HYDROGEOLOGY
EVENT GUIDE

GENERAL EVENT INFORMATION

THE PAPER VERSION

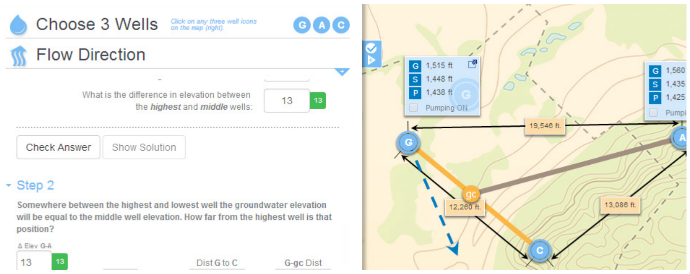
EVENT SUPERVISOR RESOURCES

HELPFUL RESOURCES

PREPARING FOR HYDROGEOLOGY

This guide is written for event supervisors, students, and team coaches who are preparing to organize or training to compete in Hydrogeology for a Science Olympiad tournament.

Hydrogeology is currently a trial event for the 2014-2015 tournament year. This event challenges student's intellect and problem-solving skills by incorporating scientific research, computer simulation, and complex real-world problems.



During the competition, teams of up to two students work through the three part event by:

- Completing a written test
- Manipulating a groundwater computer simulation
- Evaluating the flow of groundwater and the risk of contamination in a given scenario, and completing a Remediation Techniques table

This guide includes everything you need to know for a successful event, including helpful hints for preparing for competition, sample test questions for each portion of the event, and a step-by-step guide to running the Hydrogeology Challenge, the groundwater computer simulation used in Hydrogeology.

YOU CAN RUN IT! ALL YOU NEED IS TO:

- Understand the event rules
- Familiarize yourself with the Hydrogeology Challenge
- Select a scenario and write tests
- Prepare the competition area
- Run the event, tally the scores
- Have fun

The event Hydrogeology was designed by The Groundwater Foundation, a nonprofit organization that educates people and inspires action to ensure sustainable, clean groundwater for future generations. Learn more at www.groundwater.org.

GENERAL EVENT INFORMATION

EVENT SUPERVISORS: PREPARING FOR COMPETITION

Hydrogeology is a three part event. Students are tested on their knowledge of groundwater, manipulate a groundwater computer simulation (called the Hydrogeology Challenge), and evaluate solutions, based on hydrogeological evidence, to reduce anthropogenic effects on groundwater.

RULES

Rules for Hydrogeology are available from your Tournament Director. This guide is meant to be used as a supplement to the rules. Be sure to check the rules for all event parameters and suggested topics.

NEEDED EQUIPMENT

- This event requires computers or tablets with access to the internet. If you do not have computers, tablets, or Internet access, there is a paper version of Hydrogeology (check with your Tournament Director to see which version you are using). If you are using the paper version, you will need to contact The Groundwater Foundation at hydro@groundwater.org for modeling worksheets to use during your event.
- A specific URL for the Hydrogeology Challenge (groundwater simulation tool) and test results. To receive your URLs for the event, contact your Tournament Director or The Groundwater Foundation at hydro@groundwater.org.
- Print-outs of written tests
- Answer sheets to written tests (It is often helpful to bring more than one copy of the answer sheet so that volunteers may assist in grading)
- Evaluation forms
- Writing utensil

PREPARING FOR COMPETITION

- There are three parts to the Hydrogeology competition. All three parts are individually described in this guide.
- All three parts must be completed within a 50-minute time period. Please take this into consideration when writing your test questions.
- Multiple choice, matching, or fill in the blank questions are easy to grade and allow volunteers completely unfamiliar with the event to assist in grading.
- Free response or essay questions should have a rubric to assist in scoring.
- The philosophy of Science Olympiad is that the competition be inquiry-based to emphasize process skills and mental challenges using content.
- When calculations are required points should be given for both showing work and the correct answer.
- Develop appropriate questions so that all ties can be broken.
- Be sure that all teams experience the same testing conditions.
- To allow most students to be successful, it is a good idea to vary the difficulty of questions at each station. A guideline for how many questions for each level of difficulty is listed on page 3 for each tournament.

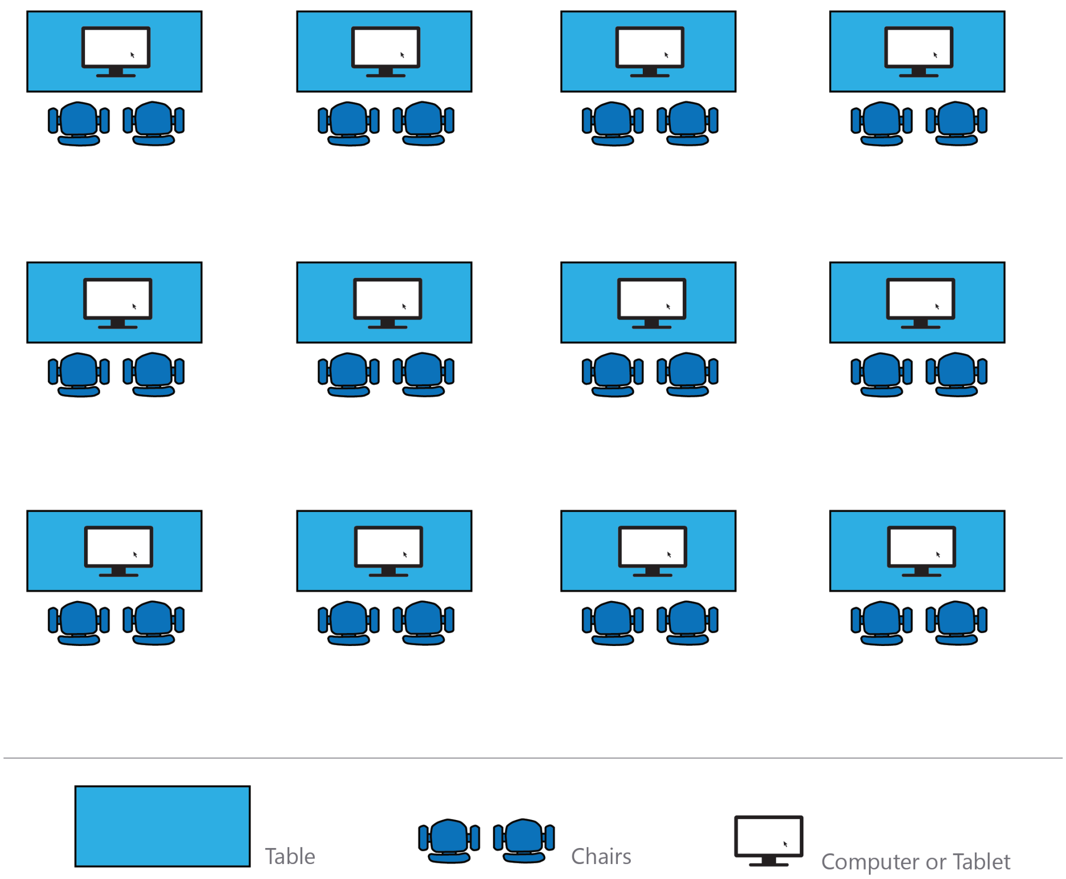
EVENT SUPERVISORS: PREPARING FOR COMPETITION (CONTINUED)

Easy – A team with basic understanding of the event topics should be able to answer correctly.
Medium – A team that has spent time studying and preparing a good note sheet for the event should be able to answer correctly.
Hard – Even if a team has adequately prepared, this type of question will stretch their thinking and be difficult to answer.
Very Hard – Only teams with exceptional knowledge of the subject matter and process skills will be able to answer this question correctly.

Regional	State	National
50% Easy	20% Easy	10% Easy
30% Medium	40% Medium	30% Medium
20% Hard	30% Hard	40% Hard
0% Very Hard	10% Very Hard	20% Very Hard

EVENT SAMPLE SETUP

The setup for Hydrogeology is very flexible. Each team station requires a writing surface, two chairs, and a computer or tablet with access to the Internet (computer or tablet not required if running the paper version - see page 15). It is important that Event Supervisors receive all needed passwords prior to the start of the event.



RECRUITING VOLUNTEERS

Hydrogeology requires groundwater expertise for two purposes: Designing the event tests and a full understanding of the groundwater modeling tool, the Hydrogeology Challenge. You may have this expertise as an event supervisor, or you may need to recruit some assistance. Even if you have groundwater expertise as an event supervisor, it is often helpful to have another expert look over your test prior to the event.

