Using Groundwater Flow Simulation Towards Quantitative-Skill Stimulation

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Activity Summary

- Discovery-based
- Hands-on
- Two-weeks of experimenting, data collecting, and calculation
- Finalized with a 5-7 page report (25% of grade)
- Group work during experiments and calculations
- Individual write-up (two to three weeks)

Content Goals

- Apply the scientific method and state uncertainties
- Quantitatively describe rates and gradients
- Make predictions of geologic changes based on physical laws and material properties
- Extrapolate from model to Earth

Attitudinal Goals

- Develop confidence in own quantitative and science skills
- Develop awareness and concern for groundwater pollution
- Have fun during the discovery process

Skills Goals

- Critical thinking, planning, performing experiments
- Math and analytical skills
- Scientific writing, tabulating, graphing
- Spatial visualizing and accurately sketching
- Working in groups, some Excel skills

Course: Earth Processes, ~50 students

- Introductory physical geology - General Education course
- No prerequisites
- Integrates lab and lectures, 4 hours/week
- Satisfies General education requirement for Natural Sciences group, Quantitative and Mathematical Science subgroup
- Is a writing/computation intensive course

Activities:

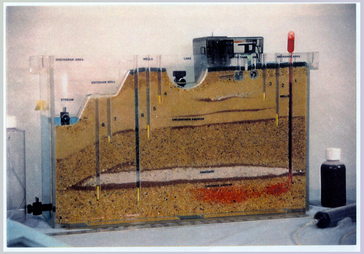
Days 1 and 2

1. Measure porosity and grain size of three aquifer sands
2. Describe and sketch the simulator
3. Describe the water table in static and running conditions

Days 3 and 4

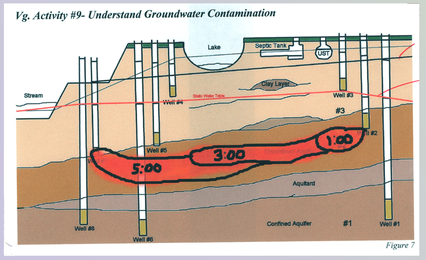
4. Determine and sketch hydraulic gradients
5. Note pressure differences and predict flow directions
6. Conduct experiments to determine groundwater flow velocities
7. Calculate hydraulic conductivity (permeability)

Materials and main experiments



The groundwater model (Crystal Scientific, L.L.C., $800) simulates the groundwater cycle. It includes a geologic cross-section through three main aquifers, several "wells", recharge area simulated by an aquarium pump, and a discharge area through spigots in a lake and a stream.

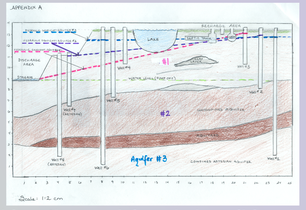
The porosity activiy



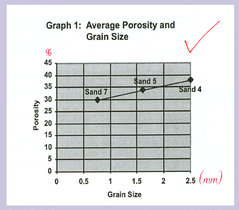
Velocity and "contamination" plumes

Table 2: Porosity and Grain Size Grain size=10 mm/# of grains; porosity = volume of pores/total volume

	Team 1		Team 2		Team 3		Team 4		Team 5		Average	
	Porosity (n)	Grain Size (d)	n	d	n	d	n	d	n	d	n	d
Sand #7	33%	.6 mm	33%	.6 mm	24%	.9 mm	24.5 %	.9 mm	35.5 %	.83 mm	30%	.77 mm
Sand #5	35%	1.45 mm	37.5 %	1.42 mm	27%	2 mm	35%	1.6 mm	37%	1.6 mm	34%	1.6 mm
Sand #6	37%	2 mm	42%	2.5 mm	34% mm	2.5 mm	38%	2.3 mm	39%	3.3 mm	38%	2.5 mm



Sketching the model and describing hydraulic gradients



Tabulating, averaging, plotting

Table 3: Velocity (distance/time) (in cm per sec)

	Test 1	Test 2	Test 3	Average
Well 1	15/39 = .39	15/36 = .42	15/35 = .43	.41
Well 2	15/113 = .13	15/132 = .11	15/127 = .12	.12
Well 3	1.5/48 = .03	2/38 = .05	2/37 = .05	.04

