The Hydrosphere

- The water on and in Earth's crust makes up the hydrosphere.
- About 97 percent of the hydrosphere is contained in the oceans.
- The water contained by landmasses—nearly all of it freshwater—makes up only about 3 percent of the hydrosphere.
- Freshwater is one of Earth's most abundant and important renewable resources.

Precipitation and Groundwater

- Evaporation of seawater introduces water into the atmosphere in the form of invisible water vapor and visible clouds.
- Precipitation brings atmospheric moisture back to Earth's surface.
- **Infiltration** is the process by which precipitation that falls on land surfaces enters the ground and becomes groundwater.
- Only a small portion of precipitation becomes runoff and is returned directly to the oceans through streams and rivers.

Groundwater Storage

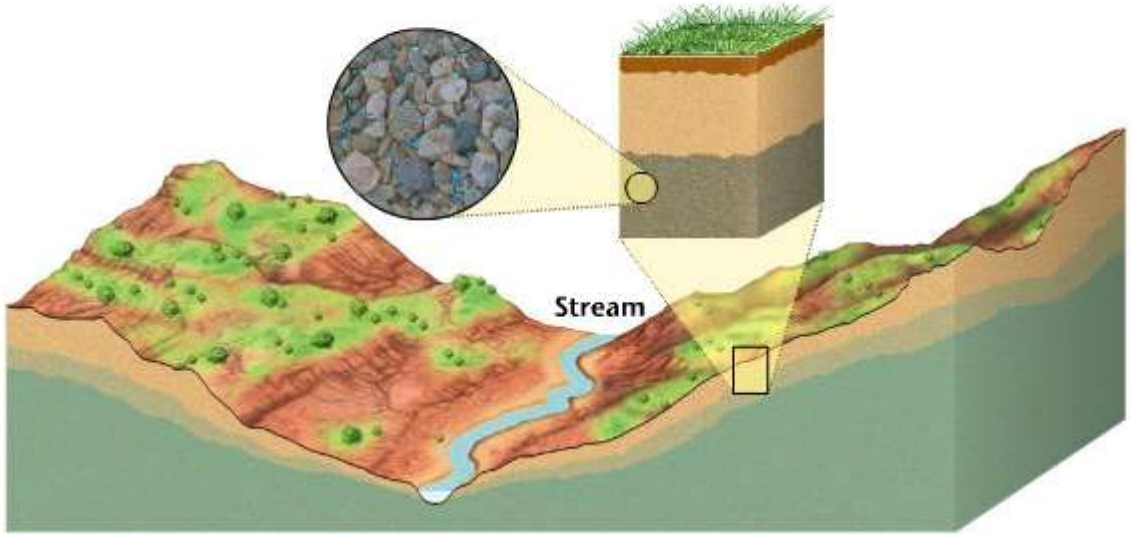
- Puddles of water that are left after a rain quickly disappear, partly by evaporating and partly by percolating into the ground.
- Subsurface Earth materials contain countless small openings, or pores, which make up a large portion of some of these materials.

Porosity is the percentage of pore space in a material.

The Zone of Saturation

- The **zone of saturation** is the depth below Earth's surface at which groundwater completely fills all the pores of a material.
- The **water table** is the upper boundary of the zone of saturation.
- Above the water table in the zone of aeration, the pores contain mostly air.

The Zone of Saturation



reset

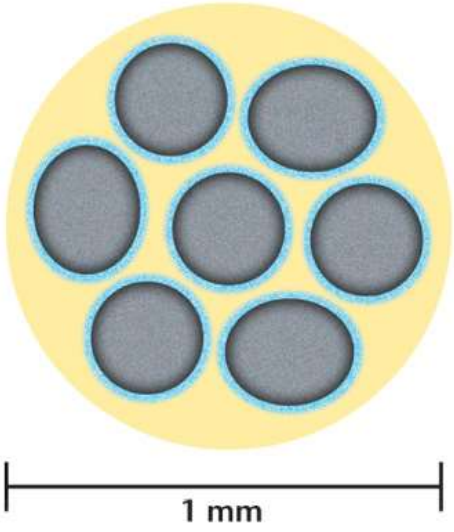
The Zone of Saturation

The Water Table

- The depth of the water table varies depending on local conditions.
- The topography of the water table follows the topography of the land above it.
- Because of its dependence on precipitation, the water table fluctuates with seasonal and other weather conditions.

