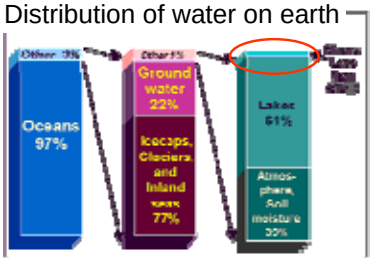
SUMMARY
Water Use Patterns

- Agriculture major user worldwide
- Population growth will increase water scarcity
- In US, post-WWII consumption has gone up significantly
  - Population growth
  - Increase in standard of living
- Increase mostly in Industrial use

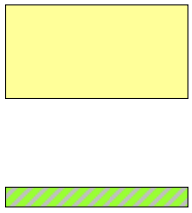
Distribution of water on earth



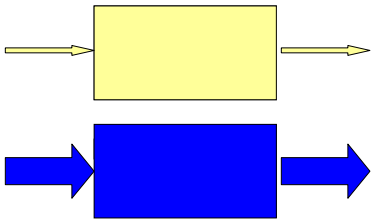
Rivers 0.0001%

How can we derive most of our water use from a small pool?

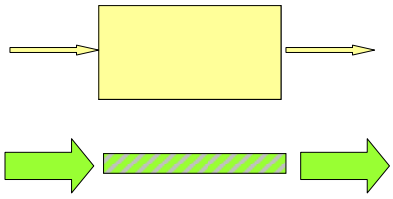
Does pool size matter?



What is the flow through?

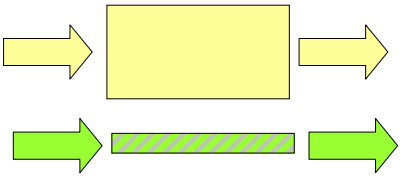


What is the flow through?



Relating Pool and Flux

Residence Time



Residence Time: Pool / Flux
Unit: time

Typical Residence Times

Deep Ground water	10,000 yrs
Icecaps & Glaciers	10,000 yrs
Oceans	1,000 yrs
Shallow groundwater	100 yrs
Soil Water	100 days
Rivers	10 days
Atmosphere	10 days

Relevance??

Relevance of Residence Time

SHORT = Flux large relative to pool

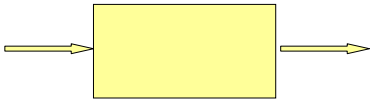
Sensitive to fluctuations in climate

e.g. River system (10 days)

Relevance of Residence Time

LONG = Flux small relative to pool

INSensitive to fluctuations in climate

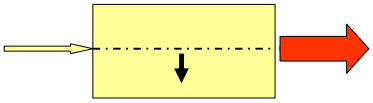


e.g. Groundwater (>100 yrs)

Relevance of Residence Time

LONG = Flux small relative to pool

If withdrawal >> Recharge rate

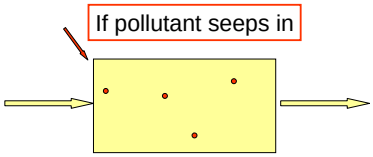


Decline in pool size & water table level

Relevance of Residence Time

LONG = Flux small relative to pool

If pollutant seeps in

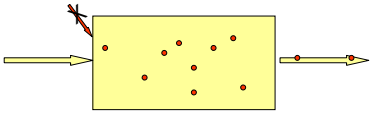


Might take a long time to pollute (dilution)

Relevance of Residence Time

LONG = Flux small relative to pool

If pool is polluted and input stops



Pollutants do not easily flush out

Relevance of Residence Time

SHORT = Flux large relative to pool

Sensitive to water pollution

Pollutants quickly flushed out

SUMMARY
Water Residence time

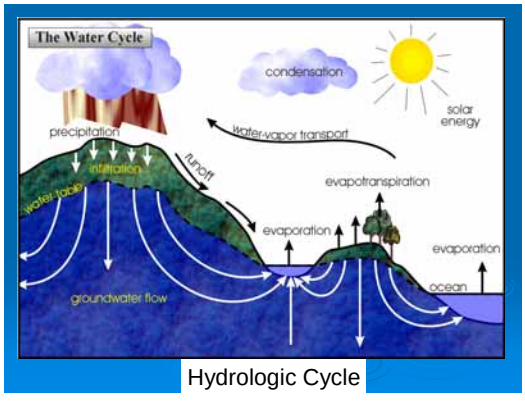
- WRT = Pool over Flux
- Most human water use from pools with short WRT (streams)
- Pools with long WRT are less sensitive to climatic variations than pools with short WRT

