WEST VIRGINIA

GROUND-WATER QUALITY

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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.

Contents

Illustrations

WEST VIRGINIA
Ground-Water Quality

The water supply for about 53 percent of West Virginia's population (fig. 1) is derived from ground-water sources—wells, springs, coal mines, and limestone mines. Although most of the urban areas obtain water for public supply from streams, 90 percent of the rural population depends on ground water for domestic use. Estimated average withdrawal of ground water during 1985 was 58.1 Mgal/d (million gallons per day) for public and self-supplied domestic use, 33.5 Mgal/d for industrial use, and 16.2 Mgal/d for agricultural use (K.E. Suder, West Virginia Geological and Economic Survey, oral commun., 1987). More than one-half of all ground water used for public supply requires treatment to meet the national drinking-water standards established by the U.S. Environmental Protection Agency (1986a,b). Concentrations of iron and manganese in ground water commonly exceed the secondary drinking-water standards of 300 μg/L (micrograms per liter) and 50 μg/L, respectively. Ground water in most of the State does not exceed the primary and secondary drinking-water standards of 10 mg/L (milligrams per liter) for nitrate (as nitrogen) and 500 mg/L for dissolved solids. Nitrate plus nitrate concentrations exceed 10 mg/L, most commonly, in ground water from limestone regions in the eastern part of the State, from alluvial aquifers (fig. 2) in areas of intensive agricultural use, and near reclaimed coal mines.

Ground-water quality has been degraded throughout the State as a result of coal mining, oil and gas drilling, and improper disposal of domestic and industrial wastes (fig. 3*B*). Site investigations, conducted by the West Virginia Department of Natural Resources (WVDNR), are continuing to identify additional areas of ground-water contamination. These areas typically are related to old industrial waste-disposal sites, many of which were never formally designated as disposal sites.

The Federal Resource Conservation and Recovery Act (RCRA) of 1976 requires monitoring of ground-water quality at 24 facilities in West Virginia, where hazardous wastes are disposed or treated. Contamination of ground water has been detected at 19 of the 24 RCRA sites (fig. 3*A*). Five sites, including two RCRA sites, were included on the National Priorities List (NPL) of hazardous-waste sites by the U.S. Environmental Protection Agency (1986c). Evaluation of these Superfund sites is required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Ground-water contamination has been detected at all five of these CERCLA sites.

In 1941, the U.S. Geological Survey, in cooperation with the West Virginia Geological and Economic Survey, established a ground-water observation network. The primary emphasis of this program has been the monitoring of water-level fluctuations; however, in 1984, collection of water-quality data was begun with the intent of sampling at 3-year intervals. Because the incorporation of water-quality data collection into the network is new, information about water-quality trends is not available.

WATER QUALITY IN PRINCIPAL AQUIFERS

There are two major types of aquifers in West Virginia—unconsolidated alluvial deposits and sedimentary bedrock. Major alluvial deposits are located along the Ohio and Kanawha Rivers and in the Teays Valley (fig. 1*A*). The maximum thickness of alluvial deposits is about 100 feet along the Ohio River and 70 feet along the Kanawha River and in the Teays Valley. Other alluvial deposits of limited extent are located along streams throughout the State. Maximum thickness of these minor deposits typically does not exceed 30 feet. About 55 percent of all ground water used for public supply is from alluvial deposits along the Ohio River.

The bedrock-aquifer system is typically composed of alternating layers of sedimentary rocks such as sandstone, siltstone, shale, limestone, and, in units of Pennsylvanian age, coal (Puente, 1985). Because of the vertical differences in lithology, aquifer units have been designated by geologic age rather than by lithologic composition. Movement of ground water in these rocks primarily is through fractures, bedding-plane separations, and, in limestone areas, solution openings. Coal mines, both active and abandoned, are an important source of water in the sedimentary bedrock. In 1980, about 70 public-supply systems obtained more than 7 Mgal/d from coal mines to serve about 82,000 individual and commercial users (Lessing and Hobba, 1981). Abandoned mines are commonly used for individual water supplies, particularly in the low-sulfur coal fields located in the southern part of the State. In the eastern part of the State, springs and flooded limestone mines are used for public and individual water supplies.

The topography of West Virginia is primarily mountainous. Little flat land is present except in river valleys and on some ridgetops. In much of the State, topography affects the shallow ground-water flow path. Although recharge occurs at all topographic settings, the flow of ground water typically is toward valleys, resulting in the youngest ground water being from hilltop wells and the oldest ground water being from valley wells. Differences in this pattern occur primarily in steeply folded rocks in the eastern part of the State and in limestone areas where the relationship of recharge and discharge areas is more complex.

Because of chemical changes that occur as ground water percolates downward into valleys or flows laterally to hillside seeps and springs, the chemical composition of ground water tends to differ with respect to topography. These differences are governed by the type and solubility of the rocks the water contacts, the length of time it is in contact with a particular type of rock, and the chemical properties of the water itself. Examples of the differences in ground-water quality that occur with respect to topography are shown in figure 4.

