resource Conservation and Recovery Act (RCRA) of 1976. In addition to these 54 RCRA sites, 13 others have been proposed or included in the National Priorities List (NPL) of hazardous-waste sites by the U.S. Environmental Protection Agency (1986c) and will be evaluated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. In addition, the U.S. Department of Defense (DOD) has identified two sites at two facilities where contamination has warranted further investigation.

Ground-water quality currently is monitored by the Water Supply and Pollution Control Division (WSPCD) and Waste Management Division (WMD) of the New Hampshire Department of Environmental Services (NHDES). The U.S. Geological Survey has been monitoring background water quality in stratified-drift aquifers since 1983 as part of a cooperative program with the NHDES to identify important stratified-drift aquifers in the State.

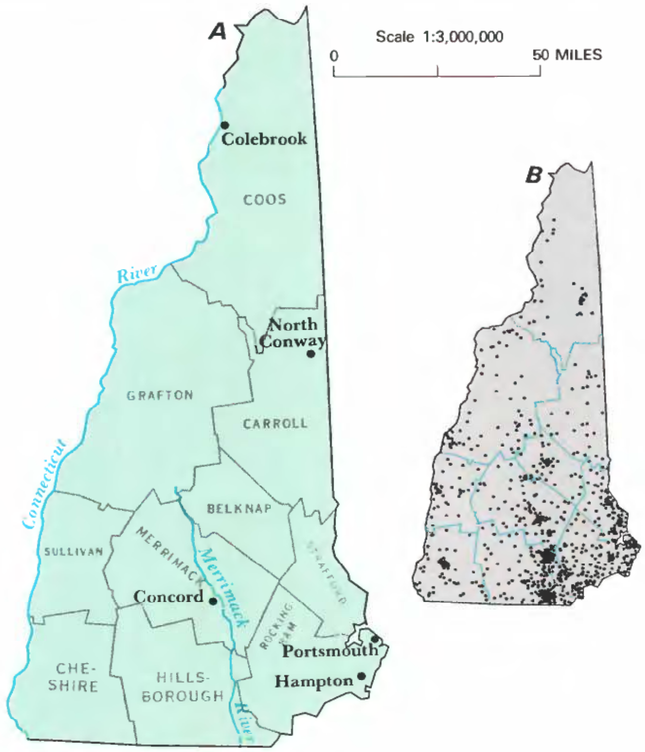

Figure 1. Selected geographic features and 1985 population distribution in New Hampshire. *A*, Counties, selected communities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted to the 1985 U.S. Bureau of the Census data for county populations.)

WATER QUALITY IN PRINCIPAL AQUIFERS

Stratified drift and crystalline bedrock comprise the principal aquifers in New Hampshire (U.S. Geological Survey, 1985, p. 303). Water from stratified-drift aquifers generally can be classified as having small concentrations of dissolved solids and being slightly acidic and soft. Stratified-drift aquifers consist of unconsolidated sand and gravel deposits that are usually less than 100 feet thick. These aquifers are commonly located along river valleys and in broad outwash plains and are bordered by till or bedrock uplands as shown by the block diagram, figure 2*B*. Water in stratified drift is generally unconfined, and depth to the water table is usually less than 20 feet. Yields from public-supply wells in stratified-drift aquifers may be as much as 1,500 gal/min (gallons per minute).

Although most of the State's ground-water withdrawals for public supply are from stratified-drift aquifers, most domestic and small public-supply wells are completed in bedrock aquifers. Water in bedrock aquifers, which consist of igneous and metamorphic rocks such as granite, gneiss, and schist, is present in fractures. Water from the bedrock aquifer can be classified as having moderate levels of dissolved solids and being slightly acidic and moderately hard to hard. Yields from wells in these aquifers typically are less than 10 gal/min, although some large-yield community and public-supply wells are located in areas where bedrock is extensively fractured.

