Introduction to the Groundwater Model

Materials:

- Groundwater model
- 2 stand pieces
- 2 1-L plastic bottles
- 2 stoppers for bottles (black) with tubing through center.
- 2 small syringes (~10 ml)
- 2 large syringes (~30 ml)
- 3 dye bottles filled with food dye diluted 2:100 (red, blue, green)
- 1 piece of 2-ft long tygon tubing. (1/8 I.D. ¼ O.D.)
- 6 tips for syringes/tubing (in small baggie)
- 5-gallon plastic buckets for clean water and wastewater
- 1 Artesian well plug (in small baggie with 6 tips)
- 1 **water soluble**, felt tipped "overhead" marker
- Alcohol wipe (in case permanent marker is accidentally used)
- 1 gallon milk jug
- 1 ~ 5 quart plastic bucket (ice cream)
- Roll of paper towels and terrycloth rags for clean up
- Water cycle poster (22x36")

Time Needed*: 45 minutes-60 minutes*

Background: Seventy percent of Wisconsin residents and ninety-five percent of Wisconsin communities rely on groundwater for their drinking water supplies. In addition, groundwater supplies most of the water found in Wisconsin's rivers, wetlands, and 15,000 lakes. Although groundwater is very important, it is a resource that is poorly understood by many people.

Groundwater is also a vulnerable resource. As an example, recent sampling shows that 38% of Wisconsin's 750,000 domestic water wells contain the residues of at least one pesticide. Approximately 10% of Wisconsin's domestic wells contain unsafe levels of nitrate, a contaminant that originates from fertilized cropland, fertilized lawns, and home sewage treatment systems. Since many everyday activities have potential to contaminate groundwater, citizen involvement is essential to preventing further groundwater degradation. If students understand how contamination occurs and understand why groundwater is so important, they are more likely to act in a way that does not contaminate groundwater.

Goal: Students will "see" groundwater and gain a basic understanding of how water and contaminants move through aquifers, and why this is important to them.

Objectives: Upon completion of this lesson, students will be able to:

- Define and describe groundwater
- Describe how water and contaminants move through the groundwater model and different aquifers
- Describe how humans can affect the quality and quantity of water in a watershed
- List several ways students can help clean up groundwater contamination

Prep: **Before the day of the lesson**, the following steps will help make the lesson run more smoothly:

1. Run water through the model to ensure that water and dye move through at a reasonable rate. Slow models might need cleaning with a dilute bleach solution (one capful of bleach per quart jar, run through until it reaches the outlet end (test by smell), and then left to sit overnight and THOROUGHLY purged the next morning.
2. Check all syringes to ensure that the tips stay on securely. Adjust or add gasket tubing (1/4" piece of 1/8" ID and 7/32" OD tubing as needed. Trim tips so water enters easily but they still fit into the piezometer and well tubes.
3. Flat-sided ¼" ID 3/8" OD plexiglass tubing can be used to reinforce the piezometer and well tubes to prevent the edges from breaking.

Before the lesson begins, set up the groundwater model by:

1. Taking the model out of box and setting the model on the wooden blocks or plexiglass stand
2. Placing the ice cream bucket under the lake/river outlet
3. Setting out the kit supplies for the model
4. Filling the gallon jug and quart bottles with water.
5. Filling the model with water to the level of the outlet, and removing air bubbles from piezometers and wells with a syringe (and thin tubing if necessary)
6. Closing the outlet for the artesian well with several stacked syringe tips.

Instructions for the educator are in normal print. Questions the educator should ask or statements the educator should make are in *italics.* Expected responses from the students are in parentheses. Notes are included to help answer questions.

I. Introduction

- *How much water do you use every day?*
  (The average person uses about 63 gallons per day.)

- *What do we use all that water for?*
  (drinking, bathing and showering, washing clothes and dishes, flushing toilets, etc.)

- *Where does your drinking water come from?*
  Did you know that in Wisconsin 70% of our drinking water comes from groundwater? That means groundwater is one of the most important things to learn about and protect! Think what would happen if you didn't have clean water, OR if you didn't have enough water!

