NORTH CAROLINA
Ground-Water Quality

In North Carolina (fig. 1*A*), about 3.2 million (55 percent) of the 5.9 million people (fig. 1*B*) rely on ground water for their water supply. The overall quality of North Carolina's ground-water resources is good; most water supplies meet drinking-water standards established by the North Carolina Administrative Code (North Carolina Department of Human Resources, 1984) with little treatment. However, treatment is required in some places to meet State drinking-water standards because of naturally occurring or human-induced water-quality problems.

Naturally occurring problems usually result from large concentrations of inorganic constituents in water. The most widespread, naturally occurring water-quality problem is the presence of saltwater at depth in all aquifers in the eastern part of the State (fig. 3*B*). Removal of salt from the water generally is impractical. The lack of large freshwater supplies has been a limiting factor in economic development of some areas of the State, particularly in parts of northeastern North Carolina and the Outer Banks.

Human-induced water-quality problems in North Carolina's aquifers (fig. 2*A*1) most commonly result from contamination of ground water by leachate from landfills and seepage from waste lagoons, underground storage tanks, septic tanks, and accidental spills of chemicals. Also, where pumping occurs near naturally occurring saltwater, the saltwater may move upward (upcone) and laterally toward pumped wells and result in increased salinity of water from the wells. Human-induced water-quality problems, though serious where they occur, are usually local in extent.

A total of 715 sites have been identified by the North Carolina Department of Human Resources (DHR) as possible sources of human-induced ground-water contamination. Included are 35 sites that require monitoring of ground-water quality under the Federal Resource Conservation and Recovery Act (RCRA) of 1976; contamination has been confirmed at 33 of these RCRA sites. Another 6 of the 715 sites are included on the U.S. Environmental Protection Agency's (EPA) National Priorities List (NPL) of hazardous-waste sites under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and 2 others were under consideration for that list as of June 1986 (U.S. Environmental Protection Agency, 1986c). As of September 1985, the U.S. Department of Defense (DOD) has identified 51 potential hazardous-waste sites at 4 facilities in North Carolina; nine sites at one facility were considered to present a hazard significant enough to warrant remedial action.

Potential for future contamination of ground water near hazardous-waste sites is significant. Ground water typically moves slowly, so that the effects of contamination may go undetected for several decades. Generally, aquifer recharge areas are most vulnerable to ground-water contamination; ground-water discharge areas, usually along streams, are least vulnerable to contamination.

WATER QUALITY IN PRINCIPAL AQUIFERS

North Carolina lies in parts of three physiographic provinces—the Atlantic Coastal Plain, Piedmont, and Blue Ridge (fig. 2*A*2). Four of the five principal aquifers (fig. 2*A*1) used for water supply in North Carolina are in unconsolidated to partly consolidated sedimentary deposits in the Coastal Plain (U.S. Geological Survey, 1985, p. 329). These four aquifers are the surficial, the Yorktown, the Castle Hayne, and the Cretaceous aquifers. The other principal aquifer is the crystalline-rock aquifer, which consists of crystalline igneous, metasedimentary, and metavolcanic rocks in the Piedmont and Blue Ridge provinces.

