1.72, Groundwater Hydrology
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Lecture Packet #12: Soil Moisture

**Terms and Interpretations**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
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<tbody>
<tr>
<td>$\theta_{pwp}$</td>
<td>Permanent wilting point water content</td>
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<tr>
<td>$\theta_{fc}$</td>
<td>Field capacity water content</td>
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<tr>
<td>$\phi$</td>
<td>Porosity</td>
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<tr>
<td>$\psi_{ae}$</td>
<td>Pressure at which air enters the system (top of the capillary fringe)</td>
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<tr>
<td>$p_0$</td>
<td>Atmospheric pressure; underground, the definition of water table</td>
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<tr>
<td>$\theta = \phi$</td>
<td>Saturation point</td>
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Unsaturated Flow: Movement of Soil Moisture

Water molecules attract each other so that at the surface there is a net downward pull on the molecule. The net effect is **surface tension**.

\[ \gamma = 72.7 \text{ dyn/cm for water and air [F/L]} \]
\[ \gamma = 29 \text{ dyn/cm for benzene} \]
\[ \gamma = 430 \text{ dyn/cm for mercury} \]

Energy/L² – the energy required to increase the area. Unlike a membrane, the surface tension doesn’t change with expansion.

Surface tension depends on:

- The substances
- Any solutes
- Temperature
- Gas Pressure
Consider a bubble of air in water:

$$\Delta P = \frac{2\gamma}{R}$$

Blowing air into the bubble decreases the pressure.

$$\gamma_{SL} = \gamma_{GS} + \gamma_{LS} \cos(\alpha)$$

$$\cos(\alpha) = \frac{\gamma_{SL} - \gamma_{GS}}{\gamma_{LG}}$$

GS = gas-solid
SL = solid-liquid
LG = liquid-gas
Capillary Rise

\[ \Delta P = \frac{2\gamma \cos(\alpha)}{r} \]

When the height of the meniscus is at steady-state, then the hydrostatic tension must balance the effect of surface tension.

\[ hg\rho = \frac{2\gamma \cos(\alpha)}{r} \]

Retention Curves or Soil Moisture Characteristic Curves

A bundle of capillaries (hydrophyllic) all of the same length with pressure adjusted at the bottom. The bundle contains a range of radii. Measure average water content as the suction is gradually increased at the bottom. Plot suction versus water content.

\[ \psi = \text{suction} \]
\[ \theta_\omega = \text{water content} \]
Pore space in rocks and soil is much more complex geometrically but analogous phenomena give rise to characteristic retention curves for a given sample material.

The shape of the retention curve for a given porous material is influenced by:

1. Texture and Structure
   a. Particle-size distribution
   b. Pore-size distribution
   c. Particle shape
   d. Specific surface

2. History of wetting and drying – Hysteresis
   a. Non-wetting phase entrapment
   b. Swelling and shrinking
   c. Ink-bottle effect – Haines Jump