# A Guide to Virginia's Ground Water

VIRGINIA WATER RESOURCES RESEARCH CENTER

VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY
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# A GUIDE TO VIRGINIA'S GROUND WATER


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Replaces original 1984 publication, *A Groundwater Primer for Virginians*,
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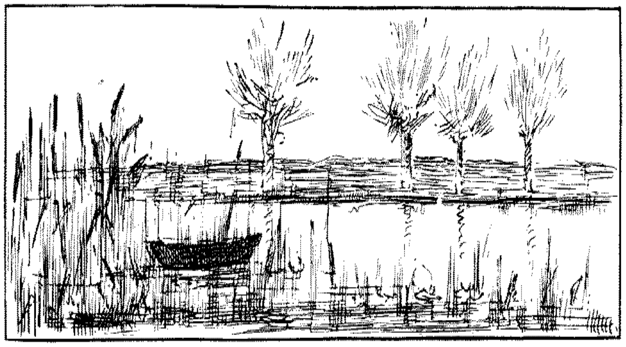
# INTRODUCTION



From the sandy Atlantic shores to the lofty Blue Ridge Mountains to the vast coalfields of southwestern Virginia, the Commonwealth has a rich and varied supply of natural resources. In the state are found extensive hardwood forests, numerous free-flowing streams and rivers, hundreds of square miles of wetlands, and abundant wildlife. Virginia also has an important and vital resource that is hidden in its natural surroundings — one that is used every day by Virginians to drink, wash, irrigate crops, manufacture food and clothing, and serves countless other useful purposes.

This hidden resource is *ground water* - the water beneath the earth's surface. It is the water source that supplies wells and springs. With the exception of ocean water, ground water makes up almost 50 percent of the world's water supply.

Nationally, the U.S. Geological Survey (USGS) estimates that 40 percent of the water used in public supply systems comes from ground water and that 97 percent of the rural population depends on ground water in their daily lives. According to the USGS, in 1992 Virginians used 195 million gallons per day of ground water. Of this total, manufacturing and agriculture used 61 percent of the total ground water withdrawn (Mgal/d). (Figure 1)

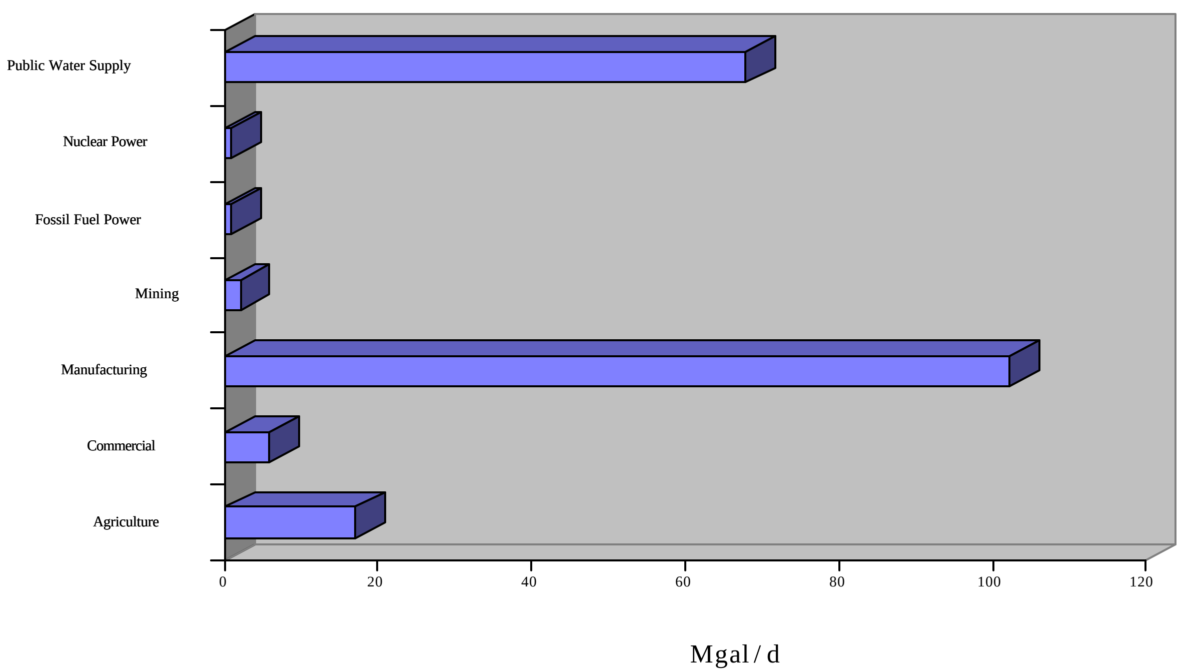



**Figure 1. Estimated ground water use in Virginia for 1992.**

# WHAT IS GROUND WATER?

Ground water is a renewable resource that is widely distributed beneath the earth's surface. Most people are surprised to learn that there is more fresh water underground than exists in surface rivers, streams, and lakes. How ground water occurs in nature, what makes it flow, how fast it moves, what threatens its quality, and how it can be protected and wisely managed are topics that will be explored in this publication.

Although Virginia's ground water quality is generally good, this vital resource is threatened by many potential contaminants, and there have been isolated cases of serious ground water pollution in the state. By law, Virginia is committed to a policy of –anti-degradationÓ of all state waters, including ground water. (See State Water Control Law 62.1-44.4(2).)

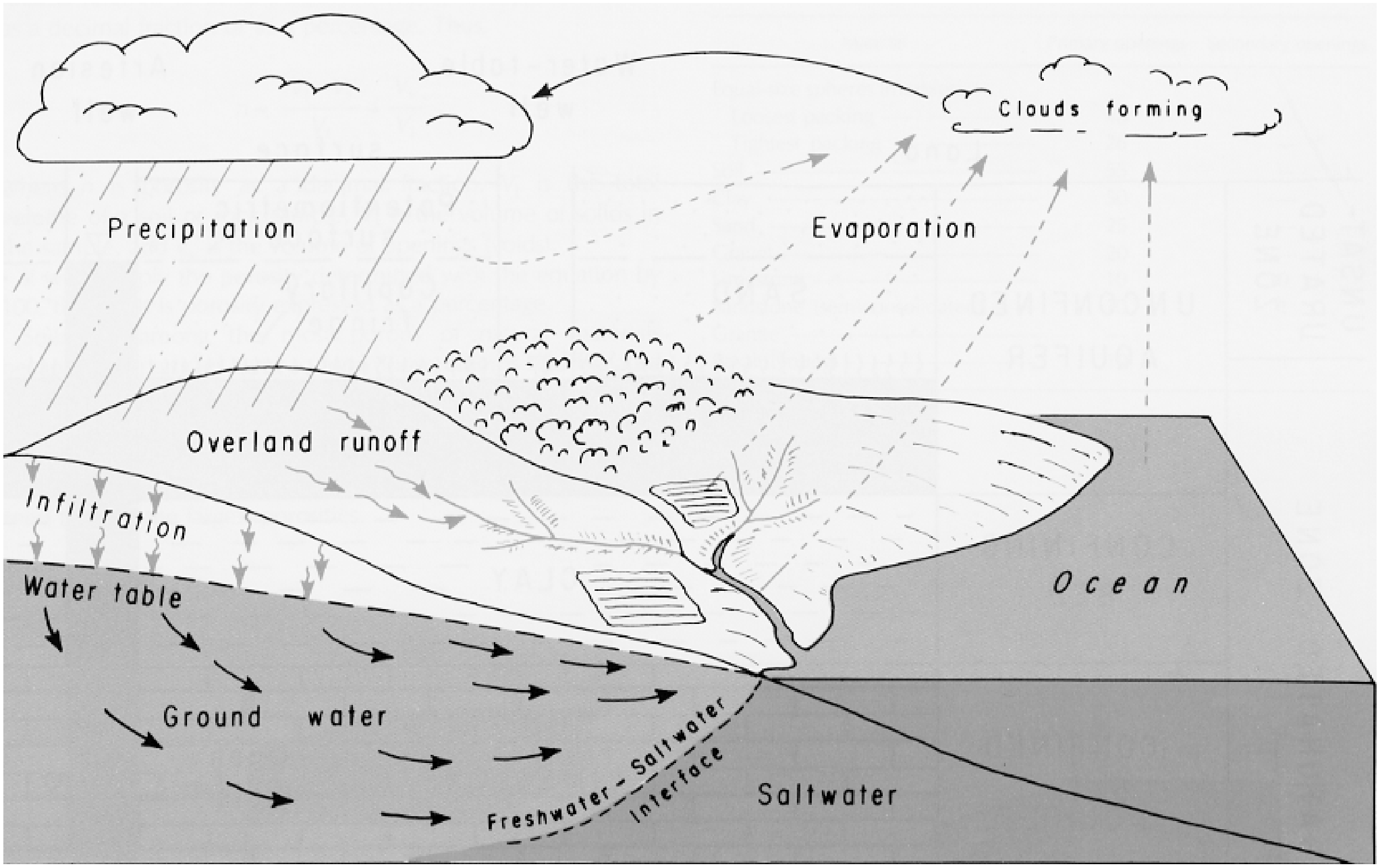
However, regulations and policy making can only go so far. The key to ensuring the quality of the state's ground water is the education of its citizens about the importance of ground water, its protection, and the prevention of ground water contamination. We should all share a deep concern for this priceless resource.

**State Water Control Law,**

**VA. Code 62.1-44.4(2)**

Water whose existing quality is better than the established standards as of the date on which such standards become effective will be maintained at high quality; provided that the Board has the power to authorize any project or development, which would constitute a new or an increased discharge of effluent to high quality water, when it has been affirmatively demonstrated that a change is justifiable to provide necessary economic or social development; and provided; further, that the necessary degree of waste treatment to maintain high quality will be required where physically and economically feasible. Present and anticipated use of such waters will be preserved and protected.

# HOW GROUND WATER OCCURS IN NATURE




Source: *Basic Ground Water Hydrology*

**Figure 2. The movement of water through the hydrologic cycle.**

## The Hydrologic Cycle

Water is in a constant state of movement over, in, and through the earth. It is in a constant state of change — from a solid, to a liquid, or to a gas. Because there is no beginning or end to the hydrologic cycle (Figure 2), the water we use today may have evaporated from an ocean, traveled through the atmosphere, fallen back to the earth's surface, gone underground, from there moved to streams leading back to the seas, and evaporated to the atmosphere many times.

When moisture enters the atmosphere, clouds are formed and produce precipitation. This precipitation falls to the earth as rain, snow, or hail. Above ground, water is readily visible in many forms — clouds, rain, snow, fog, lakes, streams, oceans, or polar icecaps. Because ground water is out of sight, our understanding of its role in the hydrologic cycle has been hindered by the difficulty of observing and measuring the properties and extent of ground water. The length of time water remains underground varies greatly. Water may spend as little as days or weeks underground or as much as 10,000 or more years, while the average turnover time for river water is about 2 weeks. Consequently, many popular misconceptions exist about ground water. Some of these beliefs are based more on folklore and fantasy than on fact. (See Ground Water Myths below)

The lack of information about the origin, occurrence, and movement of ground water has not prevented people from using it. Ground water supplies have been tapped for thousands of years, but only recently have we started to understand its characteristics and properties. Much remains to be discovered about ground water.

