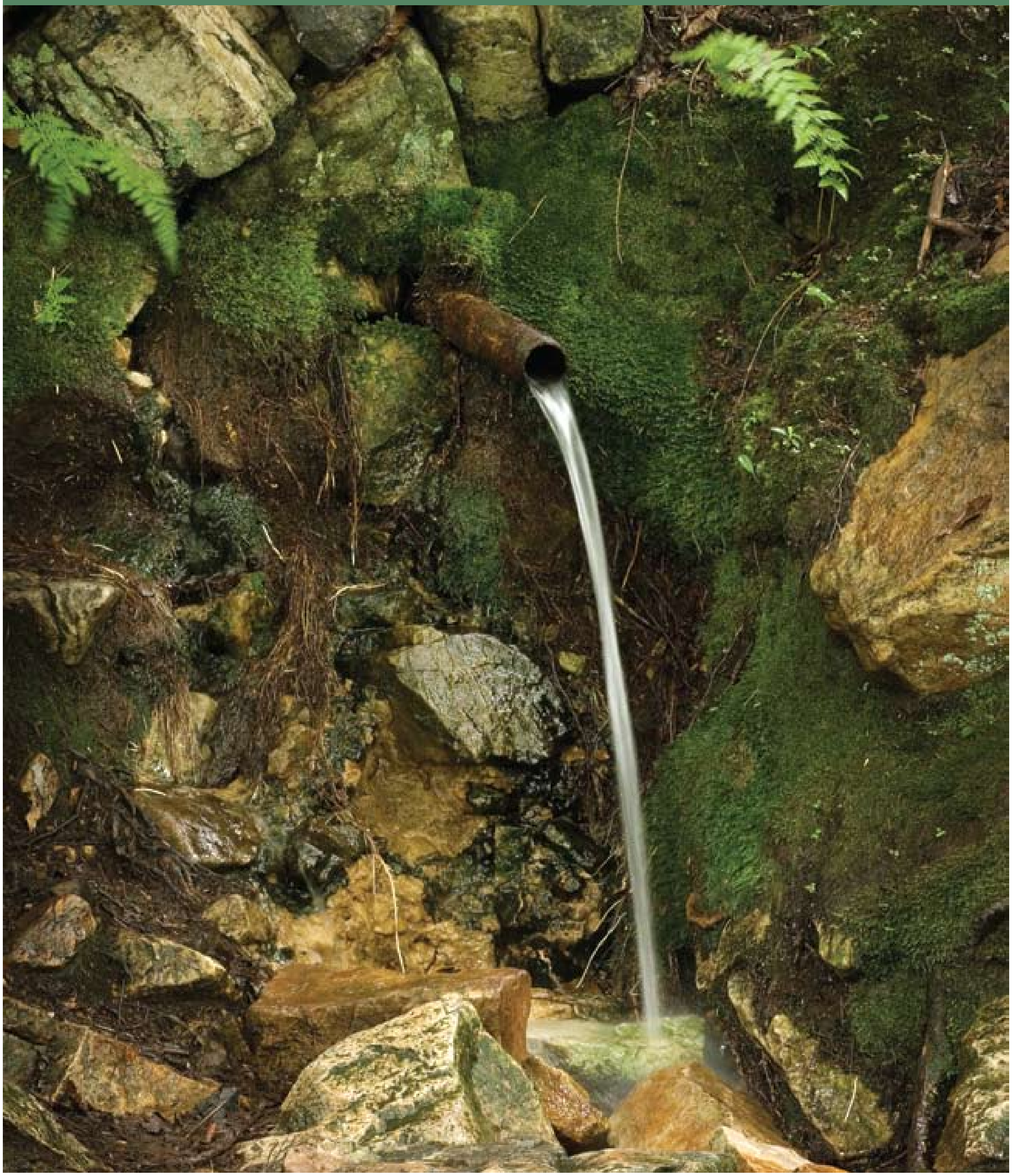
A Quick Guide to Groundwater in Pennsylvania



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Groundwater is an important source of water for households, businesses, industries, and farms across Pennsylvania. Unfortunately, human overuse and contamination is increasingly threatening groundwater. This publication will help you understand where groundwater comes from, how it is used, and how the future use of groundwater in Pennsylvania is at risk.