Look for expertise among the following entities and individuals:

- US Geological Survey (USGS)
- State geological survey or natural survey
- US Environmental Protection Agency (US EPA)
- State environmental or health agencies
- US Natural Resources Conservation Service (NRCS)
- Bureau of Reclamation
- Natural resources, conservation, groundwater, and irrigation districts
- Water utilities or water management agencies
- Engineering or environmental firms
- Professional well drillers
- Educators knowledgeable about groundwater
- Cooperative Extension specialists
- Local health departments with environmental specialists
- City or county engineers
- Universities and colleges

The day of the event it is helpful to have at least one volunteer in addition to the event supervisor. Volunteer tasks may include:

- Setting up computers prior to the event (Logging in, Pulling up Hydrogeology Challenge website using special URL)
- Check in students as they arrive
- Serve as timekeeper and give students 20-minute and 5-minute warnings
- Help grade student answers

Volunteers, except for those helping with writing the event test, do not require groundwater expertise. Your tournament director may have a volunteer pool and can assign the help you need. If not, here are some other possibilities:

- Classroom teachers, retired educators
- College students
- High school students
- Community volunteer organizations, i.e. Key Club, Rotary Club
- Colleagues
- Friends and Family

PART 1: OVERVIEW AND PREPARATION

During Part 1 of the Hydrogeology event students will take a written test. The competition must consist of at least one question from each of the following areas:

- The fundamentals of groundwater and hydrogeology
- Surface-groundwater interactions
- The relation of groundwater flow to geologic structure
- The management of contaminated groundwater

Questions can be multiple choice, true/false, fill in the blank, or short answer. Questions should become more challenging as students move from a regional tournament to Nationals. See the General Event Information on page 2 for more information on how to write questions and determine difficulty of questions. Part 1 is worth 25% of the total score (10 points).

There are lots of places to look to for inspiration when writing your own, original tests for Part 1. The Groundwater Foundation and Science Olympiad encourage new tests to be written for each tournament in order to maintain the spirit of the competition while minimizing the opportunity for advantage or cheating. Examples of approved scientific sites to help you write creative, original tests are listed below. The websites listed below are also useful to help students study and prepare for Hydrogeology. If you require additional assistance in developing your tests, email The Groundwater Foundation at hydro@groundwater.org.

THE GROUNDWATER FOUNDATION www.groundwater.org

- Groundwater and the Water Cycle – http://www.groundwater.org/get-informed/basics/cycle.html
- Wells and How They Work - http://www.groundwater.org/get-informed/basics/wells.html
- Sources of Groundwater Contamination - http://www.groundwater.org/get-informed/groundwater/contamination.html
- Groundwater Glossary - http://www.groundwater.org/get-informed/basics/glossary.html

USGS (UNITED STATES GEOLOGICAL SURVEY) www.usgs.gov

- Posters - http://water.usgs.gov/outreach/OutReach.html
- Ground Water booklet - http://pubs.usgs.gov/gip/gw/index.html
- What is Ground Water? - http://pubs.usgs.gov/of/1993/ofr93-643/
- Earth's Water: Groundwater - http://water.usgs.gov/edu/earthgw.html
- Ground Water and Surface Water: A Single Resource - http://pubs.usgs.gov/circ/circ1139/
- Sustainability of Ground-Water Resources - http://pubs.usgs.gov/circ/circ1186/
- Estimated Withdrawals from Principal Aquifers in the United States, 2000 - http://pubs.usgs.gov/circ/2005/1279/
- Estimated Use of Water in the United States in 2000 - http://pubs.usgs.gov/circ/2004/circ1268/index.html
- The Water Cycle - http://water.usgs.gov/edu/watercycle.html
- Groundwater and the Rural Homeowner - http://pubs.usgs.gov/gip/gw_ruralhomeowner/
- Contaminants Found in Groundwater - http://water.usgs.gov/edu/groundwater-contaminants.html
- Understanding and Managing the Effects of Groundwater Pumping on Streamflow - http://pubs.usgs.gov/fs/2013/3001/
- Contaminated Site Management and Remediation Investigations - http://toxics.usgs.gov/investigations/subsurface_point_index.html

US EPA (UNITED STATES ENVIRONMENTAL PROTECTION AGENCY) www.epa.gov

- All about Wetlands - http://water.epa.gov/type/wetlands/index.cfm
- Groundwater Fact Flash - http://www.epa.gov/superfund/students/clas_act/haz-ed/ff_05.htm
- Remediation Technologies - http://www.epa.gov/superfund/remedytech/remed.htm
- Citizen's Guide to Cleanup Technologies - http://www.clu-in.org/products/citguide/

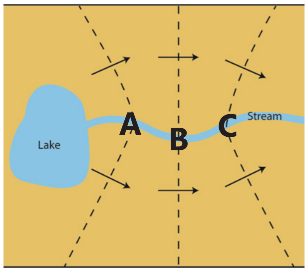
OTHER

- Remediation Technologies Screen Matrix and Reference Guide - http://www.frtr.gov/matrix2/top_page.html

PART 1: SAMPLE TEST

Event Supervisors can use the provided sample test as a guide in creating an original test for tournaments. Students may use the sample test as a way to study and prepare for the Hydrogeology event. **There are 10 points possible. Possible points are labeled next to each question.**

MULTIPLE CHOICE



1. In the image to the right, which location represents a gaining stream? (0.5 points)
   a. A
   b. B
   c. C

2. In the image to the right, which location represents a losing stream? (0.5 points)
   a. A
   b. B
   c. C

3. A DNAPL is a liquid that is ___________ than water and __________ dissolve in water. (1 point)
   a. More dense, does
   b. Less dense, does
   c. More dense, does not
   d. Less dense, does not

4. A pollutant commonly associated with feedlots, fertilizer, and agriculture is: (1 point)
   a. Lead
   b. BTEX
   c. Arsenic
   d. Nitrate

5. An artesian system is one in which ___________. (1 point)
   a. Water is unconfined
   b. There are no aquicludes
   c. Water can rise above the level of an aquifer when a well is drilled
   d. All of the above

6. An example of an organic groundwater contaminant would be ______________. (1 point)
   a. MTBE
   b. Cadmium
   c. Chlorides
   d. All of the above

7. An aquifer contains a great deal of water, but the water cannot be removed easily with an ordinary well. This is most likely due to sediment and rock characterized by: (1 point)
   a. Low porosity
   b. Poor sorting
   c. Low permeability
   d. High iron content

PART 1: SAMPLE TEST (CONTINUED)

TRUE/FALSE

8. Clay is more permeable than gravel. (0.5 points)

9. There is no soil moisture located in the unsaturated zone. (0.5 points)

SHORT ANSWER

10. Draw examples of rock formations in the boxes below that are (1 point):

Permeable	Impermeable

11. Define the following terms in one or two complete sentences (2 points):
    a. Permeability

    b. Porosity

    c. Transmissivity

    d. Aeration Zone

ANSWER KEY ON PAGE 32

PART 2: OVERVIEW AND PREPARATION

In Part 2 of Hydrogeology students will use the Hydrogeology Challenge to determine the flow of groundwater under static conditions. Supervisors will provide a unique Hydrogeology Challenge scenario URL to students. This URL can be obtained from your event director or from The Groundwater Foundation (hydro@groundwater.org). Supervisors will also provide the three wells students must use during this portion of the event (e.g. wells A, B, and C). All answers are submitted online. Part 2 is worth 25% of the total score (10 points).

HYDROGEOLOGY CHALLENGE PRACTICE

Students and Event Supervisors can practice running the Hydrogeology Challenge online at http://groundwater.beehere.net/. There are several differences between the practice version of the Hydrogeology Challenge and the testing version used in competition. **The practice version of the Hydrogeology Challenge:**

- Is accessible by the general public
- Allows students to check their answers and show the solution
- Has access to the "Reality Check" – a special feature of the Hydrogeology Challenge that explains how the Hydrogeology Challenge works and under what assumptions it computes answers

The testing version of the Hydrogeology Challenge:

- Is not accessible by the general public
- Requires a unique URL to be obtained from your event director or The Groundwater Foundation (hydro@groundwater.org)
- Does not have the option of checking answers or showing the solution
- Does not have access to the "Reality Check"
- Allows students to submit their answers for easy grading by the Event Supervisors

For a written description on how to run the Hydrogeology Challenge, please see the Hydrogeology Challenge Instructions on page 21. A video tutorial is also available at http://www.groundwater.org/kids/getinvolved/so/hydro.html.