Concentrations of iron and manganese in Pennsylvanian rocks generally are larger in ground water from valley settings than in ground water from hilltop settings (fig. 4). Where limestone is common, such as in the Upper Pennsylvanian aquifers, hardness is largest in hilltop settings and smallest in valley settings. In contrast, the sodium concentration of ground water is largest in valley settings and smallest in hilltop settings. The relation between hardness and sodium content primarily is the result of sodium-calcium ion exchange, a softening process that occurs as calcium ions are exchanged for sodium ions in clays as ground water percolates through, or flows along, clay layers. Because of differences with respect to topography, the chemical quality of water in the bedrock aquifers cannot be easily mapped on an areal basis. Wells in one topographic setting may yield water of a chemical quality very different from that in nearby wells in another topographic setting.

BACKGROUND WATER QUALITY

A graphic summary of data collected by the U.S. Geological Survey from 1950 to 1985 (fig. 2*C*) for dissolved solids, hardness (as calcium carbonate), nitrate plus nitrite (as nitrogen), iron, and manganese characterizes the variability of the chemical quality of water from alluvial and bedrock wells. Statistical computations of the percentiles were made without regard to the depth at which the sample was obtained within a given aquifer unit. Where more than one analysis was available, median values were used. Most of the data were collected as part of reconnaissance studies to describe general water resources.

Percentiles of these constituents are compared to national standards that specify the maximum acceptable concentration of a contaminant in drinking-water supplies as established by the U.S. Environmental Protection Agency (1986a,b). National drinking-water standards are classified as either primary or secondary. Primary standards are established on the basis of health-related effects and are legally enforceable. Secondary standards apply to esthetic qualities of water and are recommended guidelines. Primary drinking-water standards include maximum concentrations of 10 mg/L nitrate (as nitrogen) and 4 mg/L fluoride. Secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids, 300 μg/L iron, 50 μg/L manganese, and 2 mg/L fluoride. State drinking-water standards (West Virginia State Board of Health, 1981) are similar to national drinking-water standards.

Alluvial Aquifers

Alluvial aquifers are divided into three categories: deposits found along the Ohio River, deposits found along the Kanawha River, and other alluvial deposits including those along the Teays Valley. Chemical characteristics of water from these three aquifer groups are distinctly different. Water from alluvium along the Ohio River is very hard with a median hardness of 220 mg/L. The median concentration of manganese is 340 μg/L, which exceeds the 50 μg/L secondary drinking-water standard. In water from alluvium along the Kanawha River, median values for iron (7,200 μg/L) and manganese (450 μg/L) exceed the drinking-water standards. Water from alluvial deposits other than along the Ohio and Kanawha Rivers commonly does not exceed the drinking-water standards. Differences in the chemical quality of the water from the three alluvial aquifers appear to be related to ground-water flow patterns as well as to mineral differences in alluvial materials.

Sedimentary Bedrock Aquifers

The median values of manganese in water from the sedimentary bedrock exceed drinking-water standards in all aquifer groups except the Upper Pennsylvanian aquifers and the Cambrian and Ordovician aquifers. The median iron concentration of water from the Lower Pennsylvanian aquifers also exceeds the drinking-water standard. Manganese and iron in concentrations exceeding the drinking-water standards may cause staining of plumbing fixtures and laundry. Calcium and magnesium, which contribute to hardness, are constituents of the more soluble minerals found in the rocks of the State. These elements are particularly common in limestone. As a result, aquifers that contain large amounts of limestone yield water with larger hardness and dissolved solids than the aquifers having less limestone.

The median value for nitrate plus nitrite (as nitrogen) is smaller than 10 mg/L in all aquifers. This limit is exceeded in water from only a few wells—those located primarily in areas underlain by limestone and in agricultural areas. Data from the West Virginia Department of Health (WVDH) indicate that nitrate plus nitrite (as nitrogen) concentrations larger than 10 mg/L are common in water from alluvial deposits in farming areas, particularly along the Ohio River. Nitrate plus nitrite concentrations in excess of 10 mg/L are common in ground water near reclaimed surface mines where nitrogen fertilizers have been used.

Ground water containing concentrations of chloride in excess of the secondary drinking-water standard of 250 mg/L underlies most of the State at depths of about 300 feet below the major streams. However, in several areas saline water is at or near land surface, typically in valleys along the axes of anticlines where intensive vertical fracturing has occurred. Many of these areas have historical significance in that the saline water was used to produce salt during the 1800's.

The WVDH notifies county health departments of all water supplies that contain sodium concentrations larger than 20 mg/L. The county health departments are required to make this information available to physicians and to people on sodium-restricted diets. U.S. Geological Survey data indicate that sodium concentrations exceed 20 mg/L in water from about half of the wells that tap rocks of Pennsylvanian age.

Effects of Land Use on Water Quality

Ground-water quality has been degraded as a result of industrial waste disposal, coal mining, oil and gas drilling, agricultural activities, domestic or municipal waste disposal, transportation, and rural development. Studies by the U.S. Geological Survey, various State and Federal agencies, and academic institutions have documented many such changes.

