# Groundwater

**Groundwater** is water located beneath the ground surface in soil pore spaces and in the fractures of geologic formations. A formation of rock or soil is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces become fully saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, streams and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology, also called groundwater hydrology.

Typically groundwater is thought of as liquid water flowing through shallow aquifers, but technically it can also include soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock, and deep geothermal or oil formation water. Groundwater is hypothesized to provide lubrication which can possibly aid faults to move. Nearly any point in the Earth's subsurface has water in it, to some degree (it may be mixed with other fluids). Groundwater is not confined only to the Earth, either; subsurface water on Mars is believed to have given rise to some of the landforms observed there. Liquid water is also believed to in the subsurface of Jupiter's moon Europa.

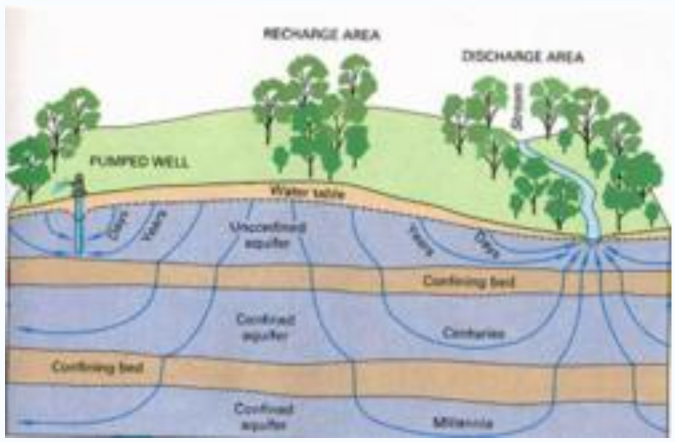
## Aquifers

An aquifer is a geologic unit (or layer) of permeable material (like sand, gravel or fractured bedrock) that is capable of providing usable quantities of water to a well. Aquifers can be *confined* or *unconfined*. A confined aquifer has a low permeability confining layer (an aquitard or aquaclude), such as clay, above and below which restricts the upward and downward movement of water from the aquifer. If a confined aquifer follows a downward grade from its *recharge zone*, groundwater can become pressurized as it flows. This can create artesian wells that flow freely without the need of a pump or rise to a higher elevation than the static water table at the above, unconfined aquifer. The depth at which the groundwater's surface is located in an *unconfined aquifer* is called the water table or phreatic surface, where water pressure is equal to atmospheric pressure. Below the water table, where generally all pore spaces are saturated with water is the phreatic zone.

The porous media in which groundwater occurs are the complex geologic materials near the earth surface; hence local details of porosity and permeability are as complex as those materials. Generally, the more productive and useful aquifers are in sedimentary geologic formations, though weathered and fractured crystalline rocks yield smaller volumes of groundwater in many environments. Among the most productive groundwater environments are unconsolidated to poorly cemented alluvial materials that have accumulated as valley-filling sediments in major river valleys and geologically subsiding structural basins.

The high specific heat capacity of water and the insulating effect of soil and rock averages out climatic fluctuations to maintain groundwater at a relatively steady temperature, approximately in the low 50's Fahrenheit. Increasingly this effect is used to heat and cool structures. During hot weather, groundwater is sometimes cool enough to be used as is, to be simply pumped through radiators in a home, then returned to the ground in another well. During cold seasons, the water, because it has a high specific heat capacity can be used as a source of heat for heat pumps that is much more efficient than using air. The relatively constant temperature of groundwater can also be used for heat pumps.

# Groundwater in the water cycle




Relative groundwater travel times

Groundwater can be a long-term 'reservoir' of the natural water cycle (with residence times from days to millennia), as opposed to short-term water reservoirs like the atmosphere and fresh surface water (which have residence times from minutes to years). The figure shows how deep groundwater (which is quite distant from the surface recharge) can take a very long time to complete its natural cycle. Groundwater is naturally replenished by surface water from precipitation, streams, and rivers when this recharge reaches the water table. It is estimated that the volume of groundwater comprises 30.1% of all freshwater resource on earth compared to 0.3% in surface freshwater; the icecaps and glaciers are the only larger sources of fresh water on earth at 68.7%.