The Hydrologic Cycle

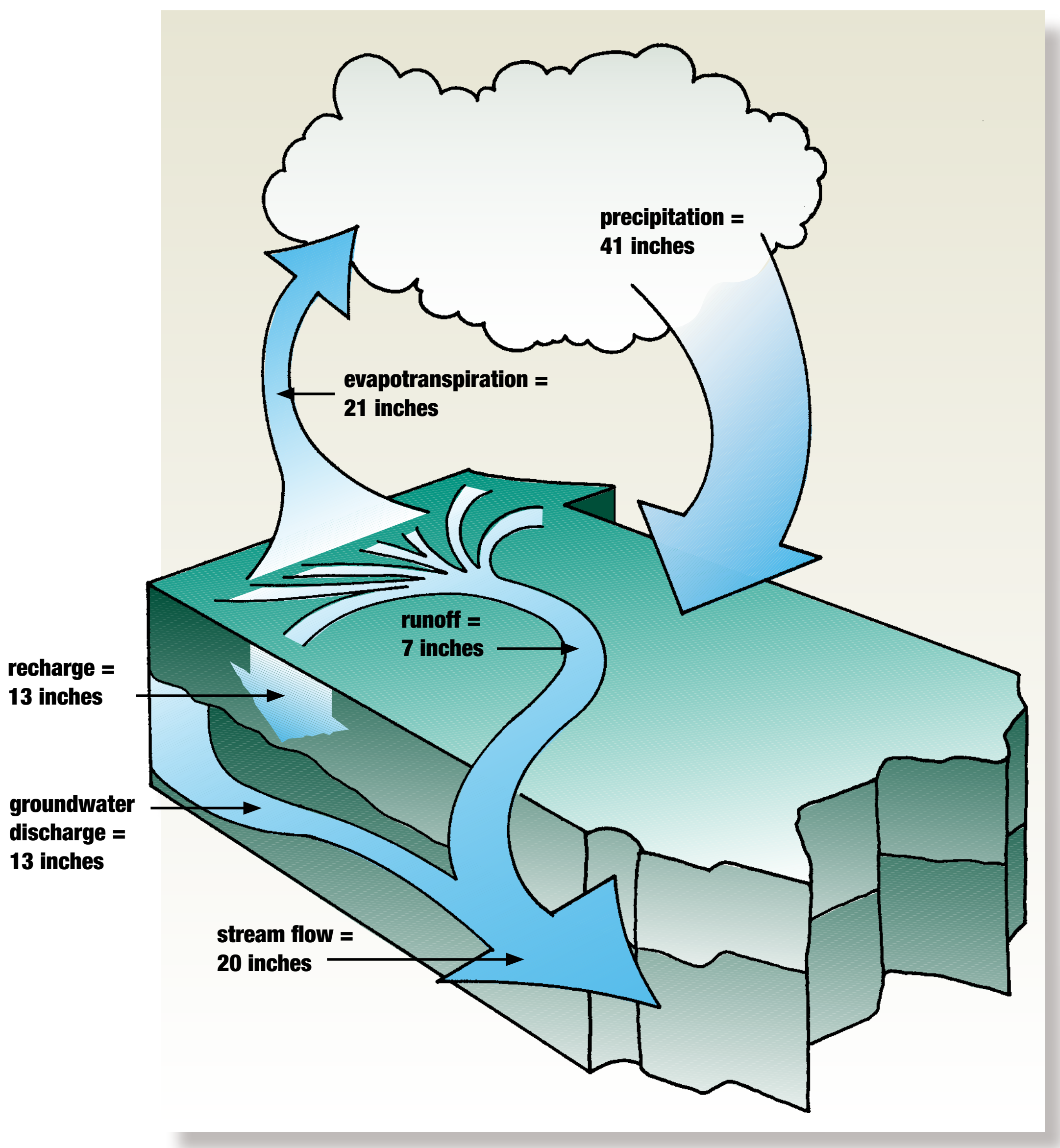
Any discussion of groundwater must start with an understanding of the hydrologic cycle, the movement of water in the environment. As the word "cycle" implies, there is no beginning or end to the hydrologic cycle; it is merely the continuous movement of water between places. Let's start with precipitation. Rain is the dominant form of precipitation across Pennsylvania, accounting for more than 75 percent of the total annual precipitation on average. Snow is the other major form of precipitation, which generally accounts for less than 10 percent of the annual precipitation in southern Pennsylvania and up to 25 percent of the annual precipitation in some northern counties. The amount of precipitation is surprisingly variable across the state, ranging from just 32 inches in Tioga County to more than 48 inches along the Allegheny Front and the Poconos. On average, the state receives approximately 40 inches of annual precipitation (rain and melted snow) as a whole.

Where does all this precipitation come from? All precipitation originates from water evaporated somewhere on the Earth's surface. Some of the rainfall in Pennsylvania comes from water that evaporated from tropical parts of the oceans. Near the equator, the sun provides enough energy throughout the year to evaporate huge quantities of water that fall as precipitation all over the world. However, precipitation during isolated thunderstorms or lake-effect snow squalls may originate from evaporation much closer to home.