BACKGROUND WATER QUALITY

A graphic summary of selected water-quality variables compiled from analyses in the files of the NHDES laboratory is presented in figure 2*C*. The summary is based on specific conductance, hardness (as calcium carbonate), nitrate plus nitrite (as nitrogen), iron, and sodium analyses of water samples collected from 1980 to 1985 from the principal aquifers in New Hampshire. Percentiles of these variables are compared to national standards that specify the maximum concentration or level of a contaminant in drinking-water supply as established by the U.S. Environmental Protection Agency (1986a,b). The primary maximum contaminant level standards are health related and are legally enforceable. The secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The primary drinking-water standards include a maximum concentration of 10 mg/L (milligrams per liter) nitrate (as nitrogen), and the secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids and 300 μg/L (micrograms per liter) iron.

Stratified-Drift Aquifers

Analyses of water from public-supply wells completed in the stratified-drift aquifers (aquifer 1) are summarized in figure 2*C*. The data are for towns with public-supply wells that pump at least 100,000 gal/d (gallons per day).

The median value of specific conductance for water in stratified-drift aquifers was 132 μS/cm (microsiemens per centimeter at 25° Celsius). Using conversion factors given by Hem (1985), this median value is equivalent to 75 to 100 mg/L of dissolved solids. The maximum observed specific conductance of water from these data was 469 μS/cm, which is equivalent to 260 to 350 mg/L of dissolved solids. The small concentrations of dissolved solids in water from stratified-drift aquifers are related to the relative insolubility of the aquifer matrix and the relatively short time that water is in contact with the aquifer.

Because calcium and magnesium, which contribute to the hardness of water, are widely distributed in the rocks and soil, they are the principal cations in most natural freshwater (Hem, 1985).

The median concentration of hardness in the stratified-drift aquifers of New Hampshire was 37 mg/L (fig. 2*C*); 75 percent of the samples mentioned in this summary had hardness concentrations of 60 mg/L or less. Water with hardness less than 60 mg/L is termed "soft".

Nitrate plus nitrite (as nitrogen) was usually less than 1 mg/L in stratified-drift aquifers (fig. 2*C*). The largest observed concentration, 3.4 mg/L, was in water from a well in Hampton and was probably caused by fertilizers and (or) septic wastes associated with nearby residential development (Bernard Lucy, New Hampshire Department of Environmental Services, written commun., 1987).

The median iron concentration for water from stratified-drift aquifers was 100 μg/L (fig. 2*C*). About 25 percent of the wells tested had iron concentrations that exceeded the 300-μg/L limit recommended by the New Hampshire Department of Environmental Services. The largest concentration was 1,200 μg/L. Increased concentrations of iron are not known to be harmful to humans. However, increased concentrations of iron can cause staining of clothes and plumbing fixtures and can impart an objectionable taste to water.

The New Hampshire Department of Environmental Services (1984) recommended that sodium concentrations in drinking water not exceed 250 mg/L for healthy people and 20 mg/L for people with cardiac or kidney problems or hypertension. Sodium concentrations in the wells sampled ranged from 1 to 58 mg/L, with a median concentration of 11 mg/L. Increased concentrations of sodium in ground water usually are caused by salt that is used for road deicing and stored in piles near roadways or by saltwater intrusion in coastal areas.

