Monitoring Contaminant Transport by "Remote Aerial Tramway"
A Draft Hydrogeology Field Exercise

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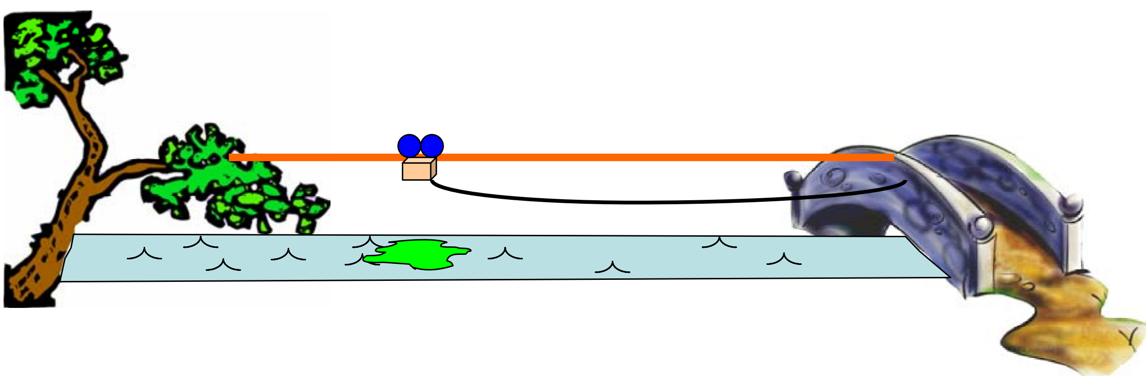
Overview

This field exercise gives students an opportunity to observe contaminant transport by conducting a tracer test in a stream. Students are introduced to the concepts of advection, dispersion, timesteps, boundary conditions, and breakthrough curves.

Field Setup

Select a stream shallow enough for students to wade for this experiment. Suspend a 50-ft climbing rope 6-ft above the water in the direction of flow and pull it taught using a cable winch (a tree and a bridge provide excellent anchor points). Place a digital camera in a container that includes a shutter servo that may be activated by radio control. Attach pulleys and a 50-ft kite string to allow the camera to be pulled along the climbing rope above the stream. In this fashion, the digital camera may be turned into a "remote aerial tramway" that can collect images of the dye as it migrates downgradient.



Before the experiment is conducted, students (working in groups of 3) are asked to predict what will happen to the dye once it is added to the water:

Q) Using a leaf, a stopwatch, and a yardstick, predict where the dye plume will be and what it will look like after 8 seconds. Draw your predicted plume on the piece of paper provided. Include a scale and show all calculations.

After the students have drawn their predicted plumes, ask them to review each other's work and discuss why they decided on their particular plume morphology. This is a great time to introduce the topics of advection and dispersion.

Enough predicting! It's time for them to test their hypotheses. To conduct the experiment, Student #1 pours a 1-mL solution of 1 g/L fluorescein dye (an environmentally-safe dye) into the stream at the upstream end of the tramway. Student

#2 triggers the camera to take a picture by radio control (t = 0 s). Student #3 then pulls the kite string to move the camera a specified distance (7 ft, for example), and waits until Student #2 triggers the camera at a pre-determined time interval (4 seconds, for example). In this fashion, successive images of the plume may collected as it migrates downstream are collected.

At this point, ask the students if the dye behaved as they predicted, then discuss why it did or did not.

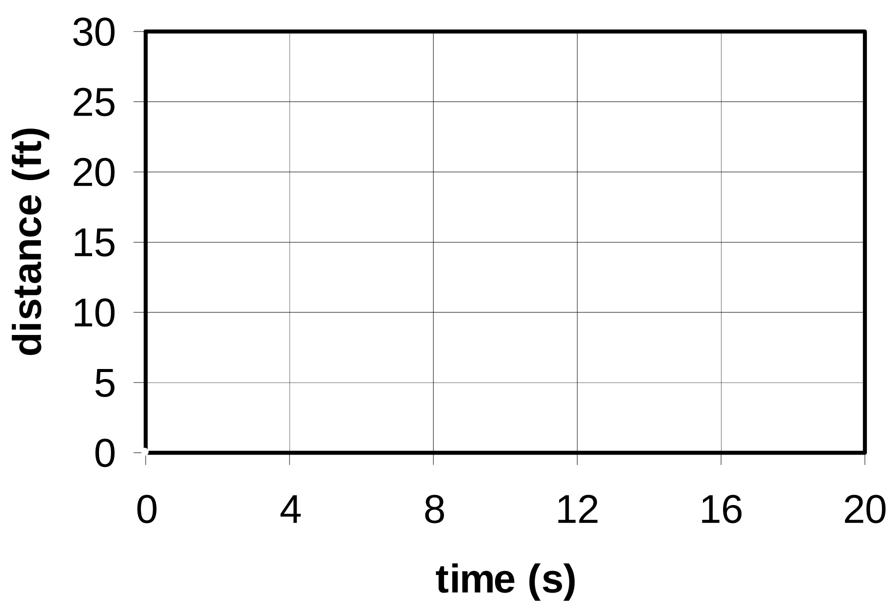
Download and show the students the images in the field using a laptop computer. If the images are substandard, select a new group of volunteers and re-run the experiment as necessary before returning to the lab.

Lab Analysis

Upon returning from the field, scale the images and print them on a 36-inch piece of paper (see handout). Ask the following questions:

1) Draw a point representing the centroid of the plume at each timestep. Measure the distance the point has moved since the dye was injected. Plot these measurements on the graph below.

