Texas Water Development Board

Understanding Aquifers:

Demonstration using a Physical Model

Part I: Aquifers Explained

Geology is the science of planet Earth, its history, and all the processes that act on it. Hydrogeology is the branch of geology which studies how water and rocks interact underground, mainly in aquifers

An aquifer is a rock unit that holds enough water to supply water to wells. Aquifers can be found in many types of rocks, such as sandstone, conglomerate, unconsolidated sand and gravel, and fractured rocks composed of limestone or igneous rocks. Here at Barton Springs in Austin, Texas, we are standing on top of the Edward's Aquifer, composed mostly of fractured limestone. These fractured rocks dissolve overtime and can create large, cave-like systems called Karst aquifers. So when you hear the word Karst, think cave. Some of these caves are big, some of them are small. Karst aquifers are different from sedimentary aquifers, where water flows mostly through the gravel and sand grains similar to a sponge.

Hydrogeologists use two terms when investigating aquifers—porosity and permeability. Porosity is all the empty pore space inside a rock given in a percent volume. Porosity represents the volume of water a rock formation can potentially hold. Permeability is how well a fluid can flow within the pore spaces of the rock within the aquifer.

For water, we describe this property as hydraulic conductivity. For example, clay and rocks like pumice may have high porosity, but because the pores do not connect with each other, the permeability of these rocks is usually low. Layers of low-permeability material such as clay and shale typically act as barriers to groundwater flow and may often function as an aquitard within a groundwater flow system.

Aquifers that are bounded on the top and bottom by aquitards are called confined aquifers. In confined aquifers the groundwater is under pressure. If penetrated by a well, the water level in a confined aquifer will rise above the top of the aquifer. In some cases, the water will reach the surface, resulting in a flowing or artesian well. Confined aquifers function differently than unconfined aquifers, which have no overlying aquitard. Unconfined aquifers occur near the Earth's surface so they may interact better to the processes that occur near or above land surface.

Because unconfined aquifers are exposed to the atmosphere, they may interact with surface water features, such as rivers and lakes. If the water levels in the aquifer are higher than in the adjacent rivers or lakes, the rivers or lakes gain water—in other words, water flows from the aquifer into the river or lake. If the water levels in the aquifer are lower than in the adjacent rivers or lakes, the rivers or lakes lose water—water flows from the river or lake into the aquifer.

Rainwater may infiltrate through the shallow soil and enter the aquifer. Plants may have root systems that extend into aquifers and use the groundwater to survive. Groundwater close to the Earth's surface may also evaporate. Hydrogeologists use the terms recharge and discharge to describe how water enters and leaves an aquifer.

One way an aquifer can discharge is through a spring. Springs occur when the water table intersects the land surface. The Barton Springs Pool is fed by this spring here. Notice the large fracture which the water flows out of.

Here, at Upper Barton Spring, water is flowing out of the ground from a karst aquifer, or small caves.

To understand better how aquifers work, many hydrogeologists and scientists develop "physical" models. To see the physical model in action, continue on to Part II.

Part 2: Unconfined/Confined Aquifers

Welcome back. Thanks for joining us for this second segment covering unconfined and confined aquifers using a physical model.

For our first demonstration, we'll look at an unconfined aquifer composed of gravel and sand. In the model, you can see the aquitard at the base of the unconfined aquifer and open to the surface at the top. We will use dye to show how water flows through the aquifer. On the right side of the tank, we have higher elevations, and to the left, we have a lake and a river. As we start to inject the dye, where do you think it will go?

Let's watch.

Did you figure it out? The dye flows from high head to low head. Head essentially means the height of the water surface. There is more horizontal movement than vertical movement. You can also see that the low-permeability aquitard is restricting the dye from flowing into deeper aquifers. Eventually, groundwater flow paths discharge the dye into the river.

For the confined aquifer, you can see it is capped by an aquitard and an aquiclude, a type of aquitard that allows no water to flow through. Watch what happens when we inject the dye.

The dye follows a similar path of the unconfined aquifer. There is little vertical movement, yet lots of horizontal movement. As the dye reaches the artesian wells, the dye flows up and discharges onto the land surface. Again, this is because confined aquifers are under pressure.

In a Fractured Bedrock Aquifer, a type of confined aquifer commonly called a karst aquifer, the surrounding rock has very low, if any permeability. Thus, it is capped by an aquiclude, a layer of rock which will not transmit water. As we inject the dye, where do you think it will go? Think about the speed of the water too. Will it flow faster or slower than the other aquifers?

Let's watch.

Look at that! The dye flows only through the fractures, not through the rock matrix. And! It flows much more quickly than the other aquifers. Again, once it reaches an artesian well, the dye discharges onto the land surface and flows into the river.

Part 3: Recharge/Surface Water Interaction

In this third and final installment, we will be looking at recharge and surface water interaction using a physical model.

For this demonstration, we will pour blue dye into the model, which represents precipitation as it drips onto the land surface. Once the blue water infiltrates the land surface and enters the aquifer, it is considered recharge. Watch carefully where the blue water goes.

On the right, you can see the dye soaking through the surface and flowing deep into the ground. It also moves horizontally, with the flow of water.

Same in this area. The blue dye can be seen moving deeper, and to the left where the head is lower.

Let's rewatch this at a faster speed so that you can see the dye move more quickly. Notice how the recharge shows up in the confined and karst aquifers as well. If there was any contamination spread over the land surface, such as from fertilizers or pesticides, the precipitation would pick it up and follow the same path as the blue dye into our aquifers. This is called non-point source pollution.

For point source pollution, contaminants are concentrated in a smaller area such as a septic tank, underground storage tank, or an oil spill. Let's see where the dye goes if these tanks have a leak.

Not only does the contamination follow groundwater flow, it can easily discharge into nearby lakes and rivers, too. For both point source and non-point source pollution, some dye remains in the ground just like actual contaminants leaving behind a residue. Cleaning up this residue can be costly, and, in most cases, it can never be completely cleaned. Be on the lookout for potential pollution, and do your best to prevent groundwater contamination.

Thanks for joining me. The next time you're out escaping the Texas heat in a cool spring, think about how that water got to you.