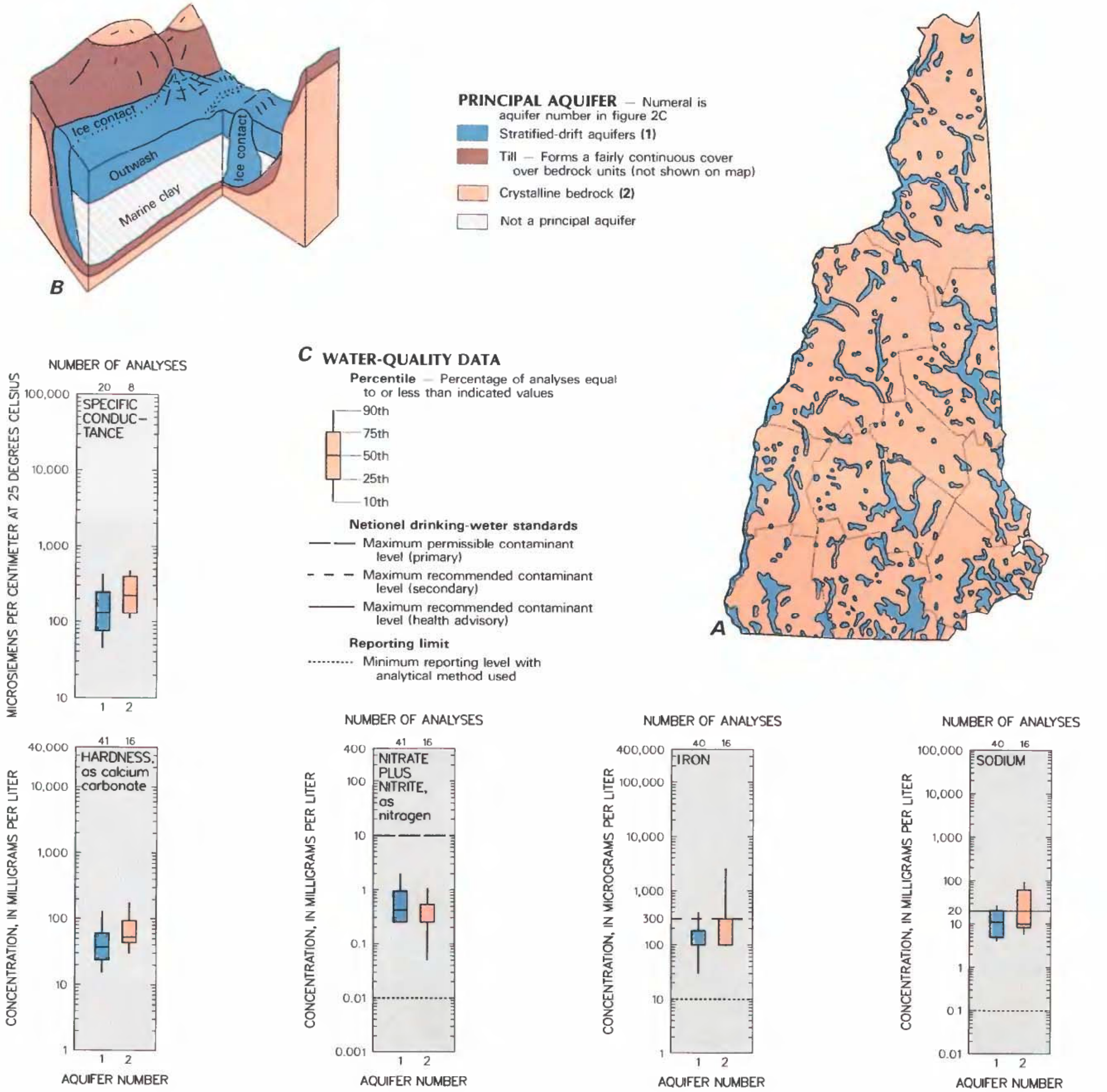

Figure 2. Principal aquifers and related water-quality data in New Hampshire. *A*, Principal aquifers; *B*, Generalized block diagram. *C*, Selected water-quality constituents and properties, as of 1980-85. (Sources: *A*, *B*, Compiled by R.E. Hammond and J.E. Cotton from U.S. Geological Survey files. *C*, Analyses compiled from New Hampshire Department of Environmental Services Laboratory files; national drinking-water standards from U.S. Environmental Protection Agency, 1986 a,b.)

