Soil Water Potential (I)

Energy flows from high to low. Likewise, water flows from high energy locations to low energy locations. (In fact, the pressure term we've seen in Darcy's law is really an energy difference.) The magnitude of the energy difference tells us the driving force, and its direction tells us the direction of flow. But the energy state of the soil water is important for understanding water content as well as water flow.

Energy has kinetic and potential forms. Kinetic energy is ½ m v^2, and v in soils in low. So potential is the form in which most energy resides in the soil.

Absolute potential is hard to determine: is the gravitational potential with respect to the center of the earth? How about temperature? But we can compare potential <u>differences</u>: for example, between two points in the soil.

Definition of soil water potential: the amount of work needed, per unit quantity of pure water, to transport the pure water from the reference state to the state in question, reversibly and isothermally.

Reversibly why? (to avoid issues of change in total entropy of the system.)

Isothermally why? (to make things easier. We'll see later in the course that temperature influences water flow, but for now we're carefully avoiding this issue.)

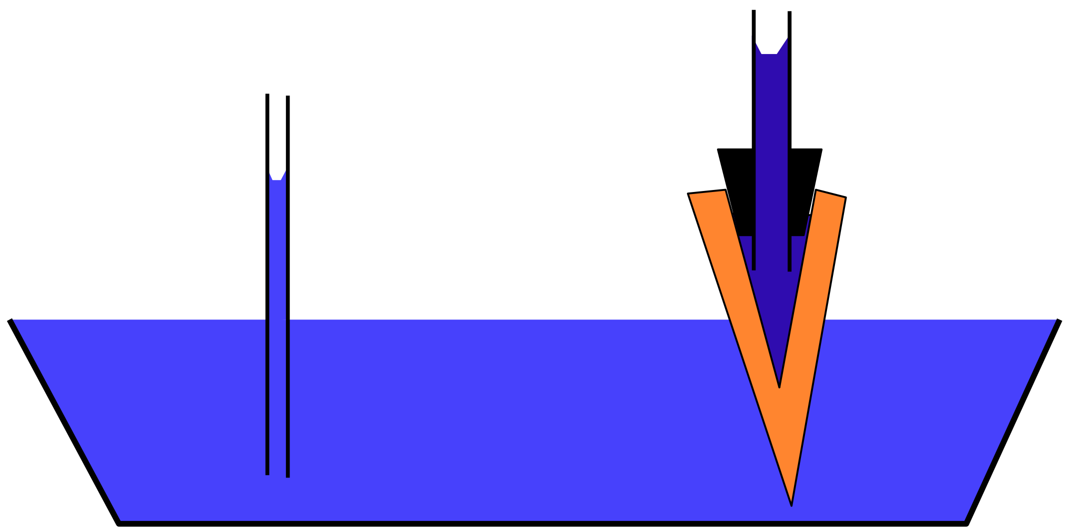
<u>The basic equation:</u>

Total potential = gravitational + pressure + matric + osmotic + overburden + pneumatic + …

$$\Psi_T = \Psi_g + \Psi_P + \Psi_m + \Psi_o + \Psi_b + \Psi_a + \ldots$$

<u>Gravitational</u>: potential with respect to an arbitrary reference point. Simply put, the vertical distance above or below the reference point. This is about potential energy, so high above the reference is positive (more energy), distance below is negative.

<u>Pressure and Matric:</u> Recall that water at the bottom of a pool is under pressure, which gives it more energy (relative to the reference, which is at atmospheric pressure). So positive pressure (sometimes called submergence potential) gives positive potential. Suction, or water tension, is the negative of pressure, and therefore gives negative potential. When this potential is negative – the water is under tension – this component of the potential is called matric potential. Remember that, in a capillary tube, the water above the water table is under tension, while that below the water table is under pressure. This illustrates how pressure and matrix tension are aspects of the same thing (see left side of figure).



<u>Osmotic:</u> putting a solute into the water generally lowers the potential, because you'd have to expend energy to extract it. Putting a semi-permeable membrane between the pure water and the solute-laden water establishes a potential difference, and water will move to equilibrium. For example, in the figure (right side) is a hollow carrot (semi-permeable membrane) with sugar-water inside it. Pure water has moved across the membrane (from high to low potential), raising the water level. The same principle is used to desalinate sea water by reverse osmosis.

Overburden: a tractor running over the soil compacts it, subjecting the soil water to increased pressure. The water flows from high potential (high pressure, under the tractor tires) to low potential areas. Similarly, to clean up a spill in your rug, you put a towel on the spill and step on it: the increased pressure potential makes the liquid freer to move. Of course, in order for the spill to move into your towel rather than somewhere else in the rug, you want a towel with a low matrix potential.

<u>Pneumatic:</u> when a high pressure system moves in, the air pressure increases. This increases pressure on the soil water, and this increased pressure confers higher potential. This is generally a small effect, but some laboratory procedures work by exposing the soil to high air pressures.

The potential of the water can be expressed in different ways depending on what units you are using. The most basic definition is energy per unit mass. But the most convenient is hydraulic head, with units of length (of a water column):

Energy per unit mass – energy (L^2 T^{-2}): J kg^{-1}
Energy per unit volume – pressure (M L^{-1} T^{-2}): pressure, e.g. bars, atm., KPa.
Energy per unit weight – hydraulic head (L): meters of water

Under most conditions in the soil, the important components of potential will be gravitational and pressure/matric.

If a system is at equilibrium (no movement), total potential is the same everywhere. Likewise, if the total potential everywhere is the same, the system is at equilibrium. Or (to word it yet a third way), you need a potential difference in order to make water move.