Water Resource Management:
Local Control & Local Solutions

A Quick Guide to Groundwater

What is groundwater?

When rain falls to the ground, the water does not stop moving. Some of it flows along the surface to streams or lakes, some of it is used by plants, some evaporates and returns to the atmosphere, and some sinks into the ground. Imagine pouring a glass of water onto a pile of sand. Where does the water go? The water moves into the spaces between the particles of sand.

Groundwater is water that is found underground in the cracks and spaces in soil, sand and rock. Groundwater is stored in--and moves slowly through--layers of soil, sand and rocks called aquifers. Aquifers typically consist of gravel, sand, sandstone, or fractured rock, like limestone. These materials are permeable because they have large connected spaces that allow water to flow through. The speed at which groundwater flows depends on the size of the spaces in the soil or rock and how well the spaces are connected.

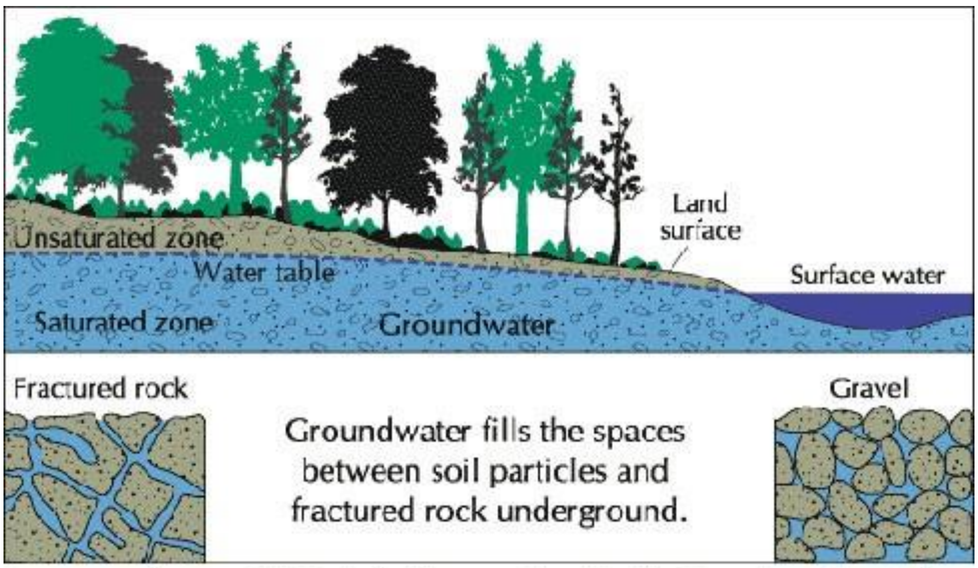


Image compliments of US Geological Survey, adapted by The Groundwater Foundation.

The area where water fills the aquifer is called the saturated zone (or saturation zone). The top of this zone is called the water table. The water table may be located only a foot below the ground's surface or it can sit hundreds of feet down.

Groundwater can be found almost everywhere. The water table may be deep or shallow; and may rise or fall depending on many factors. Heavy rains or melting snow may cause the water table to rise, or heavy pumping of groundwater supplies may cause the water table to fall.

Water in aquifers is brought to the surface naturally through a spring or can be discharged into lakes and streams. Groundwater can also be extracted through a well drilled into the aquifer. A well is a pipe in the ground that fills with groundwater. This water can be brought to the surface by a pump. Shallow wells may go dry if the water table falls below the bottom of the well. Some wells, called artesian wells, do not need a pump because of natural pressures that force the water up and out of the well.

Groundwater supplies are replenished, or recharged, by rain and snow melt. In some areas of the world,

people face serious water shortages because groundwater is used faster than it is naturally replenished. In other areas groundwater is polluted by human activities.
In areas where material above the aquifer is permeable, pollutants can readily sink into groundwater supplies. Groundwater can be polluted by landfills, septic tanks, leaky underground gas tanks, and from overuse of fertilizers and pesticides. If groundwater becomes polluted, it will no longer be safe to drink.

Groundwater is used for drinking water by more than 50 percent of the people in the United States, including almost everyone who lives in rural areas. The largest use for groundwater is to irrigate crops.

It is important for all of us to learn to protect our groundwater because of its importance as a source of water for drinking and irrigation. [1]

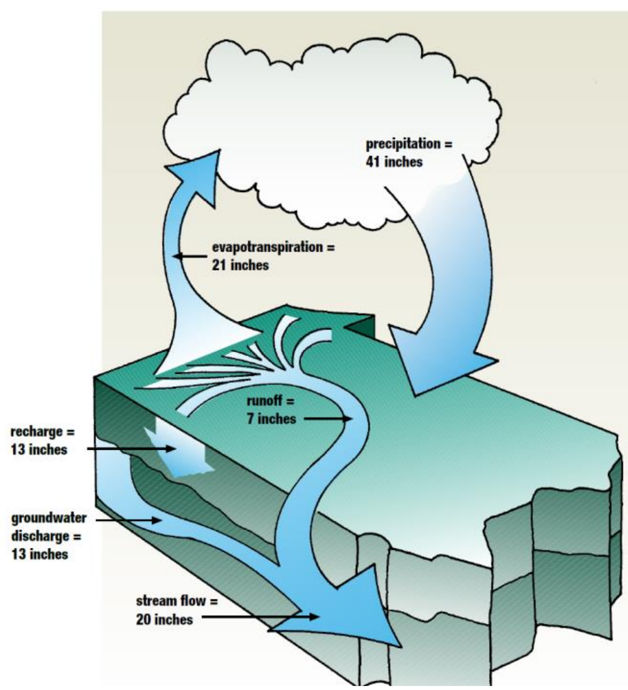
How much do we depend on groundwater?

According to 2005 United States Geological Survey (USGS) figures, groundwater provides an estimated:

- **22%** of all freshwater withdrawals
- **37%** of agricultural use (mostly for irrigation)
- **37%** of the public water supply withdrawals
- **51%** of all drinking water for the total population
- **99%** of drinking water for the rural population

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 Pocono’s. On average, the state receives approximately 40 inches of annual precipitation (rain and melted snow) as a whole.



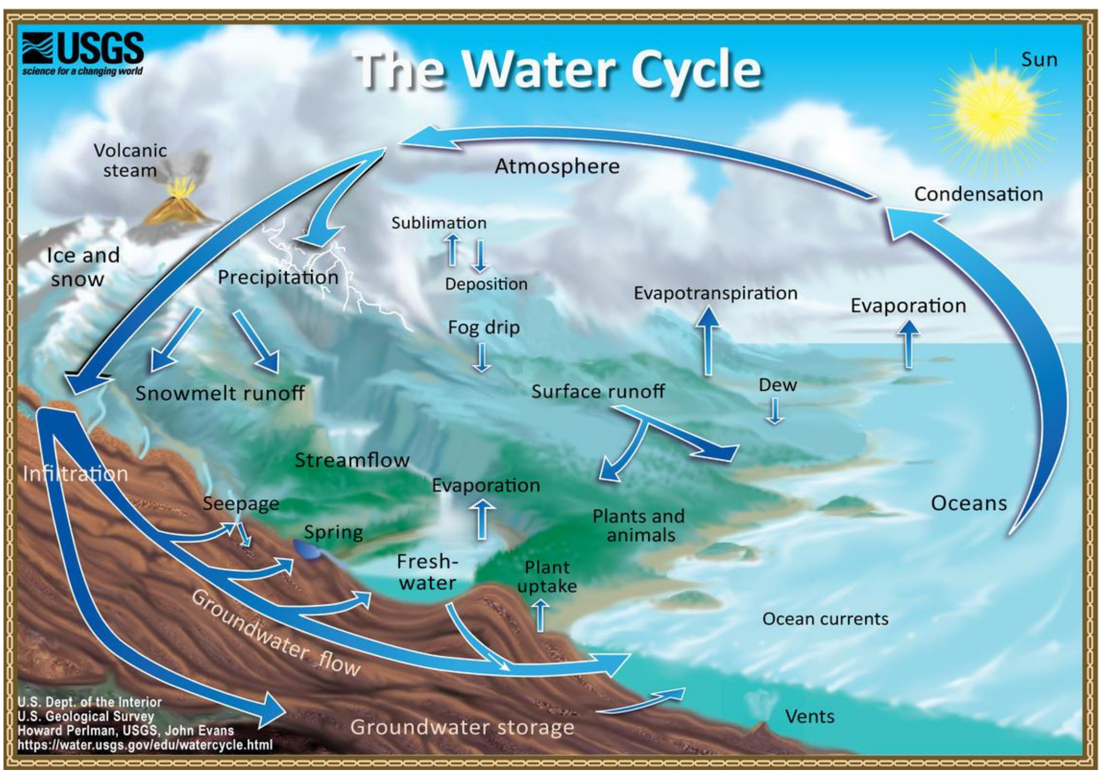
The hydrologic cycle for an average year in Pennsylvania

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. 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. [2]

Hydrologic Cycle



Evapotranspiration is the combined net effect of two processes: evaporation and transpiration. Evapotranspiration uses a larger portion of precipitation than the other processes associated with the hydrologic cycle.

Evaporation is the process of returning moisture to the atmosphere. Water on any surface, especially the surfaces of mudholes, ponds, streams, rivers, lakes, and oceans, is warmed by the sun's heat until it reaches the point at which water turns into the vapor, or gaseous, form. The water vapor then rises into the atmosphere.

Transpiration is the process by which plants return moisture to the air. Plants take up water through their roots and then lose some of the water through pores in their leaves. As hot air passes over the surface of the leaves, the moisture absorbs the heat and evaporates into the air.

Condensation is the cooling of water vapor until it becomes a liquid. As the dew point (the temperature to which a given parcel of air must be cooled, at constant barometric pressure, for water vapor to condense into water) is reached, water vapor forms tiny visible water droplets. When these droplets form in the sky and other atmospheric conditions are present, clouds will form. As the droplets collide, they merge and form larger droplets and eventually, precipitation occurs.

Precipitation is moisture that falls from the atmosphere as rain, snow, sleet, or hail. Precipitation varies in amount, intensity, and form by season and geographic location. These factors impact whether water will flow into streams or infiltrate into the ground. In most parts of the world, records are kept of snow and rainfall. This allows scientists to determine average rainfalls for a location as well as classify rainstorms based on duration, intensity and average return period. This information is crucial for crop management as well as the engineering design of water control structures and flood control.

Infiltration is the entry of water into the soil surface. Infiltration constitutes the sole source of water to sustain the growth of vegetation and it helps to sustain the groundwater supply to wells, springs and streams. The rate of infiltration is influenced by the physical characteristics of the soil, soil cover (i.e. plants), water content of the soil, soil temperature and rainfall intensity. The terms infiltration and percolation are often used interchangeably.

Percolation is the downward movement of water through soil and rock. Percolation occurs beneath the root zone. Groundwater percolates through the soil much as water fills a sponge, and moves from space to space along fractures in rock, through sand and gravel, or through channels in formations such as cavernous limestone. The terms infiltration and percolation are often used interchangeably.

Runoff is the movement of water, usually from precipitation, across the earth's surface towards stream channels, lakes, oceans, or depressions or low points in the earth's surface. The characteristics that affect the rate of runoff include rainfall duration and intensity as well as the ground's slope, soil type and ground cover

The hydrologic cycle consists of inflows, outflows, and storage. Inflows add water to the different parts of the hydrologic system, while outflows remove water. Storage is the retention of water by parts of the system. Because water movement is cyclical, an inflow for one part of the system is an outflow for another.

Looking at an aquifer as an example, percolation of water into the ground is an inflow to the aquifer. Discharge of groundwater from the aquifer to a stream is an outflow (also an inflow for the stream). Over time, if inflows to the aquifer are greater than its outflows, the amount of water stored in the aquifer will increase. Conversely, if the inflows to the aquifer are less than the outflows, the amount of water stored decreases. Inflows and outflows can occur naturally or result from human activity.

Human Impact on the Water Cycle

The earth's water supply remains constant, but man is capable of altering the cycle of that fixed supply. Population increases, rising living standards and industrial and economic growth have placed greater demands on our natural environment. Our activities can create an imbalance in the hydrologic equation and can affect the quantity and quality of natural water resources available to current and future generations.

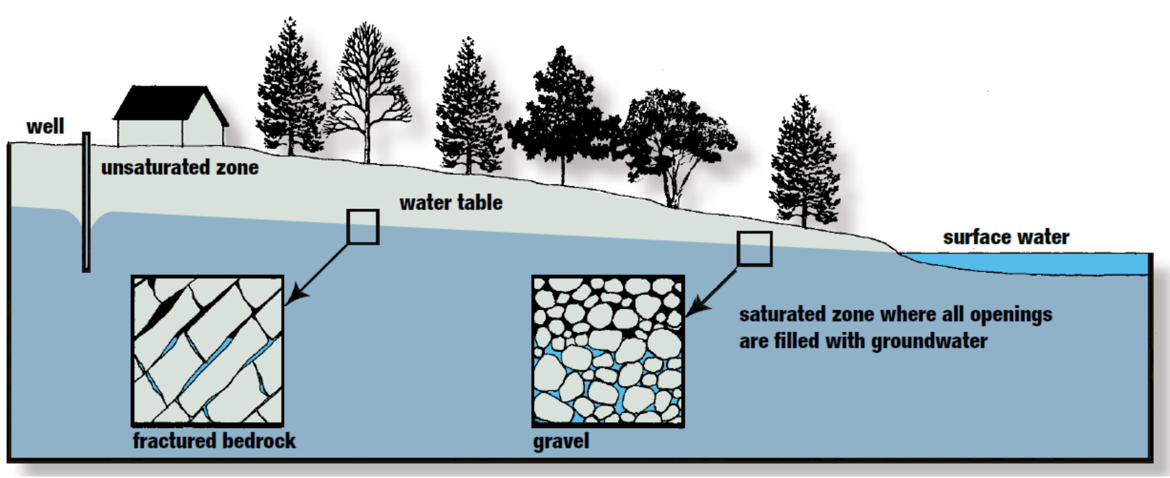
Water use by households, industries, and farms has increased due to population increase and demand. People demand clean water at reasonable costs, yet the amount of fresh water is limited and the easily accessible sources have been developed. As the population increases, so will our need to withdraw more water from rivers, lakes and aquifers, threatening local resources and future water supplies. A larger population will not only use more water but will discharge more wastewater. Domestic, agricultural, and industrial wastes, including the intensive use of pesticides, herbicides and fertilizers, often overload water supplies with hazardous chemicals and bacteria. Also, poor irrigation practices raise soil salinity and evaporation rates. These factors contribute to a reduction in the availability of potable water, putting even greater pressure on existing water resources.

