Groundwater (NOT in underground lakes and rivers!)

← Belt of soil moisture (few meters)
- wetted zone (held by surface tension)
- used by plants

← Zone of aeration – not normally saturated
"vadose" zone

← Capillary fringe (wet towel example)

← Water table
- top of zone of saturation
- varies with season, rainfall, pumping

← Zone of saturation – contains "groundwater"

All rocks below this are saturated (juvenile & volcanic water vs. meteoric)

Recharge happens where water infiltrates into water table
- general infiltration
- influent streams and lakes
- man-made settling ponds (recharge basins)

Discharge where water is removed from water table
- effluent streams and lakes
- marshes, swamps & springs
- wells (withdrawl)

Porosity ≡ open space between grains
ratio of **volume** of void to solid (e.g. sand ~25%)

Depends on:
1. sorting – better sorted = more porous
2. packing – looser packed = more porous
3. rounding – more rounded = more porous
(grain size is not a factor)

Permeability ≡ how easily water can flow through material.
(volume thru unit X-section with given pressure)

When pumping you care about:

Specific yield ≡ how much of the water you can get out
Specific retention ≡ what you can’t get out (suck a sponge – it’s still wet)

Porosity = Specific Yield + Specific Retention

Material	Porosity	Specific Yield	Specific Retention	Permeability
soil	55%	40%	15%	good
clay	50%	2%	48%	poor
sand	25%	22%	3%	excellent
gravel	20%	19%	1%	good
limestone	20%	18%	2%	poor - excell.
sandstone	11%	6%	5%	poor - good
granite	0.10%	0.09%	0.01%	very poor

Based on Table 16.1, pg. 426

∴ High porosity does NOT mean high permeability (see clay).

<u>Darcy’s Law</u> describes **rate** of groundwater flow

$$V = K * h/\ell$$

Where:

V = velocity of flow
K = hydraulic conductivity (∝permiablility)
h = drop in head
ℓ = distance
h/ℓ = “hydralic gradiant”

Greater head (pressure) = higher velocity

Example: how long for a contaminant to reach a well.

Typically a few cm/day, max. about 15 cm/day

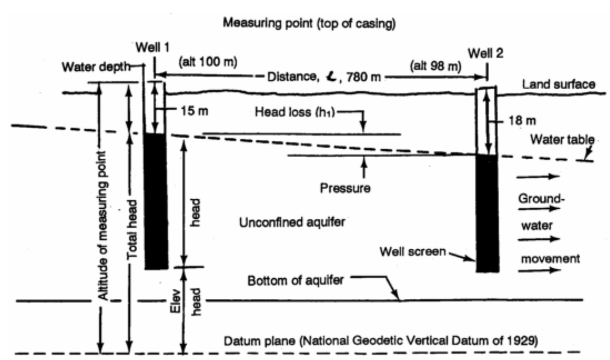


Figure 2-11. Hydraulic gradient

Aquifer ≡ permeable layer (groundwater can flow through it)

Unconfined – not under pressure (top is water table)

Confined – under pressure (artesian wells)