The sun powers the hydrologic cycle, evaporating water from all over the Earth's surface, including water in oceans, lakes, fields, lawns, rooftops, and driveways (Figure 1). Plants also use the sun's energy to evaporate water by taking it from the soil, using it to grow, and releasing it into the atmosphere through their leaves in a process called transpiration. Evaporation and transpiration are commonly combined and referred to as evapotranspiration (ET). Nearly all the precipitation that falls during the growing season in Pennsylvania is returned to the atmosphere through ET. During the winter months, however, very little ET occurs because plants do not use much water and the sun is too low in the sky to cause much evaporation. Over the entire year, about 50 percent of the precipitation that falls across the Commonwealth returns to the atmosphere through ET.

What happens to precipitation that reaches the earth and is not evaporated or transpired by plants? About seven inches of Pennsylvania's annual precipitation enters streams directly as runoff, either as overland flow, which travels over the land surface, or as interflow, which moves toward streams through soil. The remainder of the precipitation, about 13 inches, is in the form of recharge—precipitation that infiltrates the soil surface, trickles downward by gravity, and becomes the groundwater that feeds the springs, streams, and wells of Pennsylvania. Most of this recharge occurs from rain and melting snow during early spring and late fall when the soil is not frozen and plants are not actively growing. Adequate precipitation and snowmelt during these short time periods is critical for supplying groundwater underneath the surface. All groundwater was once surface water, and it will be again because groundwater is an integral part of the hydrologic cycle. This is nature's way of recycling water.

Figure 1. The hydrologic cycle for an average year in Pennsylvania.



Groundwater Basics

Precipitation that does not quickly run off into streams, is not evaporated by the sun, or does not get taken up by plant roots slowly infiltrates through layers of soil and rock to become groundwater. This infiltrating water eventually reaches a saturated layer of sand, gravel, or rock called an aquifer. Aquifers may occur a few feet below the land surface, but they are more commonly found at depths greater than 100 feet in Pennsylvania. Some groundwater occurs in the pore spaces of solid rock, but most occurs in cracks and fractures in rock layers or between sand and gravel particles. Therefore, groundwater usually occurs between and within different rocks, sands, and gravels, not as underground lakes or rivers (Figure 2).

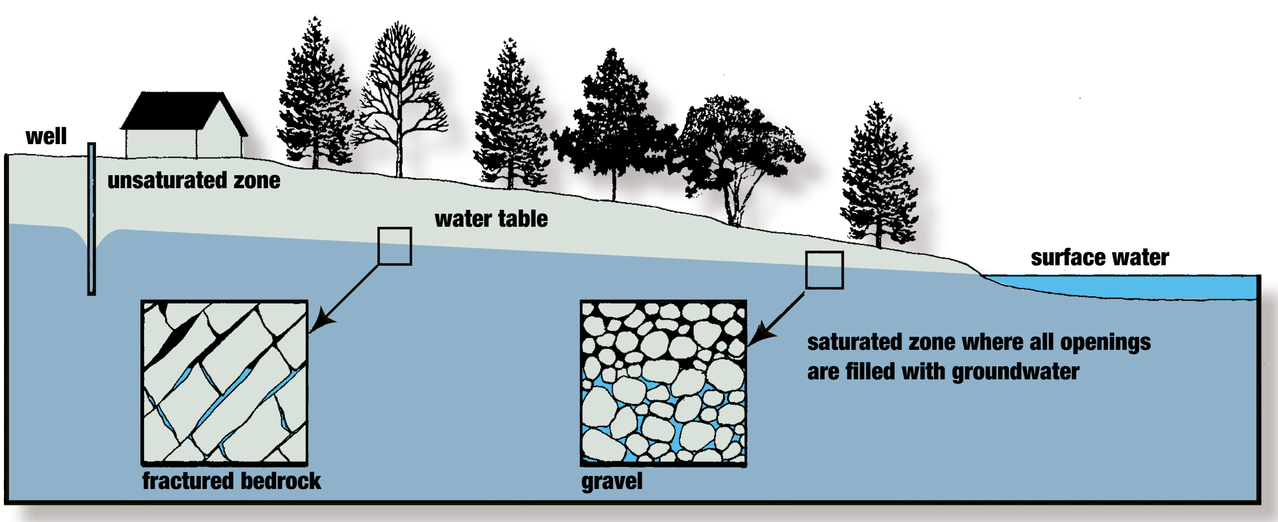
Geologic formations called aquitards may also lie within the saturated zone. These formations are usually made of clay or dense solid rock that stops infiltrating groundwater from moving vertically through it. Aquitards restrict groundwater movement to and between aquifers. Aquitards located above and below an aquifer form a confined aquifer. If this aquifer is tapped with a well, artesian pressure forces the trapped water to rise in the well to an elevation higher than the aquifer water level. If the pressure is great enough, the water may rise to the land surface, creating a flowing artesian well. An aquifer with no aquitard above it is an unconfined aquifer. In wells penetrating this type of aquifer, the water level of the well and the aquifer are the same. At any given location, several distinct aquifers may exist below the ground surface at different depths separated by aquitards.