Industry

Industrial developments are primarily located along the Ohio and Kanawha Rivers. Major industries include the manufacture of chemicals, steel, and aluminum and the production of electric power. Some of the Nation's major chemical-manufacturing complexes are located in the Kanawha River valley near Charleston and along the Ohio River. The location of the State's chemical industry has been linked to the presence of shallow salt brines and natural gas. Brines were used as early as 1900 for the manufacture of chemicals such as bromine, caustic soda, and soda ash.

Based on characteristics such as corrosivity, ignitability, reactivity, and toxicity, waste materials are classified as either hazardous or nonhazardous by the Waste Management Division of the WVDNR. Ground water has been contaminated as a result of improper disposal of both hazardous and nonhazardous industrial wastes. In 1981, West Virginia industries generated more than 8.3 million tons of hazardous wastes, about 35 percent of which was disposed of within the State (Cinquegranna and Ramey, 1982). About 92 percent of this waste was produced in Tyler, Marshall, Brooke, and Kanawha Counties. Most of the hazardous waste disposal in the State is achieved by treatment systems regulated under the National Pollutant Discharge Elimination System (NPDES) Program. Although NPDES methods of waste treatment and disposal primarily affect surface-water resources, impoundments are commonly used during treatment processes and for storage of liquid hazardous wastes. Leakage of wastes from such impoundments, especially unlined impoundments, has been a major cause of ground-water contamination (West Virginia Department of Natural Resources, 1980). Contaminants include chloride, lead, arsenic, chromium, and various organic compounds. Also, improper disposal of solid industrial wastes, both hazardous and nonhazardous, has contaminated ground water.

There are 24 RCRA facilities (fig. 3*A*) for treatment and disposal of hazardous wastes. Most of these sites involve treatment and disposal of wastes generated by the chemical industry. Other RCRA facilities involve waste treatment and disposal for aluminum, steel, and wood-preserving industries. The WVDNR has determined that contamination of ground water has occurred at 19 of the RCRA sites. However, at eight of these sites, contamination is not RCRA related. Most of the RCRA sites are located near densely populated areas along the Ohio and Kanawha Rivers and are underlain by alluvial deposits. Because of the generally permeable nature of alluvial deposits, ground water in these areas is especially susceptible to contamination by leakage of wastes from unlined impoundments. Contaminants detected in ground water at RCRA sites include chloride, mercury, phenol, carbon tetrachloride, chloroform, trichloroethylene, and benzene.

Also of concern are numerous landfill sites (fig. 3*C*) used in the past for disposal of industrial wastes. Little information about the location and types of waste material is available for many such sites. Transportation of chemicals has resulted in accidental spills that have affected ground-water quality. One such incident, involving derailment of a freight train in Mason County, resulted in the closure of the well field for the City of Point Pleasant, because of contamination by epichlorohydrin. Ground-water contamination has been detected at one Department of Defense facility (U.S. Department of Defense, 1986) and at two former ordnance facilities that are CERCLA sites. Contaminants found in ground water at these sites include trinitrotoluene (TNT), dinitrotoluene (DNT), and benzene.

Mining

The effects of coal mining on ground water are largely related to chemical characteristics of the coal and overburden material. The coal fields of West Virginia have been classified based on sulfur content—coal in the northwestern part of the State typically has a larger sulfur content than that of the southern part (fig. 2). Exposure of coal and overburden materials to air during mining increases the rate of oxidation of sulfur-bearing minerals such as pyrite. Oxidation of pyrite results in the formation of acid mine drainage, which is characterized by low pH and large concentrations of iron, manganese, hardness, and sulfate. Acid mine drainage occurs primarily in the high-sulfur coal fields, whereas alkaline mine drainage occurs primarily in the low-sulfur coal fields.

Studies by O'Steen and Rauch (1983) and McCurry and Rauch (1987) describe degradation of the chemical quality of ground water as a result of both surface and subsurface mining of coal. Their results indicate that the effects of mining are most pronounced nearest the mine and diminish with increasing distance from the mine. Acidic mine water is neutralized and diluted as it flows away from the mine and percolates through the ground-water system. Even though the acidity is neutralized in a short distance, water from wells within as much as 1,500 feet of a surface mine have shown increased iron and sulfate concentrations. Increases in iron and sulfate concentrations have been found in water from wells located near streams that receive acid mine drainage. Chemical reactions associated with increased oxidation rates, that occur as a result of mining, can cause mobilization of metals commonly found in coal.

In the low-sulfur coal fields, which are common in the southern part of the State, water from mines is used for public and individual supplies. The chemical quality of water from some of these mines does not exceed drinking-water standards before treatment. However, water from mines commonly requires treatment to decrease iron and manganese content. Most of the mine water used for supplies is derived from abandoned mines, although several communities use water pumped from active mines. Contamination of ground water can occur from chemicals used directly or indirectly in mining processes. Several McDowell County community water supplies were temporarily contaminated by chemicals used to extinguish a fire in an active underground mine. Other possible contaminants include acrylamide (found in industrial grade polyacrylamide, which is used in coal cleaning processes), oil, grease, and solvents used in association with mine equipment, and polychlorinated biphenyls (PCB's) from transformers which were typically left in the mines upon closure.

