LOCATION AND SITE CHARACTERISTICS OF THE AMBIENT GROUND-WATER-QUALITY-MONITORING NETWORK IN WEST VIRIGINIA

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LOCATION AND SITE CHARACTERISTICS OF THE AMBIENT GROUND-WATER-QUALITY-MONITORING NETWORK IN WEST VIRGINIA

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ABSTRACT

Ground-water-quality-monitoring sites have been established in compliance with the 1991 West Virginia Ground-Water Protection Act. One of the provisions of the Ground-Water Protection Act is to conduct ground-water sampling, data collection, analyses, and evaluation with sufficient frequency so as to ascertain the characteristics and quality of ground water, and to evaluate the effectiveness of the ground-water-protection programs established pursuant to the act (Chapter 20 of the code of West Virginia, 1991, Article 5-M). This report contains information for 26 monitoring sites (wells and springs) that comprise the Statewide ambient ground-water-quality-monitoring network. Areas in which monitoring sites were needed were outlined by the West Virginia Division of Environmental Protection, Office of Water Resources, in consultation with the U.S. Geological Survey (USGS). Initial sites were chosen on the basis of recent hydrogeologic investigations conducted by the USGS and from data stored in the USGS Ground-Water Site Inventory database. Areal coverage, aquifer setting, and land use of the State of West Virginia were three of the more important criteria used in selection of the sites. A field reconnaissance was conducted to locate and evaluate the adequacy of selected wells and springs and to locate additional wells and springs in those areas of the State where USGS data are sparse. Background information explaining ground-water systems and water quality within the State of West Virginia has been included in this report. Descriptive information consisting of site, geologic, well construction, and aquifer-test data has been compiled as well. The 26 sites will be sampled periodically for iron, manganese, most common ions, volatile and semivolatile organic compounds (such as pesticides and industrial solvents), and fecal coliform and fecal streptococcus bacteria.

INTRODUCTION

Recent legislation (Chapter 20 of the West Virginia Code, Article 5-M), commonly referred to as the"Ground-Water Protection Act, " was passed in March 1991 and went into effect in June 1991. One of the major provisions of the act mandated ground-water sampling, data collection, analyses, and evaluation with sufficient frequency as to ascertain the characteristics and quality of ground water, and to evaluate the effectiveness of the ground-water-protection programs established pursuant to the act. Baseline data were needed to document current water quality and to provide a database for which future data could be compared. Emphasis was placed on sampling and analyzing wells that would reflect ambient ground-water quality. Processes such as carbonate rock dissolution, pyrite oxidation, and oxidation and reduction of iron and manganese oxyhydroxides, as well as other common geochemical processes, are therefore a primary concern. Sites were then selected in various hydrogeologic settings to document the current (ambient) ground-water-quality conditions in major aquifers of West Virginia.

The West Virginia Division of Environmental Protection, Office of Water Resources (DEP-OWR), in cooperation with the U.S. Geological Survey (USGS), selected areas throughout the State in which monitoring sites would be initially needed. The areas were initially selected by DEP-OWR on the basis of several factors. First, areas of intense population growth in West Virginia's eastern panhandle (Jefferson, Berkeley, and Morgan Counties) were chosen because of the potential adverse effects of population growth on the ground-water quality of the regions underlain by susceptible Cambrian and Ordovician karst limestone aquifers (Harpers Ferry, Lefevre, and Berkeley Springs). Second, areas along the Kanawha and Ohio Rivers (Parkersburg, New Martinsville, Winfield, Point Pleasant, and Follansbee) were selected because of the high density of industrial sites along the two rivers, the threat of contamination of alluvial aquifers by organic chemicals and metals derived from industrial activity, and heavy ground-water withdrawals for public-supply, commercial, and industrial facilities. Third, abandoned coal-mined areas (Welch and Fayetteville) were selected because of the heavy demand placed on abandoned coal mines as sources of public-water supply in the southern part of the State. Fourth, the limestones of the Greenbrier Group (Bowden in Pocahontas County, Sand Spring in Tucker County, and Davis and McLaughlin Springs in Greenbrier County) were selected because of the susceptibility of contamination of this aquifer by agricultural chemicals and nitrates from manure and nitrogen-based fertilizers and direct disposal of wastes into solution channels. The remaining areas were selected to provide areal coverage of the entire State and primarily concentrated on the Appalachian Plateau and Valley and Ridge bedrock aquifers.

The next phase of this project was to locate wells and springs in areas outlined by DEP-OWR that were suitable for inclusion in a Statewide ambient ground-water-quality-monitoring network limited by certain constraints. First, limits of available funding did not allow for drilling new wells and therefore existing wells and springs were selected. The second constraint was that wells and springs selected must have long-term access for sampling. State or Federally owned wells and springs and public-supply wells and springs therefore provided the majority of sites initially selected for inclusion in the monitoring network. This is also preferable from a water-sampling perspective, in that all wells selected have pumps in place, negating the need for costly pumping equipment and laborious purging of stagnant water from unused monitoring wells to ensure collection of representative water samples. Also, many of the wells are located in State forests, State and county parks, Federal and State fish hatcheries, or municipal water-treatment plants. Land use in the recharge areas to these wells tends to be regulated; therefore, the objective of attempting to sample wells unaffected by human activity is fulfilled as much as possible.

Purpose and Scope

This report provides information for each well and spring site selected for the ambient ground-water-quality network, including information on location, latitude, longitude, elevation, topographic setting, county, aquifer, location map, station name, and lithology. In addition, data have been included on length of casing, well depth, well yield, water level, well diameter and other physical well parameters. Discharge data have also been included for each spring.

A brief summary is provided for each site, including a description of the geologic setting, pump and plumbing setup, land use, and history of the site. A table listing well or spring owners' names, addresses, telephone numbers, and points of contact is also provided.

The material in the preliminary sections of this report was derived from previously published USGS reports. Specifically, the section on physical setting was derived from the 1984 and 1985 USGS National Water Summaries (Puente, 1985; Appel, 1986). The information on the source of ground-water recharge was taken from the 1985 National Water Summary (Ferrell, 1988). The 1984 Summary provided information for the occurrence and movement of ground water as well as for the Principal Aquifers section. Finally, the water-quality section was derived mostly from the 1986 National Water Summary (Ferrell, 1988). Complete references for these publications have been included in the Selected References section. This information has been provided for the benefit of the reader.

Physical Setting

West Virginia is located in the eastern part of the United States and is bounded by Pennsylvania and Maryland to the north, Virginia to the east, Kentucky to the south, and Ohio to the west (fig. 1). West Virginia is divided into three Physiographic Provinces--the Appalachian Plateaus, the Valley and Ridge, and the Blue Ridge, each with distinctive rock types and ground-water characteristics (fig. 2). The western and central parts of the State are in the Appalachian Plateaus Physiographic Province and are underlain by nearly horizontal consolidated sedimentary rocks. Streams have eroded the rocks in these areas to form steep hills and deeply incised valleys. The Allegheny Mountains section of the Appalachian Plateaus Province is underlain by gently to moderately folded sedimentary rocks. Surface-drainage patterns are dendritic, and surface and ground-water drainage divides generally coincide and are well defined.

The eastern part of the State, except for the extreme eastern tip, is in the Valley and Ridge Province. The consolidated sedimentary rocks that underlie this area are extensively faulted and sharply folded: the folded strata form a series of broad northeast-trending valleys and ridges. Surface drainage typically forms a trellis pattern. Surface and ground-water drainage divides coincide and are clearly defined in noncarbonate areas, but generally are not clearly defined and do not coincide with surface drainage divides in carbonate areas. The Blue Ridge Province includes only a very small area along the easternmost part of the State and is, therefore, not mentioned in this report.

GROUND-WATER SYSTEMS

The aquifers and confining beds that underlie an area comprise the ground-water system of that area. Hydraulically, this system serves two functions: it stores ground water in reservoirs and transmits water from recharge areas to discharge areas. Water enters ground-water systems in recharge areas and moves both downward and laterally through fracture systems, as dictated by hydraulic gradients and hydraulic conductivities to discharge areas (Heath, 1983). The movement of ground water generally is slow and can range from a few inches to several hundred feet per year (fig. 3).

Source of Ground-Water Recharge

Precipitation is the primary source of recharge to the ground-water systems in the State. There is a significant orographic effect on the geographic distribution of precipitation. Average annual precipitation ranges from 40 in. along the western boundary of the State to about 60 in. in the higher elevations in the mountainous east-central part of the State. On the eastern side of the mountains, a well-defined rain shadow reduces average annual precipitation to about 36 in. in the eastern panhandle. Precipitation does not exhibit a strong seasonal pattern. About 60 percent of the annual precipitation occurs from March through August. July is typically the wettest month, whereas September, October, and November are typically the driest months. About 50 percent of the precipitation returns to the atmosphere by evapotranspiration. Thunderstorms are common from May through July and can produce intense local rainfall, causing flooding along unregulated streams (Appel, 1986).

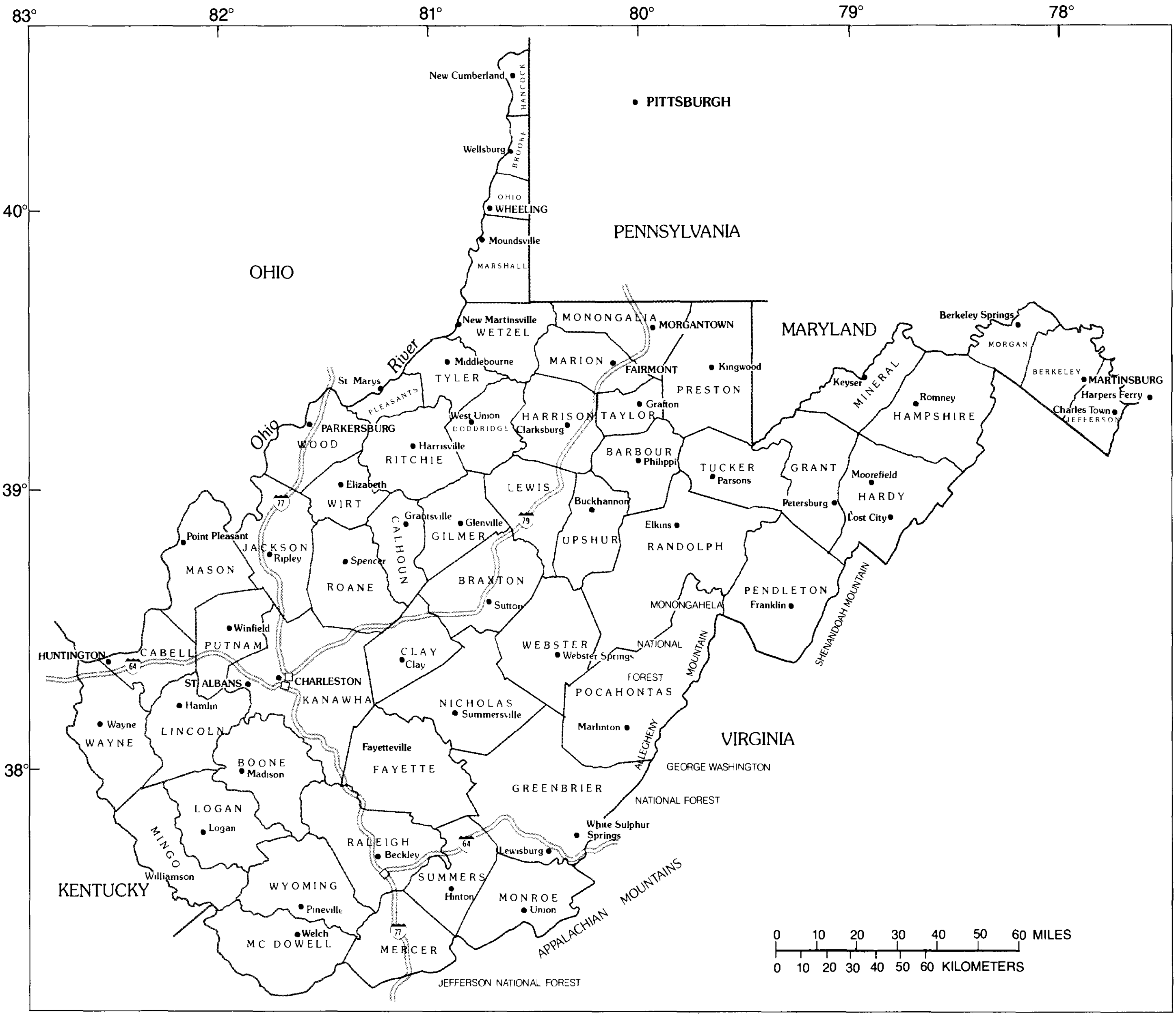

Figure 1. General location of West Virginia.

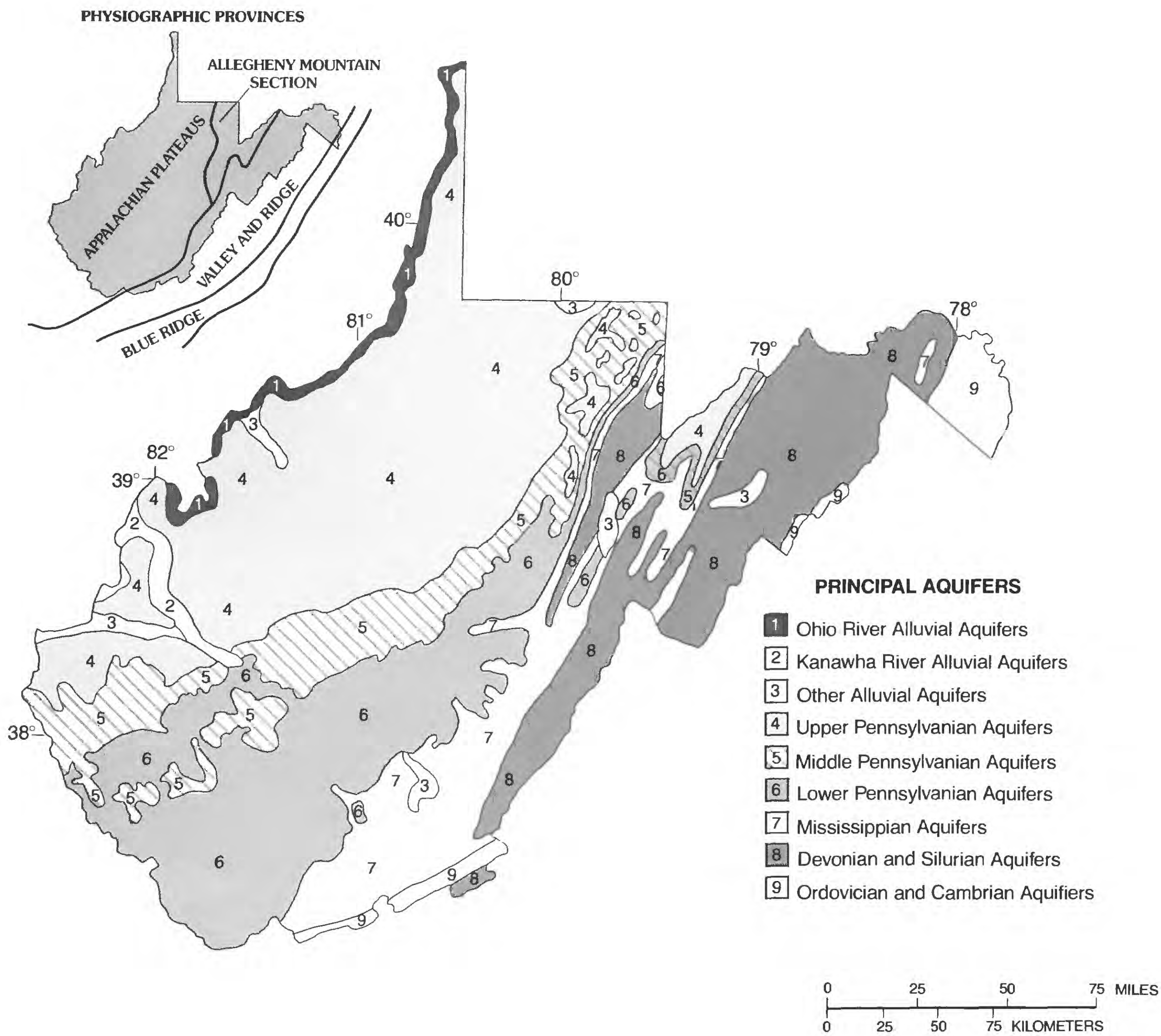

Figure 2. Principal aquifers and physiographic provinces in West Virginia. (Modified from Ferrell (1988, p. 524) and Puente (1985, p. 441).