The top of the uppermost unconfined aquifer is called the water table. During rainfall, the water table rises toward the ground surface as percolating rainfall is added to the groundwater aquifer. During dry periods, the water table will fall deeper underground as groundwater is discharged from the aquifer into springs, streams, and wells.

Directly above the water table lies the unsaturated zone, where the spaces between soil and rock particles contain both air and water—air in the larger openings, water in the smaller ones. Moisture conditions in the unsaturated zone vary greatly depending on the weather. Immediately after a heavy rain, even the large pores of the unsaturated zone may hold water. During a drought, most pores are filled with air, and the little remaining water exists in thin films around soil particles.

Groundwater does not simply remain stagnant under the ground. Rather, it moves underground from upland to lowland areas. The direction of groundwater flow underground can be determined by looking at how surface water

Figure 2. How groundwater occurs below the Earth's surface.



flows. Flowing groundwater eventually reaches a discharge point where the water table meets the land surface. Springs are a classic discharge point where groundwater bubbling to the surface can be seen. Low-lying wetlands are another example of a discharge point where groundwater is at the soil surface.

Streams and lakes are the most likely points of discharge for groundwater. Every stream has a watershed, which encompasses the land area that drains surface and groundwater into the stream. Very small streams may have a watershed of only a few acres, while major rivers have watersheds that encompass millions of acres. No matter where you stand, you are located within one small watershed that is part of many other larger watersheds. The largest rivers forming the major watersheds of Pennsylvania all flow toward one of the oceans (Figure 3).

The average Pennsylvania stream gets about two-thirds of its flow from groundwater. Except for a short time during and after rainstorms and snowmelt, streams carry water provided only by groundwater that seeps through stream banks and streambeds into the channel (this is called baseflow). The groundwater that forms a stream's baseflow during dry weather often takes a year or more to make the journey underground to the streambed. In larger rivers, it may take thousands of years for an individual water molecule to travel to the stream after it reaches the land surface as precipitation.

The situation is sometimes reversed—streams may lose some of their flow to groundwater. This happens when the water table lies below a stream and does not intersect it. In some cases, different sections of streams behave differently, with some portions gaining groundwater and other losing it. In general, as streams become larger as they near the ocean, they contain increasing amounts of groundwater.

Groundwater aquifers vary in size and composition, and the amount and quality of groundwater yielded is also different from aquifer to aquifer. There are four major types of groundwater aquifers in Pennsylvania (Figure 4).

Figure 3. The major surface watersheds of Pennsylvania.