PART 2: OVERVIEW AND PREPARATION (CONTINUED)

Event Supervisors need to obtain the following information from their event director or The Groundwater Foundation (**hydro@groundwater.org**) at least one week prior to the tournament date:

- Unique testing scenario URL
- Unique test results URL

The unique test results URL will compile students' scores to a single webpage as shown below:

Test Results

Test 2014

9/18/14

Team Name	Scenario Name	Wells	Pumping On	Flow Direction	Score
C1 Jane Doe	Event Guide Practice Exam	A, B, C	None	355°	26/26 (100%)

The students should submit their team number and school: it will display under "Team Name". The test results will also display the scenario the team used (in this case Event Guide Practice Exam), the wells that were selected (A, B, and C), if any of the wells were pumping (None), the selected flow direction (in degrees), and their total score (26/26 100%).

If students run the incorrect scenario OR use wells other than the ones specified OR turn pumping on for one or more wells, they receive zero points for Part 2. *However*, if students catch their mistake prior to the end of the 50-minute time limit they may resubmit their answers using the correct scenario, wells, and static conditions for full credit.

GRADING

A helpful rubric is provided below to assist in grading Part 2 of Hydrogeology. The rubric is designed to bring the point total to 10 points for easier grading. Teams can earn:

- 3 points for submitting answers with the correct Team Number and School, Scenario, Wells, and Pumping Conditions.
- 1 point for the correct Flow Direction (+/- 10 degrees)
- Up to 26 points pre-graded under "Score".
- 3 + 1 + 26 = 30. Divide 30 by 3 to get a total number of points out of 10. For example, if a team submitted everything correctly, had the correct flow direction, but only earned 23 out of 26 points, their total score would be 3 + 1 + 23 = 27. Then you would divide by 3 for 9 total points for part 2.

A sample test is provided on the next page.

PART 2: SAMPLE HYDROGEOLOGY CHALLENGE

IMPORTANT: Please submit your answers online for this portion of the event. **It is a good idea to write down your calculated values as you work through the Hydrogeology Challenge just in case you need to refresh the page or have computer issues.**

This section is worth a total of 10 points

DIRECTIONS:

1. Complete the Hydrogeology Challenge scenario *Event Guide Practice Exam* in static (non-pumping) conditions using wells A, B, and C. The *Event Guide Practice Exam* scenario can be found at URL: http://groundwater.beehere.net/#practice.

2. When submitting your answers:*
   Name: [Team Number and School]
   Location: [Location provided by your event director or The Groundwater Foundation, e.g. Nebraska State 2014]

*Note: When completing the *Event Guide Practice Exam* scenario at http://groundwater.beehere.net/#practice, students will not need to submit their answers. The *Event Guide Practice Exam* scenario is meant for practice only as it contains the "Check Answer" and "Show Solution" buttons. During a Science Olympiad tournament, students will be required to submit answers as shown and will not have have access to the "Check Answer" and "Show Solution" buttons.

PART 3: OVERVIEW AND PREPARATION

During Part 3 of Hydrogeology students will manipulate the groundwater challenge to determine the risk of contamination to wells. The students will also be required to fill out a Remediation Techniques Table. Part 3 is worth 50% of the total score (20 points).

INCORPORATING CONTAMINATION INTO THE HYDROGEOLOGY CHALLENGE

Part 3 of Hydrogeology introduces a contaminant to the original, unique scenario used in Part 2 of the event. Along with introducing a contaminant, other factors may be introduced as well, such as well pumping being turned on. These factors make up the "set of circumstances" Event Supervisors must create. The set of circumstances must include:

- Non-static conditions (at least one well must be pumping water)
- A pollutant (selected from the Contaminant Table on page 24)
- A pollution source to be located at one well

The set of circumstances may include:
- Well types
- Well uses
- Any other information the Event Supervisor deems relevant to the scenario

Using the information from the given set of circumstances, students will manipulate the Hydrogeology Challenge scenario to determine which wells are at risk of contamination by the pollutant and approximately how long until the contamination may occur.

Students will also need to fill out of Remediation Techniques Table. In designing the Remediation Techniques Table for your tournament, you may reference the Remediation Table located on page 27. As an Event Supervisor, you are not limited to the techniques listed in the Remediation Table. The Remediation Table is a basic guide, and the Event Supervisor may choose to use remediation techniques that are not listed in the table. Some good resources for additional remediation techniques are:

- Remediation Technologies - http://www.epa.gov/superfund/remedytech/remed.htm
- Citizen's Guide to Cleanup Technologies - http://www.clu-in.org/products/citguide/
- Remediation Technologies Screen Matrix and Reference Guide - http://www.frtr.gov/matrix2/top_page.html

PART 3: OVERVIEW AND PREPARATION (CONTINUED)

SAMPLE REMEDIATION TECHNIQUES TABLE

Remediation Technique	Definition	In-situ or ex-situ	Type (Biological, Physical, or Chemical)	Cost (low, medium, high)	Applicable to [Given Pollutant] (yes/no)
Air Stripping					
Phytoremediation					
Activated Carbon Treatment					
Bioremediation					

HELPFUL HINTS FOR CREATING YOUR OWN TABLE

- Use the following number of remediation techniques for each level of Science Olympiad tournament:
    - 3 techniques for regional tournaments
    - 4 techniques for state tournaments (as shown in picture)
    - 6 techniques for national tournament
- Consider including at least one technique that is not capable of cleaning up the pollutant given in the scenario.
- Some questions to think about when creating your table:
    - Which technique would be best if clean-up costs are limited?
    - Which techniques only contain the pollutant as opposed to remediating it?
    - Other than cost, what are some other factors that should be taken into consideration before the technique is performed?

CREATING QUESTIONS FOR PART 3

Event Supervisors are given flexibility in choosing to ask additional questions about the scenario. These questions can be multiple choice, true/false, fill in the blank, or short answer. The difficulty of these questions should reflect the level of tournament (regional, state, or national). Below are some example topics Event Supervisors may use to create additional questions for Part 3:

- The limitations/assumptions of the Hydrogeology Challenge
- If one of the given circumstances changed (for example, a well stopped pumping water), how would that affect the flow of groundwater and the risk of contamination?
- Facts about the pollutant, e.g. what are other sources of the pollutant, what type of pollutant it is, a DNAPL or LNAPL or neither, what it is commonly used for, etc.

PART 3: SAMPLE TEST

There are 20 points possible.

THE SITUATION:

The small community of Event Guide Practice Exam has experienced an underground storage tank leak near well E. Due to the leak, BTEX has contaminated the groundwater of well E. Residents are now looking to your team to determine which wells are at risk of contamination and what options the community has for remediation of their groundwater.

*The Event Guide Practice Exam scenario can be found at: http://groundwater.beehere.net/#practice.

THE FACTS:

- BTEX was found at well E
- Residents are currently pumping water from wells A, B, C, D, and G.
- Wells E and F are not currently pumping water.

YOUR MISSION:

Answer the following questions posed by Event Guide Practice Exam's residents, and complete the Remediation Table by the residents' request. You may use The Hydrogeology Challenge to help you complete your work.

1. From well E, which direction(s) is the contaminant plume most likely going to go (North, Northeast, South, etc.)? (1 point)

2. Other than well E, which well(s) are at risk of contamination? (1 point)

3. Assuming the Hydrogeology Challenge's assumptions are correct, if the residents start pumping water from well E, will that reduce the risk of contamination of any of the wells you listed in question 2? Explain your answer. (2 points)

4. Assuming the Hydrogeology Challenge's assumptions are correct, if the residents start pumping water from well E, how will that affect the velocity of the contaminant plume? (2 points)

5. Approximately how long will it take for the BTEX to travel from the source (well E) to the nearest well in danger of being contaminated? (2 points)
    a. Less than one week
    b. About one year
    c. 2-4 years
    d. More than 5 years

PART 3: SAMPLE TEST (CONTINUED)

REMEDIATION TABLE

Complete the missing information in the table below. Each row is worth 3 points (12 points total).

Remediation Technique	Definition (1 pt)	In-situ or ex-situ (0.5 pts)	Type (Biological, Physical, Chemical, Thermal, Containment Only, or Other) (0.5 pts)	Cost (low, medium, high) (0.5 pts)	Applicable to BTEX? (yes/no) (0.5 pts)
6. Air Sparging					
7. Air Stripping					
8. Permeable Reactive Barrier					
9. Thermal Treatment					

ANSWER KEY ON PAGE 33

THE PAPER VERSION

OVERVIEW

If there will not be access to internet, computers, or tablets the day of the tournament, there is a Paper Version of Hydrogeology available. Event Supervisors need to check with their tournament directors to determine which version of Hydrogeology they will be running. Students may check with their coach or Event Supervisor to determine which version of the event will be run at the upcoming tournament.

