Groundwater Connections

Lesson 3: Groundwater Flow Model Demonstration

UNIVERSITY OF CALGARY

GROUNDWATER FLOW DEMONSTRATION

Groundwater Flow Model:
A tank constructed of layered sediments of differing *porosity* and *permeability* to illustrate groundwater flow and impact of pumping.

1.0 OVERVIEW

1.1 Description of Demonstration

This demonstration consists of two parts: 1) a visualization of groundwater flow through various types of aquifers, and 2) effects of pumping on water table, nearby wells, and streams. The demonstration requires access to a ***groundwater flow model,*** which are available for purchase by schools or school districts; both low cost build your own kits and more expensive ready to use models (*Figure 1*) are available. Information about where to purchase a flow model is provided in the ***Resources*** section. If not available, a video has been provided in the ***Resources*** section, along with a list of suppliers for ordering or building a groundwater flow model.

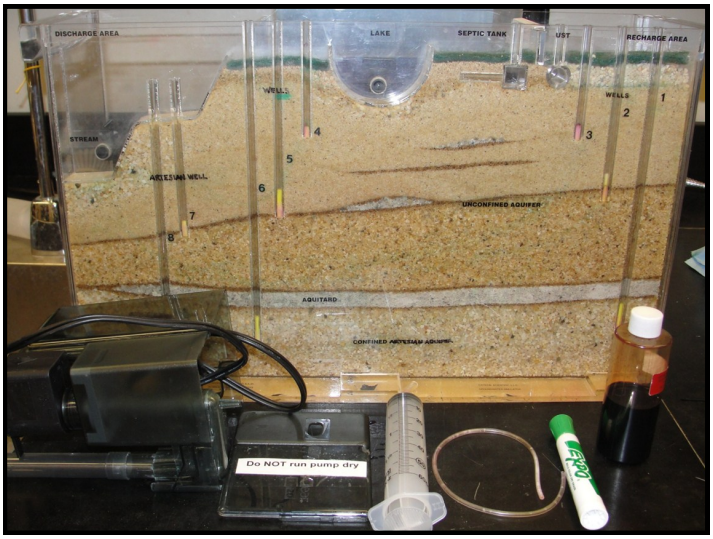


Figure 1. Groundwater Flow Model (Photo Credit: C.R. Farrow).

1.2 Learning Connections

Students will be able to:

- Observe groundwater flow, recharge, discharge, and effects of pumping in a groundwater flow model and compare to groundwater flow described in adaptive primary literature article.
- Design or create a groundwater flow model that is more representative of the geology and groundwater flow found in the Paskapoo aquifer and West Nose Creek watershed.

1.3 Curriculum Connections

Alberta Program of Studies for Science 8
Unit E: Freshwater and Saltwater Systems
STS & Knowledge Outcomes 1, 2, 3, & 4

Teaching Notes:

Groundwater Flow Models:

Information is available in the ***Resources*** section for online video or ordering a groundwater flow model for your school or school district.

Assessment/ Extension Activity:

Invite teams to design a groundwater flow model that is more representative of topography, geology, groundwater flow, and groundwater—surface water interaction found within West Nose Creek watershed.

Invite them to not only use the adapted primary literature article, but to also explore the *Fact Sheets* in the *Research Connections* section of the *Groundwater Connections* website.

2.0 Preparation and Materials

2.1 Logistics

- *Groundwater Flow Model Demonstration* - either using a model or video from the ***Resources*** *section*
- If the class is too large for a whole class groundwater flow model demonstration, the model and two labs noted in Lesson 2 (Porosity & Permeability Labs) could be set up as stations, wherein smaller groups could rotate through each of the three stations.
- Instructions for preparing materials and demonstrating the *Groundwater Flow Model Demonstration* are provided in the Appendices.