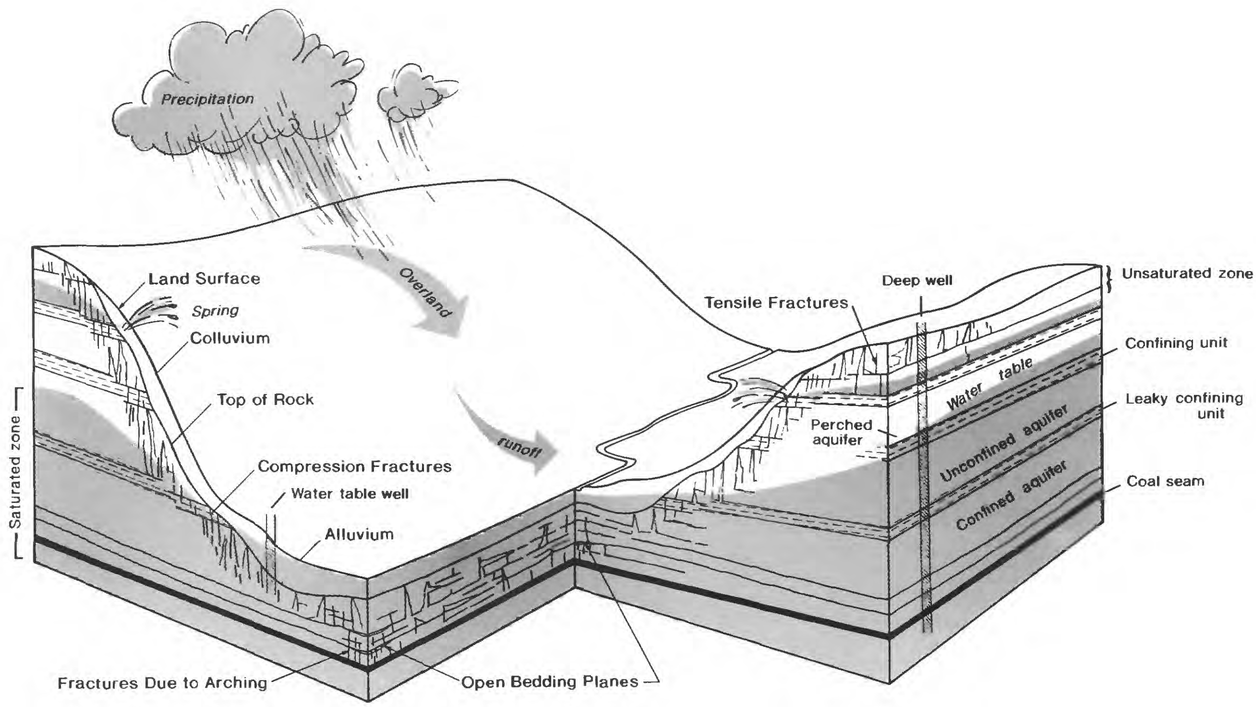

Figure 3. Generalized occurrence and movement of ground water in a typical ridge and valley system in the Appalachian Plateaus Province of West Virginia. (From Heath, 1983, p. 14).

Runoff in West Virginia changes seasonally and geographically. Average annual runoff ranges from 12 in. in the eastern panhandle to about 40 in. in the higher mountainous areas, and to about 16 in. in the western and southern parts of the State. The least amount of runoff generally is from June through November--a period of high evapotranspiration, and the most runoff generally is from December through May--a period of low evapotranspiration. In the higher mountainous areas in the east central part of the State, where average annual snowfall may be as high as 200 in., runoff is significantly affected by spring snowmelt (Appel, 1986).

As a result of evaporation and runoff, only a small part of the precipitation infiltrates the ground to recharge ground water. In the noncarbonate, consolidated-rock areas of the State, annual recharge generally ranges from 2 to 6 in. In the carbonate-rock (primarily limestone) areas in the Valley and Ridge Province, annual recharge ranges from 6 to 12 in. (Appel, 1986).

Occurrence and Movement of Ground Water

Some of the precipitation that infiltrates the Earth's surface is retained at shallow depth as soil moisture and some moves downward and into the underlying aquifers (fig. 3). Where an aquifer is overlain by permeable material, unconfined or water-table conditions exist. Local perched water-table conditions exist above impermeable rock layers (confining units), which impede the downward movement of water to the zone of saturation of an aquifer. Wells that tap unconfined aquifers are referred to as "water-table wells." Water levels in these wells indicate the position of the water table in the surrounding unconfined aquifer. Confined conditions exist where aquifers lie between or beneath confining beds. Wells drilled into confined aquifers are referred to as "artesian wells." In these wells, the water level is at some height above the top of the aquifer and represents the potentiometric surface of the confined aquifer (Ehlke and others, 1982).

Both intergranular spaces and fractures are important for storage and movement of ground water in sedimentary rocks. Intergranular spaces are voids or openings between particles of rock that were formed at the time of deposition or are the result of dissolution of cementing material or the rock particle. Primary permeability is a measure of the ease with which water will move through interconnected intergranular spaces. Unconsolidated material such as alluvium generally will deform without fracturing. Water that infiltrates unconsolidated material can deposit cementing materials in intergranular spaces. This reduces the intergranular space and the degree of interconnection, and causes the rocks to consolidate. Consolidation and cementation also make the rock more brittle and subject to fracturing. Fracturing causes openings in rocks through which water may move and is an example of "secondary permeability" (Freeze and Cherry, 1979).

Alluvium, consisting of stream or glacial-deposited sand, clay, and gravel typically overlain by fluvial silt and clay, is found in river terraces within the Ohio and Kanawha River valleys. The maximum thickness of alluvium deposits is about 100 ft along the Ohio River and 70 ft along the Kanawha River and in the Teays Valley (Ferrell, 1988).

Within the Appalachian Plateaus Physiographic Province, the bedrock consists predominantly of sandstone and shale interbedded with limestone and coal. Sandstone contains inter-granular, bedding-plane, and fracture openings and generally yields from 1 to 100 gal/min of water to wells and may yield as much as 400 gal/min (Puente, 1985). In areas where the pore spaces or fractures are filled with secondary minerals and little fracturing has occurred, a sandstone can yield little water to wells. Shale and limestone, because of their extremely small intergranular spaces, generally yield little water to wells. In areas of dense fracturing at shallow depths, shales may yield from 1 to 30 gal/min. In limestones, fractures and joints may become widened by dissolution of the calcium carbonate, increasing the ability of the rock to store and transmit large volumes of water. The number of joints, fractures, and cavities generally is greatest near land surface. Typical well yields in limestone terranes can range from 1 to 400 gal/min and may exceed 600 gal/min (Puente, 1985).

The degree of both primary and secondary permeability varies in bedrock aquifers. Primary permeability of surficial rocks in the Appalachian Plateaus and Valley and Ridge Provinces is low. Secondary permeability is much higher. Water in the nearly horizontal bedrock of the Appalachian Plateau Province flows through and is stored in joints, fractures, bedding planes and, in carbonate rocks, in solution channels (Wyrick and Borchers, 1981).

Studies by the U.S. Geological Survey indicate that fracture systems affect the occurrence and movement of ground water in a typical valley aquifer system of the Appalachian Plateaus. Ground water is mainly found in horizontal bedding-plane fractures under the valley floors and in nearly vertical and horizontal tensile fractures along the valley walls (fig. 4). The fractures pinch out under the valley walls, which form impermeable barriers. The aquifer system is confined under the valley walls and unconfined under the valley floor (Wyrick and Borchers, 1981.

The sandstone, shale, and limestone rocks in the Valley and Ridge Province are a folded series of northeastward-trending anticlines and synclines. The ridges are underlain by more resistant rock, generally sandstone, and the valleys are underlain by less resistant rock, generally shale and limestone. Permeability generally is greatest along bedding planes, fractures, and faults in the Valley and Ridge Province (Hobba, Friel, and Chisholm, 1973).

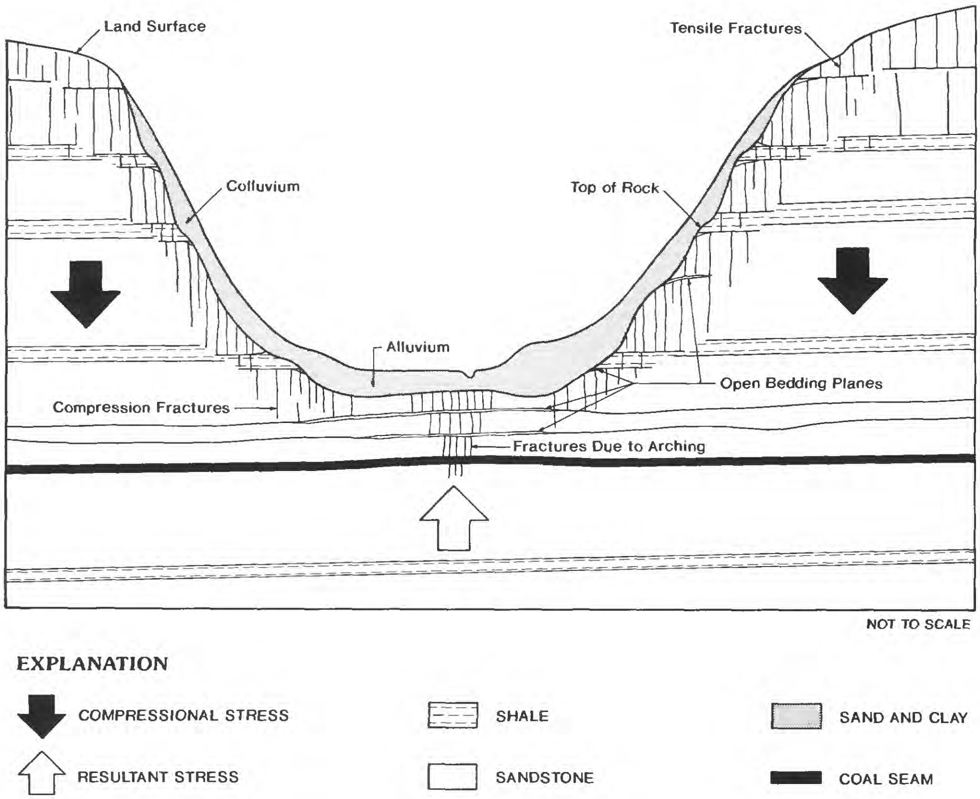

Figure 4. Generalized features of stress-relief fracturing (From Wyrick and Borchers, 1981, p. 13).

The regional ground-water-flow systems in the Appalachian Plateaus and Valley and Ridge Provinces are predominantly lateral and upward toward major valleys; the flow is slow in comparison to the more permeable surficial bedrock flow system. Vertical leakage through confining units beneath major valleys generally is upward. The deeper bedrock aquifers usually contain much older water, which is usually brackish, and has not been flushed by shallow ground-water circulation.

Principal Aquifers

Two principal types of aquifers underlie West Virginia--unconsolidated alluvial deposits and sedimentary bedrock aquifers. The major aquifers of West Virginia have been categorized informally by geologic age because of the vertical differences in lithology in the principal aquifers. The characteristics of the principal aquifers are described below and in table 1, from youngest to oldest (Puente, 1985).

The alluvial aquifers consist of Pleistocene to recent deposits of sand and gravel interbedded with silt and clay (Simard, 1989). Ground water in the alluvium generally occurs under unconfined to semiconfined conditions (Lew Baker, West Virginia Department of Health, written commun., 1994). The alluvial aquifers along the Ohio River in the western part of the State are the best sources of ground water for public supply and industrial

Table 1. *Aquifer and well characteristics for West Virginia (Modified from Puente, 1985, p. 440)*

[ft, feet; gal/min , gallons per minute]

Aquifer name and description	Depth: Common range (ft)	Depth: May exceed (ft)	Yield: Common range (gal/min)	Yield: May exceed (gal/min)	Remarks
		ALLUVIAL AQUIFERS			
Sand and gravel, interbedded with silt clay. Generally unconfined to semiconfined locally.	25-100	140	50-1,500	3,000	Used as source for public and industrial supplies along the Ohio and Kanawha Rivers. Water generally suitable for most uses but hard to very hard and has large iron sulfate, manganese, organic compounds, and chloride concentrations in some areas.
		SEDIMENTARY BEDROCK AQUIFERS			
Upper Pennsylvanian aquifers: *Dunkard Group (Permian or Pennsylvanian age), or Monongahela Group, Conemaugh Group*: Nearly horizontal, predominantly shale with sandstone, siltstone, coal, and limestone. Generally unconfined in hilltop and hillside areas to partly confined and confined in valleys.	50-300	400	1-30	200	Used mainly for domestic and farm supplies. Report of insufficient yields more common from hilltop and hillside wells than from valley wells. Water suitable for most uses, but moderately hard to very hard, alkaline, and has large iron concentration locally.
Lower Pennsylvanian aquifers: *Allegheny Formation (Middle Pennsylvanian age), Pottsville Group*: Nearly horizontal, predominantly sandstone with shale, siltstone, coal, and some limestone. Generally unconfined in hilltop and hillside areas to partly confined and confined in valleys.	50-300	400	1-100	300	Used mainly for domestic and farm supplies but has moderate-to-good potential for small industrial and public supplies. Water good for most uses, but generally hard to very hard and has large iron and manganese concentrations locally.
Mississippian aquifers: *Mauch Chunk Group, Greenbrier Group, Maccrady Formation, Pocono Group:* Moderately folded, predominantly sandstone and limestone with shale. Unconfined at shallow depth and confined at greater depth.	50-200	300	1-100	200	Yields are adequate for domestic, farm, and small commerical supplies. Predominantly limestone Greenbrier Group, a source of large-yielding springs that supply small to large industrial supplies. Yields of springs range from 50 to 2,000 gal/min and average about 180 gal/min. Water suitable for most uses but generally moderately hard to very hard and has large iron concentrations locally. Greenbrier Group aquifer very susceptible to pollution from surface sources.
Devonian aquifers: *Hampshire Formation, Chemung Group, Millboro Shale, Onesquethaw Group*: Nearly horizontal to moderately folded, predominantly shale and siltstone with sandstone and some limestone. Generally unconfined at shallow depth to confined at greater depth.	50-300	500	1-25	50	Yields adequate for domestic farm and small industrial supplies where units crop out in valley areas. Water suitable for most uses; generally soft to moderately hard, and alkaline.
Oriskany Sandstone, Helderberg Group: Very folded, predominantly limestone and sandstone with some shale. Generally unconfined at shallow depth to confined at greater depth.	50-300	500	2-200	1,000	Yields adequate for domestic, farm, and moderately large industrial and public supplies. Units are source of large springs that yield 50 to 15,000 gal/min. Water is generally suitable for most uses but is hard to very hard. Helderberg Group very susceptible to pollution from surface sources.
Silurian aquifers: *Tonoloway Formation, Wills Creek Formation, Williamsport, Sandstone*: Very folded, predominantly limestone and sandstone with shale. Generally unconfined at shallow depth to confined at greater depth.	50-300	400	1-100	200	Yields adequate for domestic, farm, and small to moderate industrial and public supplies. Units are source of large springs that yield from 10 to 1,000 gal/min. Water generally suitable for most uses but hard to very hard. Water in Tonoloway and Wills Creek Formations may have large sulfate concentrations because of presence of anhydrite. Units very susceptible to pollution from surface sources.