- *Where does groundwater come from?*
  Lots of people are surprised to find out that groundwater comes from the sky!

- Use the large water cycle poster to explore the paths that water can take after it falls. Some may run off, some is taken up by plants, some evaporates, and some soaks into the ground to become groundwater.

- *We are going to be exploring how groundwater and contaminants move through soil and rock materials, and how aquifers can store and transmit water*.

- Show the students how the model resembles the lower part of the water cycle poster. They need to get the perspective that the model is like a slice of the Earth.

Transition: *Now that we know groundwater is a valuable resource that we need to protect and conserve, let's use the models. Be sure to keep watching/observing the model to see how it changes over time.*

II. Using the Groundwater Model

- Explain some of the important "rules" when using the groundwater models:
  - *Move around the model carefully - no jumping around, which might make the model tip over.*
  - *Don't reach over the model for something. Go around to retrieve what you need.*

  Stress the need to be careful with the equipment and never force or jam anything into the syringe holes, including air. Syringes need to be kept perpendicular to the model (vertical) when pumping. Pumping at an angle can break the piezometer and well tubes.

- **Remember:** You must keep water moving through the model to have it work correctly. Choose two people in your group to be the "water watchers." Their job is to keep the water bottles full and make sure water is flowing through the model.

Steps with the Groundwater Model

- Go through the following steps in numerical order.

1. Precipitation and Recharge
2. Groundwater Definition and Movement
3. Water Table
4. Groundwater and Contaminant Movement
5. Well Drilling
6. Pumping a Residential Well
7. Landfill Leaching
8. Aquifer Types
9. Cleaning Up Groundwater
10. Pumping a High Capacity Well
11. Septic Systems
12. Crops and Lawns
13. Chemical Spill

- Complete steps in numerical order. You may not have enough time to complete all the steps.

- Throughout the lesson, remember to have the students notice the plumes of contamination. This will help give them clues to the direction both the "contaminants" and water are flowing. Also, use the model for your explanations of the terms used with groundwater.

Steps

1. Precipitation and Recharge

KEY IDEA: Groundwater is replenished by precipitation

- Point out the water in the outlet channels.

Our model already has a little groundwater in it. In the real world, where would that have come from?
(precipitation that has soaked into the ground)

Now, we're going to have a gentle summer rain shower.

- Ask the students to use the syringe to "rain" on the watershed model - squirt water across the top of the model.

What are the 7 forms of precipitation? (Rain, snow, fog, dew, frost, sleet, hail.)
Where did the water go? (It appears to have soaked into the ground.)

What happens when a lot more rain falls? Imagine a thunderstorm moving over the watershed. Dark, towering clouds billow miles into the sky. With a loud crash of thunder rain falls over the watershed – water drops land on the ground and in bodies of water, run across parking lots and seep into the ground.

- Carefully invert the plastic jars of water into the left and right inlet columns.
- *What do you think the jars are simulating?* (Precipitation that recharges groundwater)

2. Groundwater Definition and Movement

KEY IDEA: Groundwater generally moves very slowly through underground layers of soil and rock called aquifers.

- Wait a few minutes and watch the water "recharge the aquifer", that is, fill up the model. Describe to the class what you are seeing.

- *Is water moving through the model? How can you tell?* (yes, because we can see it coming out at the river, and we can observe that the water level in the bottles is going down)

- *How does the water get through the model?* (The water drops have to move around the grains of sand or pieces of gravel one by one.) *So, water underground moves pretty slowly- only about a foot per day.* Use your hands or feet to show how far that is.

- *Now that we've seen the water moving through, and we've already said this is a groundwater model, what do you think a good definition of groundwater might be?* (water under the ground that fills all the air spaces between soil and rock particles and cracks in rocks)

- *The labels on the model tell us that the areas the water is moving through are called aquifers. What is an aquifer?* (a layer of soil, like sand, or a layer of rock that can hold groundwater and can allow it to flow through to a lake, river, or well)

- *How much groundwater do you think there is underground?* (If all the groundwater under Wisconsin could be brought above ground and evenly distributed, it would create a lake one hundred feet deep over the entire state!)