Ground water can also be contaminated by leachate from coal refuse. There are about 54,000 acres of coal refuse in West Virginia (Johnson and Miller, 1979). Leachate from a coal-refuse pile on the Ohio River flood plain reportedly contaminated municipal wells in Marshall County. The contamination resulted in closure of four wells because of sulfate concentrations in excess of the secondary drinking-water standard of 250 mg/L.

Oil and Gas

Ground water has been contaminated in conjunction with oil and gas production at many places in the State. Drilling for oil and gas began in the early 1860's. Since then, several major oil and gas fields have been discovered. Saltwater associated with oil and gas in West Virginia commonly is under sufficient pressure to flow upward through oil and gas wells to land surface. Many oil and gas wells, particularly older ones, were not properly constructed or properly abandoned. Where well casings have deteriorated or have been removed during steel shortages such as occurred during World War II, migration of brines has contaminated freshwater aquifers (Bain, 1970). Disposal of brines produced in conjunction with oil and gas also can contaminate aquifers. Several companies reinject brines into oil-and-gas-producing strata for disposal and enhanced recovery processes. Reinjection requires pumping brines under pressure into brine-bearing strata. The reinjection can cause local increases in pressure in the brine-bearing stratum that can facilitate upward migration of brine and associated hydrocarbons through fractures, coreholes, uncased wells, and improperly constructed wells. Improper drilling and brine-disposal methods have resulted in numerous complaints from water-well owners concerning contamination of water supplies with drilling fluids and cuttings, oil, and natural gas.

Agriculture

The estimated total acreage of farm land decreased from 4.2 million acres in 1972 to 3.5 million acres in 1985 (West Virginia Crop Reporting Service, 1982, 1985). There is little irrigated land; most irrigation systems use surface-water sources. Ground-water use for irrigation averages less than 0.4 Mgal/d. Nitrate (as nitrogen) concentrations in excess of 10 mg/L have been detected near feedlots and in agricultural areas where fertilizers have been applied. Most instances of ground-water contamination by pesticides have occurred because they have been applied near improperly constructed or abandoned wells. These wells can provide pesticides with a direct means of entering the ground-water reservoir. Picloram and chlordane are the pesticides most commonly detected in ground water. There is no facility within the State for disposal of unwanted pesticides.

In the eastern panhandle, where valleys are underlain by very permeable limestone, agricultural wastes such as manure have contaminated ground water. Farmers in these areas are encouraged to install lined lagoons for storage of animal wastes. An inventory of 155 rural-domestic water supplies in Preston County indicated that 68 percent exceeded the primary drinking-water standard of 1 coliform colony per 100 milliliters of water (Sworobuk, 1984). Animal wastes appeared to be the major source of the coliform bacteria. Bacterial contamination is most commonly observed in improperly cased or dug wells or in wells located near septic fields.

Timber production is a major agricultural industry. Sawmills and lumber-treatment plants produce waste materials that can contaminate ground water. Leachate from sawmill wastes, analyzed by the WVDNR, contained increased concentrations of phenol, chromium, and arsenic, as well as large chemical and biological oxygen demands. Wood preservatives, such as creosote, have contaminated ground water in several areas of the State.

Domestic Waste Disposal

Mandatory permitting of municipal landfills and monitoring of ground-water quality will be implemented in June 1988 by the WVDNR, Division of Waste Management. About 65 permitted and an estimated 2,000 unpermitted landfills are used for disposal of domestic wastes. Exact locations of many of the unpermitted landfills are unknown; as a result, many sites do not appear in figure 3*C*. Limited data are available concerning the location of sites formerly used for municipal waste disposal. Ground-water contamination has been detected at some municipal landfills that have accepted industrial wastes. Because ground-water quality is monitored at few domestic-waste landfills, relatively little is known about the extent of ground-water degradation at these sites.

Transportation

Degradation of ground-water quality as a result of transportation-related activities has occurred in urban and rural areas. Underground petroleum-storage tank leaks and petroleum product spills have contaminated ground water at several locations. Application and improper storage of salt, used for deicing roads, has degraded water quality in several domestic wells (Hobba, 1985). Concentrations of chloride in ground water exceeded 3,400 mg/L at a Department of Highways salt-storage facility in Braxton County (West Virginia Department of Natural Resources and West Virginia Department of Highways, 1983). Efforts have been made to decrease ground-water contamination from improper storage of road salt by constructing buildings that fully enclose salt-storage areas.

Rural Development

In rural areas, ground-water problems are commonly associated with improper construction, location, and abandonment of water wells. Regulations requiring the certification of well drillers and standards for well construction were implemented in 1984 (West Virginia State Board of Health, 1984a,b). Many wells drilled before that time were not properly sealed or were located near septic fields. Improperly constructed wells can permit percolation of contaminants into underlying aquifers that can contaminate water in nearby wells. Improper abandonment of wells can be a potential problem. For example, many dug wells have been filled with trash that can contaminate surrounding ground water.

