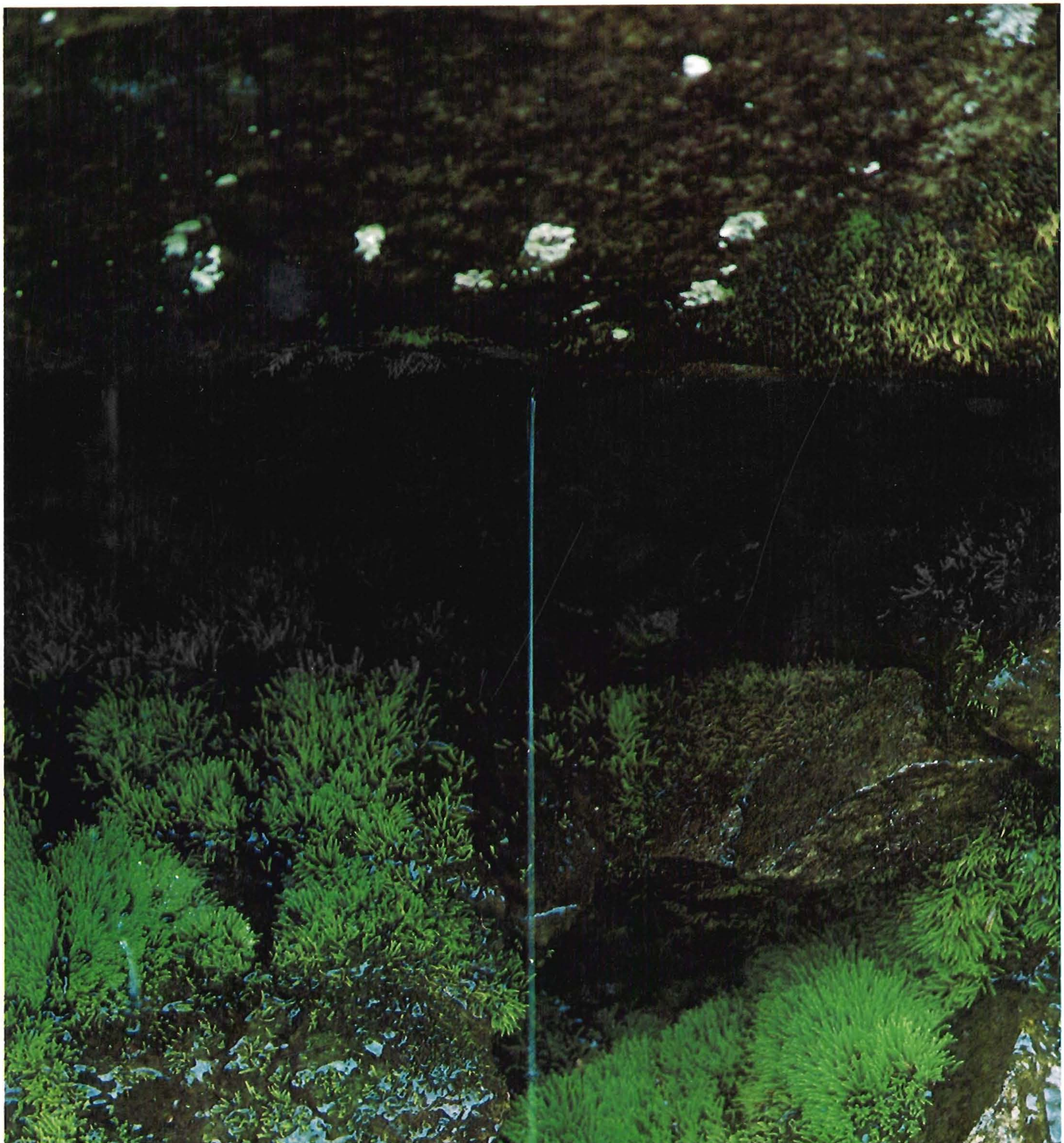
A Groundwater Primer for Virginians



A Groundwater Primer for Virginians

By

Torsten D. Sponenberg

and Jacob H. Kahn

Virginia Water Resources Research Center
Virginia Polytechnic Institute and State University
Blacksburg · 1984

The preparation of this document was financed in part through a grant from
the United States Environmental Protection Agency under Section 1143(b)
of the Safe Drinking Water Act (Grant No. C-003281-01)

Cover:
Groundwater flowing from a rock fracture in Bedford County. Photo by Edward Born
Illustrations by George H. Wills

Additional copies of this publication, while the supply lasts,
may be obtained from the Virginia Water Resources Research Center,
617 N. Main St., Blacksburg, VA 24060-3397. Single copies are provided
free to persons and organizations within Virginia. For those
out-of-state, the charge is $8 a copy if payment accompanies
order, or $10 a copy if billing is to follow

A publication of the Virginia Water Resources Research Center,
Virginia Polytechnic Institute and State University. William R. Walker,
director; Edward Born, assistant director for publications

7/84:5M

Table of Contents

Table of Contents, continued

Preface

Eight of every ten Virginians rely either partly or entirely on groundwater to supply their water needs. The Commonwealth uses nearly 400 million gallons of groundwater each day to meet industrial, agricultural and public and private water demands. Though an important natural resource, Virginia's groundwater is vulnerable because it is a hidden resource and, consequently, often a forgotten one. As Virginians plan for a future in which demand for groundwater—and the potential for groundwater contamination—will surely increase, it is critical that we be aware of how our activities affect the quantity and quality of our groundwater resources.

This booklet introduces the reader to groundwater properties, groundwater in Virginia, contaminants that can threaten our groundwater quality, legal protection of Virginia's groundwater, and ways in which each of us can help protect our groundwater.

We wish to thank members of the advisory committee who helped direct and review this and other groundwater-related publications of the Virginia Water Center: David Bailey and Moira Lux, Environmental Defense Fund; Robert Peters, John E. Sirine and Associates; L.S. Button and Helen Jeter, Soil Conservation Service; Peter Brooks, Gerard Higgins, and Robert Taylor, State Health Department; Kenneth Hinkle and P.J. Smith, State Water Control Board; John Powell and Winfield Wright, U.S. Geological Survey; Keith Cheatham, Virginia Farm Bureau Federation; and Blake Ross, Virginia Tech. We also wish to thank Stuart Kerzner of the U.S. Environmental Protection Agency (Region III) for his advice and support throughout our yearlong adult education program in groundwater protection. As generous as Mr. Kerzner and the advisory committee were in giving us assistance, the responsibility for errors and omissions is ours alone.

T.D.S and J.H.K.

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.

Groundwater. Water in a **saturated zone** under ground.

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 earth.

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 substance's ability to transmit liquids.

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.**

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. In the Triassic period, 200 million years ago, these areas were inland seas.

Unconsolidated deposits. Loose earth materials or sediments.

Unsaturated zone. The area underground in which the soil pores (spaces) are only partially filled with water.

Water table. The upper boundary of the **saturated zone.**

Water-table aquifer, or **unconfined aquifer.** A water-bearing layer whose upper boundary is the **water table.**

Introduction

Virginia has a rich and varied supply of natural resources, ranging from the sandy Atlantic shores to the lofty Blue Ridge Mountains and the vast coal fields of southwestern Virginia. 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 a major 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 serve countless other useful purposes. This "hidden" resource is *groundwater,* the water beneath the earth's surface. It is the only water that supplies wells and springs.

Eight of every ten Virginians rely either partly or entirely on groundwater for their water supply. For 1.5 million Virginians, groundwater from springs or wells is their *only* source for drinking and tasks around the home. Industry, agriculture, thermoelectric generating plants, and households in Virginia use about 400 million gallons of groundwater every day (*Figure 1*). That is equal to more than 70 gallons a day for every resident.

Everyone has heard the word "groundwater," but few people know how groundwater occurs in nature, what makes it flow, how fast it moves, what threatens its quality, and how it can be protected and wisely managed. Most people are surprised to learn that there is more fresh water underground than exists in surface rivers, streams, and lakes. This fact alone should compel us to learn more about groundwater.

Although Virginia's groundwater quality is generally good, this vital resource is threatened by many potential contaminants, and there have been isolated cases of serious groundwater pollution in the state. By law, Virginia is committed to a policy of "antidegradation" of all state waters, including groundwater. In practice, Virginia's public officials believe that the keys to ensuring the quality of the state's groundwater are *educating* citizens about the importance of groundwater protection and *preventing* groundwater contamination.

In this book you will learn about groundwater, Virginia's groundwater resources, sources of pollution, how government tries to protect Virginia's groundwater, and what we can do to protect it. By learning how we depend on it, you should come to understand why it is important for us to share a deep concern for this priceless resource.

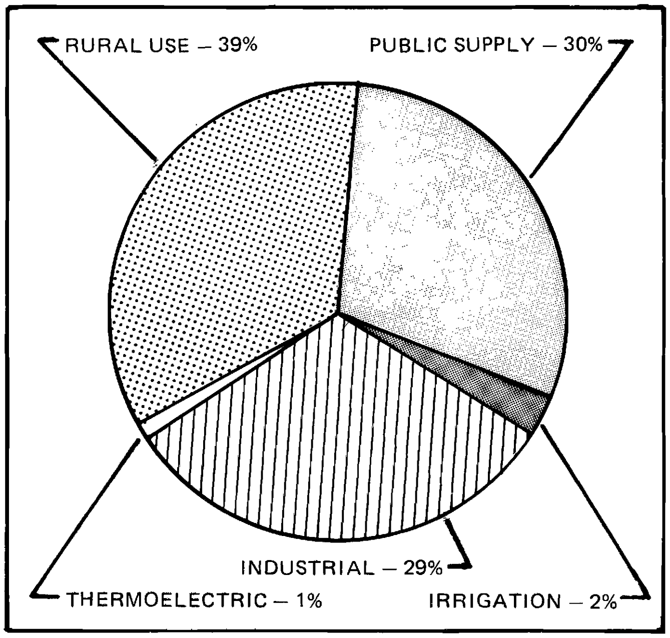


FIGURE 1
The leading use of groundwater in Virginia is rural use for livestock and domestic purposes, followed by use for public supplies and industry.