Table 1. *Aquifer and well characteristics for West Virginia (Modified from Puente, 1985, p. 440)--Continued*

Aquifer name and description	Depth: Common range (ft)	Depth: May exceed (ft)	Yield: Common range (gal/min)	Yield: May exceed (gal/min)	Remarks
SEDIMENTARY BEDROCK AQUIFERS--Continued					
McKenzie Formation, Clinton Group, Tuscarora Sandstone: Very folded, sandstone, shale, and some limestone. Generally unconfined at shallow depth to confined at greater depth.	40-250	300	1-25	50	Yields adequate for domestic and farm supplies where units crop out in valley. areas. Water suitable for most uses but hard to very hard and has large iron concentrations locally.
Ordovician aquifers: *Juniata Formation, Oswego Formation, Martinsburg Formation*: Very folded, sandstone with some shale and limestone. Generally unconfined at shallow depth to confined at greater depth.	50-200	250	1-30	50	Yields adequate for domestic and farm, and moderately large industrial and public supplies. Water generally suitable for most uses but hard to very hard and has large iron and sulfate concentrations locally.
Trenton Group, Black River Group, St. Paul Group, Beekmantown Group: Very folded, predominantly limestone with some sandstone and shale. Generally unconfined at shallow and at greater depth.	75-400	500	5-400	600	Yields adequate for domestic, farm, and moderate to large industrial and public supplies. Units are source of large springs that yield from 50 to 5,000 gal/min. Water generally suitable for most uses but hard to very hard. Units very susceptible to pollution from surface sources.
Cambrian aquifers: *Conococheague Formation, Elbrook Formation, Waynesboro Formation, Tomstown Dolomite*: Very folded, predominantly limestone with some sandstone and shale. Generally unconfined at shallow depth and confined at greater depth.	100-400	500	2-200	300	Yields adequate for domestic, farm, and moderate to large industrial and public supplies. Large springs from these units generally yield from 50 to 2,300 gal/min. Water hard to very hard but suitable for most uses. Units very susceptible to pollution from surface sources.
Chilhowee Group: Very folded, predominantly shale and sandstone. Generally unconfined at shallow depth and confined at greater depth.	50-200	250	1-25	50	Yields adequate for domestic and farm use. Generally slightly acidic, soft to moderately hard, and suitable for most uses.

use in the State, due to the high yields that can be obtained. The Parkersburg Municipal Water Plant withdraws an average of 5 Mgal/d of water from collector wells constructed within the alluvium (James Furr, Parkersburg Water Plant, written commun., 1993). Well yields depend upon the permeability, areal extent, and saturated thickness of the alluvium and the proximity of wells to rivers, where infiltration of large quantities of streamflow can be induced.

Major sources of ground water in the Appalachian Plateaus Province in the western and central parts of the State are the Upper and Lower Pennsylvanian aquifers (fig. 2). The Upper Pennsylvanian aquifers consist of the Dunkard, Monongahela, and Conemaugh Groups of Permian and Pennsylvanian age. These geologic units are primarily nearly horizontal layers of shale with thin interbeds of fine-grained sandstone, siltstone, limestone, and coal (Cardwell and others, 1968). The Lower Pennsylvanian aquifers, which consist of the Allegheny Formation and the Pottsville Group, are primarily massive coarse-grained sandstone with interbeds of shale, siltstone, coal, and limestone (Puente, 1985).

In the southeastern part of the State, the mostly noncarbonate strata (Mauch Chunk Group, Maccrady Formation, and the Pocono Group) within the Mississippian aquifers are similar in lithology and permeability to the Pennsylvanian aquifers in the Appalachian Plateaus. The rocks comprising the Mississippian aquifers, however, are gently to moderately folded. In this area, some of the sandstones are saturated and are confined by overlying and underlying shales. Under these conditions, the aquifers yield moderate to large amounts of water (Puente, 1985).

The predominantly carbonate Greenbrier Group of the Mississippian aquifers can potentially provide large quantities of ground water. Fracture openings in these strata generally have been enlarged by dissolution of the carbonate rock. Springs and wells that tap solution openings can yield more than 200 gal/min; however, in limestone areas, a well that penetrates few fractures or solution openings and is virtually dry may be only a few feet away from a well that taps a large solution opening and produces enough water to supply a small city (Puente, 1985).

Farther to the east, in the Valley and Ridge Province, the aquifers are faulted and compressed into steep folds, which greatly affects the occurrence and movement of ground water. In these areas, ground-water conditions are more variable than in the rest of the State. The principal carbonate units, such as the Helderberg Group of the Devonian aquifers and the Beekmantown Group of the Ordovician aquifers, and some of the massive sandstone units, such as the Oriskany Sandstone of the Devonian aquifers, can potentially yield large amounts of ground water. Springs with large yields (as much as 15,000 gal/min) are common in the carbonate rocks of the eastern panhandle (Puente, 1985).

The water-bearing properties of minor carbonate units, such as the Tonoloway Formation of the Silurian aquifers, the Conococheaque, Elbrook, and Waynesboro Formations, and the Tomstown Dolomite of the Cambrian aquifers, generally are comparable to those of the major carbonate units of the Mississippian, the Devonian, and Ordovician aquifers. Water storage in the minor carbonate units generally is low because of the limited areal extent of these units. The noncarbonate units in the Devonian, the Silurian, the Ordovician, and the Cambrian aquifer systems generally yield small amounts of water (less than 30 gal/min) to wells (Puente, 1985).

WATER QUALITY

The chemical quality of ground water is determined by the types and concentrations of minerals it contains. The types and concentrations of minerals present in ground water depend on the chemistry of the water that recharges the aquifer, the chemical and physical properties of the soil and rock through which the water moves, and the amount of time the water is in the ground-water system. Generally, water becomes more mineralized as it moves through the flow system. Water at depth moves slowly and typically is highly mineralized. Tables 2 and 3 list the inorganic constituents commonly found in ground water and physical properties of water that affect its quality and use (Heath, 1983).

Typically, only the upper part of a well that taps consolidated bedrock aquifers in the State is cased. The rest of the well typically is an open borehole that ranges from 10 to several hundred feet in depth and usually is 6 in. in diameter. Water typically is derived from several water-bearing zones because of the lithologic variability of the aquifers (Chet Fleming, West Virginia Rural Water Association, oral commun., 1993). The amounts and chemical properties of the water from each zone can be different; thus, the quality of water pumped from a well depends on which zones are tapped and the proportion of water derived from each zone.

A graphic summary of data collected by the USGS from 1950 to 1985 (fig. 5) 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 (Ferrell, 1988).

Percentiles of these constituents are compared to national standards that specify the maximum

Table 2. *Inorganic constituents commonly dissolved in water that are most likely to affect use of water (From Heath, 1983, p. 65)*

[mg/L, milligrams per liter]

Substance	Major natural sources	Effect on water use	Concentrations of significance (mg/L)[1]
Bicarbonate (HCO_3) and carbonate (CO_3)	Products of the solution of carbonate rocks, mainly limestone ($CaCO_3$) and dolomite ($CaMgCO_3$), containing carbon dioxide.	Control the capacity of water to neutralize strong acids. Bicarbonates of calcium and magnesium decompose in steam boilers and water heaters to form scale and and release corrosive carbonate dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.	150-200
Calcium (Ca) and magnesium (Mg)	Soils and rocks containing limestone, dolomite, and gypsum ($CaSO_4$). Small amounts from igneous and metamorphic rocks.	Prinicipal cause of hardness and of boiler scale and deposits in hot-water heaters.	25-50
Chloride (Cl)	In inland areas, primarily from seawater trapped in sediments at time of deposition; in coastal areas, from seawater in productive aquifers.	In large amounts, increases corrosiveness of water and, combination with sodium, gives water a salty taste.	250
Fluoride (F)	Both sedimentary and igneous rocks. Not widespread in occurrence.	In certain concentrations, reduces tooth decay; at higher concentrations, causes mottling of tooth enamel.	0.7-1.2[2]
Iron (Fe) and manganese (Mn)	Iron present in most soils and rocks; manganese less widely distributed.	Stain laundry; objectionable in food processing, dyeing, bleaching, ice manufacturing, brewing, and certain other industrial processes	Fe>0.3, Mn>0.05
Sodium (Na)	Same as for chloride. In some sedimentary rocks, a few hundred milligrams per liter may occur in freshwater as a result of exchange of dissolved calcium and magnesium for sodium in the aquifer materials.	See chloride. In large concentrations, may affect persons with cardiac difficulties, hypertension, and certain other medical conditions. Depending on the concentrations of calcium and magnesium also present in the water, sodium may be detrimental to certain irrigated crops.	69 (irrigation) 20-170 (health)[3]
Sulfate (SO_4)	Gypsum, pyrite (FeS), and other rocks containing sulfur (S) compounds.	In certain concentrations, gives water a bitter taste and at higher concentrations, a laxative effect. In combination with calcium, forms a hard calcium carbonate scale in steam boilers.	300-400 (taste) 600-1,000 (laxative)

[1] A range in concentration is intended to indicate the general level at which the effect on water use might become significant.
[2] Optimum range determined by the U.S. Public Health Service, depending on water intake.
[3] Lower concentration applies to drinking water for persons on a strict diet; higher concentrations are for those on a moderate diet.

Table 3. *Characteristics of water that affect water quality (From Heath, 1983, p. 65)*

[mg/L, milligrams per liter]

Substance	Principal cause	Significance	Remarks
Hardness	Calcium and magnesium dissolved in water.	Calcium and magnesium combine with soap to form an insoluble precipitate (curd) and thus hamper the formation of a lather. Hardness also affects the suitability of water for use in the textile and paper industries and certain others and in steam boilers and water heaters.	*USGS classification of hardness (mg/L as $CaCO_3$):* 0-60--soft 121-180--hard more than 180--very hard
pH (or hydrogen-ion activity)	Dissociation of water molecules and of acids and bases in water.	The pH of water is a measure of its reactive characteristics. Low values of pH, particularly below pH 4, indicate a corrosive water that will tend to dissolve metals and other substances that it contacts. High values of pH, particularly above pH 8.5, indicate an alkaline water that on heating will tend to form scale. The pH significantly affects the treatment and use of water.	*pH values:* less than 7--water is acidic; value of 7--water is neutral. more than 7--water is basic.
Specific electrical conductance	Substances that form ions when dissolved in water.	Most substances dissolved in water dissociate into ions that can conduct an electrical current. Consequently, specific electrical conductance amount of material is a valuable indicator of the amount of material dissolved in water. The larger the conductance, the more mineralized the water.	Conductance values indicate the electrical conductivity, in micromhos, of 1 cubic centimeter of water at a temperature of 25 degrees Celsius.
Total dissolved solids	Mineral substances dissolved in water.	Total dissolved solids is a measure of the total amount of minerals dissolved in water and is, therefore, a very useful parameter in the evaluation of water quality. Water containing less than 500 mg/L is preferred for domestic use and for many industrial processes.	*USGS classification of water based on dissolved solids (mg/L):* Less than 1,000--fresh 1,000-3,000--slightly saline 3,000-10,000--moderately saline 10,000-35,000--very saline more than 35,000--briny.

acceptable concentration of a contaminant in drinking-water supplies as established by the U.S. Environmental Protection Agency (1986 a, b; April, 1992). 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 a maximum concentration 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, and 50 µg/L manganese. State drinking-water standards are similar to national drinking-water standards (Ferrell, 1988).

Alluvial Aquifers

Alluvial deposits 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 drinking-water standard. In water from the alluvium along the Kanawha River, median values for iron (7,200 µg/L) and manganese (450 µg/L) exceed drinking-water standards. Water from alluvial deposits other than along the Ohio and Kanawha Rivers commonly does not exceed

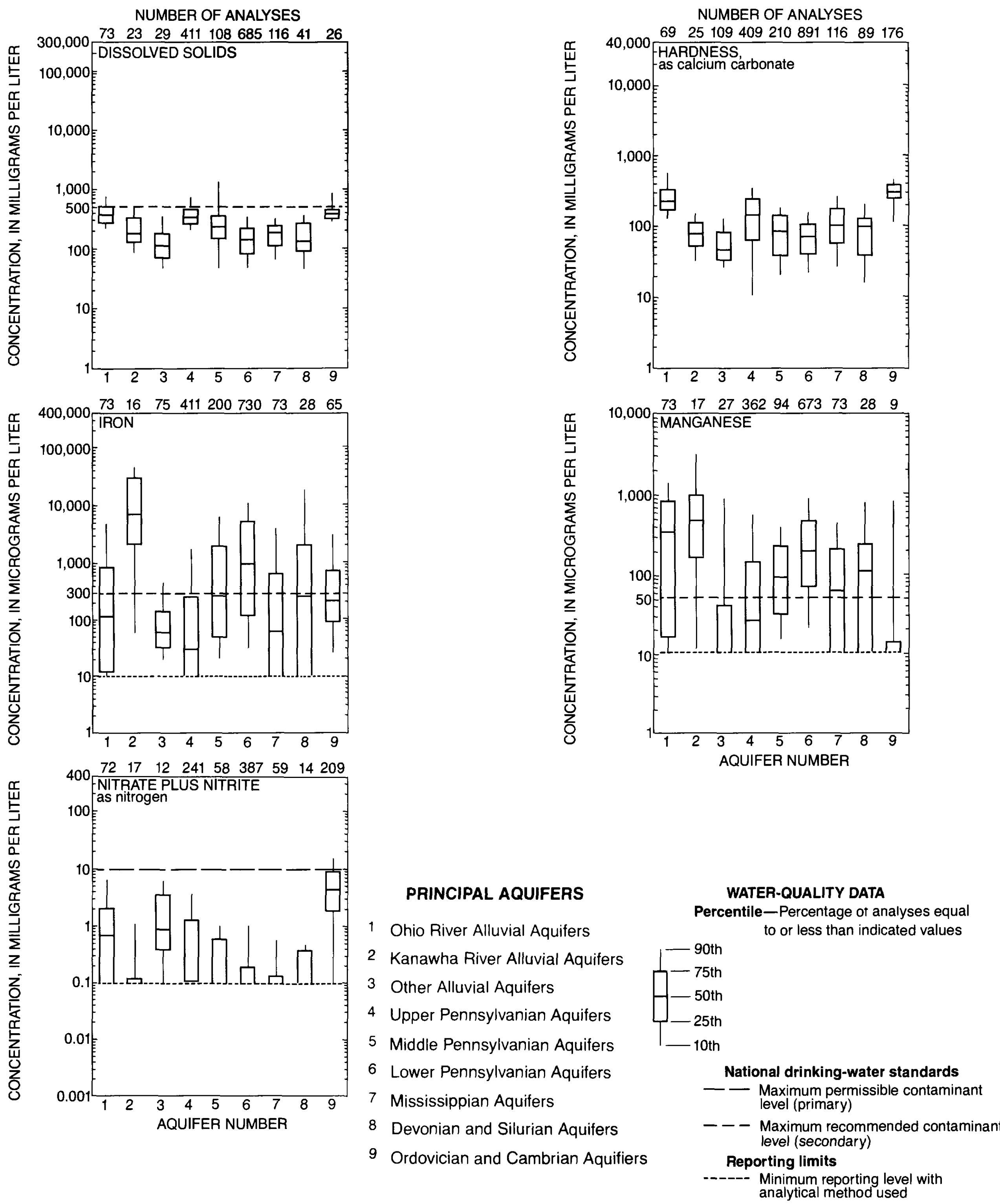

Figure 5. Water-quality data for principal aquifers in West Virginia.

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 (Ferrell, 1988).

Sedimentary Bedrock Aquifers

The median values of manganese in water from the sedimentary bedrock exceed drinking-water standards in all aquifer groups, except those of Upper Pennsylvanian, Cambrian, and Ordovician age. The median iron concentration of water from the Lower Pennsylvanian-age 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 greater hardness and dissolved solids than the aquifers with less limestone (Ferrell, 1988).

The median value for nitrate plus nitrite (as nitrogen) is less 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 indicate that nitrate concentrations greater than 10 mg/L are common in water from alluvial deposits in farming areas, particularly along the Ohio River. Nitrate concentrations in excess of 10 mg/L are common in ground water near reclaimed surface mines where nitrogen fertilizers have been used (Ferrell, 1988).

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 ft below the major streams. However, in several areas saline water is found at or near land surface, typically in valleys along the axes of anticlines where intensive vertical fracturing has occurred. Many of these areas are historically significant, in that the saline water was used to produce salt during the 1800's (Ferrell, 1988).

In much of the State, topography influences 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. Variations in this pattern do occur, particularly in the steeply folded rocks in the eastern part of the State and in limestone areas where the relation of recharge and discharge areas is more complex (Ferrell, 1988).

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 6 (Ferrell, 1988).

Concentrations of iron and manganese in rocks of Pennsylvanian age generally are greater in ground water from valley settings than in ground water from hilltop settings (fig. 6). Where limestone is common, such as the Upper Pennsylvanian aquifers, hardness is highest in hilltop settings and least in valley settings. The relation between hardness and sodium content is primarily the result of sodium-calcium ion exchange, a softening process that occurs as calcium ions are exchanged for sodium ions in clay 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 water in nearby wells in another topographic setting (Ferrell, 1988).

