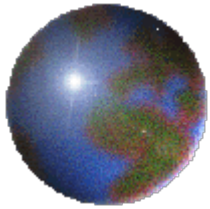


Introduction to Physical Geology

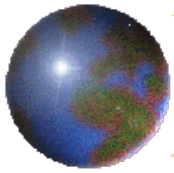


Chapter 15 Ground Water









By Dr. Jia Hui

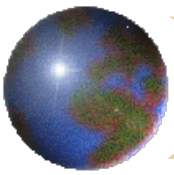
School of Earth Sciences and Engineering

Xi'an Shiyou University



Content

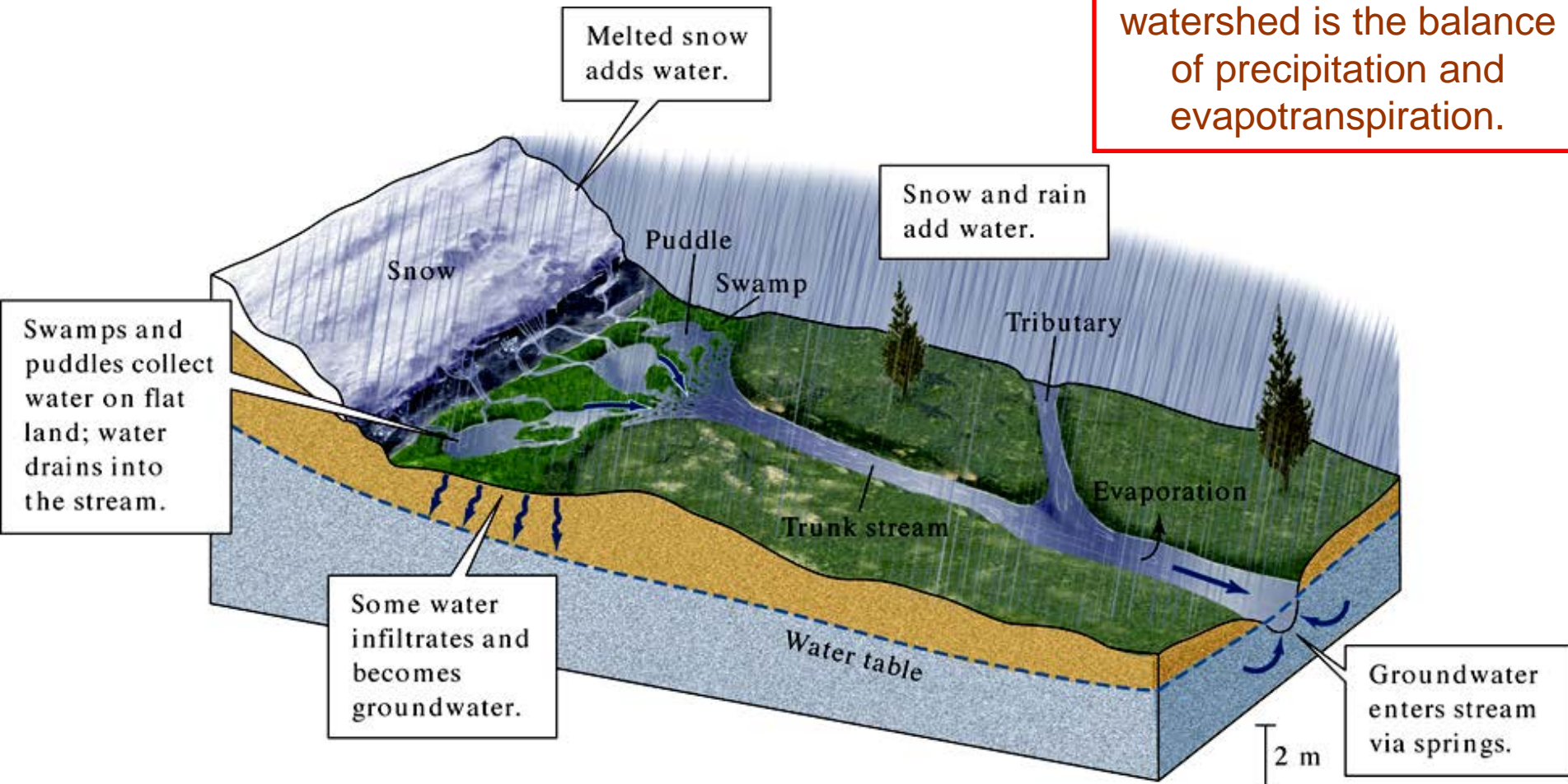
-  15.1 What Is Ground Water
-  15.2 Characteristics of Ground Water
-  15.3 Movement of Ground Water
-  15.4 Use of Ground Water
-  15.5 Ground Water Pollution
-  15.6 Caverns and Karst Topography
-  15.7 Hot Springs and Geysers
-  15.8 Geothermal Energy

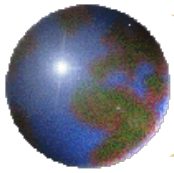


15.1 Ground Water

Groundwater: Subsurface water below the water table, which is the depth where soil becomes water saturated (i.e. all pore spaces are water filled).

Water gain within a watershed is the balance of precipitation and evapotranspiration.





15.2 Characteristics of Ground Water

* POROSITY AND PERMEABILITY

* The proportional volume of the open spaces is called the **porosity** of rock or soil.

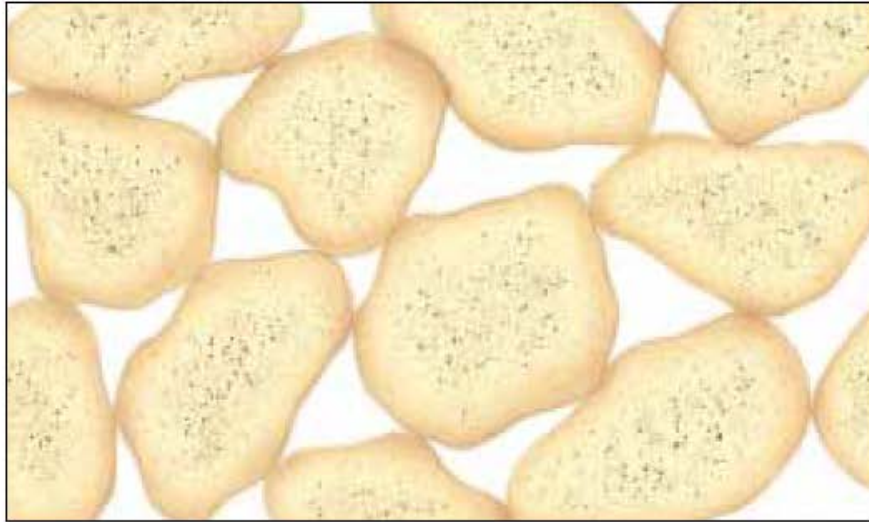
* Most rocks have lower porosities than loose sediment.

* Igneous and metamorphic rocks have very low porosities unless they are fractured.

* **Permeability** is the ability of rock or soil to transmit water (or any other fluid).

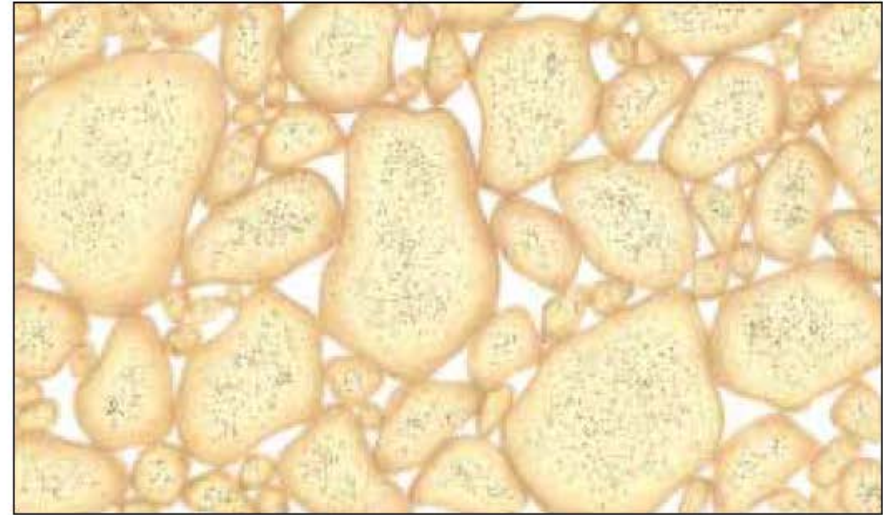
* Most materials with high porosity also have high permeability, but permeability also depends on how well the pores are connected and on pore size.