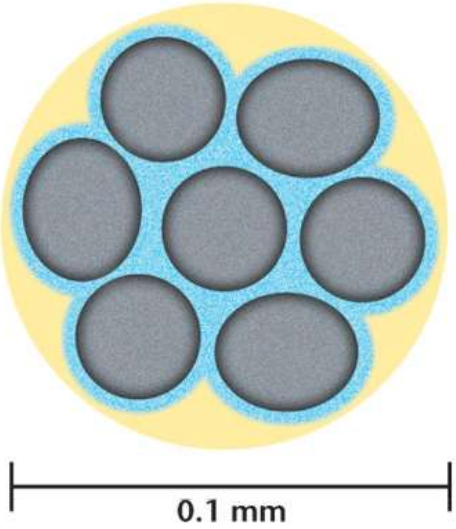
Groundwater Movement

- Groundwater flows downhill in the direction of the slope of the water table, squeezing through numerous tiny pores in the subsurface material.
- **Permeability** is the ability of a material to let water pass through it.
- Materials with large, connected pores, such as sand and gravel, have high permeabilities.



Groundwater Movement

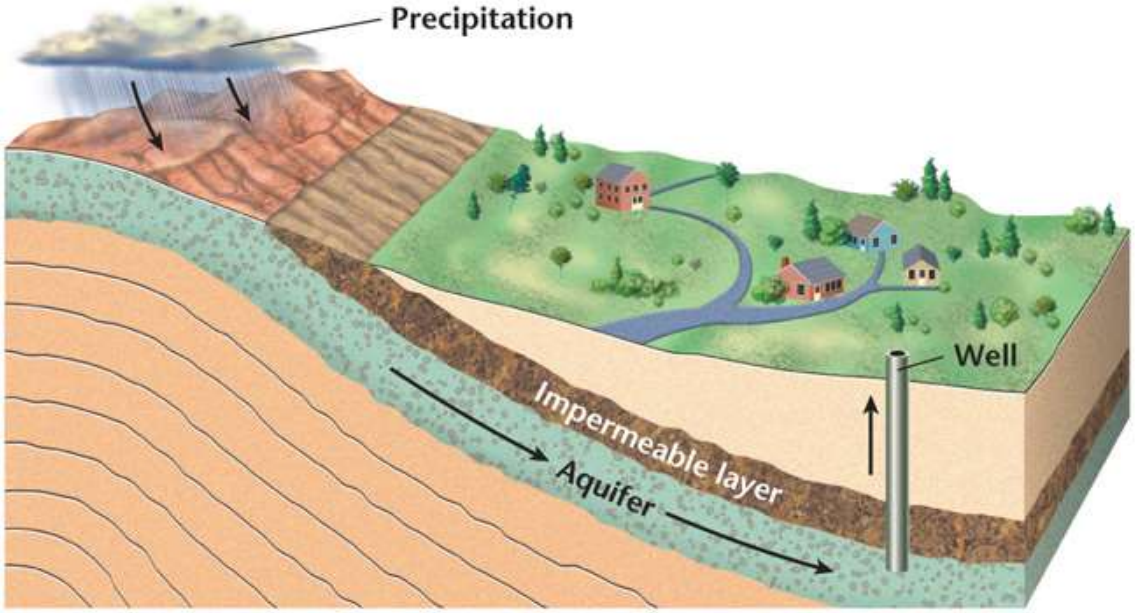
- Fine-grained materials typically have low permeabilities because their pores are so tiny.
- These materials, such as silt, clay, and shale, are said to be impermeable.



- Flow velocities through permeable materials are always higher than those through impermeable materials, regardless of the slope of the water table.

Groundwater Movement

- **Aquifers** are underground permeable layers where most groundwater flow takes place.
- Impermeable layers, called aquicludes, are barriers to groundwater flow.



