Outline

• Yay for aquifers!
• Definitions
• Flow through an aquifer
• Pumping an aquifer
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The Water Cycle

- Water storage in ice and snow
- Precipitation
- Snowmelt runoff to streams
- Infiltration
- Ground-water discharge
- Spring
- Freshwater storage
- Ground-water storage
- Water storage in oceans
- Water storage in the atmosphere
- Condensation
- Evaporation
- Transpiration
- Surface runoff
- Streamflow
ET 320,000,000
precip 379,000,000
evap 7,200,000

All numbers in acre-feet per year for Texas
86%

86%

35,000,000
9,300,000

data from Ward and Valdes (1995)
Atmosphere:
- ET: 320,000,000
- Precip: 379,000,000
- Evap: 7,200,000

Surface water:
- 47,200,000 into lakes and rivers from runoff
- 4,700,000 into lakes and rivers from rainfall

Data from Ward and Valdes (1995)

Texas coast: 35,000,000 (86%)
Other states: 9,300,000 (85%)
**atmosphere**

- ET (Evapotranspiration): 320,000,000
- Precipitation (Precip): 379,000,000
- Evaporation (Evap): 7,200,000

**surface water**

- 47,200,000 into lakes and rivers from runoff
- 4,700,000 into lakes and rivers from rainfall

**groundwater**

- Recharge: 5,100,000
- Baseflow: 1,300,000
- Texas coast: 35,000,000
- Other states: 9,300,000

Data from Ward and Valdes (1995)

All numbers in acre-feet per year for Texas

86%

1.3%

85%
# World Water Balance

Table 1.1  Estimate of the Water Balance of the World

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Surface area (km²) × 10^6</th>
<th>Volume (km³) × 10^6</th>
<th>Volume (%)</th>
<th>Equivalent depth (m) *</th>
<th>Residence time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans and seas</td>
<td>361</td>
<td>1370</td>
<td>94</td>
<td>2500</td>
<td>~4000 years</td>
</tr>
<tr>
<td>Lakes and reservoirs</td>
<td>1.55</td>
<td>0.13</td>
<td>&lt;0.01</td>
<td>0.25</td>
<td>~10 years</td>
</tr>
<tr>
<td>Swamps</td>
<td>&lt;0.1</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.007</td>
<td>1–10 years</td>
</tr>
<tr>
<td>River channels</td>
<td>&lt;0.1</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.003</td>
<td>~2 weeks</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>130</td>
<td>0.07</td>
<td>&lt;0.01</td>
<td>0.13</td>
<td>2 weeks–1 year</td>
</tr>
<tr>
<td><strong>Groundwater</strong></td>
<td>130</td>
<td>60</td>
<td>4</td>
<td>120</td>
<td>2 weeks–10,000 years</td>
</tr>
<tr>
<td>Icecaps and glaciers</td>
<td>17.8</td>
<td>30</td>
<td>2</td>
<td>60</td>
<td>10–1000 years</td>
</tr>
<tr>
<td>Atmospheric water</td>
<td>504</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>0.025</td>
<td>~10 days</td>
</tr>
<tr>
<td>Biospheric water</td>
<td>&lt;0.1</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.001</td>
<td>~1 week</td>
</tr>
</tbody>
</table>

**Source:** Nace, 1971.

*Computed as though storage were uniformly distributed over the entire surface of the earth.

From Freeze and Cherry (1979)
groundwater and Texas

• ~60 percent of the 16.6 million acre-feet of water used
• ~80 percent of groundwater is used for irrigation
• groundwater provides 39 percent of water to cities
• tastes good when yer thirsty
austin chalk
catfish farm well
Edwards aquifer

- flowing well at 40,000 gpm
- 1/4 of San Antonio’s use
- 9% of Annual Recharge
- world’s largest artesian well

National Geographic (1993)
Hickory Aquifer, sandstone
Edwards-Trinity (Plateau) Aquifer, limestone
Ogallala Aquifer, sand and gravel
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• Yay for Groundwater!
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Definitions

- Aquifer
- Aquitard/confining layer
- Vadose zone/unsaturated zone
- Water table
- Recharge
- Water level
- Unconfined aquifer
- Confined aquifer
what is an **aquifer**?