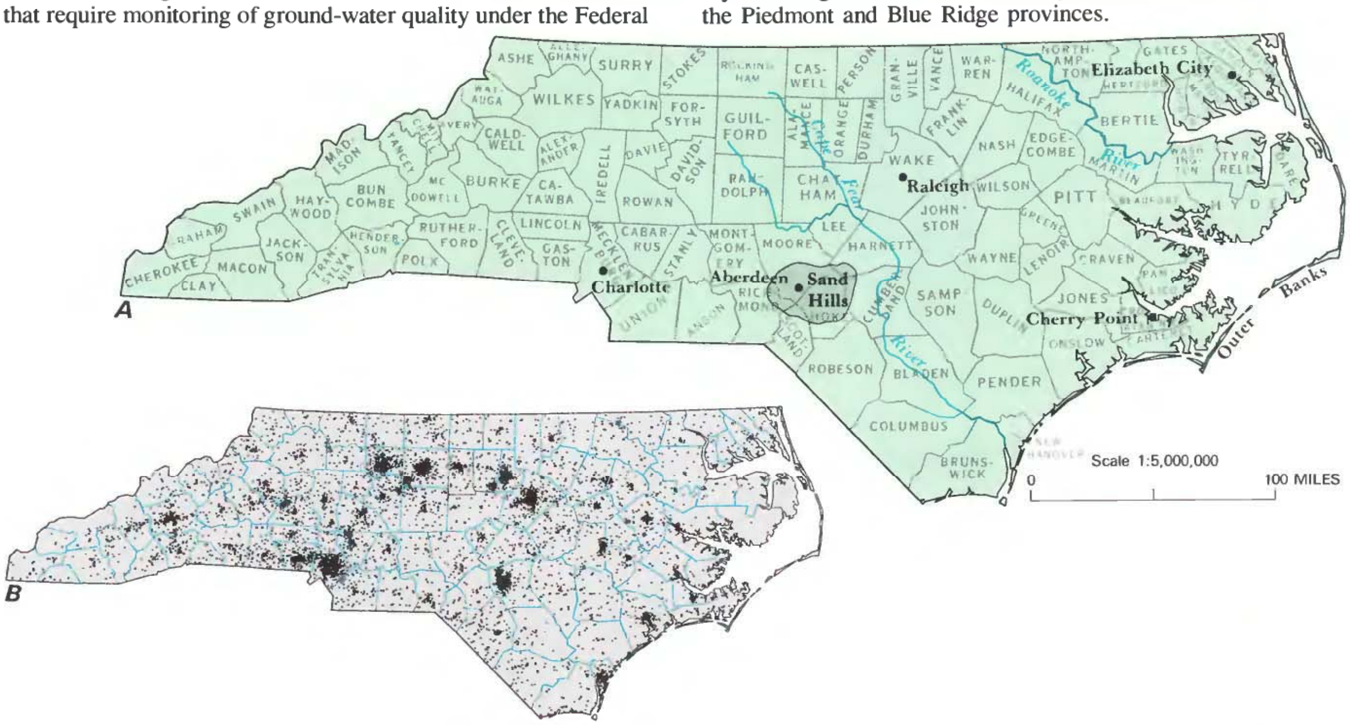

Figure 1. **Selected geographic features and 1985 population distribution in North Carolina.** *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census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

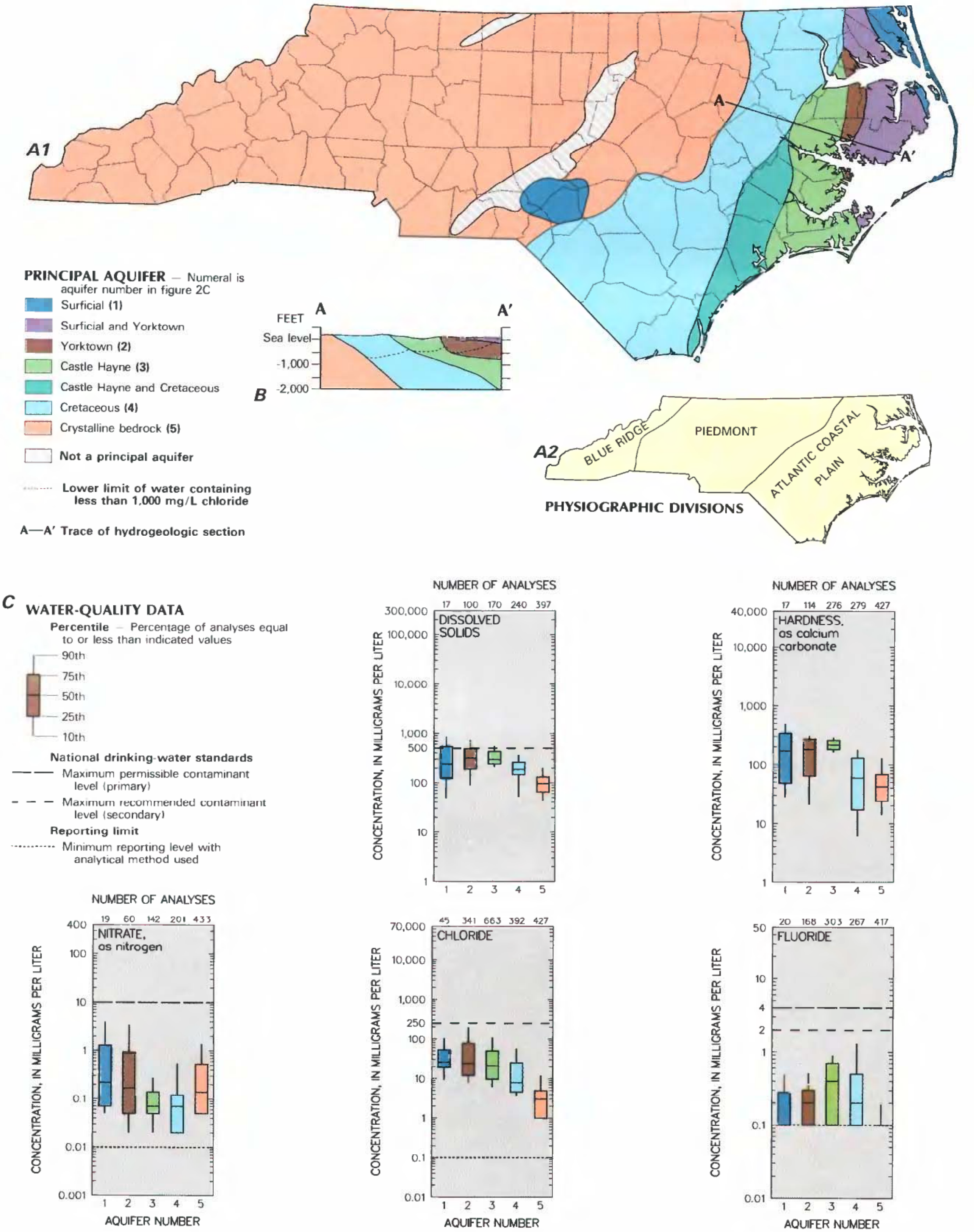

Figure 2. **Principal aquifers and related water-quality data in North Carolina.** *A1*, Principal aquifers; *A2*, Physiographic provinces. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1932-86. (Sources: *A1*, Compiled by R.W. Coble from U.S. Geological Survey and North Carolina Department of Natural Resources and Community Development files. *A2*, Fenneman, 1938; Raisz, 1954. *B*, Compiled by R.W. Coble from U.S. Geological Survey and North Carolina Department of Natural Resources and Community Development files. *C*, Analyses compiled from U.S. Geological Survey files; analyses for crystalline rock are from North Carolina Department of Natural Resources and Community Development, Division of Environmental Management; national drinking-water standards from U.S. Environmental Protection Agency, 1986b,c.)

