DELAWARE GROUND-WATER QUALITY

By Judith M. Denver

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DEPARTMENT OF THE INTERIOR

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FOREWORD

This report contains summary information on ground-water quality in one of the 50 States, Puerto Rico, the Virgin Islands, or the Trust Territories of the Pacific Islands, Saipan, Guam, and American Samoa. The material is extracted from the manuscript of the *1986 National Water Summary*, and with the exception of the illustrations, which will be reproduced in multi-color in the *1986 National Water Summary*, the format and content of this report is identical to the State ground-water-quality descriptions to be published in the *1986 National Water Summary*. Release of this information before formal publication in the *1986 National Water Summary* permits the earliest access by the public.

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Sixty-seven percent of the population in Delaware (fig. 1*B*)—about 400,000 people—is served by ground water. The Delaware Department of Natural Resources and Environmental Control reported that ground-water use for public supply in 1982 was 10.2 billion gallons of a total ground-water withdrawal of 22.1 billion gallons. The largest development of ground water is for public and industrial supply in intensely populated areas of New Castle County (fig. 1*A*), where the Potomac aquifer is the primary source.

Ground water is generally of good quality suitable for most uses except in the downdip parts of confined aquifers that contain saline water. Treatment to remove dissolved iron is needed in some parts of the unconfined aquifer, aquifers of the Chesapeake Group, and the Potomac aquifer (fig. 2). Nitrate plus nitrite concentrations commonly are a problem in the unconfined aquifer, principally in Kent and Sussex Counties in areas associated with agriculture and the poultry industry. Septic systems also are a potential source of nitrate. Intrusion of brackish or saline water has occurred in the unconfined aquifer adjacent to Delaware Bay and the Atlantic Ocean. Contamination from waste-disposal practices causes localized problems in the unconfined aquifer and subcrop areas of the Potomac aquifer system. Most of the industrial waste-disposal sites are located in New Castle County along the Delaware River (fig. 3*A*). Contaminants from these sites include iron, manganese, dissolved solids, organic acids, and volatile organic compounds.

Strict controls on waste-disposal practices and implementation of a State ground-water management strategy are intended to minimize contamination problems from newly constructed waste-disposal sites. Remedial action at four hazardous-waste sites has started or is planned under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. One site at one Federal facility was identified, in September 1985, as requiring remedial action in accordance with CERCLA. The State anticipates an increasing problem from deteriorating underground fuel-storage tanks, and has adopted standards that require monitoring around old and new tanks to detect leakage and has initiated cleanups at several sites. Nitrate contamination associated with agriculture and poultry processing will continue to be a problem.

WATER QUALITY IN PRINCIPAL AQUIFERS

Delaware has two principal types of aquifers (fig. 2*A*): the unconsolidated sedimentary deposits of the Coastal Plain that underlie the southern 94 percent of the State; and the crystalline bedrock of the Piedmont, located north of the Fall line, that comprises the remaining 6 percent. About 97 percent of all ground-water withdrawals are from the Coastal Plain aquifers (Delaware Department of Natural Resources and Environmental Control, 1982).

Eight principal Coastal Plain aquifers are used for water supply in Delaware. The aquifers are composed of sand and gravel interbedded with silt and clay. Water quality is generally suitable for most uses. Saline water is present in downdip parts of most confined Coastal Plain aquifers (Cushing and others, 1973). The Potomac and unconfined aquifers are the major water-supply sources in the State and also are the most susceptible to contamination.

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) and data from the Delaware Department of Health and Social Services is presented in figure 2*C*. The summary is based on dissolved-solids, hardness, nitrate plus nitrite (as nitrogen),chloride and iron analyses of water samples collected from 1956 to 1986 from the principal aquifers in Delaware. 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 maximum concentrations 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, 250 mg/L chloride, and 300 μg/L (micrograms per liter) iron.