Well-sorted sediment



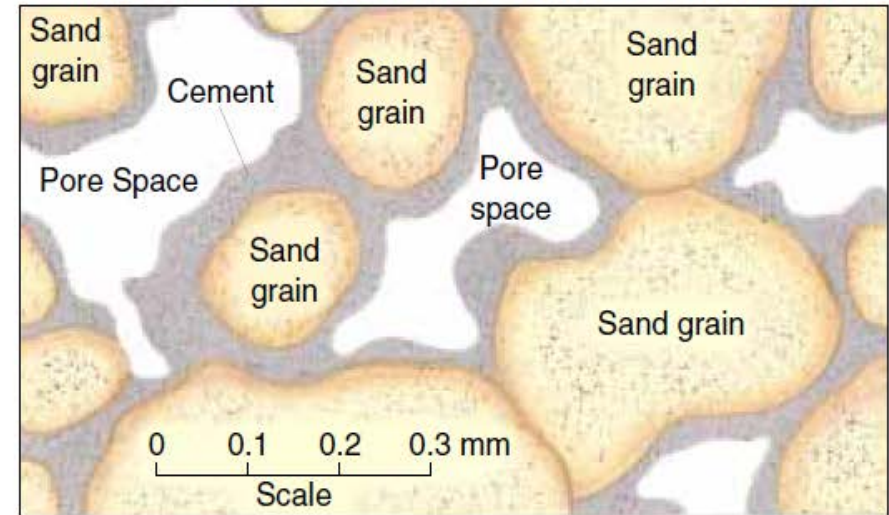
(a)

Poorly sorted sediment



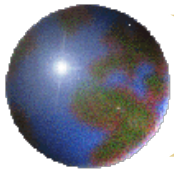
(b)

Sedimentary rock with cementing material between grains



(c)

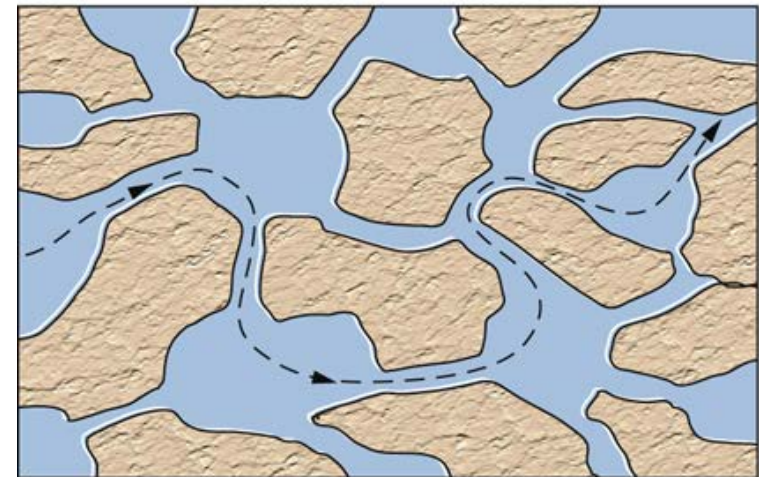
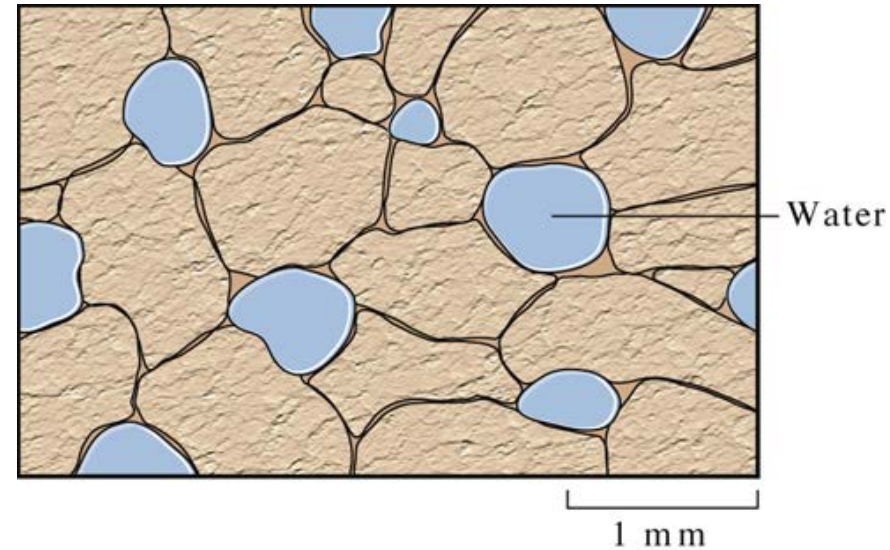
Figure 15-1 Different materials have different amounts of open pore space between grains. (a) Well-sorted sediment consists of equal-size grains and has a high porosity, about 30 percent in this case. (b) In poorly sorted sediment, small grains fill the spaces among the large ones, and porosity is lower. In this drawing it is about 15 percent. (c) Cement partly fills pore space in sedimentary rock, lowering the porosity.



15.2 Characteristics of Ground Water

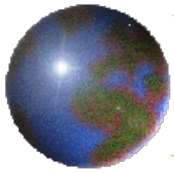
Ground water Flow

- Permeability will greatly influence flow:
 - Finer & consolidated slower
 - Courser & unconsolidated faster
 - Channels faster
- Darcey's Law: flow rate in porous material increases with pressure and shorter flow path.
 - Tortuosity (length of flow path)
 - Pressure (hydraulic head)



Which diagram illustrates a habitat with faster flow rate and why?

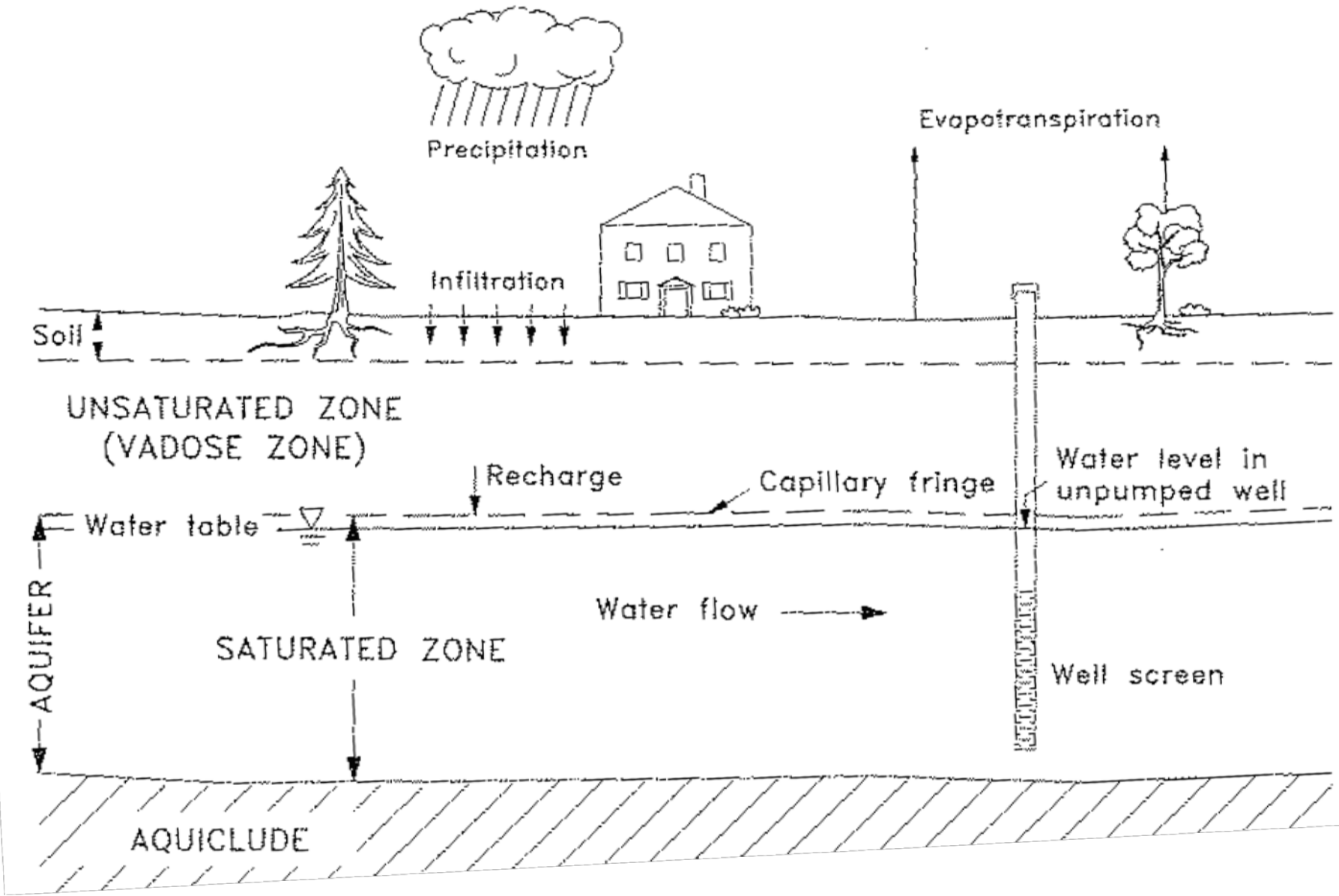
Assume equal hydraulic head.

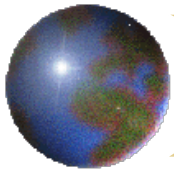


15.2 Characteristics of Ground Water

* THE WATER TABLE

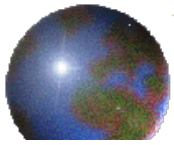
- * The **water table** is the top of the zone of saturation
- * The completely wet layer of soil and bedrock above the impermeable barrier is called the **zone of saturation**.
- * This moist surface layer is called the **soil moisture belt**.
- * An **aquifer** is any body of rock or soil that can yield economically significant quantities of water.
 - * An aquifer must be both porous and permeable so that water flows into a well to replenish water that is pumped out.