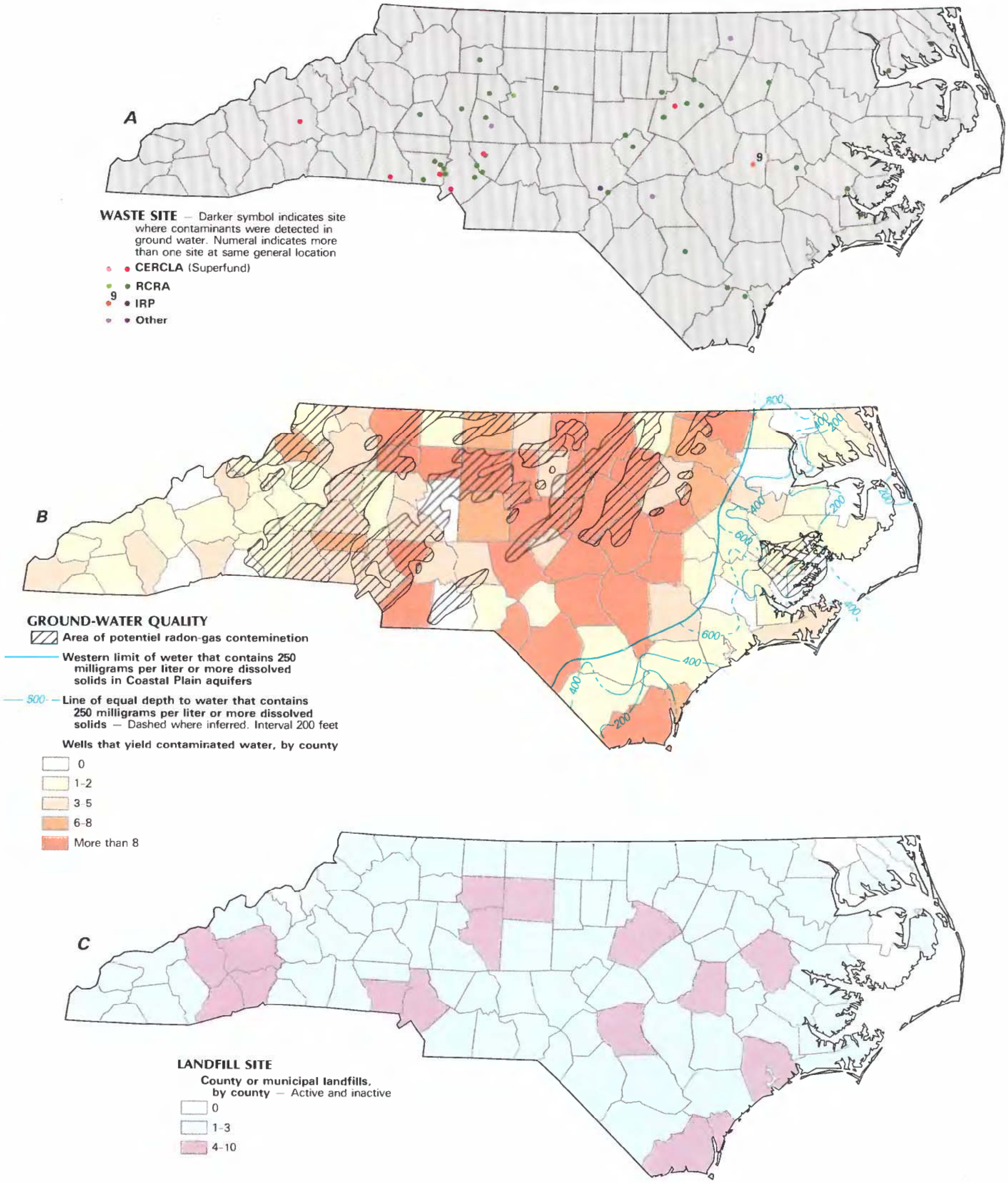

Figure 3. Selected waste sites and ground-water-quality information in North Carolina. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, as of September 1986; Resource Conservation and Recovery Act (RCRA) sites, as of September 1986; Department of Defense Installation Restoration Program (IRP) sites, as of September 1985; and other selected waste sites, as of September 1986. ***B***, Areas of naturally impaired water quality and potential contamination, and distribution of wells that yield contaminated water, as of September 1986. ***C***, County and municipal landfills, as of September 1986. (Sources: *A*, Gary Babb, Lee Crosby, and Robert Glaser, North Carolina Department of Human Resources; U.S. Department of Defense, 1986. *B*, Radon areas by A.G. Strickland from State geologic map by Brown and Parker, 1985; saltwater areas from Meisler, 1987; wells that yield contaminated water from Ted Taylor, Bill Williams, and Leon Pryor, North Carolina Department of Human Resources. *C*, Michael Babuin and Lois Walker, North Carolina Department of Human Resources.)

Generally, the background quality of freshwater in North Carolina's principal aquifers is suitable for most domestic and industrial purposes. Among the naturally occurring water-quality characteristics that may require treatment or may render ground water unsuitable for some purposes are excessive hardness, high and low pH, and large concentrations of dissolved solids, chloride, fluoride, iron, manganese, and sodium.

