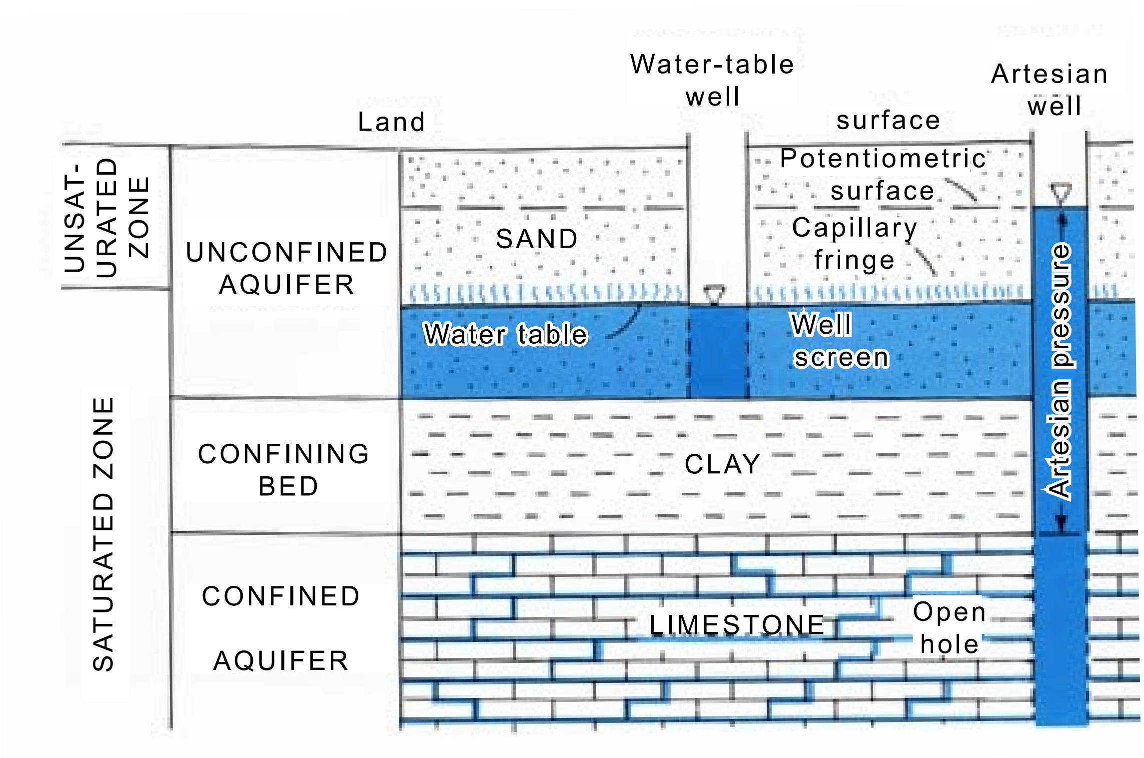
Chapter 10

Unsaturated Zone

The water table is the top of an unconfined aquifer where the water pressure is equal to atmospheric pressure. The water level in a well in an unconfined aquifer represents the water table. There is a small zone above the water table that also is 100 percent saturated. This is called the capillary fringe and the reason this is saturated is that the surface tension of water and attractive forces of the sediments wick water up from the water table and hold it in the pore spaces (sort of like the "paper towel" effect, where if a corner of a paper towel is placed into a puddle of liquid, the liquid would be pulled up into the towel by capillary tension).



Source: Heath, 1989

The area above the capillary fringe and land surface also holds water, but less than 100 percent saturation. In other words, the pore spaces are filled with both water and air. Scientists refer to the area between the water table and land surface as the unsaturated zone, zone of aeration, or vadose zone (all three terms refer to the same area). The term most people are most familiar with would be soil moisture, which refers to the water in the unsaturated zone that lies within the depth of plant roots.

The same tension that pulls water up from the water table into the capillary fringe also holds water in the unsaturated zone. The amount of water in the unsaturated zone is related to the porosity of the sediments, the thickness of the unsaturated zone, and how recent infiltration (whether from precipitation or irrigation) has occurred. Other factors, such as climate conditions and vegetation cover, also are important, but this chapter will discuss only the first three.

Porosity is the ratio of the spaces or openings in a rock or sediment compared to the total volume of the rock or sediment. Porosity is important because the smaller the pore spaces, the higher the tension between the water and the rocks or sediments. For example, in a gravel bed, the amount of water content in the unsaturated zone would be smaller than in a silt bed because the pore spaces between the gravel would be much larger in size than those in the silt. This is why the capillary fringe is quite large in clay or silt deposits verses what is observed in sand or gravel deposits. This also is why clayey soils are often referred to as poorly drained and sandy soils are often referred to as well drained.

The thickness of the unsaturated zone is important because sediments near the water table but in the unsaturated zone have a source of moisture (especially as the water table fluctuates up and down with recharge and discharge). The capillary fringe is where the sediments are completely saturated. Above the capillary fringe, water content in sediments can still be very high. The amount of water content typically will decrease with distance above the capillary fringe.

The thickness also is important because thin unsaturated zones can be entirely within the reach of plant roots (in the soil moisture zone) and affected by plant uptake. Also, depending on the climate and plant cover, water content near the land surface can evaporate and move as vapor upward through the pore spaces.

Water content in the unsaturated zone fluctuates depending on how recent infiltration has occurred. Following a rain or irrigation, the upper part of the unsaturated zone will have a high water content. Some of this water will then move downward by the force of gravity and will reach the water table. Some of the water will be lost to ET (lost to evaporation or taken up by plants). And some of the water will be held in pore spaces in the unsaturated zone. Over time, gravity will continue to pull some of the water downward and some moisture will convert to vapor and move upward. This is why water content in the unsaturated zone varies over time.

Water content can be measured in various ways in the unsaturated zone. One method involves removing a block of sediment, taking it to the laboratory, and measuring how much moisture is lost when the sample is baked. In the field, electric currents, passed through a portion of the unsaturated zone using a series of probes, can be measured to determine the water content. Neutron probes, which measure the velocity of neutrons when applied to different sediments, are used to measure changes in water content with depth and time at specific locations.

An instrument often used to examine water content in the unsaturated zone is called a tensiometer. At the beginning of this chapter, water table was defined as where the water pressure equals atmospheric pressure. This means that below the water table, water pressure is above atmospheric pressure, and above the water table, water pressure is below atmospheric pressure (we refer to this as a negative water pressure). The amount of water content is measured by measuring the water pressure.

A tensiometer consists of a sealed tube with a porous membrane over the bottom end. Tensiometers are placed at various depths in the unsaturated zone in order to measure the differences in water content with depth (the gradient in the unsaturated zone). Because the water pressure is negative in the unsaturated zone, vacuum pressure is applied to the inside of the tensiometer such that moisture will move from the sediments through the porous membrane into the tensiometer. The amount of vacuum applied and the amount of water movement into the tensiometer can be used to determine the water content at specific depths.

The unsaturated zone is important because it affects how much water recharges aquifers, relates to the health of crops and other vegetation, provides the environment that many plants and animals depend upon, and can be an important area in contaminant transport and containment. The unsaturated zone needs to be understood in order to better understand water resources and water budgets.