2.2 Class Materials

- Groundwater Flow Model Kit (available from University of Calgary)
    - Access to sink & power outlet
    - 1 — meter stick or tape measure
    - 1 — stopwatch

2.2 Student Materials

- Student *Lab Journal* (*see,* Appendix II) **and** pencil

3.0 Demonstration

The overall goal of this demonstration is to help students visualize groundwater flow through different types of sediments and interaction with surface water, along with visual effects of pumping on water levels.

As such, this demonstration models two scenarios:

- *Groundwater Flow* — students will be able to predict and observe static water levels, measure groundwater flow through different sediments, and observe groundwater—surface water interaction (discharge).
- *Impact of Pumping* — students will be able to predict and observe impact of pumping on water levels, other wells, and surface water.

3.1 Scenario 1 ~ Groundwater Flow

- Use the *Groundwater Flow Model Instructions* (Appendix I) as a guide to demonstrate and discuss groundwater recharge, flow, and discharge.
- Before each demonstration, invite students to make predictions on direction and speed of flow, and why the flows might be different in each type of aquifer. Invite them to record observations in *Figure 1* of the *Lab Journal*.
- After each observation, invite students to discuss and identify factors in the model that might affect groundwater flow (*e.g.,* topography, location and type of aquifers or aquitard, differing porosity/permeability of sediments).

3.2 Scenario 2 ~ Effects of Pumping

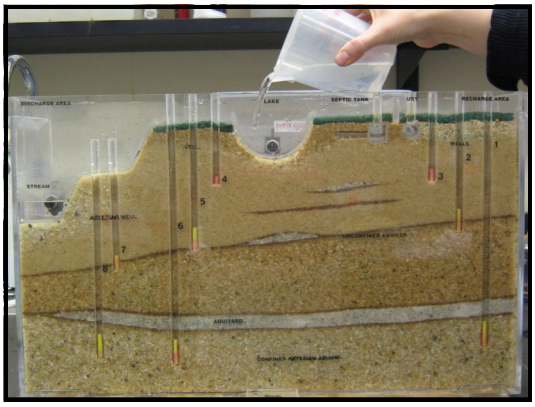
- Use the *Groundwater Flow Model Instructions* (Appendix I) as a guide to demonstrate and discuss impacts of pumping.
- Before each demonstration, invite students to make predictions about the impact of pumping on water levels and surface waters. Invite them to record observations in *Figure 1* of their *Lab Journal*.
- After each observation, invite students to discuss and identify pumping factors that affect water levels or surface waters (*e.g.,* pumping rates, number/location of wells).

4.0 Reflection & Assessment

Invite groups to reflect on and discuss how their observations matched or differed from what was discussed in the adapted primary literature article on groundwater research in the West Nose Creek watershed.

Appendix I: Groundwater Flow Model Instructions p1

A. Preparation



Step 1:

Place tank on a bench or table with access to power outlet, with enough space that a small group of students can gather to observe and measure groundwater flow on the front side of the tank.

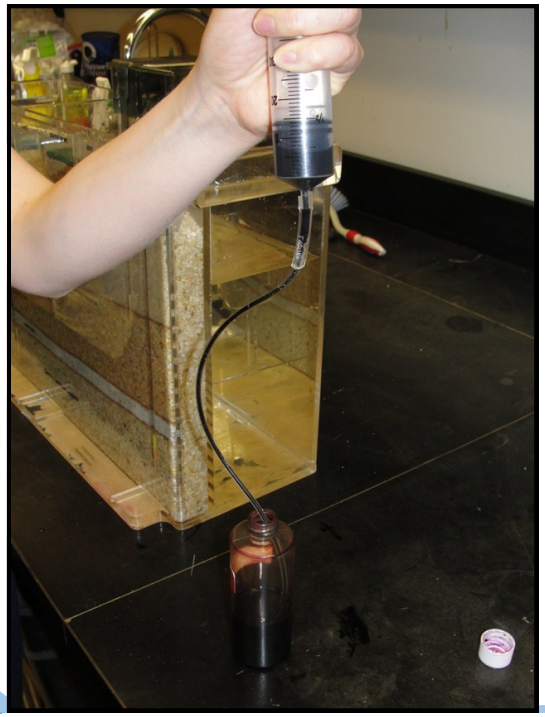
Fill the back reservoir of the groundwater flow model tank to the "water level line" marked on the side of the tank using a water pitcher or beaker. Ensure that valves V1 and V2 are open and the drainage valve (located on the backside of the tank) is closed.