NOTES:
- Groundwater is the part of the Earth's water cycle that flows underground.

- When water from rain and snowmelt soaks, or infiltrates, into the ground it follows the path of least resistance between soil and rock particles, and cracks in rocks.
- Many people picture groundwater as an underground river or lake. However, groundwater is all the water below the water table stored in an aquifer.

3. Water Table

KEY IDEA: The water table is the top of the groundwater.

- *Where do you see water coming out of the model?* (at the river) *So, do you think groundwater comes out of the ground in the real world? Why would it do that? Let's try to figure it out.*
- *In each of our piezometers, we can see some water standing at a certain height. But, to make it even easier to see, we are going to add some dye to it.*
- Ask the students to use a small syringe to inject red dye into wells B, C, D, F, and G. These are the wells that stop above the clay layer. Use enough dye so a colored spot forms in the sand at the bottom end of the well. See notes below for help.
- Ask the students to use the water soluble marker to make a dash to mark the water height on the inlets, well B, well C, well D, well F, well G, and river. Have someone help support the model as you mark the lines.
- Ask the students to connect the marks like a dot-to-dot to form the line.
- *What do you think this line represents?* (The water table - the top of the groundwater in an unconfined aquifer.)
- *Below the water table, all the spaces between the sand grains are filled with water. Above the water table, there is a mixture of water and air in the spaces.*

NOTES:

- INJECT SLOWLY OR YOU WILL BE WEARING THE DYE!
- Sometimes an air bubble gets trapped in the round well(s)---look for a gap in the dye color where there is a clear space. If this happens, the dye will not move through the model. You need to withdraw the air and the dye from the well with the syringe and then carefully re-inject the dye.
- Not all models have the wells labeled. You want the red dye in all the wells EXCEPT the three that go into the confined aquifer below the clay layer.

4. Groundwater and Contaminant Movement

KEY IDEAS: Groundwater moves toward discharge areas. Many contaminants move with the water.

Some of the dye that we put into the piezometers has spilled out into the sand. Is it going to move?

- *Which direction do you think the dye will move? Right, left, up, down, diagonal? Why?* (Groundwater moves toward the river because it is at a lower elevation than the water level in the inlet channel. Students can think of this as a "push" of the water from the bottle to the stream)
- *So the dye moves to a place where it can come out of the model. We call places where water comes out of the ground discharge areas. Looking at the model, what do you think some of these places would be in the real world?* (lakes, streams, and springs)
- *Now let's pretend the dye is a contaminant. What is a contaminant? (*Any substance that makes water unfit for use.) *We call the pattern a contaminant makes as it moves through the soil layers a plume. In a way it's like a plume of smoke: it's very dense at its source (where it first comes out) and becomes thinner the farther away from the source that you go.* See NOTES below for more info.
- *Notice how the plume eventually moves and travels to another location. There is a gap (a clearing) between the well and the plume. This is what happens when a contaminant is spilled – it eventually moves away from the source and affects other locations.*

NOTES:

- The dye pattern is the plume, which is an underground pattern of contaminant concentrations created by the movement of groundwater beneath a contaminant source. Contaminants spread mostly laterally

in the direction of groundwater movement. The source site is the highest concentration and the concentration decreases away from the source.

5. Well Drilling

KEY IDEA: Well depth varies depending on how far you have to go to reach the water table

Now that we have a basic idea about how the groundwater system works, we're going to make up a little story to see how the groundwater affects people. You have decided to build your dream cabin in the woods next to a lake. Your best friend has decided to build one near you, too.

- Ask a student to use the **water-soluble** marker to draw a cabin near the artesian well on the "land" layer. (yours)
- Ask a student to use the water soluble marker to draw a cabin higher up near the pumping wells on the "land" layer. (your best friend's)
- *Which cabin will have to drill a well deeper for water?* (The cabin closest to the pumping wells. Look at the depth of the water table. Groundwater is closer to the surface near the lake than near the pumping well.)
- *Which location is the best for the cabin? Why?* (Answers will vary.)