- an aquifer is **geologic media** that can **yield economically usable amounts of water**.
  - **Dirt and rocks**
  - **Depends on who’s using it**
what is an aquifer?

Limestone (especially karstified), sandstone, sand, gravel, fractured rocks
what is an aquitard?

- an aquitard is geologic media that can **not** yield economically usable amounts of water.
what is an **aquitard**?

- clay, shale, unfractured dense rocks
- Note: can still transmit water, but slowly

**aquitard**
what is a confining layer?

- A confining layer is an aquitard that bounds an aquifer.
what is a vadose zone?

• The vadose zone is the unsaturated geologic media between the water table and the land surface.

• Scientific side note: There is a saturated capillary zone between the vadose zone and the water table.
the vadose zone

vadose zone

aquifer

aquitard/confining layer
what is a water table?

• A water table is where the aquifer meets the vadose (unsaturated) zone.

• Scientific definition: surface on which the fluid pressure in the pores of a porous medium is exactly atmospheric.
the water table

vadose zone

water table

aquifer

aquitard/confining layer
what is recharge?

• Recharge is water that infiltrates to the water table of an aquifer.
what is a water level?

• A water level is the level at which water rests (or would rest) in a well.
the water level

vadose zone

recharge

water table

aquifer

aquitard/confining layer
2 rules of groundwater flow

- water flows downhill (to lower potential energy)

- water flows uphill to money
water flows downhill (to lower potential energy)
Groundwater Flowpaths
water levels in 2000
from the GAM report
what is an unconfined aquifer?

- An unconfined aquifer is an aquifer that is bounded by a confining layer at its bottom but not at its top.
an unconfined aquifer
what is a confined aquifer?

• A confined aquifer is an aquifer that is bounded by confining layers at its bottom and top and where the water level rises above the top of the aquifer.

Scientific side note: This is also an artesian aquifer. “Artesian” does not require water to flow at land surface.
a confined aquifer

- aquifer
- aquitard/confining layer
- aquitard/confining layer

water level
POP QUIZ!!!
confined or unconfined?
confined or unconfined?
confined or unconfined?
same aquifer: **unconfined and confined**
Major aquifers

- Ogallala
- Pecos Valley
- Edwards-Trinity (Plateau)
- Edwards (Balcones Fault Zone)
- Gulf Coast
- Trinity
- Seymour
- Carrizo-Wilcox
- Hueco-Mesilla Bolsons
same location: **confined and unconfined aquifers**
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Your aquifer as a bathtub

Recharge

Aquifer

Pumping

Spring/base flow
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Your aquifer as a bathtub

- Recharge
- Aquifer
- Pumping
- Spring/base flow
McDonald Irrigation Well, 1200 Gallons per Minute, Hereford, Texas.
2 rules of groundwater flow

- water flows downhill *(to lower potential energy)*

- water flows uphill to money
pumping a well: unconfined
pumping a well: confined
Maximum water level decline unconfined
44 feet

Water level decline due to pumping in feet

Extent of water level decline unconfined
166 feet

Transmissivity = 1,000 ft*ft/day
Pumping rate = 300 gallons per minute
Pumping time = 1 day

Unconfined storativity = 0.15
Transmissivity = 1,000 ft*ft/day
Pumping rate = 300 gallons per minute
Pumping time = 1 day

Unconfined storativity = 0.15
Confined storativity = 0.0005
‘Artesian’ zones of Texas circa 1900

Fig. 44.—Map showing artesian districts of Texas.

1. Coast Prairie system; 2. Hallettsville system; 3. Carrizo system; 4. Black and Grand prairies system; 5. Trans-Pecos Basin system; 6. Stevens County and Jack County systems.

(from R.T. Hill, 1901)
GEYSER CITY

The discovery of abundant artesian springs in 1870s Wyoming led to the building of a city centered around these natural wonders.
groundwater use in Texas (1937 to 2003)

Total volume pumped: 530,000,000 acre-feet

Texas Water Development Board data

U.S. Geological Survey data
Total water level declines in the major aquifers.
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