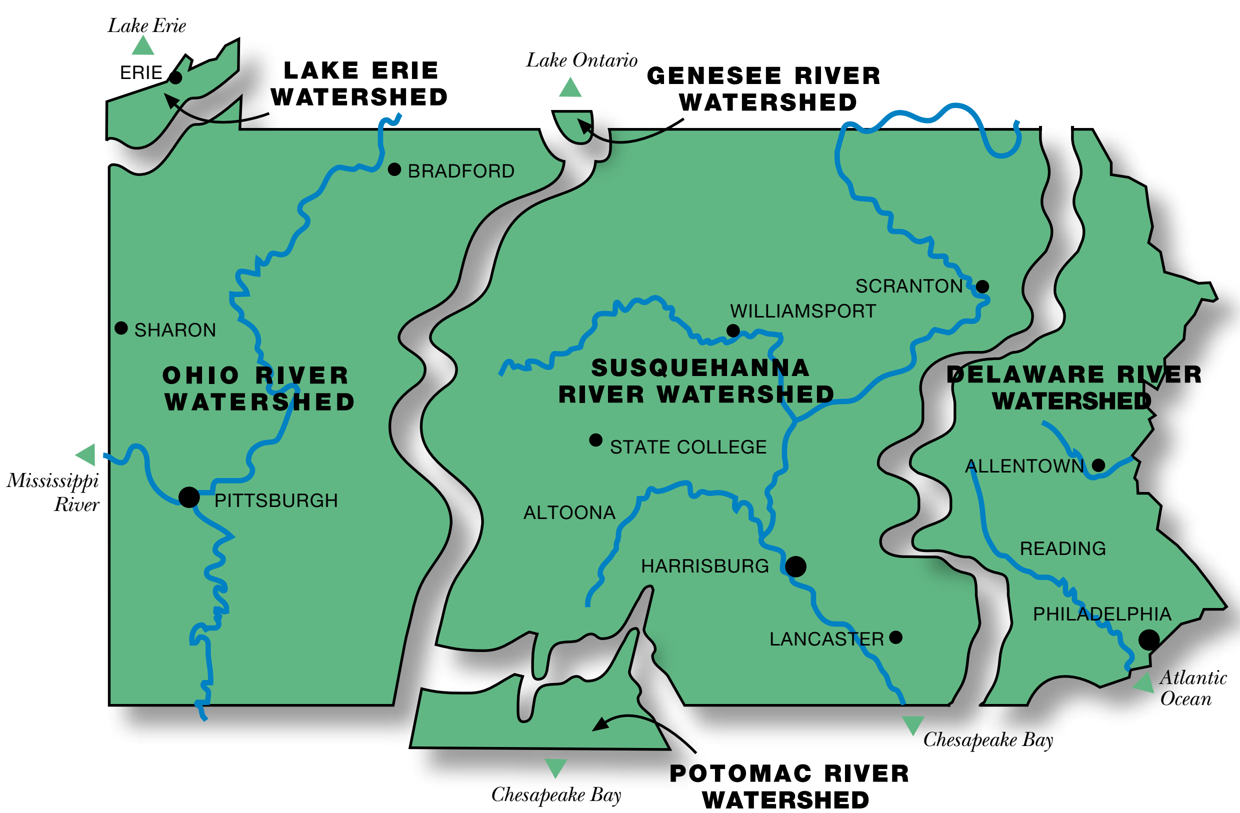
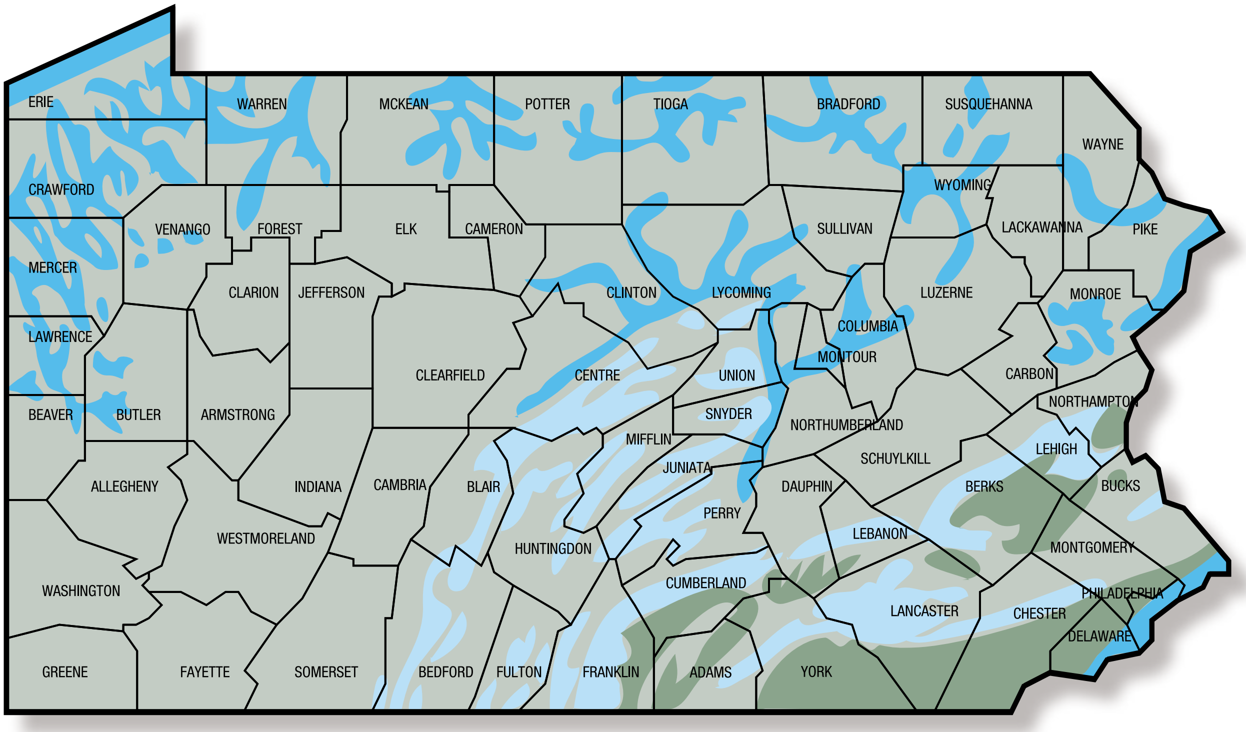


Figure 4. The four major types of groundwater aquifers in Pennsylvania.



