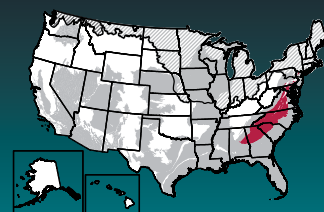


Groundwater Quality in the Piedmont and Blue Ridge Crystalline-Rock Aquifers, Eastern United States



Groundwater provides nearly 50 percent of the Nation's drinking water. To help protect this vital resource, the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Project assesses groundwater quality in aquifers that are important sources of drinking water (Burrow and Belitz, 2014). The Piedmont and Blue Ridge crystalline-rock aquifers constitute one of the important areas being evaluated.

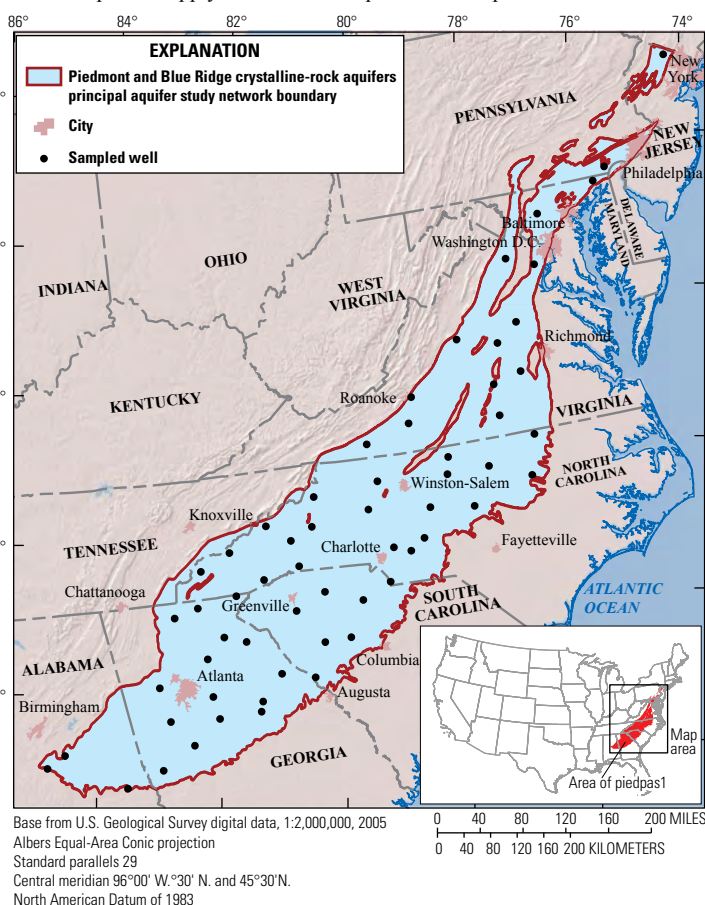
Background

The Piedmont and Blue Ridge (P&BR) crystalline-rock aquifers underlie an area with a population of more than 25 million people in 11 states. The P&BR crystalline-rock aquifers, together with the other rock types in the Piedmont and Blue Ridge regions, rank second in the Nation as a source of groundwater for private domestic supply, providing about 360 million gallons per day (Arnold and others, 2017a). These aquifers are also an important source of public supply, and about 92 million gallons per day are pumped for that use. Land use overlying the P&BR crystalline-rock aquifers is mostly undeveloped (71 percent) and agricultural (19 percent). The cities of Atlanta, Georgia, and Charlotte, North Carolina, overlie the aquifers, as well as suburbs of Richmond, Virginia; Washington, D.C.; Baltimore, Maryland; and Philadelphia, Pennsylvania.

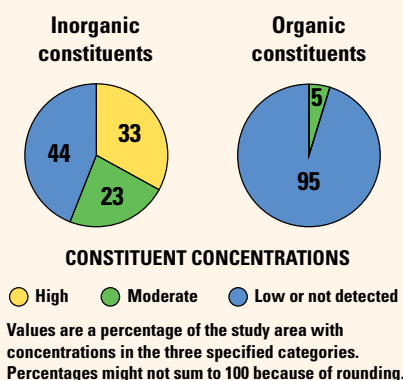
The Piedmont and Blue Ridge crystalline-rock aquifers consist of a variety of rock types such as gneiss, schist, phyllite, granite, and basalt (Chapman and others, 2013). Rocks are overlain by unconsolidated material called regolith, or saprolite, which is more permeable than the underlying bedrock and is important for storage and transmission of water. Most recharge to these aquifers is from local precipitation. Flow in the crystalline-rock aquifers is limited to fractures; thus, individual well yields are low in these aquifers relative to well yields in other bedrock types in the region (Trapp and Horn, 1997).