Radioactive radon gas dissolved in ground water and the resulting possibility of increased risk of cancer, have come to public attention recently. Results of preliminary studies indicate that the gas may accumulate to undesirable concentrations in poorly ventilated homes in areas underlain by rocks of larger-than-average uranium concentrations and low permeability. North Carolina contains abundant rocks of this type, including shale, clay, granite, and phosphate ore. Areas underlain by rocks with larger-than-average uranium content are shown in figure 3*B*. More definitive research is needed before the health risks of radon gas in ground water can be assessed accurately.

Background Water Quality

A graphic summary of selected water-quality variables compiled from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) is presented in figure 2*C*. The summary is based on dissolved-solids, hardness, nitrate (as nitrogen), chloride, and fluoride analyses of water samples collected from 1932 through 1986 from the principal aquifers in North Carolina. Percentiles of these variables (except for hardness) are compared to national standards that specify the maximum concentration or level of a contaminant in a 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 4 mg/L fluoride. The secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids, 250 mg/L chloride, and 2 mg/L fluoride. For these variables, the State drinking-water standards are the same as the national standards. As shown on figure 2*C*, 90 percent of the ground-water analyses from each of the principal aquifers in North Carolina did not exceed the primary and secondary drinking-water standards for nitrate (as nitrogen), chloride, and fluoride.

Surficial Aquifer

The surficial aquifer (fig. 2*A*1) is a principal aquifer in three relatively small areas of the State—the Sand Hills, the Outer Banks (fig. 1*A*), and parts of northeastern North Carolina. Yields to individual wells in the surficial aquifer commonly range from 25 to 200 gal/min (gallons per minute) but may exceed 500 gal/min (U.S. Geological Survey, 1985, p. 330).

The 90th-percentile concentrations of nitrate (4.0 mg/L) and fluoride (0.5 mg/L) for surficial-aquifer samples did not exceed the drinking-water standards (fig. 2*C*). Median concentrations were 240 mg/L dissolved solids, 170 mg/L hardness, 0.22 mg/L nitrate, 26 mg/L chloride, and 0.1 mg/L fluoride.

In the Sand Hills area, the surficial aquifer is used for public and individual water supplies and for irrigation of numerous golf courses. Water from the surficial aquifer in the Sand Hills area typically contained less than 25 mg/L dissolved solids and 10 mg/L hardness. However, the water tended to be acidic and, therefore, corrosive.

For much of the Outer Banks, the surficial aquifer is the only source of freshwater other than precipitation. However, freshwater is seldom found below 100 feet on the Outer Banks. To avoid saltwater contamination, supplies commonly are obtained from a large number of shallow vertical wells or from shallow horizontal wells. Because of the presence of saltwater, either naturally occurring or as a result of pumping, the dissolved-solids concentration of water obtained from the surficial aquifer in this area can exceed the 500-mg/L national secondary drinking-water standard. Also, ground water from the surficial aquifer on the Outer Banks and elsewhere in northeastern North Carolina ranged from soft to very hard, with hardness exceeding 180 mg/L in many places. Concentrations of iron larger than the 300-μg/L (micrograms per liter) national secondary drinking-water standard were common.

Yorktown Aquifer

The Yorktown aquifer (fig. 2*A*1) is shallow in the northern part of the Atlantic Coastal Plain (fig. 2*A*2). In places, such as Elizabeth City where it supplies 1.4 Mgal/d (million gallons per day) to a well field, the Yorktown is the only aquifer capable of yielding large supplies of freshwater to wells. Yields of individual wells in the Yorktown aquifer may exceed 500 gal/min, but yields of 15–90 gal/min are more common (U.S. Geological Survey, 1985, p. 330).

The 90th-percentile concentrations of nitrate (3.4 mg/L) and fluoride (0.5 mg/L) for Yorktown-aquifer samples did not exceed the drinking-water standards (fig. 2*C*). Median concentrations were 319 mg/L dissolved solids, 180 mg/L hardness, 0.17 mg/L nitrate, 24 mg/L chloride, and 0.2 mg/L fluoride. Water from the Yorktown aquifer at some places contains excessive iron.

Background concentrations of sodium are generally larger in water from the Yorktown aquifer than from any other principal aquifer; the median sodium concentration in samples from the aquifer was 38 mg/L; 25 percent of the sodium concentrations exceeded 130 mg/L. No State (North Carolina) or national standards have been established for sodium in drinking water; however, the U.S. Environmental Protection Agency (1985b, p. 46980) has proposed a health advisory guidance level maximum of 20 mg/L for sodium in drinking water. Although relatively large sodium concentrations in the Yorktown aquifer in part reflect the presence of saltwater, the ratio of sodium to other constituents is larger than would be expected just from the presence of diluted sea water. Probably, ion exchange is taking place (Wilder and others, 1978), wherein calcium in the ground water exchanges for sodium in the aquifer materials; this process increases the concentrations of sodium and decreases the concentrations of calcium in the ground water. This process would account for the larger than expected ratios of sodium to other constituents in diluted seawater. The same process may occur to varying degrees in all the Coastal Plain aquifers but appears to be pronounced in the Yorktown aquifer.