What Is Groundwater?

THE HYDROLOGIC CYCLE

Groundwater is but one stage, or form, through which water passes in the earth's *hydrologic cycle (Figure 2).* The hydrologic cycle is the continual movement of water over, in, and through the earth as it changes from one form—solid, liquid, gas—to another.

The water you use today may have evaporated from an ocean, traveled through the atmosphere, fallen back to the earth's surface, gone underground, and from there moved to streams leading back to the seas. Water is continually recycled by natural processes. Water is readily visible in many forms—clouds, rain, snow, fog, lakes, streams, oceans, polar ice caps—but as groundwater it is, by definition, out of sight. Our understanding of groundwater and its role in the hydrologic cycle has been hindered by the difficulty of observing and measuring the properties and extent of groundwater. Consequently, many popular misconceptions exist about groundwater. Some of these beliefs are based more on folklore and fantasy than on fact (see inset on page 4).

Long-standing misconceptions about groundwater's origin, occurrence, and movement have by no means prevented people from using it. Groundwater supplies have been tapped for thousands of years, but only recently have we started to understand its characteristics and manage it. Much remains to be discovered about groundwater, but wider public awareness of its nature and properties is an important first step.

WATER UNDERGROUND

When water falls to earth as rain or snow, most of it seeps into the ground. The first zone it encounters is the *unsaturated zone,* where soil pores are filled partly with air and partly with water. Plant roots, bacteria, fungi, insects, and burrowing animals are found in the unsaturated zone. Groundwater 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 (Figure 3).* The water table rises when water enters the saturated zone; the water table falls when water is pumped from the saturated zone. Water in the saturated zone is commonly referred to as *groundwater.*

Recharge

The process by which water—from rainfall, snowmelt, and other sources—flows into a water-bearing 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 unsaturated zone is important to the groundwater underlying it because incoming water seeps down through the unsaturated zone into the saturated zone. Both the quantity and quality of groundwater can be affected by the condition of the unsaturated zone in a recharge area.

Aquifers

Geologic deposits largely govern the distribution and movement of groundwater. Groundwater occurs in many types of geologic formations; those formations that will yield water in usable quantities to wells or springs are known as *aquifers.* Aquifer literally means "water-bearer;" hence, aquifers are commonly referred to as water-bearing formations.

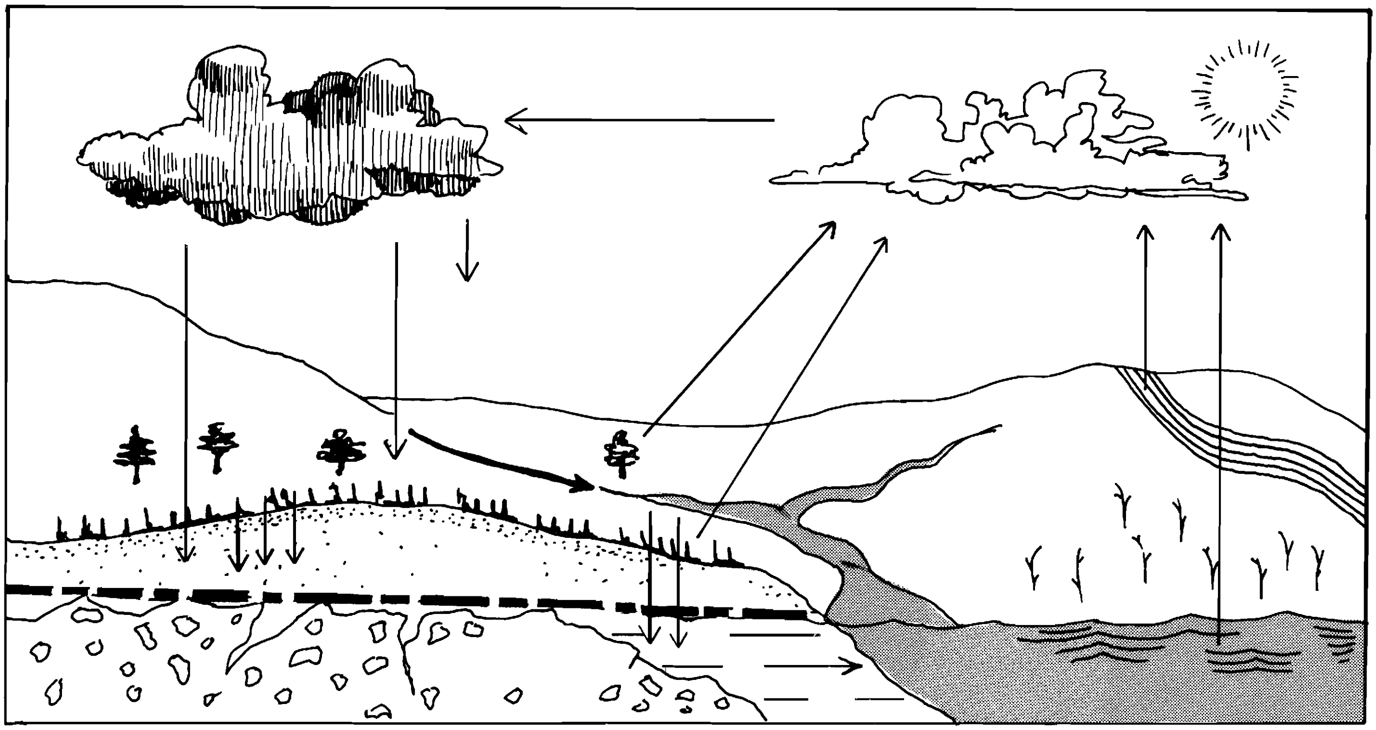


FIGURE 2
The many processes by which water moves—including precipitation, runoff, percolation, groundwater flow, evaporation, and transpiration—are collectively called the hydrologic cycle. Water travels continuously through the atmosphere, rivers, oceans, and aquifers in this never-ending cycle.

Groundwater in Unconsolidated Deposits

A common misconception is that groundwater occurs in the form of underground lakes and rivers, just as freshwater lakes and rivers occur at the earth's surface. In fact, groundwater *does not* resemble a lake. Water under the earth's surface collects in numerous pores (open spaces) between *unconsolidated,* or loose, particles of sand, gravel, rock, and soil.

A simple way to picture groundwater in an unconsolidated geologic deposit is to think of a glass fishbowl full of aquarium gravel and half full of water (*Figure 4*). The pores between gravel particles in the bottom half of the bowl are filled with water—this water in the saturated zone represents groundwater—while the pore spaces between 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.

A household sponge is also like an unconsolidated deposit. Water in a sponge is held in the many open spaces that exist between the sponge's fibers; in the same way, groundwater 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.

Groundwater in Consolidated Deposits

In addition to collecting in the networks of pores in unconsolidated deposits of sands and gravels,

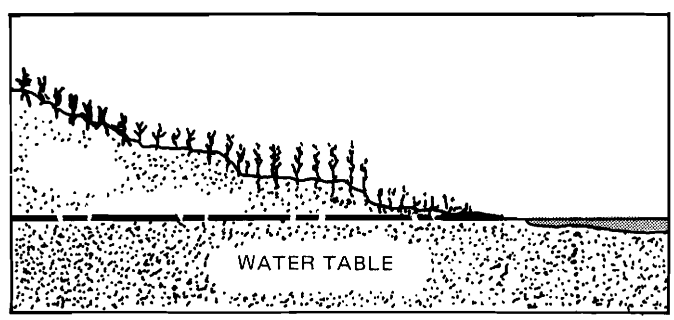


FIGURE 3
The water table is the boundary between the unsaturated zone and the saturated zone underground. The water in the saturated zone is commonly called groundwater.

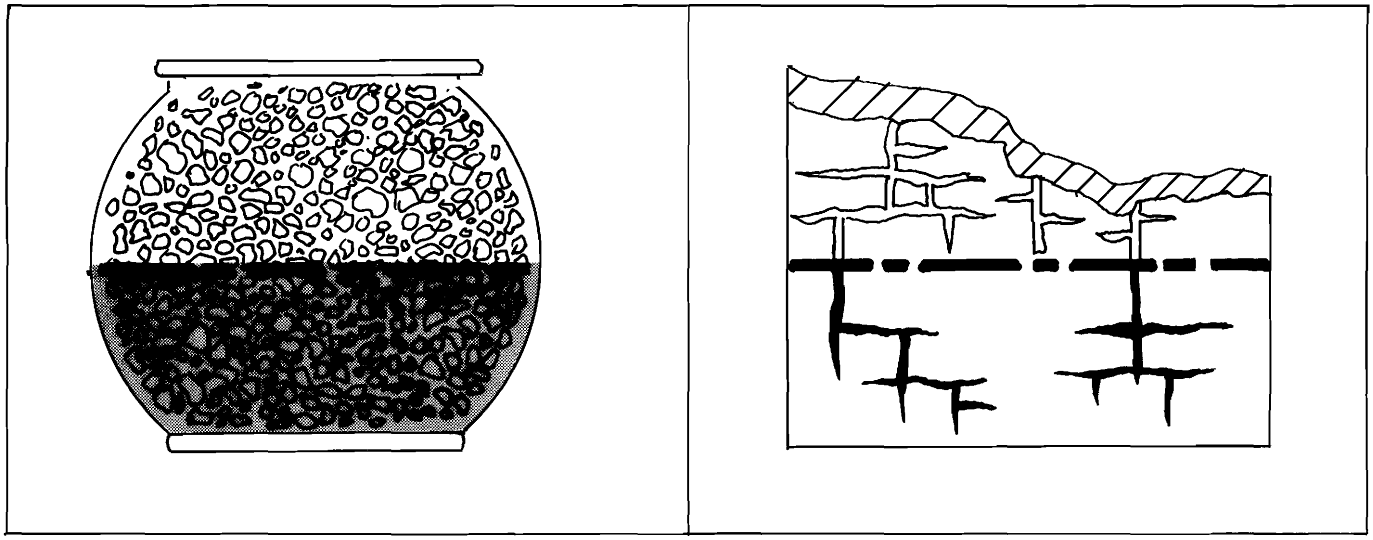


FIGURE 4

Groundwater in an unconsolidated deposit (a), represented by a half-filled fishbowl, occupies all the spaces between gravel particles. Groundwater in a consolidated deposit (b) fills cracks and channels in the rock.

groundwater also occurs in *consolidated* deposits. Consolidated deposits are solid rock masses rather than loose, individual particles. There are three general classes of consolidated rocks. Igneous rocks, such as granite, are formed directly from molten rock. Rocks that have been altered by intense heat and pressure are metamorphic rocks, for example, slate. Sedimentary rocks, such as limestone and sandstone, are formed from sediment.