POTENTIAL FOR WATER-QUALITY CHANGES

Ground-water contamination has been most extensive in the alluvial aquifers, primarily in the alluvium along the Ohio River. Many major industries and much of the population are located in river valleys, which are typically underlain by alluvial deposits. More than 50 percent of all ground water used for public supply is obtained from alluvial deposits along the Ohio River. The potential exists for migration of known contaminant plumes of benzene, phenol, and mercury into municipal well fields. The permeable nature of alluvial deposits, especially in disturbed areas where surficial clay layers have been removed, makes these deposits susceptible to contamination from surface sources.

Areas underlain by limestone, predominantly in the eastern panhandle and Pocahontas, Greenbrier, and Monroe Counties, are particularly susceptible to ground-water contamination. Many valleys in these areas are located along anticlines where intensive vertical fracturing has occurred. Because of the solubility of limestone, these fractures have been enlarged through solution, and, in some areas, karst topography has developed. Most individuals and communities in these areas obtain water supplies from ground-water sources. Recharge in these limestone areas is rapid and can occur through sinkholes, caves, and streams. These conditions make the safe disposal of wastes difficult. Sinkholes, which are recharge points for underlying aquifers, are commonly used for disposal of domestic wastes, agricultural wastes, and even dead animals. Wells drilled into caves are used as drains for highway runoff, thus permitting direct inflow of contaminants, such as road salt and spilled materials, into the ground-water reservoir.

Pesticide disposal, spills of petroleum products, and leachate from landfills and impoundments have contaminated ground water in areas underlain by limestone. Much of the State's population growth has occurred in the eastern panhandle, particularly in Berkeley and Jefferson Counties. Because of the permeable nature of the carbonate rocks in this area and anticipated population growth, the potential for further contamination of ground water is significant.

Mined-out regions are particularly susceptible to ground-water contamination. There are about 1.6 million acres of abandoned coal mines in the State. Surface mines commonly have been used as landfills. Various industrial and domestic wastes have been dumped into abandoned mine shafts. Underground mine workings are capable of acting as conduits for the movement of ground water and contaminants, and, where underground workings connect with surface mines, direct inflow to ground-water reservoirs can occur. Fracturing associated with subsidence has increased the permeability of strata overlying coal mines, especially in areas of long-wall mining. This increased permeability increases recharge rates and makes the underlying aquifer more susceptible to surface contamination. Open shafts and boreholes into abandoned mines increase the likelihood that surface contaminants will enter the ground-water system.

GROUND-WATER-QUALITY MANAGEMENT

It is the policy of West Virginia to "maintain reasonable standards of purity and quality of the water of the State consistent with (1) public health and public enjoyment thereof; (2) the propagation and protection of animal, bird, fish, aquatic and plant life; and (3) the expansion of employment opportunities, maintenance, and expansion of agriculture and the provision of a permanent foundation for healthy industrial development" [Code of West Virginia, 1931, as amended, chapter 20–5A–1 (WVC, section 20–5A–1)]. The responsibility for protection and management of ground-water resources is shared by the Departments of Natural Resources, Health, Energy, Agriculture, and Highways and the Water Resources Board. On April 3, 1986, these five departments signed a memorandum of agreement to develop a comprehensive ground-water-protection program for the State.

The Department of Natural Resources, Divisions of Waste Management and Water Resources is responsible for implementing most of the regulatory programs related to ground water (WVC, section 20–5A). The Division of Waste Management regulates the disposal of nonhazardous waste and the storage, treatment, and disposal of all hazardous wastes under provisions of the West Virginia Hazardous Waste Management Act (WVC, section 20–5E), which implements RCRA. In addition to RCRA responsibilities, the Division of Waste Management has a cooperative agreement under CERCLA with the U.S. Environmental Protection Agency to conduct preliminary assessments, site inspections, and hazard rankings at various Superfund sites in West Virginia.

The Division of Water Resources includes the Ground Water and Underground Injection Control (UIC) Office, which coordinates ground-water program activities and regulates the subsurface placement of fluids (U.S. Environmental Protection Agency, 1984). In 1986, there were no active injection wells for the disposal of hazardous materials. However, there were about 800 class-II wells for brine disposal and enhanced-recovery processes, 15 class-III wells used in solution mining, and more than 500 class-V wells, including percolation wells receiving highway drainage and wells through which coal wastes are pumped into abandoned mines.

The Permits Branch of the Division of Water Resources is responsible for issuing and enforcing Water Pollution Control permits for municipal and private sewage-treatment works and for industrial facilities, which include landfills, impoundments, and spray irrigation systems that dispose of nonhazardous wastes. Regulation of some industrial waste-disposal activities requires ground-water monitoring. Other ground-water-related responsibilities of the Water Resources Division are the reporting of accidental spills, investigation of ground-water complaints, management of ground-water data, background and compliance monitoring programs, and water-purity analyses.