Generalized map of aquifer and well characteristics in Pennsylvania

Aquifer type and description		Depth (ft) Common range	Depth (ft) May exceed	Yield (gal/min) Common range	Yield (gal/min) May exceed	Typical water quality
Unconsolidated sand and gravel aquifers: sand, gravel, clay, and silt		20–200	250	100–1,000	2,300	Soft water with less than 200 mg/l dissolved solids; some high iron concentrations
Sandstone and shale aquifers: fractured sandstone and shale		80–200	400	5–60	600	Sandstone layers have soft water with less than 200 mg/l dissolved solids; shale layers have hard water and 200–250 mg/l dissolved solids
Carbonate rock aquifers: fractured limestone and dolomite		100–250	500	5–500	3,000	Very hard water with more than 250 mg/l dissolved solids
Crystalline rock aquifers: fractured schist and gneiss		75–150	—	5–25	220	Soft water containing less than 200 mg/l dissolved solids; some moderately hard water with high iron concentrations

Note: ft = feet; mg/l = milligrams per liter; gal/min = gallons per minute

From *Pennsylvania Geological Survey*, 1999

An Important Resource

Groundwater in Pennsylvania is a vast resource and is estimated to be more than twice as abundant as the amount of water that flows annually in the state's streams. Pennsylvanians have tapped into this important resource. Each day more than one billion gallons of groundwater are pumped from aquifers throughout the state for various uses. More than half of this groundwater is used for domestic drinking-water supplies, which demand high-quality, uncontaminated water. Although smaller amounts of groundwater are used during agricultural and mining purposes, groundwater still accounts for the majority of all the water used for these activities (Figure 5).

Groundwater is especially vital to rural areas of the state. Second only to Michigan for the largest number of private water wells, Pennsylvania has more than one million private water wells supplying water to more than three million rural residents (Figure 6). An additional 20,000 new private wells are drilled each year around the state.

Although more groundwater wells are drilled each year, the total groundwater use across the state has remained relatively stable over the past few decades. Water conservation measures and education have played an important role in keeping groundwater use constant. From 1985 to 1995,

Figure 5. Groundwater use in Pennsylvania.

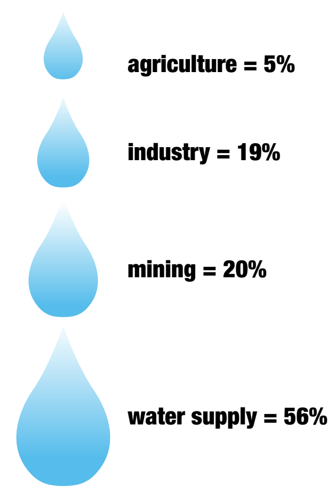
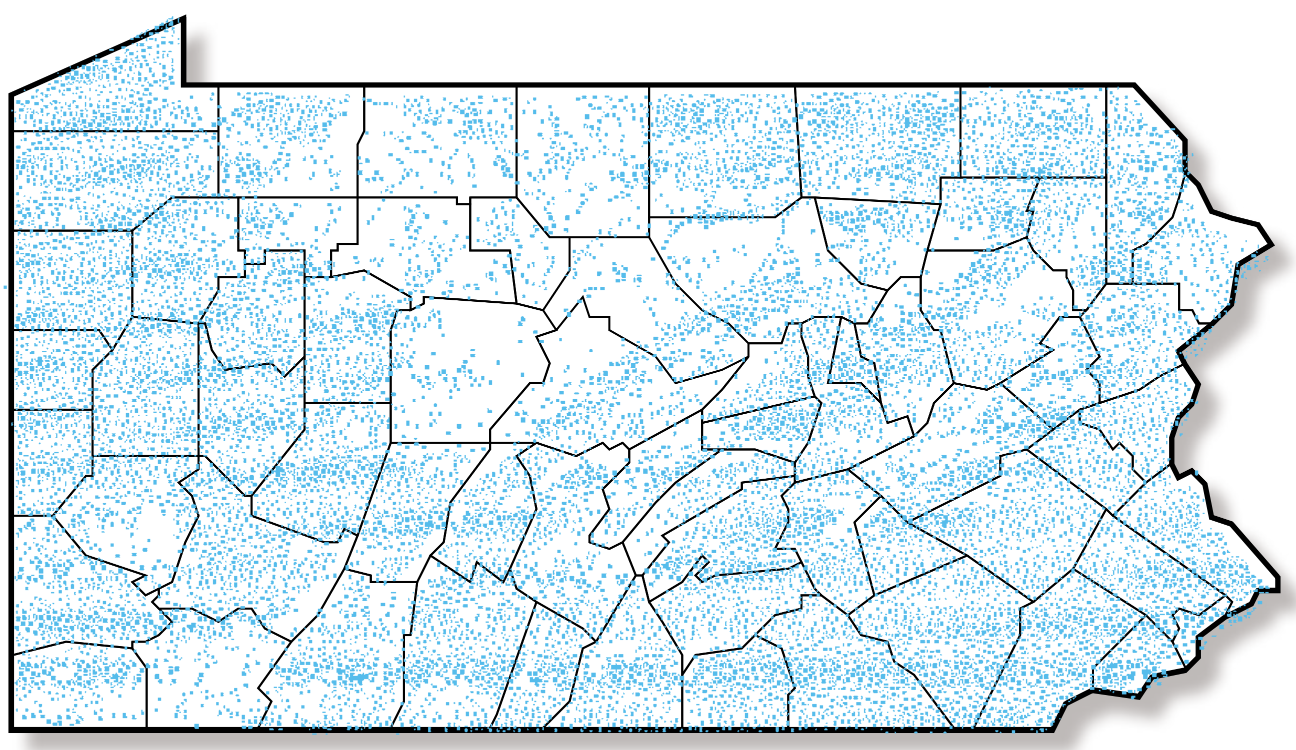