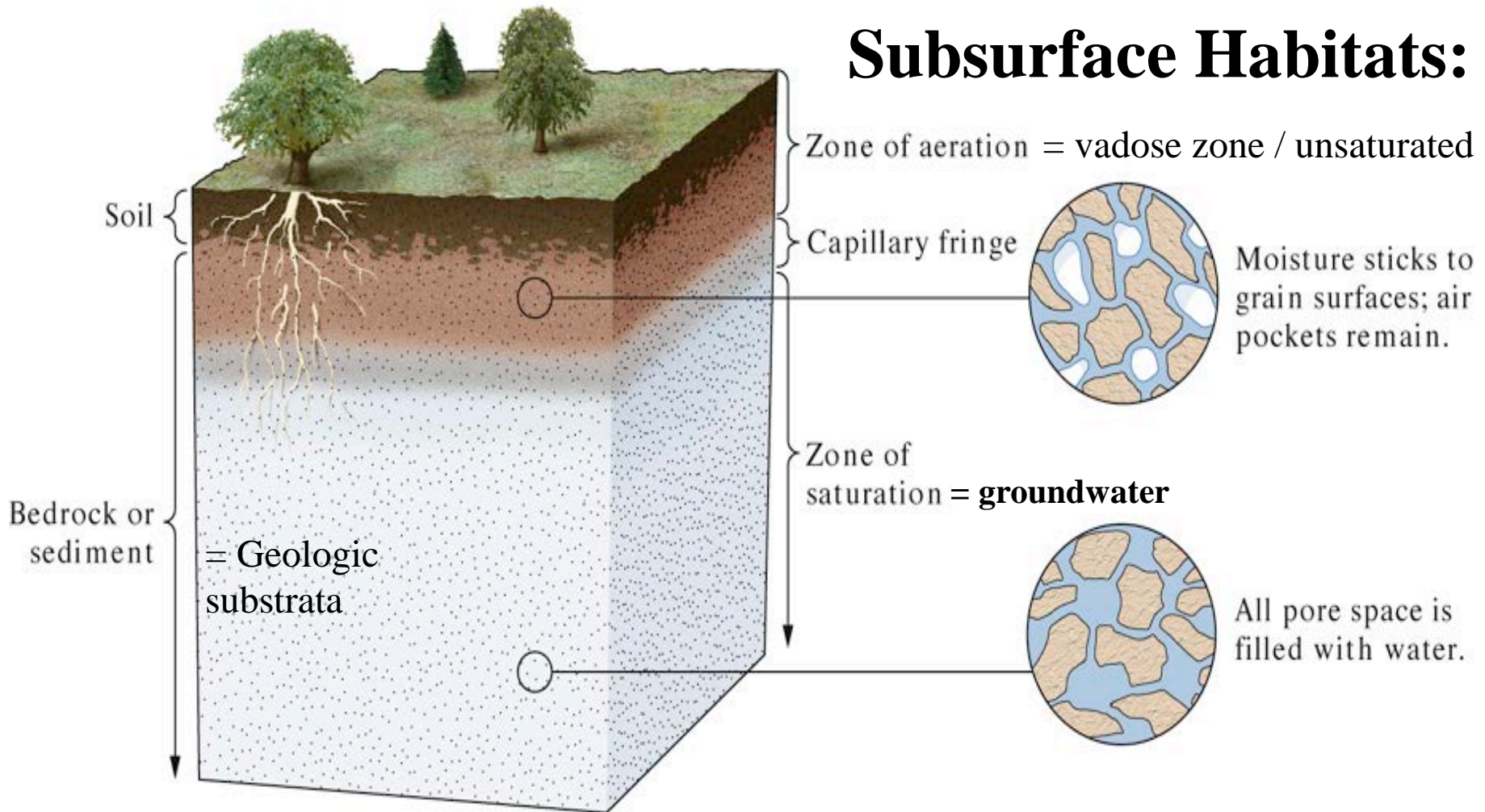
15.2 Characteristics of Ground Water

- ✦ Gravity pulls ground water downward. However, electrical forces can pull water upward through small channels.
- ✦ This upward movement of water is called **capillary action**.

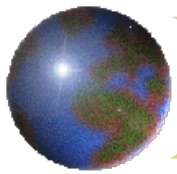


15.2 Characteristics of Ground Water

Subsurface Habitats:

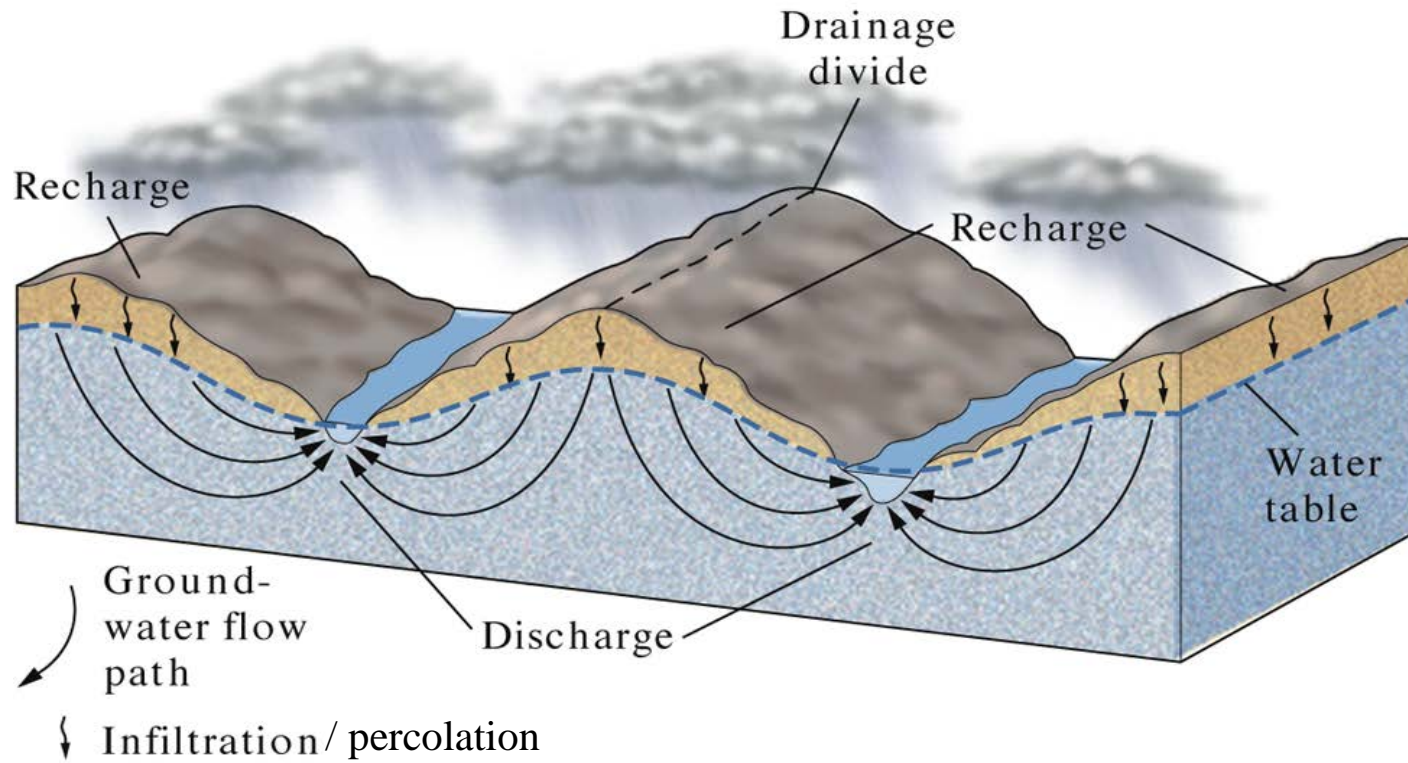


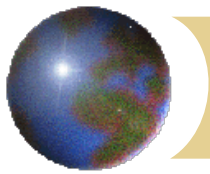
Aquifer = groundwater that is contiguous (connected) over an area. They may be unconfined from the surface, or confined from the surface by an impermeable or semi-permeable geologic strata (layer) called an aquitard.



15.3 Ground Water Movement

- ✦ Intensity/duration of precipitation.
- ✦ Vegetation cover and evapotranspiration.
- ✦ Topography and recharge zones. (*Infiltration rate is called recharge.*)
- ✦ Extent of vadose (unsaturated) Zone
- ✦ Sheet flow (runoff) vs infiltration
 - Soil texture & permeability (coarser the more infiltration)
 - Soil water content & holding capacity (high values may impede infiltration)





New Ground Water Formation

- ✚ Ground water flows from zones where the water table is highest toward areas where it is lowest.
- ✚ In general, the water table is higher beneath a hill than it is beneath an adjacent valley.
- ✚ Streams flow through most valleys. Because ground water rises beneath the valley floor, it continually feeds the stream---- **effluent** (or **gaining**) **stream**.
- ✚ In a desert, the water table commonly lies below a stream bed, and water seeps downward from the stream to the water table ----- **influent** (or **losing**) **stream**.

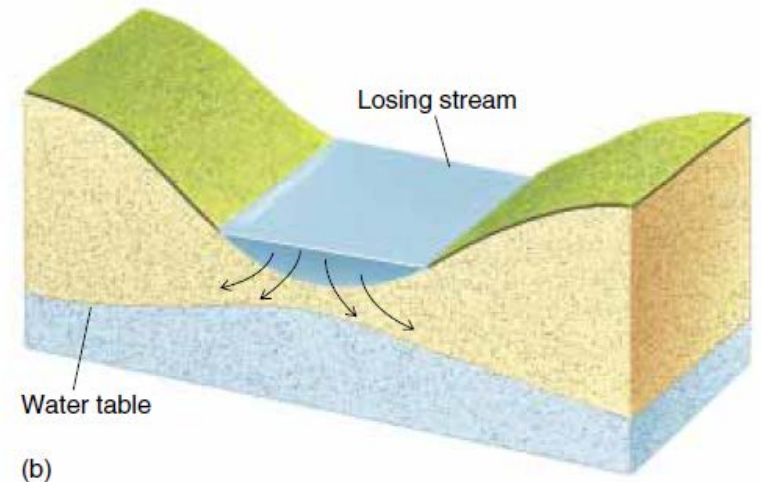
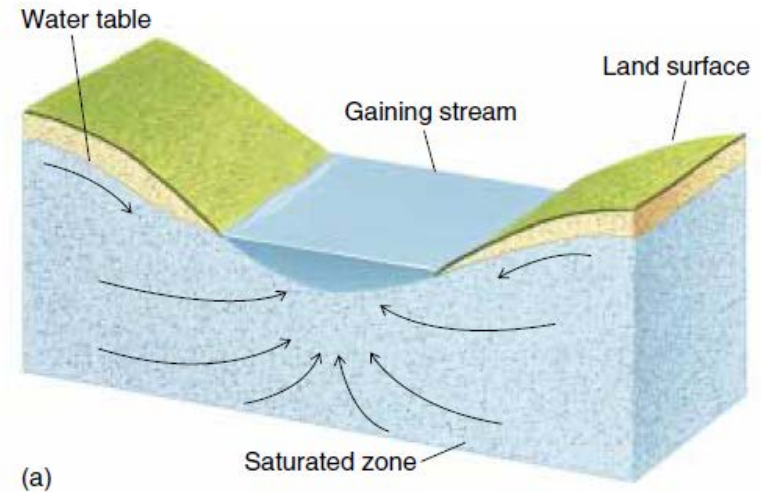
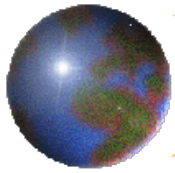


Figure 15-5 (a) In a moist climate the water table lies above the stream and ground water seeps *into* the stream. (b) A desert stream lies above the water table. Water seeps *from* the stream bed to recharge the ground-water reservoir beneath the desert.