Castle Hayne Aquifer

The Castle Hayne aquifer (fig. 2*A*1), the most productive in North Carolina, is capable of yielding more than 2,000 gal/min to individual wells. The Castle Hayne aquifer is the source of water for public supply for several Coastal Plain communities and, in places near the coast, may contain freshwater even where aquifers above and below it contain saltwater. A phosphate mine in Beaufort County pumps nearly 60 Mgal/d from the Castle Hayne aquifer to decrease the artesian pressure and dewater the overlying phosphate ore beds.

The 90th-percentile concentrations of nitrate (0.28 mg/L) and fluoride (0.9 mg/L) for water from the Castle-Hayne aquifer did not exceed the drinking-water standards (fig. 2*C*). Median concentrations were 298 mg/L dissolved solids, 215 mg/L hardness, 0.07 mg/L nitrate, 21 mg/L chloride, and 0.4 mg/L fluoride. Based on the data, water from the Castle Hayne aquifer generally is hard (121 to 180 mg/L as calcium carbonate) or very hard (greater than 180 mg/L). Hardness is less near recharge areas but increases with residence time in the limestone rocks of the aquifer.

Iron concentrations, in contrast to hardness, are more likely to exceed the State drinking-water standard of 300 μg/L in recharge areas, but the iron precipitates as the water moves into the limestone (Wilder and others, 1978). Water from the Castle Hayne aquifer also may contain silica in concentrations larger than 50 mg/L. Deeper parts of the Castle Hayne aquifer contain saltwater in many places, but the depth to water with dissolved solids of 250 mg/L or more may exceed 600 feet (fig. 3*B*).

Cretaceous Aquifer

The Cretaceous aquifer (fig. 2*A*1) is the most extensively used aquifer in the Coastal Plain and contains the best quality of water in much of the area. Yields to individual wells generally range from 200 to 400 gal/min and may exceed 1,400 gal/min (U.S. Geological Survey, 1985, p. 330).

The 90th-percentile concentrations of nitrate (0.55 mg/L) and fluoride (1.3 mg/L) for Cretaceous-aquifer samples did not exceed the drinking-water standards (fig. 2*C*). Median concentrations were 190 mg/L dissolved solids, 59 mg/L hardness, 0.07 mg/L nitrate, 8.0 mg/L chloride, and 0.2 mg/L fluoride. Based on the data, water from the Cretaceous aquifer is soft, except where it leaks downward from the overlying Castle Hayne aquifer. Once in the Cretaceous aquifer, the hardness of water from the overlying limestone aquifer is decreased by natural ion exchange of calcium and magnesium for sodium (in the clay), resulting in a soft, alkaline water that requires little or no treatment for most uses (Wilder and others, 1978).

Water from the Cretaceous aquifer, particularly in the part of the aquifer identified as the Black Creek Formation, may contain fluoride in concentrations larger than 4 mg/L, the maximum permissible concentration under national drinking-water standards (U.S. Environmental Protection Agency, 1986a). Thus, fluoride may limit the use of water for drinking from some wells in the Cretaceous aquifer. In many places, the Cretaceous aquifer also contains salty water in its deeper parts.

Crystalline Rock Aquifer

The crystalline rock aquifer (fig. 2*A*1) underlies the entire State and is the principal aquifer in the Piedmont and Blue Ridge provinces (fig. 2*A*2). In contrast to the unconsolidated to partly consolidated sediments of the four aquifers of the Atlantic Coastal Plain (fig. 2*A*1), the crystalline rocks have little storage capacity and well yields commonly range from only about 5 to 35 gal/min. However, where efforts have been made to design the wells to maximize yields and to construct wells in optimum locations, such as in valleys and draws where the chances of intercepting interconnected fractures are greatest (U.S. Geological Survey, 1985), it is common to obtain 200 gal/min or more from this aquifer (Heath and Giese, 1980). More than 50 percent of the 4 million people in the Piedmont and Blue Ridge provinces rely on water from the crystalline rock aquifer for water supply, mostly from individually owned wells in rural areas.

The quality of water from the crystalline rock aquifer generally is acceptable for human consumption and most other uses. The 90th percentile concentrations of nitrate (1.4 mg/L) and fluoride (0.2 mg/L) for water from the crystalline rock aquifer did not exceed the drinking-water standards (fig. 2*C*). Median concentrations were 96 mg/L dissolved solids, 42 mg/L hardness, 0.14 mg/L nitrate, 3.0 mg/L chloride, and 0.1 mg/L fluoride. Thus, most ground-water samples at most places did not exceed drinking-water standards; however, treatment of some supplies from the crystalline rock aquifer may be necessary. Variables and the respective drinking-water standards that were exceeded in some water samples were iron (300 μg/L), manganese (50 μg/L), and pH (6.5–8.5 units). Based on the data, the water generally was soft (hardness less than 60 mg/L as calcium carbonate) in most areas. Chemical analyses available from WATSTORE showed that background iron concentrations ranged from 100 μg/L at the 10th percentile to 1,000 μg/L at the 90th percentile; manganese concentrations ranged from 50 to 110 μg/L, and pH ranged from 6.0 to 7.4 for the same percentiles.

Effects of Land Use on Water Quality

Most observed changes in ground-water quality in North Carolina are related to patterns and trends in land-use and waste-disposal practices. Underground storage tanks, waste lagoons, and disposal landfills commonly are responsible for the point-source contamination that has been identified in North Carolina (fig. 4). The detection of petroleum, pesticide, and biological contamination in public and private wells is increasing; however, these sources of contamination commonly represent more dispersed, nonpoint sources of contamination (H.E. Mew, North Carolina Department of Natural Resources and Community Development, written commun., 1985). An estimated 68 public and 690 private wells are known to have been contaminated (fig. 3*B*) (Leon Pryor, North Carolina Department of Human Resources, written commun., September 1986; Bill Williams and Ted Taylor, Department of Human Resources, written commun., September 1986).