***GROUND WATER MYTHS***

**All ground water occurs as vast underground lakes and rivers.**

**Ground water cannot be polluted because it is so far underground.**

**If polluted or contaminated, ground water is easily cleaned as it moves through the earth.**

**Water rushes so rapidly underground that its presence can be detected by listening.**

**Ground water migrates thousands of miles through the earth.**

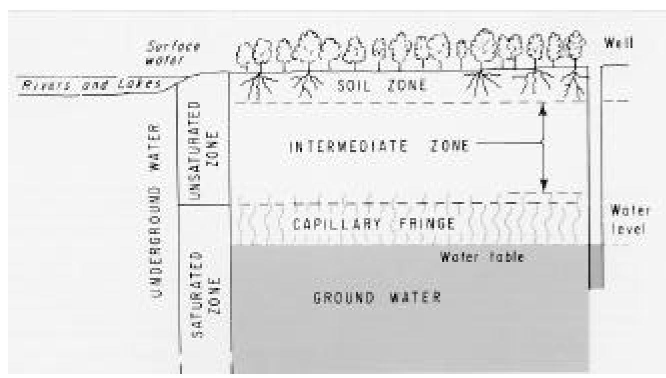
**There is no relationship between ground water and surface water.**

**Ground water is an unimportant water supply source.**

### Underground Water or Subsurface Water

Understanding the concept of the hydrologic cycle is important when discussing the occurrence of underground (or subsurface) water. When water falls to the earth as precipitation, it wets vegetation and other surfaces, and begins to infiltrate into the ground. Infiltration rates vary widely, depending on land use, the character and moisture content of the soil, and the intensity and duration of precipitation, from possibly as much as an inch per hour in mature forests on sandy soils to a few millimeters per hour in clayey and silty soils to zero in paved areas. Underground water occurs in two different zones. The first zone it encounters is the *unsaturated zone,* where soil pores are filled partly with air and partly with water. In most areas, this zone is directly beneath the earth's surface. Under-neath the unsaturated zone is the zone in which all interconnected openings are full of water. This zone is referred to as the *saturated zone* and is the ground water that supplies wells and springs. Water percolating from the land surface through the unsaturated zone recharges the saturated zone.

The unsaturated zone (Figure 3) is divided into three sections: the soil zone, the intermediate zone, and the upper part of the capillary fringe. Extending from the land surface to a maximum depth of a meter or two is the soil zone. This zone supports plant growth and is crisscrossed by live and decayed plant roots, and by animal and worm burrows. Bacteria, fungi, and insects are also found in the soil zone. The intermediate zone is beneath the soil zone and varies in depth depending on the soil type and capillary fringe thickness. The capillary fringe is situated between the unsaturated and saturated zones, beginning at the lowest part of the unsaturated zone.




Source: *Basic Ground Water Hydrology*

**Figure 3. Underground water zones**

Capillary water is the result of the attraction between soil and water. Water clings as a film on the surface of soil particles and rises in small-diameter pores against the pull of gravity. Water is drawn upward into the capillary fringe above the water table in much the same way that a sand-filled tube placed in a cup of water pulls water to the top of the tube. Water in the capillary fringe and in the overlying part of the unsaturated zone is under less pressure than the atmospheric (barometric) pressure. The water table is the level in the saturated zone at which the hydraulic pressure is equal to atmospheric pressure and is represented by the water level in unused wells. Below the water table, the hydraulic pressure increases with increasing depth.

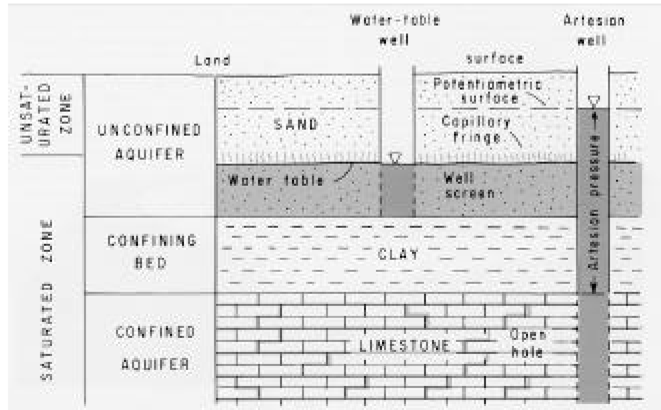
Water flows downward through the unsaturated zone into the *saturated zone,* where all pores are filled with water. The upper boundary of the saturated zone is called the *water table.* When water enters the saturated zone, the water table rises. Conversely, the water table falls when water is pumped from the saturated zone. Water in the saturated zone is commonly referred to as *ground water.* Ground water continues its movement downward and outward to hillside springs, streambeds, lakes, or oceans where evaporation takes place and the hydrologic cycle is continued.

## Aquifers

Geologic deposits largely govern the distribution and movement of ground water. Ground water occurs in many types of geologic formations; those formations that will yield water in usable quantities to wells or springs are known as *aquifers.*

### Types of Aquifers

*Aquifers* occur most commonly in unconsolidated sands and gravel, permeable sedimentary rocks such as sandstone, limestone, and dolomite, and heavily fractured rocks. For practical purposes, aquifers are categorized as unconfined and confined. (Figure 4) The water table forms the upper boundary of an *unconfined* aquifer. Water levels in wells drilled in unconfined aquifers indicate the position of the water table in the surrounding aquifer. In unconfined aquifers, the water table depth is an important factor influencing land use. A shallow water table may limit residential development due to an inability to install an on-site sewage disposal system. Also, a shallow water table may limit excavation work during construction and development of industrial sites.




Source: Basic Ground Water Hydrology

**Figure 4. Aquifers and confining beds.**

A *confined,* or artesian, aquifer is confined or –sandwichedÓ between two aquitards (layers of very low permeability). Ground water is stored and transmitted slowly in aquitards, and the development of production wells is unlikely. Clays, shales, and dense rocks are the most common aquitards.

In reality, since some water leaks through aquitards into the aquifer, most confined aquifers are –leakyÓ aquifers. If a well is drilled into a confined aquifer, pressure in the aquifer causes the water level to rise above the top of the aquifer. If the water level in the well rises above the ground surface, the well is called a *flowing artesian well.* Confined aquifers are found at greater depths than unconfined aquifers.

### Ground water in Unconsolidated Geologic Deposits

A common misconception is that ground water occurs in the form of underground lakes and rivers, just as freshwater lakes and rivers occur at the earth's surface. In fact, ground water does not resemble a lake. Water under the earth's surface collects in numerous pores (open spaces) between unconsolidated (loose) particles of sand, gravel, rock and soil. Unconsolidated geologic deposits are formed from the disintegration of consolidated rocks and range in thickness from a few centimeters to more than 12,000 meters.

A simple way to picture ground water in an unconsolidated geologic deposit is to think of a glass fishbowl full of aquarium gravel and half full of water. (Figure 5) The pores between the gravel particles in the bottom half of the bowl are filled with water — this represents ground water in the saturated zone — while the pore spaces between the gravel particles in the top half of the bowl are filled with air. The boundary between the top half and the bottom half represents the water table and the top surface of the gravel represents the earth's surface.

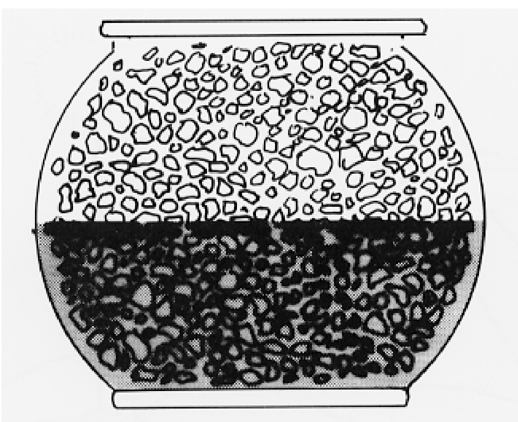


**Figure 5. Ground water in an unconsolidated geologic deposit, represented by a half-filled fishbowl of gravel, occupies all the spaces between gravel particles.**

An unconsolidated geologic deposit also resembles a household sponge. Water in a sponge is held in the many open spaces that exist between the sponge's fibers in the same way that ground water fills the open spaces that exist between particles of rock, sand, gravel, and soil in an aquifer. Virginia's Coastal Plain is a region underlain by shallow aquifers that closely resemble this sponge model.

## Ground water in Consolidated Geologic Deposits

In addition to collecting in the networks of pores in unconsolidated geologic deposits of sands and gravel, ground water also occurs in consolidated geologic deposits. Consolidated geologic deposits are solid rock masses that have been melted by heat and pressure or chemical reactions rather than loose, individual particles. There are three general classes of consolidated rocks. Igneous rocks, such as granite and basalt are formed directly from molten rock. Rocks that have been altered by intense heat and pressure are metamorphic rocks. Slate is an example of a metamorphic rock. Sedimentary rocks, such as limestone, sandstone, dolomite, shale, siltstone, and conglomerate are formed from sediment.

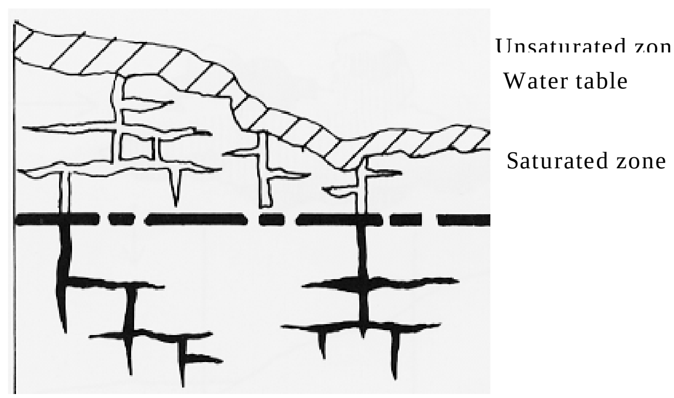



**Figure 6. Ground water in a consolidated geologic deposit fills cracks and channels in the rock.**

Ground water occurs in pores, cracks, fissures, and solution channels in consolidated geologic deposits. (Figure 6) Fissures and cracks are created by shifts and movements within the earth, and by weathering at or near the earth's surface. The size and number of fissures and cracks and the degree to which cracks intersect to form networks vary locally and regionally among geologic formations.

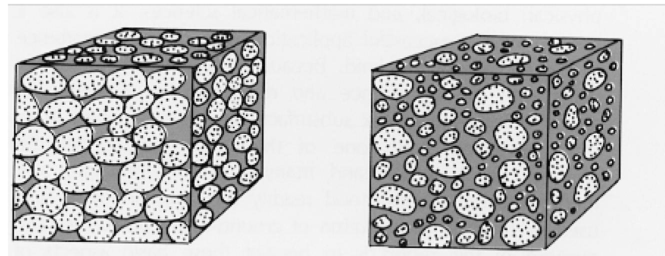
*Solution channels* begin as cracks and joints and become enlarged over time by the dissolving action of water on certain types of rock. Limestone and dolomite are particularly susceptible to this dissolving action. Rock dissolution produces irregular land surfaces known as karst landscape. Karst terrain is usually formed on limestone and dolomite but can also develop on gypsum or rock shale. Depressions known as sink holes are formed. Large areas of Virginia's Valley and Ridge region are underlain by limestone and dolomite and are identified as karst terrain.

**Solution channels are formed by ground water's dissolution of rock formations.**

Once solution channels have developed, they function more like pipes than sponges in conveying ground water. The size, number, and extent of solution channel interconnections vary among deposits and from region to region. Some channels are so well connected that they resemble streams.

## Porosity and Permeability

The porosity of unconsolidated geologic deposits can be defined as the void space or pore openings between solid particles. Porosity is primarily dependent on the range of grain size, referred to as particle sorting, and to a lesser degree on the shape of individual particles. Porosity is not directly dependent on individual particle size. Generally, smaller grain sediments are better sorted and have a higher degree of porosity; larger grain sediments are not as well sorted with a tendency for smaller grain sediments to fill the pore openings and have a lower degree of porosity. (Figure 7) This type of porosity is referred to as primary porosity. Unconsolidated material also may have some degree of secondary porosity that is due to pore spaces that are created by root holes and animal borrows.



