Lesson # 5: Groundwater Pollution

Driving Question: What are some ways that humans pollute groundwater? What are some ways that humans can clean-up groundwater?

Learning Goal:
While groundwater and surface water can be of either high or low quality, human actions can either pollute or enhance the quality of the water supply (4BM6-8 #8 p. 69; NSES 9-12F4ap. 198). Humans have developed some ways to clean-up some pollution. However, most human techniques for cleaning up pollution are difficult and expensive. Prevention of human-caused pollution is the most effective way to protect water resources.

Objectives:
O7 Build/develop a model to investigate different sources for and methods for cleaning up groundwater pollution. (constructing)
O8 Evaluate land use scenarios for potential groundwater and surface water pollution sources and impacts. (reflecting)

Assessment:
A7 Present a model and describe the source of pollution and clean-up method used.
A8a Given maps and cross-sections of a given land use situation (the Verona Valley), evaluate (identify and rank) the potential pollution sources and their impacts.
A8b Given several land use proposals for a specific location, explain the impacts of the proposed action on runoff and infiltration.

Lesson Purpose:
In this lesson, students build upon their investigation of ground water systems in Lesson #3 and surface water pollution in Lesson #4 to learn about groundwater pollution. Students will use knowledge and techniques gained from previous lessons to create effective whole class presentations. These presentations will be based on student experiences with groundwater models and small group discussions. Students will contaminate and clean-up their groundwater models from Lesson #3, and engage in writing activities and small and large group discussions. Through these experiences, students will gain an understanding of sources of groundwater pollution, processes that introduce pollutants to groundwater, and pollution reduction strategies. Students will also gain experience in presenting their science learning and their findings from investigations to their peers.

Lesson Overview:

Activity Number	Label	Function	Description
5.1	Journal Questions	Elicit Student Ideas / Establishes Purpose - This activity links to lesson 4 by exploring how pollution affects our groundwater supplies. This activity elicits student ideas and previews the new lesson for each day.	Students respond in journals to daily questions. This activity is repeated each day of this lesson, using different questions.

Activity Number	Label	Function	Description
5.2	Contaminate the Groundwater Models	Explore Ideas / Inquiry Activity – This activity links to Lesson #4 by allowing students to use their models for further learning. It also allows student to explore and test their ideas in order to build understanding of how pollution moves through groundwater systems.	Students work in small groups to contaminate their groundwater models. Groups have choices about sources of pollution.
5.3	Methods of Clean-up	Elicit Student Ideas / Presentation of Concepts - This activity elicits student ideas about potential methods of cleaning-up groundwater, provides connections between student ideas and professional cleanup practices. It also functions to build student understanding of the variety of techniques necessary for adequate pollution control.	In class discussion, students are asked to think of ways they could reduce the amount of pollution in their models by substantially cleaning up the pollution.
5.4	Clean-Up of the Groundwater Models	Construct Understanding / Inquiry Activity - This activity establishes a problem of cleaning up groundwater pollution and provides students with the opportunity to explore potential solutions through inquiry and model-building. This activity helps the students realize the difficulty of dealing with groundwater pollution, understand that solving an environmental problem may require a great deal more time, energy, and resources than preventing the problem in the first place, and elicits students' ideas and creative problem-solving strategies.	Students work in small groups to figure out how to clean up pollution in groundwater models.

Activity Number	Label	Function	Description
5.5	Presentations on group clean-up efforts	Formative Assessment/ Present Student Learning –.This activity will reinforce students' understanding by having them prepare accurate and concise presentations of their clean-up efforts. It also helps students practice their presentation skills in an authentic context and holds students accountable for their learning in a public and authentic way. Finally, this activity provides the teacher with an opportunity for formative assessment.	Student small groups present how they contaminated their model and cleaned them up.
5.6	Examine a case example of groundwater contamination: "Ground water Pollution Sources: Verona Well Field"	Apply Understanding – This activity engages students in a real groundwater pollution problem, establishes the Verona Wells problem, establishes a connection between abstract pollution problems and real peoples' lives, and provides background information for Activities 5.7 and 5.8.	Students will read about what happened at an actual groundwater contamination site and how it affected the nearby residents.
5.7	Groundwater Pollution: Mapping the Problem	Model-based Reasoning – This activity frames a scientific question based on a real-world situation, encourages students to act like scientists in using the data to come to reliable conclusions regarding a real example of groundwater pollution, introduces students to the process of scientific decision-making based on incomplete test results, helps students to integrate their understanding of several types of visual data within the context of reports from laypeople on location covered in Activity 5.6, and encourages students to use their mathematical understanding, in concert with their visual pattern-finding skills, to make sense of the terminology and types of data associated with groundwater pollution testing.	Students will be introduced to data representations that will help them draw conclusions about the location and concentration of the contamination.

Activity Number	Label	Function	Description
5.8	Groundwater Pollution: Cleaning It Up	Synthesis and Reflection – This activity allows students to synthesize their understanding from the previous lessons to create a solution to the real-world pollution problem they have been studying, helps students use what actually happened to understand the strengths and weaknesses of their own approaches and those of the government's approach, invites the students to make the connection between the necessity of group action in the face of a serious community problem and their own group work.	Students will create a clean-up solution and compare it to the actual events that took place in the Verona case.

Preconceptions:
The research literature documents the following student ideas that are not congruent with a scientific understanding of groundwater pollution. This lesson addresses some of these preconceptions by building on student ideas. The idea is to help students move their understanding towards a more scientific understanding, rather than simply correcting misconceptions. You should be aware of these preconceptions, but it does not mean that all of your students will hold these ideas. It is important for you to elicit your own students' ideas and build on their ideas during this unit.