PLEASE NOTE: **Never lift up the tank when it is filled with water. That may damage the tank. Move it only after the water is drained.**

Step 2:

Place the water pump on the backside of the model, with the drain located above the area labeled "non-recharge zone". Fill the pump with water first, then plug in, and move the knob left and right until water continuously flows through the pump into the groundwater flow model.

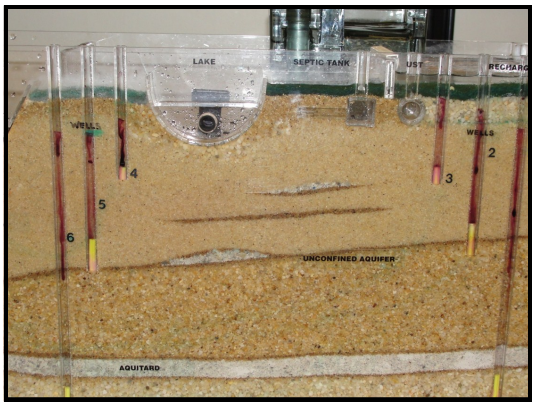
PLEASE NOTE: **Do not plug in the water pump until it has been filled with water.**



Step 3:

Prepare a dilute dye solution by adding a capful of food dye into a plastic bottle filled with water. Cap and set aside for the demonstration. Attach the clear plastic tube to the end of the small plastic syringe and set aside until you are ready to start the demonstration. The syringe and plastic tube will be used to inject dye solution into the model water wells.

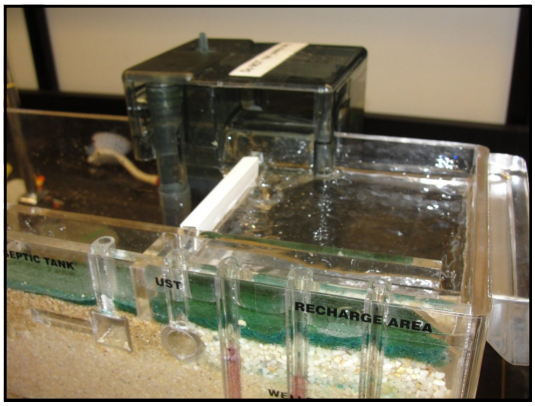
Groundwater Flow Model Instructions p2



B. Part 1 ~ Groundwater Flow

Step 1: Model & Static Water Levels

Gather students around the flow model and identify the location of the following parts: aquifers (noting differing sediment size), aquitard, wells, surface water bodies, and recharge/ discharge zones. Check to ensure that valve V1 and V2 are open and drainage valve on lower backside of tank is closed. Draw some dye solution into the syringe and inject just enough dye at water level in each well to show the **static water level**. Ask students to record the static water levels in each well across the flow model and discuss as a group why the levels might be different .



Step 2: Groundwater Recharge

Close valve V2. Slide the water pump over the “Recharge Zone”. Invite students to observe change in water levels of the Wells 1, 4, 7, and 8, along with changes in stream level. Ask them to record new water levels in the noted wells and stream, and discuss as a group why the levels changed and why they are different.