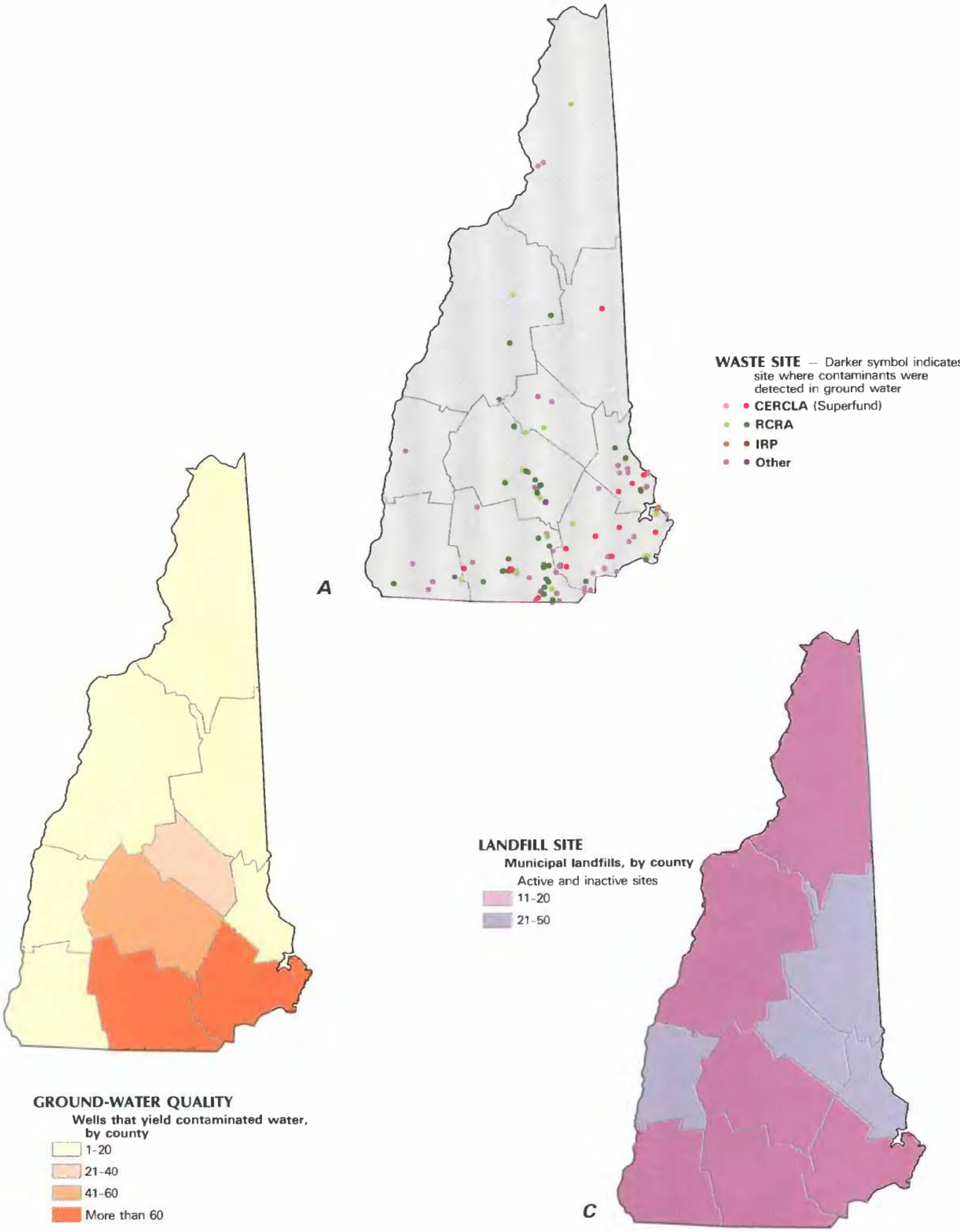

Figure 3. Selected waste sites and ground-water-quality information in New Hampshire. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; Resource Conservation and Recovery Act (RCRA) sites; Department of Defense Installation Restoration Program (IRP) sites, as of January 1987; and other selected waste sites, as of January 1987. *B*, Distribution of wells that yield contaminated water, as of January 1987. *C*, Municipal landfills, as of January 1987. (Sources: *A*, New Hampshire Department of Environmental Services, Waste Management Division files; U.S. Department of Defense, 1986. *B*, New Hampshire Departments of Environmental Services and Transportation files. *C*, New Hampshire Department of Environmental Services, Waste Management Division files.)