GROUNDWATER MYTHS

- All groundwater occurs as vast underground lakes and rivers.
- Groundwater cannot be polluted because it is so far underground.
- If polluted or contaminated, groundwater is easily cleaned as it moves through the earth.
- Water rushes so rapidly underground that its presence can be detected by listening.
- Groundwater migrates thousands of miles through the earth.
- There is no relationship between groundwater and surface water.
- Groundwater is an unimportant water supply source.

Groundwater occurs in pores, cracks, fissures, and solution channels in rock masses (*Figure 4*). 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. Large areas of Virginia's Valley and Ridge region are underlain by limestone and dolomite. Once solution channels have developed, they function more like pipes than sponges in conveying groundwater. 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

In both consolidated and unconsolidated deposits, an aquifer's storage capacity, or *porosity,* is determined by the volume of pores and cracks available to hold water. An aquifer's *permeability,* that is, its capacity to transmit water, is determined both by the size of the pores and cracks and by the extent to which they are connected.

The importance of both porosity and permeability can be seen by comparing the properties of coarse sand

and clay. Coarse sand deposits have a few large pores between grains as compared with clay, a fine-grained material that has many small pores. Clay, then, can store more water than sand. However, the pores in coarse sand are much larger than those in clay and are also highly interconnected, so sand has a higher permeability than clay. Water may move as much as several feet a day through sandy deposits. Though clay has more *total* pore space, the pores are so small that water moves very slowly through it, often just a few inches a year. Hence, wells drilled into shale or clay may produce little or no water.

The same principles apply in the case of consolidated deposits. The size of cracks and solution channels along with the number of their interconnections determine the capacity of an aquifer to store and transmit water.

Types of Aquifers

Aquifers occur most commonly in unconsolidated sands and gravels, permeable sedimentary rocks such as sandstone and limestone, and heavily fractured rocks. *Aquitards* are geologic formations with permeabilities too low to allow development of production wells. Clays, shales, and dense rocks are the most common aquitards.

There are two types of aquifers (*Figure 5*). The water table forms the upper boundary of an *unconfined,* or *water-table, aquifer.* A *confined,* or *artesian, aquifer* is confined or "sandwiched" between two aquitards. 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.

Groundwater Flow

Under natural conditions, groundwater moves "downhill" 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 between streams than it is downslope beneath 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 groundwater flow directions for water-table aquifers (*Figure 6*). The overall slope of the land surface is toward streams, valleys, and the oceans. Hence, groundwater near the water table usually moves downslope from areas

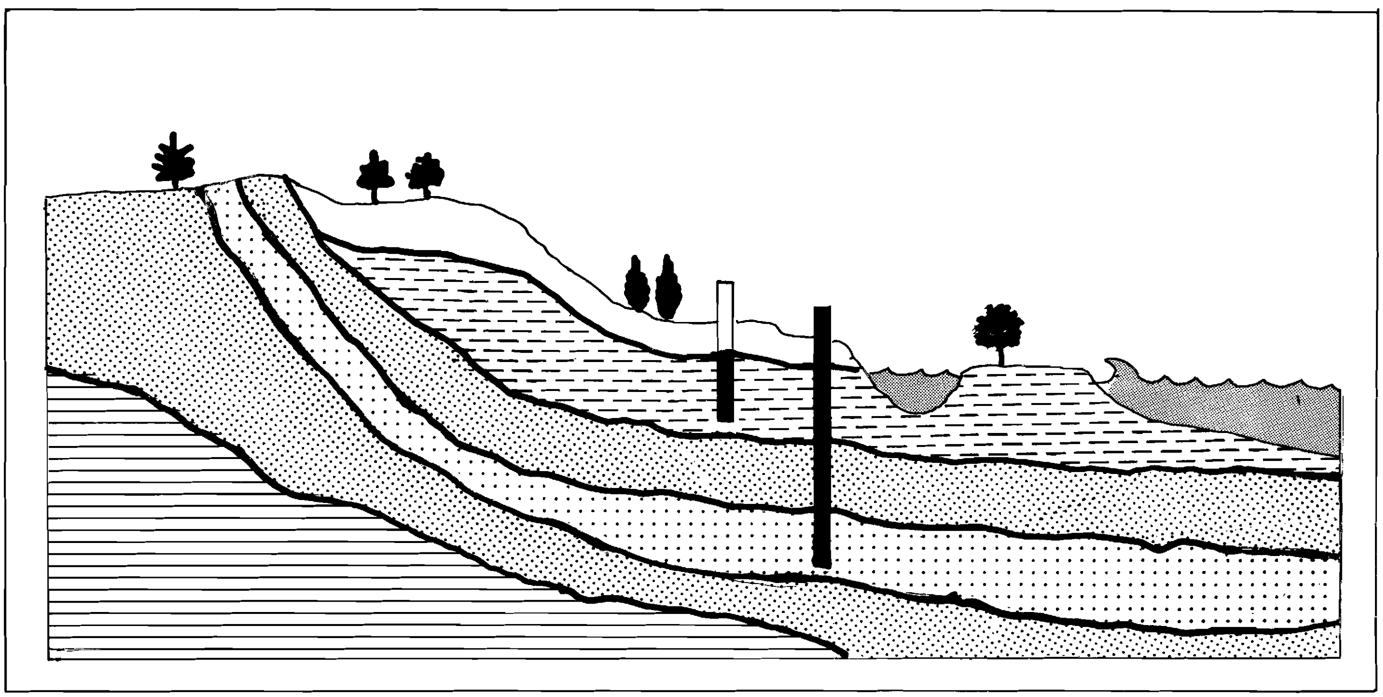


FIGURE 5

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.

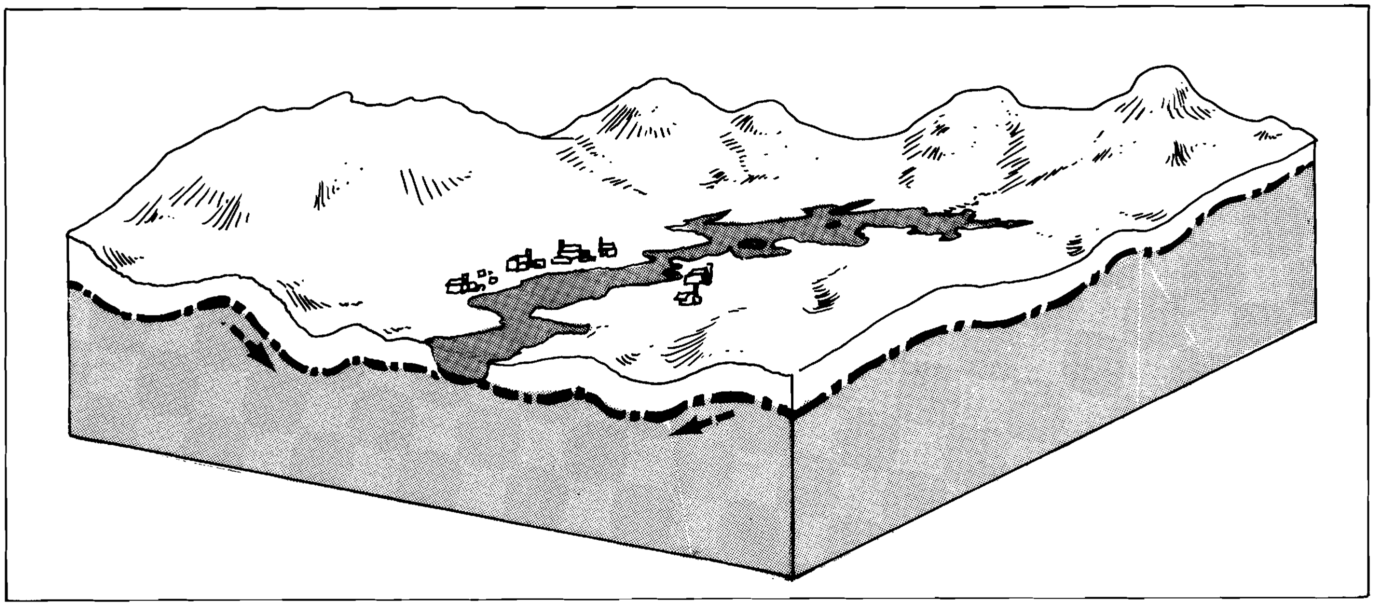


FIGURE 6
The water table is typically parallel to the earth's surface, so the slope of the land gives a general indication of groundwater flow directions.

between streams and from uplands toward the ocean. Local geologic conditions—such as the orientation of cracks and fissures in nonporous rocks—can cause complex groundwater flow patterns that do not conform to this simple flow model.