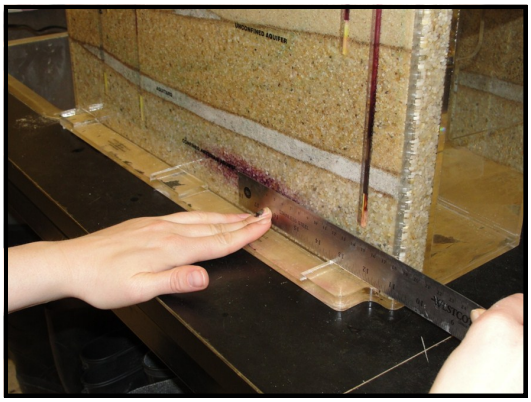
Step 3: Groundwater Flow

Advise students that you will inject dye into Well 1 to illustrate direction and groundwater flow rate through the bottom aquifer. Ask students to predict direction and rate of groundwater flow (cm/s).

Inject a dime-sized amount of dye into the bottom of Well 1, and invite two students to time the groundwater flow over a set time, for example 30 seconds and 2 minutes. Get another student to measure the distance traveled using a ruler. Note: the measurement is taken at the center of the dye “blob.” NOTE: After adding dye into Well 1, you will need to plug the small hole along the side of Well 8 with your finger; otherwise the die from Well 1 will go up Well 8 and out the hole into the stream.

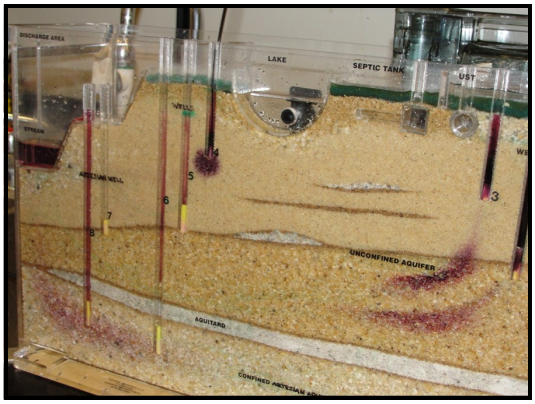
When the dye begins to flow upwards toward the stream, ask students to explain why the groundwater would not flow upwards sooner (Teacher Note: The aquitard located above this layer prevents upward flow from this confined aquifer into the layers above).

Groundwater Flow Model Instructions p3



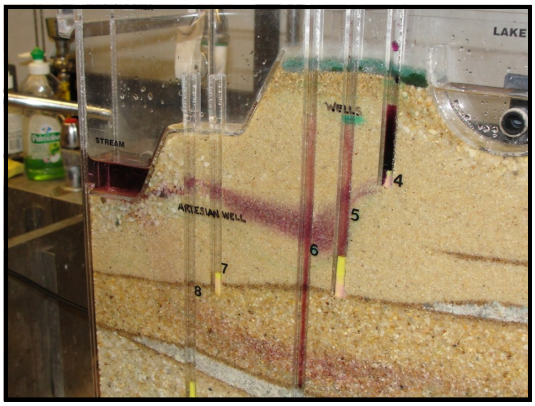
Step 4: Groundwater Flow in Confined Layer

Start the stopwatch when the blob of dye begins moving away from the bottom of Well 1 to the far left of the tank. After a set amount of time (30 seconds or 2 minutes) ask another student to measure the distance traveled over that time, divide distance (cm) by time (s) to calculate the groundwater flow velocity (cm/s). Ask students to sketch in direction of groundwater flow from this well on Figure 1 along with the flow velocity within this layer.



Step 5: Groundwater Flow in Unconfined Layer

Invite students to predict groundwater flow direction and rate when dye is injected into the bottom of Wells 2. Then inject a dime-sized amount of dye into bottom of the well. Invite one students to time the groundwater flow over a set time, for example 30 seconds and 2 minutes. Get another student to measure the distance traveled using a ruler. (Teacher Note: the measurement is taken at the center of the dye "blob.") The students can then calculate the flow velocity within the unconfined aquifer. Record the flow direction and velocity of this layer on Figure 1. Ask the group why it might be different than the confined layer (Teacher Note: difference in porosity and connectivity of pores in sediments)



Step 6: Groundwater Discharge

Invite students to predict where the groundwater will flow to if you inject dye into the bottom of Well 4. Inject a dime-sized amount of dye into the bottom of Well 4. Invite students to observe and trace the direction of flow on Figure 1. Ask the group why the groundwater ended up in the stream and whether the top aquifer had a higher or lower flow velocity than the second or bottom layers. Ask why they might have been different (Teacher Note: 1) the groundwater discharged into the stream as water table around Well 4 is higher than the stream level, and 2) each layer (or aquifer) has different permeability).