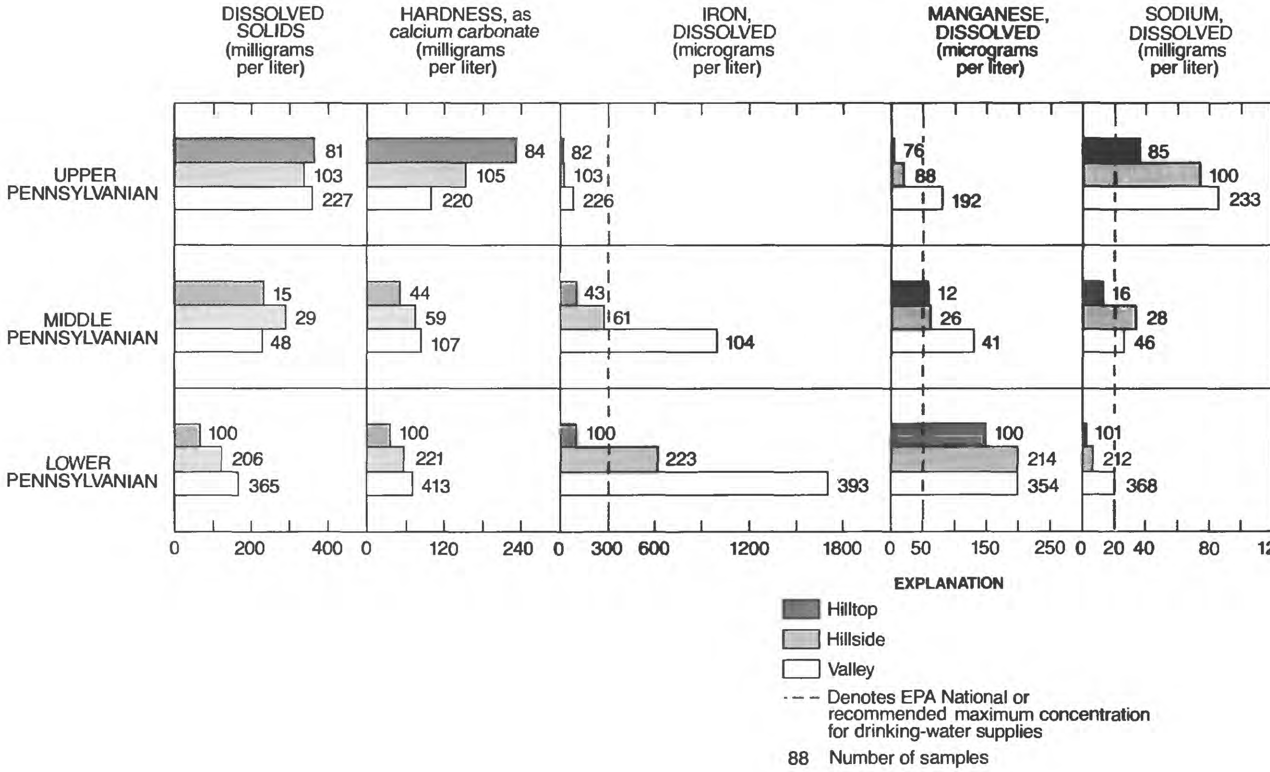

Figure 6. Variation in chemical quality of ground water with respect to geologic and topographic setting (From Ferrell, 1988, p. 527).

Factors That Affect Ground-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 USGS, various State agencies, and academic institutions have documented many such changes (Ferrell, 1988; West Virginia Department of Natural Resources, 1988; West Virginia Department of Natural Resources and West Virginia Department of Highways, 1983).

Industrial Activities

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 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 (Ferrell, 1988).

Based on characteristics such as corrosivity, ignitability, reactivity, and toxicity, waste materials are classified as either hazardous or nonhazardous by the Office of Waste Management of the West Virginia Division of Environmental Protection. 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 were 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. Improper disposal of solid-industrial wastes, both hazardous and nonhazardous, also has contaminated ground water (Ferrell, 1988).

There are 24 permitted RCRA (Resource Conservation and Recovery Act) facilities and 7 sites currently applying for permits for treatment and disposal of hazardous wastes (G. Atwell, West Virginia Division of Environmental Protection, oral commun., 1992). 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. 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 as well as other organic contaminants and metals (Ferrell, 1988).

Also of concern are numerous landfill sites 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 city of Point Pleasant's well field 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 (Comprehensive Environmental Response, Compensation, and Liability Act) sites. Contaminants found in ground water at these sites include trinitrotoluene (TNT), dinitrotoluene (DNT), and benzene (Ferrell, 1988).

Mining Activities

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 on the basis of sulfur content--coal in the northwestern part of the State typically has a higher sulfur content than that of the southern part. 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 high 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 (1986) 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. Although the acidity is neutralized in a short distance, water from wells within as much as 1,500 ft of a surface mine have shown elevated 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 (Ferrell, 1988).

In low-sulfur coal fields, which are common in the southern part of the State, water from mines is used for public, industrial, and commercial 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 acryl-amide (found in industrial grade polyacryl-amide, which is used in coal-cleaning processes), oil, grease, and solvents used in association with mine equipment, and polychlorinated biphenyls (PCB) from transformers used to power electrical mining equipment (Ferrell, 1988).

Oil and Gas Exploration and Development

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 that time, 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, or 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 (Ferrell, 1988).

Agricultural Activities

The estimated total acreage of farmland declined 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. An estimated 15.9 Mgal/d of ground water is used for other agricultural purposes. 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. Atrazine, picloram, chlorpyrifos, and chlordane are the pesticides most commonly detected in ground-water (Doug Hudson, West Virginia Department of Agriculture, oral commun., 1992). There is no facility within the State for disposal of unwanted pesticides (Ferrell, 1988).

In the eastern panhandle, where valleys are underlain by highly 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 showed that 68 percent exceeded the primary drinking-water standard of one coliform bacterium per 100 milliliters of water (Sworobuk, 1984). Animal wastes appeared to be the major source of coliform bacteria. Bacterial contamination is most commonly observed in improperly cased or dug wells or in wells located near septic fields (Ferrell, 1988).

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 (West Virginia Department of Natural Resources), contained increased concentrations of phenol, chromium, and arsenic, as well as elevated chemical and biological oxygen demands. Wood preservatives, such as creosote, have contaminated ground water in several areas of the State (Ferrell, 1988).

Waste-Disposal Activities

Mandatory permitting of municipal landfills and monitoring of ground-water quality was implemented in June 1988 by the West Virginia Department of Natural Resources, Division of Waste Management. Approximately 31 permitted landfills are used for disposal of domestic wastes (Paul Benedum, West Virginia Department of Natural Resources, oral commun., 1994). 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 (Ferrell, 1988).

Transportation Facilities

Degradation of ground water 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 West Virginia 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 reduce ground-water contamination from improper storage of road salt by constructing buildings that fully enclose salt-storage areas (Ferrell, 1988).

Rural Activities

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, 1984 a, b). Many wells drilled prior to this 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, filling dug wells with trash and other debris can contaminate surrounding ground water (Ferrell, 1988).

AMBIENT GROUND-WATER-QUALITY-MONITORING NETWORK

The major objective of the ground-water-quality-monitoring network is to determine ambient ground-water quality. An ambient ground-water-quality network provides baseline data that are needed as a reference with which to assess the effects of natural stresses on water quality, such as lithology, climate, geologic setting, seasonal variation, and land use, and to determine long-term trends in ground-water quality. The network also-provides a uniform data base that can be used to evaluate the effects of human activity on water quality and to aid in predicting changes in water quality. The ambient ground-water-quality network will provide baseline information to assess the effects of lithology, climate, geologic setting, seasonal variation, land use, and human activity on water quality.

Criteria for Site Selection

Three criteria were of primary importance in selecting sites for inclusion in the monitoring network. These three criteria were areal coverage of the State, documentation of water-quality conditions of West Virginia's major aquifers, and land use. The 26 sites selected were chosen to provide an areal coverage of ground-water quality throughout the entire State. Characterization of West Virginia's major aquifers was the second criteria. The aquifers to be documented included carbonate and noncarbonate bedrock aquifers and river valley alluvial aquifers. Land-use criteria were also considered; sites were selected in various land-use settings such as agricultural, industrial, mining, forest, urban, commercial, and rural areas. Although sites were selected in areas with different land uses, every possible attempt was made to choose sites that were minimally affected by human activity. The main goal was to characterize the background quality of West Virginia's major aquifers. In the case of some of the alluvial wells along the Ohio River and the abandoned underground coal mines, which are commonly used as water supplies, it was not possible to select sites unaffected by human activity. These sites are common public-water supplies, however, and documentation of typical water quality of these supplies was warranted. In the case of carbonate aquifers, springs were chosen instead of wells because they are directly connected to the ground-water-flow system, whereas wells may not be.

Description of Ambient Ground-Water-Monitoring Sites

Twenty-six sites were selected for initial establishment of the DEP-OWR ambient ground-water-quality-monitoring network (table 4). The 26 sites are located throughout the State in 25 of West Virginia's 55 counties (fig. 7). A brief description of each site follows. Each section includes a

Table 4. *Land use and aquifer setting at ground-water-quality monitoring sites in West Virginia*

Site identification no.	Station name	County	Land use	Aquifer setting
383038081505201	Cannery Lane	Putnam	Rural	Alluvium
393738078134601	Berkeley Springs State Park	Morgan	Urban	Sandstone
393734078134601	Berkeley Springs State Park	Morgan	Urban	Sandstone
391950078032900	LeFevre Spring - Martinsburg	Berkeley	Rural/agricultural	Limestone
392010077455201	Harpers Ferry Spring	Jefferson	Rural/agricultural	Sandstone/shale/solomite
373213081003301	Pipestem State Park	Summers	Forest	Sandstone/shale
385332078553601	Lost River State Park	Hardy	Forest	Shale
374525080324501	Davis Spring near Lewisburg	Greenbrier	Rural/agricultural	Limestone
391019080243301	Waters Smith Memorial State Park	Harrison	Rural	Shale/sandstone
390202081234201	Palestine Fish Hatchery	Wirt	Rural/forest	Sandstone/shale/limestone
401933080355501	City of Follansbee	Brooke	Urban/industrial	Alluvium
402003080360501	City of Follansbee	Brooke	Urban/industrial	Alluvium
401917080354801	City of Follansbee	Brooke	Urban/industrial	Alluvium
391717081333603	City of Parkersburg	Wood	Urban	Alluvium
391717081333802	City of Parkersburg	Wood	Urban	Alluvium
391718081333101	City of Parkersburg	Wood	Urban	Alluvium
394050080514201	City of New Martinsville	Wetzel	Urban	Alluvium
394018080513601	City of New Martinsville	Wetzel	Urban	Alluvium
393937080513801	City of New Martinsville	Wetzel	Urban	Alluvium
393911080513701	City of New Martinsville	Wetzel	Urban	Alluvium
393909080513601	City of New Martinsville	Wetzel	Urban	Alluvium
403038080332401	Oakland Public Service District	Hancock	Rural	Shale/sandstone
385419082071701	City of Point Pleasant	Mason	Commercial/industrial	Alluvium
385421082071801	City of Point Pleasant	Mason	Commercial/industrial	Alluvium
385421082072001	City of Point Pleasant	Mason	Commercial/industrial	Alluvium
385422082072201	City of Point Pleasant	Mason	Commercial/industrial	Alluvium
385407082075601	City of Point Pleasant	Mason	Commercial/industrial	Alluvium
381432081391501	Kanawha State Forest	Kanawha	Forest	Sandstone/shale/coal
03068690	Bowden Fish Hatchery	Randolph	Forest	Limestone
03068710	Bowden Fish Hatchery	Randolph	Forest	Limestone
372552081364301	City of Welch	McDowell	Mining	Coal
375416082005301	Chief Logan State Park	Logan	Forest	Sandstone/shale/coal
380318081062701	City of Fayetteville	Fayette	Mining	Coal
374758080174001	White Sulphur Springs Hatchery	Greenbrier	Urban	Sandstone/limestone
374758080174002	White Sulphur Springs Hatchery	Greenbrier	Urban	Sandstone/limestone
374802080175201	White Sulphur Springs Hatchery	Greenbrier	Urban	Sandstone/limestone
374810080173001	White Sulphur Springs Hatchery	Greenbrier	Urban	Sandstone/limestone
394047079463801	Chestnut Ridge	Monongalia	Forest	Sandstone/shale/coal
394038079461701	West Virginia University Forest	Monongalia	Forest	Sandstone/shale/coal
390324079232501	Sand Spring in Canaan Valley	Tucker	Forest/rural	Limestone
383912080224801	Holly River State Park	Webster	Forest	Sandstone/shale/coal
375811082212401	Cabwaylingo State Forest	Wayne	Forest	Sandstone/shale/coal
381625080063001	Edray Fish Hatchery	Pocahontas	Forest/rural	Limestone
381620080062001	Edray Fish Hatchery	Pocahontas	Forest/agricultural	Limestone
383409081080801	Wallback Public Hunting Area	Roane	Forest/rural	Shale/sandstone/limestone

summary of well or spring physical characteristics, history of the site, pump and plumbing setup, geologic setting, and land-use classification of the site. Points of contact and telephone numbers for the owner or operator of each site are also provided (table 5). Site descriptions, geologic descriptions, well-construction data, well descriptions, and aquifer-test data for the 26 sites are presented in Appendix A.

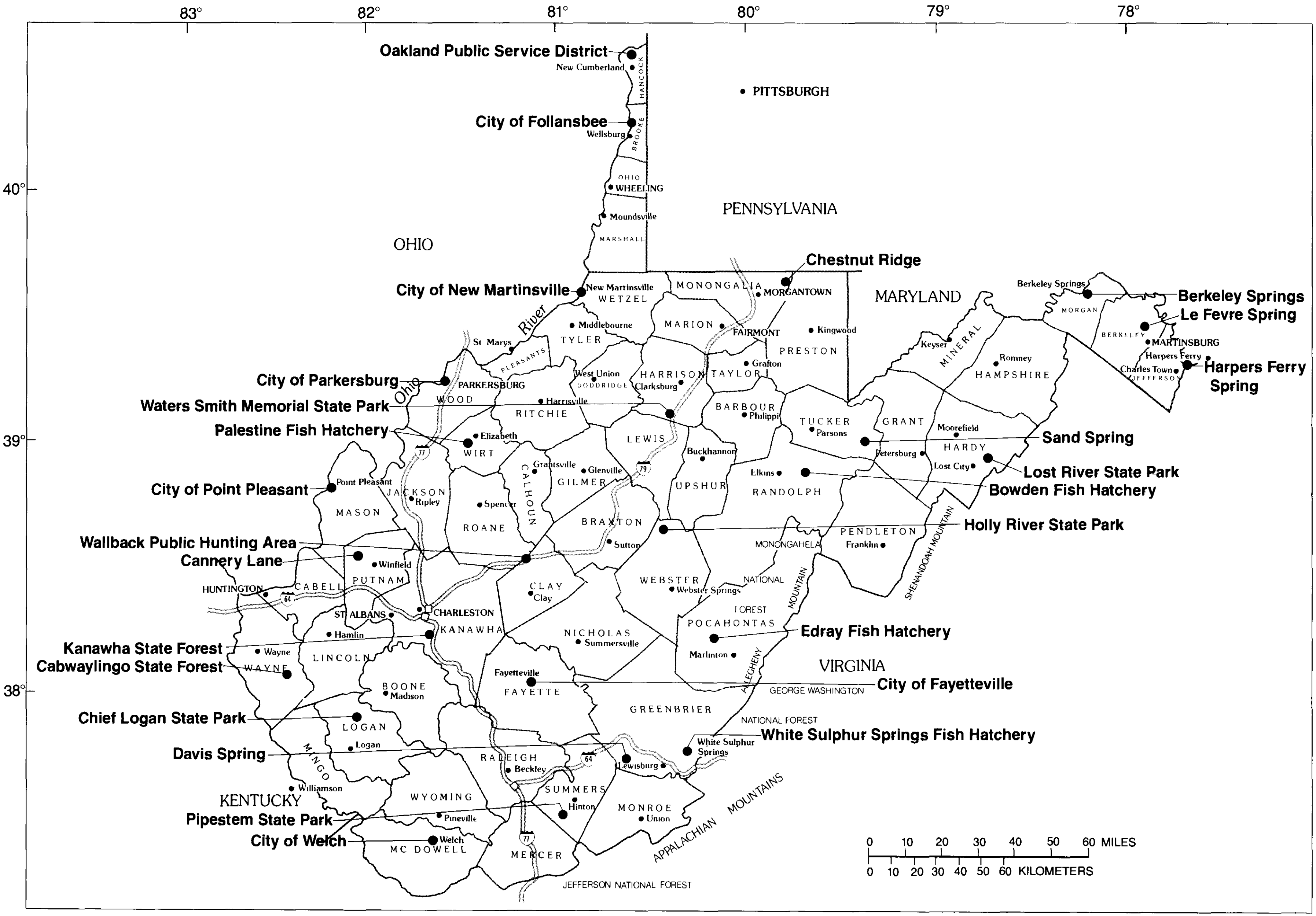

Figure 7. Location of the ground-water-quality-monitoring sites in West Virginia.