The Paper Version of Hydrogeology is similar to the online version. The event rules are the same whether running the paper version or the online version of Hydrogeology. The paper version requires these additional materials to be supplied by Event Supervisors:

- Rulers (at least one for each team)
- Colored pencils – black, red, blue, and green

The Paper Version of Hydrogeology can only be obtained from The Groundwater Foundation. Please email **hydro@groundwater.org** if you will be running the Paper Version of Hydrogeology at your upcoming tournament. The Groundwater Foundation will provide the necessary scenario, well logs, and note sheet.

SAMPLE PAPER VERSION – DEFINITIONS

WTE H-M: The difference between the water table elevation of the well with the highest water table elevation and the water table elevation of the well with the middle water table elevation.

WTE H-L: The difference between the water table elevation of the well with the highest water table elevation and the water table elevation of the well with the lowest water table elevation.

Distance H to L: The distance in miles from the well with the highest water table elevation to the well with the lowest water table elevation.

Distance H to P: The distance in miles from the well with the highest water table elevation to the point P. Point P is located between the wells with the highest and lowest water table elevations, and it has the same water table elevation as the middle well.

WTE H: The water table elevation of the well with the highest water table elevation.

WTE M: The water table elevation of the well with the middle water table elevation.

Distance Y: The distance between the well with the highest water table elevation and the contour line (green line). Distance Y should be perpendicular to the contour line. In some instances, you may have to extend the contour line in order to measure distance Y perpendicular to the contour line.

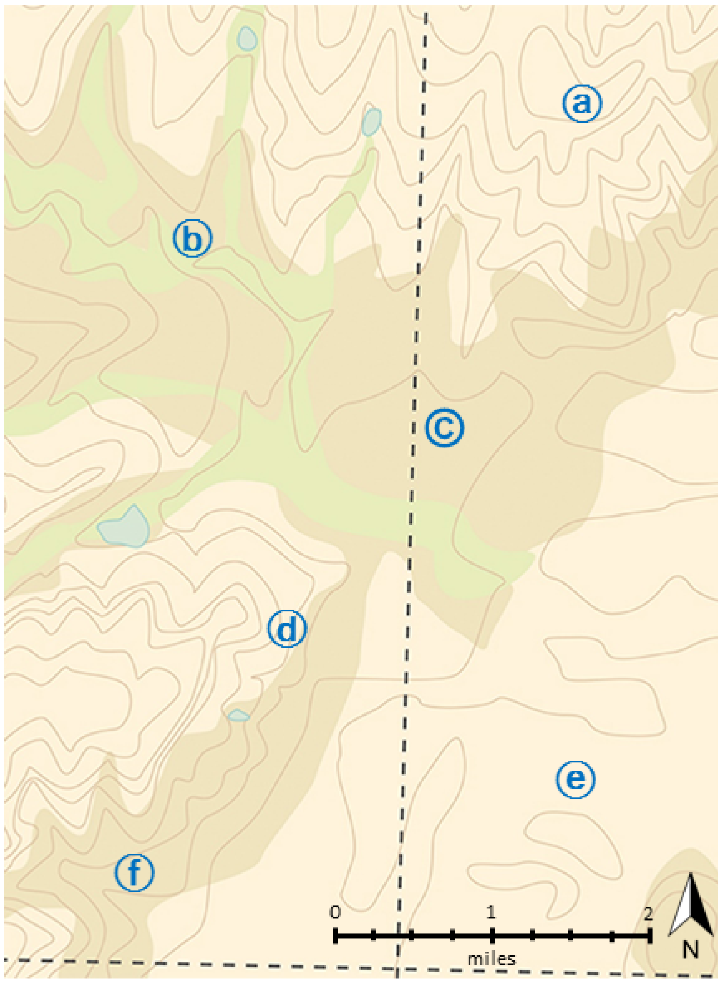
SAMPLE PAPER VERSION - SCENARIO

The Groundwater Foundation Presents:

The Hydrogeology Challenge

Scenario: Sample Paper Version

<u>To Begin</u>: Pick three wells and complete steps 1 through 3 using the Well Log Look-Up Table



Answer Key for wells A, B, and C in static conditions on Page 32

Step 1: Flow Direction

1. Draw a **black line** from the well with the highest water table elevation (WTE) to the well with the lowest WTE..
2. Find the point (P) between the highest (H) and lowest (L) wells equal to the WTE of the middle (M) well using the equation below.

$$\frac{\overset{\text{WTE H - M}}{\boxed{}}}{\underset{\text{WTE H - L}}{\boxed{}}} = \boxed{} \times \overset{\text{Distance H to L}}{\boxed{}} = \overset{\text{Distance H to P}}{\boxed{}} \text{ miles}$$

3. Mark the point between the highest and lowest wells equal to the WTE of the middle well (point P). Draw a green line from P to the middle well. You have just drawn a contour line!
4. The flow of groundwater will be perpendicular to the contour line. Draw a blue arrow representing the flow direction of groundwater. The arrow should point down gradient as groundwater flows from regions of higher elevation to regions of lower elevation.

Step 2: Gradient

1. In order to calculate the gradient, you must first find the distance (Y) from the highest well to the contour line. Draw this line in red. Remember this line should make a 90° angle with the contour line.
2. Measure the distance (Y) in feet (1 mi. = 5,280 ft.).
3. Calculate the gradient using the equation below.

$$\frac{\overset{\text{WTE H}}{\boxed{}} - \overset{\text{WTE M}}{\boxed{}}}{\underset{\text{Distance Y}}{\boxed{}}} = \boxed{} \text{ ft/ft}$$

Step 3: Horizontal Velocity.

1. Three variables are needed to calculate the horizontal velocity of groundwater. They are gradient (i), hydraulic conductivity of the soil (k), and porosity of the soil (n). You have already calculated the gradient. Use the look-up table to find the hydraulic conductivity and porosity by <u>selecting the layer of soil in the well with the highest WTE that has the highest conductivity (k) in the saturated zone (area below the water table)</u>. Then, using Darcy's equation below, calculate the horizontal velocity.

$$\frac{\overset{\text{k}}{\boxed{}} \times \overset{\text{i}}{\boxed{}}}{\underset{\text{n}}{\boxed{}}} = \boxed{} \text{ ft/day}$$

WELL LOG

Location	Well Depth	Ground Elevation	Groundwater Static Elevation	Groundwater Pumping Elevation	Depth	Lithology	Conductivity	Porosity (%)
A	140	1555	1435	1425	0-25	Clay	0.01	42
					25-55	Fine Sand	26.8	43
					55-93	Silty Sand	6.7	44
					93-140	Crs. Sand & Gravel	160.8	34
B	95	1497	1433	1413	0-15	Fine Sand	26.8	43
					15-48	Silty Sand	6.7	44
					48-72	Sandstone	26.8	33
					72-88	Crs. Sand & Gravel	160.8	34
					88-95	Sandstone	26.8	33
C	90	1504	1441	1426	0-5	Silt	4.02	46
					5-50	Silty Sand	6.7	44
					50-72	Sandstone	26.8	33
					72-90	Crs. Sand & Gravel	160.8	34
D	185	1486	1418	1398	0-15	Clay	0.01	42
					15-38	Fine Sand	26.8	33
					38-65	Silt	4.02	46
					65-112	Silty Sand	6.7	44
					112-165	Crs. Sand & Gravel	160.8	34
					165-185	Medium Sand	67.0	39
E	160	1484	1428	1408	0-3	Clay	0.01	42
					3-25	Silt	4.02	46
					25-70	Silty Sand	6.7	44
					70-105	Crs. Sand & Gravel	160.8	34
					105-160	Medium Sand	67.0	39
F	150	1493	1368	1363	0-10	Fine Sand	26.8	43
					10-55	Silty Sand	6.7	44
					55-135	Crs. Sand & Gravel	160.8	34
					135-150	Sandstone	26.8	33

RESOURCES FOR EVENT SUPERVISORS

PLANNING CHECKLIST

Lists will help keep you organized. Use this list to keep you on track while planning for a tournament.