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

Groundwater flow rates in the "spongy" type of aquifer previously described 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 rocks with solution channels, where groundwater flow resembles flow through pipes, water flows faster and in a more turbulent way, with a great deal more mixing than occurs in sponge-like formations. The natural flow of groundwater is strongly dependent on the nature of the geologic formation in which the groundwater is stored and through which it moves.

CONNECTIONS BETWEEN GROUNDWATER 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; aquifers are not "dead ends" in the hydrologic cycle. In fact, approximately 30 percent of the flow of surface streams in the United States is contributed by groundwater. Streams, lakes, springs, and wetlands receive naturally occurring groundwater discharge. A *gaining stream* is one that receives groundwater; a *losing stream* is one that recharges groundwater. 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 groundwater flow. During periods of heavy rainfall or rapid snowmelt, surface runoff is the primary contributor to stream flow. During extended dry periods, groundwater may be the only contributor to a stream's flow.

Groundwater in Virginia

As mentioned earlier, the natural occurrence of groundwater depends on geologic 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 7*). Moving from east to west, the physiographic provinces are the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian (or Cumberland) Plateau. Looking at the state's physiographic regions and their relation to the occurrence of groundwater will help us gain an understanding of Virginia's groundwater resources.

COASTAL PLAIN

Virginia's Coastal Plain is the only physiographic region in the state that is composed mostly of unconsolidated deposits. The Coastal Plain extends inland about 110 miles, from the Atlantic coast to the fall line, an imaginary north-south line that passes through Fairfax, Fredericksburg, Richmond, Petersburg, and Emporia. The fall line 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 sand, gravel, silt, 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 line to more than 3,000 feet at the Atlantic shoreline.

Almost half of the state's groundwater use occurs in the Coastal Plain, which has two separate groundwater systems (similar to the two aquifers shown in *Figure 5*). In many places, a shallow water-table aquifer system lies above relatively impermeable clay beds. This system is the source of water for hundreds of domestic and other small-capacity wells, which withdrew an estimated 15 million gallons per day in 1970. This aquifer system is similar to the sponge model described previously.

A deeper system of artesian aquifers is the principal source of groundwater in the Coastal Plain, from which wells withdraw 160 million gallons of water a day. The principal recharge area for these aquifers is the land around the fall line where the aquifers outcrop. Recharge to these aquifers can also occur through "leaks" in the confining beds above them, which are overlain by water-table aquifers. Farther east toward the coast, these aquifers become thicker and lie deep underground.

Because of the thickness and areal extent of the Coastal Plain's artesian aquifers, their groundwater storage capacity is enormous. These aquifers store more groundwater than the aquifers of any other physiographic province in Virginia. One estimate of the total amount of recoverable water in these aquifers is 3 trillion gallons. Well yields range from 100 gallons to several thousand gallons a minute. Pumping has modified the original aquifer conditions and caused a general lowering of artesian pressure.

Natural 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.

In Accomack County, on Virginia's Eastern Shore, small domestic wells withdraw water from shallow

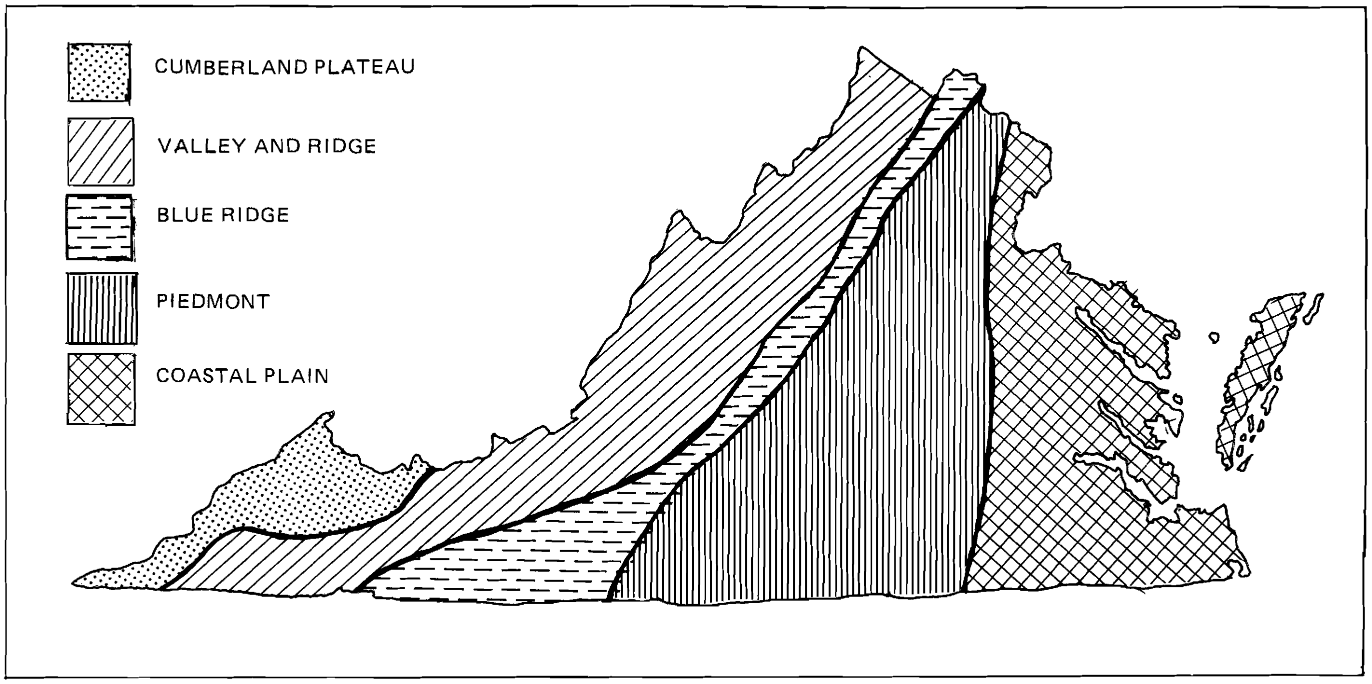


FIGURE 7
Groundwater availability varies among the five physiographic provinces of Virginia.

water-table aquifers. Deeper aquifers, at depths of 120 to 300 feet, have been tapped for domestic, municipal, and industrial supplies. High salt concentrations render Eastern Shore groundwater unpotable below a depth of about 300 feet. Poultry and produce industries are the largest groundwater users on the Eastern Shore.

PIEDMONT

The central section of Virginia, bordered by the fall line on the east and the Blue Ridge Mountains on the west, is known as the Piedmont province. The Piedmont, Virginia's largest physiographic region, is dominated by igneous and metamorphic rocks, with some areas of sedimentary rocks. No extensive unconsolidated deposits overlie the bedrock of the Piedmont; fractures and faults in the bedrock store and transmit groundwater. 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.

Groundwater production potential is much lower in the Piedmont than in the Coastal Plain. 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.

In some places, disintegration and decomposition of the granite bedrock forms 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 usually clayey. The water frequently contains relatively large amounts of iron and sulfur.

Groundwater use at many locations in the Piedmont is limited by quantity or quality problems. Because the Piedmont's subsurface geologic features are diverse, there is wide variation in groundwater quality and yield, making well site evaluation very important.

Areas of sandstone and shale that were deposited beneath ancient inland seas (Triassic Basins) are scattered throughout the Piedmont. Bedrock in these areas 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. Urban and agricultural development in the Triassic Basins is hindered by the high shrink-swell capacities and high aluminum content of the soils, so most of these areas remain forested.

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 northeasterly 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 on the eastern flank of the Blue Ridge. Sedimentary rocks are found on the western flank. The most favorable areas for groundwater accumulation are the lower slopes of the mountains.

Due largely to the rugged terrain, little residential or industrial development has occurred in the Blue Ridge. Groundwater use has been primarily limited to domestic needs. Springs are common and are often used for private water supplies. Wells in the Blue Ridge usually yield less than 20 gallons a minute and rarely yield more than 50 gallons a minute.

Groundwater in the Blue Ridge is not highly mineralized because the rocks in contact with the water are relatively insoluble, but 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. Limestone frequently contains solution channels that store and transmit groundwater. Ridges and upland areas are often underlain by sandstone and shale, which yield only enough water for rural and domestic supplies.

The relationship between groundwater 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. 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 journey through the soil. The quality of groundwater drawn from aquifers recharged this way may be very similar to that of surface water. Groundwater quality can also be adversely affected by private trash heaps or dumps located in sinkholes that receive surface runoff.

The chemical composition of the rock formations with which groundwater comes in contact also affects groundwater quality. For example, limestone formations in the Valley and Ridge region increase the "hardness" of the groundwater. Hard water creates soap films on laundered clothing, sinks, and 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, principally sandstone, shale, and coal. Gentle folding of these rock formations has created domes and basins, and faulting has occurred. Groundwater quality in the Cumberland Plateau varies with location and depth. Water of best quality is generally obtained from bedrock above stream level. 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. Water from coal seams and water contaminated by mine drainage is usually unsuitable for most uses.

Groundwater is used in the Cumberland Plateau 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. Total withdrawal in 1971 for all public supply systems in the Cumberland Plateau was about one million gallons a day, while that same year a single mining company withdrew nearly 500,000 gallons of water a day from 15 wells to process coal.

Sources of Groundwater Contamination

A common way to dispose of waste is to bury it. In doing so, we sometimes unwittingly contaminate groundwater. 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 groundwater. Because groundwater in many geologic formations moves slowly, a contamination problem can remain undiscovered for years or even decades until the "plume" of contaminated groundwater reaches an outlet (usually a well) where it is discovered. Because treating contaminated groundwater is difficult and expensive, preventing contaminants from reaching groundwater is a better approach to keeping groundwater clean.