Unconfined Aquifer

The unconfined aquifer (fig. 2*B*) is areally continuous, thickens from north to south beneath the Coastal Plain of Delaware, and serves as a recharge area for underlying aquifers (U.S. Geological Survey, 1985, p. 167). It is the principal source of domestic and some public water supplies in Kent and Sussex counties. The largest use of water from the unconfined aquifer is for crop irrigation from April through October. Withdrawals from the unconfined aquifer for irrigation in Sussex County averaged 9 Mgal/d (million gallons per day) in 1982 (Delaware Department of Natural Resources and Environmental Control, 1982).

Soil permeability and drainage can result in significant effects on water quality in the unconfined aquifer. Sodium and bicarbonate are the major ions in water under oxidizing conditions that occur beneath well-drained soils (fig. 4*A*). Where soils are poorly drained, reducing conditions prevail, and dissolved iron can be a major ion in the water (fig. 4*B*). Areas where naturally occurring dissolved iron can be a problem are primarily in western Kent County and southeastern Sussex County (fig. 3*B*). Under natural background conditions, dissolved-solids concentrations are about 60 mg/L, nitrate plus nitrite concentrations are smaller than 4 mg/L, and chloride concentrations are about 6 mg/L (Denver, 1986, p. 34).

Chesapeake Group Aquifers

Aquifers of the Chesapeake Group subcrop the unconfined aquifer in Kent and Sussex Counties (U.S. Geological Survey, 1985, p. 168). The Cheswold aquifer is a major source of water supply in the Dover area. The Pocomoke-Ocean City and Manokin aquifers are important sources of withdrawals for industrial and municipal use in Sussex County and supply large seasonal pumpage in the coastal resort areas.

Water in the Cheswold aquifer is moderately hard as a result of dissolution of carbonate (shell) material in the sediments. Nitrate plus nitrite concentrations are virtually undetectable, and chloride concentrations are very small (fig. 2*C*). Iron concentrations in water from the Pocomoke-Ocean City and the Manokin aquifers commonly exceed the 300-μg/L standard for drinking water. Although concentrations of chloride are considerably smaller than 250 mg/L in both aquifers (fig. 2*C*), saltwater intrusion is potentially a problem near the Atlantic Ocean.

Piney Point Aquifer

The Piney Point aquifer is the only completely confined unit in Delaware. It supplies 80 percent of industrial and municipal water used in Kent County (Leahy, 1982, p. 13). A natural ion-exchange process in the sediments (glauconitic greensands) enriches sodium in the water (Spoljaric, 1986). Concentrations of sodium larger than 100 mg/L have been measured. Water of the Piney Point aquifer has the largest average concentration of dissolved solids in the freshwater part of any aquifer utilized in Delaware (fig. 2*C*).

Rancocas and Magothy Aquifers

Southern New Castle County is the principal area of use of the Rancocas and Magothy aquifers. Water of the Rancocas aquifer has the most hardness and least chloride concentration of the aquifers in Delaware (fig. 2*C*). No nitrate plus nitrite was detected in any of the water samples from the Rancocas aquifer. The largest dissolved-solids concentration noted on the 90th-percentile line of the Magothy aquifer (fig. 2*C*) is from a well near Dover, where the aquifer contains brackish water.

Potomac Aquifer

The Potomac aquifer consists of several sandy zones interbedded with clay. The Potomac sands are susceptible to contamination from the surface because the overlying unconfined aquifer is relatively thin. This condition is evidenced by larger nitrate plus nitrite concentrations in the Potomac than in the other confined aquifers (fig. 2*C*). Intrusion of brackish water from the Delaware Bay into the Potomac aquifer has also been documented (Scott Phillips, U.S. Geological Survey, oral commun., 1986). The intruded water is the source of the large chloride concentrations shown in figure 2*C*.