Figure 6. Private water wells reportedly drilled between 1963 and 1994 to serve individual homes in Pennsylvania. Each dot represents one drilled well. Data from the *Pennsylvania Groundwater Information System* compiled by the Pennsylvania Geological Survey.



the population of Pennsylvania increased by nearly 300,000, but water use fell from 66 to 62 gallons per person per day. Water conservation measures, such as low-flush toilets, front-loading washing machines, low-flow showerheads, and outdoor rain barrels, can reduce household water use by 30 percent. Reduced outdoor water use is especially important because it saves water that largely evaporates (consumptive water use) as opposed to water that is simply used and put back into the ground (nonconsumptive water use). In addition to water savings, water conservation can also reduce yearly home energy costs by several hundred dollars in every home. Thus, conserving water means conserving energy.

Groundwater Threats

People from many parts of Pennsylvania are concerned about the future availability of adequate groundwater supplies for meeting home and business needs. In some cases, these concerns are due to increasing local use of groundwater that exceeds the amount of recharge that supplies the aquifer. More often, groundwater supplies are threatened by increasing impervious cover of the land surface. Each year, more land area is being covered with roofs, sidewalks, driveways, parking lots, and other surfaces that do not allow rainwater to recharge the underlying groundwater aquifers. Every acre of land that is covered with an impervious surface generates 27,000 gallons of surface runoff instead of groundwater recharge during a one-inch rainstorm. Without recharge water feeding the aquifer, groundwater mining—water being removed from the aquifer more quickly than it can be recharged—may occur.

Groundwater mining has been documented in parts of southeastern Pennsylvania, where impervious cover has increased rapidly and groundwater withdrawals have also increased. Water resources planning efforts initiated in Pennsylvania in 2003 aim to document areas where groundwater resources are currently or will be overused. With this information, local government planning officials can more adequately guide future development based on existing water resources.

The quality of groundwater is also a concern in many areas of the state. Contrary to popular belief, natural groundwater is not always free of pollutants and impurities. Some pollutants occur naturally when water interacts with impurities in the rock layers encompassing an aquifer (Figure 7). For example, hard water deposits from calcium and magnesium are common in groundwater from limestone aquifers, while hydrogen sulfide (which causes the rotten-egg odor), iron, and manganese often occur in certain sandstone and shale aquifers. Some aesthetic problems can cause additional drinking-water problems as well. Corrosive water from acidic sandstone and shale can cause the lead and copper to dissolve from household plumbing, leading to toxic concentrations capable of causing serious health effects in humans.

Human activities can also pollute groundwater aquifers. This pollution may originate from point sources (e.g., a pipe discharging into an aquifer) or, more often, from nonpoint sources (e.g, diffused flow from lawns, septic systems, and farm fields). Many groundwater pollutants from human activities cause adverse health effects (Figure 8). Coliform bacteria and *E. coli* bacteria commonly found in human or animal wastes can cause flu-like illnesses if they are consumed in drinking water, while nitrates from fertilizers can cause blue-baby syndrome in infants. Also worth noting is that some of the naturally occurring pollutants discussed above, such as iron, manganese, and sulfate, can also come from mining or other human activities. If you are interested in learning more about groundwater pollution, consult one of the many Penn State Cooperative Extension fact sheets available from your local extension office or online at http://water.cas.psu.edu/.

What Can You Do to Protect Groundwater?

Some simple actions can help to ensure the future availability and health of Pennsylvania's groundwater resources:

- Do not apply fertilizers, herbicides, or other chemicals within 100 feet of wells or springs on your property. Reduce use of these chemicals on other areas of your property.
- Use up household chemicals according to the label or dispose of them at hazardous waste drop-off locations rather than in the household garbage.
- Get your well or spring tested annually by a state-certified water-testing laboratory to detect local problems before they can contaminate the entire aquifer.
- Install water-saving devices such as front-loading washing machines or low-flow showerheads in your home to reduce your indoor water use.
- Use less water outside to reduce evaporation and consumptive water use.
- Divert runoff from roofs, sidewalks, and driveways into rain gardens or yard areas where it can recharge groundwater rather than run off.
- Encourage local government officials to restrict impervious areas and encourage infiltration of storm water in new residential, commercial, and industrial developments.
- Properly construct and maintain your on-lot septic system to prevent groundwater contamination.

Figure 7. Frequency of pollutants causing aesthetic problems in private groundwater wells in Pennsylvania. Values give percent of private wells that fail drinking-water standards or recommended levels for each pollutant. (Data from various surveys conducted by Penn State.)