Groundwater quality in the Piedmont and Blue Ridge crystalline-rock aquifers was evaluated by sampling 60 spatially distributed public-supply wells in these aquifers. The depth zone used for

public supply in these aquifers is called the study area in this report. Water-quality data, collected from this set of 60 spatially distributed wells, were used to estimate the percentage of the study area with constituent concentrations that are high, moderate, and low with respect to constituent benchmarks. The accuracy of the estimates depends upon the distribution and number of wells, not on the size of the area (Belitz and others, 2010). Groundwater for public supply is obtained from a relatively deep zone in these aquifers. The zone of the aquifer used for public supply is typically 150 to 700 feet beneath the land surface. Samples were analyzed for a large number of water-quality constituents derived from natural and human sources.



Overview of Water Quality



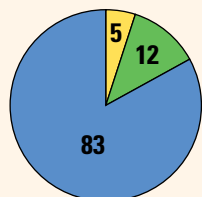
Principal Aquifer Studies are designed to evaluate groundwater used for public supply prior to any treatment. Groundwater quality is assessed by comparing constituent concentrations to benchmarks established for drinking-water quality. Benchmarks and definitions of high, moderate, and low concentrations are discussed at the bottom of page 3.

Many inorganic constituents are naturally present in groundwater. The concentrations of inorganic constituents can be affected by natural processes as well as by human activities. One or more inorganic constituents were detected at high concentrations in about 33 percent of the study area and at moderate concentrations in about 23 percent.

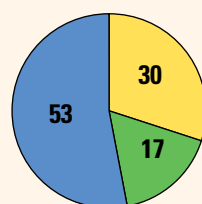
Organic constituents derived from human activities are used in household, business, industrial, and agricultural products. They can enter the environment through normal usage, spills, or improper disposal. Organic constituents were not detected at high concentrations in the study area and were detected at moderate concentrations in about 5 percent of the study area.

Results: Groundwater Quality at the Depth Zone Used for Public Supply in the Piedmont and Blue Ridge Crystalline-Rock Aquifers

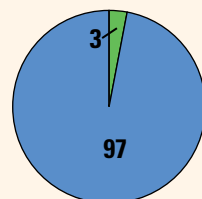
INORGANIC CONSTITUENTS



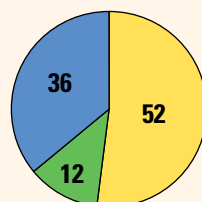
Trace elements and major and minor ions



Radioactive constituents



Nutrients



All non-health benchmarks

Inorganic Constituents With Human-Health Benchmarks

Trace elements and major and minor ions are naturally present in the minerals of rocks, soils and sediments, and in the water that comes into contact with those materials. Samples were analyzed for 34 trace elements and major and minor ions, of which 19 have human-health benchmarks. Constituents from this group were detected at high concentrations in about 5 percent of the study area (the depth zone used for public supply) and at moderate concentrations in about 12 percent. Manganese was the only constituent in this group that was detected at high concentrations. Arsenic, strontium, zinc, and uranium were detected at moderate concentrations.

Radioactivity is the release of energy or energetic particles during spontaneous decay of unstable atoms. Humans are continuously exposed to small amounts of natural radioactivity. Most of the radioactivity in groundwater comes from the decay of isotopes of uranium and thorium that are naturally present in minerals in aquifer materials. Samples were analyzed for eight radioactive constituents, of which four have human-health benchmarks. Radioactive constituents were present at high levels in about 30 percent of the study area and at moderate levels in about 17 percent. Radon (using the proposed alternative maximum contaminant level of 4,000 picocuries per liter) and gross-alpha activity were the only constituents that were present at high concentrations. Radium (combined concentration of Ra-226 and Ra-228 isotopes) was detected at moderate concentrations in 2 percent of the study area.

Nutrients are naturally present at low concentrations in groundwater; high and moderate concentrations (relative to human-health benchmarks) generally result from human activities. Samples were analyzed for five nutrients, of which two have human-health benchmarks. Common sources of nutrients, aside from soils, include fertilizer applied to crops and landscaping, seepage from septic systems, and human and animal waste. No nutrients were detected at high concentrations in the study area. Nitrate was detected at moderate concentrations in about 3 percent of the study area.

Inorganic Constituents and Field Measurements With Non-Health Benchmarks

(Not included in water-quality overview charts shown on the front page)

Some constituents affect the aesthetic properties of water, such as taste, color, and odor, or can create nuisance problems, such as staining and scaling. The benchmarks used for these constituents are non-regulatory secondary maximum contaminant level (SMCL) benchmarks established for public drinking water. Some constituents, such as fluoride and manganese, have human-health benchmarks and SMCLs. Samples were analyzed for 11 constituents that have SMCLs. One or more of these were present at high concentrations in about 52 percent of the study area and at moderate concentrations in about 12 percent.