Source: *Basic Ground Water Hydrology*, USGS.

(a) (b)

**Figure 7. Examples of (a) well-sorted sand and (b) poorly-sorted sand.**

Consolidated geologic deposits also have some degree of primary porosity. The process of converting an unconsolidated deposit to a consolidated deposit generally results in the reduction of primary porosity as pores are filled with chemical precipitates (cementation) and the deposit is physically compressed. Consolidated geologic deposits generally have a higher degree of secondary porosity than primary porosity. Secondary porosity in consolidated deposits is due to pore spaces that have been created by fracturing and solution activity along fractures. Total porosity is generally lower in consolidated deposits than in unconsolidated deposits.

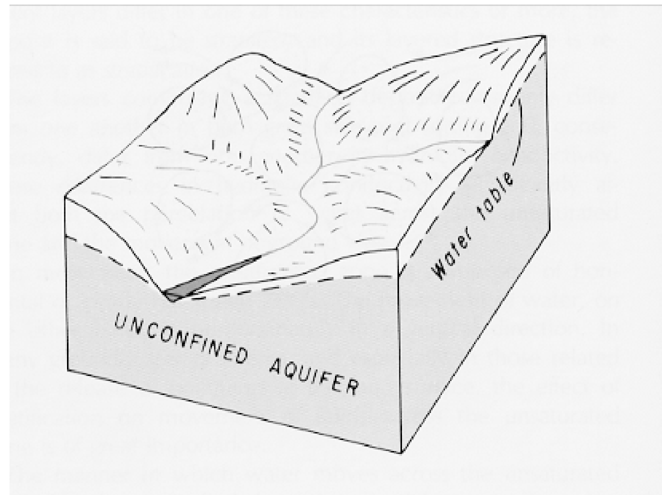
Permeability is a qualitative term that describes an aquifer's ability to transmit water. An aquifer's permeability is dependent on the extent to which the pore openings are interconnected. The degree that pore spaces are interconnected is very dependent on particle shape. Uncon-solidated geologic deposits that are formed of spherical or –ballshapedÓ particles tend to have higher permeabilities (pore spaces are more connected) than those composed of particles that tend to be flat. Permeability in consolidated geologic deposits is generally controlled by secondary porosity and is dependent on the number and degree of connection of fractures and solution features.

The importance of both porosity and permeability can be best understood by comparing coarse sand to clay, both unconsolidated geologic materials. Coarse sand deposits have varying grain sizes and are not well sorted, therefore, the porosity is lower than in clays where the grain size is well sorted. Coarse sand deposits are formed of semi-spherical ball shaped particles and have higher permeabilities than clay deposits which are formed of flat platy-shaped particles. A saturated clay deposit contains more water than an equal volume of saturated coarse sand, but the clay cannot readily transmit the water due to the low permeability.

## Ground Water Flow

Under natural conditions, ground water moves –downhillÓ under the force of gravity, until it reaches a surface outlet such as a spring, a seep along the bank of a stream, or a marsh. The depth from the land surface to the water table of an unconfined aquifer is greater along the uplands than it is downslope in the lowlands, such as a floodplain. However, in general, an area's water table topography mimics the topography of the land surface above, so the slope of the land surface can serve as a reliable indicator of regional ground water flow directions for unconfined aquifers.

The overall slope of the water table is toward streams, valleys, and the oceans. (Figure 8) This means that the ground water in unconfined aquifers usually moves from uplands toward surface waters. Local geologic conditions, such as the orientation of cracks and fissures in consolidated geologic deposits can cause complex ground water flow patterns that do not conform to this simple flow model.




Source: *Basic Ground Water Hydrology*, USGS.

**Figure 8. The water table is typically parallel to the earth's surface, so the slope of the land gives a general indication of ground water flow directions for unconfined aquifers.**

Ground water flow rates in unconsolidated geologic deposits are low, often only a few inches a day. The flow is smooth and the water travels along paths that are relatively straight and parallel to each other. But, in consolidated geologic deposits, where ground water flow resembles flow through pipes, water flows faster and in a more turbulent way, with a great deal more mixing. The natural flow of ground water is strongly dependent on the nature of the geologic formation in which the ground water is stored and through which it moves.

Ground water flow direction becomes important when choosing sites for septic systems, waste ponds, and waste disposal facilities in relation to wells. Where simple ground water flow patterns have been identified, such sites should be located downhill from wells. In areas with complex flow patterns, the surface topography cannot be dependent upon to accurately reflect the ground water flow direction. Choosing locations for waste disposal facilities requires more detailed study to ensure that the facility is built –downhill from wells with respect to ground water flow direction.

## Recharge and Discharge

The process by which water — from rainfall, snowmelt, and other sources such as streams and rivers — flows into a waterbearing geologic formation is known as *recharge.* The land surface through which a particular geologic formation is recharged is known as that formation's recharge area. Recharge of the saturated zone occurs as water seeps down through the unsaturated zone. The condition of the unsaturated zone is important to the ground water underlying it because incoming water seeping down through the unsaturated zone into the saturated zone can affect both the quantity and quality of ground water in a recharge area.

Recharge rates vary in different parts of the state depending on the amount of precipitation, air temperature, land use, and other factors. Generally, recharge areas are in topographically high places and the unsaturated zone is a very thick layer between the water table and land surface.

Discharge areas are where ground water is flowing toward the surface and escapes as springs, seepage into stream channels, lakes, or wetlands, and by evaporation from the upper part of the capillary fringe. In discharge areas, the water table is either close to or at the land surface and is usually in topographically low lying areas. In general, discharge areas are much smaller than recharge areas. (Figure 9)

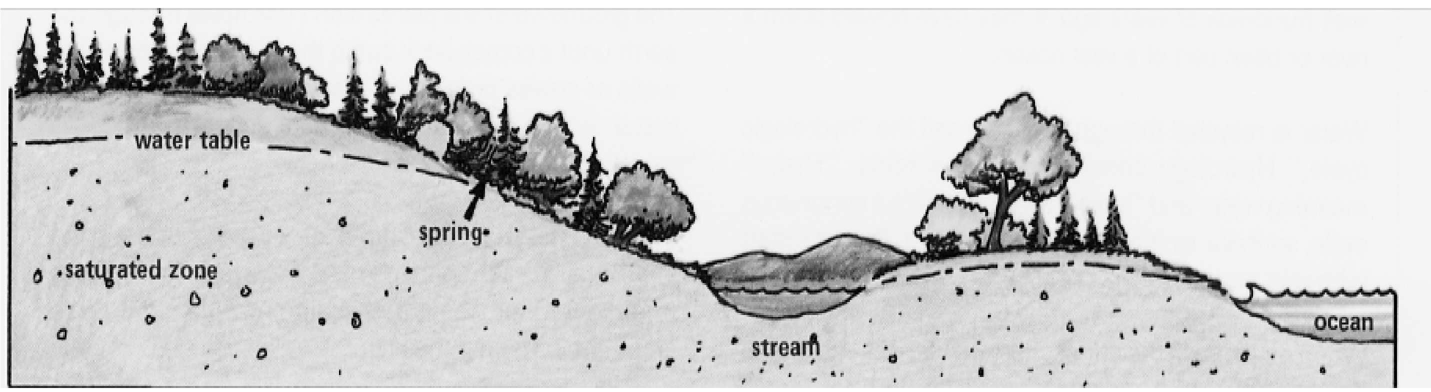



**Figure 9. Possible ground water discharge locations are springs, streams, lakes, and oceans.**

# CONNECTIONS BETWEEN GROUND WATER AND SURFACE WATER

As part of the hydrologic cycle, water moves between aquifers and surface water bodies. Aquifers do not act solely as water receivers nor are they ''dead ends'' in the hydrologic cycle. Streams, lakes, springs, and wetlands receive naturally occurring ground water discharge from aquifers. *A gaining stream is* one that receives ground water; a *losing stream is* one that recharges ground water. For example, when a stream floods, the water table near the stream banks is temporarily raised by inflow from the stream. Seasonal stream flow fluctuations can produce large variations in the amount and direction of local ground water flow. During extended dry periods, ground water discharge may be the only contributor to a stream's flow.

While interaction between surface and ground water is an important part of the hydrologic cycle, it can also play an important role in contaminant transfer. Contaminated ground water may contribute to the degradation of surface waters when and where ground water discharges occur. Understanding surface and ground water interactions and identifying discharge and recharge areas have been recognized as important considerations in water resources management.

**Stream flooding can temporarily cause the water table near the stream banks to rise.**

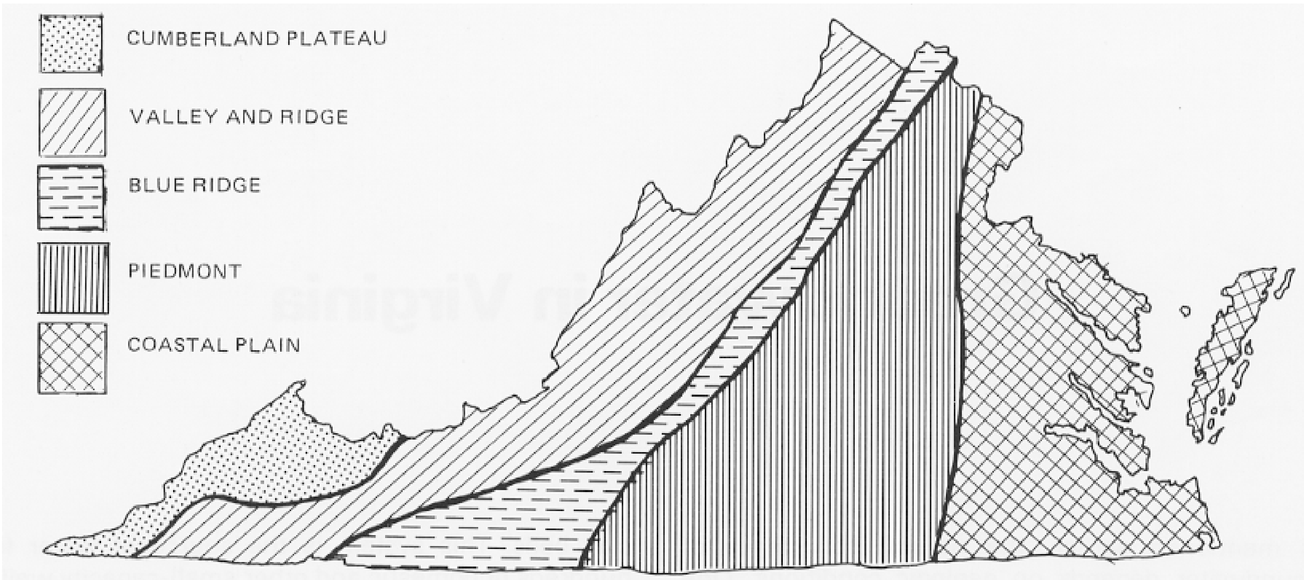



**Figure 10. Ground water availability varies among the five physiographic provinces of Virginia.**

The natural occurrence of ground water depends on the geological conditions. One way of understanding various geologic formations is to find the similarities in their histories. A region of similar geologic structure and climate that has a characteristic set of landforms is called a *physiographic province.* In Virginia, five such physiographic regions are recognized. (Figure 10) Moving from east to west, the physiographic provinces are the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Cumberland (or Appalachian) Plateau.