6. Pumping A Residential Well

KEY IDEA: Pumping a well lowers the water table around the well and may draw contaminants toward the well.

You need a lot of water for your cabin, as you have put in a washing machine and a dishwasher. You also like to have all your friends visit the cabin on the weekends, which places a greater demand on water for showering, flushing the toilets, etc.

- Insert the large syringe into the shallow pumping well. Pump water out of the well by pulling the plunger on the syringe. When the syringe is full, empty the water into a water bucket. Continue to withdraw water from the well a few more times. (Have a friend help support the model as you pump out the water to steady the model.)
- *What kind of well does this represent?* (a residential well that is pumped on and off)
- Using a water soluble marker draw the new water table line. Use the dye as a guideline.
- *What happened to the water table?* (The water table dropped in the area of the well forming a "V".) *We call the drop in the water table around a pumping well a cone of depression.*
- *What effect might this have on the area?* (Possible answers: contaminants on the surface or just below the water table could be drawn down into the well, nearby wells that are shallower than this well could go dry, groundwater flow direction in the immediate area could be reversed and flow toward the well instead of a natural discharge area like a river, lake, or spring.)

7. Landfill Leaching

KEY IDEA: Contaminants that are put on the land surface or buried beneath it can affect groundwater

The area where you live is rapidly being developed. There is an increasing amount of garbage and the local landfill is filling quickly.

- Pour about ½ inch of green dye into the landfill. Observe what happens.
- *What does the dye represent?* (the garbage, or more specifically, water that has seeped out of the garbage in the landfill). *We call that water leachate.*
- *Where will the dye move? Why?* (answers vary---toward a discharge area. The dye moves straight down until it reaches the water table. Some dye will move just under the land surface (in the zone of aeration—soil) and release into the stream.

- *There is pollution under your house now. Does this matter? Let's find out what might happen to our well.* Pump the shallow well. Point out how some dye moves down and enters the groundwater and may eventually be withdrawn from the well.
- The remaining dye will continue to move towards the nearest discharge area—the stream.
- Check back in a few minutes. *Has the green dye separated into two colors—yellow and blue? What does this separation represent?* (the two colors represent the ingredients (or chemicals) that make up the contaminant. Each chemical has its own properties that affect the rate at which it travels in water and through the aquifer.)

8. Aquifer Types

KEY IDEAS: The water in the artesian aquifer is not affected by the pollution of the sand aquifer. Artesian aquifers respond to changes in pressure.

- *Let's look at the deeper layer now- we've been pretty much ignoring it up to this point. In the real world, where might we be able to see underground layers like these? (*in a road cut or a gravel pit).
- *What's going on down there while the sand layer is being polluted?* (not much). *What separates the upper layer from the lower layer? (*a layer of clay).
- *Let's add some dye to two more wells.* BE SURE THE FLOWING ARTESIAN WELL IS PLUGGED! Use the small syringe to inject green dye into wells A and E until it spills out into the gravel below. (INJECT SLOWLY OR YOU WILL BE WEARING THE DYE!).
- *How are wells A and E different from the others? (*wells B, C, D, F, and G are in the unconfined aquifer and wells A and E are in the confined aquifer)
- *The label on the model tells us the deeper layer is called a confined aquifer. What does confined mean? (*trapped). *What is trapping the aquifer and the water in the aquifer?* (the confining layer, which contains clay. Water has a hard time moving through clay. The type of soil material affects water movement.)
- *Is the green dye moving in the confined aquifer?* (no). *Why not?* Ask a student to draw a line with the water-soluble marker that connects the water levels of the inlets and wells A and E. You should see that the line is almost horizontal.
- *The water in the upper aquifer moved from higher elevation to lower elevation. In a confined aquifer, water moves from high pressure to low pressure. Right now, the pressure is the same at all points in the aquifer, so the water is not flowing.*
- *How could we release the pressure on the confined aquifer?* (by removing the artesian well plug). Ask a student to do this. You should see the water level drop in well E, and green dye should begin to appear in the river through the artesian well. Lift the bottle a little in the left inlet for the model. You will see that as the bottle is raised and lowered, the artesian well flows faster and slower.