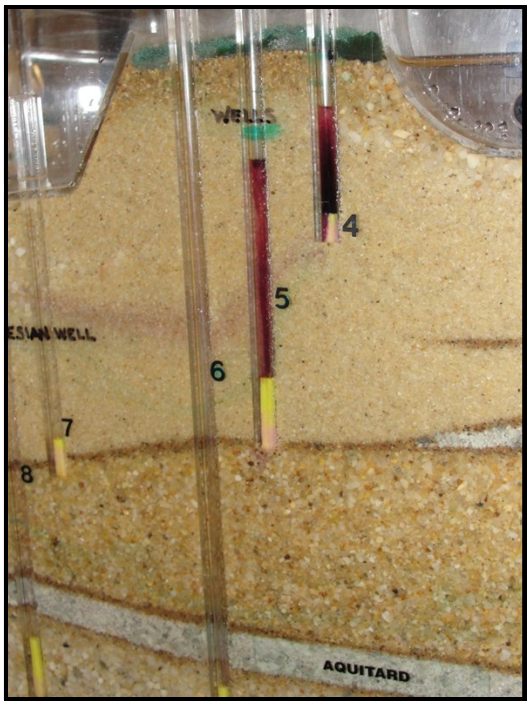
Groundwater Flow Model Instructions p4

C. Part 2 ~ Effects of Pumping

Step 1: Preparing for Pumping Test

To perform the pumping test, use the large syringe with the plastic tube attached. Start by removing any remaining dye from the wells using the large syringe and plastic tube. Once the wells are clear, add a small amount of dye at the static water level in the top of Wells 1, 5, 6, and 8.

Divide class into four groups; assign each group to monitor what happens to the water levels in each well. Ask them to predict what will happen during and after the pumping test.



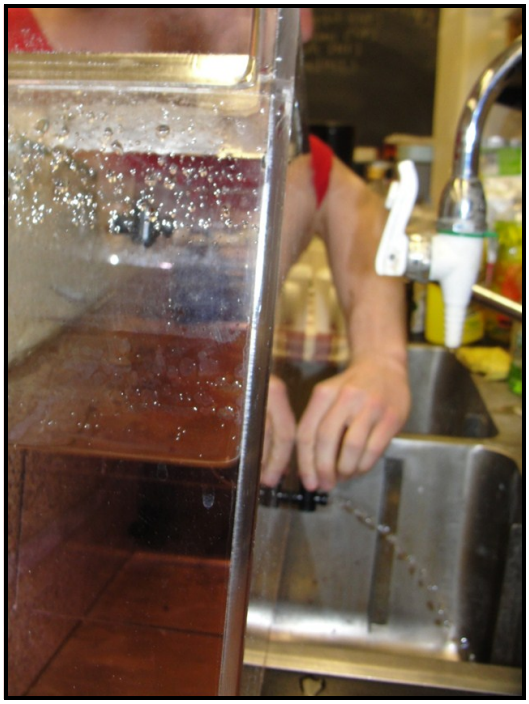
Step 2: Effects of Constant Pumping

Insert the flexible plastic tube attached to the larger syringe into the **bottom** of Well 6 and begin pumping by slowly pulling the plunger out of the syringe. When the syringe is 3/4 full, remove tube from well and discard water back into the top of the flow model tank. Repeat pumping test in Well 6 a second time.