## Coastal Plain

Virginia's Coastal Plain is the only physiographic region in the state that is composed mostly of unconsolidated geologic deposits. The Coastal Plain extends inland about 110 miles, from the Atlantic coast to the fall zone, an imaginary north-south line that passes through Fairfax, Fredericksburg, Richmond, Petersburg, and Emporia. The fall zone crosses Virginia's rivers at the points where they descend from the uplands of the Piedmont to the coastal lowlands. Coastal Plain deposits are alternating layers of unconsolidated sand, gravel, silt, shell strata, and clay. These beds do not lie flat, but slope generally southeastward. Coastal Plain deposits are wedge-shaped, thickening from a featheredge at the fall zone to more than 3,000 feet at the Atlantic shoreline.

Almost half of the state's ground water use occurs in the Coastal Plain, which has two separate ground water systems (similar to the two aquifers shown in Figure 11). In many places, a shallow unconfined aquifer lies above relatively impermeable clay beds. This system is the source of water for hundreds of domestic and other small-capacity wells, and is similar to the sponge model described previously.

A second deeper system of artesian aquifers is the principal source of ground water in the Coastal Plain, from which wells withdraw approximately 160 million gallons of water a day. The principal recharge area for these aquifers is the land around the fall zone where the aquifers outcrop. Recharge to these aquifers also occurs through –leaksÓ in the confining beds above them, which are overlain by unconfined aquifers. Farther east toward the coast, these aquifers become thicker and lie deeper underground. Because of the thickness and areal extent of the Coastal Plain’s artesian aquifers, their ground water storage capacity is enormous. These aquifers store more ground water than the aquifers of any other physiographic province in Virginia. However, pumping has modified the original aquifer conditions and caused a general lowering of artesian pressure.

Generally, the water quality in the Coastal Plain aquifers is good, except in aquifers near the ocean, where saltwater zones commonly occur. Water from the deep aquifers generally contains chloride concentrations of more than 500 parts per million on much of the lower York-James Peninsula and the Norfolk--Virginia Beach area, making the water too salty for domestic use without treatment. There is a moderate pollution potential except in the shallow aquifers where the pollution potential increases.

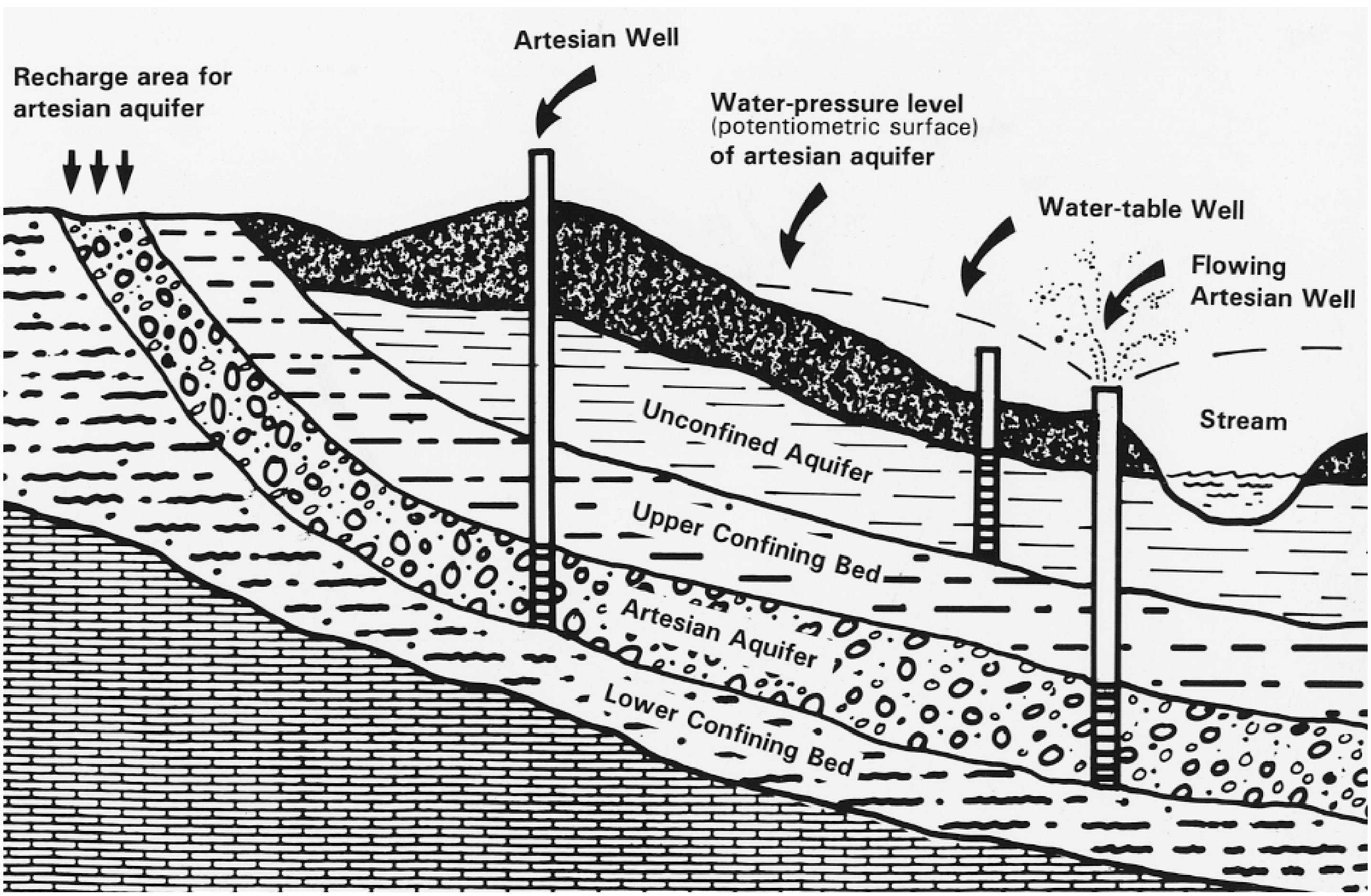



**Figure 11. When a well is drilled in a water-table aquifer, water will only rise to the top of the aquifer. An artesian aquifer is under greater pressure because it is confined between aquitards. When a well is drilled in such an aquifer, the pressure is sometimes great enough to force water all the way up to the earth’s surface**

## Piedmont

The central section of Virginia, bordered by the fall zone on the east and the Blue Ridge Mountains on the west, is known as the Piedmont province, and is Virginia's largest physiographic region. The region is largely dominated by igneous and metamorphic rocks, with some areas of sedimentary rocks. No extensive unconsolidated geologic deposits overlie the bedrock of the Piedmont; fractures and faults in the bedrock store and transmit ground water. The size and number of water-bearing fractures decrease with depth, so significant water supplies are generally limited to within a few hundred feet of the surface.

Ground water production potential is much lower in the Piedmont than in the Coastal Plain. Ground water use at many locations in the Piedmont is limited by quantity or quality problems. Because the Piedmont's subsur-face geologic features are diverse, there is a wide variation in ground water quality and yield, making well site evaluation very important. Well yields commonly range from 3 to 20 gallons a minute; yields in excess of 50 gallons a minute are considered exceptional. Fairly large yields of water may be obtained where fracture and fault systems are extensive, as in the western Piedmont along the base of the Blue Ridge Mountains. The potential for ground water pollution is low to moderate.

In some places, disintegration and decom-position of the granite bedrock form a zone of granular material, which serves as an aquifer that can supply modest quantities of water to shallow wells. Such aquifers are generally not very thick and recharge is slow since the overlying soil is mostly composed of clay. The water frequently contains relatively large amounts of iron and sulfur.

Areas of sandstone and shale are scattered throughout the Piedmont, and bedrock is usually within 2 to 10 feet of the surface. Beds of sandstone and conglomerate (fragments of rock or pebbles cemented together by another mineral substance) in these basins can serve as fair to moderately good aquifers.

## Blue Ridge

To the west of the Piedmont lies the Blue Ridge province, a relatively narrow zone of mountains with the highest elevations in the state. This province extends north-easterly from the North Carolina border across the state and is 4 to 25 miles wide.

The bedrock is near the surface, beneath a thin soil layer and weathered rock zone. Rocks below the weathered zone are relatively impervious and contain water primarily in joints, fractures, and fault zones. Igneous and metamorphic rocks are most common in the eastern flank of the Blue Ridge. Sedimentary rocks are found on the western flank. The most favorable areas for ground water accumulation are the lower slopes of the mountains. In general, well yields are low.

Ground water use has been primarily limited to domestic needs. Springs are common and are often used for private water supplies. Water found in cracks or fissures may move rapidly causing a high potential for pollution. Ground water in the Blue Ridge is not highly mineralized because the rocks in contact with the water are relatively insoluble, but the iron content of the water is high in some locations.

## Valley and Ridge

The Valley and Ridge province, to the west of the Blue Ridge Mountains, is underlain by consolidated sedimentary rocks that were deposited beneath ancient seas and have been intensely folded. Limestone, dolomite, shale, and conglomerate are the common rock types in the Valley and Ridge region. Limestone and dolomite occur beneath lowlands, such as the Shenandoah Valley, where they consistently form the most productive aquifers in Virginia's consolidated rock formations. Karst features such as sinkholes, caves, and large springs are found in the Valley and Ridge province. Limestone frequently contains underground channels that store and transmit ground water. Ridges and upland areas are often underlain by sandstone and shale, which yield limited amounts of water.

The relationship between ground water and surface water in the Valley and Ridge is more easily recognized than in the other physiographic regions. In limestone areas, sizable surface streams disappear into underground channels and, conversely, some large springs serve as headwaters of surface stream flow. Rapid movement of ground water in the limestone areas makes the pollution potential high. Aquifers are often recharged directly by streams crossing fault zones. A fault can divert surface flow and act as a pipe to carry water underground to an aquifer. Wells in the fault zones of the province generally have the greatest yields.

Recharge also occurs through surface runoff into limestone sinkholes. This direct surface water recharge to aquifers can produce serious water quality problems because the water bypasses filtration through the soil, thereby sidestepping the purification it might undergo in its movement through the soil. The quality of ground water drawn from aquifers recharged this way may be very similar to that of surface water. The chemical composition of the rock formations with which groundwater comes in contact affects ground water quality. For example, limestone formations in the Valley and Ridge region increase the hardness of the ground water. Hard water creates soap films on laundered clothing, sinks, tubs, and leaves a calcium scale behind in pots used for heating water. Mineral deposits can also accumulate on the inside of pipes that convey hard water.

## Cumberland Plateau

The Cumberland Plateau province, also known as the Appalachian Plateau, includes the southwestern tip of Virginia. This province is underlain by sedimentary rocks, primarily sandstone, shale, and coal. Gentle folding of these rock formations has created domes and basins, and faulting has occurred. Ground water quality in the Cumberland Plateau varies with location and depth. Water obtained from bedrock above the stream level is generally of the best quality. The first 100 feet of rock below stream level often contains water with high concentrations of sulfate, sulfite, nitrate, iron, and carbon dioxide. Better quality water is found at depths of 150 to 300 feet below stream level.

Ground water in the Cumberland Plateau is used mostly for domestic purposes and processing coal. Wells generally yield from 10 to 50 gallons a minute; maximum yields are in the range of a few hundred gallons a minute. The pollution potential is moderate.