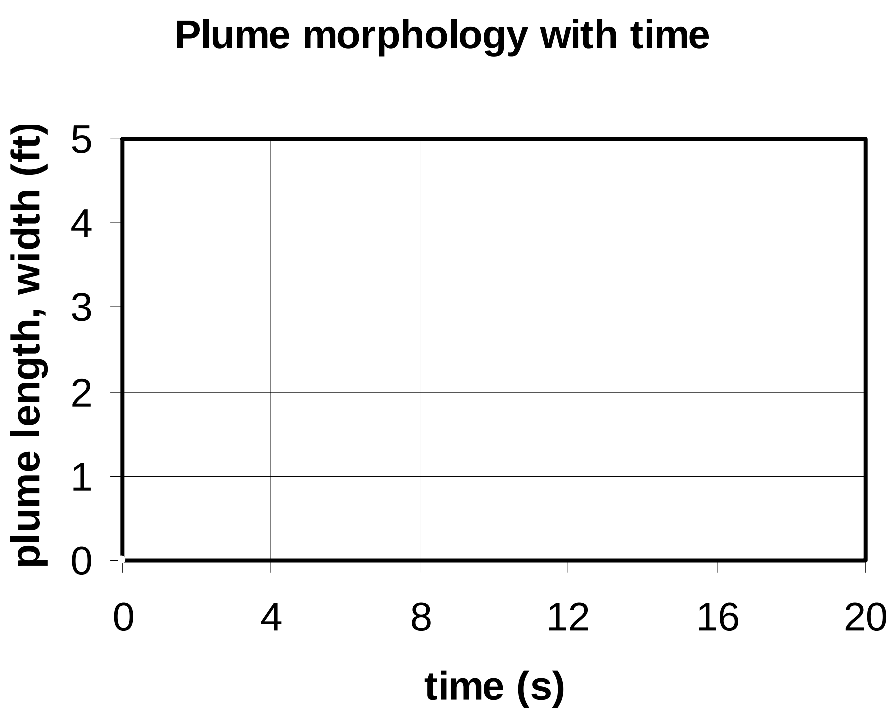
Plume location with time



Draw a straight line through the data points that passes through the graph origin (0,0). Use this line to determine the advective velocity of the fluorescein: __________.

Is this velocity representative of groundwater flow? What is a typical groundwater flow velocity?

2) Draw ovals around the plume perimeter, then determine the length and width of the plume at each timestep. Plot plume length and width on the graph below. Be sure to label your data series.



How does the plume change with time?

What's the contaminant transport process responsible for this change? ___________

What physical processes are responsible for causing the plume to change shape with time?

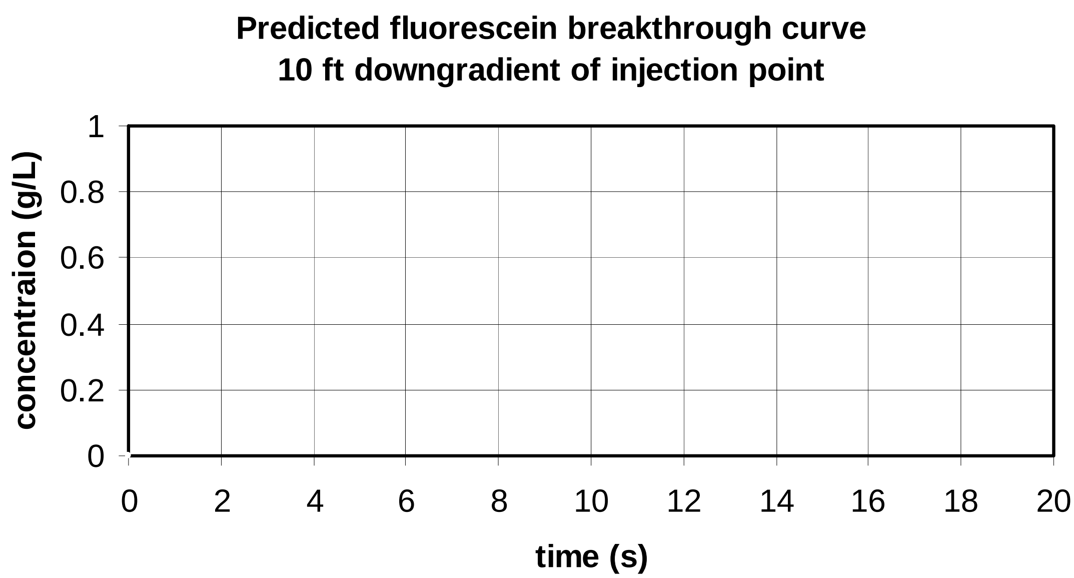
Do you think a groundwater plume would disperse more or less rapidly than a plume in a stream? Explain.

Does plume length change more or less rapidly than plume width? If so, why do you think this is?

3) During our experiment, the dye was added only momentarily. Draw what the plume would have looked like at 16 s if the dye were continuously added during the entire experiment (this would be a constant flux boundary condition).

Is this plume larger than what we observed? What does this tell you about the importance of removing contaminant source areas? If this were a groundwater plume, how easily could this plume sneak between monitoring wells and go undetected?

4) If you were monitoring fluorescein concentration at a distance 10 ft downgradient of the injection point, what would the concentration be with time? Plot your predicted concentration vs. time on the graph below (this is called a breakthrough curve). Remember that the initial concentration of the dye was 1 g/L.



5) In the plot above, draw the breakthrough curve if dye were injected continuously during the experiment (as in Question #3).

6) If you conducted the experiment again, would the plume shape be identical to what you observed? What does this tell you about the reliability of modeling contaminant transport?

This should be a successful exercise, in my opinion, as it tackles some challenging topics using an innovative approach. It requires some planning to set up, but it is tactile, visual, quantitative, conceptual, and at the very least, memorable.