Section Assessment

1. Match the following terms with their definitions.

_C_ infiltration

_B_ porosity

_D_ water table

_A_ permeability

A. the ability of a material to let water pass through

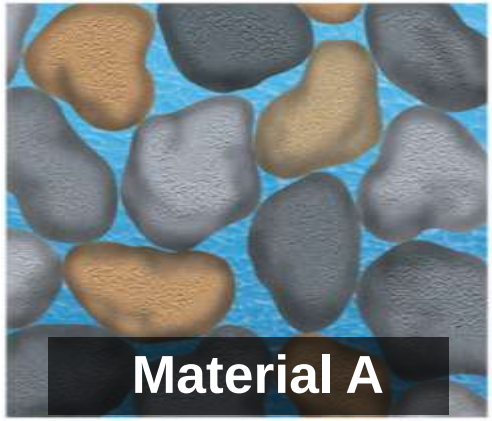
B. the percentage of pore space in a material

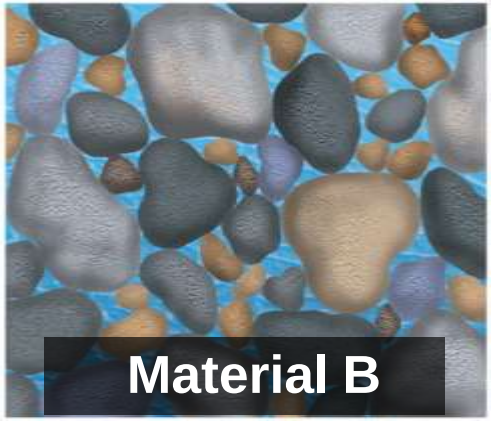
C. the process through which water enters the ground and becomes groundwater

D. the upper boundary of the zone of saturation

Section Assessment

2. Which of the following materials has the highest permeability? Explain why.





Material A has the highest level of permeability because it has the highest porosity.

Section Assessment

3. Identify whether the following statements are true or false.

true Rivers and streams hold less than .01 percent of Earth's total water supply.

false The water table is generally located near sea level.

false Because of its high permeability clay is used to line landfills.

true Only water in the zone of saturation is called groundwater.

Groundwater Erosion and Deposition

- Most groundwater contains some acid, in most cases carbonic acid.
- As a result, groundwater is usually slightly acidic and attacks carbonate rocks, especially limestone.
- Limestone consists mostly of calcium carbonate ($CaCO_3$), which dissolves readily in any kind of acid.

Dissolution by Groundwater

Caves

- A **cave** is a natural underground opening with a connection to Earth's surface.
- Practically all caves of significant size are formed when groundwater dissolves limestone.
- Most caves develop in the zone of saturation just below the water table.
- As the limestone formation becomes more permeable the resulting increased downhill flow of groundwater gradually lowers the water table.
- The thick limestone formations eventually become honeycombed with caves and caverns.

Dissolution by Groundwater

Karst Topography

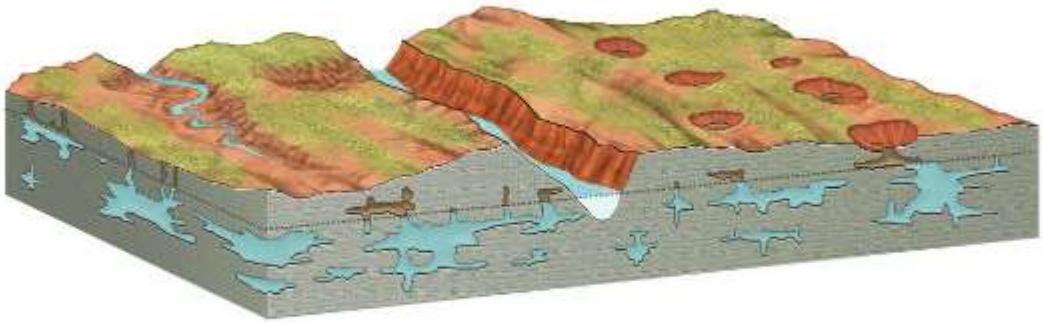
– Some of the characteristic surface features produced by the dissolution of limestone include:

- A **sinkhole** is a depression in the ground caused by the collapse of a cave or by the direct dissolution of bedrock by acidic rain or moist soil.
- A sinking stream forms when a surface stream drains into a cave system, continues underground, and leaves a dry valley above.

– **Karst topography** describes limestone regions that have sinkholes, sinks, and sinking streams.

Dissolution by Groundwater

Karst Topography



Section Assessment

2. Why do most caves form in limestone formations?

Limestone consists mostly of calcium carbonate, which dissolves readily in any kind of acid. Most groundwater contains some acid, in most cases carbonic acid. The acidic groundwater slowly dissolves any limestone that it comes in contact with.

