GROUNDWATER

Groundwater begins with precipitation that seeps into the ground. The amount of water that seeps into the ground will vary widely from place to place, depending on the slope of the land, amount and intensity of rainfall, and type of land surface. Porous, or permeable, land containing lots of sand or gravel will allow as much as 50 percent of precipitation to seep into the ground and become groundwater. In less permeable areas, as little as five percent may seep in. The rest becomes runoff or evaporates. Over half of the fresh water on Earth is stored as groundwater.

As water seeps through permeable ground, it continues downward until it reaches a depth where water has filled all the porous areas in the soil or rock. This is known as the saturated zone. The top of the saturated zone is called the water table. The water table can rise or fall according to the season of the year and the amount of precipitation that occurs. The water table is typically higher in early spring and lower in late summer. The porous area between the land surface and the water table is known as the unsaturated zone.

AQUIFERS

Water-bearing rock, sand, gravel, or soil that is capable of yielding usable amounts of groundwater is called an aquifer. The water yield from an aquifer depends greatly on the materials that make it up. Mixtures of clay, sand, and fine particles yield small amounts of water because the spaces between the particles don't allow water absorption and flow. Materials sorted into distinct layers will yield high amounts of water from coarse-grained materials like large sand grains and gravel, but low amounts from fine-grained sand, silt, or clay. Bedrock aquifers will yield substantial amounts of water if there are large openings or cracks in the rock. The capacity of soil or rock to hold water is called its porosity; the capacity for water to move through the aquifer is called permeability.

There are two types of aquifers: confined, or artesian aquifers, and unconfined, or water table aquifers. Artesian aquifers contain groundwater that is trapped under impermeable soil or rock and may be under pressure. Artesian wells are wells that pierce artesian aquifers. The water in these wells usually rises toward the surface under its own pressure. If the water level in the well is higher than the land surface, it may be a flowing artesian well. A well in an unconfined aquifer has the same water level as the water table around it.

GROUNDWATER RECHARGE

Water that seeps into an aquifer is known as recharge. Recharge comes from a variety of sources, including seepage from rain and snow melt, streams, and groundwater flow from other areas. Recharge occurs where permeable soil allows water to seep into the ground. Areas in which this occurs are called recharge areas. They may be small or quite large. A small recharge area may supply all the water to a large aquifer. Streams that recharge groundwater are called losing streams because they lose water to the surrounding soil or rock.

GROUNDWATER DISCHARGE

Groundwater can leave the ground at **discharge points**. Discharge happens continuously as long as enough water is present above the discharge point. Discharge points include springs, stream and lake beds, wells, ocean shorelines, and wetlands. Streams that receive groundwater are called **gaining streams** because they gain water from the surrounding soil or rock. In times of drought, most of the

surface water flow can come from groundwater. Plants can also contribute to groundwater discharge, because if the water table is close enough to the ground, groundwater can be discharged by plants through transpiration.

GROUNDWATER MOVEMENT

Groundwater usually moves slowly from recharge areas to discharge points. Flow rates within most aquifers can be measured in feet per day, though in karst bedrock the rate of flow can be measured in miles per hour. Flow rates are faster when cracks in rocks or very loose soil allow water to move freely. However, in dense soil, groundwater may move very slowly or not at all.

Groundwater typically moves in **parallel paths**, or layers. Since groundwater movement is slow, it doesn't create enough turbulence to cause mixing the way surface waters mix when a river or stream empties into another waterbody. That is, layers of groundwater remain relatively intact. This can be an important factor in locating and determining the movements of contaminants that might enter the groundwater supply. But eventually contaminants will disperse through part or all of an aquifer.

Wells affect groundwater flow by taking water out of an aquifer and lowering the nearby water table. Removed water is recharged from the water table, and the lowered water table caused by the well is called a **cone of depression**. The cone of depression from a well may extend to nearby lakes and streams, causing the stream to lose water to the aquifer. This is known as **induced recharge**. Streams and wetlands have been completely dried up by induced recharge from well pumping.

GROUNDWATER PROBLEMS

SOURCES OF GROUNDWATER CONTAMINATION

Groundwater contamination can come from a number of natural and human-made sources. These can include:

***Leaks and spills at factories and commercial facilities**

Spills and leaks can result from accidents, lack of employee training, improper planning, and inadequate maintenance. They are especially problematic if proper procedures are not in place to clean them up once they occur. Materials which can cause problems if spilled, include gasoline, other petroleum products, hazardous chemicals, and a variety of other materials.