SUMMARY
Water Residence time

- Groundwater (long WRT) sensitive to depletion when withdrawal rate > recharge rate
- Ground water (large pool size) is not easily contaminated (dilution)
- Once present, contaminants are note easily flushed out (flux small relative to large pool size)

SUMMARY
Water Residence time

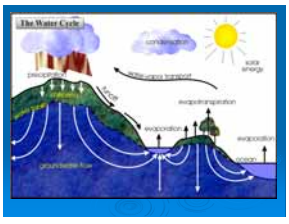
- Streams and Rivers (short WRT) are very responsive to climate
- Streams (small pool size) are easily contaminated
- Contaminants are more readily flushed out (flux large relative to small pool size)



Hydrologic Cycle

Water Balance

Globally:
P – ET = 0



No water is lost or gained….
Inputs and outputs are in balance

Water Balance

Globally:
$P - ET = 0$

Problem: Temporally and Spatially:

$P - ET \neq 0$

Inputs (precipitation) & output (evapotranspiration) are NOT in balance

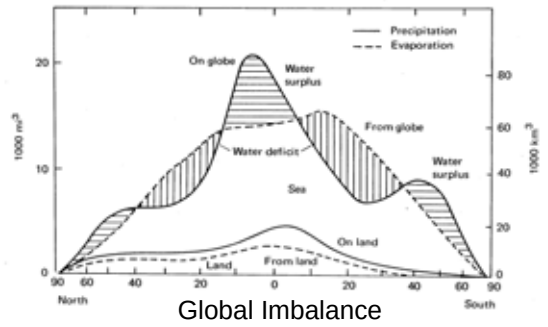
Water Balance

$P - ET > 0 \rightarrow P > ET$

Water Surplus

$P - ET < 0 \rightarrow P < Pot.\ ET$

Water Deficit



Global Imbalance

Figure 2.2 Latitudinal variation of evaporation and precipitation on the globe as well as on the land and sea areas.

Spatial/Temporal Imbalance

$P - ET \neq 0$

Site Water Balance
$Q = P - ET \pm dS \pm dG$

- P = Preciptation
- ET = Evapotranspiration
- Q = Runoff
- dS = Soil water storage
- dG = Groundwater storage

Site Water Balance

$Q = P - ET \pm dS \pm dG$

$P - ET > 0$

$Q = P - ET$ - dS – dG

recharge

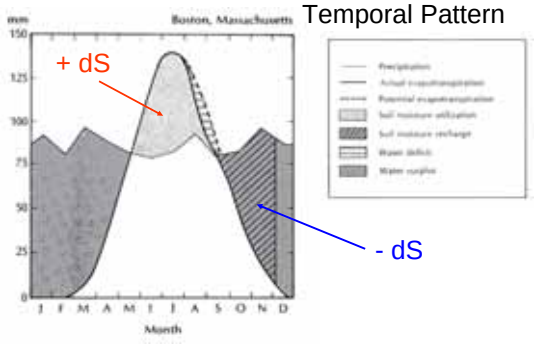
soil & groundwater = water sink

$P - ET < 0$

$Q = P - ET$ + dS + dG

discharge

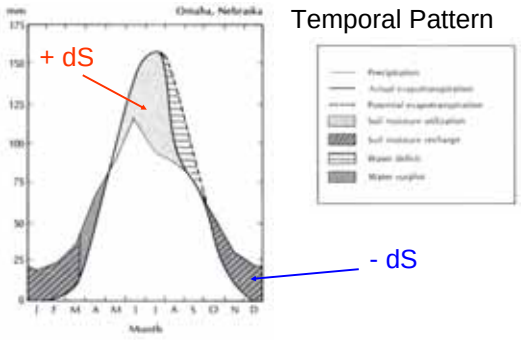
soil & groundwater = water source



Temporal Pattern

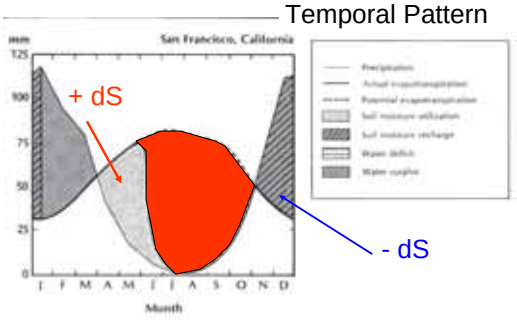
East Coast – evenly distributed rainfall