Crystalline Rock Aquifers

The crystalline rock aquifers in the Piedmont of Delaware are used for domestic, commercial, and industrial water supplies in northern New Castle County. The Piedmont bedrock is composed of granodiorite, gabbro, schist, gneiss, and a small area of marble. Little water-quality data are available for these aquifers, and water-quality characteristics shown in figure 2*C* do not include data from wells in marble.

Effects of Land Use on Water Quality

Water quality has been affected by municipal and industrial waste-disposal practices, chemical spills, leaking underground storage tanks, agricultural practices, leachate from septic tanks, and saline-water intrusion. Many types of ground-water contamination originate from point sources, such as septic tanks or landfills, that affect the aquifer directly downgradient. Agricultural applications of manure and fertilizer, and saline-water intrusion, affect ground water in extensive areas.

Waste-Disposal Practices

Two sites in Delaware are regulated under the Resource Conservation and Recovery Act (RCRA) of 1976 and contamination has been detected at both; 9 sites are included on and 4 sites are proposed for the National Priorities List (NPL) of CERCLA (fig. 3*A*), including one U.S. Department of Defense (DOD) facility site. The four sites proposed for the NPL are shown as "other sites" in figure 3*A*. Contamination has been detected in ground water at 12 of these 15 sites and 4 of them are known or suspected to have contaminated nearby domestic or public wells.

As of September 1985, 12 hazardous-waste sites at one facility in Delaware have 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 CERCLA. The EPA presently ranks these sites under a hazard ranking system and may include them in the NPL. Of the 12 sites in the program, 2 contained contaminants but did not present a hazard to the environment. One site at one facility (fig. 3*A*) was 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.

Most of the industrial disposal or spill sites that have contaminated ground water are located in New Castle County near the Delaware River (fig. 3*A*). Waste substances include volatile organic compounds such as trichloroethylene and benzene, brine sludge containing mercury, heavy metals, and vinyl chloride. In much of this area, the unconfined aquifer is thin and most of the contaminated ground water discharges to saline surface water, thus limiting the extent of the contaminant plumes within the aquifers. Little development of public and domestic water supplies has occurred in the industrialized area, although six shallow domestic wells west of the area have been contaminated by ethylene dichloride and vinyl chloride leached from disposal pits (fig. 3*A*, site A).

Disposal sites located in the sandy recharge area of the Potomac aquifer pose the greatest threat to ground-water quality in central New Castle County because of the large withdrawals from that aquifer system. Leachate from the Army Creek Landfill (fig. 3*A*, site B), used for disposal of municipal and industrial waste from 1960 to 1968, has caused the limitation of withdrawals of water from some nearby public and industrial wells in the Potomac aquifer. Recovery wells installed on the Army Creek site by New Castle County are currently being used to curtail movement of the contaminant plume and to remove contaminants from the aquifer. An alternative involving hydrologic isolation of the landfill is pending formal approval by the EPA. Leachate from the Tybouts Corner Landfill, (fig. 3*A*, site C), which previously accepted county, municipal, and industrial wastes, has contaminated two domestic wells in the Potomac aquifer. Residents in the area of the landfill that could potentially be affected have been connected to a public water system. The EPA has required extensive reconstruction, capping, and drains around the landfills. A contaminant recovery-well system also will be installed downgradient of the landfill based on EPA decision.

Two municipal water supplies have been contaminated with organic chemicals. In the town of New Castle (fig. 1*A*), a shallow infiltration system in the unconfined aquifer was contaminated with a variety of organic chemicals of an undetermined origin. These wells have been abandoned, and the town now withdraws water from the Potomac aquifer. Trichloroethylene was found in the wells used to supply the town of Smyrna (fig. 1*A*). The town installed aeration and carbon filtration to overcome the problem.

The landfills shown in figure 3*C* include only regulated countywide facilities. Previously, domestic solid waste was disposed on a less centralized, local basis, and several additional abandoned landfills are located throughout the State. No known contamination of water supply or domestic wells caused by abandoned landfills in Kent County has occurred, and only two instances of domestic well contamination in Sussex County are known. The landfills are generally located in rural areas. The two regulated landfills in New Castle County are located along the Delaware River and do not threaten water-supply wells.