Common Preconception	Goal Conception	Activity that Addresses this Preconception	What to emphasize
1. Once the pollution sinks into the ground, it doesn't affect the drinking water supply	Pollution that infiltrates into the ground will eventually move through the pore spaces, mix with the groundwater, and become part of the groundwater system.	5.1 – Journal Question on How Groundwater Pollution Affects Us Personally	Emphasize the nature of hidden threats to us – that ignorance can be bliss for only so long.

Common Preconception	Goal Conception	Activity that Addresses this Preconception	What to emphasize
2. There are only a few ways in which groundwater can be contaminated	There are a number of surface activities that can contaminate groundwater including improper chemical use and storage, leaking storage tanks, and disposal of sewage (including septic tanks)	5.2 – Groundwater Pollution Models	Emphasize that it is not only industrial activities that can pollute groundwater – ordinary people play a role as well.
3. Once groundwater is contaminated, there are no or few techniques for cleaning it.	Nature and humans have processes that can clean-up some groundwater pollution.	5.3 – Discussion of Clean-Up Methods; 5.4 – Clean-Up of the Groundwater Pollution Models; 5.8 – Groundwater Pollution: Cleaning It Up	Emphasize the complexity and cost of clean-up and the role of prevention.
4. Groundwater pollution happens at the national and state level, but does not at the local level.	Groundwater pollution affects everybody. Personal actions can affect the pollution of local groundwater resources.	5.6 -- Groundwater Pollution Sources: Verona Well Fields and 5.7 – Groundwater Pollution: Mapping the Problem	Emphasize the local nature of the pollution, its effects on local people, and the necessity of finding local solutions to the problem. Also point out that there are actions that all people take that could affect our groundwater supply.

Materials:

Activity Number	Per Student	Per Group	Per Class
5.1	Journals		Journal questions posted on overhead or blackboard
5.2	Student page	Student groundwater models	Colored powdered drink mix Paper towels Water Pre-punctured film canisters Pre-punctured straws Pre-punctured paper cups Paper or plastic cups with holes poked in the bottom (rain cups)
5.3	This is a class discussion activity only – no materials are needed.		
5.4	Student page 1 blank overhead transparency Overhead markers	Student groundwater models	Clean-up materials: Plastic spoons Paper Dixie cups Paper Towel
5.5	Student page		Overhead of teacher's scoring rubric Overhead of student presentation audience table
5.6	Student page		Overhead location map of Battle Creek Overhead map of Michigan and Verona Surface Map 1 Overheads of Verona Newspaper Article and Letter to the Editor

Activity Number	Per Student	Per Group	Per Class
5.7	Student page Colored pencils Verona Surface Maps 1 & 2 and Cross Sections 1 & 2		Overheads of Verona Surface Maps 1 & 2 and Cross Sections 1 & 2
5.8	Student page Colored pencils		Overhead of Verona Clean-Up Article

Activity 5.1: Daily Journal Questions (10 minutes)
Function/Rationale:
This activity:
1) Allows the teacher time to take roll and complete administrative duties while students enter the room. Students should be expected to complete the journal activity everyday without prompting.
2) Elicits student ideas and previews the new lesson for the day.

Directions:
1) Post journal questions on the overhead projector or chalk board. Suggested journal questions:
   A) You've seen that surface water can get polluted. Groundwater can get polluted, too. In what ways might groundwater pollution affect you personally? Give some examples.
   B) Farmers spread many fertilizers (both chemical and organic) on their fields. How would this fertilizer end up in the groundwater? *Fertilizers infiltrate into the ground when it rains and eventually reaches the aquifer.*
   C) The local drinking water utility discovers gasoline in the aquifer. How might the gasoline have gotten there? *A gas station may have a leaking underground storage tank that leaked gasoline into the ground. Infiltrating rainwater may have carried the gasoline into the aquifer.*
   D) You find out your drinking water is contaminated. How might you find out where the contamination is coming from? *Drill test wells, test the water in the wells for contamination, more contaminated water may be close to the source of contamination.*
   E) Pick a place you think would be an ideal place to live. Would you still live there if it had serious groundwater pollution?
2) Also see lesson descriptions below. Some lessons begin with guiding or review questions that could be used for the journal.
3) Students should respond individually in their journals to the daily journal questions. Review the questions. Lead a short discussion asking for sample student responses

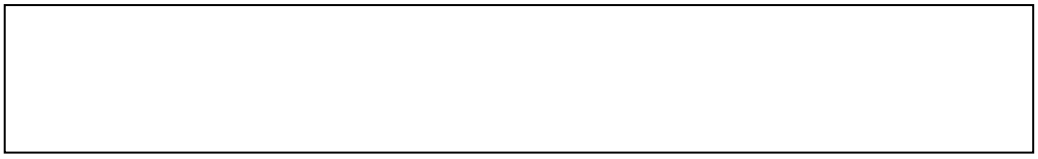
Activity: 5.2 -- Groundwater Pollution Models (30 minutes)
Function/Rationale:
This activity:
1. Continues the use of prior work from Lesson #4: students have a chance to use their models for further learning.
2. Allows students to explore and test their ideas in order to build understanding of how pollution moves through groundwater systems.
3. Develops group work skills.
4. Provides embedded assessment opportunities.

Directions:
1. Students will work in groups to create and study a groundwater contamination scenario. Students will use the same groundwater models that they built in lesson #3. Your role in the activity is to check student understanding and help students think about how realistic their models are. Students should be free to decide the method of contamination and how they should attempt to clean it up. You should check in with each group as they clean-up their models to provide guidance.

2. Students can choose to model one of the following scenarios or make up their own scenario (must be approved by you). Provide a central supply station for materials. If you feel that the large number of choices might confuse some of your students, you may wish to choose one of the examples as a teacher directed model for discussion and assign the others to your students, one example to a group.