Large cities and urban sprawl particularly affect local climate and hydrology. Urbanization is accompanied by accelerated drainage of water through road drains and city sewer systems, which even increases the magnitude of urban flood events. This alters the rates of infiltration, evaporation, and transpiration that would otherwise occur in a natural setting. The replenishing of groundwater aquifers does not occur or occurs at a slower rate.

Together, these various effects determine the amount of water in the system and can result in extremely negative consequences for river watersheds, lake levels, aquifers, and the environment as a whole. Therefore, it is vital to learn about and protect our water resources.[3]

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.



How groundwater occurs below the Earth's surface

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.

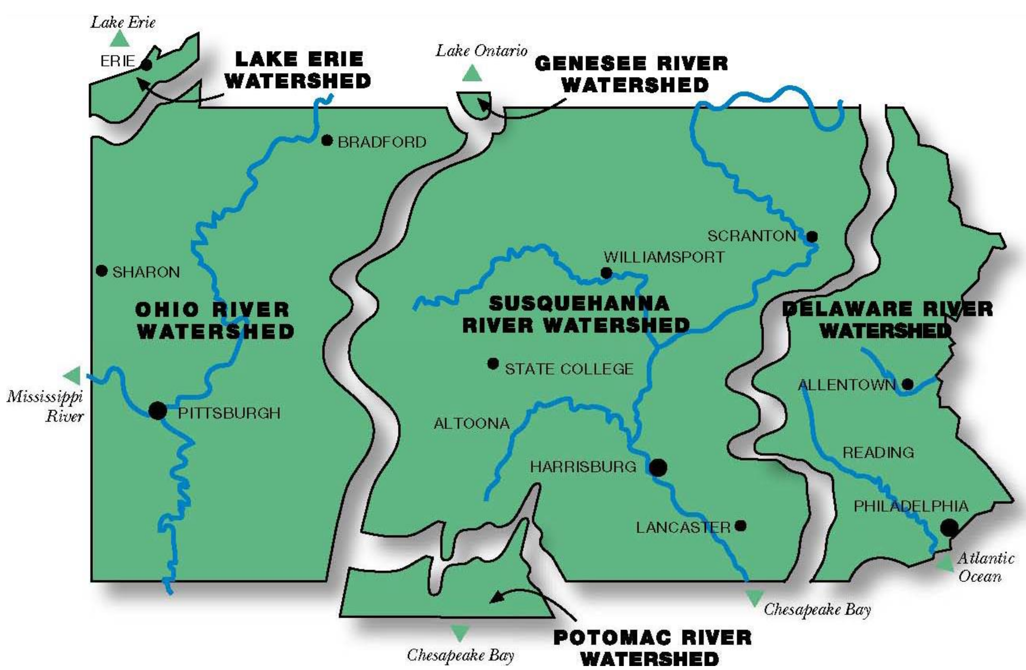
The top of the uppermost unconfined aquifer is called the water table. During rainfall, the water table rises toward the ground surface as percolating rainfall is added to the groundwater aquifer. During dry periods, the water table will fall deeper underground as groundwater is discharged from the aquifer 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. 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 the Atlantic Ocean.[2]

The major surface watersheds of Pennsylvania



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 others 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. Aquifers are classified into two general categories:

- **Confined aquifers**, consisting of limestone, sandstone, granite, or other rock, hold water in interconnected fractures, small cracks, pore spaces, spaces between rock layers, and/or solution channel openings.
- **Unconfined aquifers,** consisting of rock debris or weathered bedrock, i.e., soil particles, hold water in spaces between the particles.

Most aquifers in Pennsylvania are confined. The amount of water contained in an aquifer and its speed of movement depend on the type of soil or rock forming the aquifer. Clay, fine-grained sand, and silt hold a lot of water and release it very slowly; coarse-grained sand and gravel hold somewhat less water, but the water moves more freely. The amount of water held and yielded by confined aquifers depends on the size of the rock's openings and cracks. Limestone aquifers yield substantial amounts of water; sandstone aquifers, moderate amounts; and granite aquifers, small amounts.

The recharge area consists of the land surface from which water seeps into an aquifer. The amount of precipitation that seeps into the ground depends on several variables: the composition of the soil, the time of year, the soil's moisture content prior to a rain or snowfall event, and what covers the land surface. For example, the soil absorbs about 50 percent of the precipitation received in wooded areas, but an average of only 32 percent of precipitation seeps into the ground in developed areas. This lower percentage is caused by runoff into storm sewers or directly into streams and lakes from hard surfaces, such as roofs, parking lots, and roads.

Groundwater does not remain forever in aquifers. Groundwater, like surface water, is constantly on the move. It usually flows toward a low elevation area of discharge – spring, stream, river, lake, or wetland. Groundwater generally flows at a rate between five feet per day and five feet per year and in a direction that mimics the surface topography. It may flow in a different direction, however, if it encounters an obstructing geologic formation or if the zone of saturation lies deep within the earth. There are four major types of groundwater aquifers in Pennsylvania.

Pennsylvania's Aquifers

Pennsylvania's complex geological history has provided us with a diverse set of rock types and a varied physical geography which make generalizations about groundwater difficult. Nevertheless, hydrogeologists have identified four principal types of aquifers in the state: sand and gravel, sandstone and shale, carbonate rock, and crystalline rock.

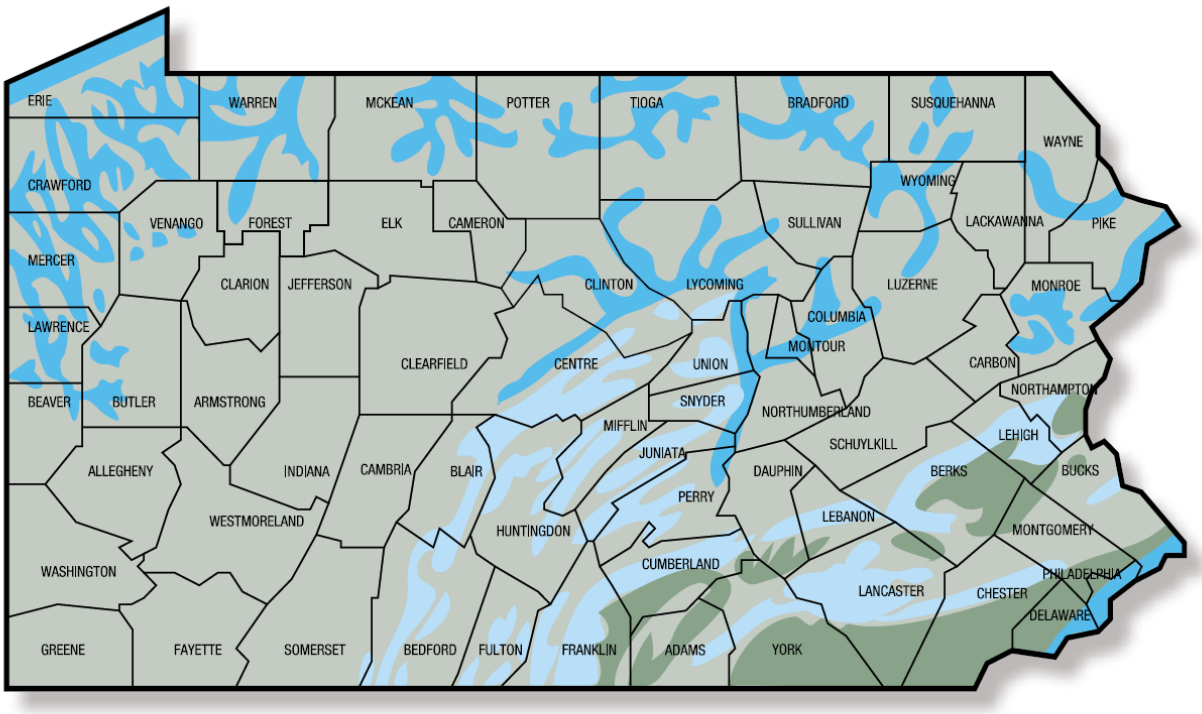
Sand and gravel aquifers are located in the southeastern coastal plain along the Delaware River, along the Lake Erie shoreline, and in most major stream valleys. Those in the Delaware estuary were deposited when the area was covered by oceans millions of years ago. Those in the rest of the state are glacial outwash and alluvial (stream) deposits from the time when part of the state was covered by glaciers. Sand and gravel aquifers contain large quantities of water which can be easily withdrawn; well yields of 1,000 gallons per minute (gal/min) are common. The natural quality of the water is good to excellent.

Sandstone and shale aquifers contain the sandstones, silts, stones, and shales that are the predominant component of Pennsylvania's bedrock. In the bedrock, these components are interlayered and there can be more than one water-bearing zone in a vertical thickness. Where sandstones are dominant the water is soft (water that is treated in which the only ion is sodium); where shales predominate the water is hard (water that contains an appreciable quantity of dissolved minerals like calcium and magnesium). Yields from these aquifers are lower than those from sand and gravel aquifers with shale yielding 5-20 gal/min and sandstone yielding 5-60 gal/min. However, drilling on a fracture intersection can increase these yields substantially.

Carbonate rock aquifers, consisting of limestone and dolomite, are located in the valleys in the central and southeastern parts of Pennsylvania. The caves, solution channels, and sinkholes of these regions are caused by water dissolving portions of the carbonate rock. As a result water can be very hard and contain relatively large amounts of dissolved solids. Yields of several thousand gallons per minute are possible.

Crystalline rock aquifers are located in most of southeastern Pennsylvania. The rock has very small fractures so storage capacity and yield are relatively low. Water is generally soft. Yields are commonly 5-25 gal/min.[5]

The 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

Generalized map of aquifer and well characteristics in Pennsylvania [2]

Water Quantity and Quality

Most people in the United States take for granted the fact that when they turn on the water tap, safe, clean, pleasant-tasting drinking water will emerge. But, did you ever stop to wonder where the water comes from or whether there will always be enough for everyone to enjoy?

Water is one of the Earth's natural resources. It is a finite resource, which means that the total amount of water is limited. Most of the world's water supply is saltwater stored in the oceans. Converting saltwater to freshwater is generally too expensive to be used for industrial, agricultural, or household purposes.

The type of water we generally use in human activities is fresh water. Only 3% of the world's water supply is fresh water and two-thirds of that is frozen, forming the polar ice caps, glaciers, and icebergs. The remaining 1% of the total world water supply is freshwater available as either surface water or groundwater; groundwater accounts for two-thirds of this amount. Surface water is water that is visible above the ground surface, such as creeks, rivers, ponds, and lakes. Groundwater is water that either fills the spaces between soil particles or penetrates the cracks and spaces within rocks.

Most people get their water from groundwater sources. Roughly 9 out of every 10 public water systems operate wells to tap groundwater and just over half of the total population served by public water systems drink water from a groundwater source. Millions more get their water from private wells, which also tap groundwater sources. Groundwater systems tend to serve smaller numbers of people, while surface water systems generally serve large populations. The quantity and quality of the world's water supply depends on how we choose to use water. Our use can be consumptive, which means that the water is not returned to nature, or nonconsumptive. Nonconsumptive use returns water, polluted or not, to the system.

Water Law in Pennsylvania

Public Trust Doctrine

The Constitution of the Commonwealth of Pennsylvania, Article I, Section 27 states, *"Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people."* The adoption of Article I, Section 27, the Environmental Rights Amendment to the PA Constitution, in 1971 represents the culmination of a major change in attitude about the use and exploitation of natural resources. At the time the Commonwealth was founded, natural resources were abundant and seemingly inexhaustible. After two hundred years of population growth and industrial development, it became evident that unrestricted use of natural resources, while creating wealth and prosperity for some, had created many problems and environmental damage that would adversely affect future generations.

The Environmental Amendment makes it clear that the Commonwealth is the trustee of Pennsylvania's public natural resources and must conserve them for the benefit of all the people. Water is a public natural resource that is required for the life and health of every person, a "vital resource." The "waters of the Commonwealth" are held in public trust by the Commonwealth. The right to "use" those waters is conferred by the state through a common law system of riparian rights. There are rules covering different classifications of waters and water use in Pennsylvania.

Surface Water vs. Groundwater Rights

Riparian Doctrine for the use of water in streams: *Each landowner adjacent to a stream can withdraw unlimited amounts of water for domestic use and reasonable extraordinary use on the property. Use of the water off the riparian property is considered "unreasonable per se."*

American Rule for withdrawal of groundwater: *A landowner can withdraw percolating groundwater for natural and ordinary uses on that land regardless of effect on neighbors.* There is no security of water rights under such a principle, i.e., "the deepest well and the most powerful pump wins."