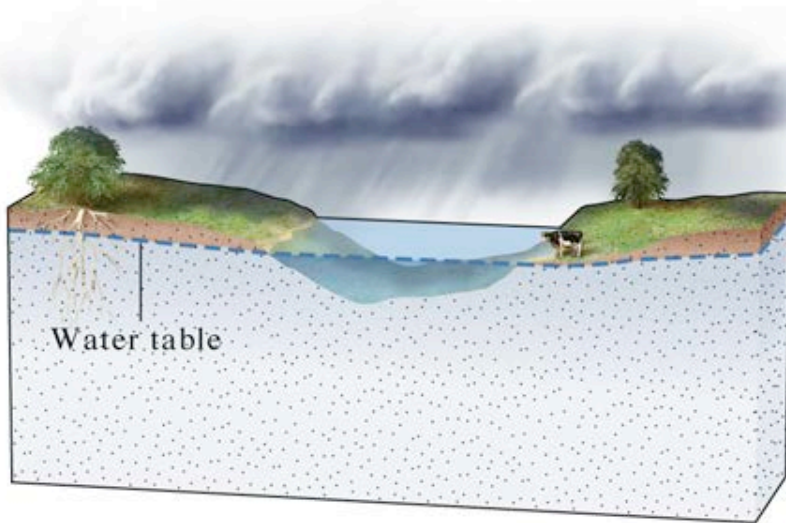


Ground Water Meets Surface Water

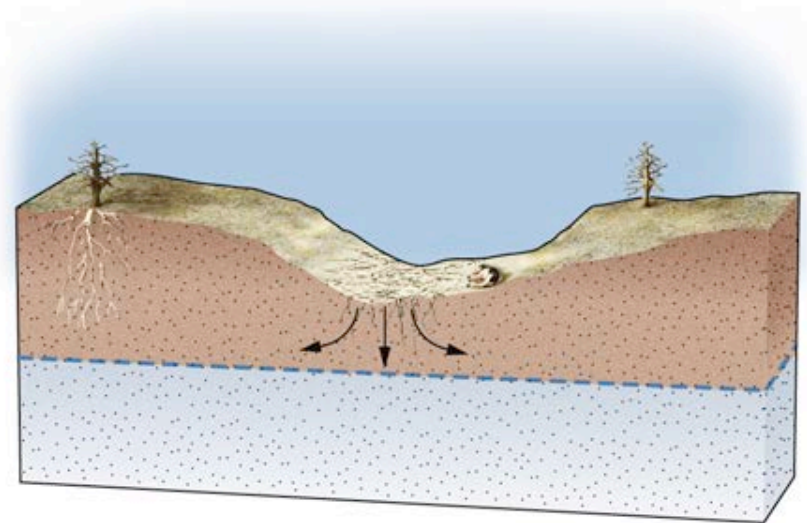
Stream and lake hydrodynamics is influenced by ground water.

Wet seasons when there's a high water, groundwater may feed the stream in addition to runoff events.

Dry seasons when the water table is low, sheet flow runoff may be the only source of stream flow, in which case the stream feeds (recharges) the groundwater.



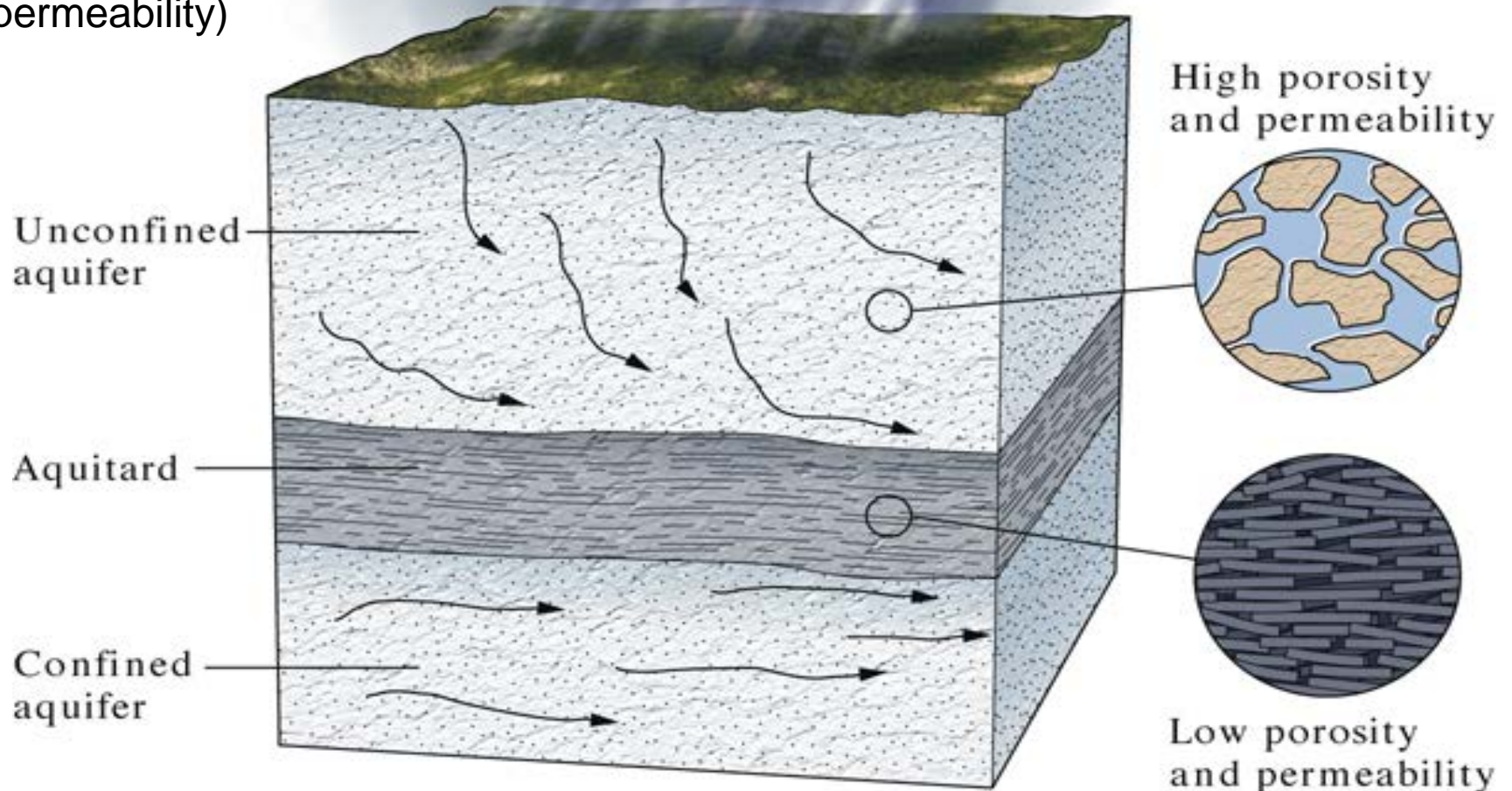
Wet season



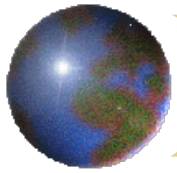
Dry Season

High Recharge:

(Storms; Flat terrain;
High permeability)

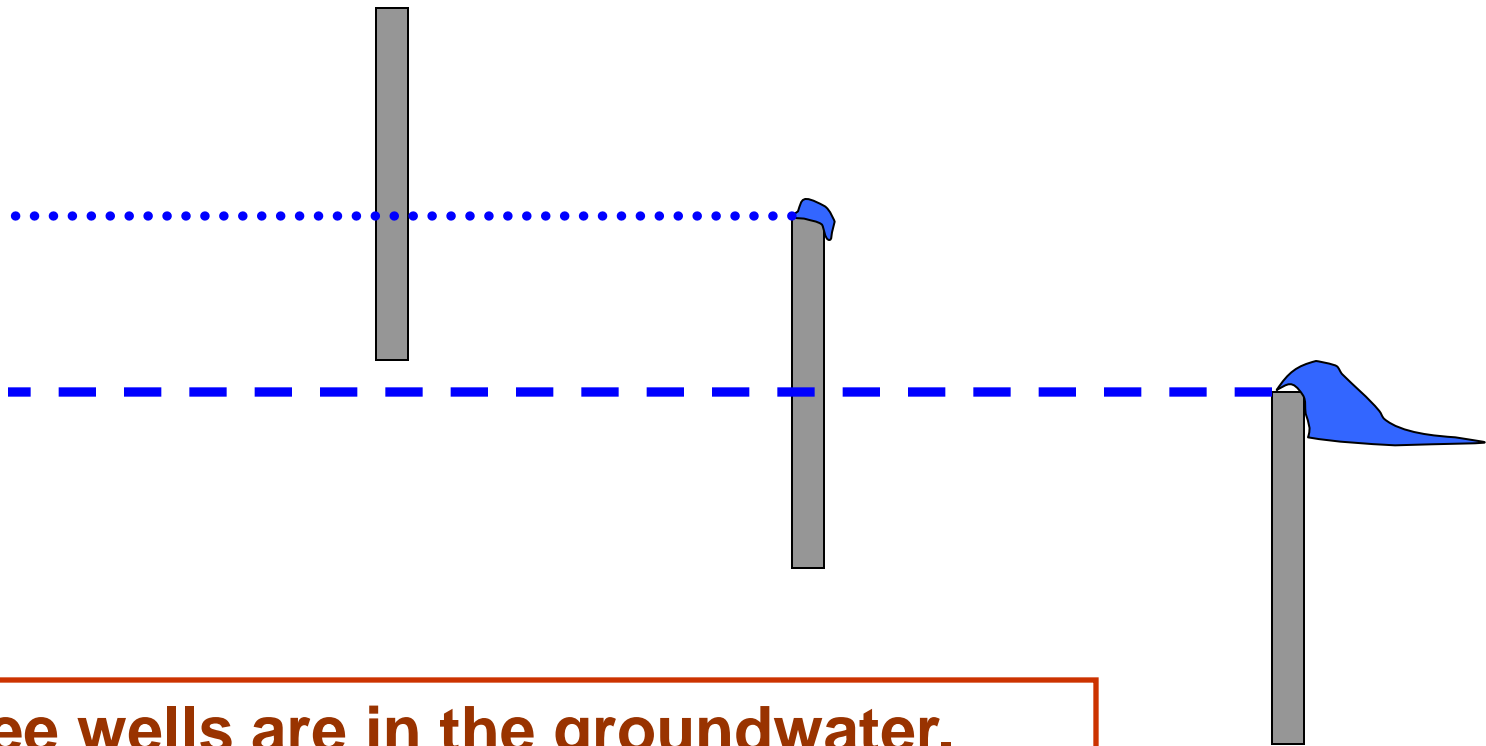


Porosity = amount of water held in a volume of sediment; fraction of sediment volume as pores and fractures; often relates to permeability but not always (e.g., biofilms; clays; disconnected channels).