Hazardous-Waste Disposal

Hazardous wastes are treated and stored at 81 of 3,030 RCRA sites. As shown in figure 3*A* contamination of shallow aquifers has been detected at 33 of these 81 sites (fig. 3*A*); two other sites have suspected contamination. No permitted commercial hazardous-waste-disposal sites are presently being operated in the State (Gary Babb, North Carolina Department of Human Resources, written commun., October 1986).

As of June 1986, ground-water contamination has been confirmed at six CERCLA sites (fig. 3*A*) in North Carolina and at two proposed NPL sites (not shown in fig. 3*A*). One former NPL site, an extensive polychlorinated biphenyl spill along 210 miles of rural roadside in Cumberland, Johnston, Harnett, Lee, Chatham, Nash, Franklin, Halifax, Hoke, Moore, and Warren Counties, was removed to a secured, monitored land fill in Warren County (fig. 3*A*).

The CERCLA Unit of DHR has evaluated 580 of 715 potential hazardous-waste sites identified by DHR for public health and environmental impact. Ground-water contamination has been confirmed at 25 of these sites and is suspected at about 405 other sites. The most common contaminants found include cadmium, chromium, arsenic, lead, pentachlorophenol (PCP), perchloroethylene (PCE), creosote, and common pesticides such as chlordane, aldrin, and heptachlor. No contamination was indicated at approximately 150 sites. The need for remedial action will be evaluated further at many of the sites. The remaining 135 sites that were identified by DHR are being investigated by other agencies.

As of September 1985, 51 hazardous-waste sites at 4 facilities in North Carolina 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 EPA Superfund program under CERCLA. The EPA presently ranks these sites under a hazard ranking system and may include them in the NPL. Nine IRP sites at one facility (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.

The vertical and lateral extent of contamination is specific to each hazardous-waste site. At one site near the town of Aberdeen in Moore County (an "Other" site in fig. 3*A*), concentrations of as much as 250 μg/L of the pesticide lindane were found at depths of 25 feet at a distance of more than 1 mile from the source of contamination (Ned Jessup, U.S. Environmental Protection Agency, Emergency Response Unit, Atlanta, Ga., oral commun., October 1986). At the same site, 1.5 miles from the source, lindane

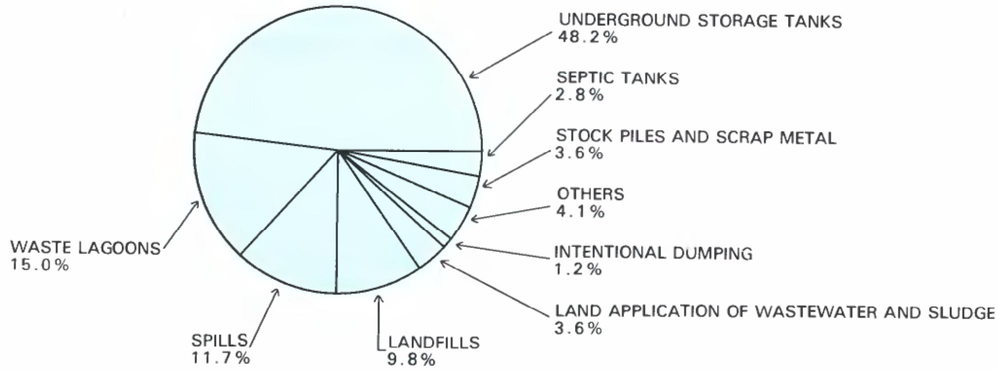

Figure 4. Percentage of total number of confirmed ground-water contamination sources by type of source for 247 selected sites. (Source: Modified from H.B. Mew, North Carolina Department of Natural Resources and Community Deveopment, written commun. 1985.)

concentrations of 12 μg/L reportedly were detected 150 feet below land surface.

Industrial Facilities

H.B. Mew (North Carolina Department of Natural Resources and Community Development, written commun. 1985) characterized the operational types of sites where ground-water contamination was confirmed (fig. 4). Landfills, waste lagoons, and leaking underground storage tanks were the most common sources of contamination from industrial sources. In a survey (Huisingh and Hatley, 1983) of sites owned by chemical companies and paint manufacturers, solvents and metal-finishing and agricultural chemicals were suggested as probable sources of ground-water contamination. Sites associated with companies that produced or distributed fiber, wood, paper, and petroleum products also were mentioned in that survey.

The sources of contamination at about one-half of the confirmed contamination sites studied by Mew were underground storage tanks (fig. 4). Since 1983, the DHR has detected petroleum products in 516 wells. An estimated 1,500 to 2,000 people are reported to have been affected (Ted Taylor, North Carolina Department of Human Resources, written commun., September 1986). In one instance, a petroleum-products operation in Scotland County contaminated the wells of 60 families who were forced to use bottled water for more than a year, while public water-supply lines were extended to their homes (Dennis Harrington, Scotland County Health Department, oral commun., September 1986). Well drillers report petroleum-products contamination as the most common reason for well replacement (Miller and others, 1977).