   A. Example #1: Fertilizer/Pesticides on Agricultural Fields - Use colored powdered drink mix to simulate contaminant. Observe the path of the contamination in the model.
   B. Example #2: Landfill - Bury a paper towel soaked in colored water. Observe the path of the contamination in the model.
   C. Example #3: Leaking Underground Storage Tank (Gasoline Station) - Bury a film canister punctured with holes and filled with colored water. Observe the path of the contamination in the model.
   D. Example #4: Abandoned Well as a Storage Unit for Wastes - Insert a straw with holes into the model to represent an abandoned well. Pour colored water into the straw to represent pollution. Observe the path of the contamination in the model.
   E. Example #5: Lagoon or Surface Contamination Model (This would be the one most like the Paint Shop in the Verona Case Study) - Place a paper cup with holes in the bottom on surface of the model. Pour colored water into the cup to simulate pollution leaking out of the old barrels at the paint shop. Observe the path of the contamination in the model.

   Encourage the students to learn how to use their writing and drawing skills as tools for decision-making by using the space on their worksheets:
   From Student Materials

   > Use the space below if you need to draw a diagram or to write some pros and cons of each example as you discuss this decision with your group:
   >
   > 

3. Ask the students to use the group work table to record their predictions regarding the outcome of the simulations they have chosen.
   From Student Materials

What the group member said about what will happen	**Initials**
Example: "I think the colored water will go straight down until it gets to a layer it can't get through. Then it might go to the side or it might stop."	*MP*

4. Have the students draw a picture of what their model looks like before they run their simulation. This is an opportunity for them to see any changes as represented in their post-simulation drawing. It is also an opportunity for you to see if the students draw

significant features of the model (confined and unconfined aquifers, confining layers, wells, etc.) – if they don't, it may be an opportunity to re-teach some of the important points of this lesson by referring back to the models and drawings they made in Lesson #3.

5. After helping the students obtain the necessary materials, make sure they don't flood their models by pouring the water too quickly while they are polluting their environment. You may need also to help them with the vocabulary they might need to accurately depict what happened.

Group Suggestions:

1) Have students take on roles from previous group work.
2) By this time, students should understand what is being asked of them on step #4 on the student worksheet, where students record each group member's contribution to the group discussion. You may need to check this out.
3) Remind students to each write down one thing they thought their group did well and one thing their group needs to work on.

Embedded Assessment:

1) Be sure students can explain what their example demonstrates regarding groundwater.
2) Guide students to make careful observations of what happens to the contamination as they run their simulation. You may need to model the type of observations that students should make.

Activity: 5.3 – Discussion of Clean-Up Methods (10 minutes)

Function/Rationale:

This activity:

1) Elicits student ideas about potential methods of cleaning-up groundwater, and provides connections between student ideas and professional cleanup practices.
2) Functions as a way to build student understanding of the variety of techniques necessary for adequate pollution control. Students may see that their common sense ideas of pollution reduction correspond in some ways with professional practice. This may reinforce their connection to the problem and the solution.
3) Helps students understand that a variety of techniques usually are necessary for adequate pollution control.

Directions:

1) Conduct a group discussion of basic groundwater clean-up methods:
   A) Pumping pollutants out of the soil and rocks.
   B) Dig up and remove the contaminated soil.
   C) Bio-remediation - introducing bacteria that can eat up the contaminants
   D) Natural processes - These processes happen naturally, without participation from humans. However, they take place very, very slowly.
   E) Dilution - contamination eventually spreads far enough that concentrations of the contamination are no longer a problem.
   F) Degradation - some chemicals will break down into other chemicals. Sometimes, these new chemicals are less harmful than the original chemical, but not always.
   G) Bio-remediation - much slower than if human induced because the bacteria take a while to find the contamination, if ever.
2) Students will plan a strategy for cleaning up their models. Students will record their strategy on their Student Resources Sheet. Encourage students to consider how feasible

it would be to implement their clean-up solutions in real life. Have them consider how their models are similar to and different from real situations.

From Student Materials

Write some of the things you and your group members said to justify your final decision. If you disagreed with the other members of your group, you can write that in, too:

What the group member said to justify or argue against a particular choice	**Initials**
Example: "Let's add a lot of water, because it will dilute everything, and it's a cheap way of solving the problem."	*MP*

3) Help the students answer the next question on their worksheet: "Do you think this plan would be feasible (possible) in real life? Why or why not?"
4) Once they have planned how to clean up the pollution in their model, students will actually implement their plan and record the results in Activity 5.4.
5) Model for students what to think about in deciding if their plan is feasible in real life. Point out that they should consider time, cost, disruption of people's lives, and materials necessary to carry out their plan.
6) When students are finished, explain that they will have to present their scenario and clean-up strategy to the rest of the class tomorrow. Do not destroy the models.

Group Suggestions:
1) You may wish to reinforce smaller group work activities by discussing with the class the ways in which you are facilitating discussion in your own group leadership as teacher.
2) This also might be the appropriate time to let the students know that they themselves will be practicing their own group presentation skills as they progress through the lesson.

Embedded Assessment:
The teacher should be observant of students at work, asking questions about the strategies they intend to use in cleaning up the pollution that they have introduced into their ground water. Sample questions: *Can a combination of methods give you better results? What would be the best choices of methods? Why do you think so? What do the others (in the group) think about this?*

Activity: 5.4 – Clean-Up of the Models (30 minutes)
Function/Rationale:
This activity:
1) Helps the students realize the difficulty of dealing with groundwater pollution.
2) Helps the students understand that solving an environmental problem may require a great deal more time, energy, and resources than preventing the problem in the first place.
3) Elicits students' ideas and creative problem-solving strategies.