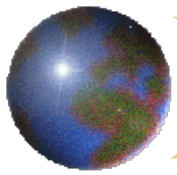


15.3 Ground Water Movement

Hydraulic Head (Δh) & Gradient (HG)

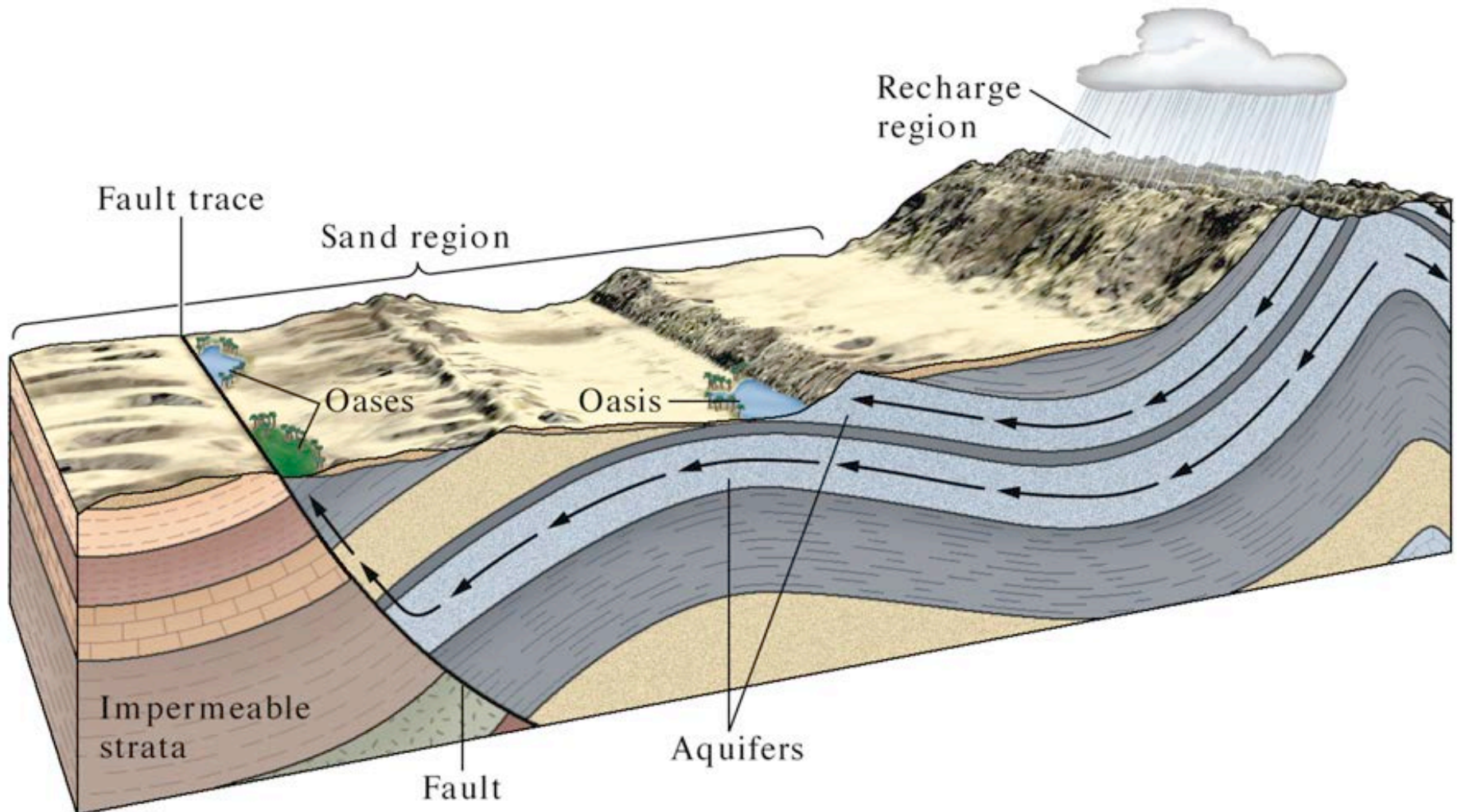


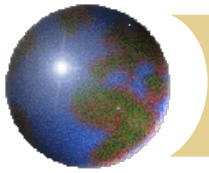
**All three wells are in the groundwater.
Explain the difference in “Artesian” flow.**



15.3 Ground Water Movement

Aquifer Flow and Oasis Formation

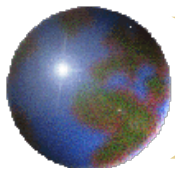




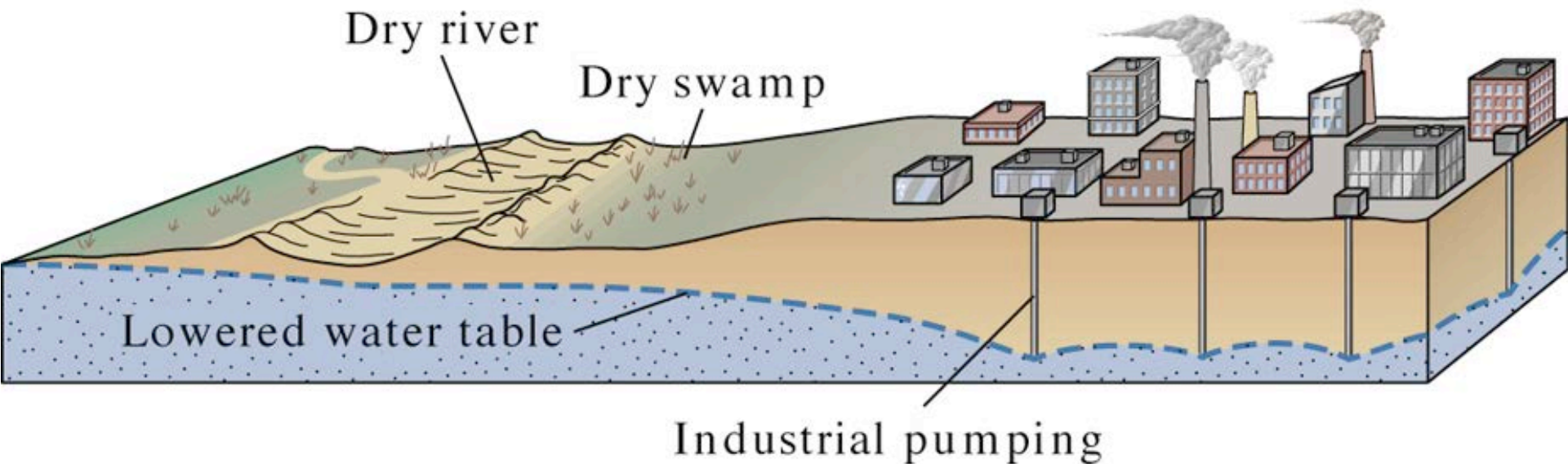
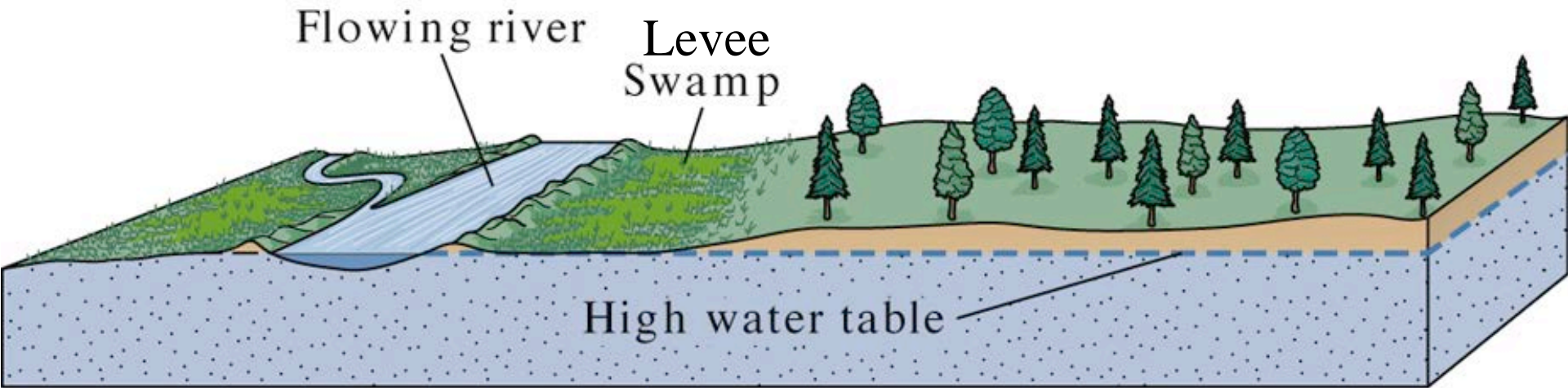
15.3 Ground Water Movement