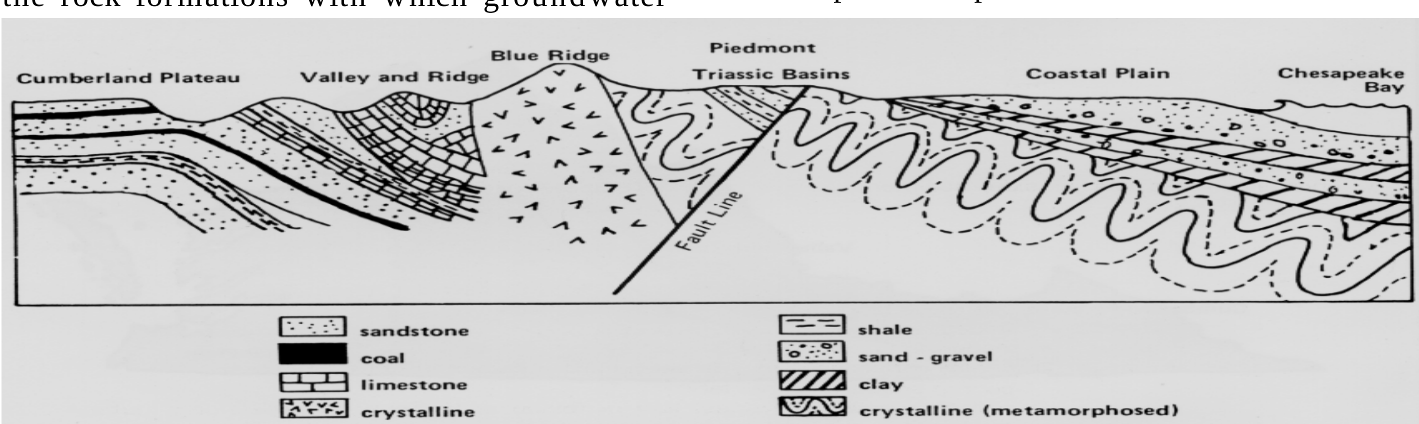



**Figure 12. A simplified cross-section of Virginia shows the five provinces: Cumberland Plateau, Valley and Ridge, Blue Ridge, Piedmont (includes Triassic Basins), and the Coastal Plain. (Used by permission of Lyle Silka, Hydrosystems, Inc.)**

## SOURCES OF GROUND WATER CONTAMINATION

Ground water contamination sources vary in many ways. Some pollutants are found statewide, while others occur locally. Obvious contamination sources, such as landfills, lagoons, and other waste facilities are easily identified. Sources not so easily recognized as potential contamination sources include agricultural, industrial, and mining operations, and naturally occurring processes such as salt water intrusion.

While it is quite common to dispose of waste by burying it, in doing so, we sometimes unwittingly contaminate ground water. Once buried, some wastes are forgotten and become more difficult to locate as time passes. Waste disposed of in surface dumps also poses a threat, especially when rainwater or snowmelt seeps down through it into ground water. Because ground water in many geologic formations moves slowly, a contamination problem can remain undiscovered for years or even decades until the –plumeÓ of contaminated ground water reaches an outlet (usually a well) where it is discovered. Because treating contaminated ground water is difficult and expensive, preventing contaminants from reaching ground water is a better approach to keeping ground water clean.

Potential contaminants that threaten Virginia’s ground water include petroleum products, solid waste, hazardous waste, on- site sewage disposal systems and cesspools, agricultural activities (fertilizers, pesticides, and animal waste), coal mining waste, and salt water intrusion.

### Leaks and Spills of Petroleum Products

Contamination of ground water by petroleum products from leaking tanks, pipelines, and spills is a common occurrence. Because oils and gasoline contain hydro-carbon components that are soluble in water, small amounts (concentrations of less than 0.005 mg/L) can be detected by taste or smell and can render water unfit for human consumption.

Underground storage tanks are recognized as one of the greatest potential threats to ground water quality. Many of these underground storage tanks (USTs) were buried since World War II and at a time when more stringent regulations were not in place. From July 1985 to June 1995, the Department of Environmental Quality received 19,000 pollution complaints. Of these complaints, over 1,600 of them related to pollution from USTs. (Figure 13) The State Water Control Board (SWCB) initiated a new program to register and regulate USTs in 1989. A fund has been established that can be used in conjunction with federal funds to finance cleanup of certain leaking USTs.

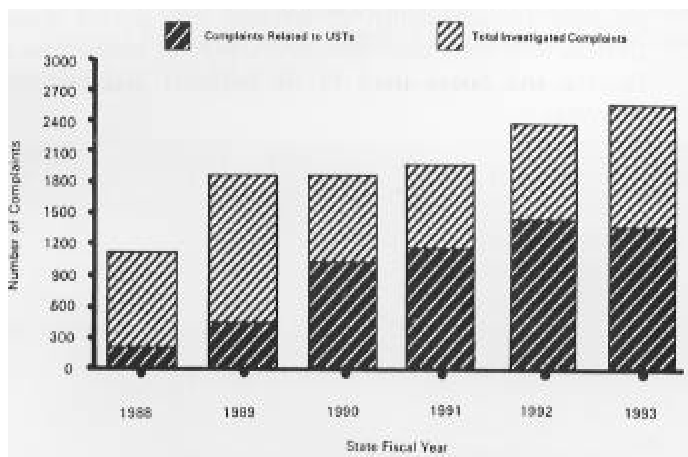



**Figure 13. Pollution complaints made by Virginians in 1993 more than doubled the number of complaints made in 1988.**

Buried home furnace oil tanks pose leakage threats as well. These tanks are generally thin-walled and are vulnerable to corrosion by soil and moisture conditions on the outside, and by accumulated water vapor on the inside. Not only is water quality at risk when leaks occur, but the homeowner loses valuable oil as well.

Motor oil can pose a threat to ground water quality. Over 4 million gallons of used oil are disposed of improperly by do-it-yourself oil changers in Virginia each year. The improper disposal of used motor oil can contaminate ground water.

## Landfills

The *1987 Ground Water Protection Strategy for Virginia* identified landfills as a priority concern for potential ground water contamination. A landfill is any land area set aside for the deposition of solid waste — our trash and garbage. Each person in the U.S. creates an average of 4.5 pounds of trash per day. A *sanitary landfill* is defined by the U.S. Environmental Protection Agency (EPA) as a site where solid waste is disposed of on land without creating public health or safety hazards, by confining the refuse to the smallest practical area, reducing it to the smallest practical volume, and covering it with a layer of earth at the end of each day's operation or more frequently if necessary. A sanitary landfill consists of successive layers of compacted waste and earth, and may be constructed on the ground surface or in excavations.

The most commonly found item in sanitary landfills is household waste. It was found that of the disposed materials in a landfill, fast food packaging only makes up 1 percent, diapers are less than 1 percent, and 9 to 12 percent of the disposed materials are plastics.

*Leaching* is the main problem with the refuse in sanitary landfills and other landfills. Rainwater and snowmelt filtering, or *percolating*, through buried refuse or refuse piles on the land surface can dissolve substances and carry them down through the landfill and into the ground below. The liquid formed by this process is called *leachate*. This leaching process is similar to the drip process of brewing coffee, in which water passes through ground coffee beans and drips into a pot. Leachate from landfills can contain hazardous substances, and if leachate is not captured and treated, it can contaminate ground water.

The hazard posed by landfill leachate to ground water quality depends on the amount of waste, its areal distribution, the composition of the waste itself, and the location, design, and operation of the landfill. Percolation of water through landfills can continue to produce leachate for years. If landfills are situated in appropriate geologic settings and are designed, constructed, and operated correctly, both ground water and surface water pollution can be eliminated or reduced.

Federal and/or state regulations govern the design, construction, and operation of all sanitary landfills, whether they are owned by a municipality or are privately owned. Standards for sanitary landfills set by federal and state authorities require monitoring wells to check for ground water contamination, bi-annual analysis of ground water samples for active and closed sanitary landfills, and remediation of ground water contaminated by leachate. Special clay and plastic liners are to be used in all new sanitary landfills. (Figure 14) There are approximately 6,000 public landfills nationwide that receive more than 75 percent of the trash produced. EPA estimates that 25 percent of the worst toxic waste sites are former landfills.

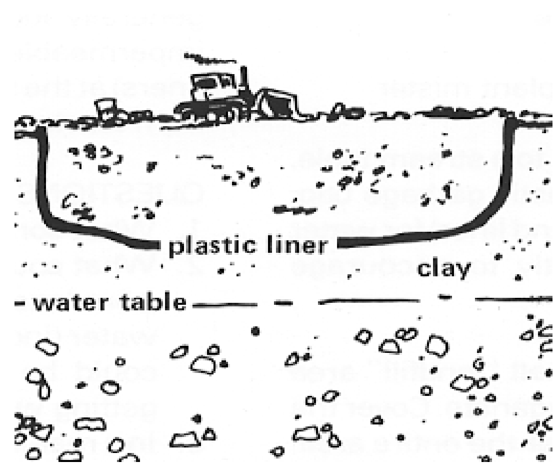



Figure 14. New landfills are designed to prevent leachate from leaving the landfill.

## Hazardous Waste

Hazardous waste is a by-product of certain manufacturing operations. Also, some commercial chemical products are considered hazardous waste once they are discarded. To be regulated as a hazardous waste, a substance must possess certain characteristics (ignitability, corrositivy, reactivity, or toxi-city) or be listed as a Specific or Non-Specific Waste on the Federal Waste Stream List.

The Comprehensive Environmental Re-sponse, Compensation, and Liability Act (CERCLA), commonly known as Superfund, was passed into law by the U.S. Congress in December 1980. Superfund established a pro-gram to identify sites where hazardous substances have been, or might be, released into the environment; to ensure that they are cleaned up by responsible parties or the government; to evaluate damages to natural resources; and to create a claims procedure for parties who have cleaned up sites or spent money to restore natural resources. In 1986, CERCLA was amended by the Super-fund Amendments and Reauthorization Act (SARA), and was an attempt by Congress to put more money to work at more sites and have faster response action. The Superfund program is administered by the EPA and it is the responsibility of the federal agency to oversee the clean up of the National Priority List (NPL) sites. The Virginia Department of Environmental Quality (DEQ) works closely with the EPA and carries out the activities required by law or legal agreements, and in the interest of the Commonwealth and its citizens. A Superfund Memorandum of Agreement (SMOA) was signed between the Department of Waste Management (now part of DEQ) and EPA defining the responsibilities, authorities, and schedules that EPA and the department must recognize for all state activities. Currently, there are 18 private and 7 federal facility NPL sites in the Commonwealth. Two sites have completed remediation and have been removed from the list.

## Onsite Sewage Disposal Systems and Cesspools

Onsite sewage disposal systems and cesspools are the largest of all contributors of wastewater to the ground and are the most frequently reported sources of ground water contamination in the United States. Cesspools, outmoded sewage systems that directly dispose of untreated wastewater in the subsurface, are no longer permitted in Virginia.

Septic systems are the most common type of sewage treatment in areas not served by municipal sewer systems. When properly sited, designed, constructed, and maintained, septic systems can remove many harmful contaminants present in household wastewater. Septic systems should be sited in unsaturated soil that will absorb all wastewater from the system and remove contaminants and disease-causing organisms before they can reach ground water.

Improperly sited septic systems may cause ponding of wastewater on the surface or may allow subsurface wastewater to move too rapidly for adequate treatment by the soil. When many septic systems are concentrated in a small area, their combined wastewater flow may exceed the soil's treatment capacity.

Poorly designed and constructed systems may leak untreated wastewater into the ground water. Even properly functioning septic systems must be periodically inspected and maintained to assure their long-term usefulness. Homeowners must also be careful not to dispose of insecticides, herbicides, or other chemicals in their sinks and toilets. Septic systems are not designed to treat these substances, which can contaminate nearby ground water and may destroy beneficial microorganisms in the septic tank and soil.

If a septic system does not adequately remove bacteria and viruses, these organisms may reach the underlying ground water. Bacteria and viruses from sewage may not travel very

far when transported by ground water through unconsolidated geologic materials. However, in fractured rocks where ground water flow rates can be high, these bacteria and viruses may be transported several miles, and can live below the water table for many days or even months. Ingestion of these bacteria can make people very ill, especially young children and those indiv-iduals with weakened immune systems.