Many of the sites where ground-water contamination has been detected were designed or originally constructed according to acceptable or state-of-the-art procedures. In the past, lagoons and trenches commonly were constructed without liners or containment structures. Commonly, the only treatment of water consisted of solidifying waste materials by allowing the liquids to evaporate or seep into the soil. At the Aberdeen site in Moore County (fig. 3*A*), for example, the waste pesticide (lindane) was disposed of in an unlined trench 750 feet long, 35 feet wide, and 15 feet deep. When the site was closed, it was covered with 6 feet of clayey soil. Afterward, ground water as far as 5 miles from the trench reportedly became contaminated to some degree (Ned Jessup, U.S. Environmental Protection Agency, Emergency Response Unit, Atlanta, Ga., oral commun., October 1986).

Agricultural Practices

The use of farm fertilizers, pesticides, and animal-waste lagoons has caused some local contamination of shallow aquifers. Pesticides have been detected in water from 202 private wells and 1 public-supply well (Bill Williams, North Carolina Department of Human Resources, written commun., September 1986; Leon Pryor, Department of Human Resources, written commun., September 1986). The public-supply well was abandoned; some of the private wells still may be in use. Contamination by pesticides is found most commonly in water from springs and shallow wells. Although many of the wells that yield contaminated water are near agricultural lands where pesticides have been applied, some of the wells seem to have been contaminated by spills that occurred during the preparation, mixing, or handling of the chemicals before application, or from infiltration of rinse water used to clean application equipment or tanks.

Although pesticide contamination occurs throughout the State, the counties of Durham, Wake, and Johnston account for 24 percent of the reported incidents (Bill Williams, North Carolina Department of Human Resources, written commun., September 1986). Chlordane, aldrin, and heptachlor were the most commonly detected pesticides in ground water; many of the occurrences of contamination appear to be associated with termite treatment.

Fertilizers caused the contamination of four public-supply wells, all of which were abandoned (Leon Pryor, North Carolina Department of Human Resources, written commun., September 1986). Data are not available to document contamination of private wells by either fertilizers or other sources of nutrients, such as nitrate (fig. 2*C*) or phosphate.

Public Facilities

Ground-water contamination at public facilities usually is associated with landfills and underground storage tanks and generally is limited in areal extent. H.E. Mew (North Carolina Department of Natural Resources and Community Development, written commun., 1985) indicated that one-third of the contaminated sites were publicly owned; of these, 23 percent were municipal or county landfills, which were also the second most common source of probable contamination in the survey described by Huisingh and Hatley (1983). Landfill leachate commonly is rich in organics and metals from chemicals in pesticide, paint, fuel containers, waste oils, and solvents.

For many years, landfills were not regulated in North Carolina; no laws prevented disposal of liquid waste in landfills, and few landfills were secured or fenced. Some landfills were located either in areas where ground-water levels were near land surface or in fractured rock that provided little filtration of leachate. Leachate from some landfills has migrated into ground and surface water, but the extent of contamination and the number of people affected generally are unknown. The State has required ground-water-quality monitoring of all new landfills since 1981 and has mandated that existing sanitary landfills be monitored beginning in 1987 (Michael Babuin, North Carolina Department of Human Resources, oral commun., September 1986). There are 208 operating landfills in North Carolina (fig. 3*C*); these include all permitted landfill sites and unpermitted RCRA sites that are landfills.

Domestic Land Use

Contamination that results from domestic land use is commonly associated with septic disposal systems or improper storage, use, or disposal of household and lawn chemicals. Berkowitz (1981) determined that 30 percent of the homes in Graham, Haywood, Jackson, and Macon Counties had drinking-water supplies that were bacteriologically contaminated (though not necessarily unfit for use). The contamination was partly caused by onsite sewage-treatment problems. Berkowitz (1981) reported that septic-system drainfields constructed where the water table is shallow did not provide effective treatment. In a separate study, Carlile and others (1981) reported that satisfactory locations for septic-tank systems are difficult to find in the Atlantic Coastal Plain, primarily because of the shallow water table. According to Carlile and others (1981), many septic-disposal systems near public- or private-supply wells are a problem of unknown magnitude. This may be related to reports that biological contamination is the leading cause of closures of public wells (Leon Pryor, North Carolina Department of Human Resources, written commun., September 1986).

Saltwater Encroachment

Saltwater encroachment is a serious problem in some coastal areas (R.C. Heath and H.B. Wilder, U.S. Geological Survey, written commun., 1979). Saltwater occurs in the sediments underlying the eastern part of the Atlantic Coastal Plain at depths controlled by both the freshwater pressure heads and the stratification of sediments. Depths to water that contain 250 mg/L or more dissolved solids generally range from 200 to 600 feet (fig. 3*B*). Saltwater encroachment induced by withdrawals from wells is an increasingly serious problem in some areas of the Coastal Plain and Outer Banks, particularly in the northeastern parts. Two public-supply wells in Hyde County have been closed because of saltwater contamination.

POTENTIAL FOR WATER-QUALITY CHANGES

The greatest potential for future changes in ground-water quality is in recharge areas in and near aquifer outcrops. Contaminants that originate in recharge areas can move into deeper parts of the aquifers and contaminate them for great distances. The farther upgradient from a discharge area that a contaminant enters the ground-water system, the deeper it penetrates into the ground-water system and the larger the area ultimately affected (Heath, 1983).

