Groundwater: Hidden Questions, Hidden Answers

by E. Calvin Alexander, Jr.

Society comments: *Despite the continued belief that groundwater is pristine and protected, groundwater contamination is widespread and increasing. A clear understanding of groundwater—where it comes from and where it goes—may help explain its vulnerability to society's actions.*

Groundwater seems somehow magical to most people. The word groundwater might evoke bucolic images of cool, clear water, sipped from a blue enamel dipper, straight from a hand pump, on a hot summer afternoon on the farm: "The best water I ever tasted." Some people will think of a grizzled old prospector, struggling across the desert to reach a cool, green oasis formed by a sparkling spring gushing from the base of a cliff. Yet others will imagine health spas whose waters have mythical restorative powers. People, individually and as governments, usually behave as if groundwater is created each night by elves or the tooth fairy and is pure, pristine and inexhaustible.

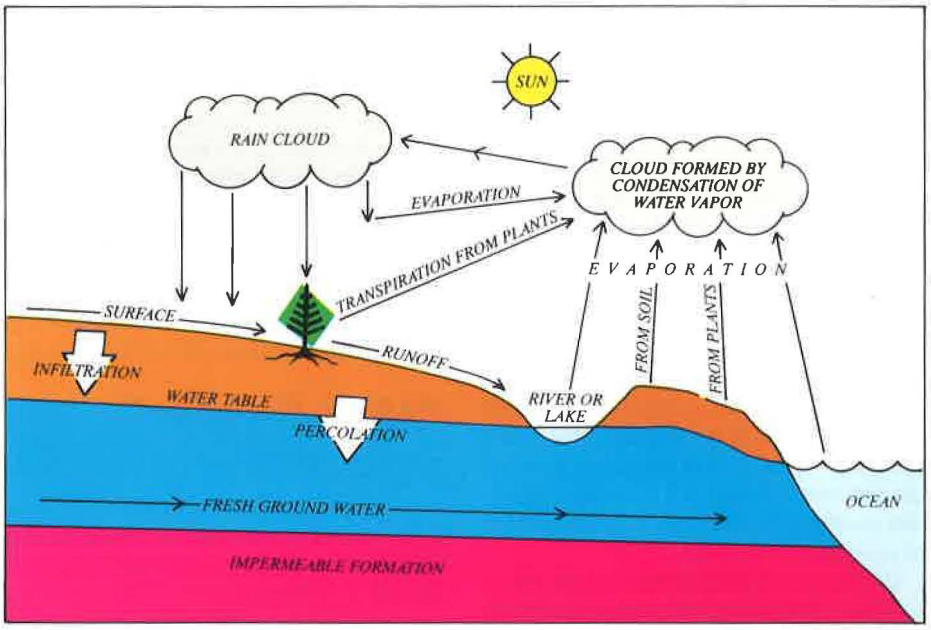
All three images are usually incorrect today and probably were always figments of romantic imaginations. The shallow farm well was (and still is in much of the Third World) a major carrier of typhoid fever and cholera. That shallow farm well is, in the United States today, probably contaminated with coliform bacteria (from fecal material), nitrates from fertilizers, and often contains traces of herbicides and pesticides. The desert spring doesn't flow anymore, because overpumping of agricultural and domestic wells has lowered the desert water table hundreds of feet. The mineral spas have proven to contain various poisonous heavy metals and often show high levels of natural radioactive materials. The quaint images are damaging in that they reflect widespread beliefs about groundwater which not only are incorrect but also produce inappropriate, counterproductive, even dangerous activities.

A fresh, cool drink from the pump: The image of well water as always being pure and drinkable is an inaccurate one. Groundwater, this country's largest and most significant source of drinking water, is a finite, exhaustible and increasingly polluted resource. Photo by Bruce Jacobson

Groundwater is not magical. It follows well-understood natural laws and its behavior can be predicted with increasing accuracy. The use and abuse of groundwater have grown exponentially during recent decades, reflecting the rise in world population and industrialization.