Unless the surrounding soil environment is capable of removing nitrate, wastewater from septic systems may also release nitrate to ground water. Nitrate inputs from septic systems may be negligible in many cases, but in areas with inadequate soil or dense development, septic systems can cause noticeable increases of nitrate in ground water. Though nitrate is a naturally occurring form of nitrogen, at concentrations above 45 parts per million (ppm), it renders water unfit for consumption by infants.

Nitrate levels above 45 ppm can cause *methemoglobinemia,* blue baby disorder, which interferes with the capacity of an infant's blood to carry oxygen. At nitrate concentrations above 450 ppm, water is unsuitable for consumption by livestock. If nitrate-laden ground water reaches surface water, it can cause algae blooms in lakes and streams, disrupting the local ecology and impairing the appearance of these water bodies (i.e., red / brown tides). Nitrate is also suspected to be a factor in certain fish and shellfish diseases such as *Pfisteria.*

The Virginia Department of Health (VDH) regulates onsite sewage disposal systems and drainfields. Before an onsite sewage disposal system can be installed, the VDH must perform a site evaluation of the soil and issue a permit. Important factors in the site evaluation include soil properties which relate to the effectiveness of the drainfield and the location of the drainfield relative to ground water and nearby drinking water wells.

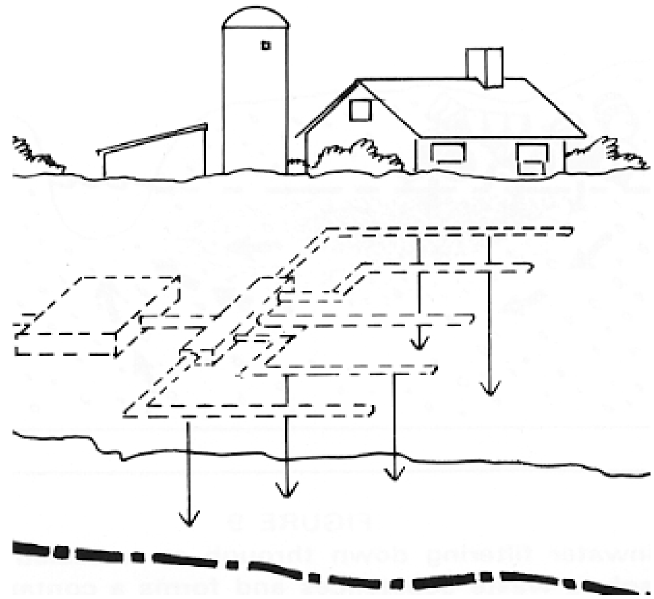


**Figure 15. Wastewater can enter the soil around septic system drainfields and contaminate ground water.**

## Agricultural Activities

Agricultural activities that can cause degradation of ground water quality include the use of fertilizers and pesticides, and storage or disposal of animal wastes. Contamination of ground water by pesticides and fertilizers depends on the rate of application, the decomposition rate, level of water solubility, soil properties, and the depth to ground water.

Nitrogen, in the form of nitrate, is the fertilizer nutrient that most commonly contaminates ground water beneath agri-cultural lands. Other sources of nitrate are human and animal wastes and atmospheric deposition. Ground water near the surface sometimes becomes contaminated by nitrate leaching from holding areas for animal wastes. Even relatively small sources such as farm manure piles, animal waste lagoons, and feedlots can contribute nitrate to ground water. In farming areas, contamination of shallow wells by nitrate and other constituents commonly occurs because of aulty well construction. If wells are not properly sealed by grout or clay along the well bore above the screen, contaminated runoff can easily make its way to the aquifer that supplies water to the well.

**A conventional lagoon for swine waste treatment. (Photo courtesy of E.R. Collins, Virginia Tech.)**

Along with a widespread increase in the use of chemical fertilizers since World War II, there has been rapid development and use of a multitude of pesticides. Pesticides refer to groups of organic compounds used to control weeds (herbicides), insects (insecticides), and fungi (fungicides). Pollution by pesticides is a potential hazard to ground water quality. Sources of pesticides may be from applications to farm fields, orchards, in and around buildings, lawns and gardens, golf courses, parks, and roadways. Problems associated with the disposal of surplus pesticides, waste pesticide materials, and pesticide containers threaten ground water resources as well.

## Coal Mining

Coal mining may contaminate ground water, but relatively little attention has been given to contamination of ground water by coal mining activities. Ways that mining can be hazardous to ground water quality include the following:

- Uncontrolled mining may pollute streams and rivers in an aquifer's recharge area.
- Mining activities may contaminate an aquifer by intersecting it, thereby intro-ducing contaminants.
- Artificial lowering of the water table may expose sulfur-bearing minerals to air, leading to the formation of an acid solution which may enter ground water.
- Tailings ponds used for disposal of wastes from a mine can contribute to ground water contamination through flooding and wastewater discharge.

The recharge and movement of ground water can be affected by coal mining processes. Surface and underground mining alter the environment and pose threats to ground water quality, but land reclamation may prevent serious damage to ground water. Mine dewatering, which involves a regional lowering of the water table, may cause a decrease in the amount of ground water supplies, a lowering of the water level below the intakes of production wells, and the oxidation of exposed minerals, which can create acidic water if the ground water levels rise again causing ground water to dissolve the oxidized minerals.

Acidic ground water is a serious problem in the coal mining areas of Appalachia. Remedies such as neutralizing acid mine-drainage and backfilling abandoned mines are very costly. In parts of Appalachia where coal mining has been carried out over long periods of time, much of the ground water is now so acidic that it may be unusable for decades.

## Salt Water Intrusion

Coastal areas can be affected by saltwater intrusion caused by heavy pumping of ground water. When significant amounts of fresh ground water are pumped out, the heavier, denser saltwater rushes in to fill the spaces. While some geologic formations have naturally occurring salty ground water, there are areas in Virginia that have a greater potential for salt water intrusion. Salt water underlies Virginia Beach, Norfolk, and parts of Chesapeake, and Portsmouth and extends westward in a wedge to the eastern parts of the Isle of Wight and Southampton Counties. Concentrations of 250 milligram per litter (mg/l) can be found at 100 feet below sea level in extreme southeastern Virginia to 1,400 feet below sea level in the Northern Neck. The entire Eastern Shore area of Virginia has salt water at depths of 300 feet or more. Large amounts of saltwater contamination (the standard for safe drink-ing water is 250 milligrams per liter (mg/l) of chloride) can make aquifers unusable for human and animal consumption. (Figure 16)

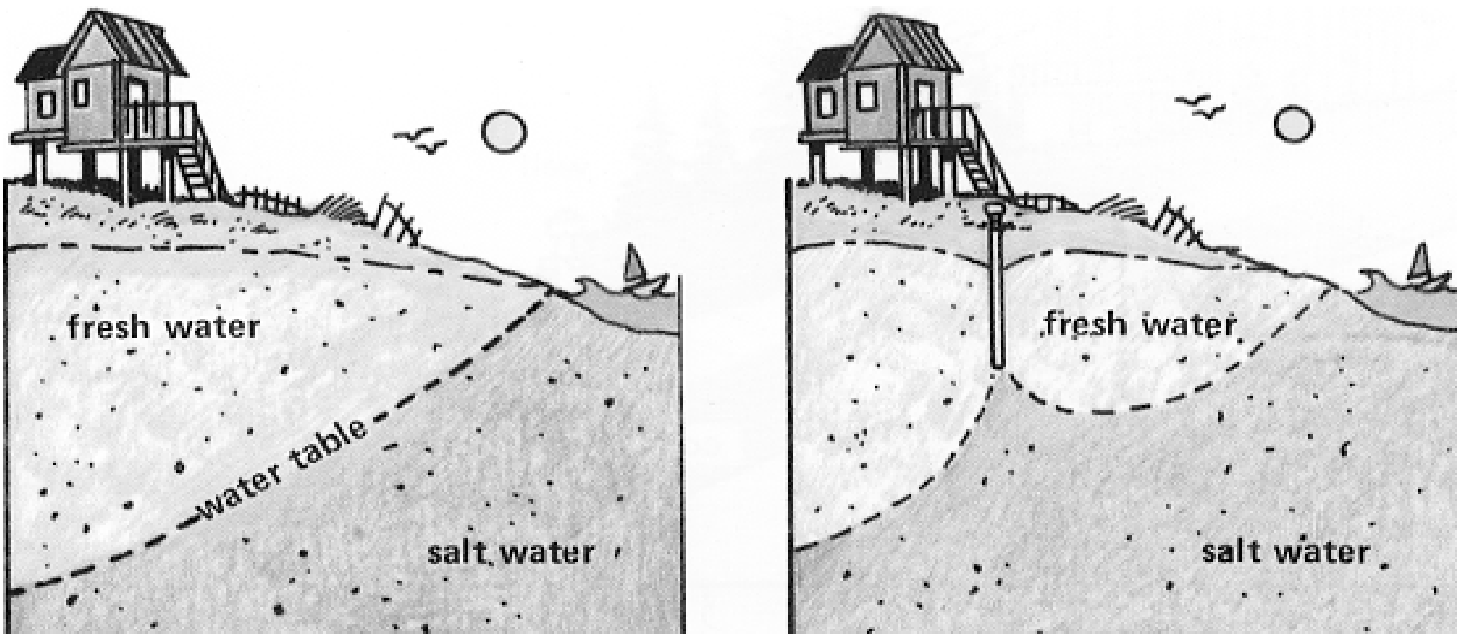
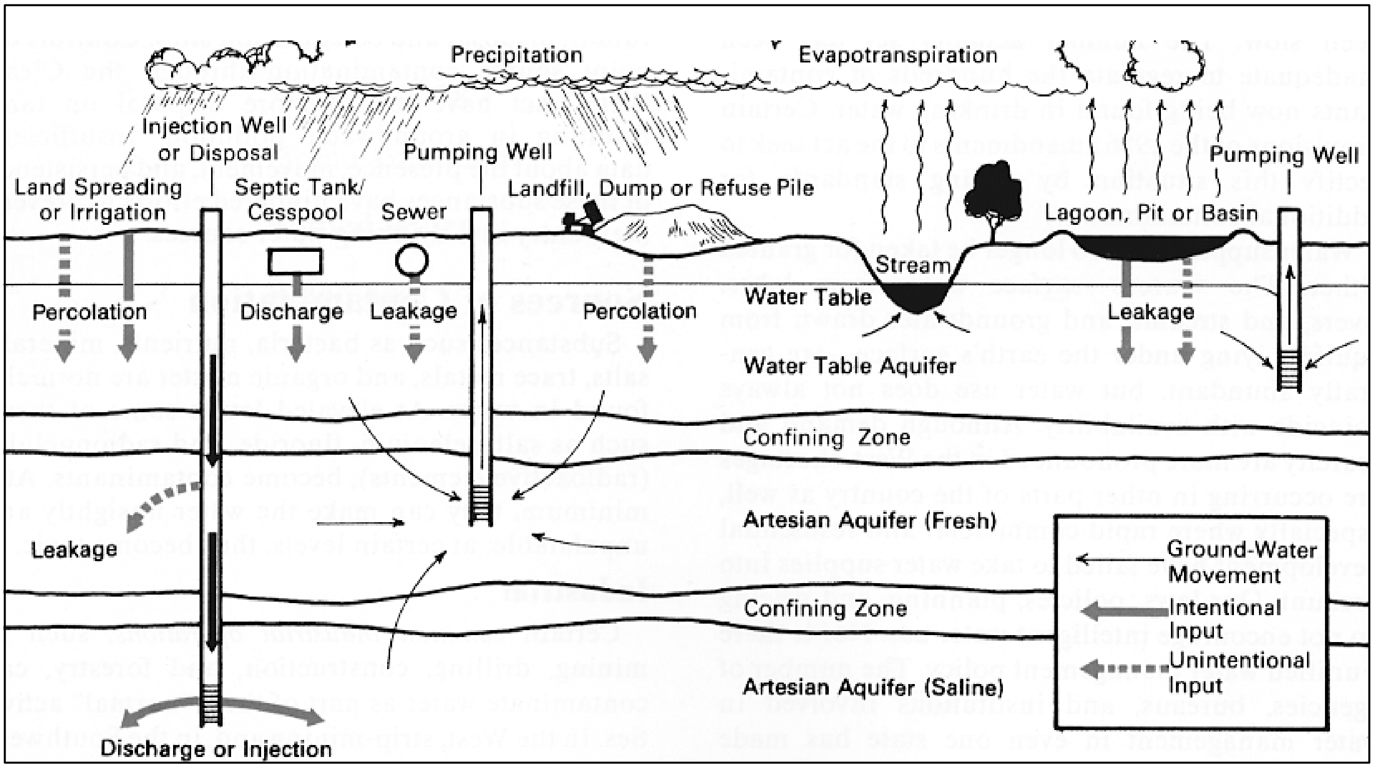