Aging underground storage tanks will continue to be a major hazard to ground water and a source for future adverse water-quality changes. Underground storage tanks are in use throughout the State. One area of major concern is the Sand Hills (fig. 2*A*1) where acidic ground water hastens the deterioration of underground metal tanks and the release of contaminants. Once in the ground, contaminants will be relatively unrestricted in movement, because of the large permeability and small clay content of the sediments that underlie the Sand Hills. In addition, acidic ground water inhibits soil absorption or adsorption of many contaminants.

The cumulative effects of some agricultural practices also may cause adverse water-quality changes. Pesticides and fertilizers are being used more frequently and in larger amounts, particularly in the Atlantic Coastal Plain. Improper use, storage, or disposal of these chemicals also could result in severe contamination of ground water. The trend toward minimum-tillage farming and a resulting reliance on herbicides may present an additional source of ground-water contamination. Chemirrigation also is increasing. Application of these agricultural chemicals with excessive amounts of irrigation water can increase the chances that the chemicals will enter the ground-water system. The State is formulating regulations to control the increased use of chemirrigation and to license users.

GROUND-WATER-QUALITY MANAGEMENT

The North Carolina Department of Natural Resources and Community Development (NRCD) maintains a statewide ground-water-quality network to monitor background water quality and implements an incident-management program to investigate reported ground-water contamination. The DHR monitors all permitted solid-waste landfills in the State for ground-water contamination. Operators of wastewater-treatment plants, lagoons, and land-application systems are required to submit results of self-monitoring to the NRCD. The U.S. Geological Survey maintains cooperative agreements with NRCD and DHR, but no ground-water-quality studies are being conducted (1986) under these agreements. However, the U.S. Geological Survey currently is conducting several interpretive studies of ground-water quality with other cooperating agencies, including a study of the effects of urbanization on ground-water quality in the City of Charlotte and throughout Mecklenburg County, and a study of the ground-water supply and potential for contamination at the Cherry Point Marine Corps Air Station in Craven County.

The NRCD implements most of the regulatory and planning procedures related to ground-water resources in North Carolina. The Division of Environmental Management (DEM) within NRCD has the major responsibility for ground-water management and regulatory programs. The North Carolina Environmental Management Commission (EMC) has broad authority over the permitting process for land development that may affect ground water. In 1983, the Commission adopted standards and classified the State's ground waters according to best-usage criteria. All applicable EMC permit applications are reviewed by the Groundwater Section, DEM, for compliance with established standards.

The National Pollution Discharge Elimination System (NPDES), or point-source permit program, is administered by the DEM Water Quality Section under authority of North Carolina General Statute (NCGS) 143–215.1. This is a Federal permitting program over which the State has primacy. Although these permits primarily regulate facilities that discharge to surface water, they also include unlined basins and holding ponds that have the potential to contaminate ground water.

The nondischarge-permit program, which regulates waste-disposal activities that do not include discharges to surface water, is a State program also administered by the DEM Water Quality Section under authority of NCGS 143–215.1. The program is, in essence, a ground-water-permit program that regulates activities, such as sewer-line extensions, sludge disposal and other land-application systems, and waste lagoons that do not discharge to surface water.

Monitoring to assure compliance with permit conditions is an important element of the ground-water permitting program to control ground-water pollution. The DEM Groundwater Section has developed an extensive compliance-monitoring program. An estimated 750 wells are being monitored by the owners in accordance with conditions of the permits, most of which are nondischarge permits.

The DEM Groundwater Section also has implemented a program for Underground Injection Control (UIC) (U.S. Environmental Protection Agency, 1984). A UIC permit is required for wells that are to be used for injection, recharge, or disposal. Injection wells for waste disposal, other than class-V wells (for injection of heated water into the ground), are prohibited by State statute. Presently, the DEM is developing rules for the regulation of underground storage tanks.

Landfills in North Carolina are regulated by the Solid and Hazardous Waste Management Branch in the DHR, Division of Health Services, under authority of the North Carolina General

Statutes. Under a formal Memorandum of Agreement between the DHR and the NRCD, "DHR will provide NRCD with a copy of each permit application for a landfill or for a hazardous-waste facility that requires ground-water monitoring and (or) ground-water protection standards, and a copy of each application for a modification of such facilities." Hazardous-waste-facility permits are reviewed to assure compliance with State ground-water regulations.

The DHR, through its Division of Health Services, is responsible for monitoring solid-waste and hazardous-waste-disposal sites. Data collected in this monitoring program are shared with the DEM Groundwater Section under the Memorandum of Agreement.

Mining in North Carolina is regulated under the Mining Act of 1971, NCGS 74–50, which requires a permit for any mining activity. This permit program is administered by the Land Quality Section of the NRCD, Division of Land Resources; those mining permit applications involving areas where ground water may be affected are reviewed by the DEM Groundwater Section.

Under the North Carolina Coastal Area Management Act of 1974, permits are required (under NCGS 113A–118) for any development in coastal "areas of environmental concern" designated by the State. This Act is administered by the NRCD Division of Coastal Management, and any projects requiring a permit that may affect ground water are reviewed by the DEM.

The Division of Health Services of DHR is responsible for the human-health aspects of public water-supply systems, including review of plans and specifications for water-treatment and distribution facilities, approval of sources of raw water, establishment of drinking-water standards, and requirements for monitoring the quality of drinking water delivered by public systems.

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