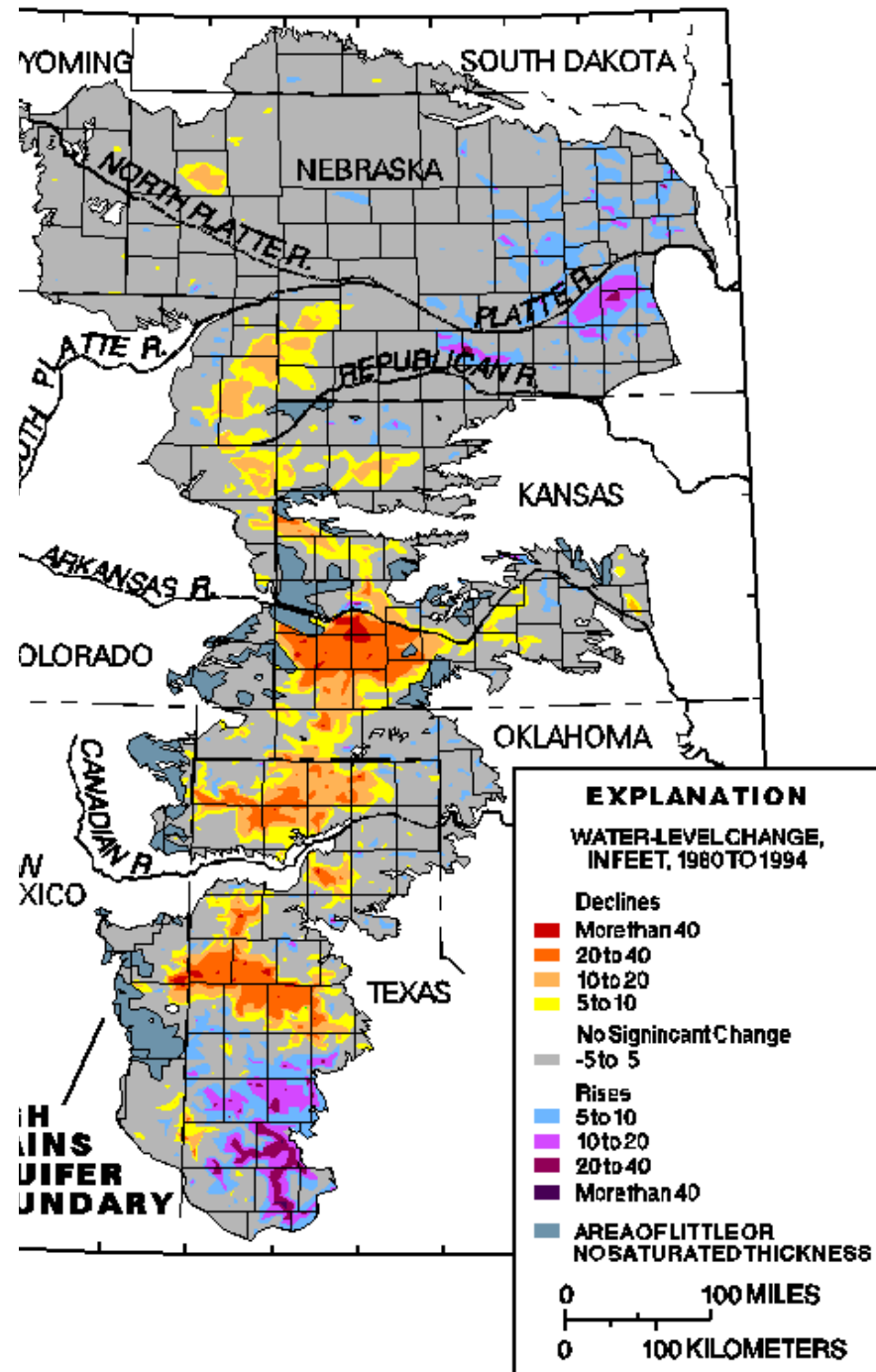
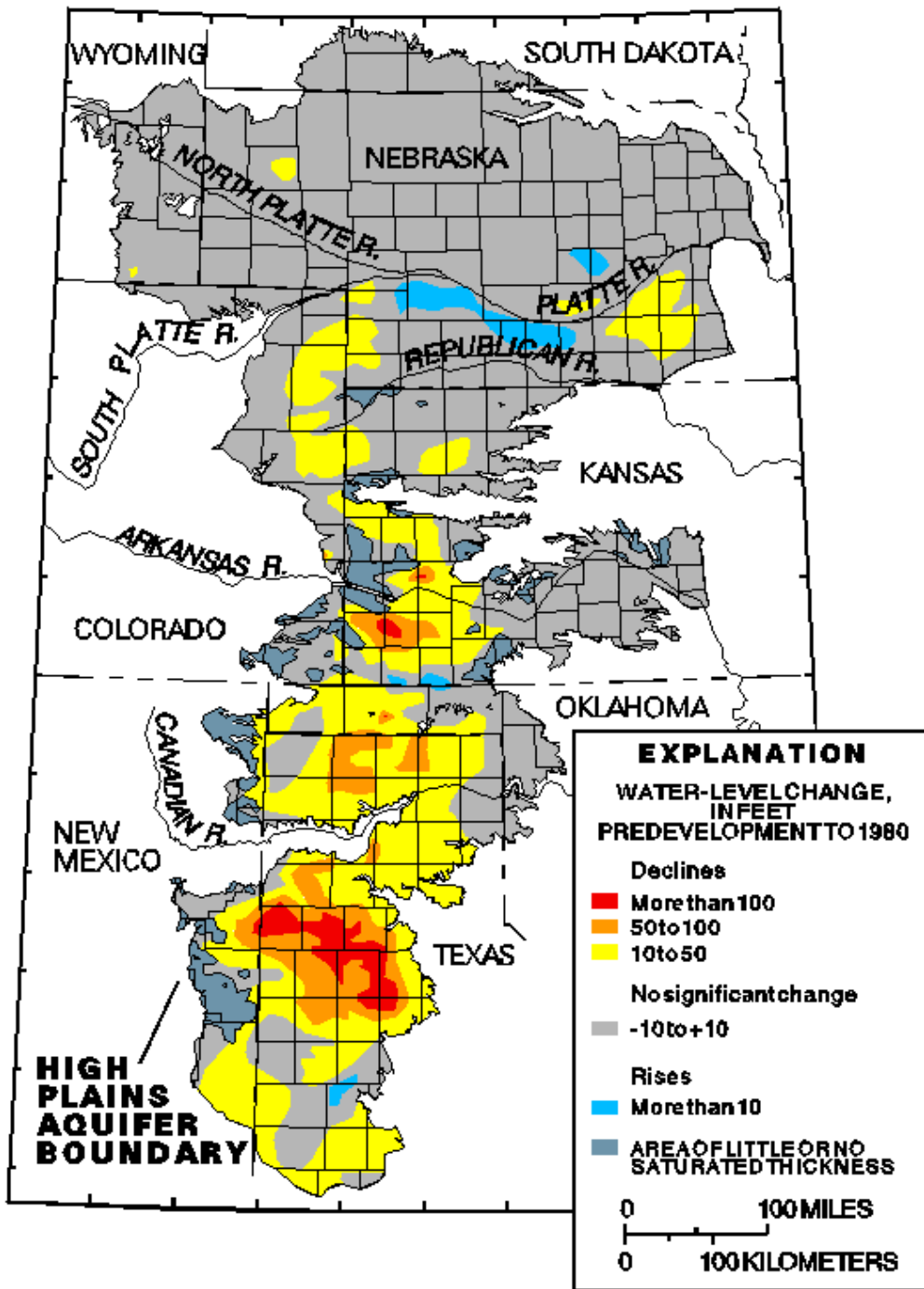
Human Impacts on Groundwaters, Streams and Wetlands

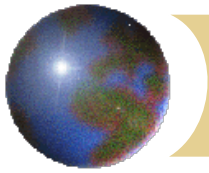
- ⊕ Groundwater or surface pumping:
 - ⊠ agriculture
 - ⊠ industry
 - ⊠ drinking waters.
- ⊕ Clearing riparian forests & wetlands
- ⊕ Draining and filling for “development”.
- ⊕ Damming and flooding
- ⊕ Diversion channels for water supply.



15.3 Ground Water Movement



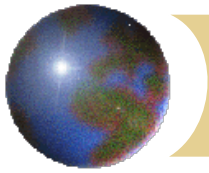




15.4 Use of Ground Water

*GROUND-WATER DEPLETION

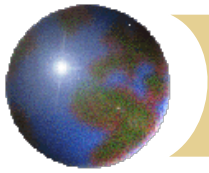
- * If ground water is pumped from a well faster than it can flow through the aquifer, a **cone of depression** forms around the well.
- * If the aquifer has good permeability, water flows back toward the well in a few days or weeks after the pump is turned off, and the cone of depression disappears.
- * However, deep wells and high-speed pumps can extract ground water more rapidly than the hydrologic cycle recharges it.



15.4 Use of Ground Water

*SUBSIDENCE

- * Excessive removal of ground water can cause **subsidence**, the sinking or settling of the Earth's surface.
- * Subsidence rates can reach 5 to 10 centimeters per year.
- * Unfortunately, subsidence is **not a reversible process**. When rock and soil contract, their porosity **is permanently reduced** so that ground-water reserves cannot be completely recharged even if water becomes abundant again.