4) Gives the students feedback on the efficacy of their plans.

Directions:

1) Students should implement their plan for cleaning up the pollution in their model. Again, you will need to be sure that students don't flood their models as they try to clean up the pollution.
2) After students have implemented their model the following questions will help them think about the results. You may wish to have the students look at all of the questions before beginning to answer them, in order to help them use their time more effectively.
3) Note that question #5 requires students to complete a table. Questions #6 and #7 are individual response questions.

From Student Materials

3) Did your plan work? Why or why not?
4) Do you think this plan would be feasible (possible) in real life? Why or why not?
5) How is your clean-up model similar to and different from what might happen in real life?

	My Ideas	Other Ideas (from people in my group)
Similar		
Different		

6) Can you imagine this happening in real life? Should people care about pollution? Why or why not?
7) How could we prevent this sort of pollution and clean-up problem from happening in the first place?

Group Suggestions:

1) Have the students, if they don't spontaneously do so, change roles from Activity 5.2. At this point, it might be a good time to initiate a brief discussion of how roles can be equitably assigned, and how real scientists determine who does what on a scientific project.
2) As students, in groups, complete the table above, you can track the kind of discussions they are having by circulating among the groups and asking to see what they have produced so far.
3) For groups that are dominated by one person and his or her solution, or for groups that have settled on a solution without much discussion, you may want to take on the temporary role of a dissenter. Ask questions like "Did you think about _____?"

Embedded Assessment:

1) Listen to student discussions about why their plan did or did not work. Students may not be familiar with the concept of dilution. They may see that if they pump water into the ground, the colored water becomes lighter in tint but they may not recognize this as dilution. Help them link this phenomenon to the concept of dilution.

2) Sometimes, students end up destroying their models in order to clean it up. Help these students recognize the potentially greater impact that their solution would have on the people and land than if they did nothing.

Activity: 5.5 – Small Group Presentations of Clean-Up Approaches (30 minutes)
Function/Rationale:
This activity:
1) Will reinforce students' understanding by having them prepare accurate and concise descriptions of their clean-up efforts.
2) Will help students practice their presentation skills as part of a group effort in the authentic context of sharing their findings with fellow students.
3) Provide students with an opportunity to practice using their understanding of groundwater pollution processes by explaining their model and results to others.
4) Hold students accountable for their learning in a public and authentic way.

Directions:
1) Have students follow these instructions:

From Student Materials

1) Your group will present your model, your clean-up plan, and your results to the rest of the class. Each person in your group will help with presentation.
2) As a group, decide what each of you should say about your model. Your presentation should include the following information:
   A) A description of the pollution example your group carried out.
   B) A description of how the pollution moved through the model. In other words, what happened to the pollution?
   C) A description of the clean-up plan.
   D) An explanation of whether or not the clean-up plan worked and why.

2) Following this, have students read the following tips on presentation skills from their worksheets:

From Student Materials

Tips for presenters

It's hard not to notice successful people giving presentations all the time in our society, whether its sports stars talking to the press after a great game, actors and actresses giving their Oscar speeches, or talented comedians working their magic.

Regular people in regular jobs also present to their co-workers more often than you might think, and it often makes a difference in their careers. Here are some guidelines for doing a good presentation:

1) Establish eye contact with different members of the audience.

2) Rehearse what you're going to say before you get up to present – this will make both you and your audience more comfortable. Practicing your opening line a few times will lead you into the rest of the presentation.

3) In a scientific presentation, it can be especially helpful to use drawings, physical models, or other visual aids to engage your audience. Make sure your drawings or models are large enough for the audience to see your ideas.

3) This may be another instance when you can talk about your own role as teacher and how you prepare for your own presentations to your classes and/or at meetings and conferences. You might solicit students' own experiences from drama, music, and other areas of their lives.

4) Help students compose their presentations. Be sure each group member has a role. If students do not include all of the elements in step 2d (An explanation of whether or not the clean-up plan worked and why), ask leading questions to help them give the required information. Also, ask group presenters to consider how their models are similar to or different from real life. Finally, probe whether or not they think that their clean-up plan would be feasible in real life.

5) Describe the use of the scoring rubric below (you may wish to use the overhead copy). The first group chosen to present should be one that you feel will be a good model for the other groups.

	2 points	**4 points**	**6 points**
Pollution Scenario	The pollution scenario is not clearly presented	Some elements of pollution scenario are clearly presented	The pollution scenario is clearly presented.
What Happens	Students did not describe how the pollution moved through the system	Students describe how the pollution moved through the system but do not explain why.	Students describe how the pollution moved through the system and why.
Solution/Clean-up	It is not clear how the contamination will be cleaned up.	It is somewhat clear how the contamination will be cleaned up.	It is very clear how the contamination will be cleaned up.
Description of the clean-up method and why it did or did not work.	Students did not describe whether or not the clean-up method worked.	Students describe why the clean-up did or did not work yet offer no explanations.	Students are able to state whether or not the clean-up worked and why. Students describe whether the clean-up worked and offer ideas as to why the cleanup was effective/ineffective

6) Describe the use of the student rubric. Establish the expectations for the student presenters and the audience during the presentations. Use the overhead transparency provided:

From Student Materials

Group Number	**Scenario - What were they modeling?**	**Clean Up - How did they try to clean up the pollution?**	**How realistic was the model & why?**
The line below is an example			
Group 7	Abandoned Well	Capped the well. Drilled wells to pump out contamination.	This model did not treat the contaminated water that was pumped out.