Municipal Water Supplies: Riparian common law views transfer of water as *"unreasonable per se."* However, court decisions have said that municipalities should not be prohibited from withdrawing water from outside their boundaries, but replacement of supplies affected by that withdrawal may be required.

Riparian vs. Prior Appropriation Systems

Most states east of the Mississippi River have riparian systems of water rights based on English common law, interpreted and modified by court decisions. Historically, **under common law**, riparian doctrine said that unlimited reasonable use on the property was allowed, but that any use off the property was considered *unreasonable per se*. Over time the courts have modified their interpretation to allow for certain non-riparian uses such as public water supply. Riparian systems recognize that water resources are to be shared, but there is no guarantee of a certain share. In states west of the Mississippi (which were established later) water was more scarce and water rights associated with land holdings were appropriated to the first settlers. Under prior appropriation statutes there are no requirement to share the resource. ***"First in time means first in line."***

Water Use in Pennsylvania

There is no comprehensive water management system in Pennsylvania. Certain aspects of water use are regulated by the following agencies.

River Basin Commissions: The Susquehanna River Basin Commission (SRBC) and the Delaware River Basin Commission (DRBC) grant water allocation permits for withdrawals of surface or groundwater greater than 100,000 gallon**s** per day (GPD). In addition, the DRBC requires permits for withdrawals greater than 10,000 GPD in Groundwater Protection Areas. These two river basin commissions are unique in the United States for possessing this regulatory authority. They also have "consumptive use" rules that require reduction in consumptive use of water during droughts or payment of fees to provide storage in reservoirs for release during low flows.

The **Department of Environmental Protection** (DEP) Bureau of Water Supply Management grants allocation permits to public water systems that use surface water, which account for about 10% of all withdrawals.

DEP also grants permits for the wells or springs of bottled or bulk water producers.

The **PA Fish and Boat Commission** monitors the effects of proposed withdrawals on stream flows and aquatic habitats. The U.S. Fish & Wildlife Service also monitors stream flows and habitats.

Other agencies which influence water quantity include the **Environmental Protection Agency (DEP),** the **Natural Resources and Conservation Service (NRCS),** the **Federal Energy Regulatory Commission (FERC),** the **National Oceanic and Aerospace Administration (NOAA),** the **U.S. Forest Service**, and the **federal and state Offices of Mining.**

Agricultural & Industrial Water Usage

In the United States, 450 billion gallons of water are withdrawn per day from ground and surface waters for a variety of uses. Of that 450 billion gallons, only 100 billion gallons are actually consumed. The remaining 350 billion gallons are withdrawn for nonconsumptive industrial and agricultural uses.

Industry is the largest withdrawer of water but not the largest consumer. Much of the water withdrawn for industry is returned to its source after being used for cooling or other purposes.

Agriculture is the largest user of water due to irrigation. It takes over 1 million gallons of water a year to irrigate one acre of farmland in arid conditions. Most of the water used by irrigation re-enters the hydrologic cycle through evapotranspiration. Although it has only 28% of the U.S. population, the arid West accounts for 80% of the average water consumed daily due to extensive irrigation.

Household Water Usage

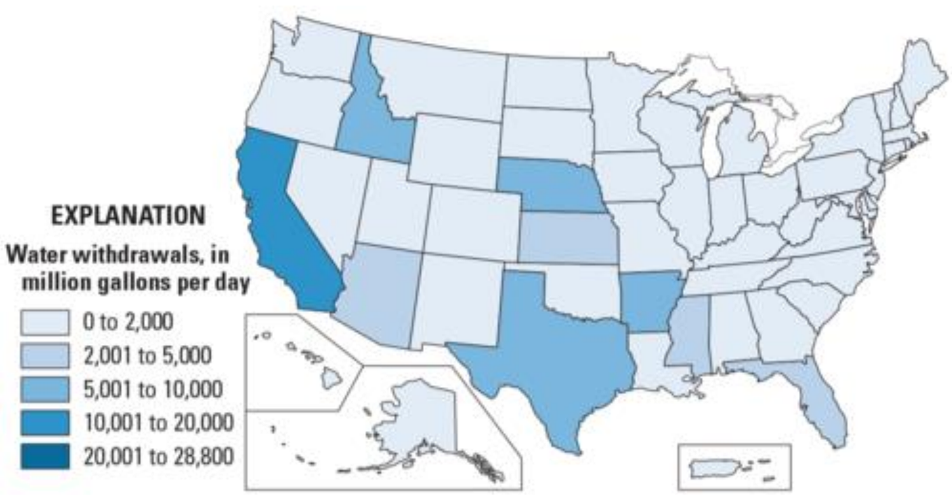
In the past 30 years, the U.S. population has grown 52% while the total water use has tripled. On average, Americans use approximately 80 to 100 gallons of water per person per day. Much of this water eventually returns to the water supply after having passed through a waste water treatment facility or domestic septic systems.

An important resource

Groundwater use in the United States

Of the total fresh groundwater withdrawals nationwide (82,300 Mgal/d), irrigation accounted for 70 percent, primarily in California, Arkansas, Nebraska, Idaho, and Texas. Fresh groundwater irrigation withdrawals in these five States cumulatively accounted for 46 percent of the total fresh groundwater withdrawals for all categories nationwide. Nearly all groundwater withdrawals (97 percent) were from fresh water, predominantly used for irrigation. Saline groundwater withdrawals were predominantly used for mining (80 percent) and occurred in Texas, California, and Oklahoma. Irrigation used greater than three times more fresh groundwater than public supply, which was the next largest use of fresh groundwater in the Nation.

Groundwater withdrawals by State, 2015



Groundwater use, by category of use, 2015

Groundwater is an important natural resource, especially in those parts of the country that don't have ample surface-water sources, such as the arid West. It often takes more work and costs more to access groundwater as opposed to surface water; but where there is little water on the land surface, groundwater an supply the water needs of people.

This diagram uses a "cylinder and pipe" layout to show the source (surface water or groundwater) of the Nation's freshwater and for what purposes the water was used in 2015. The data are broken out for each category of use by surface water and groundwater as the source.

Data are rounded and are reported in million gallons per day (Mgal/d).

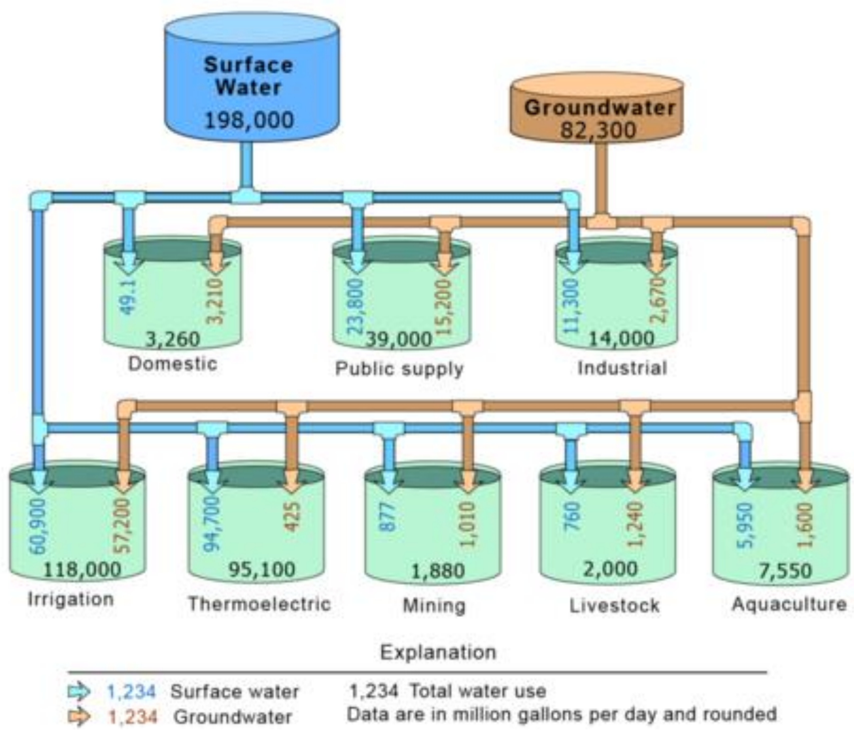
The top row of cylinders represents where America's freshwater came from (source) in 2015, either from surface water (blue) or from groundwater (brown). You can see most of the water we use came from surface-water sources, such as rivers and lakes. About 26 percent of water used came from groundwater. The pipes leading out of the surface-water and groundwater cylinders on the top row and flowing into the bottom rows of cylinders (green) show the categories of water use where the water was sent after being withdrawn from a river, lake, reservoir, or well.

For example, the blue pipe coming out of the surface-water cylinder and entering the public supply cylinder shows that 23,800 Mgal/d of water was withdrawn from surface-water sources for public-supply uses (you probably get your water this way). Likewise, the brown pipe shows that public-suppliers withdrew another 15,200 Mgal/d of water from groundwater sources.

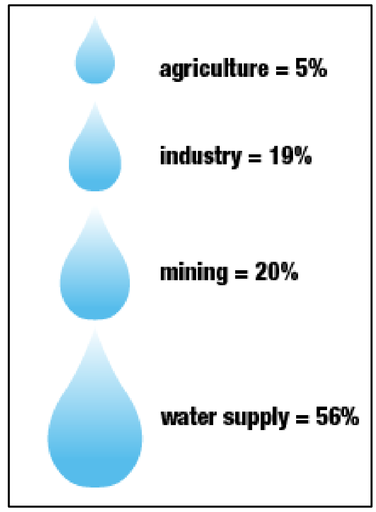
Each green cylinder represents a category of water use. The industrial cylinder, for instance, shows how much groundwater, surface water, and total water was used in the United States, each day, by industries.

You can see that although the Nation uses much more surface water than groundwater, groundwater has significant importance for some of the categories. Almost all self-supplied domestic water came from groundwater; over 40 percent of irrigation water was groundwater; and more groundwater than surface water was used for livestock purposes.[8]

Source and use of freshwater in the United States, 2015 [8]



Groundwater use in Pennsylvania



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.

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. 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, 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. [2]

Climate Change and Water

Water Resources

Many water supply sources (rivers, lakes, groundwater basins, etc.) are already over allocated, suffer degraded water quality, and are often not in sufficient condition to support endangered species. Climate change will exacerbate these water challenges, leading to insufficient water for people and the environment and making it increasingly difficult to meet the needs of both. Implementing actions now to improve water quality and supplies, protect aquatic ecosystems, and improve flood management not only makes sense, but early action will also help reduce future impacts related to climate change. Even if greenhouse gas emissions are reduced today, there is already warming “in the pipeline” that will create additional impacts. Adaptation is not a solution to climate change, but given the importance of our water resources, immediate action is needed to avert significant societal impacts. [6]

Water Quality

Higher water temperatures and changes in the timing, intensity, and duration of precipitation can affect water quality. Higher temperatures reduce dissolved oxygen levels, which can have an effect on aquatic life. Where streamflow and lake levels fall, there will be less dilution of pollutants; however, increased frequency and intensity of rainfall will produce more pollution and sedimentation due to runoff.

Flood magnitudes and frequencies will very likely increase in most regions — mainly a result of increased precipitation intensity and variability — and increasing temperatures are expected to intensify the climate's hydrologic cycle and melt snowpacks more rapidly. Flooding can affect water quality, as large volumes of water can transport contaminants into water bodies and also overload storm and wastewater systems.

Higher temperatures, particularly in the summer, earlier snowmelt, and potential decreases in summer precipitation could increase risk of drought. The frequency and intensity of floods and droughts could increase, even in the same areas.

Sea level rise may also affect freshwater quality by increasing the salinity of coastal rivers and bays and causing saltwater intrusion, movement of saline water into fresh groundwater resources in coastal regions.

Changes in water quality could have implications for all types of uses. For example, higher temperatures and changes in water supply and quality could affect recreational use of lakes and rivers or productivity of freshwater fisheries. Certain species of fish could find temperatures too warm and migrate to more northern or higher altitude locations where water is cooler.

Climate Adaptation and Erosion & Sedimentation

EPA works with local, state and tribal governments to reduce runoff and improve water quality by minimizing the introduction of sediment into rivers, lakes and streams.

Climate changes, such as more frequent and intense rain events, can increase erosion and result in greater amounts of sediment washing into rivers, lakes and streams.

More frequent and intense rain events, can increase sediment loading from stormwater runoff. Stronger storms, higher river levels, and faster stream velocity can increase erosion and result in increased suspended sediment (turbidity) in water bodies as well as affect normal distribution of sediment along river, lake and stream beds. These climate impacts can challenge efforts to maintain water quality through effective erosion and sediment control management efforts.

Excessive levels of suspended stream sediment (turbidity) or a change in sediment distribution resulting from more frequent and intense storms can negatively ecosystem health. The impacts from changing levels of erosion and sedimentation threaten fish, invertebrates and aquatic vegetation, in particular.

Increased sediment and erosion in rivers, lakes and streams can also affect water quality and availability of drinking water sources. For example, increased sedimentation can affect the storage capacity of reservoirs and increase the need for treatment at water utilities.[6]

Mining and Water Use

Like all other industries, mining corporations need water to make bare rock give up its valuable minerals. Mining water use is water for the extraction of minerals that may be in the form of such solids as coal, iron, sand, and gravel; such liquids as crude petroleum; and such gases as natural gas. The category includes quarrying, milling (crushing, screening, washing, and flotation of mined materials), re-injecting extracted water for secondary oil recovery, and other operations associated with mining activities.