DISCUSS WITH THE TOURNAMENT DIRECTOR:

- ☐ Date, time, and place of the tournament
- ☐ Number of teams expected to compete
- ☐ Hydrogeology facility requirements:
    - -Availability of computers/laptops/internet access
    - -Necessary passwords for logging onto computers
- ☐ Tournament schedule
- ☐ Tournament specific rules and score reporting procedure
- ☐ Availability of volunteers
- ☐ Communication with coaches/teams prior to the tournament

VOLUNTEERS:

- ☐ Determine if you will need an expert volunteer to help create the test
- ☐ If no volunteers are assigned by the Tournament Director, recruit at least one additional volunteer to help you the day of the tournament
- ☐ Review rules and test with volunteers before tournament
- ☐ Have volunteers assist with the following tasks the day of the tournament:
    - -Log on to computers and access unique Hydrogeology Challenge URL
    - -Team check-in
    - -Keep time
    - -Grade tests
    - -Tally scores, break all ties
    - -Double-check scores, turn in to tournament officials

TESTS AND FORMS TO CREATE IN ADVANCE:

- ☐ Test for Parts 1-3
- ☐ Answer Key for Test
- ☐ Team Score Sheet
- ☐ Evaluations

PACKING LIST FOR DAY OF TOURNAMENT:

- ☐ Copies of test for all three parts of event
- ☐ Multiple answer keys for test to assist with volunteer grading
- ☐ Copies of Team Score Sheet (see page 20)
- ☐ Copies of students evaluations (see page 21)
- ☐ Stopwatch or other device with timing capability
- ☐ Calculator(s)
- ☐ Extra pens and pencils
- ☐ Snacks and drinks for your volunteers (might be provided by the tournament director or hosts)

AFTER EVENT:

- ☐ Thank volunteers
- ☐ Submit all results and paperwork to tournament officials
- ☐ Submit evaluations to The Groundwater Foundation (hydro@groundwater.org)

TIPS

Use these tips to help you run a stress-free Hydrogeology competition!

- Test the scenario URL and the test result URL as soon as possible to ensure they are both working properly.
- Have a friend, colleague, or groundwater expert (see page 4) look over your written test prior to the competition and check for any errors and/or confusing questions.
- Arrive to the room at least an hour before the competition begins to set up computers.
- Pull up the Hydrogeology Challenge scenario on each computer prior to the event starting. In order to keep the individual scenarios a secret, the URL's can be quite complicated.
- Prior to the start of the event, explain the following to the competing students:
    - This is the Division C Hydrogeology trial event. This event is still in the process of being created and updated. Students can help improve and influence the future of Hydrogeology by completing the evaluation forms.
    - Read all directions carefully.
    - Each team will have 50 minutes to complete the event. Time updates will be given.
    - Have fun!
- If a glitch occurs in the Hydrogeology Challenge - do not panic! Have the students write down their answers, refresh the screen, and re-input their answers. Computer glitches can occur even under the best of circumstances. Make note of the glitch and email the problem to hydro@groundwater.org.
- Print a couple extra tests and answer keys for the day of the event. Teams have been known to sign-up late! Extra answer keys are always helpful if you have volunteers to help you grade.
- Be creative and have fun!

SAMPLE SCORE SHEET

Team Number: _______ Raw Score: _____ Rank: _____

Name(s): ____

School Name: ____

Point Totals

Section	Possible Points	Actual Points
Part 1: Groundwater Concepts and Vocabulary	10	
Part 2: The Hydrogeology Challagene--Static Conditions	10	
Part 3: Contamanations Risk and Remediation	20	
	Total	
1st Tiebreaker: Highest Score on Part 3	.1	
2nd Tiebreaker: Highest score on pre-selected test questions	.01 per question	
	Total Points with Tiebreaker	

HELPFUL RESOURCES

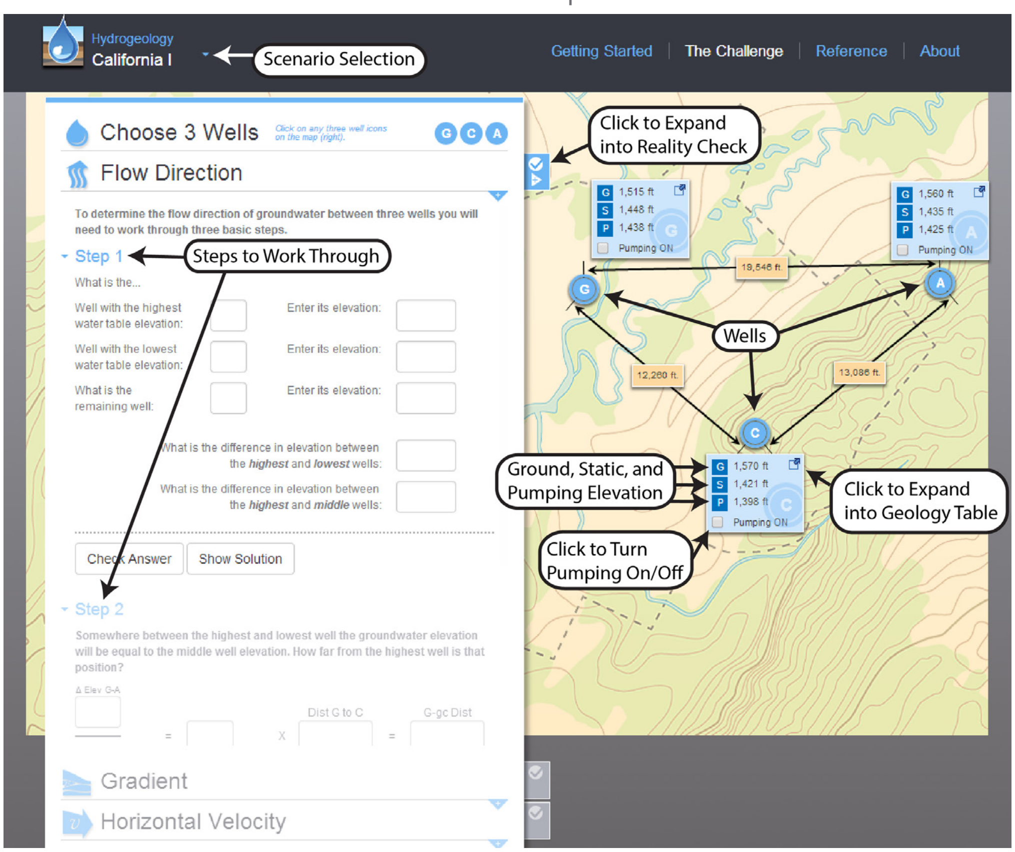
INSTRUCTIONS FOR USING THE HYDROGEOLOGY CHALLENGE

INTRODUCTION

The Hydrogeology Challenge is a learning tool that introduces students to basic groundwater modeling concepts. It uses simple calculations and assumptions to present groundwater flow in a fun and easy to understand manner. Use the following instructions as a guide to get you started with The Hydrogeology Challenge. You'll be an expert in no time!

ABBREVIATIONS

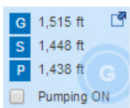
G	Ground Elevation
S	Water Table Elevation in Static Conditions
P	Water Table Elevation in Pumping Conditions
i	Gradient
n	Porosity
K	Hydraulic Conductivity
ft	Feet
Elev X-Y	The difference between the water table elevation of well X and the water table elevation of well Y
Elevation X	The water table elevation of well X
Dist X to Y	The distance between well X and well Y
X-xy Dist	The distance between well X and the point (xy) between well X and Y that has a water table elevation equal to the water table elevation of the middle well



INSTRUCTIONS FOR USING THE HYDROGEOLOGY CHALLENGE (CONTINUED)

THE BASICS OF RUNNING THE HYDROGEOLOGY CHALLENGE:

- Go to http://groundwater.beehere.net/.
- Click the 'Start the Challenge' button.
- Select a scenario from the blue arrow drop down box (e.g. Event Guide Practice Exam).
- Prepare your model to determine groundwater flow direction, gradient, and horizontal velocity:
  - Select three wells (depending on your browser, you may have to single- or double-click)
  - You now have the option of turning well pumping on. We recommend you work through the model in static conditions first (well pumping off). If you wish to turn pumping on for a selected well, click on the white box that is labeled 'Pumping On' in the blue well pop-up box.



Note: You may move the blue pop-up box to a new location on your screen by clicking and dragging.

FLOW DIRECTION

Now you are ready to calculate the flow direction. To determine the flow direction of ground water between three wells you will need to work through the three basic steps.

- Step 1: Fill in the blank boxes with the necessary information. When filling in information about water table elevation, make sure to use the 'Water table elevation in Static conditions (S)' for wells that are not pumping and use the 'Water table elevation in Pumping conditions (P)' for wells that are pumping. You must fill in all of the boxes for Step 1 before you may move on to Step 2.
- Step 2: Fill in the blank boxes with the necessary information. Make sure to round your answers to the stated amount of decimal places. The distance between wells is shown on the map. You may use a calculator to help you answer the math questions. Upon completion of step 2, you will notice a grey line appears on your map. This is your water table contour line.
- Step 3: Select the direction of groundwater flow by clicking and dragging the blue dot around the compass.  Groundwater flows from regions of higher elevation to regions of lower elevation.