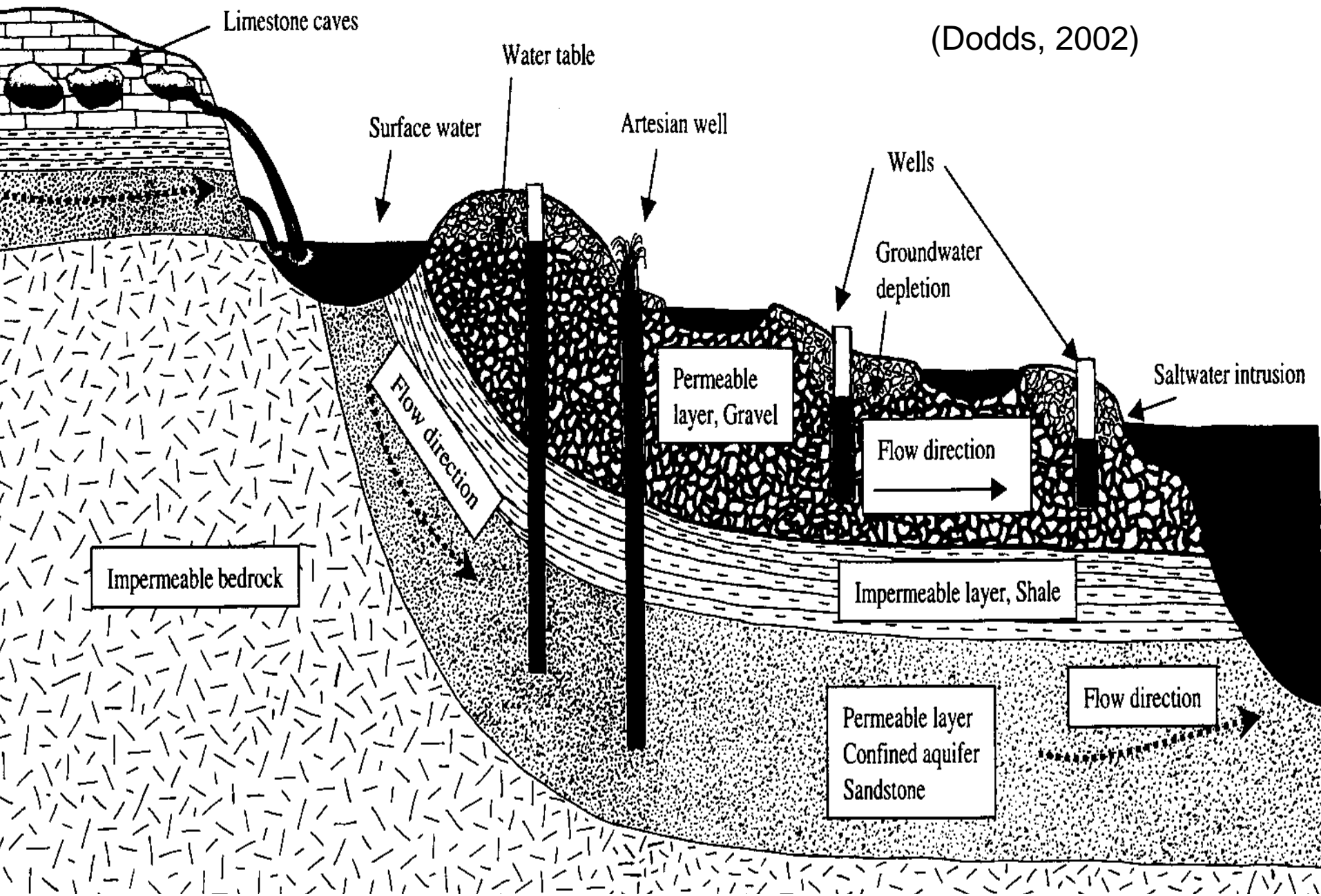


15.4 Use of Ground Water

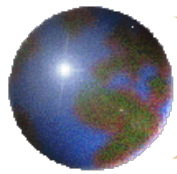
✚ SALT-WATER INTRUSION

- ✚ Fresh water floats on top of salty water because it is less dense.
- ✚ If too much fresh water is pumped to the surface, the salty water rises into the aquifer and contaminates wells.

(Dodds, 2002)



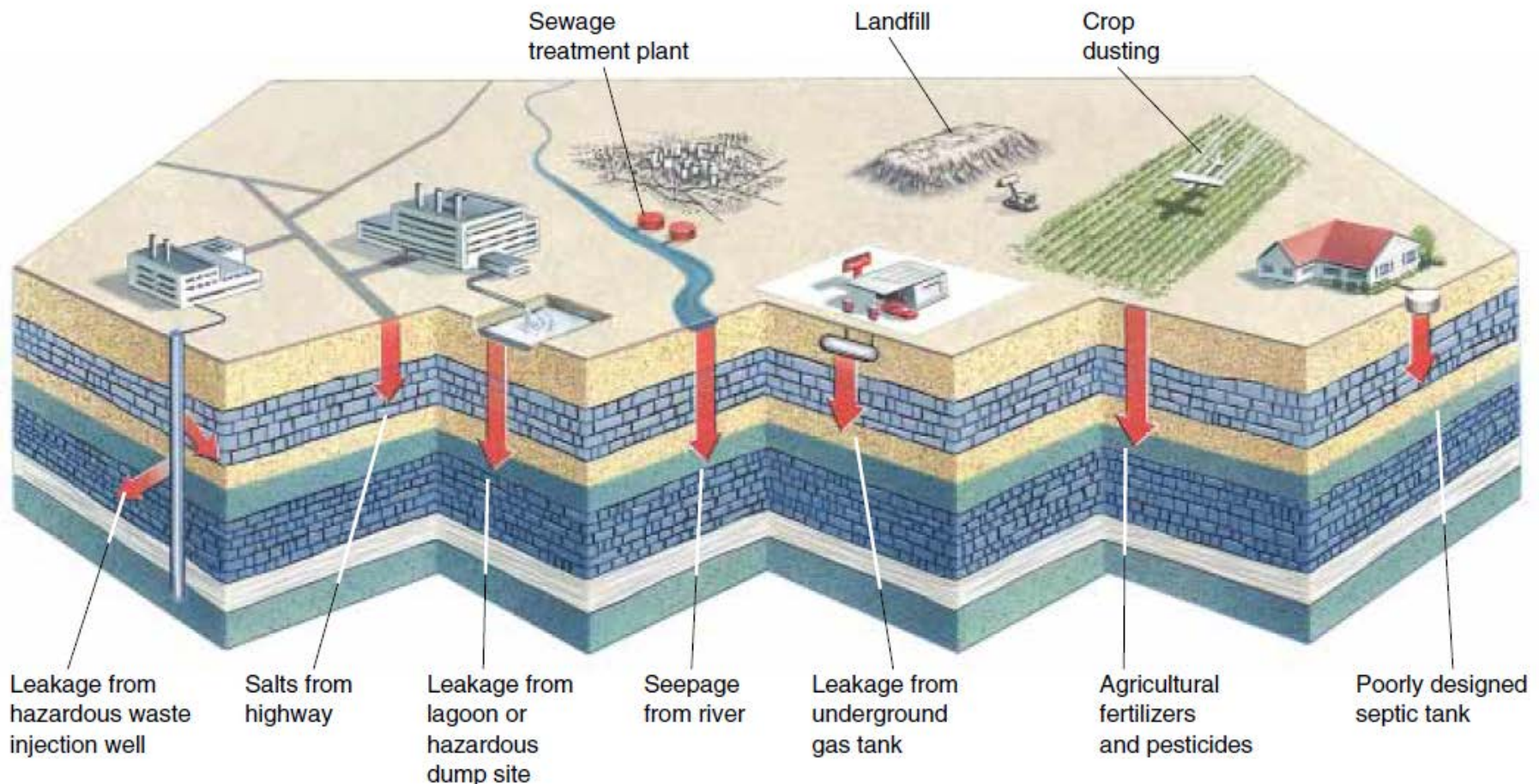
* Pumped wells can deplete groundwater. * There may be connections with seawater.

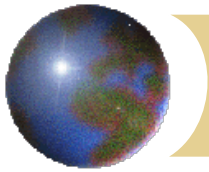


15.5 Ground Water Pollution

⊕ AQUIFER CONTAMINATION

- ⊞ There are many sources of ground-water pollution





15.5 Ground Water Pollution

* TREATING A CONTAMINATED AQUIFER

* *Discovery*

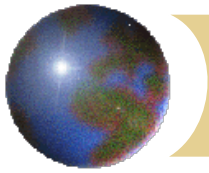
- * In the ideal situation, the contaminant source is discovered before a pollutant can enter the aquifer.

* *Elimination of the Source*

- * If an underground tank is leaking, the remaining liquid in the tank can be pumped out and the tank dug from the ground.

* *Monitoring*

- * A hydrogeologist monitors the contaminants to determine how far, in what direction, and how rapidly the plume is moving and whether the contaminant is becoming diluted.



15.5 Ground Water Pollution

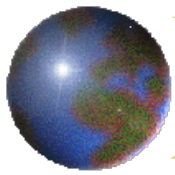
* TREATING A CONTAMINATED AQUIFER

* *Modeling*

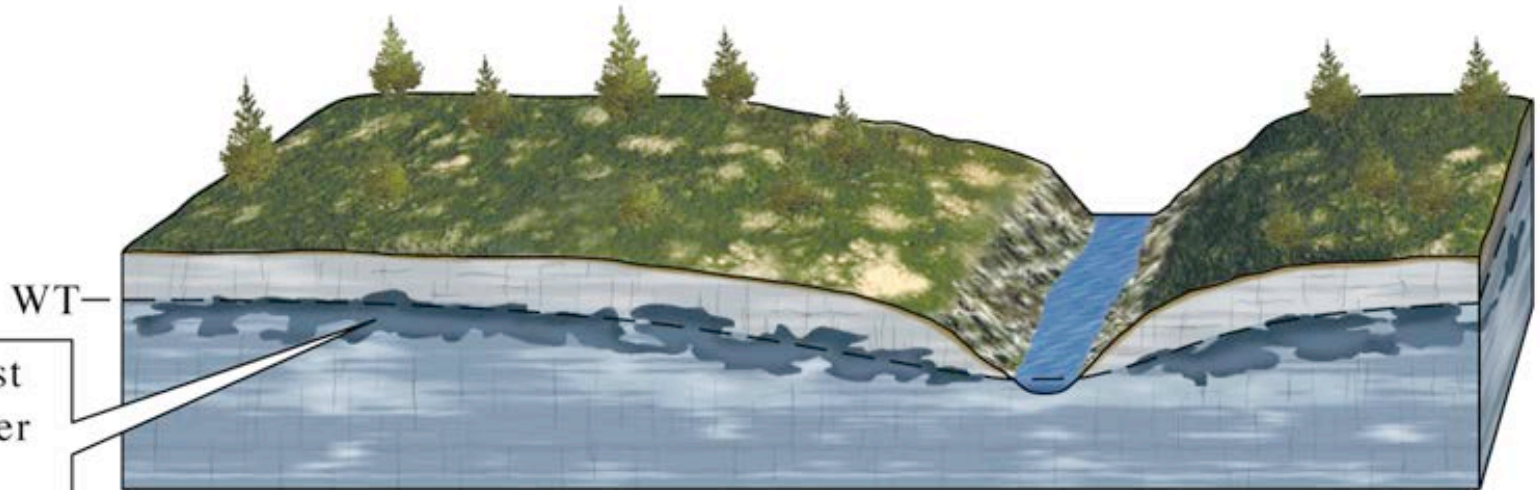
- * a computer model to predict future spread of the contaminant through the aquifer. The model considers the permeability of the aquifer, directions of ground-water flow, and mixing rates of ground water.