It's difficult to eliminate accidental spills, but they can be reduced and the damage they cause can be minimized by proper design and maintenance of facilities and proper employee training. The Emergency Planning and Community Right-to-Know Act of 1986 (SARA Title III) requires states, communities, and businesses to have plans for responding quickly in the event of an accidental spill. Workers must be informed as to what hazardous chemicals they may be working with, and what to do in case of an accident. This act has prevented or reduced many instances of groundwater contamination.

***Improper hazardous waste disposal**

Improper industrial waste disposal can come from a variety of sources, including major industrial plants and small businesses. The local dry cleaner uses a number of solvents and hazardous chemicals for cleaning clothes, and these must be handled as carefully as any other hazardous waste to prevent groundwater contamination. Industrial wastes can create groundwater pollution problems that take years to resolve.

The disposal of hazardous industrial wastes is now carefully regulated under the Resource Conservation and Recovery Act (RCRA), which requires industry to have a "cradle to grave" system of tracking hazardous wastes. This system is designed to prevent inadvertent (and sometimes purposeful) release of hazardous materials into the environment by requiring businesses to report hazardous wastes and account for their proper disposal (except for some small quantity generators). The law establishes severe penalties for noncompliance. Another Federal law, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) responds to environmental threats from improper disposal of hazardous wastes and sets standards for cleanup—even for sites that were contaminated years ago where the source of contamination may not be easily identifiable.

Individuals can also be sources of hazardous waste pollution. If you dump oil in your driveway, pour paint thinner in the toilet, or dispose of wastewater with hazardous cleaners in the bathtub, you could be a source of hazardous pollution. Ways to avoid this are to recycle oil and other petroleum based chemicals at service stations or recycling centers. Avoid using hazardous chemicals when possible and substitute more environmentally friendly materials. Many communities sponsor household chemical disposal days so that individuals can take solvents and other hazardous wastes to a site for proper disposal.

***Improper use and disposal of pesticides**

Pesticides used on farms and even on individual lawns can create serious groundwater pollution. Improper pesticide use can cause people and animals to become ill, kill plants, and have adverse effects on aquatic life in nearby streams. Improper pesticide use can include excessive or ill-timed application, improper storage, or improper disposal of excess pesticides. If you overuse pesticides on your yard, you could be polluting your own groundwater. It's been estimated that individuals use over 100 times as much pesticides and fertilizer on their yards as farmers use on the same amount of land.

Avoiding pesticide pollution of groundwater is relatively easy. Follow instructions carefully. Reduce pesticide use in areas known to be recharge areas for groundwater. Use natural pest control methods rather than chemicals. Homeowners can substitute biocontrol agents, like praying mantises or ladybugs, for pesticides. Other natural insect repellents include plants like mint (which discourages ants), garlic, and marigolds.

***Leachate from landfills**

If landfills are not properly constructed, liquid from decomposition of materials, or **leachate**, can leak out of the landfill into an aquifer. Leachate can contain high levels of bacteria, hazardous chemicals, metals, and ammonia. Runoff water from landfills after rains can also carry pollution to groundwater recharge areas—and hence into groundwater.

New landfill construction methods are designed to prevent pollution of groundwater. Landfills are now built with liners to prevent leachate from seeping through soil into aquifers. Leachate collection systems store the liquid away from the water table. Clay caps prevent rainwater runoff from carrying pollutants from the landfill into the groundwater.

***Septic systems**

Septic systems can be a source of groundwater pollution if too many systems are located in an area, if a system is overloaded or not working properly, or if a system is improperly used for disposal of chemicals or other materials. If a septic system is not working properly, it can contaminate groundwater with bacteria, viruses, and hazardous cleaning materials or household chemicals. Even properly working well-maintained septic systems can contribute nitrates to groundwater. These can show up in well water around the septic system.

Methods of preventing groundwater pollution from septic systems include proper system installation and maintenance. If the concentration of households in an area is too great, then a public sewer and waste treatment system may be necessary. Dumping hazardous chemicals into septic systems should also be avoided.

***Saline Intrusion**

In coastal areas, too much demand on potable groundwater can create induced recharge from ocean waters, resulting in saline intrusion into groundwater supplies. This can also happen in times of severe drought. (Induced recharge can not only contaminate groundwater, but enough induced recharge has been known to dry up wetland areas and destroy habitats for wildlife.)

