Infiltration and Soil Water
Notes

Infiltration: flow of water from the ground surface down into the soil

Soil: an unconsolidated aggregate of mineral and rock fragments ranging in size from tiny clay and silt particles to sand and sometimes even including pebbles and boulders.

I. Soils

A. The Rock Cycle: 3 types of rocks

- **Igneous**: cooled and solidified from hot molten lava
- **Sedimentary**: sediment and rock fragments that are compacted and cemented together
- **Metamorphic:** the result of igneous and sedimentary rock changing in form and mineral structure due to excessive heat and pressure.

- In hydrology and engineering, all of the sediment and unconsolidated, granular material (that has some open pore space) that overlies bedrock is considered **soil.** Derived from the chemical decomposition or mechanical disintegration of rock.

    - **Unconsolidated** means fragmented and not cemented together. Think of sand.
    - **Soil and sediment** are used interchangably in this sense.

B. Porosity and Permeability

Porosity: amount of pore space in rock material compared to the total volume of rock. Vp/Vt. How much water the rock can hold. Ratio, unitless

- **Medium:** an environment, soil, bread, sponge, filter
- Many things are porous and can hold a lot of water, but that doesn't mean it can transmit water through it.
  E.g. Sponge: lots of pore space, can hold a lot of water, but doesn't allow water through it very well. Also, clay.

Permeability: the ease with which water can be transmitted through rock material. Depends on the interconnectedness of the pore spaces. (ft/s, cm/day)

Specific Yield: The volume of water that drains by gravity from a volume of rock, compared to the total volume of rock material present. Vg/Vt, ratio or Vd/Vt

Specific Retention (Field Capacity): The volume of water remaining (capillary water) after a given volume of rock material has been drained by gravity. Vc/Vt, ratio or Vh/Vt

C. Soil Classification

- Soils are classified by the size and shape of their particles.
- Naturally occurring soil is generally a mixture of different sized particles. The soil is **graded**. You can classify the soil by the percentage of each size it contains.

Four major classifications by grain-size:

1. Gravel: 2mm-75 mm
2. Sand: 0.05mm-2mm
3. Silt: 0.002mm-0.05mm, fine, powder-like
4. Clay: less than 0.002 mm, very tiny particles

- Gravel, sand, silt are relatively coarse-grained, bulky particles. Clay is fine and has a plate-like shape to its particles, high affinity for water.
- **Loam:** a combination of sand and silt that also contains organic material and is suitable for the growth of plants or crops.

SOIL CLASSIFICATION TRIANGLE
Figure 1.13

Example 1: A soil sample contains 20% sand, 60% clay, and 20% silt. How would this soil be classified?

Example 2: A soil sample contains 50% sand, 10% clay, and 40% silt. How would this soil be classified?

Eaxmple 3: A soil sample contains 25% sand, 50% silt, and 25% clay. How would this soil be classified?

- When the proportion of clay exceeds 20%, the clay will generally dominate the soil characteristics and behavior.

- In general, the more large sized particles, the more permeable the soil is. E.g. Water will drain quicker from gravel than silt.

- Porosity, however, does not depend on grain size. It depends on grain shape, arrangement, and degree of assortment. E.g. a silty soil can contain as much pore space, or water holding capacity, as a coarse gravel. However, the size of each of the pores and the hydraulic properties (ability to move the water through) will not be the same.

Example 2: A soil sample contains 50% sand, 10% clay, and 40% silt. Using Figure 1.13, how would this soil be classified? Would you expect this soil to have a high, medium, or low infiltration rate?

Notice how the triangle is sectioned off into zones of soil type. Also, notice how the percentage and lines for sand are tilted downward. The percentage and lines for clay are horizontal, and the percentage and lines for silt are slanted upward. For 50%, locate the 50% on the Percent Sand side. Then follow that line downward until you hit the line for the next percentage (Percent Clay, 10%). Find 10% on the clay side and follow that line horizontally until it hits the Percent Sand line. They will meet at whatever the Percentage Silt is. You can check it by finding 40% on the Silt side and follow that line upward until it meets the other two lines. Read off the type of soil where the 3 lines meet.