Aquiclude ≡ impermeable layer (barrier to groundwater flow) “confining layer

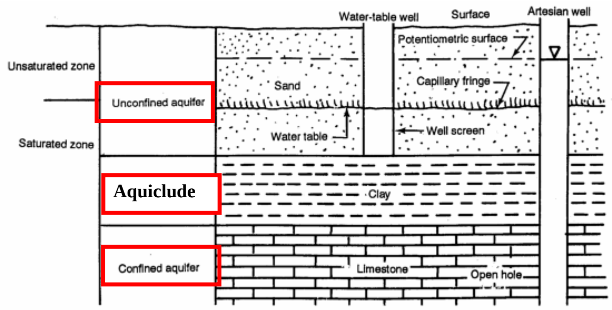


Figure 2-12. Unconfined aquifer

http://www.globalsecurity.org/military/library/policy/army/fm/5-484/Ch2.htm

Artesian wells

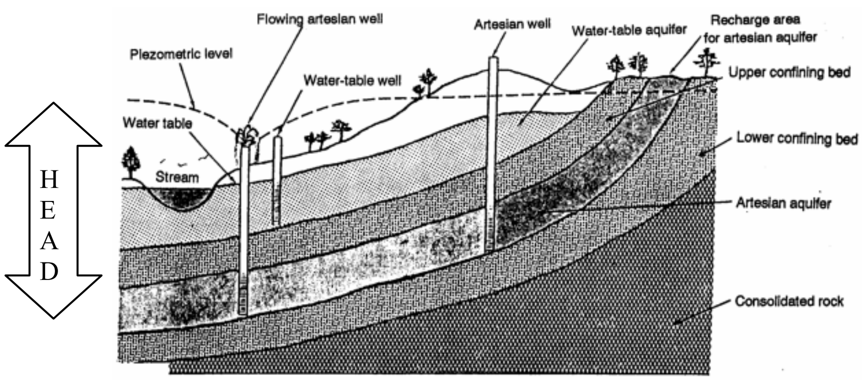


Figure 2-13. Flowing artesian well

Springs

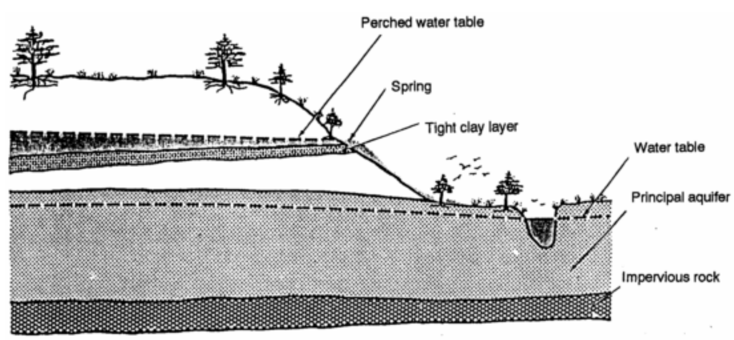


Figure 2-14. Perched water table

Oases

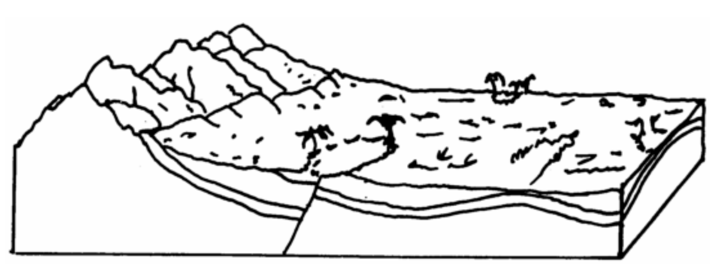
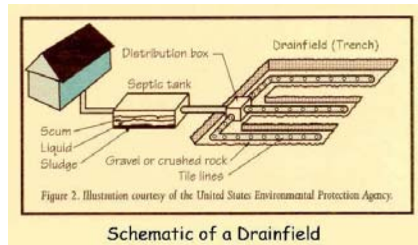


Figure 2-37. Oasis

Ground water problems

1) Contamination (pollution)

- industrial leaks, spills and intentional dumping
  - tetrachloroethlyene, PCE or "perc." (dry cleaning fluid)
    - 900 wells in Calif. – 5% of water supply
  - Perchlorate (explosives, rocket fuel)
  - Erin Brockovich – "hexavalent chromium"
- land fills – clay or plastic lining
- leaky underground storages tanks
- agricultural runoff – pesticides & fertilizers
- poorly designed septic tanks



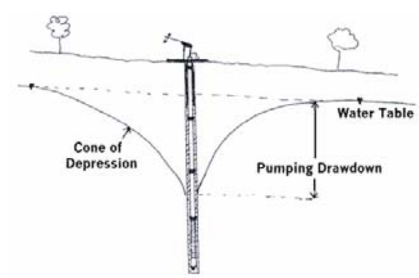
Schematic of a Drainfield

San Gabriel Valley

- 170-square-mile, 45 water suppliers
- 90% of water to > 1,000,000 people
- >59 wells (of > 400) were found to be contaminated

2) Subsidence ≡ compaction of aquifer caused by withdrawal

- Ground surface can drop several meters
  - annual U.S. damage ~ $400 million
  - San Joaquin Valley – 9m in 50 yrs
  - Imperial Valley, Indian Wells Valley
  - Texas, Florida
- Porosity is reduced forever



3) Lowering of water table (cone of depression)

4) Water mining (withdrawl >> recharge)
Mining water from ice ages.

- Example: Ogallala aquifer,
  - dropped > 15m in 30yr in places

5) Saltwater intrusion