The Department of Health (WVC, section 16–1) is responsible for the protection of drinking-water supplies, including the regulation of all drinking-water wells, both public and private. The Environmental Engineering Division of the WVDH has primacy for the "Safe Drinking Water Act" to develop laws, design standards, policies, and regulations for public water supplies. This Division also has the authority to enforce drinking-water standards for public-water systems, to issue construction and operating permits for public water systems, and to train and certify well drillers and public water-supply operators. The WVDH laboratories perform chemical, bacteriological, and radiological analyses of drinking water on a routine basis for public water supplies and, at the request of county health departments, for private water supplies. County health departments are responsible for site inspection and issuance of permits for construction of domestic water wells and sampling for contaminants. The county health departments also are responsible for inspection and issuance of permits for the installation and operation of septic-tank systems and other onsite sewage-disposal systems, as well as the regulation of septic disposal.

The Department of Energy, created in 1985, is responsible for the regulation of the coal, petroleum, and natural gas industries (WVC, §22). The Division of Mining and Minerals requires mine operators to prevent or minimize degradation of the quality and quantity of ground-water resources. The Oil and Gas Division is responsible for preventing the contamination of freshwater by saltwater and by other contaminants associated with the oil and gas industry.

The Department of Agriculture, Plant Pest Control Division, is involved with the usage of pesticides. Responsibilities include training and certification of pesticide applicators, establishment of standards for powerline and right-of-way spraying, and investigation of ground-water complaints involving pesticide contamination. Other activities of the Department of Agriculture related to ground water include dispensing information about proper disposal practices for agricultural wastes, such as fertilizers, manure, and dead animals.

The Department of Highways (DOH) is responsible for the prevention of contamination of ground water by highway deicing materials and highway runoff, the regulation of salvage yards (WVC, section 17–23), and the management of materials stored at DOH maintenance facilities.

The Water Resources Board (WRB) is an independent agency composed of five members appointed by the Governor. It is responsible for the promulgation of regulations needed to protect the waters of the State (WVC, section 20–5, section 20–5A, section 29A–1–1). Regulations written by the WRB include standards of water quality and rules establishing the State's participation in the National Pollutant Discharge Elimination System (NPDES) under the Federal Water Pollution Control Act. The WRB also hears appeals of orders and other actions of the Chief of the Division of Water Resources, Department of Natural Resources.

Development of a ground-water-protection policy and related legislation is needed to provide for the future management of West Virginia's water resources. A computerized data base for qualitative and quantitative ground-water information is being developed to facilitate data management. There also is a need for a statewide ground-water-quality monitoring network that includes sampling for organic compounds.

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Figure 1. **Selected geographic features and 1985 population distribution in West Virginia.** *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.)