Table 5. *Points of contact and facility telephone numbers for the ground-water-quality-monitoring sites in West Virginia*

Station name	County	Point of contact	Telephone number (310)
Cannery Lane	Putnam	Elmer Young	755-2134
Berkeley Springs State Park	Morgan	Robert Ebert	258-2711
LeFevre Spring - Martinsburg	Berkeley	Daniel Campbell	229-5255
Harpers Ferry Spring	Jefferson	John Heafer	535-6555
Pipestem State Park	Summers	Charles Hatcher	466-1800
Lost River State Park	Hardy	Dorinda Taylor	897-5372
Davis Spring nearLewisburg	Greenbrier	John Detch	645-2421
Waters Smith Memorial State Park	Harrison	Larry Jones	745-3081
Palestine Fish Hatchery	Wirt	James Gould	275-6531
City of Follansbee	Brooke	Jack Macintosh	527-0533
City of Parkersburg	Wood	James Furr	424-8532
City of New Martinsville	Wetzel	David Rogers	455-9130
Oakland Public Service District	Hancock	Dane Kuzma	797-8353
City of Point Pleasant	Mason	Daniel Rogers	675-3500
Kanawha State Forest	Kanawha	Alvin Gale	346-5654
Bowden Fish Hatchery	Randolph	Patrick Mulane	636-2823
City of Welch	McDowell	Frazier Baker	436-4027
Chief Logan State Park	Logan	Daniel Johnson	792-7125
City of Fayetteville	Fayette	Cecil Gibson	574-0101
White Sulphur Springs Fish Hatchery	Greenbrier	Robert Shaver	536-1361
Chestnut Ridge Park	Monongalia	Maintenance	594-1773
Sand Spring in Canaan Valley	Tucker	Timberline Pres.	866-4766
Holly River State Park	Webster	Robert Doolittle	493-6353
Cabwaylingo State Forest	Wayne	Peter Meddings	385-4255
Edray Fish Hatchery	Pocahontas	Clyde Lewis	799-6461
Wallback Public Hunting Area	Roane	Jerry Duffield	364-8524

Cannery Lane-Putnam County

The Cannery Lane well is a public-water supply serving approximately 10 residences near Winfield, W. Va., directly across the Kanawha River from the small community of Bancroft in Putnam County. The name Cannery Lane is derived from the previous owner, a commercial-canning facility. The cannery was demolished but the well was retained for use by residents of the area. The well is 130 ft deep and is drilled in alluvial sand, gravel, and clay deposits of the Kanawha River (Elmer Young, landowner, oral commun., 1992). Total well depth of 130 ft indicates that the well might also tap the underlying Monongahela bedrock aquifer. It is unclear at present if the well is deriving most of its water from the alluvial sand and gravel sediments or from the underlying bedrock aquifer. According to the current caretaker of the well, it is believed that the well derives most of its water from sand and gravel alluvial deposits (Elmer Young, landowner, oral commun., 1992). Initial water-quality samples collected at the site indicate a type of water common in alluvial aquifers. The location map for this well is the 1:24,000 USGS topographic quadrangle for Bancroft, W. Va. (U.S. Geological Survey, 1975d). Water samples can be collected from a tap in a nearby wellhouse.

Berkeley Springs-Morgan County

Berkeley Springs is a historic series of springs in Morgan County for which the town of Berkeley Springs was named. The springs were popular as part of a resort that was established in the mid- to late 1800's. Berkeley Springs State Park is based around these thermal springs. Isotopic analysis of the O_{18}/O_{16} ratio and the tritium content of the water indicate that the springs are derived from thermally heated water in the permeable Oriskany Sandstone, but also derive a part of their recharge from younger shallow ground water. The springs are an important source of drinking water for the city of Berkeley Springs (Hobba and others, 1979).

The rate at which the spring discharges is approximately 1,020 gal/min. Several springs are included in the USGS GWSI database for the site because the springs discharge at several locations in a broad area; hence, the use of the plural term "Springs," rather than "Spring." Land use in the area is primarily urban. The location map for the springs is the 1:24,000 USGS topographic quadrangle for Hancock, W. Va. (U.S. Geological Survey, 1971). Water samples can be collected at any of the numerous springs in the park or at one of the troughs that collect and convey the water to bath houses and other areas of the park.

LeFevre Spring-Berkeley County

LeFevre Spring is one of the primary sources of water for the city of Martinsburg in Berkeley County. The spring derives its recharge from the limestones and dolomite of the Beekmantown Group. The Beekmantown Group is one of the primary sources of water for public, industrial, and agricultural use in Berkeley and Jefferson Counties in West Virginia's eastern panhandle. Approximate discharge for the spring ranges throughout the year but has been measured at 673 gal/min (McColloch, 1986). The land use of the area near the spring is considered rural to agricultural. The location map for this spring is the Inwood, W. Va.-Va. 1:24,000 USGS topographic quadrangle (U.S. Geological Survey, 1979). Water samples can be collected at the spring itself or at a culvert pipe outlet.

Harpers Ferry Spring-Jefferson County

Harpers Ferry Spring is located near Elks Run and the Baltimore and Ohio rail line northwest of the city of Harpers Ferry in Jefferson County. The spring is used as a secondary source of water for the town of Harpers Ferry; the primary sources are surface-water intakes on Elk Run and the Potomac River. A concrete basin was constructed to contain the spring. Discharge was estimated at 85 gal/min (Price and others, 1936). The spring derives its water from the sandstone, shale, dolomite, and limestone of the Waynesboro Formation. The surrounding area is primarily rural and agricultural. Water samples can be collected directly from the concrete collection box. The location map for the spring is the Charles Town, W. Va.-Va.-Md. 1:24,000 USGS topographic quadrangle (U.S. Geological Survey, 1984).

Pipestem State Park-Summers County

The well at Pipestem State Park is located near the Mountain Lodge at the bottom of the aerial tramway, approximately 300 ft from the left bank of the Bluestone River in Summers County. Total depth of the well is 160 ft. The water in the well is derived from the Hinton Formation of Mississippian age. The land-use classification for the area is forested. Water samples can be collected from a tap inside a nearby wellhouse. The only water-treatment system, a chlorinator, can easily be bypassed so that a raw-water sample can be collected. The location map for the well is the 1:24,000 USGS topographic quadrangle for Flat Top, W. Va. (U.S. Geological Survey, 1968).

Lost River State Park-Hardy County

Lost River State Park has a 180-ft-deep well that is located in a stone wellhouse behind the main park headquarters, near the town of Lost River in Hardy County. The well derives its water from the Hampshire Formation, which predominately consists of shale. No chlorination or other treatment has been placed on the well. The land-use classification for the area is forested. Water samples can be collected from a tap inside the wellhouse. The location map for the well is the 1:24,000 USGS topographic quadrangle for Lost River State Park, W. Va. (U.S. Geological Survey, 1967b).

Davis Spring-Greenbrier County

Davis Spring, located near the community of Fort Spring in Greenbrier County, is the largest spring in the State of West Virginia. Discharge from the spring was measured at 9,870 gal/min (Chisholm and Frye, 1976). Water from the spring is derived from the Greenbrier Group (McColloch, 1986). Land use in the area near the spring is primarily rural and agricultural. The Greenbrier Group is primarily composed of limestone. It is an important source of water for public, domestic, industrial, and agricultural use in the Valley and Ridge Province of West Virginia. Water samples can be collected at several locations near the spring where water emerges from the ground. The location map for the spring is the 1:24,000 USGS topographic quadrangle for Asbury, W. Va. (U.S. Geological Survey, 1972).

Waters Smith Memorial State Park-Harrison County

There are two springs located at the Waters Smith Memorial State Park near the community of West Milford in Harrison County. The two springs are within 50 ft of one another in two small depressions. The park maintenance building is located nearby. The springs provide water to a small wetland approximately 150 ft below the spring. One of the springs was enclosed in a stone springhouse. The other spring also was enclosed in a springhouse which has not been maintained. Discharge from the two springs was less than 2 gal/min during a very dry period in October 1992. Sampling at this spring should be conducted with the expectation of reduced discharge in late summer to early fall. Although discharge was low at the time of initial inventory of the spring, sufficient water was available in the springhouse for sampling. Land use in the area near the spring is rural. The spring derives its water from the Conemaugh Formation. The location map for the springs is the 1:24,000 USGS topographic quadrangle for West Milford, W. Va. (U.S. Geological Survey, 1976a).

Palestine Fish Hatchery-Wirt County

The well at the Palestine Fish Hatchery is located near the town of Elizabeth in Wirt County. The well is located in the basement of the assistant superintendent's residence. Total well depth is 90 ft. The first 31 ft is 6 in. in diameter; the interval from 31 to 90 ft is only 4 in. in diameter. No chlorination or other water-treatment systems are located at this site. A large storage tank, approximately 80 gal, is located at the wellhead. Care should be taken to assure that the 80-gal tank has been purged before sampling; therefore, sampling could be conducted after the well has been run for such things as showers, laundry, and dishwashing. It is possible that a tap could be placed on the incoming line to avoid prolonged purging of the well, but is probably not needed due to the continual purging that the well receives throughout the day. Land use in the area is primarily rural to forested. The well derives its water from the Dunkard Formation. Water samples can be collected at an outside tap near the rear of the house. The location map for the site is the USGS 1:24,000 topographic quadrangle for Elizabeth, W. Va. (U.S. Geological Survey, 1975a).

City of Follansbee-Brooke County

Follansbee's well field is located in a sand and gravel alluvial aquifer bordering the Ohio River in Brooke County of West Virginia's northern panhandle, and provides an average of 500,000 gal/d of water to industrial, commercial, and domestic users (Jack MacIntosh, Follansbee Water Department, oral commun., 1993). The well field consists of three active wells and one abandoned well. The unused well (well 2) was abandoned because of contamination by volatile organic chemicals. Steel mills, metal fabrication plants, chemical plants, and railway haulage lines that are less than 50 ft from the public-supply wells are all potential sources of contamination for the aquifer. The land use in the area is therefore considered industrial and urban. The sand and gravel aquifer is approximately 75 to 80 ft deep, composed of 60 to 70 ft of glacial outwash sand-and-gravel (Simard, 1989), and covered by a thin (5- to 15-ft thick) fluvial silt and clay confining unit. This confining unit is believed to retard downward percolation of contaminated surface water into the deeper sand and gravel alluvial aquifer (Chet Fleming, West Virginia Rural Water Association, oral commun., 1993). Raw-water samples can be collected from taps inside the main building of the water plant. The location map for the Follansbee well field is the Steubenville East, Ohio-W. Va.-Pa. 1:24,000 USGS topographic quadrangle (U.S. Geological Survey, 1978).

City of Parkersburg-Wood County

Parkersburg derives its water from five Ranney-type-collector wells completed in alluvial sand and gravel sediments of the Ohio River in Wood County. Data for three of the five wells, wells 1, 2, and 3 on the east bank of the Ohio River, are presented in Appendix A. There were incomplete data available for wells 4 and 5, wells completed in the sand and gravel alluvial deposit of Neal Island; therefore, these data are not presented in this report. The wells range in depth from 45 to 51 ft and supply an average of 5.0 Mgal/d of water to domestic, industrial, and commercial users (Steve Dugan, Parkersburg Water Plant, oral commun., 1991). The geologic setting is similar to that of Follansbee, in that the deeper sand and gravel aquifer is covered by a thin silt and clay confining unit. The sand and gravel aquifer is approximately 15 to 25 ft in thickness and the silt and clay confining unit ranges from 17 to 37 ft. The silt and clay confining unit also contains a significant portion of sand, which is not present at the Follansbee site. Land use in the area near the Parkersburg well field is similar to land use at Follansbee. The area is surrounded by steel mills, metal-fabrication facilities, and other industrial and commercial facilities. A major railway route passes within several hundred yards of the well field. The land-use classification for the area therefore is considered industrial and urban. Raw-water samples can be collected from taps inside the main building of the waterplant. The Parkersburg, W. Va.-Ohio USGS 1:24,000 topographic quadrangle (U.S. Geological Survey, 1975) is the location map for this site.

City of New Martinsville-Wetzel County

The city of New Martinsville pumps an average of 1.4 Mgal/d of water from five wells completed in the sand and gravel alluvial aquifer that borders the Ohio River in Wetzel County (Thomas Morris, New Martinsville Water Dept., oral commun., 1992). The sand-and-gravel layer ranges from 22 to 35 ft in thickness. A confining unit composed of sand and clay with some gravel overlies the sand aquifer and ranges from 24 to 45 ft thick. Well depths for the five wells range from 57 to 82 ft. Raw-water samples can be collected from taps inside the respective waterplant facilities. Land use for the area is similar to that of Follansbee and Parkersburg, except that the area does not have industrial activity. Commercial facilities and individual residences comprise the major part of land around the city's wells. Unlike other typical water facilities, New Martinsville has five separate waterplants centered around the five primary wells. The wells are therefore scattered over a wide area rather than being concentrated in one location as at the Follansbee and Parkersburg waterplants. Of the five wells, the Benjamin Drive well appears to be the best candidate for long-term sampling on the basis of past and present maintenance records. The location map for the New Martinsville wells is the New Martinsville, W. Va.-Ohio 1:24,000 USGS topographic quadrangle (U.S. Geological Survey, 1976h).

Oakland Public Service District-Hancock County

The Oakland Public Service District pumps an average of 110,000 gal/d of water from five wells completed in bedrock in Hancock County (Michelle Dennis, Oakland Public Service District, oral commun., 1992). Complete data for all five wells are not available. All the wells are of similar depth and withdraw water from the same aquifer. Data for one of the five wells was thorough and indicates a well depth of 95 ft, completed in the Conemaugh Formation. The well is located in a flood plain; therefore, an 8-ft section of casing has been placed on the well above land surface to prevent contamination of the well by infiltration of flood waters along the top of the casing. A driller's log for the well indicates that the major lithology is sandstone with some siltstone. The well field is in a remote area and the land-use classification for the site is rural. The East Liverpool South Ohio-W. Va.-Pa. USGS 1:24,000 topographic quadrangle is the location map for the site (U.S. Geological Survey, 1985).

City of Point Pleasant-Mason County

The city of Point Pleasant pumps an average of 1.0 Mgal/d of water from five wells located in sand and gravel alluvial sediments that border the Ohio River in Mason County (Daniel Rogers, Point Pleasant Water Department, oral commun., 1992). Well depths for the five wells range from 80 to 85 ft. Well log data for Point Pleasant currently are unavailable, but the geologic setting is similar to that of Follansbee, Parkersburg, and New Martinsville. The primary aquifer from which the wells derive water is the sand and gravel alluvial aquifer bordering the Ohio River. A fluvial clay and sand confining unit could also be present at the site. Drillers' logs will help to confirm the geologic setting once they are available. The land use in the area near the well field is not as heavily developed by industry as is the land at Follansbee and Parkersburg. Several industrial and commercial facilities are present near the well field, and the land-use classification for the area is commercial to industrial. Railway routes are also located near the well field and are potential sources of contamination. Raw-water samples can be collected at each individual well inside the concrete structures that house the pumps, or inside the main waterplant. The Cheshire, Ohio-W. Va. and Addison, Ohio-W. Va. 1:24,000 USGS topographic quadrangles are the location maps for the well field (U.S. Geological Survey, 1975c).

Kanawha State Forest-Kanawha County

An 80-ft-deep well provides water for the Davis Creek Campground in the Kanawha State Forest in Kanawha County. The well is completed in the Kanawha Formation, which is a sandstone, shale, and coal aquifer. The land-use classification for the area is forested. No water-treatment devices, such as chlorinators or water softeners, have been placed on the well. Raw-water samples can be collected from a tap inside the room housing the pressure tank located between the two restrooms at the Davis Creek Campground. The location map for the Kanawha State Forest well is the 1:24,000 USGS topographic quadrangle for Racine, W. Va. (U.S. Geological Survey, 1976b).