Groundwater Systems

- The average length of time that groundwater remains underground is several hundred years.
- Groundwater eventually returns to Earth's surface.
- In most cases, groundwater emerges wherever the water table intersects Earth's surface.

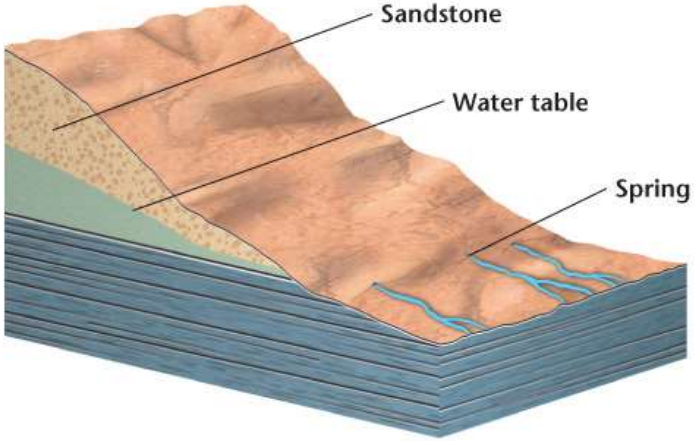
Springs

- Aquifers are permeable underground layers through which groundwater moves with relative ease.
- Aquicludes, such as layers of clay or shale, block groundwater movement.

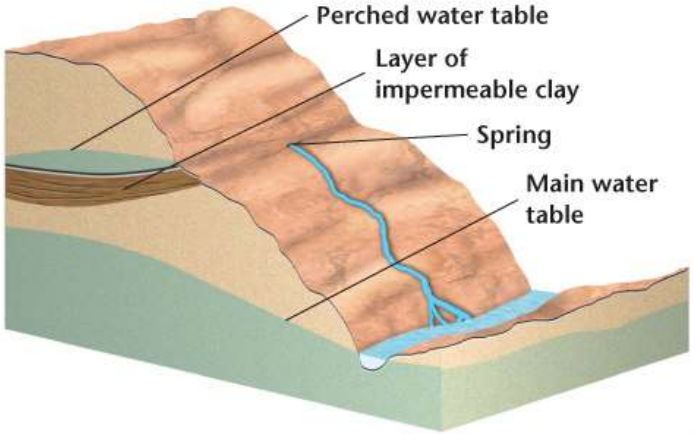
Springs, or natural discharges of groundwater, tend to occur where an aquifer and an aquiclude come in contact with Earth's surface.

Springs

Emergence of Springs



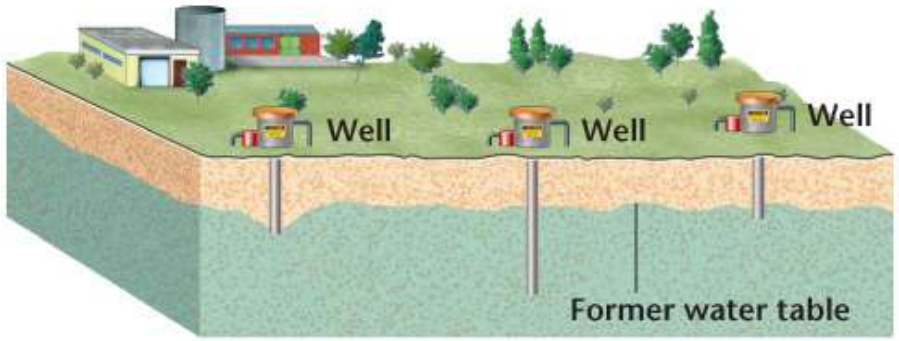
– In regions of near-horizontal sedimentary rocks, springs often emerge on the sides of valleys at about the same elevation, at the bases of aquifers.



– Springs may also emerge at the edges of perched water tables. A perched water table is a zone of saturation that overlies an aquiclude that separates it from the main water table below.

Wells

- **Wells** are holes dug or drilled deep into the ground to reach a reservoir of groundwater.
- To produce water, a well must tap into an aquifer.
- The simplest wells are those that are dug or drilled below the water table, into the zone of saturation, and into what is called a water-table aquifer.