Crystalline-Bedrock Aquifers

Analyses of water from public-supply wells completed in bedrock (aquifer 2) are summarized in figure 2*C*. The yields of these wells range from 40,000 to 1,500,000 gal/d.

Water from bedrock aquifers had larger specific conductances and, therefore, more dissolved solids than water from stratified drift (fig. 2*C*). The median specific conductance is 222 μS/cm in bedrock, which is equivalent to 120 to 170 mg/L dissolved solids.

The hardness of water from bedrock ranges from 24 to 182 mg/L, with a median value of 53 mg/L. This water was generally harder than water from stratified drift, and about 50 percent of the samples are moderately hard to very hard (fig. 2*C*).

Water from the crystalline-bedrock aquifer had nitrate plus nitrite as nitrogen concentrations that are slightly smaller than those in stratified-drift aquifers, ranging from 0.05 to 1.5 mg/L with a median value of 0.25 mg/L. The most common sources of increased concentrations of nitrogen in ground water are faulty septic systems and fertilizers.

Iron is found in ground water that is in contact with iron-rich crystalline rocks. The median value was 100 μg/L, but almost one-third of all wells sampled had iron concentrations at or larger than 300 μg/L, the recommended limit for drinking water. Filtration is commonly used to control elevated concentrations of iron in drinking water and water used in trout and salmon hatcheries. Sodium in bedrock aquifers ranged from 1 to 97 mg/L with a median concentration of 10 mg/L.

Levels of arsenic in excess of the State and Federal maximum contaminant level of 50 μg/L were detected in 10 to 15 percent of the bedrock wells tested in private, State, and municipal programs. Arsenic can have as its source sulfide minerals in bedrock, such as pyrite (U.S. Environmental Protection Agency, 1981) or detergents present in septic waste (Boudette and others, 1985).

Radon-222, which may be carcinogenic when inhaled, has been found in water from bedrock wells in New Hampshire. Radon levels generally were largest in water from granites containing the micas muscovite and biotite. Other sources include quartz monzonite, granite, high- and low-grade metamorphic rocks, and diorite (Hall and others, 1985). Other radionuclides found in bedrock wells include uranium, radium-222, and radium-228. The NHDES estimates that significant concentrations of these constituents occur in 5 percent of bedrock wells.

EFFECTS OF LAND USE ON WATER QUALITY

Ground-water quality has deteriorated in some areas, especially urban areas, mostly because of road salting and salt storage, leaking underground petroleum storage tanks, and underground disposal of septic waste. In addition, ground-water contamination has occurred near hazardous-waste disposal sites and landfills. Except for contamination by road salt, only localized ground-water contamination has occurred in New Hampshire.

Waste Disposal

New Hampshire currently has 13 hazardous-waste sites that are included on the NPL of CERCLA (U.S. Environmental Protection Agency, 1986c). Most of these sites are located in southern and southeastern New Hampshire in Hillsborough, Rockingham, and Strafford Counties (fig. 3*A*). At least 3 public-supply wells and more than 30 private wells near these CERCLA sites have been contaminated. In addition, hazardous wastes are treated, stored, or disposed of at 54 RCRA sites within New Hampshire (fig. 3*A*). Ground-water contamination has been detected at 35 of these RCRA sites (K. Marschner, New Hampshire Department of Environmental Services, written commun., 1987).

As of September 1985, 22 hazardous-waste sites at 4 facilities in New Hampshire had been identified by the DOD as part of their Installation Restoration Program (IRP) as having potential for contamination (U.S. Department of Defense, 1986). The IRP, established in 1976, parallels the U.S. Environmental Protection Agency (EPA) Superfund program under the CERCLA of 1980. EPA presently ranks these sites under a hazard ranking system and may include them in the NPL. Two sites at two facilities (fig. 3*A*) were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. The remaining sites were scheduled for confirmation studies to determine if remedial action is required.