Mining withdrawals for the Nation, 2000

For 2000, withdrawals were an estimated 137,000 million gallons per day (Mgal/d), or 153,000 thousand acre-feet per year. Irrigation withdrawals were 40 percent of total freshwater withdrawals and 65 percent of total freshwater withdrawals for all categories excluding thermo-electric power. Surface water accounted for 58 percent of the total irrigation withdrawals. About 61,900 thousand acres were irrigated in 2000. Of this total acreage, about 29,400 thousand acres were irrigated with surface (flood) systems; 28,300 thousand acres with sprinkler systems; and 4,180 thousand acres with micro-irrigation systems. Application rates were calculated by dividing total withdrawals by irrigated acres. The average application rate was 2.48 acre-feet per acre for the United States.[9]

Mining withdrawals, by State, 2000

For 2000, an estimated 3,490 Mgal/d, or 3,920 thousand acre-feet per year, were used. Mining withdrawals were nearly 1 percent of total withdrawals and less than 2 percent of total withdrawals for all categories excluding thermoelectric power. Groundwater was the source for 58 percent of total withdrawals for mining. Most of the groundwater withdrawals for mining (62 percent) were saline, and most of the surface-water withdrawals (85 percent) were fresh water. Saline groundwater withdrawals and fresh surface-water withdrawals each represented 36 percentof the total withdrawals for mining. [9]

Note: For 2000, the estimate of mining water use for the United States was based on estimates of total withdrawals for mining in 22 States, rather than on estimates from all States.

Mining and water quality

Acid mine drainage, sometimes referred to as AMD, results when the mineral pyrite (FeS2) is exposed to air and water, resulting in the formation of sulfuric acid and iron hydroxide.

AMD may come from strip mines, coming out of old coal refuse or bony piles, but the biggest and "worst" pollution comes from old, abandoned deep mines. AMD is the most common form of water pollution in Pennsylvania and in other states where vast amounts of mining took place in the past.

Water that has come in contact with pyrite in coal or near coal seams usually has a characteristic orange-red or yellow-orange color -- hence the popular name "yellow boy" for the deposits in streams. The orange material is iron oxide, which is basically rust. Many people refer to these streams as "sulfur streams".

But if the discharge is white, it is especially high in aluminum or black if a discharge is especially high in manganese. And sometimes, the worst mine discharges are clear because they are so highly acidic that the minerals remain dissolved and do not precipitate out right away.

Even in moderate concentrations, AMD is toxic to fish and aquatic insects that fish eat. AMD has four characteristics, although not all discharges have all of these characteristics:

- High acidity, hence it is sometimes called "acid mine drainage"
- High metal concentrations -- iron is most common
- High sulfate levels
- Excessive suspended solids, which result in siltation that smothers insects

Pyrite is commonly present in coal seams and in the rock layers overlying coal seams. AMD formation occurs during surface mining when the overlying rocks are broken and removed to get at the coal. It can also occur in deep mines which allow the entry of oxygen to pyrite bearing coal seams.

The products of AMD formation, acidity and iron, can devastate water resources by lowering the pH and coating stream bottoms with iron hydroxide, forming the familiar orange colored *"yellow boy"* common in areas with abandoned mine drainage.

Many areas also contain naturally occurring limestone (CaCO3) deposits which neutralizes acidity. To determine whether or not a mine will create acidic drainage, coal companies must analyze how much pyrite and neutralizers are in the rocks which will be disturbed by mining. Then DEP can determine whether or not a site can be mined without harming the environment.

By law, DEP cannot issue a permit for new coal mining where it is determined mining will cause acid mine drainage.

As acidity increases, fewer and fewer living things can tolerate the harsh conditions. And the corrosive acid also attacks culverts and bridge abutments, resulting in a shorter than normal life span for exposed infrastructure.

Small amounts of AMD can harm the life in streams because the metals, sulfates and/or other suspended solids drop out of the water and coat the rocks and gravel on the stream bottom. When this happens, the insects that live on and under the rocks literally are smothered because they cannot get oxygen out of the water. And if the aquatic insects die, the fish have little or no food.

Most of the pollution, by far, comes from old mining that took place before the 1977 law, the Surface Mining Control and Reclamation Act or SMCRA. Occasionally, current mine operators have a problem that results in a fish kill or an orange stream, but SMCRA holds them accountable -- they pay fines and must quickly remedy such situations today.

When water comes into contact with pyrite in coal and the rock surrounding it (the overburden), chemical reactions take place which cause the water to gain acidity and to pick up in solution iron, aluminum, manganese and other minerals. Precipitation of these minerals gives the water its tell-tale color.

In deep mines, the metals are dissolved in the water and stay in solution beneath the earth due to the lack of oxygen. When water emerges from the mine through a shaft, bore hole or natural cracks in the earth, it reacts with the oxygen once it hits the air. When that happens, chemical reactions take place that bring the minerals out of solution and they precipitate in the stream, leaving deposits of iron, manganese and aluminum on rocks and the stream bed.

The effect of AMD on local streams varies with the size of the stream and the total pollution load put on the stream. The pollution load is the product of the concentration of contaminants and the stream's flow.

Recent research has shown that mine drainage also has many other metals in lower concentrations, including some relatively high priced metals such as strontium and magnesium. Resource Recovery efforts are under way to recover and sell iron and aluminum from mine drainage because of their higher concentrations, but the idea of recovering other metals has been suggested.[11]

Natural Gas Impacts

Water Issues

Water usage has been a concern in other states where deep well drilling and hydrofracing have generated both a demand for large quantities of water and resulting waste fluids that require removal and treatment. The millions of gallons of water required for drilling and the associated waste products are also major concerns here in Pennsylvania. Like in other states, the source of water used in drilling raises an issue, as do the waste fluids, their treatment and disposal, and natural bodies of water in the vicinities of drilling activity and the communities tied to them.

The Susquehanna River Basin Commission regulates significant water use within its jurisdiction, and recently ruled that companies can purchase water from other permitted users with excess capacity without prior approval of the SRBC, provided the total amounts used do not exceed the permitted quantity. The result has been widespread interest among natural gas companies in purchasing water from municipal water systems and other already permitted users. If approached by such a company, municipal water systems need to carefully consider how much surplus capacity they can sell without jeopardizing other users or other future water dependent economic development opportunities.

One of the primary water concerns with deep gas well drilling technologies is the withdrawal of large volumes (millions of gallons) of water, used mostly in the hydro-fracturing process. The volume of waste fluids produced during gas well drilling and operation can vary considerably depending on the depth and location of the gas well. One study in Pennsylvania found that the average volumes of water produced during shallow gas well drilling in western Pennsylvania was 25,000 gallons during drilling, 50,000 gallons during stimulation, and 150 gallons per day during production. Newer technologies that rely more on hydro-fracturing the deeper gas wells may use more than one million gallons.

These large water withdrawals may come from many sources (streams, ponds, lakes, etc.) and can have significant effects if not performed carefully. Water withdrawals generally exceeding 10,000 gallons per day require permits, or registration with DEP under authority of the Water Resources Planning Act. Withdrawals occurring in the Susquehanna or Delaware River watersheds also require permits from the Susquehanna River Basin Commission or the Delaware River Basin Commission. In addition, the Clean Streams Law limits the amount of water that can be withdrawn from streams to maintain sufficient stream flows to protect aquatic life. These various regulations have all caused the shutting down of gas well drilling operations that failed to acquire the proper permits or exceeded allowable withdrawals from streams.

Erosion & Stormwater

In relation to water concerns, gas well construction involves extensive earth disturbance including roads, drilling pads and pipelines that can speed erosion. Drilling pads alone may be four to six acres in size for deeper gas wells, a larger portion of disturbed earth than shallow well pads. Various regulations, especially through DEP, are in place to protect surface water and groundwater from erosion and sedimentation due to these disturbances. Erosion and sediment plans require gas companies to use preventative measures such as filter fence, sediment traps, vegetation, hay bales, culverts with energy dissipaters and rocked road entrances to minimize erosion. These plans also include a requirement to restore vegetation to the drill site within nine months of well completion by planting grass, trees or crop plots. The DEP's Bureau of Oil and Gas and each individual county's conservation district oversee the enforcement of erosion and sediment regulations related to gas well operations.

Groundwater

Many residents throughout Pennsylvania voice concerns about private water well and spring contamination that can occur from gas well drilling, but the reality of these fears has shown to be less prominent than assumed. Data collected thus far from various regulatory agencies responsible for enforcement of gas well drilling regulations indicate that more than 95 percent of complaints received from homeowners suspecting problems from nearby gas well drilling are instead due to pre-existing problems or other land-use activities, such as agriculture. However, when contamination does occur as a result of drilling, the impacts can vary greatly, and while the instances are low, it is important to be aware of the range of possible complications.

When pollution of private water supplies from gas well activity transpires it is often documented as primarily stemming from absent or corroded well casings on older or abandoned gas wells. That does not mean that there are not pollution risks in newer deep well drilling. While the top-hole water from the initial stages of drilling is usually representative of groundwater used for local water wells and springs, the remaining water encountered during gas well drilling (bottom hole, stimulation and production fluids) may be contaminated with various water pollutants. Groundwater pollution can result from flooded or leaking brine holding pits that contain bottom-hole stimulation and production fluids from direct discharge of brines to the land surface.

In the event of these types of mishaps and negligence, pollution can still occur despite the variety of regulations through DEP and the SRBC and DRBC. Some water quality parameters that may occur at high levels in gas well wastes and can impact drinking water quality (either aesthetic or health effects) are barium, chlorides, sodium, iron, lead, manganese, and arsenic. When contamination does occur it should be noted that gas well brines are highly mineralized and contain levels of some pollutants that are far above levels considered safe for drinking water supplies. As a result, even small amounts of brine pollution can result in significant impacts to drinking water supplies. In addition to the pollutants previously listed, other water quality parameters that may be increased due to negligent drilling operations, such as methane migration into water wells, can be found in related publications available through the local Penn State Cooperative Extension office.[10]

Land Use Planning and Its Effects on Groundwater

Groundwater and Land Use

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. 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.

The main sources of groundwater contamination in order of national prominence are:

- **Industrial wastes**
- **Municipal landfills**
- **Agricultural Chemicals**
- **Septic system/cesspools**
- **Leaks from pipelines and underground tanks**
- **Animal wastes**
- **Acid mine drainage**
- **Oil field brines**
- **Saltwater intrusion**
- **Irrigation return flow**

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. 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.[2]

Land Use Planning

Land use decisions can have significant and unanticipated impacts on groundwater and surface water resources. It is critical when developing a land use plan that groundwater resources be addressed as well as the implications of the plan on those resources. Many Pennsylvania communities rely on groundwater; therefore, it is important to protect the community's water supply.

An understanding of a watershed and aquifer recharge area is the foundation upon which an effective source protection plan is built. In order to plan and implement protection strategies, there is a need to assess current conditions and how changes in land use, contamination, protection, and restoration efforts impact groundwater resources over time.

There are several steps to obtain this information.

- Identify water supply resources. Gather existing information about the location of water supply resources in the community, including watersheds and groundwater recharge areas that drain to intake or wells.
- Evaluate current and future land uses. Determine land use and the purpose for which it is being managed (agriculture, commercial, industrial, residential, etc.). Evaluate how potential development and other land use changes will impact source lands over time.
- Determine land ownership patterns and key landowners whose property is significant to the health of the watershed.
- Assess threats and monitor water quality. Monitor water quality throughout your source area in order to understand the link between current land use and water quality. Establish a baseline for your watershed for monitoring changes to water quality in the future.[12]

Federal and State Monitoring Requirements

- **Clean Water Act (CWA)**. The federal CWA establishes minimum monitoring requirements, although states can require more stringent monitoring of state-issued permits. Currently, 47 of the 50 states administer their own permit programs. States are required to produce an assessment of ambient water conditions (CWA305b). There are also guidelines for "monitoring and reporting, enforcement, funding, personnel, and manpower," (CWA 304i), and requirements for the development of water quality standards and the establishment of "designated uses," including the use of the water source as a drinking water supply (CWA 301, 510).
- **National Pollutant Discharge Elimination System (NPDES)**. As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating point sources (including municipal wastewater treatment plants and industrial discharges). Phase I of the NPDES storm water program requires NPDES permit coverage for large or medium municipalities. Phase II extends coverage to certain regulated small municipal separate storm sewer systems and small construction activities. Phase II Stormwater Management Permits will likely require monitoring, but this will vary from state to state. Additional federal monitoring requirements may be established through NPDES permits to track point sources of pollution. There is some room for negotiating monitoring requirements of watershed-based permits – this can be done when developing NPDES permits for multiple point sources located within defined boundaries. For instance, some ambient monitoring may be required as a condition of the permit.
- **303(d) list**. Section 303(d) of the Clean Water Act requires that states identify waters that do not meet or are not expected to meet applicable water quality standards. These water bodies are compiled into a list known as the 303(d), meaning that it is impaired. The Clean Water Act requires communities to monitor and track the contaminants of concern.