Bowden Fish Hatchery-Randolph County

Two springs serve the Federal fish hatchery at Bowden in Randolph County. Both springs are located in the Greenbrier Limestone. North Spring has an estimated discharge of 1,370 gal/min and has been improved by the addition of a concrete spring box. The estimated discharge of the second spring, South Spring, is 1,190 gal/min. Both springs are located in a valley on the banks of Shaver's Fork. Raw-water samples can be collected from either spring. North Spring has higher sustained flows during the summer and early fall when ground-water levels are low; therefore, it should be selected as the sampling point. South Spring might not supply adequate quantities of water for sampling during low flow periods. The land use in the area is primarily forested. Raw water samples can be collected at either spring or at taps in the main hatchery building. The location map for these two springs is the USGS 1:24,000 topographic quadrangle for Bowden, W. Va. (U.S. Geological Survey, 1976c).

City of Welch-McDowell County

Seven wells are located in the well field that supplies water for the city of Welch in McDowell County. Only one of the seven wells, well 7, is currently being used. The other six wells are maintained as standbys in the event that well 7 should have to be taken off-line for maintenance or other reasons. The original well 7 was drilled to a depth of more than 600 ft and was designed to tap abandoned mine workings in the Pocahontas No. 4 coal seam. The initial well was drilled into a pillar of coal, rather than into one of the entry ways of the abandoned coal mine. A second well was drilled to a depth of 577 ft, only 30 ft away from the first well. This second well also was numbered well 7. A remark was placed in the USGS GWSI database that the original well was abandoned and a new well drilled. An average of 500,000 gal/d of water is pumped from abandoned mine workings in the Pocahontas No. 4 coal seam. Land use in the area is primarily forested, but some surface mining has taken place on the hillsides above the well. Surface-mining activities, however, are not expected to affect the quality of water in the Pocahontas No. 4 coal seam 600 ft below. A tap is present on the main waterline from well 7, where raw-water samples can be easily collected. The location map for the Welch well is the 1:24,000 USGS topographic quadrangle for Welch, W. Va. (U.S. Geological Survey, 1976d).

Chief Logan State Park-Logan County

A 122-ft-deep well supplies water for restrooms in one of the picnic areas in Chief Logan State Park in Logan County. The well is completed in the Kanawha Formation, which consists of sandstone, shale, and coal. The land-use classification for the area is forested; surface mining is not evident in the area. Raw-water samples can be collected from a tap in a storage building housing the pressure tank, fuse box, and control box for the well. No water-treatment systems, such as chlorinators or water softeners, are present at this site. The location map for the Chief Logan State Park well is the 1:24,000 USGS topographic quadrangle for Chapmanville, W. Va. (U.S. Geological Survey, 1976f).

City of Fayetteville-Fayette County

In October 1991, a well was drilled south of Fayetteville in Fayette County to augment a surface-water supply where flow was low because of droughts earlier that year. This new well was drilled to a depth of 612 ft and completed in the Sewell coal seam of the abandoned mine workings of the Kaymoor-Lochgelly coal mines. An average of 400,000 gal/d of water is pumped from the abandoned mine workings (Larry Vassil, Fayetteville Water Department, oral commun., 1992). Land-use classification for the area near the well is urban to commercial. Land-use activities near the surface should not have a major impact on the quality of water in abandoned mine workings 600 ft below. The location map for the Fayetteville well is the 1:24,000 USGS topographic quadrangle for Fayetteville, W. Va. (U.S. Geological Survey, 1976e).

White Sulphur Springs Fish Hatchery-Greenbrier County

Three wells and two springs provide water for fishery activities at the White Sulphur Springs Fish Hatchery in Greenbrier County. Two wells, A and B, are located within 5 ft of one another and yield 300 and 400 gal/min, respectively. Well A is 165 ft deep and well B is 207 ft deep. It is uncertain as to which aquifer these wells are tapping, but they are most likely deriving water from the Oriskany Sandstone and the Helderberg Limestone. A third well, well E, is one of the old public-supply wells for the city of White Sulphur Springs, but the well is now owned by the U.S. Fish and Wildlife Service. It is drilled approximately 181 ft deep and yields 300 gal/min. This well also derives most of its water from the Oriskany Sandstone and Helderberg Limestone. One of the springs yields 730 gal/min (Erskine, 1948). Combined yield of the springs at the time of a site visit in September 1992 was less than 10 gal/min. Water levels at the nearby Greenbrier County observation well were the lowest measured in more than 15 years (Robert Shaver, U.S. Fish and Wildlife, oral commun., 1992). The Oriskany Sandstone and Marcellus Shale are the sources of water for the springs. Water from the three wells and two springs is combined into a common collection main inside one of the hatchery buildings. Personnel from the U.S. Fish and Wildlife Service have requested that water samples be collected in sterile containers to prevent the introduction of bacteria and viruses that can be harmful to fish. The land-use classification for the area is urban to commercial. The location map for the White Sulphur Springs Hatchery sites is the 1:24,000 USGS topographic quadrangle for White Sulphur Springs, W. Va. (U.S. Geological Survey, 1983).

Chestnut Ridge-Monongalia County

Two wells were inventoried near Cooper's Rock State Forest in Monongalia County. The first well is located at the office and maintenance area of one of West Virginia University's research forests on Chestnut Ridge. This well is 125 ft deep, is estimated to yield 8 gal/min, and is completed in the Pottsville Formation. Raw-water samples can be collected from a large concrete holding tank buried near the office building. Sufficient purging might not be possible to assure collection of a representative water sample at the West Virginia University Forest well as this well has a 500-gal concrete holding tank and has no plumbing provisions for bypassing the tank for sampling. Unless the plumbing is modified to bypass the large holding tank, this site should not be sampled but could serve as a standby in case the remaining well could not be sampled due to well maintainence, plumbing problems, or contamination.

A second well was inventoried nearby at the Monongalia County Chestnut Ridge Park because of concerns about the quality of water in the 500-gal storage tank. The Chestnut Ridge Park well is 190 ft deep, has an estimated yield of 8 gal/min, and is completed in the Pottsville Formation (Cardwell and others, 1968). Raw-water samples can be collected from an outside hydrant at the Chestnut Ridge well. Land-use classification for the area is forested. The location map for the West Virginia University Forest and Chestnut Ridge wells is the Lake Lynn, Pa.-W. Va. 1:24,000 USGS topographic quadrangle (U.S. Geological Survey, 1976g).

Sand Spring in Canaan Valley-Tucker County

Sand Spring is located in the Timberline subdivision of Canaan Valley in Tucker County. The spring discharge was measured at 108 gal/min on July 16, 1991. The Greenbrier Limestone, which comprises the majority of the valley floor in Canaan Valley, is the aquifer from which Sand Spring is derived. The spring is unimproved and raw-water samples can be collected in the headwaters of the small unnamed stream that forms there, or from several areas around the spring where ground water seeps to the surface. The land-use classification for the area is rural to forested. The location map for the site is the 1:24,000 USGS topographic quadrangle for Blackwater Falls, W. Va. (U.S. Geological Survey, 1981a).

Holly River State Park-Webster County

The well that serves one of the campgrounds in Holly River State Park in Webster County is approximately 110 ft deep, is estimated to yield 21 gal/min, and is completed in the Kanawha Formation. The well is located in a small wellhouse near the entrance to the park. A chlorinator is the only form of water treatment present at the site. The chlorinator can be bypassed and a raw-water sample can be collected from a tap located in the plumbing ahead of the chlorinator. The pump must be running to obtain a representative sample. Road deicing operations on State Route 20 nearby pose a threat of contamination by chloride. The location map for the Holly River State Park well is the 1:24,000 USGS topographic quadrangle for Hacker Valley, W. Va. (U.S. Geological Survey, 1967a).

Cabwaylingo State Forest-Wayne County

A 108-ft-deep well with an estimated yield of 16 gal/min provides water for two cabins in Cabwaylingo State Forest in Wayne County. The well is located in a stone wellhouse and is completed in the Kanawha Formation. Land-use classification for the area is forested. A chlorinator is the only form of water treatment present at the site. At present, there is no tap for obtaining a raw-water sample prior to chlorination, but the chlorinator can easily be disconnected during purging and sampling. It would be relatively easy with some minor plumbing modifications to place a tap on the line ahead of the chlorinator. The location map for the Cabwaylingo well is the 1:24,000 USGS topographic quadrangle for Wilsondale, W. Va. (U.S. Geological Survey, 1981b).

Edray Fish Hatchery-Pocahontas County

The Edray Fish Hatchery near Edray in Pocahontas County derives its water supply from two springs, McLaughlin and Averill Springs, that emerge from the Greenbrier Limestone Formation. Both springs have measured discharges of 2,000 gal/min (Price and others, 1936). The two springs are the primary source of water for the Edray Fish Hatchery. Land-use classification for the area is rural forested. During site visits in October 1993, discharge at Averill Spring was significantly less than that of McLaughlin Spring. McLaughlin Spring should therefore be used as the sampling point for the Edray Fish Hatchery site and Averill Spring used as a backup in case McLaughlin Spring is contaminated or cannot be sampled for some reason. The location map for the springs is the 1:24,000 USGS topographic quadrangle for Edray, W. Va. (U.S. Geological Survey, 1977).

Wallback Public Hunting Area-Roane County

The backup water supply for the maintenance area at the Wallback Public Hunting Area in Roane County is a 90-ft-deep well completed in the Conemaugh Group. The Conemaugh Group primarily consists of shale, siltstone, and sandstone with some thin units of coal and limestone. This well was the primary source of water for a farm that formerly was located at the site. The well is currently unused, but all plumbing and electrical wiring remains in place and the well is available for sampling. Care should be taken when sampling the well to ensure that purging requirements are satisfied, as the well is unused and stagnant water can accumulate in the casing. No chlorination or other treatment systems are present on the well. Raw-water samples can be collected at the well head or inside the nearby barn at an indoor tap. Land-use classification for the area is rural to forested. Nearby road-deicing operations on Interstate 79 could be a potential source of chloride contamination. The location map for the Wallback Public Hunting Area well is the 1:24,000 USGS topographic quadrangle for Newton, W. Va. (U.S. Geological Survey, 1975e).

SUMMARY

Twenty-six sites comprised of wells and springs have been selected for initial site establishment of the West Virginia Division of Environmental Protection-Office of Water Resources ambient ground-water-quality-monitoring network. The 26 sites are scattered throughout the State in 25 of West Virginia's 55 counties. Sites have been selected in the alluvial aquifer bordering the Ohio River in Follansbee, New Martinsville, Point Pleasant, and Parkersburg, and along the Kanawha River near Winfield (Cannery Lane Well). These alluvial aquifers are in areas characterized by heavy industrial activity.

Two springs, Lefevre Spring in Martinsburg and Harpers Ferry's old public-supply spring, were selected within the Cambro-Ordovician karst limestone and dolomite aquifers of West Virginia's eastern panhandle. A third spring in the eastern panhandle, Berkeley Springs in Morgan County, which derives water from the Oriskany Sandstone was also selected. These sites were selected because of rapid population growth, industrial, and commercial development of West Virginia's eastern panhandle and because of the susceptibility of "karst" aquifers to contamination.

Coal mines are used as sources of public- water supply in the southern coal fields of West Virginia. Two sites, the cities of Welch in McDowell County and Fayetteville in Fayette County, were selected to characterize the water in these important coal aquifers. The city of Welch pumps water from abandoned mine workings in the Pocahontas No. 4 coal seam. Fayetteville pumps water from abandoned mine workings in the Sewell coal seam.

The Greenbrier Limestone is a large "karst" aquifer that supplies water for public, domestic, commercial, and agricultural supplies in the Valley and Ridge Province in the eastern part of West Virginia. The karstic nature of this aquifer makes it susceptible to contamination from agricultural, industrial, commercial, and urban activities. Four sites present in the Greenbrier aquifer--Davis Spring in Greenbrier County, Sand Spring in Tucker County (Canaan Valley), and the springs at the Federal fish hatchery near Bowden in Randolph County and the State fish hatchery at Edray in Pocahontas County--are, therefore, included in the network. Also, the Greenbrier aquifer is one of the most prolific aquifers within the State and is commonly used in agricultural areas of the eastern part of the State. Contamination of the Greenbrier aquifer by pesticides, fertilizers, and other agricultural chemicals is also a primary concern.

The remaining sites were selected primarily in sandstone, shale, and coal aquifers of West Virginia's Appalachian Plateau, and to a lesser extent the Valley and Ridge Provinces. Sites selected in these aquifers included one site in the Hinton, one site in the Hampshire, one site in the Dunkard, two sites in the Conemaugh, four sites in the Kanawha, one site in the Marcellus shale, and one site in lower Devonian Formations.

Future sites selected for the monitoring network should include additional sites in the Dunkard and Allegheny Formations of the Appalachian Plateaus. Currently (1995), no sites have been selected in the Allegheny Formation, a relatively minor aquifer of limited outcrop and areal extent. Thin aquifers of Ordovician, Devonian, and Mississippian age, such as the Martinsburg Shale Formation, Chemung Formation, and Pocono Group, also have not been selected at the present time. However, sites have been selected in all the major aquifers throughout the State.

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_____ **1975f,** Addison, Ohio-W.Va., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
_____ **1976a,** West Milford, W. Va., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
_____ **1976b,** Racine, W. Va., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
_____ **1976c,** Bowden, W. Va., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
_____ **1976d,** Welch, W. Va., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000 map, scale 1:24,000, 1 sheet.
_____ **1976e,** Fayetteville, W. Va., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
_____ **1976f,** Chapmanville, W. Va., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
_____ **1976g**, Lake Lynn, Pa.-W. Va., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
_____ **1976h**, New Martinsville, W. Va.-Ohio, 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
_____ **1977**, Edray, W. Va., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
_____ **1978**, Steubenville East, Ohio-W. Va.-Pa., 7.5-minute quadrangle: U.S. Geological Survey topographic map, scale 1:24,000, 1 sheet.
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APPENDIXES

Appendix A. *Ambient ground-water-quality-monitoring network in West Virginia--Site descriptions for wells and springs*

[° ' ", degree, minute, second; --, no data available; DEP-OWR, Division of Environmental Protection Office of Water Resources]

Site identification no.	Station name	Location map	County	Altitude of land surface (feet)	Latitude (° ' ")	Longitude (° ' ")
383038081505201	Cannery Lane	Bancroft, W. Va.	Putnam	579	38 30 38	81 50 52
393738078134601	Berkeley Springs #1	Hancock, W. Va.	Morgan	630	39 37 38	78 13 46
393734078134601	Berkeley Springs #2	Hancock, W. Va.	Morgan	620	39 37 34	78 13 46
391950078032900	Lefevre Spring	Inwood, W. Va.	Berkeley	555	39 19 53	78 03 31
392010077455201	Harpers Ferry Spring	Charles Town,W. Va.	Jefferson	400	39 20 10	77 45 52
373213081003301	Pipestem State Park	Flat Top, W. Va.	Summers	1,545	37 32 13	81 00 33
385332078553601	Lost River State Park	Lost River State Park, W. Va.	Hardy	2,055	38 53 32	78 55 36
374525080324501	Davis Spring	Asbury, W. Va.	Greenbrier	1,650	37 45 25	80 32 45
391019080243301	Waters Smith State Park	West Milford, W. Va.	Harrison	80	39 10 19	80 24 33
390202081234201	Palestine Hatchery	Elizabeth, W. Va.	Wirt	740	39 02 02	81 23 42
401933080355501	Follansbee A	Steubenville East, Ohio	Brooke	600	40 19 33	80 35 55
402003080360501	Follansbee B	Steubenville East, Ohio	Brooke	670	40 20 03	80 36 05
401917080354801	Follansbee	Steubenville East, Ohio	Brooke	665	40 19 17	80 35 48
391717081333603	Parkersburg #2	Parkersburg, W. Va.	Wood	600	39 17 34	81 33 40
391717081333802	Parkersburg #1	Parkersburg, W. Va.	Wood	600	39 17 18	81 33 38
391718081333101	Parkersburg #3	Parkersburg, W. Va.	Wood	600	39 17 50	81 33 33
394050080514201	New Martinsville #1	New Martinsville,W. Va.	Wetzel	639	39 40 50	80 51 49
394018080513601	New Martinsville #2	New Martinsville,W. Va.	Wetzel	658	39 40 18	80 51 49
393937080513801	New Martinsville #3	New Martinsville,W. Va.	Wetzel	644	39 39 38	80 51 50
393911080513701	New Martinsville #4	New Martinsville,W. Va.	Wetzel	633	39 39 13	80 51 49
393909080513601	New Martinsville #5	New Martinsville,W. Va.	Wetzel	633	39 39 11	80 51 49
403038080332401	Oakland Public Service	East Liverpool South, Ohio	Hancock	970	40 30 38	80 33 24
385419082071701	Point Pleasant #1	Cheshire, Ohio	Mason	590	38 54 19	82 07 17
385421082071801	Point Pleasant #2	Cheshire, Ohio	Mason	590	38 54 21	82 07 18
385421082072001	Point Pleasant #3	Cheshire, Ohio	Mason	590	38 54 21	82 07 20
385422082072201	Point Pleasant #4	Cheshire, Ohio	Mason	590	38 54 22	82 07 22
385407082075601	Point Pleasant # 5	Addison, Ohio	Mason	560	38 54 07	82 07 56
381432081391501	Kanawha State Forest	Racine, W. Va.	Kanawha	980	38 14 32	81 39 15
03068690	North Spring A	Bowden, W. Va.	Randolph	2,225	38 54 43	79 42 16
03068710	South Spring A	Bowden, W. Va.	Randolph	2,225	38 54 38	79 42 22