The Delaware Solid Waste Authority now manages all domestic and industrial nonhazardous solid-waste disposal in the State. New municipal landfills are lined, and ground-water quality is closely monitored. Abandoned landfills that contaminate the ground water generally are unlined and located in abandoned sand and gravel pits. Trash commonly was disposed in pits that intersected the water table. Leachate from the abandoned municipal landfills contains detectable concentrations of organic carcinogens for which no health standards have been established. The most extensive water-quality problem caused by landfill leachate is related to organic decomposition of the trash that produces anaerobic conditions in the ground water and mobilizes iron and manganese.

Underground Fuel-Storage Tanks

State officials are aware of 10 domestic and 5 public-supply wells that have been contaminated by leaking underground fuel-storage tanks. More than 100 instances of leaking tanks have been documented by the presence of fumes in basements and other subsurface structures. The State believes that the potential problems with hydrocarbons are much greater than known because of the large number of aging gasoline tanks located in densely populated areas.

Products leaking from underground storage tanks generally float on top of the water table. Leaks are commonly detected by the presence of benzene, xylene, and toluene in the ground water.

Agricultural Practices

The most widespread land use in the Coastal Plain of Delaware is agriculture. Contamination of the unconfined aquifer by agricultural nutrients, particularly by nitrate, has been documented extensively in areas of crop production (Ritter and Chirnside, 1982; Denver, 1986). Poultry production is a major industry, and large quantities of poultry manure are being stored and spread on fields. Some of the largest nitrate plus nitrite concentrations reported in Delaware were in the unconfined aquifer downgradient from chicken houses (Ritter and Chirnside, 1982, p. 138). Chloride, calcium, magnesium, and potassium concentrations also are increased above background levels in areas affected by agriculture (fig. 4*C*). Insecticide and herbicide use has increased greatly in the last 10 years but no intensive study of their effects on ground water has been conducted.

Most of the known nitrate problems are in Sussex County in areas with well-drained soils where fertilizers leach readily into the aquifer. Several areas of nitrate problems in Kent and Sussex Counties are shown in figure 3*B*. There also is evidence that irrigation promotes nutrient leaching. Nutrients have moved more deeply into the unconfined aquifer in irrigated areas than in nonirrigated areas.

The number of wells and people affected by nitrates has not been documented, and no documented health problems have been associated with large nitrate concentrations in Delaware. In Kent and Sussex Counties, agricultural acreage is increasing, and irrigated acreage has almost doubled from 1974 to 1983 (Ritter and others, 1985). These trends indicate that nutrient contamination in the unconfined aquifer will continue to increase.

Septic Systems

Leachate from domestic septic systems also is a cause of nitrate contamination in the unconfined aquifer. Septic system leachate generally is not a problem on isolated lots in rural areas. It can, however, be a problem in developments with closely spaced, individual septic systems. Septic contamination of the unconfined aquifer was documented in private wells in an unsewered development south of Dover, and is suspected at several mobile home parks with individual septic systems (R. B. Howell, Delaware Department of Public Health and Social Services, oral commun., 1986).

Saline-Water Intrusion

As a result of ground-water pumping, saline water has intruded the unconfined aquifer along the Atlantic coast (fig. 3*B*). Chloride concentrations exceeding the drinking-water standard of 250 mg/L currently are a problem in shallow domestic wells in South Bethany and on Fenwick Island. Some problems also have been detected near the Indian River Inlet and at some locations along the Delaware Bay. Public-water suppliers in the coastal resort towns that previously withdrew water from the unconfined aquifer either have drilled deeper wells into the confined Chesapeake Group aquifers or have moved their well fields inland. The Chesapeake Group aquifers used for public supplies presently (1986) are not affected by saline-water intrusion in Delaware.