Table 4: Hydraulic Gradient (hw-hs)/L

	Elements Used	Gradient
Aquifer #1	lake, stream	(26-19)/36 = .194
Aquifer #2	well #2, well #7	(25-23)/34 = .09
Aquifer #3	well #6, well #1	(3.5-3)/39 = .01

Table 5: Hydraulic Conductivity/Permeability (Velocity x porosity/hydraulic gradient)

	Conductivity Permeability (cm/s)
Aquifer #1	(.04 x .3)/.194 = .06
Aquifer #2	(.12 x .34)/.09 = .45
Aquifer #3	(.41 x .38)/.01 = 15.6

Table 6: Cross-Sectional Aquifer Area (length x width)

	Area
Aquifer #1	7 x 2.54 = 17.78 sq. cm
Aquifer #2	6.5 x 2.54 = 16.51 sq. cm
Aquifer #3	7 x 2.54 = 17.78 sq. cm

Table 7: Aquifer Discharge (Conductivity x hydraulic gradient x cross-sectional area)

	Cubic cm per day (Second)	Cubic inches per sec	Cubic feet per day	Gallons per day
Aquifer #1	17.78 x 1.94 x .06 = .21	.21/16.39 = .01	(.01/1728) x 60 x 60 x 24 = .5	7.48 x .5 = 3.74
Aquifer #2	16.51 x .09 x .45 = .67	.67/16.39 = .04	(.04/1728) x 60 x 60 x 24 = 2	7.48 x 2 = 14.96
Aquifer #3	17.78 x .01 x 15.6= 2.78	2.78/16.39 = .17	(.17/1728) x 60 x 60 x 24 = 8.5	7.48 x 8.5 = 63.58

Sig figs. !

Calculations, unit conversion

Quantitative skills addressed

Activity	Higher order skills	Basic skills	Geometry	Graphs	Statistics	Technology
Porosity and grain size	Estimation Design of experiments Problem solving Data collection Compare to nature	Arithmetic: Percentage		Curve fitting	Averaging and uncertainty	Excel spreadsheet
Hydraulic gradient	Problem solving Data collection Compare to nature	Unit conversion	2D visualization Slope System of coordinates			
Velocity and direction of flow	Models: Predict, Compare to nature Design of experiments Problem solving Data collection	Simple equations Unit conversion			Averaging and uncertainty	
Hydraulic conductivity	Compare to nature Estimation Problem solving	Significant figures				
Discharge			3D visualization Area calculation			
Final report	Writing: Express descriptive and quantitative facts and interpretations effectively					

Grading

Groundwater Simulation Project and Report Grading Sheet

Name:_____ Grade: __

- o ___/5 Organization /neatness
- o ___/5 Sketch of the simulator included and completely labeled
- o ___/5 Description of simulator connections to real life: pump, recharge/discharge
- o ___/5 Sketches and explanation of the water table & of pressure surfaces
- o ___/5 Direction of flow + forces that determine flow path
- o ___/5 Porosity experiment
- o ___/5 Porosity plot
- o ___/5 Discuss errors/why scientific
- o ___/10 Tables (with caption)
- o ___/5 Unit converted correctly
- o ___/5 Applied rules of significant figures
- o ___/10 Calculations - examples
- o ___/10 Contamination scenario - connections to real life
- o___/10 Discussion: compare and contrast aquifer properties; discuss hypotheses
- o ___/5 Spelling
- o ___/5 Sentence structure

Additional comments:

Student Opinions

Things that helped you learn:

"Experiments"
"Working in groups helped because I felt comfortable asking them questions"
"Getting my team members wet"
"It was fun and encouraging, we did many different experiments that she wanted us to have fun with"

Things that hinder or interfere with learning:

"Directions for groundwater project were a little bit confusing."
"Sometimes we did not have enough time to finish"
"Too many calculations"

Suggestions on ways to improve learning:

"Maybe allow more time for the groundwater project. - Other than that, good job!"
"You are doing great! :-)"
"Increase the lab time"

Acknowledgements

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