Groundwater is increasingly polluted. It is often recycled many times. It is very finite and all too exhaustible. *Groundwater is not put in place by elves or the tooth fairy but is an integral part of the natural hydrologic cycle.*

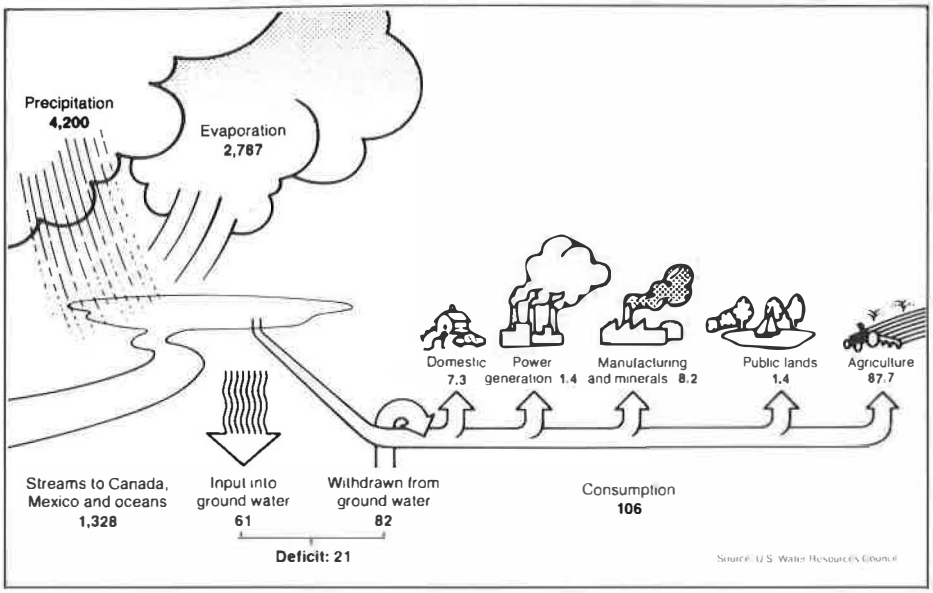
Groundwater is the largest and most significant source of fresh, potable water available to humankind. Much of its mystique comes from two properties: first, groundwater is in the ground and therefore invisible most of the time; second, groundwater occurs in an amazing range of conditions. Its invisibility and variability are challenging to professional hydrologists and frustrating to those who use or attempt to regulate the use of groundwater.



The hydrologic cycle: Groundwater plays an integral part in the continuous evaporation-transpiration-precipitation process. Reprinted courtesy of High Plains Underground Water Conservation District No. 1

General Characteristics

Groundwater is, by definition, water in the ground, or water below the surface of the earth. The solid materials which make up the earth's surface contain a wide variety and density of holes, cracks and crevices: The "solid" earth is porous. In most places, the pores nearest the surface are partially filled with air. At some depth (which varies from zero to many thousands of feet), the pores are filled with water. The imaginary surface which separates the water-filled pores from the partially air-filled pores is called the *water table.*



OVERUSING A LIMITED SUPPLY
The many users of groundwater are withdrawing from the supply faster than it is being recharged. Such overdrafting may result in the depletion of groundwater supplies.
(All figures are in billions of gallons per day.)
by Christopher Blumrich, Newsweek.
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Most experts consider *groundwater* to be that water contained in pores below the water table. If a natural geologic material contains groundwater which can be extracted in significant quantities, that natural formation is called an *aquifer.*

The amount of groundwater which can be extracted from an aquifer is controlled by the aquifer's porosity and permeability. *Porosity* is the fraction of the material which is holes rather than solids. Porosity determines how much water is in an aquifer. *Permeability* is a measure of how easily fluid moves through the material. Permeability is determined by the connectedness of the pores and controls the fraction of the water in an aquifer that can be extracted in a reasonable time. Natural materials vary enormously in terms of porosity and permeability. Natural materials with low permeabilities are called *aquitards* or *confining beds.* These aquitards or confining beds serve to partially isolate (in varying degrees) aquifers from one another and from the surface.