**Figure 16. Overpumping of fresh ground water near the coast allows heavier, denser saltwater to intrude. This problem is called saltwater intrusion.**

# WHAT WE CAN DO TO PROTECT GROUND WATER




Source: U.S. Environmental Protection Agency

**Figure 17. Potential sources of ground water contamination.**

Many of our everyday activities have an impact on ground water quality. With over one million Virginians depending *entirely* on ground water to supply their domestic water needs, it is vital that citizens take action to protect this resource. Users of private water wells have a great deal of control over the quality of their own well water because the recharge area that serves the well is frequently on the same property as the well itself. Well users often are unaware of the link between the quality of water delivered by the well and the conditions on the land surface where rainwater and snowmelt begin to percolate into the ground and recharge the aquifer from which the well draws water. This means that the well users are largely responsible for the quality of their own well water and perhaps for the quality of their neighbor's water.

Eliminating practices that threaten ground water quality can go a long way toward maintaining clean water. Much of the effort aimed at ground water protection involves avoiding harmful practices that might contaminant ground water. Listed below are some guidelines to protect ground water:

## Petroleum Products

Dispose of used motor oil properly. Used motor oil poured in backyards, in streams and rivers, along roadsides, or down storm sewers, can eventually pollute Virginia's water. For do-it-yourself oil changers, collecting used motor oil for recycling is an easy way to protect ground water. Used oil collection centers are located at participating service stations throughout the state. Contact your local service station to find the collection center nearest you. Underground home furnace oil tanks can leak and pollute ground water. Check the area around the tank site for noticeable discharges and monitor the oil level in the tank for possible leakage.

## Pesticides and Commercial Fertilizers

Fertilizers and pesticides should be used with caution on lawns, vegetable and flower gardens, and crop fields. Some fertilizers and pesticides can move with rainwater and snowmelt as they percolate through the soil to ground water or runoff the land surface into streams. The application directions for these substances should be followed care-fully. Do not apply more than is recom-mended.

Improper disposal of pesticides and empty pesticide containers can harm humans and animals and can be a potential source of ground and surface water contamination. Empty pesticide containers and unwanted leftovers should be discarded by taking them to a pesticide collection center, the product's supplier, an approved industrial waste ser-vice, or an approved commercial incinerator. For information about disposal facilities in your area, contact your local extension agent.

The Virginia Department of Agriculture and Consumer Services (VDACS), in cooperation with the Pesticide Control Board and local governments, began a pilot program in 1990 to dispose of unwanted pesticides and recycle used pesticide containers. Half of the coun-ties in the Commonwealth have participated in the disposal program. Contact VDACS or your local extension agent for information.

## Onsite Sewage Disposal Systems

Many homes in Virginia are not connected to a municipal wastewater treatment plant and must rely on an onsite sewage disposal system. These systems can threaten ground water quality when they are improperly designed or poorly maintained. More than 90 percent of the onsite sewage systems installed in Virginia are conventional septic systems. The conventional septic system consists of a septic tank, a flow splitting device (most commonly a distribution box), absorption trenches (drainfield), and soil beneath and around the absorption trenches. (Figure 18)

If the septic tank is not maintained properly, solids may be carried into the distribution lines, resulting in clogged lines and a clogged drainfield. In turn, wastewater can back up into the house's plumbing system or rise to the ground above the drain field. This waste-water can carry disease-causing organisms and pose health hazards. Generally, most families need to pump their tank every three to five years or when the tank reaches the one-third full mark. Onsite sewage disposal systems that are located too close to water wells or uphill from water wells also can pose water quality threats.

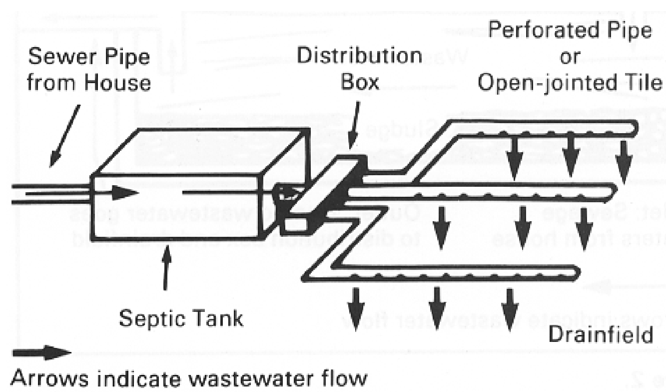



**Figure 18. Conventional onsite sewage waste disposal system.**

**Never** pour or flush toxic or hazardous substances into the septic system. They can pass through a septic system and con-taminate ground water. Such toxic and hazardous chemicals include paints, var-nishes, thinners, waste oils, photographic solutions, and pesticides. Many organic chemicals are marketed under various brand names as septic or sewage system cleansers. Some of these chemicals are toxic and can contribute to ground water contamination and should not be used.

Do not drive cars, tractors, or other heavy equipment over an onsite waste disposal system (particularly the drainfield). The system is not designed to carry heavy loads and there is a risk that parts of the disposal system can be crushed and require replacement. Driving small residential lawn and garden equipment over drainage fields is usually not a problem.

For more information about onsite sewage disposal systems and their maintenance, contact your local health department or the web site: www.vdh.state.va.us/oehs/0.3.htm.

## Water Wells

Private wells can also contribute to ground water contamination if they are poorly constructed or improperly maintained. If little or no grout seals the space between the well casing and the hole in which it is placed, water running over the land surface can flow directly down to the water table carrying a variety of dissolved substances with it. The well pump can then draw these potential contaminants into a home's water system.

Wells should be covered at the top with a cap that will protect the well from surface contaminants. The soil around the wellhead should be graded so that it diverts surface runoff water away from the wellhead.

Pesticides and fertilizers should not be stored in the immediate vicinity of a well. Waste should not be dumped close to the well. Never install underground tanks for storing fuel oil, gasoline, or and diesel fuel near a well. Other sources that pose contamination threats are livestock pens, barns, and abandoned wells that have not been properly filled in and sealed.

Water from private wells should be tested at least once a year by a reputable laboratory experienced in testing drinking water. State-certified laboratories for testing water are located throughout Virginia and can test private well water. Contact your local health department or extension agent for information on water testing or the section on **Information Sources for Water-Related Issues, Programs, and Regulations** in this publication.

## Water Conservation

Conserving household water not only saves water, but money and energy as well. The less water used means the less waste water going through municipal systems or on-site disposal systems for treatment. Buy and install flow restrictors in faucets and shower heads to reduce water use with little or no inconvenience to you and your family. Almost half of all water use in American homes is for flushing toilets. One easy way to reduce the amount of water used to flush toilets is to rinse out an empty plastic one gallon milk jug, cut off the top half, place clean, heavy stones in the bottom half to add weight, and submerge it in the toilet tank so that it does not interfere with the flushing mechanisms. (Figure 19) This will reduce the amount of water entering the toilet tank after each flush and will conserve water.

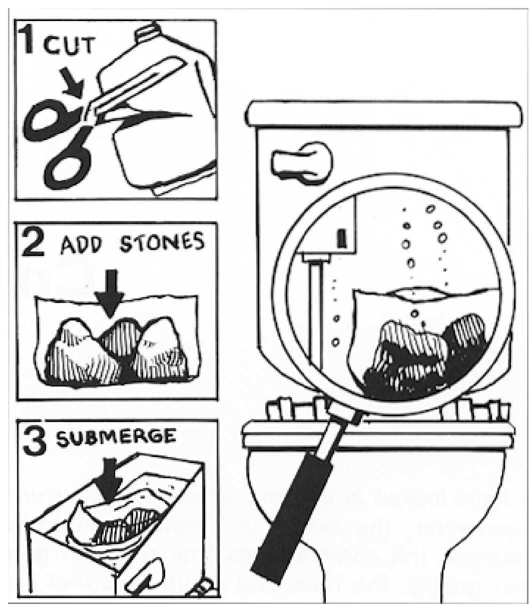



**Figure 19. An inexpensive toilet-tank device made out of a milk jug and stones will help conserve water.**

Look for water leaks around the home. A leaking toilet can waste up to 200 gallons of water a day and a dripping faucet can waste up to 20 gallons a day. Even a small leak can add hundreds of gallons of wastewater into an onsite disposal system causing a premature system failure.

# AGENCIES THAT PROTECT VIRGINIA'S GROUND WATER

Legal authority to protect Virginia's ground water begins with the Virginia Constitution, which describes the General Assembly's legislative power and the Commonwealth's policy to protect natural resources. Article Xl of the Constitution states that it is the Commonwealth's policy –to protect its atmosphere, lands, and waters from pollution, impairment, or destruction, for the benefit, enjoyment, and general welfare of Virginia's citizens.Ó

In 1986, the Virginia Ground Water Protection Steering Committee (GWPSC) was formed. As a result of this committee's efforts, *A Ground Water Protection Strategy for Virginia* was developed and adopted by the state. The first committee was chaired by the Virginia Water Control Board, and included representatives from those agencies whose programs could affect ground water quality. Since 1988, the GWPSC has con-tinued to meet and publish an annual report, and in 1990 produced the *1990 Supplement to the Ground Water Protection Strategy for Virginia.* This report reaffirmed the five potential sources of ground water pollution: waste disposal systems, landfills, pesticides and fertilizers, underground storage tanks, and waste lagoons, and assessed the state's progress in implementing the recommen-dations from the 1987 plan. A review of the state's progress in carrying out the *Strategy's* recommendations for 1990 to 1995 was published in the *1995 Supplement* and the steering committee's course for the next five years was defined.

The steering committee's agenda for 1996-2000 calls for increased public education on ground water, and continued interagency cooperation and coordination. In addition, the GWPSC established the following priorities for the next four years:

- ***Continue to publish annual reports and other reports informing citizens, officials, and businesses about ground water and state programs;***
- ***Continue to promote voluntary wellhead protection efforts and testing of private water wells;***
- ***Reassert the following five priority areas of concern: underground storage tanks, landfills, waste lagoons, septic tanks, and pesticide and fertilizers;***
- ***Give a high priority to exploring opportunities for improving research and information collection and dis-semination.***
- ***Continue to seek ways to maximize the use of limited resources through coordination of activities among state agencies, localities, between the state and localities, and between public and private entities; and***
- ***Seek ways of improving existing programs, and ways to tie planning for ground water protection to planning for economic development.***

Current GWPSC membership includes the: Virginia Department of Environmental Quality (DEQ), Virginia Department of Conservation and Recreation (DCR), Virginia Department of Health (VDH), Virginia Cooperative Extension, Virginia Department of Agriculture and Consumer Services (VDACS), Chesapeake Bay Local Assistance Department (CBLAD), Virginia Department of Mines, Minerals, and Energy (DMME), the Division of Consolidated Laboratory Services (DCLS) of the Department of General Services, Department of Business Assistance, and the Water Resources Division of the U.S. Geological Survey (USGS).