POTENTIAL FOR WATER-QUALITY CHANGES

The potential for new sources of contamination in the aquifers of Delaware is generally decreasing because of recent Federal and State regulations governing waste disposal and increased public awareness of ground water and its importance. Cleanup efforts are planned or underway for several sites. Areas of the aquifers that are contaminated or threatened by contamination may cause local availability problems as water use increases.

Nitrate contamination of the unconfined aquifer associated with crop production has the potential to increase as more acreage is put into production and irrigation increases. Increasing irrigation efficiency, better poultry manure storage, and use of proper spreading rates for fertilizers, encouraged by the State, will help decrease nutrient contamination of ground water. Some problems are unavoidable in the sandy soils common to Delaware (Ritter and Manger, 1985), where infiltration rates are rapid and percolation of contaminants is facilitated. The State also has new regulations for septic systems which eventually should decrease the extent of aquifer contamination from septic systems. The extent of ground-water contamination from herbicides and insecticides in the unconfined aquifer is undefined.

Legislation and regulations have recently been developed that regulate installation of new underground fuel-storage tanks and require existing tank systems to be upgraded by 1991.

GROUND-WATER-QUALITY MANAGEMENT

Two State agencies are responsible for different aspects of ground-water quality. The Department of Natural Resources and Environmental Control allocates water use, issues permits, and monitors waste-disposal sites. The Department of Health and Social Services monitors the quality of public water supplies. One Federal interstate agency, the Delaware River Basin Commission, is involved in basin-wide ground-water planning and management.

Delaware is using the National Interim Primary and Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1986a,b) in the implementation of the Safe Drinking Water Act (SDWA) and RCRA under delegation of authority from the Federal government. The Underground Injection Control Program of the SDWA is used to regulate cooling-water returns from ground-water heat pumps. Delaware also has regulations for other types of waste injection, although, at the present time, there are no injection wells in the State. Hazardous material is tracked under RCRA by the waste manifest system.

Under CERCLA, also called Superfund, EPA has made decisions on remedial actions to be taken at Tybouts Corner Landfill (fig. 3*A*, site C) and at site D (fig. 3*A*) and is in the process of selecting alternatives for remedial action at Army Creek Landfill (fig. 3*A*, site B) and at site A (fig. 3*A*). Response time and actions taken to handle spills of hazardous chemicals under CERCLA authority in Delaware are considered to be good by State officials.

Delaware adopted a ground-water protection strategy in 1983 as a result of Section 208 of the Clean Water Act. The State is currently reviewing the strategy and plans to update it to meet current needs. The strategy allows for differential protection of ground water by permitting some limited degradation in areas where the public and environment are not adversely affected. The goal of the program is to manage ground water so that there will be enough for future needs. Permits are issued for well construction, water development, and waste disposal. All ground-water-management decisions attempt to integrate surface- and ground-water quality and quantity considerations. Data on water use and water quality are available to support State ground-water protection programs. Additional regulations in the State require that all well drillers and septic system designers and installers be licensed. Geologists in the private sector also must be registered.

The Information and Education Office of the Department of Natural Resources and Environmental Control provides public educational brochures that explain ground-water concerns and existing regulatory programs. A State Water Conference also is held yearly to inform the public about current water issues and regulations.

The presence of toxic substances and organics in ground water is receiving increasing attention through monitoring of waste sites and analyses of water from public wells.