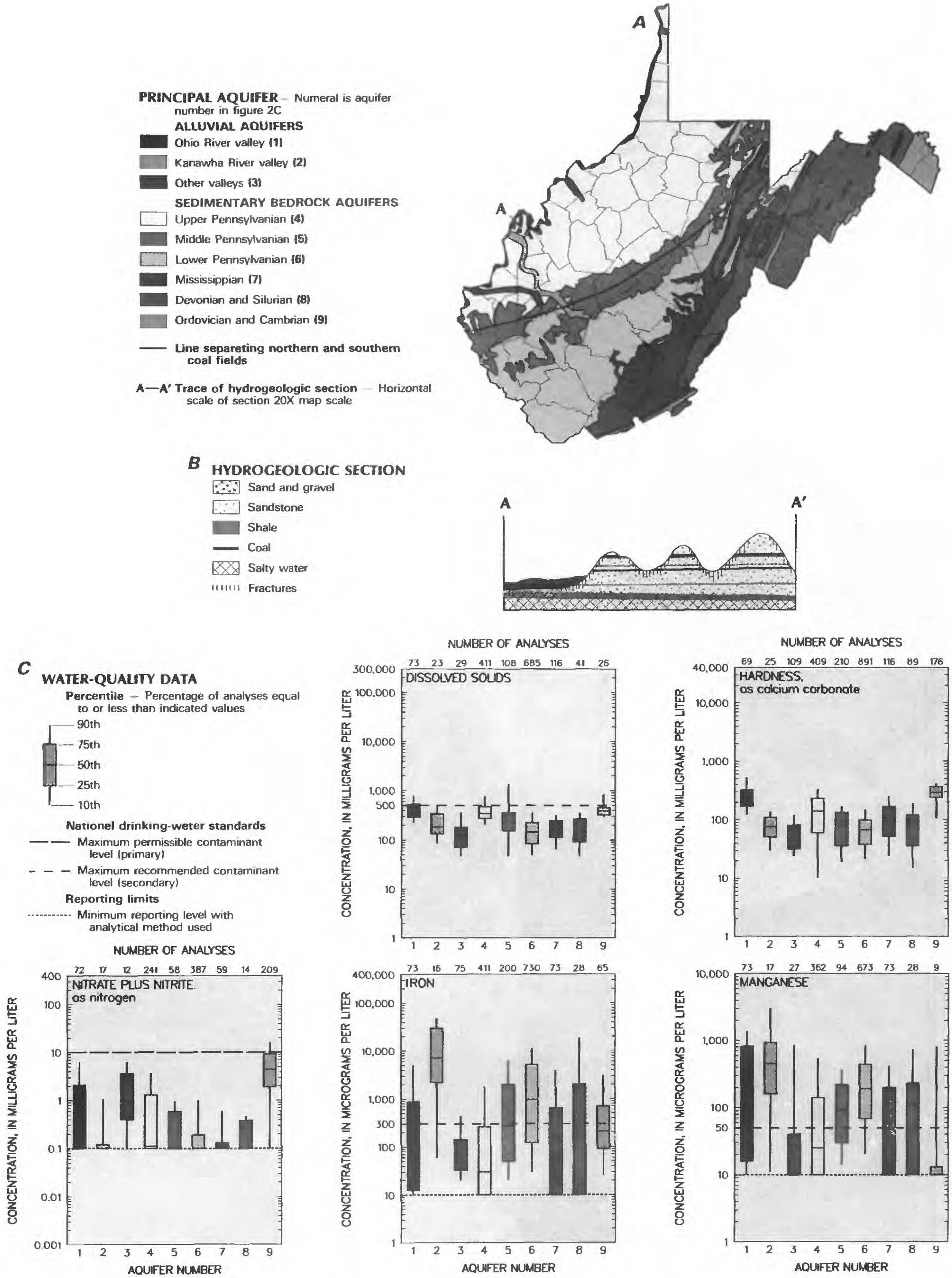

Figure 2. **Principal aquifer groups and related water-quality data in West Virginia.** *A*, Principal aquifer groups. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1950-85 (Sources: *A*, *B*, Modified from Puente, 1985, and Cardwell and others, 1968. *C*, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986a,b.)