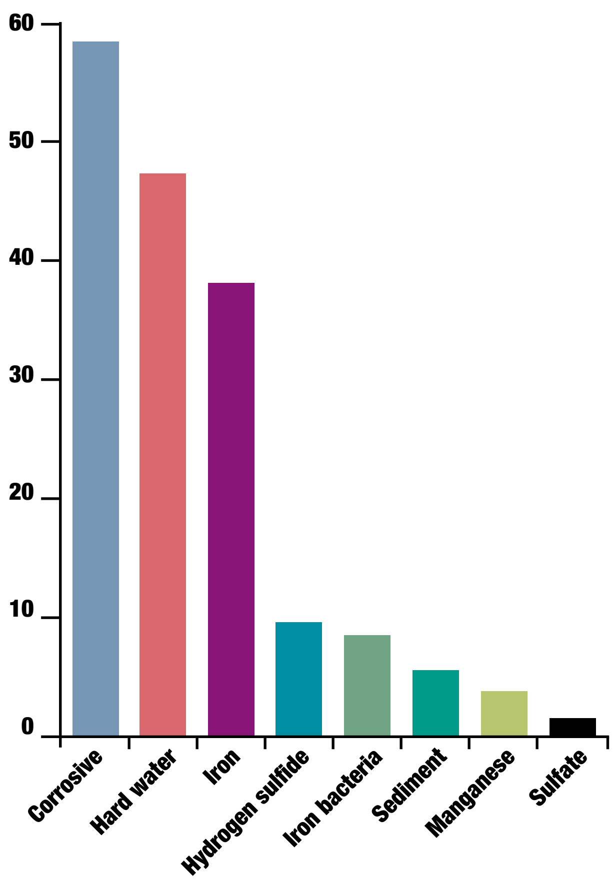
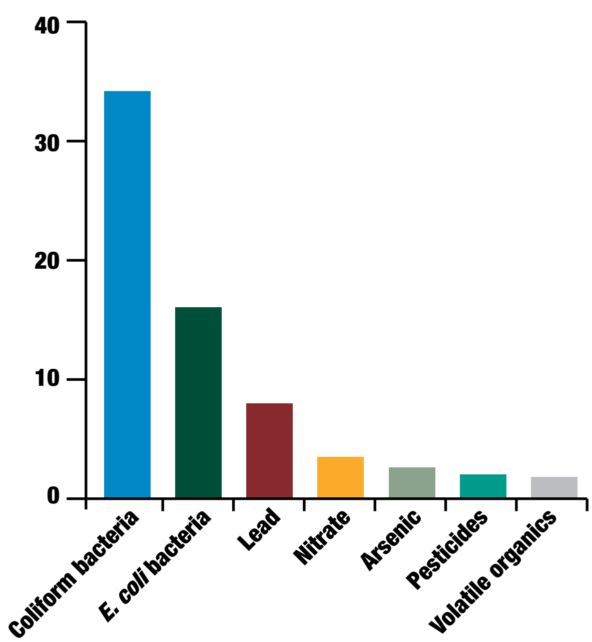


Figure 8. Frequency of various health-related pollutants in private groundwater wells throughout Pennsylvania. Values give the percent of private wells that fail drinking-water standards for each pollutant. (Data from various surveys conducted by Penn State.)



Further Information

For additional information on groundwater resources in Pennsylvania and steps to protect groundwater, see the following publications and Web sites.

PUBLICATIONS

Citizens' Guide to Groundwater Protection. Washington, D.C.: U.S. Environmental Protection Agency Office of Water, 1990.

The Geology of Pennsylvania's Groundwater by G.M. Fleeger. 3rd ed. Educational Series 3. Harrisburg: Pennsylvania Geological Survey, 1999.

Groundwater Protection and Management in Pennsylvania: An Introductory Guide for Citizens and Local Officials. 3rd ed. Washington, D.C.: League of Women Voters, 2001.

Pennsylvania Groundwater Quality. U.S. Geological Survey Water Supply Paper 2325, National Water Summary. Reston, Va.: U.S. Geological Survey, 1986.

Protecting Your Groundwater. Educating for Action. League of Women Voters Education Fund, Pub No. 180. Washington, D.C.: League of Women Voters, 1994.

WEB SITES

American Ground Water Trust:
http://www.agwt.org/index.htm

National Ground Water Association:
http://www.ngwa.org/

Pennsylvania Ground Water Association:
http://www.pgwa.org/

Pennsylvania Groundwater Online (DCNR):
http://www.dcnr.state.pa.us/topogeo/groundwater/

Pennsylvania Master Well Owner Network:
http://mwon.cas.psu.edu/

Penn State Water Resources Extension:
http://water.cas.psu.edu/

USGS Water Resources of Pennsylvania:
http://pa.water.usgs.gov/

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