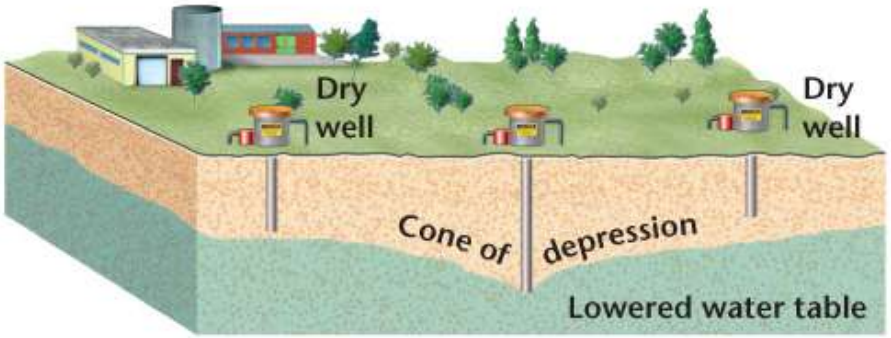
Before heavy pumping

Wells

- Overpumping of the well lowers the water level in it and produces a cone of depression in the water table around the well.

Drawdown is the difference between the original water-table level and the water level in the pumped well.

Recharge is the process in which water from precipitation and runoff is added back to the zone of saturation.



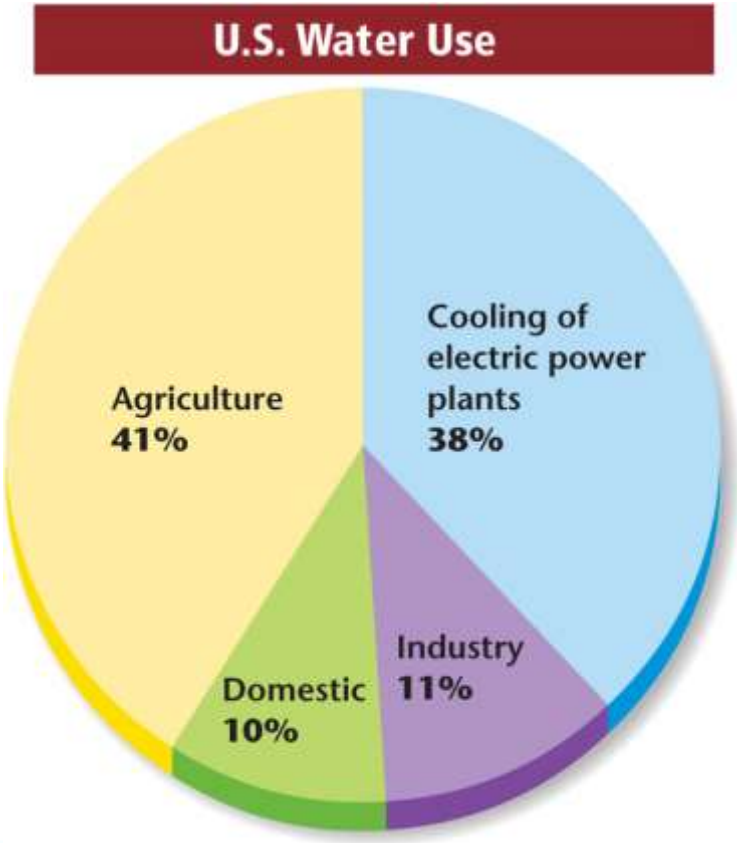
After heavy pumping

Confined Aquifers

- Water-table aquifers are unconfined and unprotected, and thus, they are easily polluted.
- More reliable and less easily polluted water supplies can be found in deeper aquifers, called confined aquifers, which are generally sandwiched between aquicludes.
- The aquicludes form barriers that prevent pollutants from reaching such aquifers.

Threats to Our Water Supply

- Freshwater is Earth's most precious natural resource.
- Human demands for freshwater include household use, agriculture, and industry.