Comprehensive Source Protection Plan

As communities develop a schedule to implement a comprehensive plan, communities need to have information on groundwater and surface water resources and protection to make sound planning decisions.[4]

Planning Element	Relationship to Groundwater
Issues and Opportunities	Important issues may include: • What amount of water is needed for future homes, farms, and businesses? • Is the needed water available; how will it be provided; and at what cost? • How will growth affect the future quality and quantity of available groundwater? • Is there a need for community wellhead protection planning?
Housing	• Additional houses increase the demand for clean water and other services. • Paved areas may reduce the amount of groundwater recharge. • More homes may mean more fertilizer and pesticide use. • The potential for household chemicals or used oil to be dumped on the ground or into septic systems increases. • Decisions must be made on whether new houses will have public sewers or private on-site wastewater disposal systems.
Transportation	New roads needed to serve growing areas may mean: • More runoff of water off impervious surfaces that might have recharged groundwater. • More salt to keep the new streets safe in winter, which may seep into groundwater. • More chemicals leaking from automobiles and entering storm sewers or seeping into the ground.
Utilities and Community Facilities	• Communities must assess future water needs and the ability of existing systems to meet future needs, including the infrastructure and any environmental limitations to the siting of new wells or reservoirs.
Agricultural, natural, and cultural resources	• Groundwater provides the majority of the water in many Pennsylvania lakes, streams, and wetlands. • Pumping municipal, industrial, agricultural, or other high-capacity wells may reduce flow to surface water bodies. • Agricultural land use may increase potential for groundwater contamination from fertilizers and pesticides. • Groundwater information is important in assessing the ability of the resource to sustain growth over the long term.
Economic Development	• Water demand may increase from new residences and businesses. • Water costs may increase due to pumping from deeper aquifers or adding new wells to the system to meet demand. • New high capacity wells could affect groundwater quantity and sensitive surface water resources. • New businesses may have facilities, operations, or land use practices that could cause accidental spills or other groundwater contamination.
Intergovernmental Cooperation	• Because groundwater impacts go beyond political boundaries, a coordinated effort is important to avoid potential problems. Working together can maximize the use and protection of the available water resources.
Land Use	• Many land uses (agricultural, urban, residential, commercial, industrial) have the potential to impact groundwater. • Impermeable areas such as buildings, roads, houses, and parking lots prevent precipitation from infiltrating into the subsurface, increasing runoff and potential flooding. • Water and sewer service plans, subdivision plans, and wellhead or source water protection plans are all forms of land use planning that can mitigate groundwater impacts.

Clean drinking water is only assured by building multiple barriers that balance remediation and treatment with prevention, weighing such factors as costs, effectiveness, types of contaminants and threats, and local resources. Yet the cost of cleaning up contamination often exceeds the cost of prevention, making the creation of a comprehensive source protection plan fundamental. Such a plan should focus on preventing contamination from nonpoint source pollution by managing and protecting land that supplies drinking water.

Carefully consider the following outline when creating a plan to protect source water.

- **Prevention**: Identifying and protecting highly sensitive lands that are vulnerable to development allows municipalities and water supplies to be proactive about protection and avoid costly mitigation or restoration action. Source protection includes land conservation, land use controls, regulations, and best management practices.
- **Remediation**: In most drinking water watersheds, contaminants and/or threats to water quality from septic systems, agricultural operations, lawn maintenance, underground storage tanks, and other point and nonpoint sources of pollution exist. Source protection plans should identify the greatest contaminants and outline a plan to clean up existing pollution, using such tools as agricultural and residential best management practices, and riparian restoration.
- **Preparation**: Preparation means knowing and being ready to deal with potential pollution.[12]

Regulatory Tools

Land use controls such as zoning and subdivision requirements are the most powerful regulatory tools for protecting source lands, giving local governments the legal authority to control activities that threaten drinking water supplies. Such techniques offer an important vehicle to address nonpoint source pollution on privately owned land, which makes up a majority of most water source areas.

Zoning Controls

Zoning is a land use control that can be helpful in protecting a municipality's groundwater resources. Zoning controls the location and intensity of land uses so that, for example, activities that have the potential to contaminate groundwater resources can be prevented from locating close to sensitive areas. The authority to zone, which comes from the Pennsylvania's Municipalities Planning Code, is based on a local government's "police power" to create ordinances to protect and promote public health, safety, and the general welfare. The Planning Code specifically includes among the purposes of zoning the provision of safe, reliable, and adequate water supplies, and the preservation of forests, wetlands, aquifers, floodplains, prime agricultural land, and environmentally sensitive areas. Special zoning options that may be appropriate for use in high priority water supply areas include:

1. Cluster (or Open Space) zoning and Incentive zoning: <u>cluster zoning</u> provides for higher concentration of development on a smaller portion of land; only a portion of the parcel is developed while the remaining open space is permanently protected through conservation easement. <u>Incentive zoning</u> allows developers to expand the number of lots in exchange for dedicating additional open space. Incentives are offered to developers for clustering new houses in the least environmentally sensitive areas while permanently preserving as open space the more vulnerable areas (e.g., riparian zones, wetlands, and buffers).

2. Watershed/aquifer overlay zoning techniques identify and limit by ordinance or regulation certain harmful activities in environmentally sensitive watershed or aquifer areas (e.g., prohibiting land uses not compatible with source protection or limiting the density of residential housing in the overlay district).

3. Open space dedications require developers to dedicate a certain amount of land as permanently protected open space when building a new development, or they can be required to pay a cash fee which can be used to purchase land elsewhere in the town for open space purposes.

4. Agricultural zoning districts may be established where land uses that are incompatible with agriculture are prohibited. Usually these districts are established in areas of a community with productive soils and active farms. Even though a municipality may have agricultural zoning districts, some caution is advised. This type of zoning prevents or reduces development and associated threats to groundwater resources, but some agricultural activities can themselves cause contamination. Therefore, agricultural districts can help in groundwater protection efforts only if farmers are well educated about and use safe methods of pesticide, fertilizer, and animal manure application.

5. Planned residential development (PRD) offers another way to preserve open space. A PRD project is usually used for large-scale development that includes different types of housing, businesses, offices, open space, and recreational facilities. The plan concentrates the building activity on the most suitable sites, thereby accommodating natural features and contributing to groundwater protection.

6. Wellhead and aquifer protection districts are specially created zones around wells or above drinking water aquifers that have more stringent protection standards than other districts in a municipality. Certain land uses may be prohibited entirely, and others may be allowed only as conditional uses or as special exceptions under strict performance standards.

7. Performance zoning dates from the early 1970s and is intended to improve land use management for the protection of natural resources. Performance zoning, in its purest form, would allow all land uses in all zoning districts, provided they conform to established standards. However, municipalities generally use a hybrid version that combines conventional and full-scale performance zoning. An example of performance zoning in some municipalities includes no development is permitted in floodplains and wetlands – 100 percent of these areas must remain as open space.[14]

Subdivision Controls

In Pennsylvania, Article V of the Municipalities Planning Code grants authority to municipalities to regulate the subdivision of land and the improvement of parcels for use as residential, commercial, or industrial building sites. The regulations are intended to ensure that building sites will have adequate water supply, wastewater disposal, and accessibility for emergency vehicles. Communities without a zoning ordinance are authorized to use their subdivision and land development ordinance to set minimum lot area and setback. These communities are thus able to control, to some degree, development that might impact groundwater resources. Subdivision regulations establish general site design standards, which can greatly reduce harmful impacts on sensitive land and receiving waters. Examples of protective subdivision controls include:

1. Ensuring that septic systems and storm water infiltration structures do not contaminate groundwater.
2. Implementing erosion and sedimentation controls in areas undergoing development; and
3. Requiring certain site design measures, such as aquatic buffers, on-site storm water management, and preservation of certain trees. Towns can also adopt separate road and drainage standards as part of their subdivision regulations and make other site proposal changes to limit the impact of development on water supplies.[12]

Sediment and Erosion Control Measures

Sediment and erosion control measures address runoff from agricultural operations and construction sites. Proposed development plans may contain provisions to control accelerated erosion and sedimentation and reduce the danger from storm water runoff at a proposed site.

Storm Water Management Measures

Storm water discharges are generated by rain or snowmelt run off from land and impervious areas such as paved streets, parking lots, and building rooftops, and often contain pollutants that impact water quality. Most urban storm water discharges are considered point sources and require permitting through the U.S. Environmental Protection Agency's National Pollutant Discharge Elimination System (NPDES).

Non-Storm Water Management Measures

Communities can also address polluted runoff from non-storm water sources, such as septic systems, sanitary sewers, car washing, residential pesticide use, and road maintenance.[12]

Whatever mix of water source protection strategies you incorporate into a plan, keep in mind that the ultimate goal is the implementation of on-the-ground action steps that meet the following objectives:

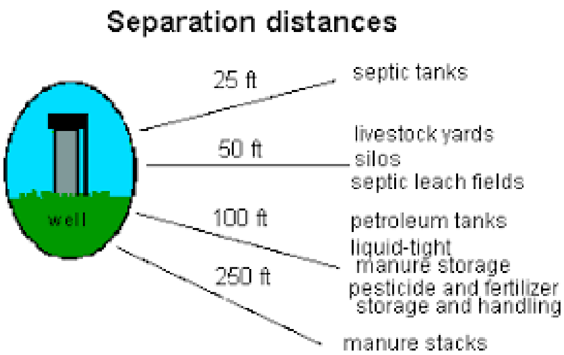
- Protecting or restoring natural lands and hydrologic processes in order to maintain a healthy watershed and buffer water resources from pollution
- Successful containment, mitigation, or elimination of existing sources of contamination
- Transforming the behavior of residents, landowners, businesses, and governments to minimize the impact of their activities on water quality

Groundwater Contamination

The vulnerability potential of an aquifer to groundwater contamination is in large part a function of the susceptibility of its recharge area to infiltration. Areas that are replenished at a high rate are generally more vulnerable to pollution than those replenished at a slower rate. Unconfined aquifers that do not have a cover of dense material are susceptible to contamination. Bedrock areas with large fractures are also susceptible by providing pathways for the contaminants. Confined, deep aquifers tend to be better protected with a dense layer of clay material. Wells that connect two aquifers increase the chance of cross contamination between the aquifers.

In addition to serving as a source of drinking water, a well can act as a direct pathway from the land surface into the water supply. Thus a major consideration in groundwater contamination is the position and condition of the well. Most of the contaminants that commonly cause concern originate above ground, often as the result of human activities.

Soil overlying the water table provides the primary protection against groundwater pollution. Bacteria, sediment, and other insoluble forms of contamination become trapped within the soil pores. Some chemicals are absorbed or react chemically with various soil constituents, thereby preventing or slowing the migration of these pollutants into the groundwater. In addition, plants and soil microorganisms use some potential pollutants, such as nitrogen, as nutrients for growth, thereby depleting the amount that reaches the groundwater.



Just as any man-made filtering device can be overloaded, so can the natural filtering capacity of soil. Large amounts of potential pollutants concentrated in a small area can cause localized groundwater contamination, depending on the depth and type of soil above the water table.

To help protect water wells against contamination, it is important to use the natural protection that soil provides by maintaining adequate separation distances between wells and potential sources of contamination.

After an aquifer has been contaminated it is difficult to entirely define or isolate a contaminant plume. It is also difficult and extremely costly to remove it. Even after the source of contamination has been removed, an aquifer may remain contaminated for anywhere from a few years to a few centuries. Thus, it is often unrealistic to talk about a "cure" for groundwater contamination. Prevention is the key, and prevention includes finding the major sources of contamination, and learning to control them.[3]

Contaminants and Drinking Water Standards

Pure water contains nothing but the essential chemical elements of water (i.e. two parts hydrogen and one part oxygen). Drinking water usually carries a certain amount of minerals which it acquires from its source, treatment, storage, distribution, and household plumbing conditions. These minerals and elements generally occur at very low levels and do not pose a significant risk to health.

A wide variety of chemicals and compounds can become groundwater contaminants if discharged to the subsurface environment. They range from inorganic compounds, to organic compounds, to synthetic compounds, such as pesticides, and other contaminants. Because drinking water systems get their water from a groundwater (and surface water) source, once the source becomes contaminated, the drinking water can also become contaminated. Shallower drinking water wells, which are most likely to be owned and operated by private and small public water systems, are usually more susceptible to contamination than deep wells, which are usually operated by large public water utilities.

In 1974, the United States Congress recognized the importance of protecting our nation's public water supplies by adopting the Safe Drinking Water Act (SDWA). The SDWA authorized USEPA to develop regulations, to set nationwide uniform drinking water quality standards for all States, and to implement programs to ensure the safety of public water supplies and protect public health. Congress re-emphasized its support for safe drinking water by adopting updated versions of the SDWA in 1986 and 1996.

USEPA has defined drinking water standards according to the latest available human health risk studies, and to provide water systems with a basis for determining drinking water safety. While the standards should be applied to all water systems, the SDWA requires that only public water systems be regulated to ensure that these standards are maintained. A public water system is a water system which serves 25 or more people or 15 or more service connections for at least 60 days out of the year. Systems which do not meet this definition are classified as private water systems and are not subject to federal regulation.

Drinking water standards for contaminants that could affect health are called Primary Drinking Water Standards and are enforceable by law for public water systems. Primary standards are usually established through Maximum Contaminant Levels (MCLs) but may also be established through a mandatory treatment technique requirement.

Secondary Drinking Water Standards, also known as **Secondary Maximum Contaminant Levels (SMCL)**, are concentration limits for nuisance contaminants, which may have aesthetic effects such as taste, odor, or staining.

A laboratory analysis of water identifies the concentrations of contaminants. Concentrations are usually reported in milligrams per liter, (mg/l). One mg/l is equal to one part per million. Advanced laboratory analysis techniques, in some instances, will allow contamination to be reported in micrograms per liter or parts per billion, (ppb).

Inorganic substances are those that do not contain carbon. These include most elements and simple compounds, such as nitrogen and heavy metals.

Organic substances are those that contain carbon. These include many complex, and groups of complex, substances along with living things.

The **Other** category includes some of the physical properties that can occur in groundwater.