Invite students to record new water levels in Wells 1, 5, 6, and 8 during and after pumping. What was the impact on shallow wells such as Well 5 after constant pumping from the deeper well such as Well 6 (Teacher Note: water table will be drawn down which will lower the water level in Well 5). Invite students to discuss what the impact is on Well 1 (Teacher Note: the water level in Well 1 will drop since Well 1 and Well 6 are in the same confined aquifer. As water is drawn into Well 6 at a faster rate than recharge, the water level drops in Well 1)

Also, ask students to think about what impact constant pumping might have on nearby surface water bodies such as the stream (Teacher Note: stream levels could drop, if over-pumping occurs close to a stream; i.e., water table is drawn down below level of the stream bottom).

Groundwater Flow Model Instructions

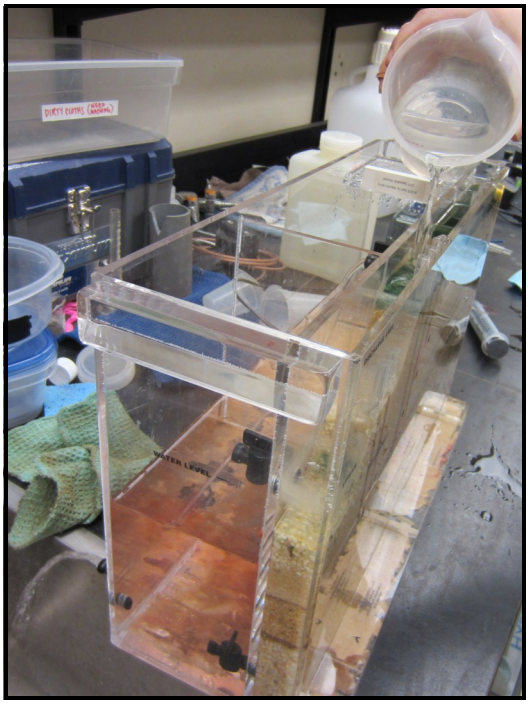


D. Clean-up Procedure

Step 1: Removing Dye Solution from Wells

Be sure valves V1 and V2 are open. Use the syringe with the plastic tube to remove the dye from each well. Water will need to be run through the groundwater tank to remove any remaining dye from the system. Once the dye has moved through the sediment, unplug the pump, remove if from the back of the model and empty the remaining water from it. Place the tank over a large sink and turn the valve at the back of the tank to begin draining the water

PLEASE NOTE: **Never lift up the tank when it is filled with water. That may damage the tank. Move it only after the water is drained.**



Step 2: Removing Dye Solution from Aquifers

As the water drains out the back of the groundwater flow model use a beaker to pour clean water over the model. This will circulate water through the system and remove any remaining dye from the sediment.