For helpful information about the assumptions of the Hydrogeology Challenge, you may click the reality check button for each section.

To check your answers select the 'Check Answer' button. Correct answers are highlighted in green, incorrect answers are highlighted in red. To view the correct answers, select the 'Show Solution' button.

GRADIENT

- Step 1: Click on 'Reveal Distance Y'. Distance Y is the flow distance perpendicular to the water table contour (grey line) that you determined in Flow Direction. Distance Y will appear on your map.
- Step 2: Complete the formula to determine the gradient (i). Once again, make sure to round your answers to stated amount of decimal places.
  - A visual of the gradient will appear as a yellow arrow under the Step 2 equation. You are now ready to proceed to the final portion: Horizontal Velocity.

INSTRUCTIONS FOR USING THE HYDROGEOLOGY CHALLENGE (CONTINUED)

HORIZONTAL VELOCITY

Horizontal Velocity is calculated using Darcy's Law. Darcy's Law requires the hydraulic conductivity (K) and porosity (n) of the soil through which the groundwater is moving. To find these values, open the Geology Table of the well with the highest water table elevation (this is the well the groundwater will be flowing from). The Geology Table shows the lithology (soil type) where the well is located. The depth is listed as feet below the surface. To select your K and n values, choose the layer of soil with the highest conductivity (K) in the saturated zone (area below the water table).

- Step 1: Determine your hydraulic conductivity (K) and porosity (n). Fill in the blank boxes with the necessary information. You may back track to Gradient if you forgot your gradient value. Remember, porosity is entered in as a decimal, so a porosity of 45% would be entered as 0.45.
- Step 2: Complete the equation (Darcy's Law) to calculate Horizontal velocity.

FINISH

Congratulations! You have successfully calculated the speed and direction of groundwater flow. You may now click the 'All Done' button. A prompt will appear allowing you two choices:

- "Continue with Previous Selection," to continue in the same scenario
- "Begin a New Scenario," to choose a brand new scenario

If you "Begin a New Scenario", don't forget to try the Hydrogeology Challenge with well pumping ON!

CONTAMINANT TABLE

Category	Sub-Category	Pollutant	About	DNAPL or LNAPL?*	Sources
Volatile Organic Compounds (VOCs)**	Halogenated	Carbon Tetrachloride	A grain fumigant used to make refrigerants and propellants for aerosol cans as well as a solvent and dry cleaning agent.	DNAPL	Disposal in landfills; Accidental releases from production uses; Grain storage facility
		Chloroform	A chemical that was used as an extraction solvent and is now mainly used to make propellant and refrigerant.	DNAPL	Pulp and paper mills; Municipal and industrial waste water; Large processing facilities; Septic systems
		Perchloroethylene (PCE)	A solvent often used for dry cleaning and metal degreasing.	DNAPL	Dry cleaners; Textile operations; Metal degreasing activities
		Trichloroethylene (TCE)	An industrial solvent commonly used for metal degreasing, refrigerant manufacturing, and cleaning kerosene-fueled rocket engines.	DNAPL	Industrial degreasing operations; Automotive industry; Metal machining industry; Chemical waste sites; Leaky storage tanks and pipelines; Landfills
		Fluorotrichloromethane (Freon 11)	Prior to 1996 this compound was widely used as a refrigerant. Freon-11 was banned in 1996 for its ozone depletion potential.	DNAPL	Illegal drug labs; Landfills; Industrial solvent spills
	Nonhalogenated	Acetone	A common solvent used for cleaning, nail polish remover, and paint thinner.		Production wastewater; Landfills
		Methanol	A naturally occurring substance often used as a gasoline additive, paint stripper, propellant for aerosol cans, and cleaners.		Release from tank truck or rail cars; Underground methanol storage tank
		Benzene, Toluene, Ethylbenzene, and Xylene (BTEX)	A group of naturally-occurring chemicals that are typically found in petroleum products. They have a strong odor and are highly flammable.	LNAPL	Leaks from underground storage tanks; Fuel spills; Landfills: Pipeline leaks
		Methyl Tert-Butyl Ether (MTBE)	A manufactured chemical compound used as a fuel additive and solvent. It has an offensive taste and color.		Leaks from underground or aboveground storage tanks; Fuels spills; Pipeline leaks; Landfills
Semivolatile Organic Compounds (SVOCs)	Halogenated	Pentachlorophenol (PCP)	A white solid that is used as a wood preservative and was used as a herbicide in the past. Herbicide use of PCP was banned in 1987.	DNAPL	Leaching from treated wood products; Spills at industrial facilities; Hazardous waste sites; Atmospheric deposition in precipitation
		Polychlorinated Biphenyls (PCBs)	PCBs were banned in 1977, but before then they were used as coolants and lubricants. They can still be found in some products today such as fluorescent lighting and electrical devices that use PCB capacitors.	DNAPL	Landfill; Discharge of waste chemicals
	Nonhalogenated	Polycyclic Aromatic Hydrocarbons (PAHs)	A group of over 100 combinations of hydrocarbons that can be found naturally in the environment but can also be manmade. PAHs are used for research purposes as well as to make dyes, plastics, pesticides, and medicines.		Buried construction waste or ash; Onsite petroleum release; Coal-tar based sealcoats
		Pesticides	All chemicals that are used to kill or control pests.		Agriculture; Silviculture (Forest Management)

CONTAMINANT TABLE (CONTINUED)

Category	Sub-Category	Pollutant	About	DNAPL or LNAPL?*	Sources
Petroleum Byproducts		Creosote	A wood preservative used for commercial purposes only. It is obtained from high temperature distillation of coal tar.	DNAPL	Runoff from railroad ties and utility poles.
		Coal Tar	A by-product of carbonized coal. It is a brown or black liquid of extremely high viscosity.	DNAPL	Underground storage tanks; Coal tar facilities
		Crude Oil	A liquid petroleum that is highly viscous and has a higher density than light crude oil.	LNAPL/ DNAPL	Underground storage tanks; Pipeline leaks; Spills at industrial facilities; Oil spills
		Diesel	A heavy distillant that is used as fuel.	LNAPL	Underground storage tanks; Pipeline leaks; Spills at industrial facilities; Fuel spills
		Gasoline	A refined petroleum that is used as fuel in internal combustion engines.	LNAPL	Underground storage tanks; Pipeline leaks; Spills at industrial facilities; Fuel spills
		Benzene, Toluene, Ethylbenzene, and Xylene (BTEX)	A group of naturally-occurring chemicals that are typically found in petroleum products. They have a strong odor and are highly flammable.	LNAPL	Leaks from underground storage tanks; Fuel spills; Landfills; Pipeline leaks
		Methyl Tert-Butyl Ether (MTBE)	A manufactured chemical compound used as a fuel additive and solvent. It has an offensive taste and odor.		Leaks from underground/aboveground tanks; Fuel spills; Pipeline leaks; Landfills
Inorganics	Metals	Cadmium	A metal used for metal plating and coating operations, solar batteries and pigments.		Corrosion of galvanized pipes, Erosion of natural deposits; Discharge from metal refineries; Runoff from waste batteries and paints; Landfills
		Lead	A metal used in roofing, plumbing, storage batteries, etc. It used to be used in paints.		Pipes and other types of plumbing; Landfills; Car batteries; Natural deposits
		Nickel	A metal that is used for making stainless steel, coinage, rechargeable batteries, guitar strings, etc.		Natural deposits; Industrial facilities; Landfills
		Copper	A metal used to make electrical wiring and household plumbing materials. Copper compounds can be used as pesticide.		Natural deposits; Mining; Farming; Manufacturing operations; Municipal or industrial wastewater; Corrosion of pipes
		Chromium	A metal often used as a surface coating. It has also been used for making dyes, wood preservatives, synthetic rubies, leather tanning, etc.		Manufacturing operations; Municipal or industrial wastewater; Improper disposal
		Iron	A metal used in making steel. The cheapest available metal and the most widely used metal.		Natural deposits; Landfills
		Aluminum	The second most used metal behind iron. Used in the manufacturing of transportation vehicles, packaging materials, a wide variety of household items, etc.		Natural deposits; Coagulants in water treatment facilities; Landfills

CONTAMINANT TABLE (CONTINUED)