Potential contaminants that threaten Virginia's groundwater include petroleum products, solid waste, hazardous waste, sewage, fertilizers and pesticides, animal waste, radioactive waste, and coal mining waste.

LEAKS AND SPILLS OF PETROLEUM PRODUCTS

Crude oil and its derivatives contain compounds that are soluble in water. Gasoline, for example, can be detected in drinking water by taste and smell at concentrations of only a few parts per billion.

The Water Center estimates that as many as 2,000 of the state's 30,000 to 40,000 underground gasoline storage tanks are leaking. Leaking gasoline tanks at Virginia service stations are one of the state's biggest groundwater quality threats.

The number of complaints of groundwater contaminated by petroleum rose nearly fivefold in Virginia from 1978 to 1983. A large number of these contamination incidents may be due to underground storage tank leaks. Sixty complaints from citizens whose well water had been contaminated by a petroleum product were received in 1983 by the State Water Control Board.

Alexandria, Virginia, has adopted amendments to its Fire Prevention Code that enable it to deal with both the potential fire hazard and the environmental threats posed by leaking gasoline storage tanks. For existing storage tanks, hydrostatic tests are required every five years and a daily log of pump and tank readings is also required. Cathodic protection and installation of monitoring wells are required at all new tank sites, regardless of the tank size. Alexandria is one of the first jurisdictions in Virginia to pass legislation addressing this threat. Some groups now advocate adopting statewide regulations for petroleum product storage tanks.

Buried home furnace oil tanks pose leakage threats. They 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 also can pose a threat to groundwater quality. Over 4 million gallons of used oil are disposed of improperly by do-it-yourself oil changers in Virginia each year. As little as one quart of oil can contaminate up to 2 million gallons of drinking water (*Figure 8).*

LANDFILLS

A landfill is any land area set aside for the deposit of solid waste—our trash and garbage. 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. Many older waste disposal sites are open dumps or poorly operated landfills. Newer landfills are generally better located and operated, but fewer than 10 percent of the refuse disposal sites in the United States meet EPA's definition of a well-operated, properly located landfill.

Refuse in sanitary landfills and dumps is subject to *leaching.* 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

FIGURE 8
Used motor oil should always be recycled (a). If one quart of motor oil is carelessly dumped (b), it can contaminate up to 2 million gallons of drinking water.

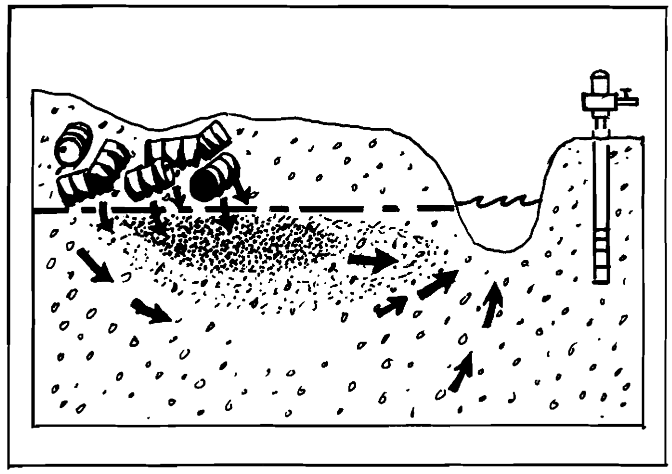


FIGURE 9
Rainwater filtering down through an unsealed landfill dissolves waste substances and forms a contaminated liquid, or leachate, which can pollute groundwater.

pot. Leachate from landfills can contain large amounts of hazardous substances, and if leachate is not captured on its way out of the landfill and treated, it can contaminate groundwater (*Figure 9*).

The hazard posed by landfill leachate to groundwater 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 many decades. If landfills are situated in appropriate geologic settings, both groundwater and surface water pollution can be reduced.

In addition to properly designed and managed landfills, private dumps and trash heaps exist throughout the state. The refuse in these dumps often is not sorted to remove items that—if exposed to leaching—could pose threats to groundwater. Dumps frequently remain exposed to rainfall and snow, thereby allowing the leaching process to occur.

HAZARDOUS WASTE

Over 100 hazardous waste sites have been identified in Virginia. Four of these sites, in Nelson, Roanoke, Smyth, and York counties, have been included on EPA's national priorities list for federal superfund cleanup. Runoff and leachate from 80,000 tons of acidic waste have caused several major fish kills in the Piney and Tye rivers in Nelson County. Electroplating-process waste has polluted groundwater at a site in Roanoke County. Eleven million tons of mercury-

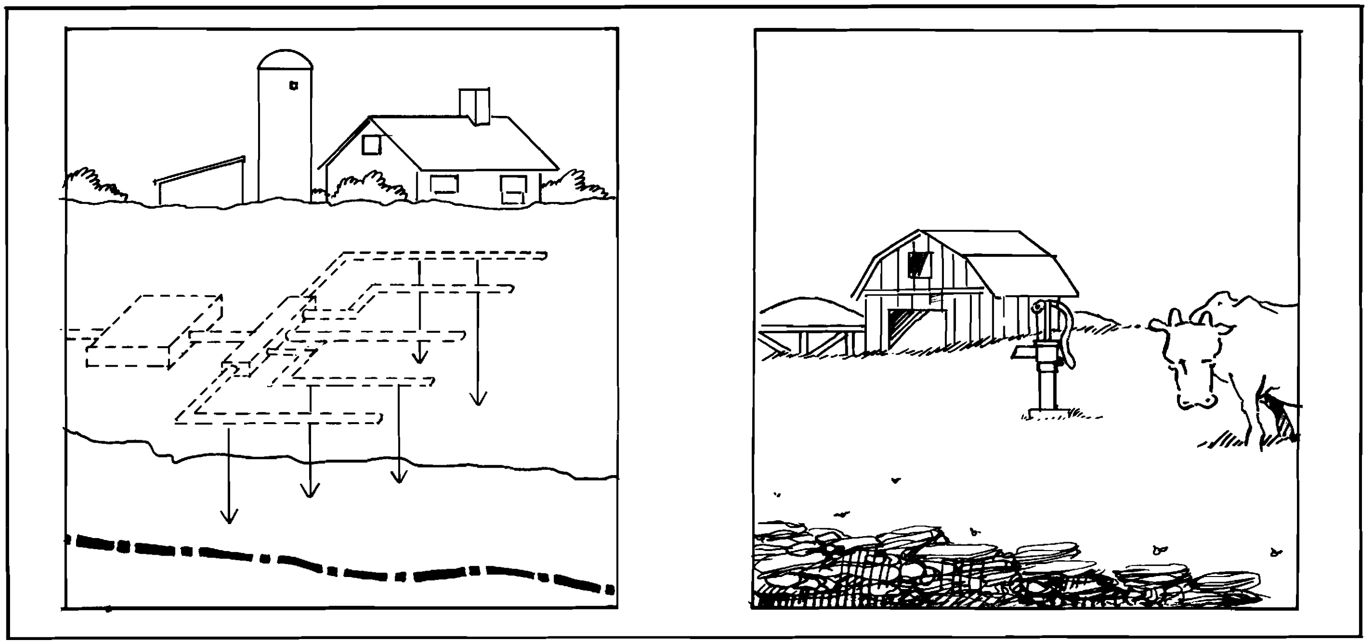


FIGURE 10

Wastewater enters the soil around septic system drainfield (a) and can contaminate groundwater, particularly when the system is in a bad location, is poorly designed, or is not properly maintained. Livestock waste can pollute a farm's groundwater supply if the waste is stored too close to a well (b).

enriched waste in disposal ponds in Smyth County have polluted 81 miles of the North Fork of the Holston River; consumption of fish caught in this reach has been prohibited since 1970. Fly ash deposited in borrow pits has polluted groundwater with vanadium along Chisman Creek in York County.

SEPTIC SYSTEMS AND CESSPOOLS

Septic tanks and cesspools are the largest of all contributors of wastewater to the ground and are the most frequently reported sources of groundwater contamination in the United States (*Figure 10*). Wastewater from septic systems includes many types of contaminants: nitrate, harmful bacteria, viruses, and commonly used chemical substances such as pesticides, paints, varnishes, and thinners. Though nitrate is a naturally occurring form of nitrogen, at concentrations above 45 parts per million it renders water unfit for consumption by infants. Nitrate can cause *methemoglobinemia*—"blue baby" disorder—which interferes with the capacity of an infant's blood to carry oxygen. At nitrate concentrations above 450 parts per million, water is unsuitable for consumption by livestock.

Evidence indicates that bacteria and viruses from sewage do not travel very far when transported by groundwater through granular geologic materials. However, in fractured rocks where groundwater flow rates can be high, these bacteria and viruses may be transported several miles. These microorganisms can live below the water table for many days or even months, and some can create health problems if consumed by people.

FARMING ACTIVITIES

Farming activities that can cause degradation of groundwater quality include use of fertilizers and pesticides, and storage or disposal of livestock and fowl wastes on land (*Figure 10*).

The most widespread effects are caused by the use of fertilizers. Nitrogen in the form of nitrate is the fertilizer nutrient that most commonly contaminates groundwater beneath agricultural lands. In areas where nitrate contamination is extensive, fertilizer is usually the source.

Groundwater near the surface sometimes becomes contaminated by nitrate leaching from holding areas for livestock and fowl wastes. Even relatively small sources such as farm manure piles, fowl-waste lagoons, and feedlots can contribute nitrate to groundwater. But if these contamination sources are not directly over aquifers, or if there are no groundwater users nearby, the contamination is rarely very significant. In farming areas, contamination of shallow wells by nitrate and other constituents commonly occurs because of faulty 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. Water well drilling is not a regulated industry in Virginia. No certification, based on knowledge or skills tests, is required of water well drillers who conduct business in the state, nor are drillers required to follow construction standards when drilling private wells.