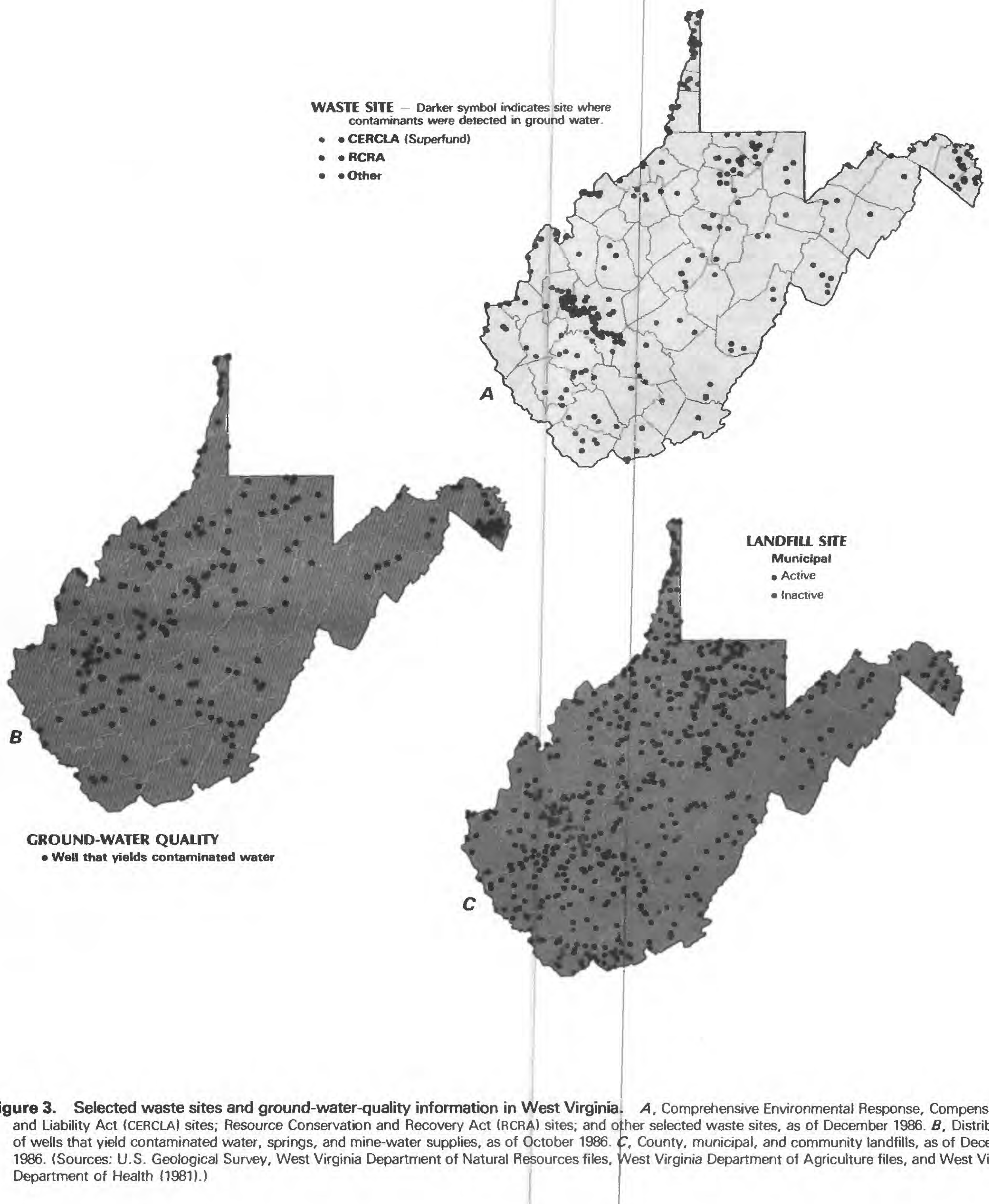

Figure 3. Selected waste sites and ground-water-quality information in West Virginia. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; Resource Conservation and Recovery Act (RCRA) sites; and other selected waste sites, as of December 1986. *B*, Distribution of wells that yield contaminated water, springs, and mine-water supplies, as of October 1986. *C*, County, municipal, and community landfills, as of December 1986. (Sources: U.S. Geological Survey, West Virginia Department of Natural Resources files, West Virginia Department of Agriculture files, and West Virginia Department of Health (1981).)

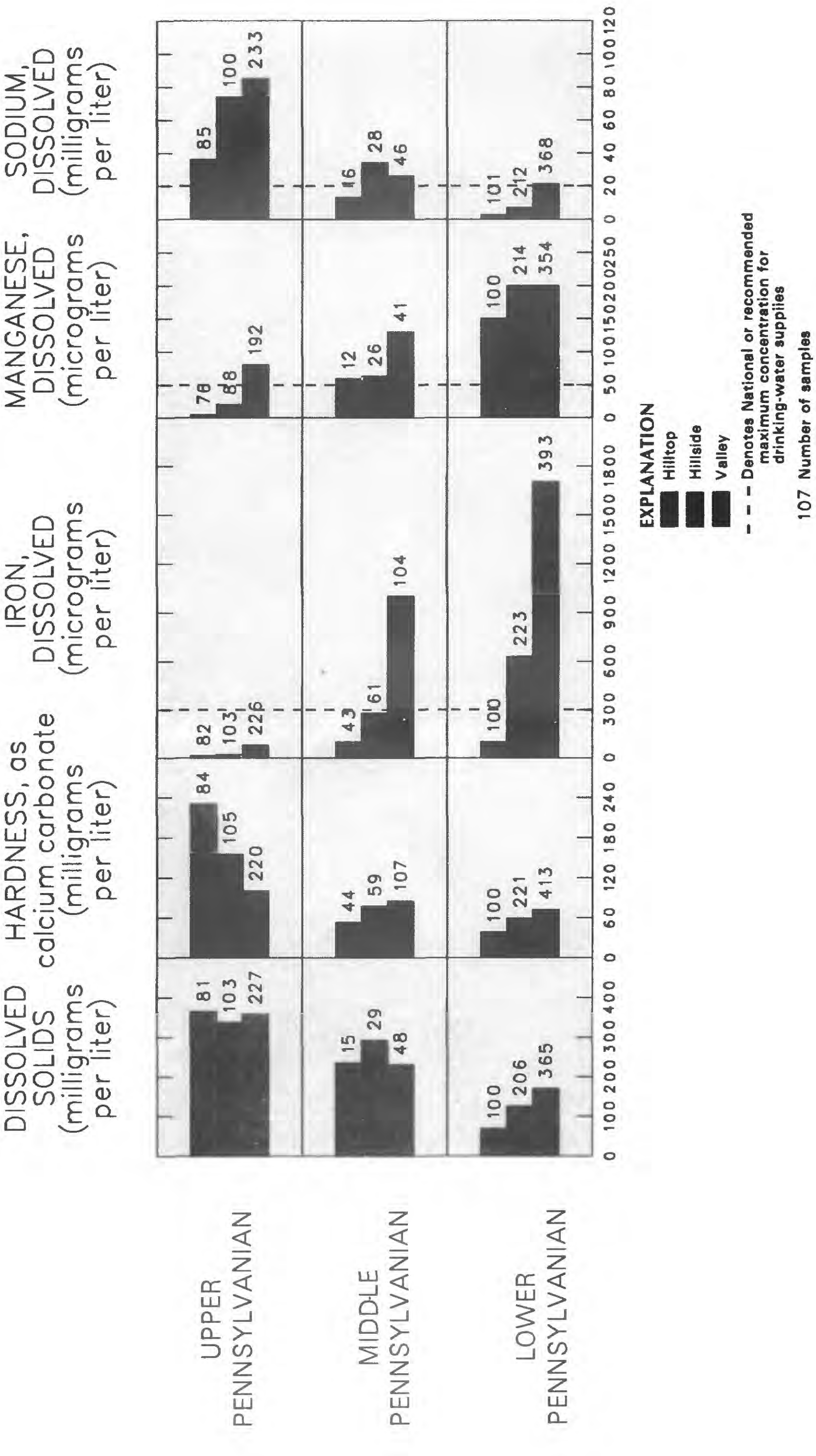

Figure 4. **Variation in the chemical quality of ground water with respect to topographic setting. Median values are used for concentrations.** (Source: U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986b.)

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