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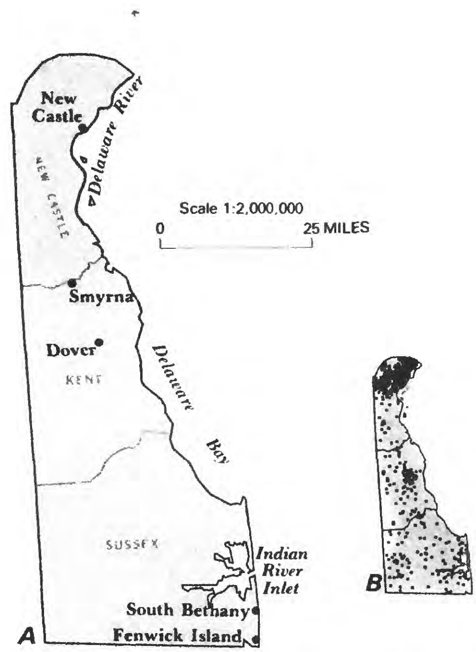

Figure 1. Selected geographic features and 1985 population distribution in Delaware. *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people within a census tract. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial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

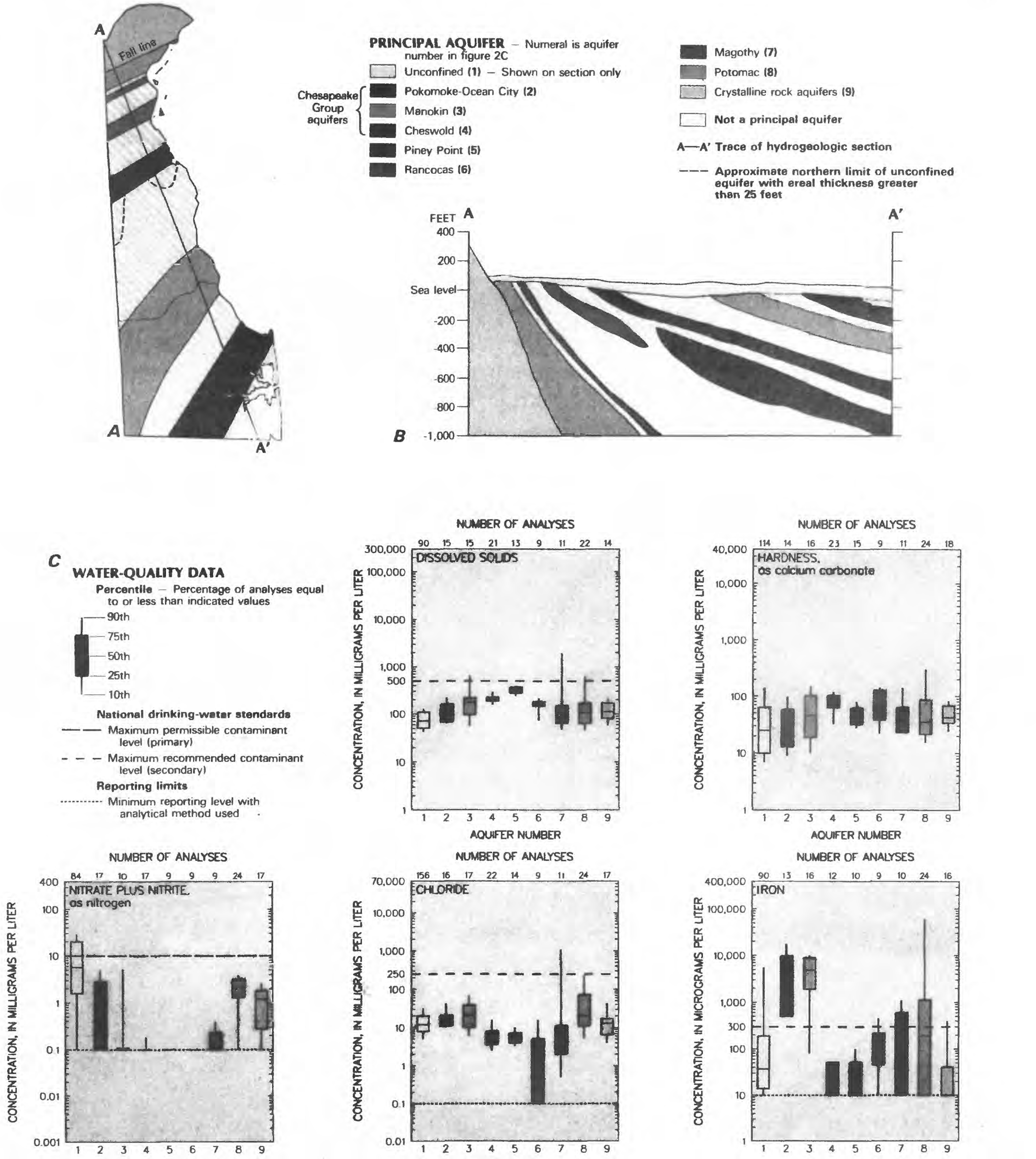

Figure 2. Principal aquifers and related water-quality data in Delaware. *A*, Principal aquifers. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1956-86. (Sources: *A*, *B*, Cushing and others, 1973; Sundstrom and Pickett, 1971; Hodges, 1984. *C*, Analyses compiled from Delaware Department of Health and Social Services, 1986, and U.S. Geological Survey, 1976-86; national drinking-water standards from U.S. Environmental Protection Agency, 1986a, b.)