Owner	Ownership date	Log type	Site visit	Station remarks	Site identification no.
Elmer Young	--	-	10-06-92	W. Va. DEP-OWR ambient ground-water monitoring site	383038081505201
W. Va. Department. of Commerce and Parks	--	-	07-22-85	--	393738078134601
W. Va. Department of Commerce and Parks	00-00-00	-	07-22-85	--	393734078134601
James Lawrence	00-00-59	-	06-06-85	Recanvassed for project 445405800	391950078032900
Harpers Ferry Public-Supply Spring	--	-	05-15-85	--	392010077455201
W. Va. Department of Commerce and Parks	--	-	09-25-92	W. Va. DEP-OWR ambient ground-water monitoring site	373213081003301
W. Va. Department of Commerce and Parks	00-00-35	-	09-23-92	W. Va. DEP-OWR ambient ground-water monitoring site	385332078553601
--	--	-	--	--	374525080324501
W. Va. Department of Commerce and Parks	--	-	10-13-92	--	391019080243301
W. Va. Department of Natural Resources	--	-	10-05-92	Well located at assistant superintendent's house	390202081234201
City of Follansbee	00-00-47	-	--	--	401933080355501
City of Follansbee	00-00-47	-	--	--	402003080360501
City of Follansbee	12-01-47	-	08-19-82	--	401917080354801
City of Parkersburg	00-00-49	-	06-07-83	--	391717081333603
City of Parkersburg	00-00-46	-	06-07-83	--	391717081333802
City of Parkersburg	00-00-49	-	06-07-83	--	391718081333101
City of New Martinsville	00-00-58	-	08-05-82	--	394050080514201
City of New Martinsville	12-00-67	-	08-05-82	--	394018080513601
City of New Martinsville	12-11-75	-	--	--	393937080513801
City of New Martinsville	--	-	08-05-82	--	393911080513701
City of New Martinsville	00-00-46	-	--	--	393909080513601
Oakland Public Service District	01-00-90	Drillers	--	W. Va. DEP-OWR ambient ground-water monitoring site	403038080332401
City of Point Pleasant	10-02-80	Drillers	10-15-82	--	385419082071701
City of Point Pleasant	09-21-80	Drillers	10-15-82	--	385421082071801
City of Point Pleasant	12-10-80	Drillers	10-15-82	--	385421082072001
City of Point Pleasant	02-05-81	Drillers	10-15-82	--	385422082072201
City of Point Pleasant	00-00-42	-	--	--	385407082075601
W. Va. Department of Commerce and Parks	--	-	09-29-92	Local surface-water drainage is Davis Creek	381432081391501
U.S. Fish and Wildlife Well	--	-	--	--	03068690
U.S. Fish and Wildlife Well	--	-	--	--	03068710

Appendix A. *Ambient ground-water-quality-monitoring network in West Virginia--Site descriptions for wells and springs* --Continued

Site identification no.	Station name	Location map	County	Altitude of land surface (feet)	Latitude (° ' ")	Longitude (° ' ")
372552081364301	Welch well # 7	Welch, W. Va.	McDowell	1,540	37 25 52	81 36 43
375416082005301	Chief Logan State Park	Chapmanville, W. Va.	Logan	800	37 54 16	82 00 53
380318081062701	Fayetteville Water	Fayetteville, W. Va.	Fayette	1,790	38 03 18	81 06 27
374758080174001	U.S. Fish and Wildlife	White Sulphur Springs, W. Va.	Greenbrier	1,880	37 47 58	80 17 40
374758080174002	U.S. Fish and Wildlife	White Sulphur Springs, W. Va.	Greenbrier	1,880	37 47 58	80 17 40
374802080175201	U.S. Fish and Wildlife	White Sulphur Springs, W. Va.	Greenbrier	1,915	37 48 02	80 17 52
374810080173001	U.S. Fish and Wildlife	White Sulphur Springs, W. Va.	Greenbrier	1,920	37 48 10	80 17 30
394047079463801	Chestnut Ridge Park	Lake Lynn, Pa.-W. Va.	Monongalia	2,230	39 40 47	79 46 38
394038079461701	WVU Forest	Lake Lynn, Pa.-W. Va.	Preston	2,261	39 40 38	79 46 17
390324079232501	Sand Spring	Blackwater Falls, W. Va.	Tucker	3,240	39 03 24	79 23 25
383912080224801	Holly River State Park	Hacker Valley, W. Va.	Webster	1,500	38 39 12	80 22 48
375811082212401	Cabwaylingo State Park	Wilsondale, W. Va.	Wayne	740	37 58 11	82 21 24
381625080063001	McLaughlin Spring	Edray, W. Va.	Pocahontas	2,400	38 16 25	80 06 30
381620080062001	Averill Spring	Edray, W. Va.	Pocahontas	2,400	38 16 20	80 06 20
383409081080801	Wallback Hunting Area	Newton, W. Va.	Roane	775	38 34 09	81 08 08

Ownership	Ownership date	Log type	Site visit	Station remarks	Site identification no.
City of Welch	01-29-91	-	09-28-92	Second well no. 7, original well abandoned	372552081364301
W. Va. Department of Commerce and Parks	09-30-92	-	09-30-92	W. Va. DEP-OWR ambient ground-water monitoring site	375416082005301
City of Fayetteville	10-00-91	Drillers	09-25-92	Well located in green wooden storage building	380318081062701
U.S. Fish and Wildlife Well A	--	-	09-23-92	W. Va. DEP-OWR ambient ground-water monitoring site	374758080174001
U.S. Fish and Wildlife Well B	--	-	09-23-92	W. Va. DEP-OWR ambient ground-water monitoring site	374758080174002
U.S. Fish and Wildlife Well E	--	-	09-23-92	W. Va. DEP-OWR ambient ground-water monitoring site	374802080175201
U.S. Fish and Wildlife Well	--	-	--	--	374810080173001
Monongalia County	--	-	10-13-92	W. Va. DEP-OWR ambient ground-water monitoring site	394047079463801
West Virginia University Forest	06-00-85	-	10-14-92	W. Va. DEP-OWR ambient ground-water monitoring site	394038079461701
Timberline Conservancy/ timberline	--	-	06-06-91	--	390324079232501
W. Va. Department of Commerce and Parks	00-00-70	-	10-13-92	W. Va. DEP-OWR ambient ground-water monitoring site	383912080224801
W. Va. Department of Commerce and Parks	--	-	09-30-92	W. Va. DEP-OWR ambient ground-water monitoring site	375811082212401
W. Va. Department of Natural Resources	--	-	--	--	381625080063001
W. Va. Department of Natural Resources	--	-	--	--	381620080062001
W. Va. Department of Natural Resources WallbackHunting Area	--	-	--	W. Va. DEP-OWR ambient ground-water monitoring site	383409081080801

Appendix B. *Ambient ground-water-monitoring network in West Virginia--Geologic descriptions for wells and springs*

[-- , no data available]

[*Aquifer codes*: 367bkmn, Beekmantown 344mrcl, Marcellus 321mngl, Monongahela 111alvm, alluvium
321cnmg, Conemaugh 327knwh, Kanawha 334grbr, Greenbrier 327pcns, Pocahontas
327newr, New River 347dvnnl, lower Devonian 331mcck, Mauch Chunk 317dkrd, Dunkard
321cnmg, Conemaugh 331msspu, upper Mississippian 377tmsn, Tomstown

Site identification no.	Method of altitude measurement	Altitude accuracy (feet)	Type of site	Type of spring	Perennial spring	Improve-ments	Topographic setting	Aquifer code	Lithology
383038081505201	Map	10	Well	--	--	--	Flood plain	321mngl	Undifferentiated sedimentary
393738078134601	Map	10	Spring	--	Yes	Concrete basin	Hillside	344mrcl	Shale
393734078134601	Map	10	Spring	--	Yes	Concrete basin	Hillside	344mrcl	Shale
391950078032900	Map	5	Spring	Karst	Yes	Pond	Undulating	367bkmn	Limestone
392010077455201	Map	20	Spring	--	Yes	Concrete basin	Valley flat	377tmsn	Undifferentiated sedimentary
373213081003301	Map	10	Well	--	--	--	Flood plain	331msspu	Undifferentiated sedimentary
385332078553601	Map	10	Well	--	--	--	Hillside	341dvnum	Shale
374525080324501	Map	20	Spring	--	--	--	-	334grbr	Limestone
391019080243301	Map	10	Spring	Fracture depression	Yes	Spring house	Hillside	321cnmg	Undifferentiated sedimentary
390202081234201	Map	5	Well	--	--	--	Terrace	317dkrd	Undifferentiated sedimentary
401933080355501	Map	20	Well	--	--	--	Terrace	111alvm	Alluvium
402003080360501	Map	20	Well	--	--	--	Terrace	111alvm	Alluvium
401917080354801	Map	5	Well	--	--	--	Flood plain	111alvm	Alluvium
391717081333603	Map	5	Collector	--	--	--	Terrace	111alvm	Alluvium
391717081333802	Map	5	Collector	--	--	--	Terrace	111alvm	Alluvium
391718081333101	Map	5	Collector	--	--	--	Terrace	111alvm	Alluvium
394050080514201	Map	5	Well	--	--	--	Flood plain	111alvm	Alluvium
394018080513601	Map	5	Well	--	--	--	Flood plain	111alvm	Alluvium
393937080513801	Map	10	Well	--	--	--	Flood plain	111alvm	Alluvium
393911080513701	Map	10	Well	--	--	--	Flood plain	111alvm	Alluvium
393909080513601	Map	10	Well	--	--	--	Flood plain	111alvm	Alluvium
403038080332401	Map	10	Well	--	--	--	Streambed	321cnmg	Sandstone
385419082071701	Map	5	Well	--	--	--	Flood plain	111alvm	Alluvium
385421082071801	Map	5	Well	--	--	--	Flood plain	111alvm	Alluvium
385421082072001	Map	5	Well	--	--	--	Flood plain	111alvm	Alluvium
385422082072201	Map	5	Well	--	--	--	Flood plain	111alvm	Alluvium
385407082075601	Map	10	Collector	--	--	--	Flood plain	111alvm	Alluvium
381432081391501	Map	10	Well	--	--	--	Valley flat	327knwh	Sandstone
03068690	--	20	Spring	--	--	--	Hillside	334grbr	Limestone
03068710	--	20	Spring	--	--	--	Valley flat	334grbr	Limestone
372552081364301	Map	10	Well	--	--	--	Upland draw	327pcns	Coal
375416082005301	Map	10	Well	--	--	--	Upland draw	327knwh	--
380318081062701	Map	10	Well	--	--	--	Hillside	327newr	Undifferentiated sedimentary
374758080174001	Map	10	Well	--	--	--	Valley flat	347dvnnl	Undifferentiated sedimentary
374758080174002	Map	10	Well	--	--	--	Valley flat	347dvnnl	Undifferentiated sedimentary

Description of material	Contributing units	Aquifer type	Primary use of water	Site identification no.
Depth of well indicates bedrock below.	Principal aquifer	Mixed	Public supply	383038081505201
--	Principal aquifer	--	Public supply	393738078134601
--	Principal aquifer	--	Public supply	393734078134601
--				
--	Principal aquifer	--	Public supply	391950078032900
--	Principal aquifer	--	Public supply	392010077455201
Well located in Hinton Formation.	Principal aquifer	Confined multiple	Park	373213081003301
Hampshire Formation of upper Devonian system.	Principal aquifer	Confined multiple	Park	385332078553601
--	Principal aquifer	--	Unused	374525080324501
Two springs present near wetland.	Principal aquifer	--	Unused	391019080243301
Well may also show effects of shallow quaternary alluvium but will be predominately of Dunkard origin.	Principal aquifer	Mixed	Household	390202081234201
--	Principal aquifer	--	Public supply	401933080355501
--	Principal aquifer	--	Public supply	402003080360501
--	Principal aquifer	--	Pubic supply	401917080354801
--	Principal aquifer	--	Public supply	391717081333603
--	Principal aquifer	--	Public supply	391717081333802
--	Principal aquifer	--	Public supply	391718081333101
--	Principal aquifer	--	Public supply	394050080514201
--	Principal aquifer	--	Public supply	394018080513601
--	Principal aquifer	--	Public supply	393937080513801
--	Principal aquifer	--	Public supply	393911080513701
--	Principal aquifer	--	Public supply	393909080513601
--	Principal aquifer	Confined multiple	Public supply	403038080332401
--	Principal aquifer	--	Public supply	385419082071701
--	Principal aquifer	--	Public supply	385421082071801
--	Principal aquifer	--	Public supply	385421082072001
--	Principal aquifer	--	Public supply	385422082072201
--	Principal aquifer	--	Public supply	385407082075601
Well located within Kanawha Formation (sandstone, shale, and coal mixed aquifer).	Principal aquifer	Mixed	Park	381432081391501
--	Principal aquifer	--	Commercial	03068690
--	Principal aquifer	--	Commercial	03608710
Target zone for well is Pocahontas No.4 coal seam in abandoned mine workings.	Principal aquifer	Confined multiple	Public supply	372552081364301
--	Principal aquifer	Mixed	Other	375416082005301
The upper part of New River group is primary aquifer.	Prinicipal aquifer	Confined multiple	Public supply	380318081062701
Most water probably derived from Oriskany Sandstone and Helderberg Limestone.	Secondary aquifer	Mixed	Commercial	374758080174001
Most water probably derived from Oriskany Sandstone and Helderberg Limestone.	Secondary aquifer	Mixed	Commercial	374758080174002

Appendix B. *Ambient ground-water-monitoring network in West Virginia--Geologic descriptions for wells and springs*--Continued

Site identification no.	Method of altitude measurement	Altitude accuracy (feet)	Type of site	Type of spring	Perennial spring	Improve-ments	Topographic setting	Aquifer code	Lithology
374802080175201	Map	10	Well	--	--	--	Hillside	347dvnnl	Undifferentiated sedimentary
374810080173001	--	20	-	--	--	--	Valley flat	347dvnnl	-
394047079463801	--	10	Well	--	--	--	--	331mcck	Undifferentiated sedimentary
394038079461701	Map	3	Well	--	--	--	--	331mcck	Undifferentiated sedimentary
390324079232501	Altimeter	2	Spring	Fracture depression	Yes	None	Swamp	334grbr	Limestone
383912080224801	Map	--	Well	--	--	--	Valley flat	327knwh	Undifferentiated sedimentary
375811082212401	Map	--	Well	--	--	--	Valley flat	327knwh	--
381625080063001	--	20	Spring	--	--	--	Hillside	334grbr	Limestone
381620080062001	--	20	Spring	--	--	--	Hillside	334grbr	Limestone
383409081080801	Map	5	Well	--	--	--	Upland draw	--	--