In this case, the soil is a **silty sand**. Since there is less than 20% clay, it will not behave like a clay. Gravel has a very high infiltration rate. Sand has a higher infiltration rate (and larger particle size) than silt. Since there is almost the same amount of sand and silt, this soil will have a **medium infiltration rate.**

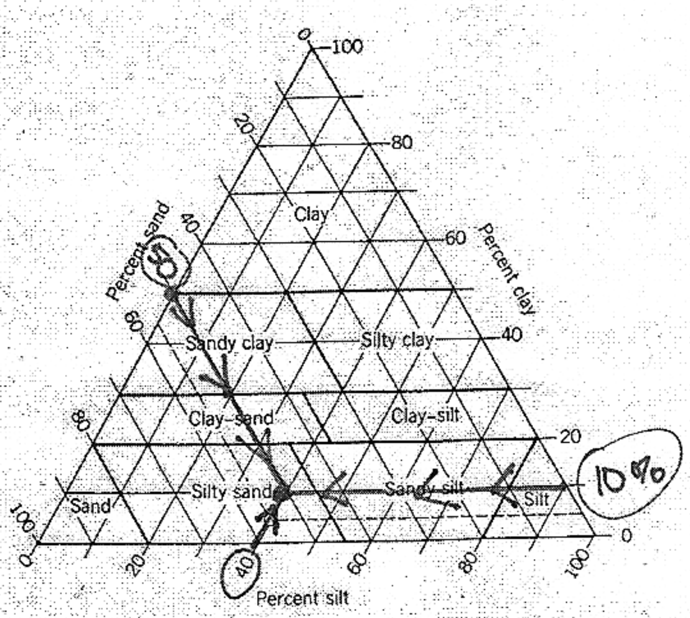

FIGURE 1.13
Triangular soil classification chart. (From Hough, *Basic Soils Engineering*, with permission of the Ronald Press)

II. Process of Infiltration

Top soil: has most of your decaying organic material
Soil, sediment: all the rest of the unconsolidated rock fragments that contain pore spaces
Bedrock: solid, cemented, consolidated rock with a negligible amount of pores space. Water can't get through it.

Process of Infiltration

- Rain falls on dry soil, molecular forces draw water into the soil (**adhesive forces**: Oxygens on soil attract hydrogens of water and pull water in).
- Water adheres to soil grains by forming hydrogen bonds with the mineral surfaces.
- As more water enters the soil, surface tension forces cause water to enter most of the small pores forming menisci at the interfaces between air and water, between soil grains.
- As more water seeps into the soil, it destroys the menisci and the force of gravity takes over and moves water downward.
- Once the rain stops and the supply of water tapers off, water drains by gravity until mensci begin to reappear and the forces of surface tension again dominate, holding water in the pores.

A. Zones of Subsurface Water

- **Groundwater:** water that fills the pores of soil
- **Soil Water:** Water that partially fills the pores of soil. Air is also partially present in the pores at the same time. Located above the water table.
- **Saturated Zone (groundwater zone):** The areas of soil where water completely saturates the pores spaces of soil.
- **Unsaturated Zone (vadose zone):** The areas of soil that are not saturated with water. Water and air are present in the pore spaces.
- **Water table:** the top (air-water interface) of the saturated zone. Fluctuates with recharge and pumping.
- **Capillary Fringe:** Soil zone just above the water table where the forces of capillary suction produced by surface tension in tiny soil pores in the dry soil above act on the groundwater, pulling it upward, against the force of gravity.
- Process of infiltration is a little more complicated than water just flowing downward into the soil. Evaporation, osmotic pressure from plant roots, capillarity can pull water upward.

B. Effects of Rainfall Intensity

- The less water infiltrates into the ground, the more runoff will result.
- More runoff can result in more soil erosion which takes away the good organic top soil and microorganisms essential for soil fertility and plant growth.
- Impact of heavy rainfall can actually rearrange grains in the soil surface, resulting in smaller grains being pounded into the pores of smaller grains, plugging up the pore spaces. Water will then collect on the surface, causing more runoff.
- What can you do to enhance infiltration and prevent runoff?
  - Plant grass, vegetation: the roots lock the soil in massive units that resist erosion and the stems of the plants act to slow water down along the surface.
  - "Conservation tillage": reduced tillage, less tractor, prevents compaction. Also, after harvest, add debris (organic) to surface to suck in water and cover soil.
- Q=CIA, Q is discharge rate of runoff, C describes the land surface. When C=1, the land will not infiltrate water, asphalt, all runs off. As C decreases, the land will infiltrate more water, resulting in smaller runoff rate, Q.

C. Effect of Clay on Infiltration Rates

- Clays are composed of extremely small, individual mineral grains. Clay grains are MUCH smaller than other soil grains and have a large surface area that carries a negative charge. Therefore, clays are more chemically active, attract water even more than other soils. When water enters the crystalline structure of clay, it causes the volume of the clay to increase dramatically, it swells, can clog pores, prevent infiltration.

D. Other Factors Affecting Infiltration Rate

- Increased temperature, increases infiltration rate
- Frost can slow infiltration rate
- If soil is initially wet, infiltration rate will be slower
- Vegetative cover increases infiltration rate

E. Measuring Infiltration

- Really no way of directly measuring infiltration
- Can measure average rainfall depth coming in, and the runoff going out and subtract the two to get how much infiltrated. This ignores evap.