Careful planning of coastal communities and water conservation are ways to avoid saline intrusion into groundwater supplies.

***Salts and chemicals used to deice roads**

In northern climates, tons of salt and other chemicals are used for deicing roads, and these can create groundwater contamination problems. Runoff from storage areas and highways can seep into the ground and cause high levels of chlorides in well water. Prevention of pollution from this source can be through protection of storage areas, minimal salt use, and substitution of other materials, such as sand or gravel.

***Liquid waste storage lagoons**

Storage lagoons are used by industries, farms, cities, and mines as a way of preventing pollution by allowing solid wastes to settle before wastewater is released. However, storage lagoons can cause groundwater pollution if they leak or overflow. They can be sources of bacterial or chemical groundwater pollution.

Groundwater contamination from lagoons can be avoided through proper installation and maintenance and by locating lagoons away from sensitive groundwater areas.

***Fertilizers**

Like pesticides, misuse of fertilizers can cause groundwater pollution. Overuse can allow nitrates from fertilizer to seep into the water table. In sensitive groundwater areas, rainfall seepage can cause fertilizer to migrate and contaminate an aquifer.

Careful use can avoid or minimize these problems.

***Animal wastes**

Animal wastes are sources of bacteria and nitrates. They can contaminate groundwater if too many animals are located in too small a lot, or if the lot has improper drainage. Lagoons used to trap animal wastes can be a source of groundwater pollution if they leak or if the water table is too close to the land surface. Proper siting of animal lots, along with regular cleaning and avoiding overloading, can prevent animal waste pollution. Wastes can be recovered and used as fertilizer.

***Leaking underground storage tanks**

Leaking underground tanks are a potentially large groundwater pollution problem. And no one is really sure how large the problem will be. It's been estimated that the locations of only **half** of all the underground storage tanks are known in the U.S. Many of these are old, corroded, and beginning to leak and cause problems. Underground storage tanks are commonly found at service stations, where gasoline pollution is a potential problem. Many stations have replaced old steel tanks and piping, with fiberglass tanks and piping that don't corrode.

Federal law now requires that owners/operators of USTs prevent the release of product into the environment. This may require the owner/operator to install storage tanks that have a secondary containment system should the primary tank fail. Careful monitoring of tank inventories can be used to detect leaks and correct them, and tanks that are no longer in use must be closed by either removing them or filling them with inert materials.

***Pipeline breaks**

Pipeline breaks can be sources of localized groundwater pollution. Breaks can be severe enough so that they are immediately detected, or they may be small and cause significant groundwater contamination before they are noticed. Pipeline breaks can cause pollution from sewage, petroleum products, or other chemicals. They can occur around roadways due to vibration from vehicles, or they can even be caused by plant roots, which slowly crack pipes and cause leaks. Careful inspection of

pipelines and regular maintenance can reduce pollution problems from this source.

***Inadequately sealed wells or abandoned wells**

It's sometimes difficult to imagine wells, our chief way of tapping into groundwater supplies, as a source of groundwater pollution, but they can be pathways for pollutants to enter the groundwater system. If a well isn't sealed or cased properly, polluted water from runoff can enter at the well cover or along its walls and be channeled directly into groundwater. Open abandoned wells can be a significant source of groundwater pollution. And if a well is deep enough to reach a layer of groundwater that is otherwise protected by impermeable soil from pollution from surface seepage, it can create severe contamination of an otherwise pure water source.

Groundwater pollution from wells can be prevented by properly sealing wells which will no longer be used with concrete or earth. Well covers and tight casings are used as temporary measures. Procedures have also been developed to properly seal and plug abandoned wells.

***Underground injection wells**

Underground injection wells are a method of waste disposal. Wastes disposed by this method include industrial chemicals, sewage effluent, cooling water, storm water, and salt water. Typically, injection wells inject wastes below sources of drinking water, but if injection wells have leaks or are used improperly, they can inject wastes directly into a usable groundwater supply.

Injection wells are carefully monitored by state and federal regulations to prevent pollution. Businesses using injection wells are required to have permits for their use and to comply with permit conditions.

***Radon contamination**

Radon is a naturally occurring radioactive element that has been linked to cancer in humans. It occurs in certain geologic areas, and can be an air or water pollutant. Radon can collect as a gas in a basement, or it can contaminate well water. Test kits for radon detection are available for individual use. Once detected, radon can be removed from a home or a water well.