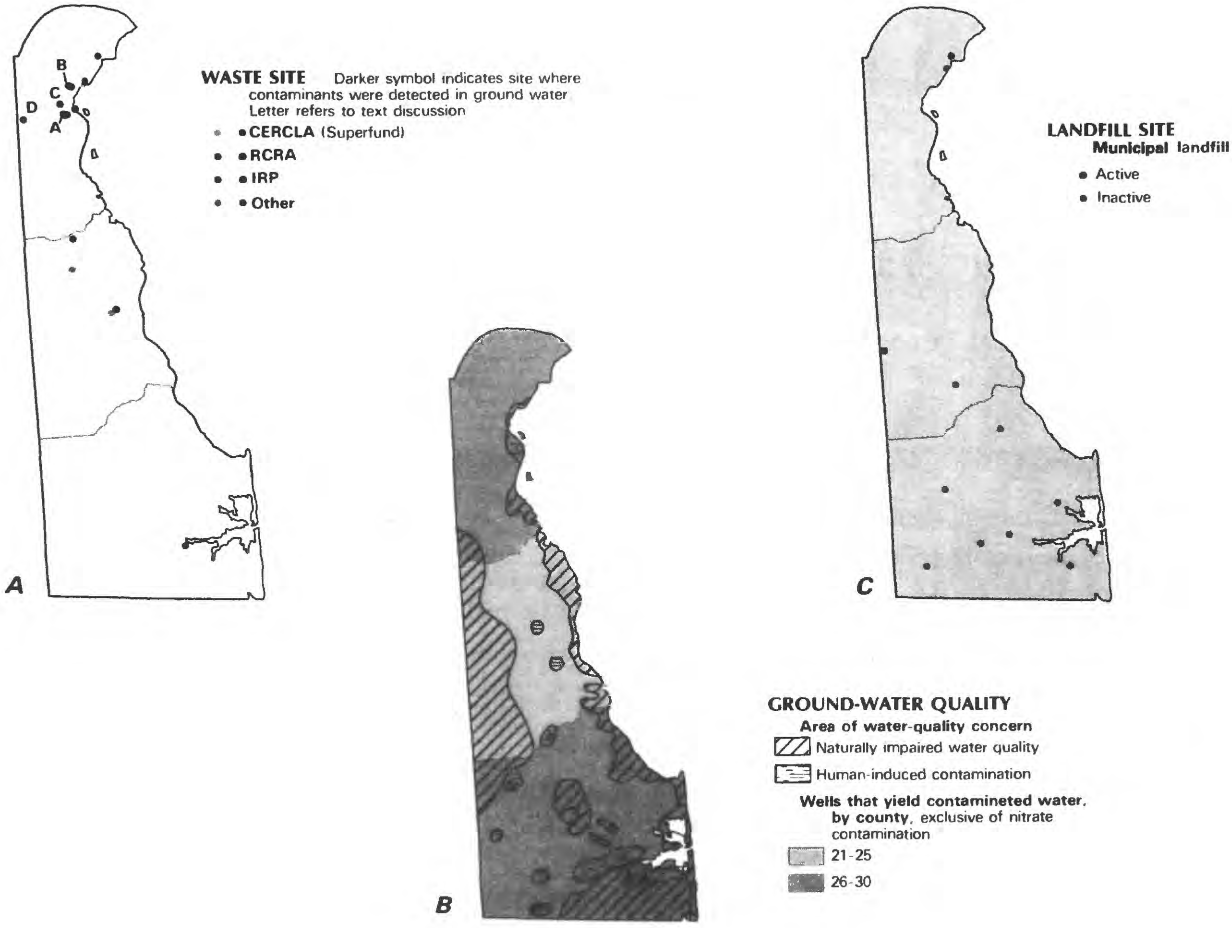

Figure 3. Selected waste sites and ground-water-quality information in Delaware. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; Resource Conservation and Recovery Act (RCRA) sites; Department of Defense Installation Restoration Program (IRP) sites; and other selected waste sites, as of August 1986. *B*, Areas of naturally impaired water quality, areas of human-induced contamination, and distribution of wells that yield contaminated water, as of August 1986. *C*, County landfills, as of August 1986. (Sources: *A*, Augustus Mergenthaler, Delaware