7) Have each group give their presentations to the class.
8) Allow time for the class to ask questions of the presenting groups. You may wish to model this for the students by asking groups questions that highlight conceptual aspects of:
    - the source of the pollution
    - where and how the pollution spread and why
    - what were the similarities and differences with other groups' models

Group Suggestions:

1) It might be necessary to assign roles. These roles do not all have to be speaking roles, as long as everyone has a part to play in the presentation.
2) Clearly establish expectations for presenters and audience members during the presentations.
3) Remind students to evaluate their group work for today.

Embedded Assessment:

1) As you circulate from group to group during the completion of the presentation plans, you can assess students' understanding of your directions. You may wish to repeat the questions from the directions.
2) Students who in other situations are productive on worksheets but who are not productive in this case may be anxious about presenting and so may need some extra help.
3) Students may not wish to be constructively critical of other students' presentations – this may be a good opportunity to discuss the value of peer review and dialogue in scientific inquiry. You can model this in your evaluation and commentary on the students' reports. Make both positive comments and constructive suggestions. Ask students from other groups to do the same.
4) Members of the reporting group should be encouraged to offer rebuttals for suggestions that don't fit the problem they are reporting.

Activity: 5.6 – Introduction to Verona Well Fields (20 minutes)
Function/Rationale:
This activity:
1) Engages students in a real groundwater pollution problem.
2) Establishes the Verona Wells problem.
3) Establishes a connection between abstract pollution problems and real people's lives.
4) Provides background information for Activities 5.7 and 5.8.

Directions:
1) Use the Location Map overhead and Surface Map #1 to give the background of the Verona pollution case. Your introduction should include some or all of these points:
   - The location of Battle Creek in relation to Lansing.
   - Verona Valley is a subdivision in Battle Creek. Point out the locations of the points of interest and their significance. For example: The housing subdivisions are located near an industrial area.
   - Most of the residents get their water from the Verona Well Field. This is a well field for the whole city of Battle Creek, not just the Verona Valley residents. Some residents have their own wells.
   - The case started around 1981. Many people in the Verona Valley were getting sick with serious diseases like leukemia. The State Department of Natural Resources was worried about possible leaks into the groundwater from a nearby landfill (not shown on the maps). The DEQ went door-to-door, sampling people's tap water. They found a number of highly toxic chemicals in the drinking water and suggested that the residents switch from their private wells to the city water supply. The residents replied that they were using the city water supply. That is when the state DEQ and the City of Battle Creek realized they had a real big problem.

2) In groups or individually, ask the students to read the Verona Newspaper Article and Letter to the Editor and work together to answer the questions.

<u>From Student Materials</u>

Tainted Water in Tiny Michigan Township

BATTLE CREEK, MICHIGAN – Bill Pritchard's neighborhood in Pennfield Township has always been close-knit. Many of the 500 or so residents have owned their small, older homes for a good number of years. About a third are retired. Most people in the area, called the Verona Valley, just north of Battle Creek, don't hesitate to drop in on each other unannounced…. (continues)

A reconstructed letter to the editor from a Verona resident

To the Editor:

I am writing to express my outrage at the situation with the drinking water pollution that affects all of the homes in Verona, Michigan. Not only does the water here taste so bad that we cannot use it for drinking, cooking or even taking a bath, but it has caused serious health problems to many members of this community. For me, the problems are life-threatening–two of my teeth are crumbling, (continues)

3) Have students discuss the following questions as a group and write down their own answers.
   - How has the pollution of the groundwater changed the lives of the people in Verona Valley? *They aren't able to rely on safe drinking water the way they used to. It has changed their daily habits significantly, and the pollution in the water may have contributed to a large number of serious health problems.*
     How long has this been going on? *At least since 1981, when the Michigan DNR found alarming levels of more than 20 toxic chemicals.*
   - Do you know of similar cases where ground water pollution has affected people's lives? *(Students may have heard of cases in Lansing and nearby areas.)* How do news stories like this make you feel?
4) In the next part of the activity, ask the students to imagine that they are reporters who have been given the job of interviewing people who live in Verona Valley and writing a news story about their pollution problem. Each member of the group should write a question for the residents who were drinking the polluted water. They may need help designing the questions to obtain information that would help people who don't live there to better understand the pollution problem in Verona Valley.

Question for Verona Valley resident	**Initials**
What government agencies have been involved in helping the community deal with the problem? What have they done?	

Group Suggestions:
1) You may wish to emphasize the usefulness of group work in helping group members make sense of text that includes scientific terminology and ideas by modeling what happens when an individual reads a complicated text versus what is possible in a group reading.
2) Let the students know in the reporter activity that the other members of their group can provide valuable feedback as they draft and revise their questions.

Embedded Assessment:
1) These articles contain technical vocabulary. You may need to pay attention to student reading difficulties with terms such as "tri-chloro-ethylene"," mutagenic", and "carcinogenic" and provide definitions and other reading support.
2) This may also be an opportunity to ask substantive questions regarding the content of the articles. For example, you might ask students to really consider the effect of having no usable water – if they have ever experienced a boil order, or other times when water wasn't available for short periods, what would it be like with no water for months? Here are a few examples of this type of question:

   - Why did the Verona residents stop drinking the water from the wells?
   - What is so bad about ingesting TCE?
   - How many people get their water from the Verona Well Field?

Activity: 5.7 – Verona Wells: Mapping the Problem (30 minutes)
Function/Rationale:
This activity:
1) Frames a scientific question based on a real-world situation.
2) Encourages students to act like scientists in using the data to come to reliable conclusions regarding a real example of groundwater pollution.
3) Introduces students to the process of scientific decision-making based on incomplete test results.
4) Helps students to integrate their understanding of several types of visual data within the context of reports from laypeople on location covered in Activity 5.6.
5) Encourages students to use their mathematical understanding, in concert with their visual pattern-finding skills, to make sense of the terminology and types of data associated with groundwater pollution testing.