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 organic insecticides and herbicides. Pollution by pesticides is an important potential hazard to groundwater quality. Because of the immense size to which the pesticide industry has grown, the problems associated with the disposal of surplus and waste pesticide materials and pesticide containers have become acute.

RADIOACTIVE WASTE

The nuclear power industry generates radioactive waste in several different ways. These include uranium mining, milling, refining, and enrichment; fuel fabrication, consumption, and reprocessing; and waste solidification.

An undesirable by-product of mining and milling uranium ore is the production of large volumes (hundreds of millions of cubic meters a year in North America) of waste rock from mining and tailings from milling. Waste rock and tailings are a form of solid, low-level radioactive waste. They are usually piled on the land surface or used as fill material in depressions confined by small earth embankments or dams. Extremely small amounts of radium 226, a radioactive substance, leached from waste rock or tailings into groundwater can render the water unfit for human consumption. Uranium mining in North America generally occurs in sparsely populated areas. In these areas, groundwater quality has, until recently, not been a subject of significant concern. The extent to which radium 226 and other hazardous constituents from waste rock or tailings enter groundwater, and their fate within groundwater flow systems, is not known. Currently there is a proposal to mine uranium in Pittsylvania County, Virginia.

In the uranium refining process, small quantities of solid or semisolid, low-level radioactive wastes are generated. Radium 226 is the isotope of main concern.

Various types of radioactive waste are also produced by nuclear reactors, weapons production, biological laboratories, and hospitals. Proper containment and burial of some types of radioactive waste, such as waste from nuclear power plants, remains a problem. Wastes containing certain cesium, strontium, and cobalt radionuclides need several hundred years to decay to very low radioactivity levels.

COAL MINING

Coal mining may contaminate groundwater, but because contamination of surface water by mining activities is of such a serious nature, relatively little attention has been given to contamination of groundwater. Ways that mining can be hazardous to groundwater quality include the following:

1. Uncontrolled mining may pollute streams and rivers in an aquifer's recharge area.

2. Mining activities may contaminate an aquifer by intersecting it, thereby introducing contaminants.

3. Artificial lowering of the water table may expose sulfur-bearing minerals to oxygen, leading to the formation of an acid solution which may enter groundwater.

4. Tailings ponds used for disposal of wastes from a mine can contribute to groundwater contamination.

The recharge and movement of groundwater can be affected by coal mining processes. Surface and underground mining alter the environment and pose threats to groundwater quality, but good reclamation may prevent serious damage to groundwater. Mine dewatering, which involves a regional lowering of the water table, may cause a decrease in the amount of groundwater supplied, 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 groundwater levels rise again and groundwater dissolves the oxidized minerals.

Acidic groundwater 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 groundwater is now so acidic that it may be unusable for decades.

Legal Protection of Virginia's Groundwater

Legal authority to protect Virginia's groundwater begins with the Virginia Constitution, which describes the General Assembly's legislative power and the Commonwealth's policy to protect natural resources. Article XI 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. Legal protection of Virginia's groundwater is provided by the State Water Control Law, State Water Control Board permit programs and regulations, the Virginia Oil and Gas Act, the Groundwater Act of 1973, hazardous and solid waste laws, coal wastewater injection regulations, and federal laws.

STATE WATER CONTROL LAW

The State Water Control Law was enacted by the General Assembly to give substance to Virginia's natural resources protection policy. The Water Control Law provides for an "anti-degradation" policy pertaining to "state waters," including all water on the surface and underground. The law states that the Commonwealth's water policy is as follows:

1. To protect existing high-quality state waters and to restore other state waters to a quality sufficient for all reasonable public uses;
2. To safeguard clean state waters from pollution;
3. To prevent any increase in pollution;
4. To reduce existing pollution; and
5. To promote water resources conservation and management.

The Water Control Law also states that it is against public policy to discharge harmful substances or inadequately treated waste into state waters in ways that would impair the quality and, hence, the use of state waters. However, the Water Control Law does authorize new or increased discharges to high-quality water if it is demonstrated that such discharges are justified for necessary economic or social development. Any necessary waste treatment of the discharge is required by law where physically and economically feasible.

Provisions of the Water Control Law make any person, firm, or corporation liable for causing or permitting a discharge of oil into state waters. Liability also extends to the owner of a facility, vessel, or vehicle from which oil discharges into state waters. All costs for cleanup and property damage are included in this liability. The state oil spill contingency fund may be used for the cleanup if the discharger will not clean up the spill or cannot be identified.

STATE WATER CONTROL BOARD

The State Water Control Board (SWCB) has the responsibility to enforce and administer the Water Control Law, and to supervise and control the quality, management, and distribution of all state waters. The SWCB also establishes water quality standards, issues permits for discharges into state waters, and adopts regulations to enforce the general water quality management program of the board.

An important SWCB activity is administering the National Pollutant Discharge Elimination System (NPDES) in Virginia. The NPDES permit program applies to discharges of pollutants into or adjacent to state waters. As applied to groundwater, the NPDES regulation specifies that no right exists to dispose of pollutants in a well, except as authorized by an NPDES permit issued by the SWCB. A permit authorizing discharge into a well must control the disposal to prevent pollution and protect beneficial uses of both ground and surface waters.

Other SWCB regulations also apply to maintaining groundwater quality. Discharging pollutants into deep aquifers is contrary to SWCB policy. The SWCB water resources policy requires that total withdrawals from an aquifer not exceed estimated recharge, except for short periods (one or two years).

VIRGINIA OIL AND GAS ACT

Provisions of the Virginia Oil and Gas Act make it the responsibility of the Virginia Oil and Gas Inspector to prevent contamination or pollution of state waters by oil, gas, or salt water during development of oil and gas resources.

GROUNDWATER ACT OF 1973

While other laws focus on protecting groundwater quality, the principal focus of the Groundwater Act of 1973 is to protect the *quantity* of groundwater. The act provides that the SWCB can declare an area to be a groundwater management area if it finds that groundwater levels there are declining, that wells in the area interfere with each other, or that the available groundwater supply is overdrawn or polluted. Two sections of eastern Virginia have been designated as groundwater management areas (*Figure 11*). Once an area is declared a groundwater management area, a permit or a certificate of right is required to construct or operate a well there, *unless* the use of the withdrawn groundwater would fall into an exempted category. Groundwater uses exempt from permit requirements are crop and livestock watering; any single industrial or commercial use of less than 50,000 gallons a day; and human consumption or domestic use purposes (this exception also applies to municipal withdrawals). A "grandfather" provision of the law exists, but rights granted under this provision may be limited in the future by the General Assembly.

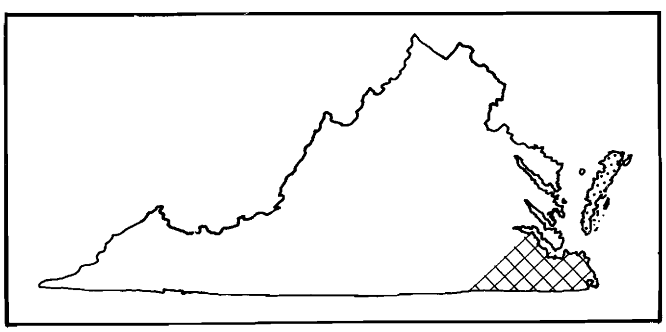


FIGURE 11
Virginia has two groundwater management areas where groundwater supplies are limited and groundwater use is carefully regulated: (1) the Southeastern Virginia area and (2) the Eastern Shore area.

HAZARDOUS AND SOLID WASTE LAWS

The State Health Commissioner is charged with protecting the Commonwealth's groundwater through the hazardous waste management facility permitting process. The Commissioner, appointed by the Governor, supervises and manages the State Department of Health in accordance with the policies, rules, and regulations made by the State Board of Health. The Commissioner can issue permits for landfills and for the transport, storage, and treatment of hazardous waste. Permits may be amended or revoked if contamination or pollution threats to groundwater arise.

Hazardous and solid waste laws are enforced by the State Board of Health. The State Board of Health consists of nine Virginia residents appointed by the Governor for terms of four years each. The State Board of Health also has adopted the EPA's hazardous waste management regulations. These regulations establish groundwater protection programs that apply to hazardous waste management facilities. These programs have four basic parts:

1. Sampling groundwater regularly to determine whether hazardous substances are present;
2. Establishing a groundwater protection standard for a specific facility if contamination is found at that facility;
3. Monitoring compliance to ensure that the groundwater protection standard is not exceeded; and
4. Taking corrective action when the groundwater protection standard is exceeded.

The State Board of Health also has banned the underground injection of hazardous wastes.

INJECTION OF COAL WASTEWATER

At coal preparation plants, coal is crushed, screened, then washed with water to remove inorganic impurities. The resulting wastewater can be acidic and may contain heavy metals and complex organic compounds in concentrations that are harmful to aquatic life and, sometimes, to higher forms of life. Injecting untreated coal wastewater into abandoned mines can be a less expensive way to dispose of it than treating the wastewater and discharging it into a river or stream, but injection can contaminate groundwater if wastewater leaks out of an abandoned mine.

In December 1983, the SWCB voted to consider allowing the injection of untreated coal preparation plant wastewater into abandoned mines in Virginia on a "case-by-case" basis. Before allowing injection, the SWCB can require a coal company to agree to set up a monitoring program that enables the SWCB to determine if a leaking abandoned mine is causing groundwater pollution, and to set up an abatement program should pollution occur. The Division of Mined Land Reclamation, in cooperation with the SWCB, has thus far issued a permit to one coal company to inject untreated coal preparation wastewater into an abandoned mine. The permit requires the company to regularly sample and analyze the wastewater, and to monitor conditions in and adjacent to the injection mine.