Maximum Contaminant Level (MCL) is the highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

The **Maximum Contaminant Level Goal (MCLG)** is the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.[3]

Agricultural Sources of Contamination

Pesticides, fertilizers, herbicides and animal waste are agricultural sources of groundwater contamination. The means of agricultural contamination are varied and numerous, but some examples follow:

- spillage of fertilizers and pesticides during handling
- runoff from the loading and washing of pesticide sprayers or other application equipment
- using chemicals uphill from or within a few hundred feet of a well

Agricultural land that lacks sufficient drainage is considered by many farmers to be lost income land. So they may install drain tiles or drainage wells to make the land more productive. The drainage well then serves as a direct conduit to groundwater for agricultural wastes which are washed down with the runoff.

Storage of agricultural chemicals near conduits to groundwater, such as open and abandoned wells, sink holes, or surface depressions where ponded water contamination is likely to accumulate. Contamination may also occur when chemicals are stored in uncovered areas, unprotected from wind and rain, or are stored in locations where the groundwater flows from the direction of the chemical storage to the well.

Mixing and distributing pesticides and fertilizers with irrigation water can cause groundwater contamination if more chemicals are applied than crops can use. Irrigation also poses a problem if chemicals back-siphon from the holding tank directly into the aquifer through irrigation well.

Fields with over-applied or misapplied fertilizers, herbicides, insecticides, and fungicides could introduce these contaminants into the groundwater: organic compounds, excess nitrogen, cadmium, chloride, mercury, and selenium.

Feedlots are potential contamination sources. Animal waste is often collected in impoundments from which the wastes may infiltrate the groundwater. Runoff could also enter an aquifer through a poorly sealed well casing. Livestock waste is a source of: nitrate, coliform bacteria, total dissolved solids, and sulfates.

Within the garage or farm equipment shed, chemicals that are improperly stored or disposed of that could potentially contaminate groundwater include: paint containing lead and barium, gasoline and oils containing volatile organic compounds, barium from diesel fuel combustion, and rinsate containing residues of pesticides or fertilizers.

Many sources of groundwater contamination can originate in the house or other farm residences such as trailers or housing units. Leaks, spills, overloading, or poor maintenance of septic systems can result in the following contaminants entering groundwater: coliform bacteria, nitrate, total dissolved solids, chloride, sodium, sulfates, detergents, and chromium.

Both aboveground and underground storage tanks are at risk of leaking and releasing gasoline, which contains benzene.

Abandoned wells that have not been plugged or dismantled provide a potential pathway (direct route) for water to flow directly from the surface to the aquifer, carrying whatever contaminants are on the surface into the groundwater.

Open wells can become contaminated by the working fluids, such as grease and oils from the pump or from contaminants from the surface if the well cap is not tight or if the casing lining the well is cracked or corroded. In addition, many older farm wells were merely shallow holes dug into the ground. These wells can easily be contaminated and are also a safety hazard to children and animals.[3]

Residential Sources of Contamination

A major cause of groundwater contamination is effluent (outflow) from septic tanks and cesspools. Misuse of these systems for disposal of anything other than domestic or sanitary waste can pose a substantial threat to groundwater and makes the system subject to Federal regulation. Residential wastewater systems can be a source of many categories of contaminants, including bacteria, viruses, nitrates from human waste, and organic compounds.

Improperly storing or disposing of household chemicals such as paints, synthetic detergents, solvents, oils, medicines, disinfectants, pool chemicals, pesticides, batteries, gasoline and diesel fuel can lead to groundwater contamination. When stored in garages or basements with floor drains, spills and flooding may introduce such contaminants into the groundwater. When thrown in the household trash, the products will eventually be carried into the groundwater because community landfills are not equipped to handle hazardous materials. Similarly, wastes dumped or buried in the ground can contaminate the soil and leach into the groundwater.

As urban areas grow, there is an increase in rain water runoff caused by the addition of paved surfaces. Some municipalities use storm water drainage wells to dispose of this additional runoff, particularly if the area is not served by storm sewers nor has a limited sewer system. These low-cost, low-tech wells can serve as a conduit to groundwater for runoff from streets, roofs, construction sites, and landscaped areas. Storm water drainage wells that communities use to control water during storm events pose a threat to groundwater particularly in karst areas or areas with a high water table.

Fertilizers, herbicides, insecticides, fungicides and pesticides applied to the lawn and garden contain hazardous chemicals that can travel through the soil and contaminate groundwater.

More than 11 million tons of salt are applied to roads in the Unites States annually. As ice and snow melt, or rain falls, the salt is washed into the surrounding soil. Salt also enters groundwater from improperly protected storage stockpiles.

In the garage, items that are improperly used, stored, or disposed of may potentially contaminate groundwater, especially if there is a drain to the ground in the floor of the garage. Sources include:

batteries that contain lead, cadmium, or mercury; paint containing lead and barium; gasoline and oils containing volatile organic compounds; and barium from diesel fuel combustion.

Water used in the home and entering a septic system or sewer system may contain: detergents from dishwashing and laundry; organic compounds from garbage disposal; bacteria, nitrates, and sulfates from sewage; greases and oils; cleaning agents, aerosol sprays, coolants and solvents which all contain carbon tetrachloride; and household pesticides.

Water percolating through landfills is known as leachate. Leachate from landfills that contain household and other waste may pick up: dissolved solids, volatile organic compounds, acidity, toxic chemicals such as carbon tetrachloride, and heavy metals such as manganese.

Lawns with over-applied or misapplied fertilizers, herbicides, insecticides and fungicides might introduce these contaminants into the groundwater: many organic compounds, excess nitrogen, cadmium, chloride, and mercury.

Contaminants from the road or driveway that might enter groundwater include: chloride and sodium from road salts, organic compounds from oil and gasoline spills, and cleaning agents, aerosol sprays, coolants and solvents may contain carbon tetrachloride.[3]

Industrial Sources of Contamination

Modern economic activity requires transportation and storage of material used in manufacturing, processing, and construction. Along the way, some of this material can be lost through spillage, leakage, or improper handling. Even the cleanup of spills may pose a threat to groundwater when the spills are flushed with water rather than cleaned up with absorbent substances.

The disposal of wastes associated with the above activities contributes another source of groundwater contamination. Some businesses, usually without access to sewer systems, rely on shallow underground disposal. They use cesspools or dry holes, or send the wastewater into septic tanks. Any of these forms of disposal can lead to contamination of underground sources of drinking water. Dry holes and cesspools introduce wastes directly into the ground. Septic systems cannot treat industrial wastes. Wastewater disposal practices of certain types of businesses, such as automobile service stations, dry cleaners, electrical component or machine manufacturers, photo processors, and metal platers or fabricators are of particular concern because the waste they generate is likely to contain toxic chemicals. Other industrial sources of contamination include cleaning off holding tanks or spraying equipment on the open ground, disposing of waste in septic systems or dry wells, and storing hazardous materials in uncovered areas or in areas that do not have pads with drains or catchment basins.

Although businesses may run a "clean shop", small amounts of waste fluids can end up on the shop floor and be washed down floor drains. These drains may be connected to shallow injection well systems, which are not designed to handle the industrial chemicals typically used by businesses such as those listed above. Even low concentrations of certain contaminants can accumulate through time.

Underground and above ground storage tanks holding petroleum products, acids, solvents and chemicals can develop leaks from corrosion, defects, improper installation, or mechanical failure of the pipes and fittings.

Mining of fuel and non-fuel minerals can create many opportunities for groundwater contamination. The problems stem from the mining process itself, disposal of wastes, and processing of the ores and the wastes it creates.[3]

Natural Sources of Contamination

Groundwater contains some impurities, even if it is unaffected by human activities. The types and concentrations of natural impurities depend on the nature of the geological material through which the groundwater moves and the quality of the recharge water. Groundwater moving through sedimentary rocks and soils may pick up a wide range of compounds such as magnesium, calcium, and chlorides. Some aquifers have high natural concentration of dissolved constituents such as arsenic, boron, and selenium. The effect of these natural sources of contamination on groundwater quality depends on the type of contaminant and its concentration. Many of the following contaminants occur naturally: aluminum, arsenic, coliform bacteria, manganese, mercury, nitrate, iron, lead, hardness, and sulfate.[3]

Groundwater Contamination in the United States

While we should bear in mind that groundwater contamination is a problem, and that serious efforts are needed to safeguard our groundwater resources, it should be noted that only a small percentage of the potentially available groundwater is polluted. Using approximate figures for total available groundwater and the known extent of groundwater contamination, in 1984 the U.S. Office of Technology Assessment (OTA) estimated that somewhere between 1 to 2 percent of the nation's groundwater was contaminated. This report conceded that this may be an underestimate because monitoring for contamination has focused on public water supplies, which are generally afforded some level of protection, while the release of substances known to contaminate groundwater is undoubtedly more widespread. Nevertheless, this recognized contamination is significant because it is often near heavily populated areas where potable water supplies are needed and the demand for groundwater continues to increase.

Currently, the groundwater contaminants that are of greatest concern are synthetic compounds. These man-made contaminants are usually divided into organic substances, i.e., compounds based on carbon, and inorganic substances, which are not based on carbon. However, many other contaminants not synthesized by man are also of concern. These include various naturally occurring elements, e.g., arsenic and radionuclides, and microbiological contaminants. Microbiological contaminants include bacteria, viruses, and parasites such as *Cryptosporidium*. Six well-documented outbreaks of Cryptosporidiosis attributed to drinking water have been recognized in the United States, including an outbreak in Milwaukee in 1993 that affected over 400,000 people. While these breakouts occurred in surface water, Cryptosporidium has also been known to occur in groundwater.

Because of its widespread occurrence, the inorganic compound that is perhaps of greatest concern in groundwater is nitrate. U.S. EPA estimates that 52 percent of the community water wells and 57 percent of the domestic water wells in the country contain nitrate. Nitrate in groundwater at certain levels can lead to health problems in infants. For example, blue baby syndrome, also known as Methemoglobinemia, is caused by high nitrate contamination in groundwater resulting in decreased oxygen carrying capacity of hemoglobin in babies leading to death. The groundwater gets contaminated by leaching of nitrate generated from fertilizer used in agricultural lands, inadequate design and maintenance of septic systems, unlined waste water holding ponds, leaking sewer lines, and improper sludge and manure application. It may also be related to some pesticides (DDT, PCBs etc), which cause ecotoxicological problems in the food chains of living organisms, which kills aquatic animals.

At least 65,000 synthetic organic chemicals are in common use in the U.S. today, and this number continues to grow each year. Organic chemicals have become a more frequently detected contaminant in groundwater supplies. The 1984 OTA report listed 175 different organic compounds that have been found in groundwater, and EPA groundwater surveys conducted over the last decade confirm the widespread occurrence of organic contaminants. The increased detection of these compounds is due largely to the fact they are so much a part of everyday life. Solvents, pesticides, paints, inks, dyes, varnishes, and gasoline are just a few of the ubiquitous products that contain organic chemicals.[3]

Principal Sources of Contamination in Pennsylvania

The potential for groundwater contamination varies across Pennsylvania depends on the types of land use activities in an area, as well as the area's geologic characteristics. In the state as a whole, the most significant sources of contamination are:

1. *Underground and aboveground storage tanks* constitute a serious pollution risk. Although many industrial and commercial storage tanks have been removed, many others remain in the ground. Of particular concern are old tanks for agricultural and personal use for which records are sketchy or nonexistent. Contaminants from storage tanks include hydrocarbons, especially gasoline, solvents, and other organic chemicals, some of which are known or suspected carcinogens. Federal and state regulations required that all existing tank systems be upgraded, replaced, or closed by December 1998.

2. *Oil and gas drilling operations* frequently cause contamination, chiefly from petroleum products and brine, the brackish water containing sulfates and chlorides that may be injected into the ground during oil and gas production operations. If not managed correctly, this brine may migrate to an aquifer. Oil spills on the land surface are also dangerous. Although the amounts may be small, oil from equipment failures can degrade a shallow aquifer.

3. *Agriculture* can contribute significantly to groundwater pollution. Problems include:

   - Nitrates from fertilizers and manure, which are soluble and easily get into groundwater
   - Herbicides and pesticides, some of which are soluble
   - Disease-causing microorganisms from animal waste and improperly treated sewage
   - Irrigation water, which can carry mineral salts, metals, nitrates, phosphates, and pesticides to groundwater. Although irrigation is not as widely used in this state as in other sections of the nation, if its use increases so will the potential threat.

   Similar threats to groundwater contamination can result from management activities (using fertilizers, herbicides, pesticides, and irrigation) on golf courses and playing fields.

4. *Malfunctioning on-lot sewage systems*, which serve one or a few private households, pose of the largest threats to groundwater in Pennsylvania. Although properly installed and maintained systems can help recharge the groundwater, the Department of Environmental Protection estimates that 35 percent of on-lot sewage systems malfunction and cause groundwater pollution.

5. *Waste disposal sites (including landfills for municipal and hazardous waste), storage pits, lagoons, and other surface impoundments* pose an obvious risk of contamination. Although new installations must meet stricter standards than were previously required, especially for monitoring to detect leaks quickly, pollution from abandoned sites and illegal dumping remains a critical problem.

6. *Industrial production sites, as well as small industrial and retail sites (such as dry cleaners and gas stations)*, can also cause contamination from leaky storage tanks, hazardous material spills, runoff from unprotected stockpiles, or improper handling of waste.

7. *Coal mining* has contributed to water pollution problems in broad areas of the state. Acid mine drainage releases iron, manganese, and sulfates to groundwater and surface water. Although current mining methods aim to prevent pollution from acid mine drainage, they still pose a threat. The scope of the acid mine drainage problem left from earlier years is overwhelming. Despite efforts to seal old deep mines and reclaim strip-mined land, thousands of acid mine drainage points remain active.