# Ground Water Protection Steering Committee Membership

Ground water protection activities within the GWPSC member agencies include the following:

**Virginia Department of Environmental Quality (DEQ) - Water and Waste Divisions:**

- statewide ground water resource management
- ground water withdrawal activities in designated Ground Water Management Areas
- Underground Storage Tank/Leaking Underground Storage Tank (UST/LUST) programs (registration, inspection, remediation)
- Aboveground Storage Tank (AST) pro-gram (registration, inspection, remedia-tion)
- Virginia Pollutant Abatement (VPA) program (pits, ponds, lagoons) and land application of non-hazardous wastes
- municipal wastewater treatment (joint program with VDH)
- solid waste management program (landfills)
- hazardous waste management (Resource Conservation and Recovery Act (RCRA), and Superfund)
- Voluntary Remediation Program (VRP)
- pollution prevention programs (P2)
- education, outreach, and technical assistance

**Virginia Department of Health (VDH):**

- onsite sewage disposal
- domestic water well construction standards
- public water supply
- municipal wastewater treatment (joint program with DEQ)
- education, outreach, and technical assistance

**Virginia Department of Conservation and Recreation (DCR):**

- nonpoint source control programs
- education, outreach, and technical assistance

**Virginia Cooperative Extension Service (VCE):**

- education, outreach, and technical assistance
- countywide Household Water Testing and Information Program
- Farmstead Assessment System
- research, data collection, information transfer

**Virginia Department of Agriculture and Consumer Services (VDACS):**

- certification/regulation of pesticide and herbicide applicators
- integrated pest management
- Pesticide and Ground Water State Management Plan
- Agricultural Stewardship Program
- education, outreach, and technical assistance

**Virginia Department of Mines, Minerals, and Energy (DMME):**

- geologic mapping, drill cutting, and core analysis
- mine regulation
- oil and gas well regulation
- education, outreach, and technical assistance

**Virginia Department of Housing and Community Development (VDH&C):**

- Community Development Block Grants planning grants and construction grants for water and sewer development

**Chesapeake Bay Local Assistance Department (CBLAD):**

- land use planning assistance
- education, outreach, and technical assistance

**Virginia Department of Business Assistance (VDBA) (consists of three divisions of the former Virginia Department of Economic Development):**

- principal point of contact between Commonwealth's basic employers and state government
- strengthen Commonwealth's economy by insuring that the needs of businesses are addressed
- technical assistance, ombudsman services, training, and financial assistance

**Virginia Department of General Services - Division of Consolidated Laboratory Services (DCLS):**

- chemical and microbiological testing of samples to support ground water programs for regulatory, monitoring, and study purposes
- organic, inorganic, radiological, and microbiological analyses of potential ground water contaminants such as pesticides, metals, solid, and hazardous wastes

**U.S. Geological Survey (USGS), Water Resources Division:**

- ongoing ground water data collection for long-term evaluation and planning
- evaluation and tracking of effects of withdrawals on ground water quantity and quality in the Coastal Plain
- statewide ground water level and quality observation-well networks
- targeted interpretive studies to address specific ground water resource information needs
- assessment of the role of ground water in protection of the Chesapeake Bay
- determination of the effects of land use activities on ground water quality
- outreach, education, and technical assistance

# INFORMATION SOURCES FOR WATER RELATED PROGRAMS, ISSUES, AND REGULATIONS

Many of the state's agencies have information about their programs and resource materials on the Internet. The following is a list of the some of the members of the Ground Water Protection Steering Committee who have world wide web sites. Agencies not listed may be contacted through their regular mailing addresses.

**Virginia World Wide Web**: http: //www.state.va.us

**Virginia state agencies, boards, commissions, and councils**: http://www.state.va.us/ home/ govvaagy.html

**Virginia Department of Environmental Quality**: http://www.deq.state.va.us

**Virginia Department of Health**: http:// www.vdh.state.va.us

**Virginia Department of Conservation and Recreation**:
http://www.state.va.us/~dcr/dcr_home.htm

**Virginia Cooperative Extension**: http: //ext.vt.edu

**Virginia Department of Agriculture and Consumer Services**: http://www.state.va.us /~vdacs/vdacs.htm

**Chesapeake Bay Local Assistance Department**:
http://www.state.va.us/cbladhomepg.htm

**U. S. Geological Survey**: http:// www-va. usgs.gov

**Other agencies available to help with ground water protection needs include:**

**Virginia Water Resources Research Center**: http://www.vwrrc.vt.edu/vwrrc/vwrrc.htm provides information about drinking water and water related topics; funds for research on related water issues.

**Virginia Rural Water Association (540) 261-7178**

provides community technical assistance with public and private water systems

**Safe Drinking Water Act Hotline**
**(800) 426-4791**
provides information about drinking water contaminants and their standards.

**National Drinking Water Clearinghouse (800) 624-8301**

provides drinking water information and news for America's small communities.

**Southeast Rural Community Assistance Project, Inc. (540) 345-1184**

provides assistance to individual households to assess ground water quality and threats to ground water; provides project funding to communities for engineering predevelop-ment studies to assist in gathering data to apply for federal grant and loan programs.

**The following is a short list of some of the many books, brochures, and booklets available for additional information about drinking water problems, water con-servation, and ground water contamination**.

*Drinking Water. . . An Endangered Resource.* 1988. S.U. Lester and B. Lipsett, Citizen's Clearinghouse for Hazardous Wastes, Inc., P.O. Box 6806, Falls Church, VA 22040; (703) 237-2249; 48 pages.

*Drinking Water Filters: What You Need to Know.* 1988. Stephen U. Lester and Brian Lipsett, Citizen's Clearinghouse for Hazardous Wastes, Inc, (P.O. Box 6806, Falls Church, VA 22216; (703) 237-2249; 40 pages.

*The Poisoned Well: New Strategies for Ground water Protection.* 1989. Ed. Eric P. Jorgensen, Sierra Club Legal Defense Fund. Washington, DC / Covelo, CA: Island Press. 415 pages.

*Safety on Tap: A Citizen's Drinking Water Handbook.* 1987. League of Women Voters Education Fund (1730 M Street NW, Washington, DC 20036; (202) 429-1965; publication #840, 68 pages.

*Water Quality Self-Help Checklist.* American Farm Bureau Federation, Natural and Environmental Resources Division (225 Touhy Avenue, Park Ridge, IL 60068; (312) 399-5700; $1). 14 pages.

*Private Well Regulations, VR 355-34-100,* Bureau of Sewage and Water Services, Department of Health, Main Street Station, 1500 East Main St., Richmond, VA 23219. April 1992.

*A Guide to Private Wells*, Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, 10 Sandy Hall, Blacksburg, VA 24061, 40 pages .

*A Guide to the National Drinking Water Standards and Private Water Systems*, Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, 10 Sandy Hall, Blacksburg, VA 24061, 74 pages.

**Publications available from the American Ground Water Trust, P. O. Box 1796, 16 Centre St., Concord, NH 03301. (603)228-5444. Fax: (603)228-6557.**

America's Priceless Ground Water Resource
Before You Hire a Water Witch
Domestic Water Treatment for Homeowners
Everything You Ever Wanted to Know About Septic Tanks
Ground Water Heat Pumps
Ground Water Pollution Control
Water Conservation in the Home
When You Need a Water Well
Rural Drinking Water — Private Wells or Public Water Supply?

**Publications available from the Virginia Cooperative Extension Distribution Center, Virginia Polytechnic Institute and State University, Landsdowne St., Blacksburg, VA 24060, (540)231-6192.**

***Water***

*Household Water Treatment,*, publication 356-481.
*Interpreting Your Water Test Report*, pub-lication 356-489.
*Household Water Testing*, publication 356-485.
*Bacteria and Other Microorganisms in Household Water*, publication 356-487.
*Hydrogen Sulfide in Household Water*, pub-lication 356-488.
*Virginia Farm*A*Syst*, publication 442-900.
*Nitrates in Household Water*, publication 356-484.
*Home Water Quality Problems — Causes and Treatments, publication 356-482.*
*Questions to Ask When Purchasing Water Treatment Equipment*, publication 356-*480*
*Lead in Household Water*, publication 356-483.
*Buying Bottled Water*, publication 356-486.

***Onsite Wastewater Treatment Systems***

*Septic System Maintenance*, publication 448-400
*Maintenance of Mound Septic Systems*, publication 448-401
*Maintenance of Low Pressure Distribution Septic Systems*, publication 448-402
*Alternative Onsite Wastewater Treatment and Disposal Systems*, publication 448-403
*Individual Homeowner and Small Com-munity Wastewater Treatment and Disposal Options*, publication 448-406
*Planting on Your Septic Drain Field*, publication 426-617

# GLOSSARY

**Aquifer.** A water-bearing layer of permeable rock, sand, or gravel that can yield usable quantities of water to a well or spring.
**Aquitard**. A rock or clay layer that is not permeable enough to yield usable quantities of water to a well or spring.
**Artesian aquifer, or confined aquifer**. A water-bearing layer which has an aquitard both above and below it.
**Consolidated deposits**. Solid or hardened rock masses.
**Dolomite**. A mineral composed of calcium magnesium carbonate.
**Ground water**. Water in a saturated zone (aquifer) underground.
**Hydrologic cycle**. A continual sequence of conditions through which water passes by processes, such as precipitation and evaporation, from the atmosphere to the land or oceans and eventually back to the atmosphere.
**Igneous**. Rocks formed by solidification of molten rock material (magma) within the earth.
**Injection**. The pumping of liquid waste into the ground through wells for disposal.
**Leachate**. A solution formed by leaching.
**Leaching**. Dissolving by the action of a percolating liquid such as rainwater seeping into the soil.
**Metamorphic**. Rock that has been changed to a more compact and crystalline form by intense heat and pressure within the earth.
**Percolating**. Oozing or seeping through permeable material such as soil.
**Permeable**. Material through which liquids can readily pass.
**Permeability**. A measure of a soil's ability to transmit water.
**Physiographic province**. A region with a characteristic landscape, commonly the product of a specific geologic structure and climate.
**Porosity**. A measure of the amount of open space in a material, particularly the water storage capacity of a substance.
**Recharge**. The flow of water into the saturated zone or groundwater.
**Recharge area**. The portion of the land surface through which water seeps into the ground to recharge a particular aquifer.
**Saturated zone**. The area underground in which all available spaces are filled with water.
**Sedimentary**. Rock formed from particles deposited by water, wind, or ice
**Sinkhole**. A hollow or depression, usually in a limestone area, that is often connected to an underground channel.
**Solution channel**. An underground opening or passage formed by the dissolving action of water on rocks such as limestone or dolomite.
**Triassic basins**. A series of long. narrow deposits of sedimentary rocks in the Piedmont Region. In the Triassic period, 200 million years ago, these areas were inland seas.
**Unconfined aquifer**. A waterbearing layer whose upper boundary is the water table.
**Unconsolidated deposits**. Loose earth materials or sediments.
**Unsaturated zone**. The area below ground surface in which the soil pores (spaces) are partially filled with water and partially by air.
**Water table**. The upper boundary of the saturated zone.

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