FEDERAL LAWS AND PROGRAMS PERTAINING TO GROUNDWATER

Federal laws of the 1970's and earlier were deisgned to deal with a variety of environmental issues including pesticides, water pollution, mine reclamation, and hazardous waste. Groundwater protection was of limited concern then because our knowledge of the scope and implications of groundwater quality and quantity problems was limited. Nevertheless, a number of broad, federal environmental laws provide substantial protection for groundwater resources. Many federal environmental programs are designed by Congress to be implemented at the state level. Such laws include the Comprehensive Environmental Response, Compensation and Liability Act of 1980, Resource Conservation and Recovery Act, Clean Water Act, Federal Insecticide, Fungicide and Rodenticide Act, Toxic Substances Control Act, Surface Mining Control and Reclamation Act, and Safe Drinking Water Act (SDWA). Two programs under the SDWA are targeted specifically at groundwater: the Sole-Source Aquifer (SSA) program, and the Underground Injection Control (UIC) program.

The SSA program under the SDWA permits citizens to petition EPA for designation of an area as a sole-source aquifer if it is a principal water supply. It provides for EPA to review all federally funded projects that may affect the quality of groundwater in the area. No aquifers in Virginia have been designated as sole-source aquifers.

Well injection is the placement of fluids into the ground (except drilling muds and similar materials used in well construction) through a well that has been bored, drilled, driven, or dug. The objective of the UIC program is to protect groundwater—that serves, or potentially could serve, as a source of drinking water—from contamination by well injection. The SDWA requires EPA to prescribe a UIC program for each state and jurisdiction that does not choose to assume the primary role of designing and implementing a state-operated UIC program. EPA has recently established UIC programs for Virginia and 21 other states and jurisdictions that have chosen not to design and implement their own UIC programs.

EPA recognizes five classes of injection wells. *Class I* wells are used to inject industrial, municipal, or nuclear wastes beneath the deepest layer containing a drinking water source. *Class II* wells are used to store hydrocarbons, to inject fluids that aid in recovery of oil and gas, or to dispose of fluids that are brought to the surface during oil and gas production. *Class III* wells are those used to inject fluids for solution mining of minerals, for converting oil shale and coal into gas, or for recovering geothermal energy. *Class IV* wells are used to inject radioactive or hazardous waste into or above layers that contain drinking water sources. Use of Class IV injection wells is banned by EPA. *Class V* wells are all injection wells that are not included in Classes I-IV, such as air-conditioning return-flow wells, and artificial recharge wells. There are no Class I, II, III, or IV wells in Virginia. The UIC program for Virginia requires builders of new Class I, II, and III wells to apply for permits before construction. As mentioned above, the state has a prohibition against underground injection of any hazardous waste. In the future the UIC program will adopt regulations for Class V wells in Virginia.

This material is condensed from Jacks, M.T., 1984. "Legal Authority to Protect Groundwater in Virginia." *Virginia's Groundwater: Proceedings of a Symposium Organized by the Environmental Defense Fund.* Virginia Water Resources Research Center, Blacksburg.

What We Can Do to Protect Groundwater

Many everyday activities have an impact on groundwater quality. In 1980 nearly three of every ten Virginians depended *entirely* on groundwater to supply their domestic water needs. Such users of domestic 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.* This means that the *well users,* usually the property owners or tenants, *are largely responsible for the quality of their own well water and perhaps for the quality of their neighbors' water.* 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 smowmelt begin to percolate into the ground and recharge the aquifer from which the well draws.

For Virginians relying on municipal supplies drawn from surface waters, which are augmented by pumped groundwater at times, the link between activities on their property and groundwater quality can be harder to understand. This awareness gap exists partly because their water source is often remote, and partly because the groundwater portion of the water flowing from the tap appears no different from the surface water portion. Well users know that groundwater serves as their only water source for domestic needs, but urban or suburban dwellers may not know the amount groundwater contributes at any one time to their water supply.

Eliminating practices that threaten groundwater quality can go a long way toward maintaining clean water. Much of the effort aimed at groundwater protection involves "keeping your house clean," that is, avoiding harmful practices and adopting good ones. Described below are some practices that citizens can adopt, and some bad practices that should be stopped.

PESTICIDES AND COMMERCIAL FERTILIZERS

Fertilizers and pesticides should be used carefully on lawns, vegetable and flower gardens, and crop fields. Some fertilizers and pesticides can travel in rainwater and snowmelt as they percolate through the soil to groundwater or run off the land surface into streams. The application directions for these substances should be followed carefully; do not apply more than is recommended (*Figure 12*).

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

SEPTIC SYSTEMS

Septic systems can threaten groundwater quality when they are improperly designed or poorly maintained. If a septic tank is not pumped out frequently enough, solids may be carried into the distribution lines, resulting in clogged lines and a clogged drain field. In turn, wastewater can back up into the house's plumbing system or rise to the ground above the drain field. This wastewater can carry disease-causing organisms and pose health hazards. Septic systems that are located too close to water wells or uphill from water wells also can pose water quality threats.

If toxic or hazardous substances are poured or flushed

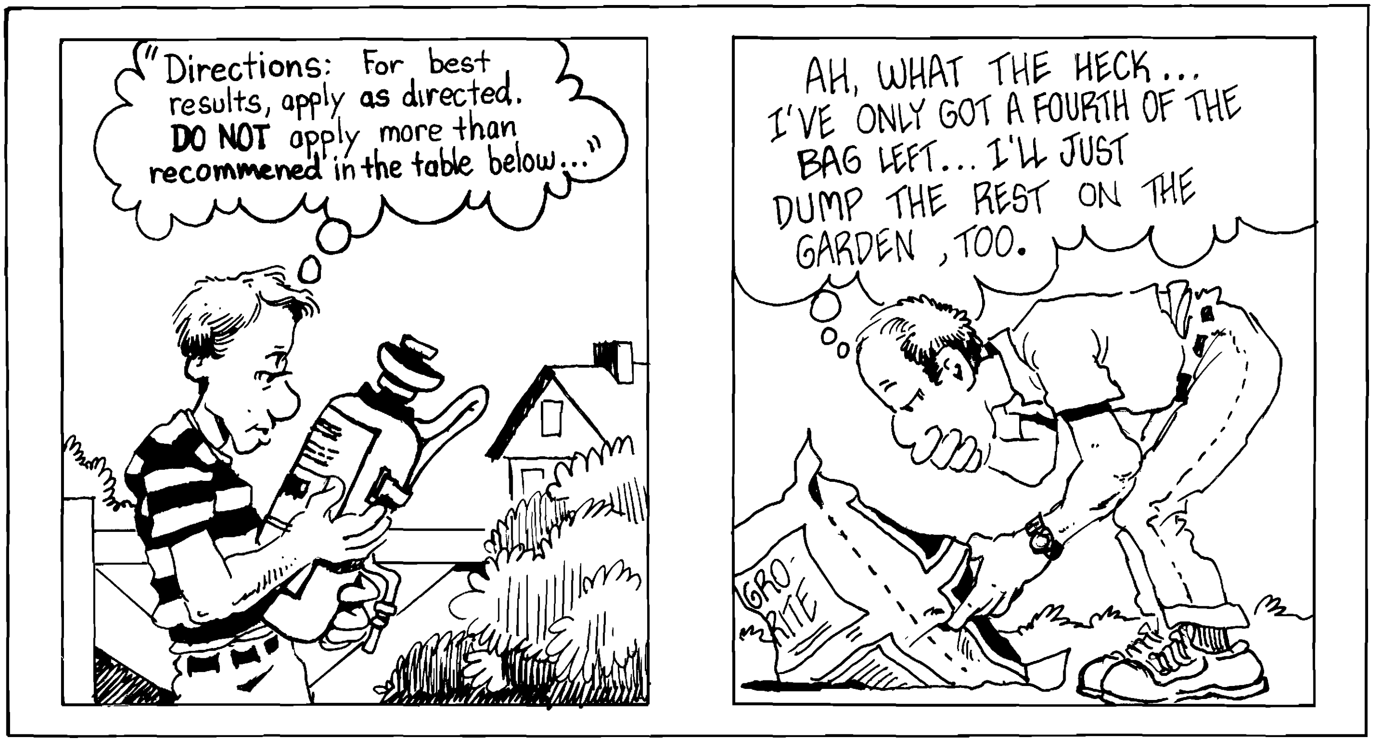


FIGURE 12
Always follow directions when using pesticides and fertilizers (a); these substances can contaminate surface water and aquifers if too much is applied (b).

into a house's plumbing system, they can pass through a septic system and contaminate groundwater. Such toxic and hazardous chemicals include paints, varnishes, thinners, waste oils, photographic solutions, pesticides, and herbicides (*Figure 13*). 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 groundwater contamination; they should not be used.

For more information on septic system use and maintenance, consult a sanitarian at your local health department.

USED OIL RECYCLING PROGRAM

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 groundwater. Used oil collection centers are located at participating service stations throughout the state. Collection centers can be located by phoning the Virginia Office of Emergency Services at this toll-free number: 1-800-552-3831.

FIGURE 13
Never dump toxic substances into household plumbing. They can pass through a septic system or sewage treatment plant and contaminate water supplies.