Description of material	Contributing units	Aquifer type	Primary use of water	Site identification no.
Most water probably derived from Oriskany Sandstone and Helderberg Limestone.	Principal aquifer	Mixed	Commercial	374802080175201
--	--	--	--	374810080173001
Well may be affected by thin overlying outcrop of Mauch Chunk or underlying Allegheny Groups Pottsville primary aquifer.	Secondary aquifer	Confined multiple	Domestic	394047079463801
Well primarily in Pottsville Formation but may also be affected by thin overlying Mauch Chunk or underlying Allegheny.	Secondary aquifer	Mixed	Institution	394038079461701
--	Principal aquifer	--	Unused	390324079232501
--	Prinicipal aquifer	Mixed	Public supply	383912080224801
--	Principal aquifer	Mixed	Public supply	375811082212401
--	--	--	--	381625080063001
--	--	--	--	381620080062001
--	--	Mixed	--	383409081080801

Appendix C. *Ambient ground-water-monitoring network in West Virginia--Construction data for wells and springs*

[--, no data available]

Site identification no.	Date of construction	Method of construction	Type of pump	Type of surface seal	Type of finish	Bottom of seal (feet)	Method of develop-ment	Special treatment during develop-ment
383038081505201	00-00-37	--	Submersible	--	--	--	--	--
393738078134601	--	--	--	--	--	--	--	--
393734078134601	--	--	--	--	--	--	--	--
391950078032900	--	--	--	--	--	--	--	--
392010077455201	--	--	--	--	--	--	--	--
373213081003301	--	--	Submersible	Cement grout	--	26	--	--
385332078553601	00-00-35	Cable tool	Submersible	None	Open hole	--	--	--
374525080324501	--	--	--	--	--	--	--	--
391019080243301	--	--	--	--	--	--	--	--
390202081234201	00-00-35	--	Jet	--	Open hole	--	--	--
401933080355501	00-00-47	Cable tool	--	--	Gravel with screen	0	--	--
402003080360501	--	Cable tool	Centrifugal	--	Gravel with screen	0	--	--
401917080354801	12-01-47	--	Turbine	--	--	--	--	--
391717081333603	00-00-49	--	Turbine	--	--	0	--	--
391717081333802	00-00-46	--	Turbine	--	--	0	--	--
391718081333101	00-00-49	--	Turbine	--	--	0	--	--
394050080514201	00-00-58	--	Turbine	--	--	--	--	--
394018080513601	12-00-67	--	Turbine	--	--	--	--	--
393937080513801	12-11-75	--	--	--	--	--	--	--
393911080513701	--	--	Turbine	--	--	--	--	--
393909080513601	01-03-47	--	--	--	--	--	--	--
403038080332401	01-00-90	Cable tool	Submersible	Cement grout	Open hole	--	Pumped	--
385419082071701	10-02-80	Cable tool	Turbine	--	Gravel with screen	--	Surged	Chemical
385421082071801	09-21-80	Cable tool	Turbine	--	Gravel with screen	--	Surged	Chemical
385421082072001	12-10-80	Cable tool	Turbine	--	Gravel with screen	--	Surged	Chemical
385422082072201	02-05-81	Cable tool	Turbine	--	Gravel with screen	--	Surged	Chemical
385407082075601	00-00-42	Dug	--	--	Horizontal gallery	--	--	--
381432081391501	07-10-38	--	Submersible	--	Open hole	--	--	--
03068690	--	--	--	--	--	--	--	--
03068710	--	--	--	--	--	--	--	--
372552081364301	01-29-81	Air rotary	Turbine	None	Open hole	--	--	--
375416082005301	00-00-68	Air rotary	Submersible	--	--	--	--	--
380318081062701	10-00-91	Air rotary	Submersible	Cement grout	--	--	Pumped	--
374758080174001	--	--	Turbine	Cement grout	--	--	--	--
374758080174002	--	--	Turbine	Cement grout	--	--	--	--
374802080175201	--	--	Submersible	--	--	--	--	--
374810080173001	--	--	--	--	--	--	--	--
394047079463801	--	--	Submersible	--	--	--	--	--
394038079461701	06-00-85	Air rotary	Submersible	Cement grout	Open hole	--	Pumped	--
390324079232501	--	--	--	--	--	--	--	--
383912080224801	00-00-70	--	Submersible	Cement grout	--	--	--	--
375811082212401	00-00-37	--	Submersible	Cement grout	--	--	--	--
381625080063001	--	--	--	--	--	--	--	--
381620080062001	--	--	--	--	--	--	--	--
383409081080801	--	--	Submersible	--	--	--	--	--

Bottom of interval (feet)	Diameter of interval (inches)	Top of open interval (feet)	Type of open-ings	Top of casing (feet)	Bottom of casing (feet)	Diameter of casing (inches)	Casing material	Type of power	Horse power	Rate capa-city of lift device	Pump intake set-ting (feet)	Site identification no.
130.0	6	--	--	-2.5	--	6	Steel	Electric	1.0	18	125	383038081505201
--	--	--	--	--	--	--	--	--	--	--	--	393738078134601
--	--	--	--	--	--	--	--	--	--	--	--	393734078134601
--	--	--	--	--	--	--	--	--	--	--	--	391950078032900
--	--	--	--	--	--	--	--	--	--	--	--	392010077455201
160	10	--	--	-3.1	26.9	8	Steel	Electric	--	25	155	373213081003301
180	6	--	--	-.3	19.7	6	Steel	Electric	2.5	--	166	385332078553601
--	--	--	--	--	--	--	--	--	--	--	--	374525080324501
--	--	--	--	--	--	--	--	--	--	--	--	391019080243301
90.0	6	--	--	-.65	20.0	6	Steel	--	.75	--	67	390202081234201
--	--	--	--	.0	--	20	--	--	--	--	--	401933080355501
--	--	--	--	.0	--	12	--	Electric	--	--	--	402003080360501
75.0	20	--	--	.0	--	20	--	Electric	20.0	--	63	401917080354801
50.8	--	--	--	--	--	--	--	Electric	75.0	--	--	391717081333603
56.2	156	--	--	--	--	--	--	Electric	75.0	--	--	391717081333802
45.7	--	--	--	--	--	--	--	Electric	75.0	--	--	391718081333101
--	--	--	--	--	--	--	--	Electric	50.0	--	--	394050080514201
82.0	20	67.0	Screen	.0	67.0	20	Steel	Electric	50.0	--	--	394018080513601
74.5	20	59.5	Screen	.0	59.5	20	--	--	--	--	--	393937080513801
--	--	--	--	--	--	--	--	Electric	40.0	--	--	393911080513701
--	--	--	--	--	--	--	--	--	--	--	--	393909080513601
95.0	10	32.0	Fractured rock	8.0	24.0	10	Steel	Electric	10.0	150	83	403038080332401
81.0	20	66.0	Screen	3.7	66.0	12	Steel	Electric	25.0	--	--	385419082071701
84.0	20	69.0	Screen	3.7	69.0	12	Steel	Electric	25.0	--	--	385421082071801
84.5	20	69.5	Screen	3.6	69.5	12	Steel	Electric	25.0	--	--	385421082072001
84.0	20	69.0	Screen	3.7	69.0	12	Steel	Electric	25.0	--	--	385422082072201
80.0	--	--	--	--	--	--	--	--	--	--	--	385407082075601
80.0	8	--	--	-.4	--	8.	Steel	Electric	.75	10	77	381432081391501
--	--	--	--	--	--	--	--	--	--	--	--	03068690
--	--	--	--	--	--	--	--	--	--	--	--	03068710
577	12	565	Other	.0	20.0	12	Steel	Electric	--	600	530	372552081364301
122	8	--	--	-1.9	20.0	8	Steel	Electric	5.0	--	117	375416082005301
612	12	--	--	-2.0	18.0	12	Steel	Electric	125	600	608	380318081062701
165	6	--	--	-1.6	--	6	Steel	Electric	20.0	300	155	374758080174001
207	8	--	--	-1.1	--	8	Steel	Electric	30.0	400	170	374758080174002
181	6	--	--	-1.3	--	6	Steel	--	--	300	151	374802080175201
--	--	--	--	--	--	--	--	--	--	--	--	374810080173001
190	6	--	--	-1.3	18.7	6	Steel	Electric	--	--	150	394047079463801
125	6	--	--	-.35	22.6	6	Steel	Electric	.75	--	--	394038079461701
--	--	--	--	--	--	--	--	--	--	--	--	390324079232501
110	6	--	--	-3.0	37.0	6	Steel	Electric	2.5	19	88	383912080224801
108	--	--	--	-1.5	--	--	Steel	--	1.0	16	78	375811082212401
--	--	--	--	--	--	--	--	--	--	--	--	381625080063001
--	--	--	--	--	--	--	--	--	--	--	--	381620080062001
90.0	6	--	--	.50	20.0	6	Steel	Electric	.5	--	82	383409081080801

Appendix D. *Ambient ground-water-quality-monitoring network in West Virginia--Water-level data for wells and springs*

[--, no data available; USGS, U.S. Geological Survey]

Site identification no.	Depth of well source	Water-level source	Method water level measured	Water-level status	Date water level measured	Depth of well (feet)	Water level measured (feet below land surface)
383038081505201	Owner	--	--	--	--	130.0	--
393738078134601	--	--	--	--	--	--	--
393734078134601	--	--	--	--	--	--	--
391950078032900	--	--	--	--	--	--	--
392010077455201	--	--	--	--	--	--	--
373213081003301	Owner	--	--	--	--	160	--
385332078553601	Owner	Geologist	Steel tape	Recently pumped	09-11-92	180	36.3
374525080324501	--	--	--	--	--	--	--
391019080243301	--	--	--	--	--	--	--
390202081234201	USGS	USGS	Steel tape	Recently pumped	10-05-92	90.0	12.7
401933080355501	--	--	--	--	--	75.0	--
402003080360501	--	--	--	--	--	80.0	--
401917080354801	--	--	--	--	--	75.0	--
391717081333603	--	--	--	--	--	50.8	--
391717081333802	--	--	--	--	--	56.2	--
391718081333101	--	--	--	--	--	45.7	--
394050080514201	--	--	--	--	--	73.3	--
394018080513601	--	Owner	Reported	--	11-01-80	82.0	35.7
393937080513801	--	Driller	Reported	--	12-11-75	74.5	45.0
393911080513701	--	Driller	Reported	--	11-1-80	59.0	36.7
393909080513601	--	Driller	Reported	--	11-01-80	57.5	37.0
403038080332401	Driller	Reported	Reported	--	01-00-90	95.0	16.5
385419082071701	--	USGS	Steel tape	--	10-28-82	81.0	40.9
385421082071801	--	USGS	Steel tape	--	10-28-82	84.0	43.1
385421082072001	--	USGS	Steel tape	--	10-28-82	84.5	43.8
385422082072201	--	USGS	Steel tape	--	10-28-82	84.0	44.1
385407082075601	Reported	--	--	--	--	80.0	--
381432081391501	Owner	USGS	Steel tape	Recently pumped	09-29-92	80.0	12.8
03068690	--	--	--	--	--	--	--
03068710	--	--	--	--	--	--	--
372552081364301	Logs	Owner	Reported	--	01-29-92	577	282
375416082005301	USGS	USGS	Steel tape	Recently pumped	09-30-92	122	36.7
380318081062701	Driller	Driller	Reported	--	10-00-91	612	527
374758080174001	Owner	Owner	Reported	Recently pumped	10-19-92	165	8.05
374758080174002	Owner	Owner	Reported	Recently pumped	10-19-92	207	7.95
374802080175201	Owner	Owner	Reported	Recently pumped	10-19-92	181	7.00
374810080173001	--	--	--	--	--	--	--
394047079463801	USGS	USGS	Steel tape	Recently pumped	10-13-92	190	65.6
394038079461701	Owner	USGS	Steel tape	Recently pumped	10-13-92	125	61.6
390324079232501	--	--	--	--	--	--	--
383912080224801	Owner	USGS	Steel tape	Pumping	10-13-92	110	35.9
375811082212401	USGS	USGS	Steel tape	Recently pumped	09-30-92	108	16.0
381625080063001	--	--	--	--	--	--	--
381620080062001	--	--	--	--	--	--	--
383409081080801	USGS	USGS	Steel tape	--	10-09-92	90.0	17.6

Description of this measuring point	Remarks	Site identification no.
Measuring point is top edge of casing.	--	383038081505201
--	--	393738078134601
--	Also known as Lord Fairfax Spring.	393734078134601
--	Recanvassed for 05800 project 6/6/85.	391950078032900
--	--	392010077455201
Top edge of hole in well cap.	--	373213081003301
In pit edge of casing, measuring point is about 1,000 feet as it is in a pit.	--	385332078553601
--	--	374525080324501
--	--	391019080243301
Measuring point is top edge of casing 0.65 feet above garage floor.	--	390202081234201
--	--	401933080355501
--	--	402003080360501
--	--	401917080354801
--	--	391717081333603
--	--	391717081333802
--	--	391718081333101
--	--	394050080514201
--	--	394018080513601
--	--	393937080513801
--	--	393911080513701
--	--	393909080513601
Measuring point is referenced to ground level due to 8 feet of casing stickup.	--	403038080332401
--	--	385419082071701
--	--	385421082071801
--	--	385421082072001
--	--	385422082072201
All information was taken from 1978 report.	--	385407082075601
Measuring point is edge of steel casing 0.40 feet above land surface.	Water -quality sample can be taken in room with tank.	381432081391501
--	--	03068690
--	--	03068710
--	Second Welch well no. 7, original abandoned.	372552081364301
--	--	375416082005301
Measuring point is top edge of casing.	--	380318081062701
Measuring point is top edge of concrete pad.	--	374758080174001
Measuring point is top edge of concrete pad.	--	374758080174002
Measuring point is top edge of casing.	--	374802080175201
--	--	374810080173001
Measuring point is top edge of casing.	--	394047079463801
Measuring point is top edge of casing.	--	394038079461701
--	--	390324079232501
Measuring point is top edge of casing.	--	383912080224801
--	--	375811082212401
--	--	381625080063001
--	--	381620080062001
Measuring point is hole in well cap 0.50 feet below land surface.	--	383409081080801

Appendix E. *Ambient ground-water-quality-monitoring network in West Virginia--*
Aquifer test data

[--, no data available]

Site identification no.	Static water level (feet)	Pumping water level (feet)	Discharge (gallons per minute)	Drawdown (feet)	Specific capacity [(gallon per minute) per foot]	Pumping periods (hours)
383038081505201	--	--	25.0	--	--	--
393738078134601	--	--	3,020	--	--	--
393734078134601	--	--	1,020	--	--	--
391950078032900	--	--	500	--	--	--
392010077455201	--	--	201	--	--	--
373213081003301	--	--	25.0	--	--	--
385332078553601	36.3	38.0	8.00	1.7	4.7	30.0
374525080324501	--	--	--	--	--	--
391019080243301	--	--	4.00	--	--	--
390202081234201	--	--	10.0	--	--	--
401933080355501	46.0	53.0	700	7.00	100	--
402003080360501	--	--	220	--	--	24.0
401917080354801	34.8	47.8	750	13.0	57.7	--
391717081333603	--	--	693	--	--	--
391717081333802	--	--	1,540	--	--	--
391718081333101	--	--	1,000	--	--	--
394050080514201	--	--	750	9.00	83.0	--
394018080513601	54.7	70.0	700	16.0	43.7	--
393937080513801	45.0	61.0	550	16.0	34.4	8.0
393911080513701	31.6	42.7	500	11.2	44.6	--
393909080513601	37.0	48.4	328	11.3	28.9	--
403038080332401	16.5	41.0	200	24.5	8.16	48.0
385419082071701	--	52.8	500	13.3	37.6	8.5
385421082071801	39.5	57.0	500	15.0	33.3	8.0
385421082072001	42.0	56.6	500	12.6	39.7	9.0
385422082072201	44.0	59.7	500	15.5	32.3	8.0
385407082075601	44.2	--	--	--	--	--
381432081391501	--	--	10.0	12.6	--	--
03068690	--	--	--	--	132	--
03068710	-	--	--	1.00	102	--
372552081364301	282	282	600	--	--	--
375416082005301	--	--	--	--	--	--
380318081062701	527	--	600	--	--	--
374758080174001	--	--	300	--	--	--
374758080174002	--	--	400	--	--	--
374802080175201	--	--	300	--	--	--
374810080173001	--	--	--	--	--	--
394047079463801	--	--	8.00	--	--	--
394038079461701	--	--	8.00	--	--	--
390324079232501	--	--	350	--	--	--
383912080224801	--	--	21.0	--	--	--
375811082212401	16.0	18.8	16.0	1.98	8.1	15.0
381625080063001	--	--	--	--	--	--
381620080062001	--	--	--	--	--	--
383409081080801	--	--	--	--	--	--