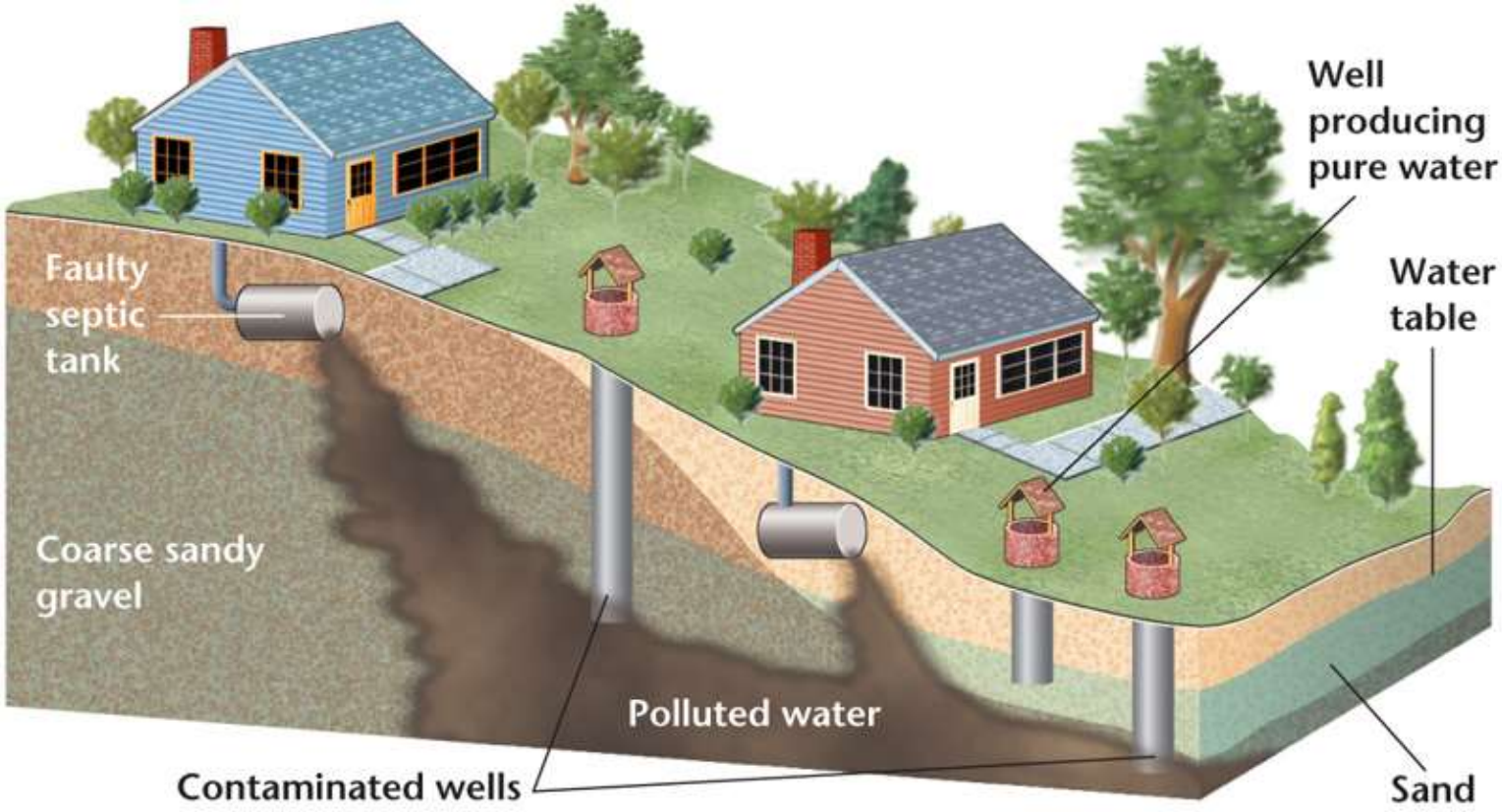
Threats to Our Water Supply

Pollution in Groundwater

- Water-table unconfined aquifers are the most easily polluted groundwater reservoirs.
- Confined aquifers, though somewhat protected from local pollution, become contaminated when their recharge areas are polluted.
- The most common sources of groundwater pollution are sewage, industrial waste, landfills, and agricultural chemicals.

Threats to Our Water Supply

Pollution in Groundwater



Threats to Our Water Supply

Salt

- In many coastal areas, the contamination of freshwater by salt water is the major problem.
- In such areas, the fresh groundwater near Earth's surface is underlain by denser, salty seawater.
- The overpumping of wells can cause the underlying salt water to rise into the wells and contaminate the freshwater aquifer.