Category	Sub-Category	Pollutant	About	DNAPL or LNAPL?*	Sources
Inorganics	Radionuclides	Radium	A highly radioactive metal with a half-life of 1601 years. It decays into radon gas.		Natural deposits
		Radon	A radioactive gas that is the result of decaying Radium.		From natural deposits of radium
		Uranium	A weakly radioactive metal that is used to produce nuclear energy.		Natural deposits; Mining/milling waste
	Other inorganics	Arsenic	A poisonous element that is used to strengthen alloys of copper and lead. It has also been used in the production of pesticides.		Natural deposits; Mining
		Nitrate	(NO_3) Essential plant nutrient that in excess can accelerate eutrophication in aquatic plant growth and cause hypoxia (low levels of dissolved oxygen) to human and other warm-blooded animals.		Human/animal waste; Feedlots; Industrial waste from food processing; Septic tanks; Fertilizer and agriculture
		Chlorides (Salts)	A group of salts that are very soluble in water. They are found naturally in seawater, but it only takes a small amount of chlorides to contaminate freshwater.		Natural deposits; Road salts; Fertilizer; Water-softener; Human/animal waste
Explosives		2, 4, 6-trinotro-toluene (TNT)	An explosive compound commonly used for military and industrial applications. TNT-production ended in the mid-1980s.		Active and former U.S. Military installations; Army ammunition plants
		Hexahydro- 1, 3, 5 -triazine (RDX)	A highly explosive, synthetic product that has been used in the manufacture of explosives.		Active and former U.S. Military installations; Army ammunition plants
Pathogens		E. Coli	A type of coliform bacteria that live in water that may cause symptoms such as vomiting and diarrhea.		Bodily waste; Animal waste; Naturally in soil

*DNAPL stands for Dense Non-Aqueous Liquids and LNAPL stands for Light Non-Aqueous Phase Liquids.
**The various colors (Red, Blue, Green) represent the tournaments at which the pollutant or pollutant category may be used in competition. Red categories may be used at regional, state, and national tournaments. Blue pollutants may be used at state and national tournaments. Green pollutants may be used at national tournaments only.

Contaminant Pool				
Regional (Red)	State (Blue and Red)		National (Green, Blue, and Red)	
VOCs-- category only SVOCs--category only Petroleum Byproducts -- category only Inorganics --category only Explosives--category only Pathogens --category only	All of the categories from Regional plus the following:		All of the categories and pollutants from Regional and State plus the following:	
	Nitrate Arsenic Chlorides (Salts) DNAPL LNAPL Pesticides Gasoline Diesel MTBE	BTEX PAHs Cadmium Lead Aluminum Chromium Copper Nickel Iron	Carbon Tetrachloride Chloroform Freon 11 Acetone Methanol PCP PCE PCBs TCE	Creosote Coal Tar Extra Heavy Crude Oil Radium Radon Uranium TNT RDX E. Coli

SUGGESTED REMEDIATION TECHNIQUES

Regional (Red)	State (Blue and Red)	National (Green, Blue, and Red)
Air stripping Bioremediation Activated Carbon Treatment (Assuming Pumping) Phytoremediation Monitored Natural Attenuation Reverse Osmosis Vertical Egineered Barriers (VEB) Incineration	All of the categories from Regional plus the following: Permeable Reactive Barrier (PRB) Chemical Reduction Oxidation Air Sparging Bioslurping or Dual Phase Extraction Precipitation/Coagulation/Flocculation	All of the categories and pollutants from Regional and State plus any other techiques found in the Remediation Technologies Screening Matrix

*The cost of a remediation technique can vary greatly and depends upon many factors. This table is meant to be an estimated cost based on data from the Remediation Technologies Screening Matrix and Reference Guide (1994) as well as professional opinion.

GLOSSARY

Aeration zone: The zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. Plant roots can capture the moisture passing through this zone, but it cannot provide water for wells. Also known as the unsaturated zone or vadose zone.

Aquifer: An underground geological formation able to store and yield water.

Cone of depression: The zone around a well in an unconfined aquifer that is normally saturated, but becomes unsaturated as a well is pumped, leaving an area where the water table dips down to form a cone shape. The shape of the cone is influenced by porosity and the water yield or pumping rate of the well.

Confining layer: Geologic material with little or no permeability or hydraulic conductivity. Water does not pass through this layer or the rate of movement is extremely slow.

Darcy's Law: Describes the flow of a fluid through a porous medium. There are several different ways of expressing Darcy's basic equation, but the Hydrogeology Challenge uses V = Ki/n where V is the seepage velocity of groundwater, K is the hydraulic conductivity, i is the gradient of the water table, and n is the porosity.

Dense Non-Aqueous Phase Liquid (DNAPL): A liquid that is both denser than water and does not dissolve in water.

Depletion: The loss of water from surface water reservoirs or groundwater aquifers at a rate greater than that of recharge.

Discharge: An outflow of water from a stream, pipe, groundwater aquifer, or watershed; the opposite of recharge.

Drawdown: A lowering of the groundwater level caused by pumping.

Ex-Situ: Not in the natural or original position or place, off-site. Ex-situ remediation techniques involve removing the contaminated groundwater from underground and treating at an aboveground facility.

Flow rate: The time required for a volume of groundwater to move between points. Typically groundwater moves very slowly—sometimes only inches per year.

Groundwater: Water found in the spaces between soil (gravel, sand, silt, and clay) particles and cracks in rocks underground (located in the saturation zone). Groundwater is a natural resource that is used for drinking, recreation, industry, and growing crops.

Halogenated SVOCs: An SVOC containing one of the halogen elements located in the seventh column of the periodic table (e.g. fluorine, chlorine, bromine, or iodine).

Halogenated VOCs: A VOC containing one of the halogen elements located in the seventh column of the periodic table (e.g. fluorine, chlorine, bromine, or iodine).

Hydraulic Conductivity: A measure of the aquifer's ability to transmit water through pore spaces and fractures when submitted to a hydraulic gradient.

Hydrologic cycle: (also known as the water cycle) The paths water takes through its various states--vapor, liquid, solid--as it moves throughout the oceans, atmosphere, groundwater, streams, etc.

GLOSSARY

Hydrogeology: The study of interrelationships of geologic materials and processes with water, especially groundwater.

Impermeable layer: A layer of material (such as clay) in an aquifer through which water does not pass.

Infiltration: Flow of water from the land surface into the subsurface.

Infiltration rate: The quantity of water that enters the soil surface in a specified time interval. Often expressed in volume of water per unit of soil surface area per unit of time.

In-Situ: In the natural or original position or place. In-situ remediation techniques take place underground where the contaminated groundwater is located.

Light Non-Aqueous Phase Liquid (LNAPL): A liquid that is does not dissolve in water and has a lower density than water.

Lithology: The physical characteristics of a rock or stratigraphic unit.

Monitoring well: A non-pumping well, generally of small diameter, that is used to measure the elevation of a water table or water quality.

Nonhalogenated SVOCs: An SVOC that does not contain one of the halogen elements located in the seventh column of the periodic table (e.g. fluorine, chlorine, bromine, or iodine).

Nonhalogenated VOCs: A VOC that does not contain one of the halogen elements located in the seventh column of the periodic table (e.g. fluorine, chlorine, bromine, or iodine).

Overwithdrawal: Withdrawal of groundwater over a period of time that exceeds the recharge rate of the supply aquifer. Also referred to as overdraft or mining the aquifer.

Permeable/Permeability: Capable of transmitting water (porous rock, sediment, or soil); the rate at which water moves through rocks or soil.

Permeable layer: A layer of porous material (rock, soil, unconsolidated sediment); in an aquifer, the layer through which water freely passes as it moves through the ground.

Plume: In groundwater a plume 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 has the highest concentration, and the concentration decreases away from the source.

Pore space: Openings between geologic material found underground. Also referred to as void space or interstices.

Porosity: The ratio of the volume of void or air spaces in a rock or sediment to the total volume of the rock or sediment. The capacity of rock or soil to hold water varies with the material. For example, saturated sand contains about 20% water; gravel, 25%; and clay, 48%.

Recharge: Water added to an aquifer. For example, when rainwater seeps into the ground. Recharge may occur artificially through injection wells or by spreading water over recharge basins.

GLOSSARY

Recharge rate: The quantity of water per unit of time that replenishes or refills an aquifer.

Recharge zone or area: An area where permeable soil or rock allows water to seep into the ground to replenish an aquifer.

Remediation: Containment, treatment or removal of contaminated groundwater. May also include containment, treatment or removal of contaminated soil above the water table.

Residence time: Period of time that groundwater remains in an aquifer.

Safe yield: The annual amount of water that can be taken from a source of supply over a period of years without depleting that source beyond its ability to be replenished naturally in "wet years." Also called sustainable yield.