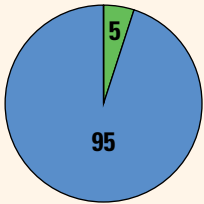
The total dissolved solids (TDS) concentration is a measure of the salinity of the groundwater, and all water naturally contains TDS as a result of the weathering and dissolution of minerals in rocks and sediments. Concentrations of TDS can be high because of natural factors or as a result of human activities such as applications of road salt, fertilizers, or other chemicals to the land surface in urban or agricultural areas. Concentrations of TDS were high in about 3 percent of the study area. Chloride, fluoride, and sulfate—constituents that contribute to TDS concentrations—were detected at moderate concentrations.

Anoxic conditions in groundwater (low amounts of dissolved oxygen) can result in the release of iron and manganese in minerals to the groundwater. Manganese was present at high concentrations relative to the SMCL in about 15 percent of the study area. Iron was present at high concentrations relative to the SMCL in about 12 percent of the study area.

In some areas, the pH of the groundwater was not in the SMCL range of 6.5 to 8.5. The pH did not meet the standard in 35 percent of the study area, typically because it was less than 6.5, which is acidic and potentially corrosive.

Results: Groundwater Quality at the Depth Zone Used for Public Supply in the Piedmont and Blue Ridge Crystalline-Rock Aquifers

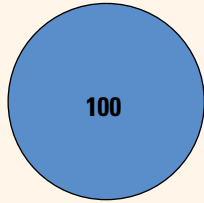
ORGANIC CONSTITUENTS



VOCs

Volatile Organic Compounds With Human-Health Benchmarks

Volatile organic compounds (VOCs) are present in many household, commercial, industrial, and agricultural products and are characterized by their tendency to volatilize (evaporate). Samples were analyzed for 90 VOCs, of which 38 have human-health benchmarks. VOCs were detected at moderate concentrations in 5 percent of the study area but were not detected at high concentrations. Compounds detected at moderate concentrations were the disinfection byproduct chloroform and the solvent trichloroethylene (TCE).



Pesticides

Pesticides With Human-Health Benchmarks

Pesticides, including herbicides, insecticides, and fumigants, are applied to crops, gardens and lawns, around buildings, and along roads to help control unwanted vegetation (weeds), insects, fungi, and other pests. Samples were analyzed for 227 pesticide compounds (pesticides and their breakdown products), of which 119 have human-health benchmarks. Pesticides were not detected at high or moderate concentrations in the study area.

BENCHMARKS FOR EVALUATING GROUNDWATER QUALITY

The USGS NAWQA Project uses benchmarks established for drinking water to provide context for evaluating the quality of untreated groundwater. The quality of water received by consumers can be different than untreated water, because after withdrawal, groundwater may be treated prior to delivery. Federal regulatory benchmarks for protecting human health are used for this evaluation of water quality when available. Otherwise, non-regulatory human-health benchmarks and non-regulatory aesthetic benchmarks are used. Not all constituents analyzed have benchmarks and, thus, are not considered in this context. Out of 55 inorganic constituents and properties and 317 organic constituents, 24 and 157, respectively, have human-health benchmarks.

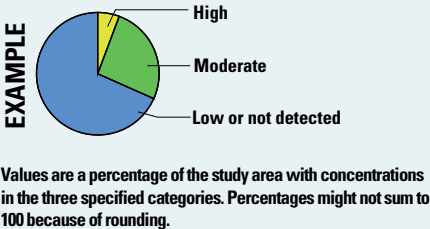
Concentrations are considered high if they are greater than a human-health benchmark (Toccalino and others, 2014) or SMCL. For inorganic constituents, concentrations are moderate if they are greater than one-half of a benchmark. For organic constituents, concentrations are moderate if they are greater than one-tenth of a benchmark; this lower threshold is used because organic constituents are generally less prevalent and have lower concentrations relative to benchmarks than inorganic constituents (Toccalino and others, 2004).

Benchmark Type and Value for Selected Constituents

This table presents benchmarks for those constituents detected at high concentrations in the Piedmont and Blue Ridge crystalline-rock aquifers. Benchmark types are regulatory U.S. Environmental Protection Agency maximum contaminant levels (MCLs), non-regulatory health-based screening levels (HBSLs), and non-regulatory secondary maximum contaminant levels (SMCLs).