Directions:
1) Use the overhead transparencies of Surface Map 1 and Cross-Section1 to explain the context of the groundwater pollution problem. Remind students about how the two maps fit together. Ask the students to follow you in marking the points of interest on the map. Here are the points of interest:

   A. Housing subdivision
   B. Railroad Car Paint Shop
   C. Railroad Tracks
   D. Verona Pump Station
   E. Drinking Water Wells
   F. Battle Creek River

2) Help the students make the connection between the points of interest on the map and cross-section to the newspaper article and letter to the editor from Activity 5.6. Establish the problem: Where is the pollution coming from?
3) Ask the students to work within their groups to state the importance of each of the points of interest in the table on their worksheets. Below is the table from the Student Materials. The italics show the answers that you may guide your students towards. Students will not think of all of these possibilities, and they may think of more possibilities that are not listed. These answers are provided to you as starting points to help you help your students.

Point of interest	**What the group member said about the importance of the point of interest**	*Initials*
Housing subdivision	*Example:* "It could be that the people who live there are dumping their oil or paint on the ground and it's getting into the groundwater."	*PZ*
Railroad Car Paint Shop	*This is a likely source of pollution. Paint shops have solvents, paints, and other toxic chemicals. If they are stored improperly, they could leak into the ground and get into the groundwater.*	

Point of interest	**What the group member said about the importance of the point of interest**	*Initials*
Verona Pump Station	*The pump station is an industrial site. Maybe some contamination occurred during construction or maintenance.*	
Drinking Water Wells	*Wells provide conduits for pollution to leak into the aquifer below. If there are any abandoned or uncapped wells in the area, polluted water could have leaked into the aquifer.*	
Battle Creek River	*The river is connected to the groundwater system. It is possible that pollution in the river leaked into the groundwater system.*	

4) Help the students understand the questions a scientist would ask in this situation by asking the students:
   A. How will we find out where the pollution is coming from? What do we need to do? *Drill wells and test the water.*
   B. What data do we need? *We need to know the concentrations of pollutants from different sites.*
5) Show the students the Surface Map 2 overhead and ask them to find their copies in the student packet. Point out the locations of the wells and how to interpret the data associated with each water sample from the wells.
6) Either read or have individual students read the text on their worksheet to their group members. Because the idea of "parts per billion" is most likely foreign to the students, but crucial to understanding the data in this activity and the next, it's important to assess the students' understanding of this concept.

<u>From Student Materials</u>

Surface Map #2
On Surface Map #2, you can see additional marks on the map from what you saw on Surface Map #1. These marks (the T stands for "testing well") indicate the position of new wells the scientists drilled. The numbers next to the marks indicate the amount of pollution in the water samples they tested from those wells. For example, if you see a mark that says T200, it means that the level of pollution in that sample was 200 parts pollution per billion parts water. If you see a mark that says T1000, that sample had 5 times more pollution.

There's something else that's new on Surface Map #2: the curved line that surrounds all of the drinking wells and the testing wells. This line is called an "iso-concentration line." "Iso" means "same," and what this line shows is where the water samples all had the same amount of pollution. The water samples taken from wells on the inside of that line had more pollution, and the water samples taken from wells outside the line had less pollution.

In other words, an iso-concentration line outlines the level of contamination in a particular area. Samples with more than 10 ppb are of concern because of the accumulated health affects from drinking this water.

7) Point out the 10ppb iso-concentration line. Explain that it shows where scientists think the groundwater contains 10 ppb of pollution. Explain that the students will use the data on Map #2 to draw in the rest of the iso-concentration lines. Model drawing the lines on the overhead and have students draw in the same lines on their maps. It is suggested that you model all of the lines, asking students as you draw where they think the lines should go. You will draw three lines (100 ppb, 1000 ppb, and 1000 ppb). A key is provided. The procedure for drawing the iso-concentration lines is as follows.
   A) Begin with the 100 ppb line.
   B) Pick two wells with contamination levels greater than 10 ppb and less than 1000 ppb.
   C) Locate a point in the space between the two wells that should represent 100 ppb. It the two wells are T25 and T250, the 100ppb line will be somewhere between, but probably closer to the T25 well than the T250 well.
   D) Repeat the above procedure, interpolating and drawing the 100 ppb iso-concentration line in the spaces between the wells until you come back to the wells where you started and you have a circle drawn on the map.
   E) Repeat the above steps for the 1000 ppb line and the 10,000 ppb line.

8) Model for students how to color in the area between the iso-concentration lines.

From Student Materials

Concentration Level	**How much of the pollutant does each liter of water contain?**	**How much in a bathtub full (about 200 liters, or 53 gallons)**	**Color**
Greater than 10,000 parts per billion	More than 10 mg	More than 2000 mg	Red
1,000 – 10,000 parts per billion	1 – 10 mg	200 – 2000 mg	Orange
100 – 1,000 parts per billion	0.1 – 1 mg	20 – 200 mg	Blue
10-100 parts per billion	0.01 – 0.1 mg	2 - 20 mg	Green

9) This may also be an opportune time to introduce the idea of the use of scientific sampling as a way of minimizing time, energy, and expense while still obtaining enough data with which to find patterns. Ask the students:
   A) What do these data mean? *The numbers show how many parts per billion of pollution there are in the sample from the well.*
   B) How can we see a pattern? *Since we think the pollution is spreading, like a plume of smoke from a chimney, we can see if we can separate the locations with different concentrations by drawing lines. By doing so, we will be able to use the water samples to get a better idea of how the pollution has spread within the sampling area.*