Salt water intrusion: Process by which an aquifer is overdrafted creating a flow imbalance within an area that results in salt water encroaching into a fresh water aquifer.

Saturation zone: The portion below the earth's surface that is saturated with water is called the zone of saturation. The upper surface of this zone, open to atmospheric pressure, is known as the water table.

Semi-Volatile Organic Compounds (SVOCs): Organic compounds that have a boiling point higher than water and may vaporize when exposed to temperatures above room temperature.

Subsidence: A depression of the land surface as a result of groundwater being pumped. Cracks and fissures can appear in the land. Subsidence is virtually an irreversible process.

Surface water: Water above the surface of the land, including lakes, rivers, streams, ponds, floodwater, and runoff.

Transmissivity: A measure of the capability of the entire thickness of an aquifer to transmit water. Also known as coefficient of transmissivity.

Volatile Organic Compounds (VOCs): Organic compounds that have high vapor pressure and low water solubility.

Water table: The top of an unconfined aquifer; indicates the level below which soil and rock are saturated with water. The upper surface of the saturation zone.

Well: A bored, drilled or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies to inject, extract or monitor water.

Well closure: The process of sealing a well that is no longer being used to prevent groundwater contamination and harm to people and animals.

Well siting: Location of a well placed to best protect water quality, access adequate water quantity, and allow for inspection and maintenance of the well.

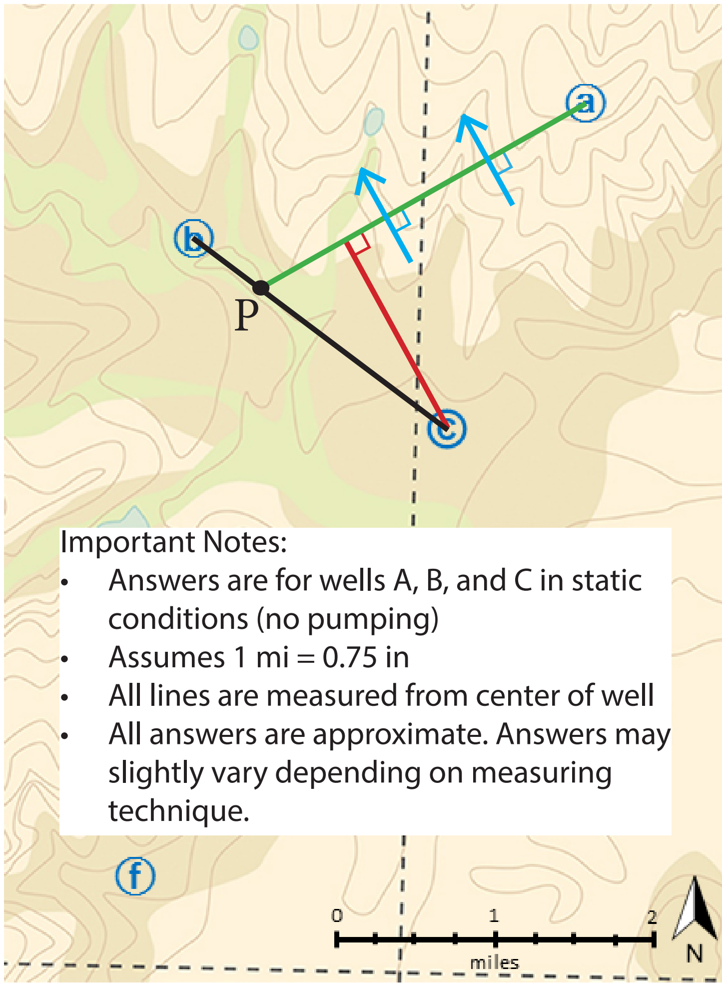
Wellhead protection area: A protected surface and subsurface zone surrounding a well or well field supplying a public water system to keep contaminants from reaching the well water.

The Groundwater Foundation Presents:

The Hydrogeology Challenge

Scenario: Sample Paper Version

To Begin: Pick three wells and complete steps 1 through 3 using the Well Log Look-Up Table



Important Notes:

- Answers are for wells A, B, and C in static conditions (no pumping)
- Assumes 1 mi = 0.75 in
- All lines are measured from center of well
- All answers are approximate. Answers may slightly vary depending on measuring technique.

Step 1: Flow Direction

1. Draw a **black line** from the well with the highest water table elevation (WTE) to the well with the lowest WTE.
2. Find the point (P) between the highest (H) and lowest (L) wells equal to the WTE of the middle (M) well using the equation below.

$$\frac{\boxed{6}_{\text{WTE H - M}}}{\boxed{8}_{\text{WTE H - L}}} = \boxed{0.75} \times \underset{\text{Distance H to L}}{\boxed{2.08 \text{ mi.}}} = \underset{\text{Distance H to P}}{\boxed{1.56}} \text{ miles}$$

1.56 miles = 1.17 inches

3. Mark the point between the highest and lowest wells equal to the WTE of the middle well (point P). Draw a green line from P to the middle well. You have just drawn a contour line!
4. The flow of groundwater will be perpendicular to the contour line. Draw a blue arrow representing the flow direction of groundwater. The arrow should point down gradient as groundwater flows from regions of higher elevation to regions of lower elevation.

Step 2: Gradient

1. In order to calculate the gradient, you must first find the distance (Y) from the highest well to the contour line. Draw this line in red. Remember this line should make a 90° angle with the contour line.
2. Measure the distance (Y) in feet (1 mi. = 5,280 ft.).
3. Calculate the gradient using the equation below.

Distance Y = 1.06 inches
= 1.41 miles
= 7445 feet

$$\frac{\underset{\text{WTE H}}{\boxed{1441 \text{ ft.}}} - \underset{\text{WTE M}}{\boxed{1433 \text{ ft.}}}}{\underset{\text{Distance Y}}{\boxed{7445 \text{ ft.}}}} = \boxed{0.001} \text{ ft/ft}$$

Step 3: Horizontal Velocity.

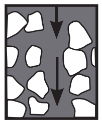
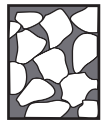
1. Three variables are needed to calculate the horizontal velocity of groundwater. They are gradient (i), hydraulic conductivity of the soil (k), and porosity of the soil (n). You have already calculated the gradient. Use the look-up table to find the hydraulic conductivity and porosity by selecting the layer of soil in the well with the highest WTE that has the highest conductivity (k) in the saturated zone (area below the water table). Then, using Darcy's equation below, calculate the horizontal velocity.

$$\frac{\underset{k}{\boxed{160.8}} \times \underset{i}{\boxed{0.001}}}{\underset{n}{\boxed{0.34}}} = \boxed{0.47} \text{ ft/day}$$

SAMPLE TEST ANSWER KEY: PARTS 1 AND 3

PART 1

1. C 2. A 3. C 4. D 5. C 6. A 7. C 8. False 9. False

10. Permeable  Impermeable 

11. a. **Permeability**: Capable of transmitting water (porous rock, sediment, or soil); the rate at which water moves through rocks or soil.

b. **Porosity**: The ratio of the volume of void or air spaces in a rock or sediment to the total volume of the rock or sediment. The capacity of rock or soil to hold water varies with the material. For example, saturated small grain sand contains less water than coarse gravel.

c. **Transmissivity**: A measure of the capability of the entire thickness of an aquifer to transmit water. Also known as coefficient of transmissivity.

d. **Aeration Zone:** The zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. Plant roots can capture the moisture passing through this zone, but it cannot provide water for wells. Also known as the unsaturated zone or vadose zone.

PART 3

1. South. However, the plume could disperse from west to southeast/east since all of the wells located in those areas have lower water table elevations (WTEs).

2. Wells F and G and possibly D since those three wells have lower WTEs.

3. Yes, pumping water from well E will lower the WTE to 2,460 ft. This will remove the risk of well D becoming contaminated because well D's WTE is 2,467 ft.

4. Pumping water will lower the WTE and the gradient, slowing the velocity of the contaminant plume.

5. C) 2-4 years

6.-9. See Remediation Table on page 27

HG NOTES

SCIENCE OLYMPIAD

Science Olympiad is a nonprofit organization devoted to improving the quality of science education, increasing student interest in science and providing recognition for outstanding achievement in science education by both students and teachers.

These goals are accomplished through classroom activities, research, training workshops, and the encouragement of intramural, district, regional, state, and national tournaments.

Science Olympiad tournaments are academic competitions that consist of a series of individual and team events which students prepare for during the school year. These competitions are balanced among the various science disciplines of biology, earth science, chemistry, physics, computers, and technology.

For more information about Science Olympiad, visit their official website at www.soinc.org.

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Science Olympiad

Exploring the World of Science

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