[Abbreviations: ppb, part per billion or microgram per liter (µg/L); ppm, part per million or milligram per liter (mg/L); pCi/L, picocurie per liter]

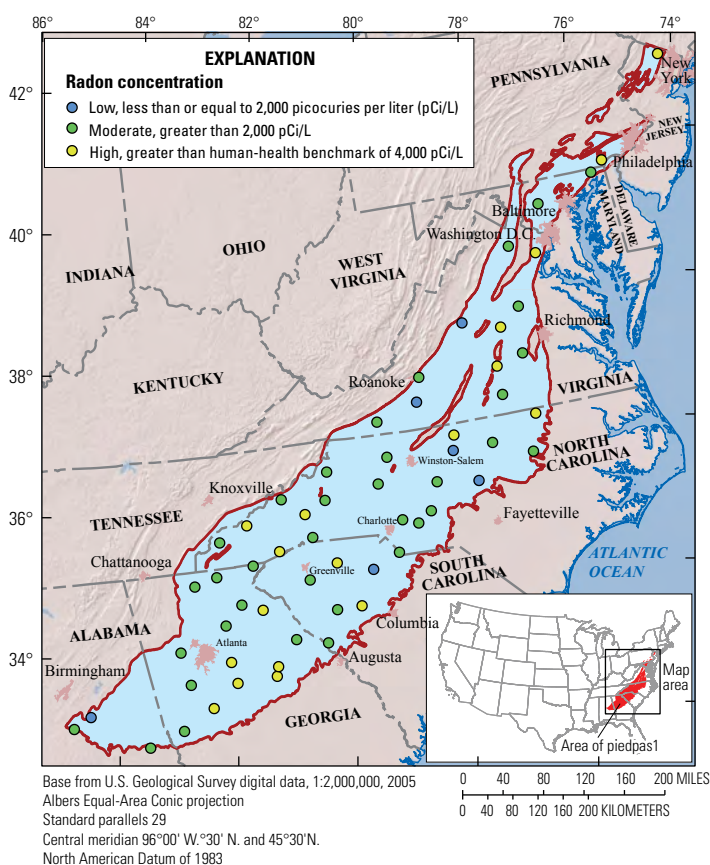
PERCENTAGE OF STUDY AREA



Constituent	Benchmark		Constituent	Benchmark	
	Type	Value		Type	Value
Radon	Proposed MCL	4,000 pCi/L	pH	SMCL	6.5–8.5
Gross-alpha activity	MCL	15 pCi/L	Manganese	SMCL	50 ppb
Manganese	HBSL	300 ppb	Iron	SMCL	300 ppb
Total dissolved solids (TDS)	SMCL	500 ppm	Sulfate	SMCL	250 ppm
Chloride	SMCL	250 ppm			

Radon Concentrations Are Among the Highest in the Nation

Concentrations of radon were greater than 4,000 picocuries per liter (pCi/L) in 30 percent of the wells sampled. Although the proposed radon MCL has not been adopted, radon is considered the second leading cause of lung cancer (U.S. Environmental Protection Agency, 2016). Radon concentrations in domestic wells in the Piedmont and Blue Ridge crystalline-rock aquifers are among the highest in the Nation (DeSimone and others, 2014). Crystalline rocks represent a group of rocks with similar origins (igneous and metamorphic), but rocks are made up of a wide variety of mineral types. Although rocks categorized as crystalline have relatively high radon concentrations, concentrations of radon vary from high to quite low within this group, depending on factors such as the amount of uranium in the parent rock. Chapman and others (2013) found that water from wells in crystalline rocks such as granite had higher radon concentrations than from wells in rocks such as basalt and diabase.



By Bruce Lindsey

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Principal Aquifer Studies

The USGS NAWQA Project has been assessing the quality of ground-water since 1991. The NAWQA studies include Land Use Studies (LUS), Major Aquifer Studies (MAS), and Principal Aquifer Studies (PAS). These three study types are based on sampling networks of wells distributed across an area of interest. The LUS networks typically consist of observation wells that are relatively shallow, MAS networks typically consist of domestic-supply wells that are intermediate in depth, and PAS networks typically consist of public-supply wells that are relatively deep. A national synthesis of shallow and intermediate depth groundwater quality was reported by DeSimone and others (2014), and a regional synthesis of shallow and intermediate depth groundwater quality from Piedmont and Blue Ridge crystalline-rock aquifers was reported by Lindsey and others (2014). This fact sheet provides a summary of PAS data for 60 public-supply wells sampled in 2014 in the Piedmont and Blue Ridge crystalline-rock aquifers (data available in Arnold and others, 2017b).

The PAS assessments like this one allow for the comparison of constituent concentrations in untreated groundwater with benchmarks established for the protection of human health and for aesthetic qualities of drinking water and also provide a basis for comparison of groundwater quality among the principal aquifers. The data collected by the NAWQA Project include chemical analyses generally not available as part of regulatory compliance monitoring, including measurements at concentrations much lower than the levels used as human-health benchmarks and measurements of constituents that can be used to trace the sources and movement of groundwater.

For more information

Technical reports and hydrologic data collected for the USGS NAWQA Project may be obtained from:

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