* *Remediation*

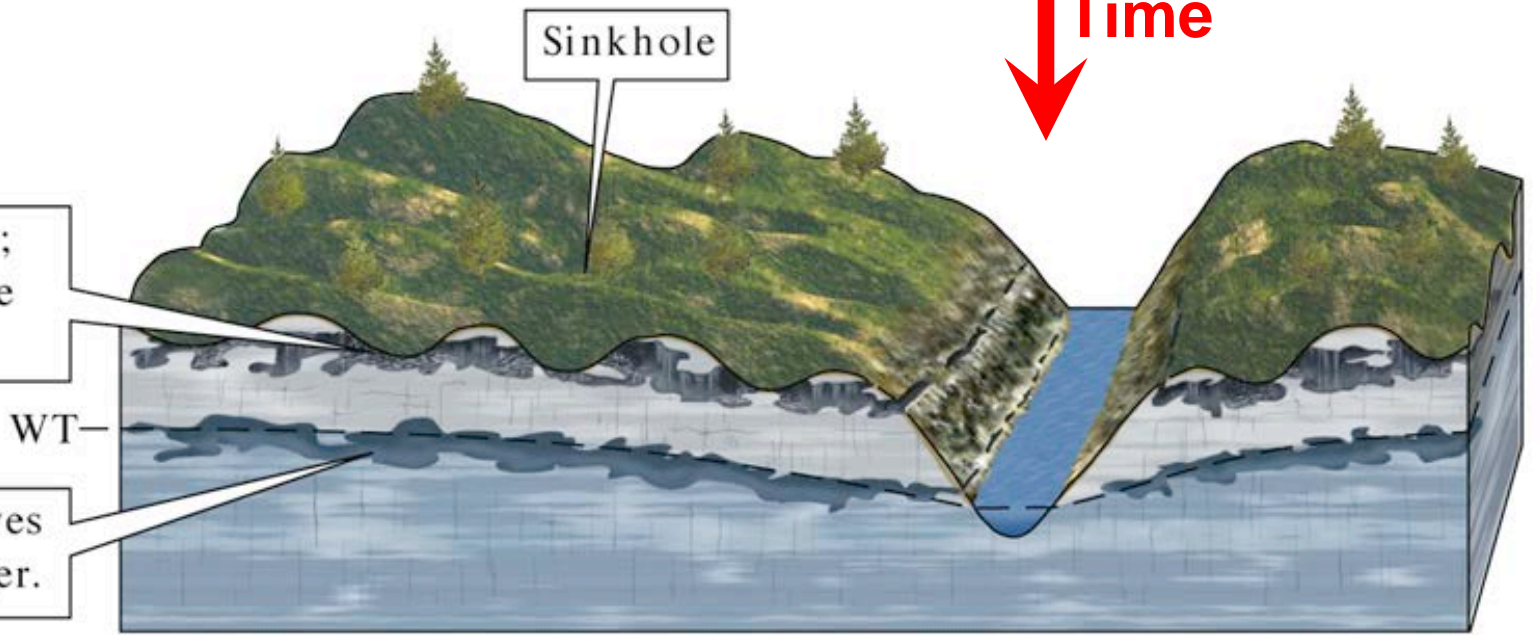
- * Remediation is so **difficult and expensive**.
- * Contaminated ground water can be contained by building an underground barrier to isolate it from other parts of the aquifer.
- * **Bioremediation** uses microorganisms to decompose a contaminant.

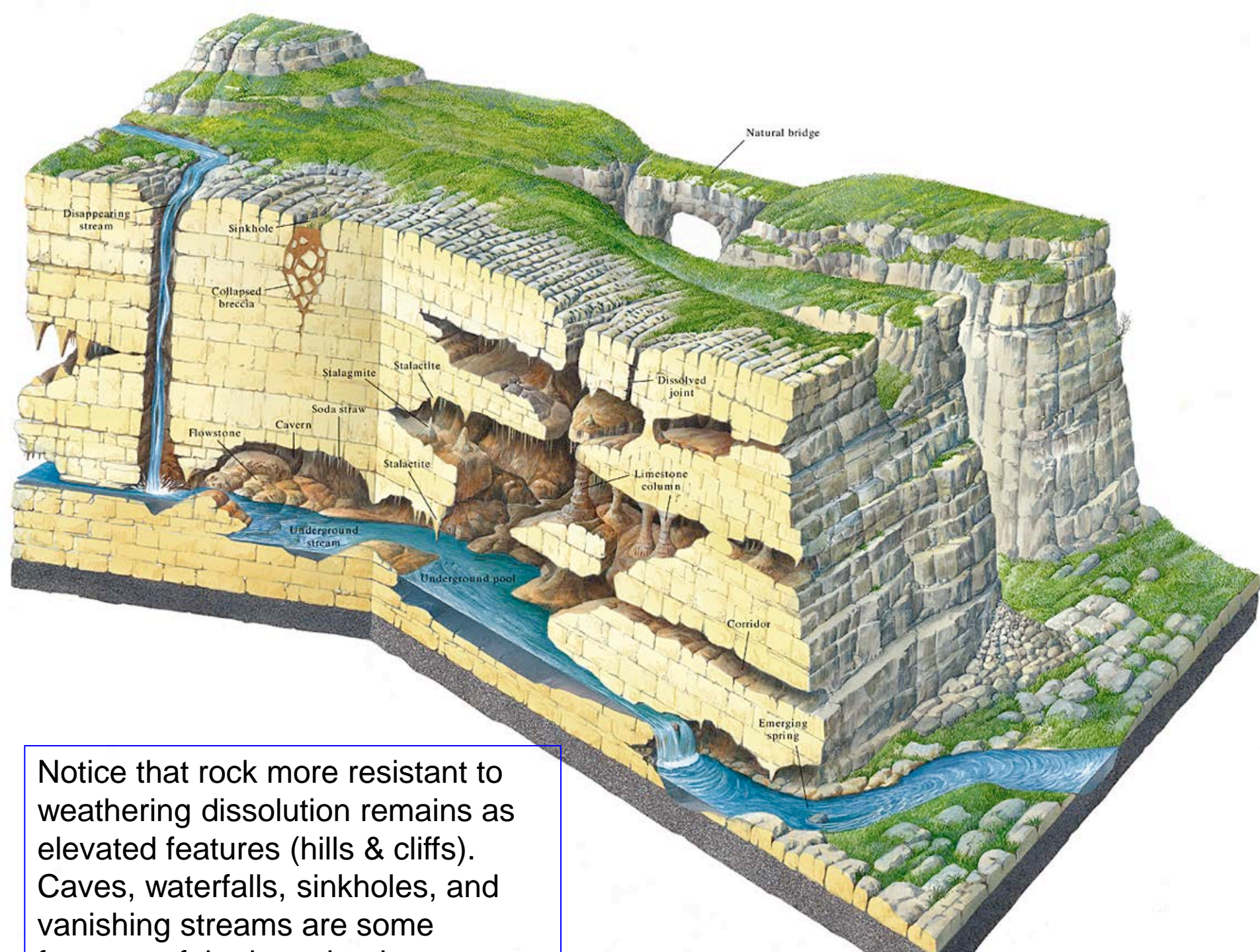


15.6 Limestone Aquifers & Karst Topography

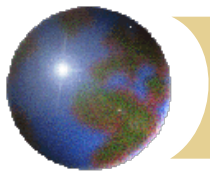


Time



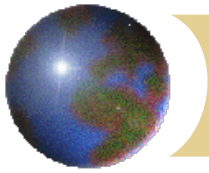


Notice that rock more resistant to weathering dissolution remains as elevated features (hills & cliffs). Caves, waterfalls, sinkholes, and vanishing streams are some



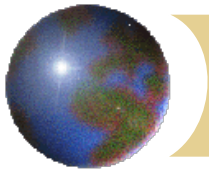
15.7 Hot Springs and Geysers

- * Hot water naturally flows to the surface to produce **hot springs**.
- * Ground water can be **heated in three different ways**:
 - * The Earth's temperature increases by about 30 °C per kilometer in the upper portion of the crust.
 - * In regions of recent volcanism, magma or hot igneous rock may remain near the surface and can heat ground water at relatively shallow depths.
 - * Many hot springs have the odor of rotten eggs from small amounts of hydrogen sulfide (H_2S) dissolved in the hot water. The water in these springs is heated by chemical reactions.



15.7 Hot Springs and Geysers

- ❖ **Geysers** violently erupt hot water and steam.
- ❖ Geysers generally form over open cracks and channels in hot underground rock.
- ❖ The rising pressure forces some of the bubbles upward past the constriction and short bursts of steam and water spurt from the geyser.



15.8 Geothermal Energy

- * Energy extracted from the Earth's heat is called **geothermal energy**.
- * The **major problem** with current methods of extracting energy from the Earth is that they work only where deep ground water is heated naturally.
- * As long as coal and petroleum prices are low, there is little incentive to develop geothermal projects to compete with coal- and oil-fired electric generating plants.