Organic compounds, mostly solvents from industrial waste, are some of the major ground-water contaminants in the State. Landfills, transfer stations, waste lagoons, drum-storage sites, and illegal discharge are the most common sources of organic contaminants. The most common organic contaminants are dichloroethane, trichloroethylene, tetrachloroethane, benzene, ethylbenzene, and toluene. Inorganic contaminants include hydrochloric acid and trace metals, such as chromium, cadmium, copper, and lead.

Septic Waste

About 50 percent of the State's population uses septic systems that discharge underground. The State also contains 95 sludge-disposal sites and 50 sites with lagoons for disposal of septic wastes. Contamination of public wells with septic waste is not a major problem in New Hampshire. However, in areas with many underground septic systems such as North Conway (Carroll County), increased concentrations of nitrate have been detected in ground water (Johnson and others, 1986).

Solid-Waste Landfills

In 1980, the annual generation of solid waste in New Hampshire was more than 927,000 tons (2.3 million cubic yards) (New Hampshire Office of State Planning, 1981). This waste has been disposed of at 246 sites (fig. 3*C*), 83 of which remain active in 1987. Four of these landfill sites were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. Leachate produced by rain seeping through solid waste commonly contains increased concentrations of calcium, sodium, iron, sulfate, and chloride. Trace metals, such as lead, nickel, and cadmium, and organic compounds, such as phenols, trichloroethylene, and tetrahydrofuran also are commonly detected in landfill leachate. The four landfill sites included on the CERCLA list have caused contamination of many private wells.

Urbanization

New Hampshire's population grew 25 percent from 1970 to 1980 (U.S. Bureau of the Census, 1982). Much of this growth has been in the southern part of the State in Hillsborough, Merrimack, and Rockingham Counties. However, some areas in northern New Hampshire near recreation areas, such as Lake Winnipesaukee and the White Mountains, also have been developed in recent years.

The use of salt, mostly sodium chloride, for deicing roads began in the 1940's and increased steadily until the 1970's. In the early to mid-1960's, the annual salt usage on State highways was about 85,000 tons, but in the late 1960's and early 1970's, about 150,000 tons of salt was used annually (Hall, 1975). Examples of increases in chloride in public-supply well water from 1915 to 1970 are shown in figure 4 for the towns of Portsmouth, Colebrook, and Hampton. Before road salting began, natural (background) concentrations of chloride in ground water appear to have been smaller than 10 mg/L at each of these locations. Chloride increases have occurred mainly in urban areas and along highways; upland areas above highways have been unaffected.

Since 1979, the New Hampshire Department of Transportation has replaced 267 wells contaminated by road salt, but funds have not been available to replace all contaminated wells (W. Campbell, New Hampshire Department of Transportation, written commun., 1986). Wells contaminated by road salt are represented by about 79 percent of all wells that yield contaminated water shown in figure 3*B*.