The last major generality of groundwater is its source. Groundwater originates as precipitation—water or ice which falls from the sky onto the surface of the earth. A variable fraction of that preciptation sinks into the ground and becomes, temporarily, groundwater. The critical questions which should be asked about the groundwater in any aquifer include when, where and at what rate the preciptation entered the ground. The "when" determines the *age* of the groundwater. The age of groundwater is the length of time it has been underground. The "where" determines the aquifer's *recharge zone.* The "at what rate" determines the *recharge rate* of the aquifer. If water is removed from an aquifer faster than it is recharged, the aquifer will inevitably go dry.

"Mind-Boggling" Differences

Most people act on the belief that there is only one kind of groundwater or aquifer or confining bed, or that all groundwater is the same age and is recharged at the same rate in the same place. In actuality, range in these properties is mind-boggling.

The quantity and quality of groundwater vary enormously. In some places, there is so much groundwater that getting rid of it is a problem. In other places no extractable water can be found, no matter how deep a well might be drilled. The quality ranges from almost "pure" precipitation to water which is saltier than the sea.

Many important aquifers are made of sand or gravel, in which the porosity consists of the tiny holes between the grains. In these aquifers the water tends to move very slowly. In other aquifers the important porosity consists of cracks, fissures and, in some cases, caves, through which actual underground rivers flow. Water in such aquifers can move as rapidly as it does in a surface stream.

Most confining beds are relatively impermeable because they contain clay. These beds, however, are often cut by joints, cracks and faults through which water can move quite rapidly. Recently it has been found, in addition, that organic solvents can break down clay minerals and destroy the impermeable nature of confining beds. *When industrial wastes are being disposed of, "impermeable clay liners" often prove to be entirely too permeable.* Finally, the best confining bed on earth fails when someone drills a hole through it. Amazing numbers of wells have been drilled and abandoned in many places.

The age of groundwater ranges from a few minutes or hours in some cases to millions of years in others. The problems associated with using very young water are completely different from those associated with using very old water. The recharge rate may be very high or essentially zero. The recharge zone may be directly underfoot or hundreds of miles away.

The Realities

The problem is not in understanding any particular aquifer system but rather in the unthinking application of knowledge gained on one aquifer to a different kind of aquifer. Specific rules, regulations and laws which attempt to regulate several different aquifers are almost certain to mismanage some if not all of them. No substitute exists for a detailed understanding of "your" particular aquifer.

Use, abuse and pollution of groundwater is increasing worldwide. The parallel to humanity's use, abuse and pollution of surface water is striking. All of the problems we have faced regarding surface water pollution are being repeated. Groundwater is still viewed, by many, as an inexhaustible resource which can absorb any amount of pollution—the same view held about rivers and lakes 50 years ago. The past decade has brought the beginnings of a turnaround in surface water pollution. *Groundwaters, however, once polluted, are much more difficult to "clean up" than rivers or lakes. The overuse and pollution of groundwater will be issues of concern for generations to come.*

The solution to the problem must start at home. Rudyard Kipling said it well in his poem *Natural Theology:*

...My privy and well drain into each other
After the custom of Christendie...
Fevers and fluxes are wasting my mother.
Why has the Lord afflicted me?

...As was the sowing so the reaping
Is now and evermore shall be.
Thou art delivered into thine own keeping.
Only Thyself hath afflicted thee!

About the author: Dr. Alexander is associate professor of geology and geophysics at the University of Minnesota. He has been conducting research on groundwater pollution in southeastern Minnesota for the past seven years.

Recommended Further Reading

"Our Most Precious Resource: Water," by Thomas Y. Canby. *National Geographic*, vol. 158, no. 2, August 1980, pp. 144-179.