10) Have students answer the following questions in their groups.
    A) What do the points on the maps with numbers (for example T200) show you? *How many parts per billion of pollution there were in the water sample from that well?*

    B) How were these points created – what did the scientists do to obtain these numbers? *They mapped out locations for a small, but reliable, number of test wells to draw water from, drilled them, and then measured the amount of pollution in the water samples.*

11) Using the overhead, show students Cross-Section 1. Have student identify the groundwater system features on their own copies of the cross-section. Also note the location of the river and the Verona Well Field. Ask the students the following questions.
    A) Are there any confined aquifers in this cross-section? *NO*
    B) What does this mean for the aquifers? *All of the aquifers are susceptible to pollution from the surface because there are no confining layers above that will protect them.*

12) Show the students Cross-Section 2. Have the students color in the appropriate parts of the cross-section.

13) Ask the students to put it together Surface Map 2 with Cross-Section 2 so that they can see how they match.

14) You may either have students work in groups to answer the following questions or lead the whole class through the following questions together.
    A) Using the data from the map and the cross-section, what patterns do you see? Where did the pollution come from? *The railroad paint shop.*
    B) Which way is the pollution moving? *1. toward the river 2. Deeper.* Why? *1. Groundwater can connect to river systems. 2. Wells draw water toward them. 3. Gravity pulls water down.*
    C) How did the pollution get to the wells? *As the wells pumped water for the city, they drew water toward them, and this water had been polluted by the toxic chemicals from the Railroad Paint Shop.*

15) *Ask the students to work with their groups in completing the following table on their worksheets.*

From Student Materials

The answers in italics below are provided to you to help you guide your students.

Point of interest	**Contaminated? At what level?**	**How do you know? (Evidence)**	**Initials**
Housing subdivision	*Probably Not – Less than 10 ppb*	*Outside the 10ppb line However, no wells are here to be sure*	
Railroad Car Paint Shop	*Yes- Greater than 11,000 ppb*	*Is inside the 10,000 ppb line and nearest well is 11,000ppb*	
Railroad Tracks	*Yes – depends where, but much of the railroad tracks are within the polluted zone*	*A big section of the railroad tracks is within the 10ppb area, and some is even inside the 10,000 ppb area (depending on how students drew the iso-concentration lines.*	
Verona Pump Station	*A little bit – around 100 ppb*	*The pump station is between the 10 and 100 ppb lines.*	
Drinking Water Wells	*Some of the drinking water wells contaminated up to 100 ppb*	*Some of the wells are located between the 10 and 100 ppb lines*	
Battle Creek River	*??*	*No conclusive data. Didn't sample the river or sample across the river.*	

16) Ask them: "How do you think the pollution got to the Verona Well Field Drinking Wells? What is your evidence?" As they fill in this question on their worksheets, remind them that although the data may look complex, if they work together, they are more likely to find the answer.

17) Let the students know that in the next activity they will learn how close they were to what the actual scientists concluded.

Group Suggestions:

1) This activity relies on back-and-forth movement among teacher-led/teacher modeling structures, small group work, and individual work. Establish a clear signal so that students know when they need to cease talking in groups and pay attention to the teacher.
2) Remind students that they are responsible for helping each other in their small groups. However, helping each other does not mean doing another person's work or allowing another person to copy. Help your students be each other's teachers.

3) When students complete the final table, suggest that they divide up the points of interest. Have each person determine the contamination level and evidence for one location and then share the information with the rest of the group.
4) Remind students to grade their own work in the group and their effectiveness of their group overall for today.

Embedded Assessment:
1) You may need to ask the students questions regarding how the points of interest match on the surface map and on the cross section. For example, you might ask one member of a pair of students to hold the representations together and the other member of the pair to point out two matching points of interest. Then you could have the whole class do this for a particular point of interest, giving you visual confirmation of which students understand the correspondence of features and which do not.

2) Ask questions as students are coloring to be sure they understand what they are coloring. Students may not make the connection right away that the colors represent levels of contamination. Questions you might ask include:

   A) Why is this area green and this area red?
   B) Tell me what this pattern is showing us.
   C) If I drill a well here, what will the concentration of the pollution in the water be?
   D) Similar questions could be asked on the cross-section:
   E) What is the concentration of pollution at this level below ground?
   F) If we drilled a well here that was 30 feet deep, what would the level of pollution be?

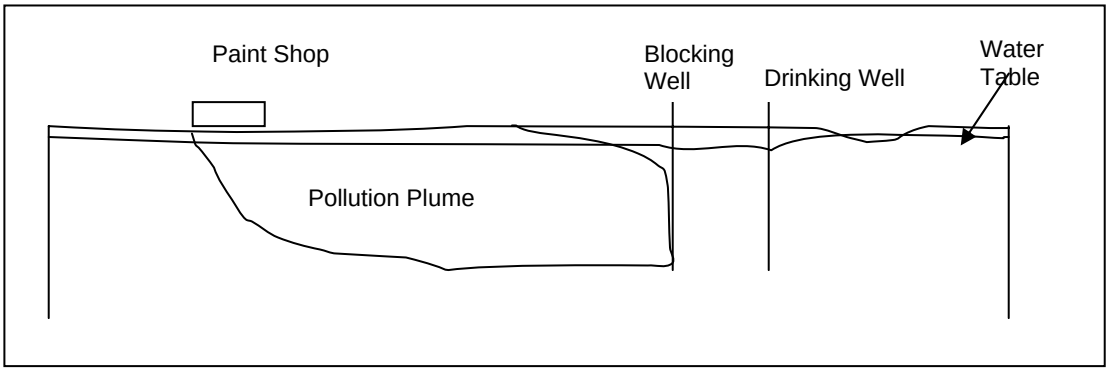
3) One way to assess the students' understanding of the idea of concentrations expressed in parts per sample is to ask them to create their own examples. For instance, "What is the concentration of blue M&M candies in a bag?" or "What is the concentration of Americans in the world population?"