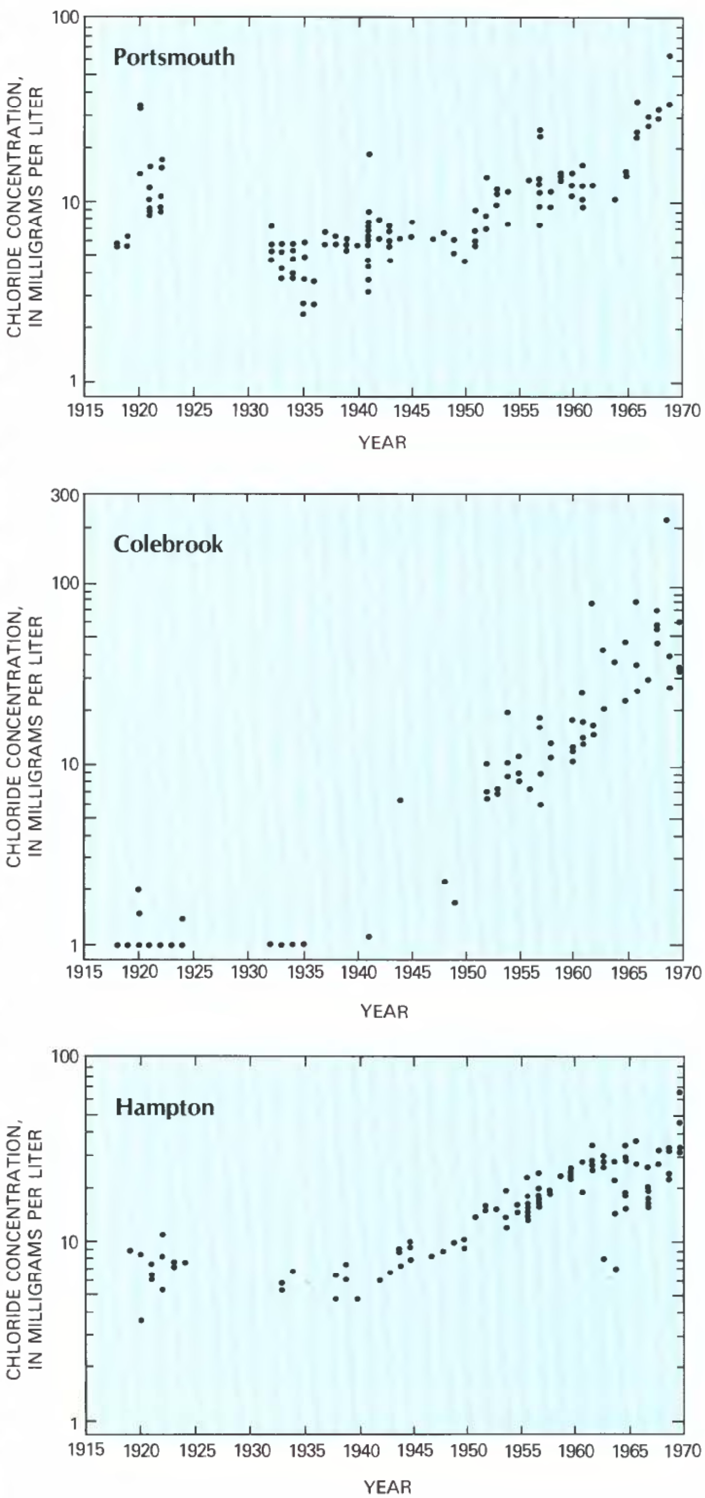

Figure 4. Variations in chloride concentrations in water from the Portsmouth, Colebrook, and Hampton public-supply wells, 1918–70. (Source: Modified from Hall, 1975.)

Some vegetation, such as elms, maples and grasses, that has little tolerance to salt and that is located near salted highways has been killed or damaged. Water that contains salt is corrosive to home water systems; corrosion may result in increased concentrations of iron, copper, zinc, and cadmium in drinking water. Ingestion of sodium also can create complications for people with heart, kidney, and liver ailments and especially for those with hypertension who are on sodium-restricted diets (Hall, 1975).

In New Hampshire, at least 20 incidences are reported annually of gasoline and petroleum products leaking from storage tanks; more than 35 major water supplies have been contaminated (Sills and others, 1985). The Water Supply and Pollution Control Division of NHDES estimates that at least 70 private wells have been contaminated by gasoline in the past few years (B. Foster, New Hampshire Department of Environmental Services, written commun., 1986). Several chemicals that are present in gasoline, such as benzene and ethylene dibromide, are carcinogenic. Because technology to clean ground water is relatively new and expensive, the standard remedy has been to provide alternative water supplies to affected residents.

Potential for Changes in Water Quality

Stratified-drift aquifers in New Hampshire are susceptible to contamination because they are usually less than 100 feet thick, unconfined, and have permeable materials in the thin unsaturated zones above the water table. A well that pumps 1,000,000 gal/d in such an aquifer may draw water from an area as large as 1.7 square miles (Morrissey, 1986). If contaminants enter the ground within this contributing area, they may eventually contaminate water from the well. Protection zones around public-supply wells in New Hampshire are usually 400 feet in diameter—an area much smaller than the contributing area. Under the 1986 amendments to the Federal Safe Drinking Water Act, the NHDES plans to protect the contributing areas of supply wells. State regulations for protecting areas that contribute ground water to wells probably will be developed by 1990.