Congratulations! You have completed the basic groundwater model lesson. If you have more than ten minutes left, proceed to #10. If not, conclude your lesson with #9- Cleaning up Groundwater.

9. Cleaning Up Groundwater

KEY IDEA: In the real world, groundwater is naturally cleaned by recharge, but this process takes a long time. We can install wells to remove contaminants and speed the process up.

Our groundwater model has become quite a mess. How do you think we can clean it up? In the real world, groundwater may slowly clean itself up if clean rainwater comes into the aquifer and moves the contaminated water away. But people can also clean groundwater up by installing a well, or using an existing well, to try to pull some of the contaminated water back out of the aquifer.

- **Be sure to stress safety to the students and remind them to be extremely careful of the expensive and fragile equipment.**
- First and foremost, keep water moving through the model. This will help get most of the dye out.
- **DO NOT TURN THE MODEL OVER TO DUMP THE SAND OUT.** It costs a lot of money to rebuild the model.
- Use the syringes to withdraw the dye from the wells. Remind the students to keep the syringes upright when pumping. If the old groundwater models with square openings are being used, then students will

have to use the small tubing connected to the medium tubing connected to a syringe to pump the piezometers/wells.

- Wipe off the outside of the model and any marker lines with a paper towel.
- Wipe off and dry all equipment and place back inside the storage unit.
- Once the major clean up is done, start the **Conclusion** (see below).

10. Pumping High Capacity Well

KEY IDEA: Pumping a large volume of water from a well can lower the water table, and even change the normal direction of groundwater flow.

The farming has gone so well that the area is becoming known for its tasty vegetables. But the area is hit with a drought and many of the local farmers (including you) need to irrigate your land to keep your farm producing crops.

- Insert the smallest diameter tube that's connected to the next size tube into the shallow pumping well. Attach a large syringe to the end of the tubing and pull the plunger. There will be some resistance. Be careful not to pull the plunger all the way out of the syringe. You will be withdrawing air and water. After the syringe fills with water, take the syringe off and squirt the water in the bucket. Withdraw one more syringe of water. Remove the tubing from the syringe. The water will continue to drip from the tube, so let is hang down and drip onto the ground or in a bucket. You have created a siphon.
- *What does this siphon represent?* (a high capacity well, or a well that pumps a large quantity of water for a long period of time such as a municipal well, an irrigation well, a well used for bottling water, or an industrial well for a paper mill, etc.)
- *What effect does this have on the water table?* (Possible answers: continuous pumping creates a cone of depression; if the well is close to a stream, the well withdrawal could reverse the groundwater flow direction. Instead of groundwater feeding into the river, water is being pulled from the river towards the well.)

11. Septic System

KEY IDEA: Homes need a way to dispose of human wastes. Septic systems put partially treated wastewater back into the groundwater and may affect its quality.

Let's continue on with our discussion about your cabin and the neighborhood you live in. Any house or cabin needs a way to get rid of human waste. Both cabins will need a septic system, since they are located in a rural area.

What is a septic system? (It is a way to dispose of and treat human wastes in areas where there are no central sewers. It consists of a large underground tank (usually 1000 gallons or more) where wastes are settled and stored until they move out into a drainfield,. In the drainfield, the wastewater is filtered and receives some treatment before it soaks away into the ground and possibly reaches the groundwater.)

- Use the **water-soluble** marker to draw septic tanks to the left of each cabin.
- Use a small syringe to inject a small amount of blue dye on the land surface directly above the tank. Observe what happens. Use a large syringe to rain water on the cabin. Observe.
- *What do you think is going to happen here?* (The blue dye from the septic tank will flow towards the discharge area and may cross the path of water supply for the well. If this happens, the well water will become contaminated.)
- *Which house location is better now?* (The cabin next to the artesian well is in the better location because their water is coming from the confined aquifer, which isn't affected by the septic tank. The cabin by the pumping wells is pumping water from the unconfined aquifer, which is now contaminated with septic waste.)

12. Crops and Lawns

KEY IDEA: When chemicals are applied to plants to protect them and help them grow, some of the chemical is used by the plant, but some may reach the groundwater.