Temporal Pattern



Midwest - summer rainfall
SW – monsoonal rainfall pattern

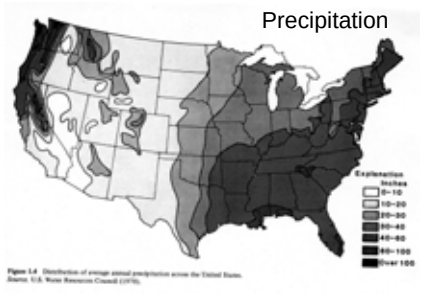
Temporal Pattern



California (Mediterranean) = rainfall in winter

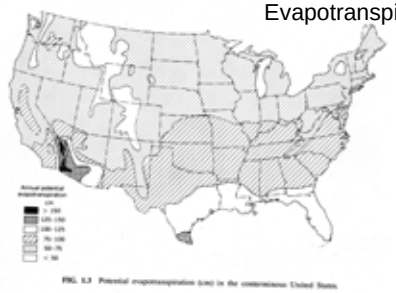
Spatial Pattern (US)

Precipitation



Spatial Pattern (US)

Potential Evapotranspiration



Spatial Water Balance

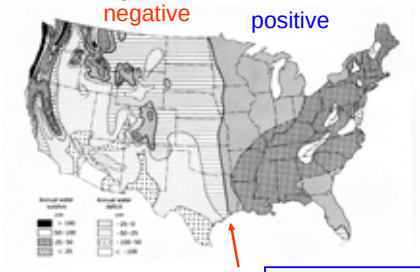
P – ET > 0 → P > ET

Water Surplus

P – ET < 0 → P < Pot. ET

Water Deficit

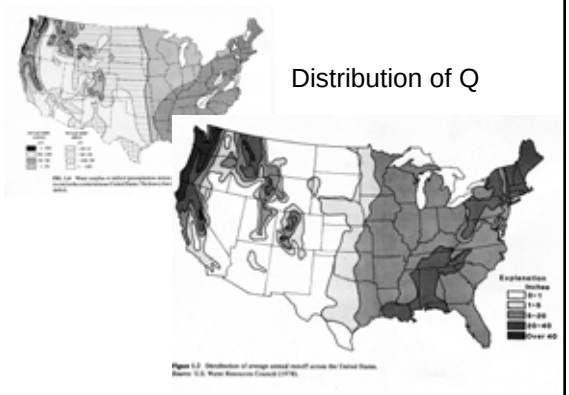
Regional Water balance



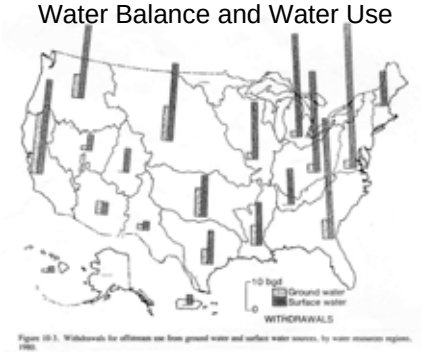
Avg Precip = 76 cm
Avg ET = 50 cm (70%)

Average Surplus: 26 cm

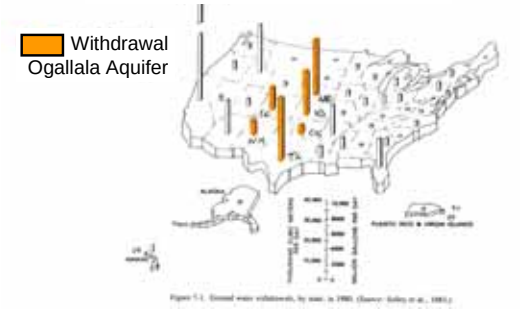
Distribution of Q



Water Balance and Water Use



Water Balance and Water Use
Groundwater Withdrawal



Water Table declines

SUMMARY
Water Balance

- On a global scale P-ET=0
- On a regional scale P-ET ≠ 0
- When P > ET : **Water Surplus**
- When P < ET : **Water Deficit**

SUMMARY
Water Balance

- Site Water Balance
  $Q = P - ET \pm dS \pm dG$
- During periods of drought (low P), soil and GW become water sources (**discharge**)
- During wet periods (P>ET) soil and GW become water sinks (**recharge**)