Continued increases in population will increase the demand for water and will result in increased waste disposal, which has the potential to threaten ground-water quality. The quality of water from wells that obtain significant amounts of water from infiltration through river and lake beds may actually improve if the chemical quality of the surface water improves. Ground-water-protection ordinances for entire aquifers, and especially for contributing areas to wells, will help to preserve the quality of ground water.

GROUND-WATER-QUALITY MANAGEMENT

The New Hampshire Legislature recently established the Department of Environmental Services as the agency responsible for coordinating and managing water and waste. This new agency has four divisions that previously were independent agencies. The Commissioner of the Department is appointed by the Governor. The four divisions are:

Water Resources Division (WRD) (formerly Water Resources Board)
Water Supply and Pollution Control Division (WSPCD) (formerly Water Supply and Pollution Control Commission)
Waste Management Division (WMD) (formerly Division of Public Health Services)
Air Resources Division (ARD) (formerly Air Resources Agency)

The WSPCD has responsibility for water quality and related water-supply aspects of ground-water protection, whereas the WRD will manage water quantity by collecting data for water use, mapping ground-water resources, licensing well drillers, and collecting and assessing well-completion reports. The WMD is responsible for permitting facilities for solid- and hazardous-waste disposal and the Environmental Health Risk Assessment Unit of the New Hampshire Department of Public Health Services is responsible for assessing health risks related to ground-water use.

The Geological Survey, in cooperation with the New Hampshire Water Resources Division, completed the reconnaissance or "availability" mapping of the State's sand and gravel aquifers in 1977. The WSPCD has used these preliminary ground-water maps to construct "Non-Point Pollution Source Maps" for each municipality in New Hampshire. These maps show landfills, disposal sites, salt piles, areas of pesticide use, and areas of numerous septic tanks. Surface-water resources and areas with private and public wells are also shown. A document titled "Ground Water Protection Manual—A Guide for Local Action" also was published.

Although preliminary maps may be adequate for planning, implementing plans and policies requires more detailed information about the ground-water resource. Therefore, the U.S. Geological Survey, in cooperation with the WRD, started a program, which began in 1983 and is expected to be completed in 1993, to provide detailed maps of sand and gravel aquifers in New Hampshire. These maps will be the basis for future ground-water-management planning for State and local officials.

The WSPCD enforces the State Groundwater Protection Rules, Ws410, which require that the ground-water quality in the State not be degraded below background quality. These rules require a permit for discharges that may adversely affect ground-water quality and outline the requirements for monitoring and hydrogeologic studies. The WSPCD also regulates all septic systems in the State and administers the Federal Underground Injection Control (UIC) program, which includes a survey of potential sources of ground-water contamination.

The WMD issues permits for waste-disposal sites in the State and is responsible for siting all new hazardous-waste treatment and disposal facilities in New Hampshire. The issues concerning ground-water impact and permitting of these facilities are coordinated with the WSPCD.

The WSPCD has developed rules (Ws411) for storing petroleum products in underground tanks that apply to all nonresidential tanks with a capacity greater than 1,100 gallons; the rules apply to the registration, maintenance, inventory, leak detection, and installation of new equipment and include reporting requirements.

Ground-water quality is currently controlled by the State permitting system, the Federal Clean Water Act, the Federal UIC program, Safe Drinking Water Act, CERCLA, and RCRA. The NHDES maintains a laboratory for testing water for State and Federal programs in accordance with the quality-assurance quality-control requirements of each program. The NHDES laboratory also analyzes water from private wells and public-water supplies.

Although State and Federal efforts to protect ground water are important to management strategies, local ordinances and initiatives also are important. A few towns have adopted aquifer-protection ordinances that include regulations for underground storage tanks, zoning above aquifers, purchases of land to protect aquifers, and tax incentives to discourage development of open land over sensitive aquifers. Many other towns are considering similar ordinances to protect ground-water quality. The New Hampshire Office of State Planning is establishing rules governing local water-resource management and protection planning.

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