Groundwater makes up about twenty percent of the world's fresh water supply, which is about 0.61 percent of the entire world's water supply. (Environment Canada Website)

# Problems

## Overdraft

Groundwater is a highly useful and abundant resource, but in arid or semi-arid regions it is in a pre-development state. The most evident problem that may result from this is a lowering of the water table beyond the reach of existing wells. Wells must consequently be deepened to reach the groundwater; in some places (e.g., California, Texas and India) the water table has dropped hundreds of feet from well pumping. A lowered water table may, in turn, cause other problems such as subsidence and saltwater intrusion.

## Subsidence

In its natural equilibrium state, the hydraulic pressure of groundwater in the pore spaces of the aquifer and the aquitard supports some of the weight of the overlying sediments. When groundwater is removed from aquifers, due to excessive pumping, pore pressures in the aquifer drop, and compression of the aquifer may occur. This compression may be partially recoverable if pressures rebound, but much of it is not. When the aquifer gets compressed it may cause land subsidence, a drop in the ground surface. The city of New Orleans, Louisiana is actually below sea level today, and its subsidence is partly caused by removal of groundwater from the various aquifer/aquitard systems beneath it. In the first half of the 20th Century, the city of San Jose, California dropped 13 feet due to land subsidence caused by overpumping; this subsidence has been halted with improved groundwater management.

## Seawater intrusion

Generally, in very humid or undeveloped regions, the shape of the water table mimics the slope of the surface. The recharge zone of an aquifer near the seacoast is likely to be inland, often at considerable distance. In these coastal areas, a lowered water table may induce sea water to reverse the flow toward the sea. Sea water moving inland is called a saltwater intrusion. Alternatively, salt from mineral beds may leach into the groundwater of its own accord.

## Mining

Sometimes the water movement from the recharge zone to the place where it is withdrawn may take centuries (see figure above). When the usage of water is greater than the recharge, it is referred to as *mining* water (the water is often called fossil water because of its geologic age). Under those circumstances it is not a renewable resource.

## Pollution

Iron oxide staining caused by reticulation from an unconfined aquifer in karst topography. Perth, Western Australia.

Not all groundwater problems are caused by over-extraction.Pollutants released to the ground can work their way down into groundwater. Movement of water and dispersion within the aquifer spreads the pollutant over a wider area, which can then intersect with groundwater wells or find their way back into surface water, making the water supplies unsafe. The interaction of groundwater contamination with surface waters is analyzed by use of hydrology transport models.

The stratigraphy of the area plays an important role in the transport of these pollutants. An area can have layers of sandy soil, fractured bedrock, clay, or hardpan. Areas of karst topography on limestone bedrock are sometimes vulnerable to surface pollution from groundwater. See environmental engineering and remediation. Water table conditions are of great importance for drinking water supplies, agricultural irrigation, waste disposal (including nuclear waste), and other ecological issues.

Upon commercial real estate property transactions both groundwater and soil are the subjects of scrutiny, with a Phase I Environmental Site Assessment normally being prepared to investigate and disclose potential pollution issues.

Love Canal was one of the most widely known examples of groundwater pollution. In 1978, residents of the Love Canal neighborhood in upstate New York noticed high rates of cancer, and an alarming number of birth defects. This was eventually traced to organic solvents and dioxins from an industrial landfill that the neighbourhood had been built over and around, which had then infiltrated into the water supply and evaporated in basements to further contaminate the air. 800 families were reimbursed for their homes and moved, after extensive legal battles and media coverage.

Another example of widespread groundwater pollution is in the Ganges Plain of northern India and Bangladesh where severe contamination of groundwater by naturally occurring arsenic affects 25% of water wells in the shallower of two regional aquifers. The pollution occurs because aquifer sediments contain organic matter (dead plant material) that generates anaerobic (an environment without oxygen) conditions in the aquifer. These conditions result in the microbial dissolution of iron oxides in the sediment and thus the release of the arsenic, normally strongly bound to iron oxides, into the water. As a consequence, arsenic-rich groundwater is often iron-rich, although secondary processes often obscure the association of dissolved arsenic and dissolved iron.

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