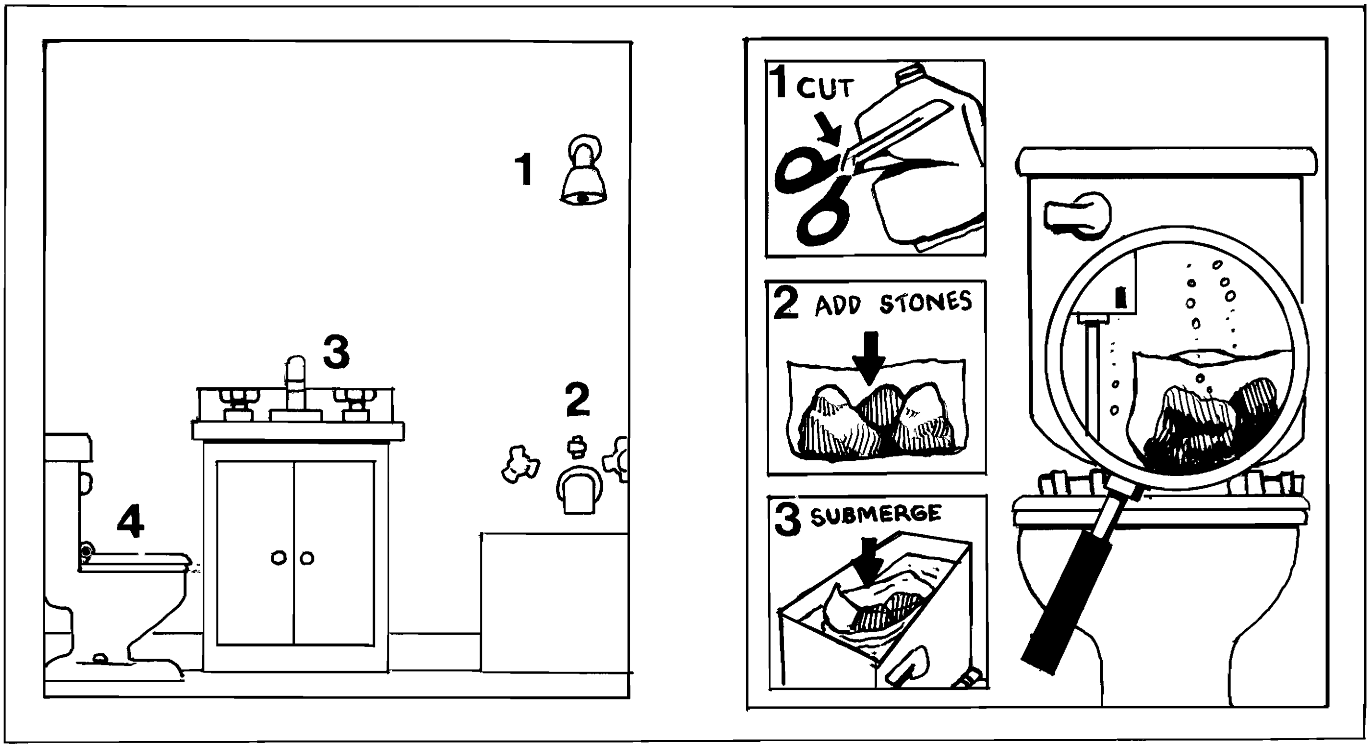


FIGURE 14
The majority of household water use is in the bathroom. Simple, inexpensive conservation devices can be installed in the bathroom (a), including a toilet-tank device made out of a milk jug and stones (b). Saving water is an easy way to save energy, money, and natural resources.

WATER WELLS

Private wells can also contribute to groundwater 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 plumbing system.

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

Pesticides, fertilizers, and herbicides should not be stored in the immediate vicinity of a well. Waste should not be dumped near a well. Underground tanks for storing fuel oil, gasoline, and diesel should not be installed near a well. Other sources that pose contamination threats are livestock pens, barns, and abandoned wells that have not been properly filled in and plugged.

Water from private wells should be tested at least once a year by a reputable private laboratory experienced in testing drinking water. State-certified laboratories for testing water are located throughout Virginia and can test private well water. Local health departments can offer information on water testing.

WATER CONSERVATION

Conserving household water saves the user not only water, but money and energy as well. The less water used means the less water going through municipal systems or septic systems for treatment. For under a dollar, you can buy and install flow restrictors in faucets and shower heads to reduce water use with little or no inconvenience to you and your family (*Figure 14*). Almost *half* of all water use in American homes is for flushing toilets. One easy way to reduce this amount 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. A leaky toilet is one of the biggest household water wasters; it can waste *more than 500 gallons of water a day.*

Conclusion

We have looked at the properties and occurrence of groundwater, the extent of Virginia's groundwater resources, the contaminants that threaten groundwater quality, the laws and regulations that protect groundwater in Virginia, and the ways in which each of us can help protect our groundwater resources. Now it is time to put Virginia's groundwater problems in perspective.

On the whole, Virginia has abundant groundwater of good quality. In fact, the condition of Virginia's groundwater resources is considerably better than that of groundwater in other parts of the country. Most contamination problems appear to be local in nature, and significant shortages exist only in southeastern Virginia.

However, as we plan for a future in which the demand for groundwater—as well as the potential for groundwater contamination—will surely increase, it is critical that we consider how our activities affect groundwater resources. Groundwater use in Virginia increased 39 percent between 1970 and 1980. Our challenge as citizens, both individually and collectively, is to safeguard our groundwater. The old maxim "an ounce of prevention is worth a pound of cure" is certainly applicable. The future quality and quantity of our groundwater depend on concerned citizens who take personal responsibility for protecting this resource. With wise management of Virginia's groundwater, this valuable, hidden resource will continue to supply the needs of the Commonwealth for many generations to come.

References

American Institute of Professional Geologists, 1983. *Groundwater Issues and Answers.* Arvada, Colorado.

Cox, W.E., 1976. "Ground Water Management in Virginia: A Comparative Evaluation of the Institutional Framework." Ph.D. dissertation. Virginia Polytechnic Institute and State University, Blacksburg.

Freeze, R.A. and J.A. Cherry, 1979. *Groundwater.* Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Heath, R.C., 1983. *Basic Ground-Water Hydrology.* Water-Supply Paper 2220. U.S. Geological Survey, Reston, Virginia.

Jacks, M.T., 1984. "Legal Authority to Protect Groundwater in Virginia." *Virginia's Groundwater: Proceedings of a Symposium Organized by the Environmental Defense Fund.* Virginia Water Resources Research Center, Blacksburg.

Edward E. Johnson, Inc., 1966. *Ground Water and Wells.* St. Paul, Minnesota: Edward E. Johnson, Inc.

Kull, T.K., 1983. *Water Use in Virginia, 1980.* SWCB Basic Data Bulletin 59. Virginia State Water Control Board, Richmond.

Miller, J.C., P.S. Hackenberry, and F.A. DeLuca, 1977. *Groundwater Pollution Problems in the Southeastern United States.* Report No. EPA-600/3-77-012. U.S. Environmental Protection Agency, Washington.

National Water Well Association, 1977. *America's Priceless Ground Water Resource.* National Water Well Association, Worthington, Ohio.

Pye, V.I., R. Patrick, and J. Quarles, 1983. *Groundwater Contamination in the United States.* Philadelphia: University of Pennsylvania Press.

Todd, D.K., 1980. *Groundwater Hydrology.* New York: John Wiley & Sons.

References

American Institute of Professional Geologists, 1983. *Groundwater Issues and Answers.* Arvada, Colorado.

Cox, W.E., 1976. "Ground Water Management in Virginia: A Comparative Evaluation of the Institutional Framework." Ph.D. dissertation. Virginia Polytechnic Institute and State University, Blacksburg.

Freeze, R.A. and J.A. Cherry, 1979. *Groundwater.* Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Heath, R.C., 1983. *Basic Ground-Water Hydrology.* Water-Supply Paper 2220. U.S. Geological Survey, Reston, Virginia.

Jacks, M.T., 1984. "Legal Authority to Protect Groundwater in Virginia." *Virginia's Groundwater: Proceedings of a Symposium Organized by the Environmental Defense Fund.* Virginia Water Resources Research Center, Blacksburg.

Edward E. Johnson, Inc., 1966. *Ground Water and Wells.* St. Paul, Minnesota: Edward E. Johnson, Inc.

Kull, T.K., 1983. *Water Use in Virginia, 1980.* SWCB Basic Data Bulletin 59. Virginia State Water Control Board, Richmond.

Miller, J.C., P.S. Hackenberry, and F.A. DeLuca, 1977. *Groundwater Pollution Problems in the Southeastern United States.* Report No. EPA-600/3-77-012. U.S. Environmental Protection Agency, Washington.

National Water Well Association, 1977. *America's Priceless Ground Water Resource.* National Water Well Association, Worthington, Ohio.

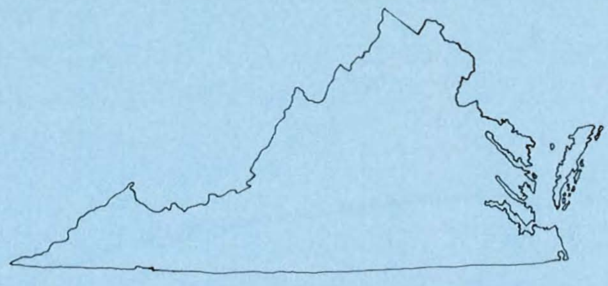
Pye, V.I., R. Patrick, and J. Quarles, 1983. *Groundwater Contamination in the United States.* Philadelphia: University of Pennsylvania Press.

Todd, D.K., 1980. *Groundwater Hydrology.* New York: John Wiley & Sons.

Groundwater Protection — It's Up to You!

The Virginia Water Resources Research Center
has booklets and brochures on septic system maintenance,
water wells, and residential water conservation.
To obtain these publications write:

Virginia Water Resources Research Center
Virginia Polytechnic Institute
and State University
617 North Main Street
Blacksburg, VA 24060-3397



Groundwater Protection — It's Up to You!

A publication of the
Virginia Water Resources Research Center
Virginia Polytechnic Institute and State University
617 North Main Street
Blacksburg, Virginia 24060-3397