Since you have been spending so much time at your cabin, you have decided to clear some land and put in some crops and a very large garden. Your best friend has done the same. In fact, all of your neighbors in the 5-mile area see what you both have done and decided to do the same. Also, you enjoy having beautiful and lush lawns, which requires regular fertilizing and doses of weed-killer.

- Fold a paper towel so it's two layers thick and put it on the "land" surface to the left of the landfill. Using a small syringe, squirt a small amount of green dye on the paper towel.
- Then fill a large syringe with water and have it "rain" on the dye.
- *What do you think the green dye represents?* (fertilizer, pesticides, a spill)
- *Let's say the dye represents fertilizer applied to a crop. What does the part that stayed on the paper towel represent?* (the part that was used by the plants or held by the soil) *What happens if the plants do not use all the fertilizer?* (excess fertilizer may runoff into surface water and/or infiltrate into groundwater)

13. Chemical Spill

KEY IDEA: Old unused wells can act as conduits, or channels to move contaminants from the surface into the groundwater.

NOTE: Not all models have injection wells, so you may not be able to do this activity.

A chemical truck making a delivery in the area crashed in icy weather. The driver was fine, but the truck split open and the liquid chemical drained out. The chemicals flowed off the road into an old well that is not being used any more.

- Use a small syringe to inject green dye into the black injection well. Keep injecting dye until you see it appear in the model.
- *A town gets its drinking water out of well A. What is going to happen to the town's water? Why?* (The town's drinking water will become contaminated because the well is located downgradient from the injection well.)
- *What does this tell us about the importance of old unused wells?* (They can allow contaminants into the groundwater, because they are a direct connection to groundwater without the filtering effect of soil. We should keep them covered and protected at a minimum, and preferably we should properly fill them if we are not going to use them any more.

How can we fix this problem? It's important to remember that our problem has two parts to it: we want to have clean drinking water, but we also need to be sure the groundwater is clean again. To get clean drinking water, we can drill a new well for the town's water; use chemicals or bacteria to treat the water; or withdraw water from a well upgradient from the spill. To clean and protect the groundwater, though, we'll need to withdraw the contaminant and water back out of the injection well using the small syringe and properly cover and seal the old abandoned well (injection well) so no other contaminants can get into the well.

Transition: *Now that we have used the groundwater model to learn more about the movement of groundwater and what affects groundwater, let's start the clean-up process and then we will talk about some of the things we observed.*

III. Clean-up (10 minutes) - see no. 9 above.

Transition: Okay, now that we have started the clean up, let's move onto the conclusion of the lesson. **(Remind students to keep water moving through the model during the conclusion.)**

IV. Conclusion

- *What were some of the things that you noticed while using the groundwater model?*
- *Were you surprised by anything? Did you learn anything new?*
- *Do you think scenarios like these could really happen?*
- *What can YOU do to help prevent contamination of groundwater?*
  - recycle, so fewer things go into the landfill

- conserve water, so you reduce the amount of water that is pumped out of the aquifer
- encourage others to use native plants in their yards that need less fertilizer and water
- reduce the amount of pavement (impervious surfaces) around your house and community
- do not pour oil or other waste products on the ground (including cleaning supplies)
- use environmentally friendly cleaning products like baking soda and vinegar
- inform others about what you have learned today

- *So there are several things that you can do to help the quality and the quantity of the groundwater here in Wisconsin!*
- Does anyone have any questions?

V. Final clean up

- Continue moving water through the model, so all the dye can be removed.
- Use syringes (and possibly tubing) to get any remaining dye out of wells and to remove plumes that are close to the wells.
- Make sure the water soluble marker is wiped off the front of the model.
- After you have quit running water through the model, use the tubes and syringes to lower the water levels at the outlet areas. You may wish to start a siphon in each outlet channel, then let the model set for a while until more water enters the channel. Repeat until there is just enough water in the model to cover the confining layer (clay), so it doesn't dry out and crack.
- Carefully double-check to make sure all materials are there for whoever uses the model next.