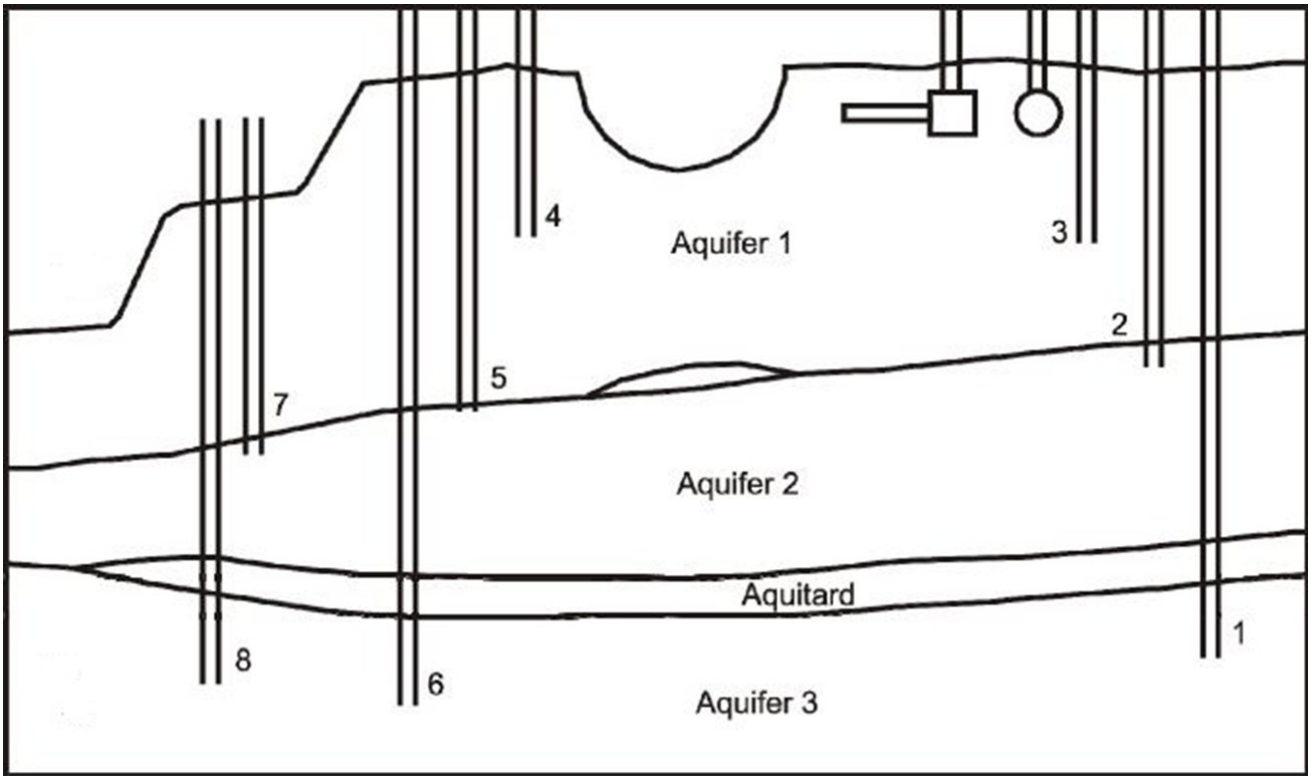
Appendix II: Student Lab Journal p1

Groundwater Flow Model Demonstration

Scenario 1 ~ Groundwater Flow

Use the following diagram of the groundwater flow model to record:

- Static Water Levels before recharge & Water Levels after recharge
- Groundwater flow direction and velocity in confined aquifer (Aquifer 3)
- Groundwater flow direction and velocity in unconfined aquifer (Aquifer 2)
- Groundwater flow direction in Aquifer 1.



Scenario 2 ~ Impacts of Pumping

- Record new water levels in Wells 1, 5, 6, and 8 after constant pumping from Well 6. Why did the levels change?

- Predict and explain what would happen to Well 4 and stream water levels if over-pumping were to occur in Well 6.

Appendix II: Student Lab Journal p2

Assessing What We Have Learned

Based on what you learned from the APL research article about the influence of topography and geology on groundwater recharge, flow, and discharge, how would you re-design the Groundwater Flow Model to better represent what we know and do not know about the groundwater flow in the West Nose Creek watershed. Use this space to create a new design similar to the figure of the model shown on page 1.

RESOURCES:

Groundwater Flow Models

Bow River Basin Waterscape Teachers' Guide (Junior High):
p. 34, Going With the Flow
http://www.calgary.ca/UEP/Water/Pages/Youth-education/Teacher's-Guides-to-the-Bow-River-Basin-Waterscape-Poster.aspx

Iowa State University Chapter of the Soil & Water Conservation Society
http://www.stuorg.iastate.edu/swcc/GFM/GFM_main.html
Video (16:14 min): http://vimeo.com/12375824

University of Wisconsin Stevens Point Student Chapter of American Water Resources Assoc.
http://stuorgs.uwsp.edu/awra/pages/Groundwater-Model-Project.aspx
Guides: http://www.uwsp.edu/cnr-ap/watershed/Pages/GroundwaterModelWorkshop.aspx

Creative Labworks, Inc. - Build your own Groundwater Flow Simulator
http://www.shop.creativelabworks.com/Envision-Groundwater-Flow

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