Department of Natural Resources and Environmental Control, written commun., 1986. *B*, R.B. Howell, Delaware Department of Health and Social Services, oral commun., 1986; Ritter and Chirnside, 1982; Robertson, 1977. *C*, M.A. Apgar, Delaware Department of Natural Resources and Environmental Control, written commun., 1986.)

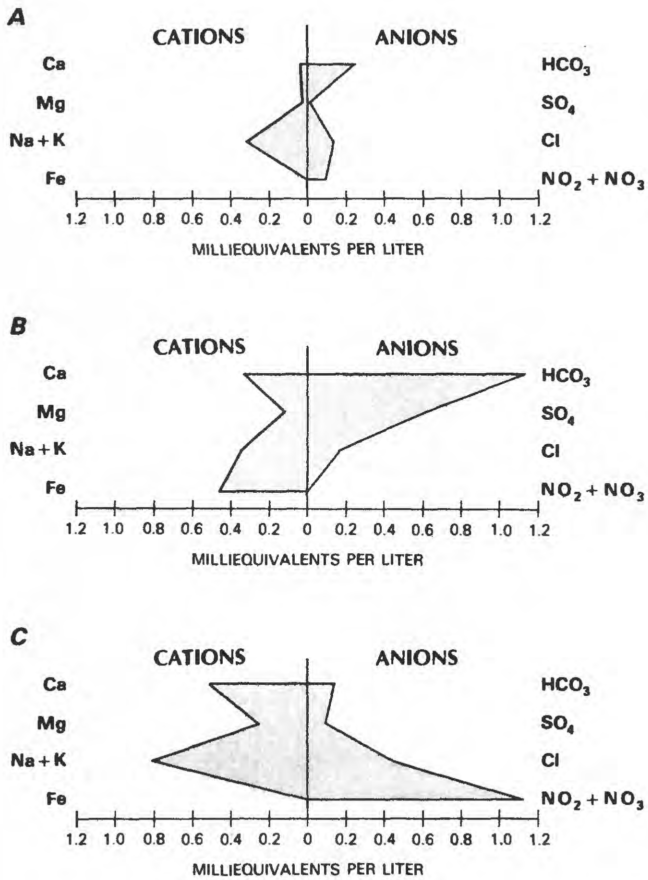

Figure 4. Water-quality characteristics in the unconfined aquifer, Delaware. *A*, Background water, oxidizing environment. *B*, Background water, reducing environment. *C*, Water affected by agriculture. (Source: *A*, *B*, *C*, Denver, 1986.)