8. *Household, lawn, and garden activities* pose yet another threat to groundwater because of improperly used and/or disposed of chemicals. Cleaning compounds, paints, pesticides, oil, and antifreeze are often improperly sent to landfills with garbage, dumped on the ground, or in sewers or septic tanks. Lawn fertilizers and pesticides frequently are applied too liberally or at the wrong time,

and excess washes off to the nearest stream or migrates through the soil to groundwater. Although the amount of contaminants coming from any one household may be small, the combined total from many households warrants concern.

9. *Abandoned oil and gas wells and municipal and commercial water wells* represent a more serious threat than generally recognized. Improperly plugged and sealed wells are sometimes used for illegal waste dumping. They serve as a path for contaminants to reach groundwater. Inadequate or deteriorated well casings or grouting can result in the contamination of more than one aquifer or the spreading of contaminants from one aquifer to another.
10. *Poorly constructed or deteriorated private wells* present a similar problem. Depending on the specifications used, between 40 and 80 percent of private wells in Pennsylvania have structural deficiencies and could provide a way for polluted surface water to contaminate groundwater. There is no statewide and little local regulation of the design or construction of private wells.
11. *Road deicing operations* can result in groundwater contamination from salt spread on roads or stored without adequate protection against runoff.
12. *Over pumping of wells* can lead to groundwater contamination as, for example, in southeastern Pennsylvania, where seawater has been pulled into drinking water aquifers.[6]

Few natural mechanisms can remove contamination once water reaches the saturated zone. To date, rather than treating water while in the ground, most individuals and communities have coped with contamination by:

- Finding another source (a new well or a public water supplier).
- Blending the water with uncontaminated water to reduce contamination to an acceptable level.
- Treating the water after withdrawal from the aquifer.

All these ways of coping with the problem are costly. Rather than waiting for a crisis to happen, many communities in Pennsylvania already have taken the initiative and adopted specific groundwater protection measures.

Groundwater Protection or Wellhead Protection

Wellhead protection refers to protecting a defined area that contributes groundwater to, and could contaminated, public water supply wells or springs. Wellhead protection areas may include only a portion of the aquifer from which groundwater is withdrawn. For example, if groundwater flows away from the well faster than it may be pumped out, then the area down-gradient of the well would not be include in the wellhead protection area.

Groundwater, or aquifer, protection refers to protecting the whole water resource on a watershed basis. It considers future uses of water and uses other than public consumption, such as the provision of flow to streams and rivers. An area that depends on the private wells for drinking water will need to consider protecting the entire aquifer, not just the portion of the aquifer that supplies public water wells.[6]

Recommendations

Low Impact Development (LID)

Picture the grime of city streets -- oil, grease and soot from cars and trucks; pet waste; trash and litter; sediment and debris from construction sites; and a mix of toxic chemicals. Now picture the same streets after a rainstorm. They look cleaner, right? Sure, but the debris and contaminants haven't just disappeared -- they've been swept through street drains and underground pipes then washed directly into the nearby river, lake or bay.

Wherever humans have paved or built over the natural world, dirty rainwater tends to run straight into our waterways, contaminating the water, destroying habitat and damaging property. Known as urban runoff, this type of pollution can have serious consequences, from fouling drinking water to closing beaches and poisoning shellfish beds. Indeed, the U.S. Environmental Protection Agency now considers urban runoff and pollution from other diffuse sources the greatest contaminant threat to our nation's waters. The good news is that there are a number of proven solutions that towns and cities can use to reduce runoff pollution.

One new and exciting approach has emerged in recent years. "Low-impact development" uses both simple common sense and technology to help rainfall evaporate back into the atmosphere or soak into the ground, rather than polluting the nearest water body. Strategically placed beds of native plants, rain barrels, "green roofs," porous surfaces for parking lots and roads, and other tools are a few examples of low impact development. In effect, low-impact development mimics nature's own filtering systems. The result is less water pollution from dirty runoff, less flooding, replenished groundwater supplies -- and often, more natural-looking, aesthetically pleasing cityscapes.

Use **low impact development** (LID), also known as green infrastructure, principles. LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions. LID has been characterized as a sustainable stormwater practice by the Water Environment Research Foundation and others.

LID can be applied to new development, redevelopment, or as retrofits to existing development. LID has been adapted to a range of land uses from high density ultra-urban settings to low density development.

- Use rainwater cisterns, vegetated swales and depressions to reduce runoff.
- Reduce the amount of impervious site area.
- Filter surface runoff.
- Use pervious paving materials.

Like most big cities, our nation's capital has lost most of its natural groundcover to buildings, sidewalks, streets and other hard surfaces. Without the buffering, filtering, and overall ability to soak up water that natural groundcover provides, heavy rains send dirty runoff washing into the Anacostia and Potomac rivers, and eventually into the Chesapeake Bay. To help curb this contamination, the Washington Navy Yard has replaced sections of waterproof blacktop with bricklike tiles, as pictured right that allow water to seep through to the ground below. In addition, the Navy has added trees and rows of plants to several parking lots within its vast complex to help capture runoff.[5]

Follow EPA's **Green Infrastructure/low impact development** policy for managing stormwater. Green Infrastructure is an adaptable term used to describe an array of products, technologies, and practices that use natural systems – or engineered systems that mimic the natural hydrologic cycle processes – to enhance overall environmental quality and provide utility services. As a general principal, Green Infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff. When used as components of a stormwater management system, Green Infrastructure practices such as green roofs, porous and permeable pavements, rain gardens, and vegetated swales and median strips, and protection and enhancement of riparian buffers and floodplains can produce a variety of environmental benefits. In addition to effectively retaining and infiltrating rainfall, these technologies can simultaneously help filter air pollutants, reduce energy demands, mitigate urban heat islands, and sequester carbon while also providing communities with aesthetic and natural resource benefits. Green infrastructure also includes decentralized harvesting approaches, such as the use of rain barrels and cisterns to capture and reuse rainfall. These techniques can be used to keep rainwater out of the sewer system so that it does not contribute to a sewer overflow and also to reduce the amount of untreated runoff discharging to groundwater and surface water resources.

Green infrastructure has a number of environmental and economic benefits in addition to reducing the volume of sewer overflows and runoff.

- *Cleaner Water* – Vegetation, green space and water reuse reduce the volumes of stormwater runoff and, in combined systems, the volume of combined sewer overflows, as well as reduce concentrations of pollutants in those discharges.
- *Enhanced Water Supplies* – Most green infiltration approaches involve allowing stormwater to percolate through the soil where it recharges the groundwater and the base flow for streams, thus ensuring adequate water supplies for humans and more stable aquatic ecosystems. In addition, capturing and using stormwater conserves water supplies.
- *Cleaner Air* – Trees and vegetation improve air quality by filtering many airborne pollutants and can help reduce the amount of respiratory illness. Transportation and community planning and design efforts that facilitate shorter commute distances and the ability to walk to destinations will also reduce vehicle emissions.
- *Reduced Urban Temperatures* – Summer city temperatures can average 10ºF higher than nearby suburban temperatures. High temperatures are also linked to higher ground level ozone concentrations. Vegetation creates shade, reduces the amount of heat absorbing materials and emits water vapor – all of which cool hot air. Limiting impervious surface and using light colored impervious surfaces (e.g., porous concrete) also mitigate urban temperatures.
- *Moderate the Impacts of Climate Change* – Climate change impacts and effects vary regionally, but green infrastructure techniques provide adaptation benefits for a wide array of circumstances, by conserving and reusing water, promoting groundwater recharge, reducing surface water discharges that could contribute to flooding. In addition, there are mitigation benefits such as reduced energy demands and carbon sequestration by vegetation.
- *Increased Energy Efficiency* – Green space helps lower ambient temperatures and, when incorporated on and around buildings, helps shade and insulate buildings from wide temperature swings, decreasing the energy needed for heating and cooling. Further, diverting stormwater from wastewater collection, conveyance and treatment systems reduces the amount of energy needed to pump and treat the water. Energy efficiency not only reduces costs, but also reduces generation of greenhouse gases.
- *Source Water Protection* – Green infrastructure practices provide pollutant removal benefits, thereby providing some protection for both groundwater and surface water sources of drinking water. In addition, green infrastructure provides groundwater recharge benefits.
- *Community Benefits* – Trees and plants improve urban aesthetics and community livability by providing recreational and wildlife areas. Studies show that property values are higher when trees and other vegetation are present.
- *Cost Savings* – Green infrastructure may save capital costs associated with paving, creating curbs and gutters, building large collection and conveyance systems, and digging big tunnels and centralized stormwater ponds; operations and maintenance expenses for treatment plants, pumping stations, pipes, and other hard infrastructure; energy costs for pumping water around; cost of treatment during wet weather; and costs of repairing the damage caused by stormwater, such as streambank restoration.

Integrated Pest Management

Use **Integrated Pest Management** (IPM) to reduce water pollution from pesticides. Integrated Pest Management is the coordinated use of pest and environmental information along with available pest control methods, including cultural, biological, genetic and chemical methods, to prevent unacceptable levels of pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

Stormwater Management in Pennsylvania

Plan for stormwater events in the overall management of surface water runoff as described in the Pennsylvania Department of Environmental Protection's Fact Sheet, "Stormwater Management in Pennsylvania."

How to Conserve Water and Use It Effectively and Efficiently

Water users can be divided into two basic groups: **system users** (such as residential users, industries, and farmers) and **system operators** (such as municipalities, state and local governments, and privately owned suppliers). These users can choose from among many different water use efficiency practices, which fall into two categories:

- Engineering practices: practices based on modifications in plumbing, fixtures, or water supply operating procedures
- Behavioral practices: practices based on changing water use habits [4]

Engineering Practices for Residential Users

Plumbing

An engineering practice for individual residential water users is the installation of indoor plumbing fixtures that save water or the replacement of existing plumbing equipment with equipment that uses less water. Low-flow plumbing fixtures and retrofit programs are permanent, one-time conservation measures that can be implemented automatically with little or no additional cost over their lifetimes. In some cases, they can even save the resident money over the long term.

- **Low-Flush Toilets.** Residential demands account for about three-fourths of the total urban water demand. Indoor use accounts for roughly 60 percent of all residential use, and of this, toilets (at 3.5 gallons per flush) use nearly 40 percent. Toilets, showers, and faucets combined represent two-thirds of all indoor water use. More than 4.8 billion gallons of water is flushed down toilets each day in the United States. The average American uses about 9,000 gallons of water to flush 230 gallons of waste down the toilet per year. In new construction and building rehabilitation or remodeling there is a great potential to reduce water consumption by installing low-flush toilets.

  Conventional toilets use 3.5 to 5 gallons or more of water per flush, but low-flush toilets use only 1.6 gallons of water or less. Since low-flush toilets use less water, they also reduce the volume of wastewater produced.

- **Low-Flow Showerheads.** Showers account for about 20 percent of total indoor water use. By replacing standard 4.5-gallon-per-minute showerheads with 2.5-gallon-per-minute heads, which cost less than $25 each, a family of four can save approximately 20,000 gallons of water per year. Although individual preferences determine optimal shower flow rates, properly designed low-flow showerheads are available to provide the quality of service found in higher-volume models.

- **Faucet Aerators.** Faucet aerators, which break the flowing water into fine droplets and entrain air while maintaining wetting effectiveness, are inexpensive devices that can be installed in sinks to reduce water use. Aerators can be easily installed and can reduce the water use at a faucet by as much as 60 percent while still maintaining a strong flow. More efficient kitchen and bathroom faucets that use only 2 gallons of water per minute--unlike standard faucets, which use 3 to 5 gallons per minute--are also available.

- **Pressure Reduction.** Because flow rate is related to pressure, the maximum water flow from a fixture operating on a fixed setting can be reduced if the water pressure is reduced. For example, a reduction in pressure from 100 pounds per square inch to 50 psi at an outlet can result in a water flow reduction of about one-third.

  Homeowners can reduce the water pressure in a home by installing pressure-reducing valves. The use of such valves might be one way to decrease water consumption in homes that are served by municipal water systems. For homes served by wells, reducing the system pressure can save both water and energy. Many water use fixtures in a home, however, such as washing machines and toilets, operate on a controlled amount of water, so a reduction in water pressure would have little effect on water use at those locations.

  A reduction in water pressure can save water in other ways: it can reduce the likelihood of leaking water pipes, leaking water heaters, and dripping faucets. It can also help reduce dishwasher and washing machine noise and breakdowns in a plumbing system.[7]

Landscaping

Lawn and landscape maintenance often requires large amounts of water, particularly in areas with low rainfall. Outdoor residential water use varies greatly depending on geographic location and season. On an annual average basis, outdoor water use in the arid West and Southwest is much greater than that in the East or Midwest. Nationally, lawn care accounts for about 32 percent of the total residential outdoor use. Other outdoor uses include washing automobiles, maintaining swimming pools, and cleaning sidewalks and driveways.

- **Landscape Irrigation.** One method of water conservation in landscaping uses plants that need little water, thereby saving not only water but labor and fertilizer as well. A similar method is grouping plants with similar water needs. Scheduling lawn irrigation for specific early morning or evening hours can reduce water wasted due to evaporation during daylight hours. Other practices include the use of low-precipitation-rate sprinklers that have better distribution uniformity, bubbler/soaker systems, or drip irrigation systems.

- **Xeriscape Landscapes. "**Xeriscaping" by definition is landscaping designed specifically for areas that are susceptible to drought or for properties where water conservation is practiced. Careful design of landscapes could significantly reduce water usage nationwide. Xeriscape landscaping is an innovative, comprehensive approach to landscaping for water conservation and pollution prevention. Traditional landscapes might incorporate one or two principles of water conservation, but xeriscape landscaping uses all of the following: planning and design, soil analysis, selection of suitable plants, practical turf areas, efficient irrigation, use of mulches, and appropriate maintenance. Benefits of xeriscape landscaping include reduced water use, decreased energy use (less pumping and treatment required), reduced heating and cooling costs because of carefully placed trees, decreased storm water and irrigation runoff, fewer yard wastes, increased habitat for plants and animals, and lower labor and maintenance costs.[4]

Behavioral Practices for Residential Users

Behavioral practices involve changing water use habits so that water is used more efficiently, thus reducing the overall water consumption in a home. These practices require a change in behavior, not modifications in the existing plumbing or fixtures in a home. Behavioral practices for residential water users can be applied both indoors in the kitchen, bathroom, and laundry room and outdoors.

In the kitchen, for example, 10 to 20 gallons of water a day can be saved by running the dishwasher only when it is full. New, more efficient models may use as little as 4.5 gallons of water per load (gpl). Automatic dishwashers save water, as well as energy, by limiting hot water use. If dishes are washed by hand, water can be saved by filling the sink or a dishpan with water rather than running the water continuously. An open conventional faucet lets about 5 gallons of water flow every 2 minutes.

Water can be saved in the bathroom by turning off the faucet while brushing teeth or shaving. Water can be saved by taking short showers rather than long showers or baths and turning the water off while soaping. This water savings can be increased even further by installing low-flow showerheads, as discussed earlier. Toilets should be used only to carry away human waste.

Households with lead-based solder in pipes that flush the first several gallons of water should collect this water for alternative non-potable uses (e.g., plant watering).

Water can be saved in the laundry room by adjusting water levels in the washing machine to match the size of the load. Conventional, top-loading clothes washers use about 40-50 gpl. Great strides have recently been made to improve the reliability and ease of front-loading automatic clothes washers, which use less water, about 27/gpl, and energy. Front-loaders are more efficient and wash with much less water and detergent. If washing is done by hand, the water should not be left running. A laundry tub should be filled with water, and the wash and rinse water should be reused as much as possible.

Outdoor water use can be reduced by watering the lawn early in the morning or late in the evening and on cooler days, when possible, to reduce evaporation. Allowing the grass to grow slightly taller will reduce water loss by providing more ground shade for the roots and by promoting water retention in the soil. Growing plants that are suited to the area ("indigenous" plants) can save more than 50 percent of the water normally used to care for outdoor plants.

As much as 150 gallons of water can be saved when washing a car by turning the hose off between rinses. The car should be washed on the lawn if possible to reduce runoff.

Additional savings of water can result from sweeping sidewalks and driveways instead of hosing them down. Washing a sidewalk or driveway with a hose uses about 50 gallons of water every 5 minutes. If a home has an outdoor pool, water can be saved by covering the pool when it is not in use. [4]

Engineering Practices for Industrial/Commercial Users

Industrial/commercial users can apply a number of conservation and water use efficiency practices. Some of these practices can also be applied by users in the other water use categories.

Water Reuse and Recycling

Water reuse is the use of wastewater or reclaimed water from one application such as municipal wastewater treatment for another application such as landscape watering. The reused water must be used for a beneficial purpose and in accordance with applicable rules (such as local ordinances governing water reuse). Some potential applications for the reuse of wastewater or reclaimed water include other industrial uses, landscape irrigation, agricultural irrigation, aesthetic uses such as fountains, and fire protection. Factors that should be considered in an industrial water reuse program include:

- Identification of water reuse opportunities
- Determination of the minimum water quality needed for the given use
- Identification of wastewater sources that satisfy the water quality requirements
- Determination of how the water can be transported to the new use

The reuse of wastewater or reclaimed water is beneficial because it reduces the demands on available surface and groundwater resources. Perhaps the greatest benefit of establishing water reuse programs is their contribution in delaying or eliminating the need to expand potable water supply and treatment facilities. Water recycling is the reuse of water for the same application for which it was originally used.

Recycled water might require treatment before it can be used again. Factors that should be considered in a water recycling program include:

- Identification of water reuse opportunities
- Evaluation of the minimum water quality needed for a particular use
- Evaluation of water quality degradation resulting from the use
- Determination of the treatment steps, if any, that might be required to prepare the water for recycling [4]

Landscape Irrigation

Another way that industrial/commercial facilities can reduce water use is through the implementation of efficient landscape irrigation practices. There are several general ways that water can be more efficiently used for landscape irrigation, including the design of landscapes for low maintenance and low water requirements (refer to the previous section on xeriscape landscaping), the use of water-efficient irrigation equipment such as drip systems or deep root systems, the proper maintenance of irrigation equipment to ensure that it is working properly, the distribution of irrigation equipment to make sure that water is dispensed evenly over areas where it is needed, and the scheduling of irrigation to ensure maximum water use. [4]

Behavioral Practices

Behavioral practices involve modifying water use habits to achieve more efficient use of water, thus reducing overall water consumption by an industrial/commercial facility. Changes in behavior can save water without modifying the existing equipment at a facility.

Monitoring the amount of water used by an industrial/commercial facility can provide baseline information on quantities of overall company water use, the seasonal and hourly patterns of water use, and the quantities and quality of water use in individual processes. Baseline information on water use can be used to set company goals and to develop specific water use efficiency measures. Monitoring can make employees more aware of water use rates and makes it easier to measure the results of conservation efforts. The use of meters on individual pieces of water-using equipment can provide direct information on the efficiency of water use. Records of meter readings can be used to identify changes in water use rates and possible problems in a system.

Many of the practices described in the section for residential users can also be applied by commercial users. These include low-flow fixtures, water-efficient landscaping, and water reuse and recycling (e.g., using recycled wash water for pre-rinse). [4]

Engineering Practices for Agricultural Users

No-Till

No-till farming is a way of growing crops from year to year without disturbing the soil through tillage. No-till is an emergent agricultural technique which can increases the amount of water in the soil and decrease erosion. It may also increase the amount and variety of life in and on the soil and it increases herbicide usage.

No-till improves soil quality (soil function), carbon, organic matter, aggregates, protecting the soil from erosion, evaporation of water, and structural breakdown. A reduction in tillage passes helps prevent the compaction of soil.

Crop residues left intact help both natural precipitation and irrigation water infiltrate the soil where it can be used. The crop residue left on the soil surface also limits evaporation, conserving water for plant growth. Since there is less soil compaction and no tillage-pan, soil absorbs more water and plants are able to grow their roots deeper into the soil and suck up more water.

Tilling a field reduces the amount of water, via evaporation, around 1/3 to 3/4 inches (0.85 to 1.9 cm) per pass. By no-tilling, this water stays in the soil, available to the plants.

Water Reuse and Recycling

Agricultural irrigation represents approximately 40 percent of the total water demand nationwide. Given that high demand, significant water conservation benefits could result from irrigating with reused or recycled water.

Water reuse is the use of wastewater or reclaimed water from one application for another application. Reused water must be used for a beneficial purpose and in accordance with applicable rules (USEPA,

1991a). Water recycling is the reuse of water for the same application for which it was originally intended.

Factors that should be considered in an agricultural water reuse program include:

1. The identification of water reuse opportunities
2. Determination of the minimum water quality needed for the given use
3. Identification of wastewater sources that satisfy the water quality requirements
4. Determination of how the water can be transported to the new use

Water reuse for irrigation is already in widespread use in rural areas and is also applicable in areas where agricultural sites are near urban areas and can easily be integrated with urban reuse applications. [4]

Behavioral Practices

Behavioral practices involve changing water use habits to achieve more efficient use of water. Behavioral practices for agricultural water users can be applied to irrigation application rates and timing. Changes in water use behavior can be implemented without modifying existing equipment.

For example, better irrigation scheduling can result in a reduction in the amount of water that is required to irrigate a crop effectively. The careful choice of irrigation application rates and timing can help farmers to maintain yields with less water. In making scheduling decisions, irrigators should consider:

- The uncertainty of rainfall and crop water demand
- The limited water storage capacity of many irrigated soils
- The limited pumping capacity of irrigation systems
- Rising pumping costs as a result of higher energy prices

Local U.S.D.A. Natural Resources Conservation Service, Conservation District, and Cooperative Extension Service offices can play an important role in promoting better irrigation scheduling. Accurate information on crop water use requires information on solar radiation and other weather variables that can be collected by local weather stations. An additional method that can be used to improve irrigation scheduling and might result in high returns is the use of equipment such as resistance blocks, tensiometers, and neutron probes to monitor soil moisture conditions to help in determining when water should be applied. [4]

Incorporate Best Management Practices

Best Management Practices (BMPs) are considered to be the “best” guidelines and/or practices under current technology and understanding. BMPs can be initiated in the planning and design phases of projects in order to obtain the most benefit. BMPs have been prepared for numerous facets of development including: watershed management and protection; water quality protection; flora and fauna habitat protection; as well as residential well, septic system, and storm water control system design, construction and maintenance and/or monitoring.

Non-structural BMPs specify procedures to reduce runoff and pollutants and emphasize educational activities to change individual behavior. Structural BMPs are constructed systems or devices designed to filter pollutants.

These tools should be integrated with a community's other source protection efforts; alone they cannot adequately address all source protection challenges. Along with public education, BMPs can help change behavior over time.

A summary of BMPs that relate to the management of conservation lands follows.

- Design buffers to meet unique needs, varying width based on such ecological factors as stream-bank slope, vegetation, and stream size
- Install natural storm water management techniques for all new development

Forestry related BMPs:

- Use trees, shrub roots, duff, and grasses to slow the flow of runoff, hold buffers in place, and prevent erosion
- Provide the best possible forest cover throughout the watershed; forest cover can help manage sediment runoff and help control nonpoint source pollution
- Use BMPs such as removing trees without disturbing ground cover and maintaining buffer zones of standing trees and undisturbed soils along streams will mitigate impacts to water resources

Agricultural BMPs:

- Use proper pesticide management and less toxic, rapidly degradable pesticides with low leaching potentials
- Develop a program of integrated pest management
- Consider non-chemical pest control methods and prevention techniques
- Apply manure and fertilizer based on crop needs as determined by soil testing
- Apply nutrients at the root level
- Consider crop rotation to recover nutrients left in the soil
- Store manure at least 100 feet from domestic wells
- Cover stockpiled manure and bedding, especially in high rainfall areas
- Control grazing and keep livestock off pastures in the winter
- Use conservation tillage to help reduce erosion and runoff from agricultural fields
- Employ planting methods such as contouring and strip cropping
- Develop and implement nutrient management plans
- Fence livestock out of streams

Public Education

Local official should make it public policy to encourage voluntary actions by residents to protect groundwater. Although unlikely to work as the sole means of preserving groundwater, a voluntary program can be a valuable supplement to governmental regulations. Inspiring residents voluntarily to change their lifestyle and actions requires that they understand why change is needed and what actions should be changed.

A public information program about the value of groundwater protection could, for example, describe how improper waste disposal, the overuse of lawn and garden chemicals, and poorly maintained septic systems threaten groundwater quality. The program should then explain what individuals can do to minimize or eliminate these threats. It should further explain that although the actions of individuals may seem inconsequential, when multiplied by thousands of households in an aquifer area, these actions may have very serious consequences.

You may have noticed signs along roadways informing drivers when they enter a public water supply area. These signs include information about whom to call if a chemical spill occurs along the road. This road sign program has been a useful tool for raising public awareness about threats to community supplies. [6]

Public education programs can also be used to inform the public about the basics of water use efficiency:

- How water is delivered to them
- The costs of water service
- Why water conservation is important
- How they can participate in conservation efforts

Public education is an essential component of a successful water conservation program. A number of tools can be used to educate the public: bill inserts, feature articles and announcements in the news media, workshops, booklets, posters and bumper stickers, and the distribution of water-saving devices. Public school education is also an important means for instilling water conservation awareness.

Another way to provide public information and education, as well as to collect real-world data on water conservation and use efficiency, is through the use of demonstration projects.

Planning for Resource Protection

Monitoring and managing land use and waste disposal practices around water supply sources can potentially reduce the need for new water supply development and keep water treatment costs to a minimum. Adverse effects on a water supply source can be lessened through land use controls such as land preservation, non-regulatory and regulatory watershed programs, environmental assessment requirements, and zoning. The protection of a water source by a utility can range from simple sanitary surveys of a watershed to the development and implementation of complex land use controls.

Water supply source protection should play an important role in the overall management of a municipal water utility. Contamination of a water source can result from point and nonpoint sources of pollution such as chemical spills, waste discharges, or the improper use and runoff of insecticides and herbicides. The contamination of a water supply source can result in the need to develop expensive treatment systems or to find new sources for water supply.[4]

Drought Management Planning

When less rain falls than usual, there is less water to maintain normal soil moisture, stream flows, and reservoir levels and to recharge groundwater. Falling levels of surface waters create unattractive areas of exposed shoreline and reduce the capacity of surface waters to dilute and carry municipal and industrial wastewater. Water quality often decreases as water quantity decreases, adversely affecting fish and wildlife habitats. In addition, dry conditions make trees more prone to insect damage and disease and increase the potential for grass and forest fires.

A drought management plan should address a range of issues, from political and technical matters to public involvement. Managing a resource essential to people's welfare during disaster and dealing with the associated emotional, economic, and physical consequences makes drought management a very challenging task.[4]

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