Activity: 5.8 – Groundwater Pollution: Cleaning It Up (20-30 minutes)
Function/Rationale:
This activity:
1) Allows students to synthesize their understanding from the previous lessons to create a solution to the real-world pollution problem they have been studying.
2) Helps students use what actually happened to understand the strengths and weaknesses of their own approaches and those of the government's approach.
3) Invites the students to make the connection between the necessity of group action in the face of a serious community problem and their own group work.

Directions:
1) Ask the students to work in their groups on a solution to the Verona Valley pollution problem: *"Now that you have seen the extent of the pollution problem in the Verona Valley, it's time to think about how you would go about cleaning it up. Working with your group, think about the ways you cleaned your groundwater models, and how what you found during that activity applies in this case. Remember: you don't have to get every single drop of pollution out of the ground, but the residents are counting on you to make their water safe again!"*
2) You will need to help the students divide and conquer with this task. Remind the students of their own efforts and results from their models and ask them to build on prior experience, just as scientists do. A list of previous choices is provided for the students on their worksheets:

A. Pumping
B. Dig up and remove the contaminated soil.
C. Bio-remediation - introducing bacteria that can eat up the contaminants
D. Natural processes - These processes happen naturally, without participation from humans. However, they take place very, very slowly.
E. Dilution - contamination eventually spreads far enough that concentrations of the contamination are no longer a problem.
F. Degradation - some chemicals will break down into other chemicals. Sometimes, these new chemicals are less harmful than the original chemical, but not always.
G. Bio-remediation - much slower than if human induced because the bacteria take a while to find the contamination, if ever.

3) Let the students know that you're not looking for perfection, but that the water needs to be made safe for drinking. You might ask them what difference that will make in the Verona residents' lives.
4) Emphasize that the "questions to consider" are there to actually help them experience the type of dialogue that scientists engage in.
5) If there is time, a representative from each group might briefly describe their solution, with informal responses encouraged from the rest of the class.
6) Have students read the reading about the Verona Wells clean-up. Notice that there are three places within the reading where students should stop to answer questions or draw a picture. These questions are intended to help students pick out some of the important parts of the reading.
   A) The first question regarding this reading comes after the first paragraph:
   Question: List three groups that might have different perspectives on how to clean-up the Verona Well Fields." 1) *Government 2) Citizens 3) Companies*
   This is an opportunity for you to introduce the political context of science, helping the students to see that scientific solutions are situated in a real and often contentious world.
   B) At the end of the first page, students are asked to draw a picture of how the blocking wells work. This should be a cross-section picture.



Towards the end of the reading students are asked to list and explain the purpose three other solutions, besides the blocking wells, used to clean-up Verona Wells. *1) Removal of chemical storage tanks to get rid of the source of the pollutants, 2) removal of soil and soil extraction system to get rid of the chemicals in the soils, 3) purge wells to get rid of the pollution in the water near the Paint Shop.*

7) Have students work in groups to discuss the following questions. Students should write individual answers after discussing the questions in their groups.
   A) Do you think that the EPA and the Department of Natural Resources acted effectively in this situation? Why or why not? Students should include reasons for their answers. Encourage students to think about the perspectives of three different groups they listed above and the challenges that the EPA and Department of Natural Resources had to try to meet everyone's interests and needs.
   B) Would you be satisfied with the solution if you lived in the Verona Valley? Why or why not? This question encourages students to place themselves in Verona Valley and consider the problem from the perspective of the residents.
   C) Many people may think that what happened in Verona Valley only matters to people who live there. How do you think what happened in Verona Valley might be relevant to people who live in Lansing? This question links Verona Valley to Lansing in an attempt to help students recognize that what happened in Verona Valley could happen in Lansing. Share with students that, in fact, Lansing has experienced similar pollution of its drinking water aquifer. Vinyl chloride from the Motor Wheel Plant in Lansing has leaked into the Saginaw Aquifer. Just like in the Verona Valley, this pollution contaminated aquifer from which the city takes its drinking water. In both Verona Valley and Lansing, the EPA designated the pollution sites as Superfund Sites, a designation usually reserved for highly polluted sites. Superfund status made both sites eligible for Federal clean-up assistance. The Motor Wheel Site was de-listed from the Superfund list in 2000. Just like in Verona Valley, the Lansing Board of Water and Light took some of its drinking water wells in the North Lansing Well Field out of drinking water production and used them exclusively to pump polluted water out of the aquifer. The result has been that most of the vinyl chloride in the drinking water is moving towards the North Lansing Well Field and is not endangering the rest of the Lansing water wells. Unlike Verona Valley, the pollution never got into the city's drinking water, people have not become ill from the pollution, and very few people even know that the situation exists.

Group Suggestions:

1) Planning a solution for cleaning-up the Verona Valley is a much unstructured activity. You may find that you need to provide more structure to students to guide their work. You might suggest to students that they choose two or three methods listed and describe how they might use them in Verona Valley.
2) If groups seem to be arriving at a solution too quickly, you can encourage deeper reflection by asking questions that challenge the students to defend their approach.
3) In terms of group work, as you circulate among the groups, remind each one that everyone should be heard if they are to arrive at the best solution.
4) Guide students to complete the embedded questions and drawing tasks during the reading. This strategy will help them understand the technical aspects of the article.
5) Remind students that they have been working together as a group for the past four weeks and should be able to discuss the questions as a group and then write down their own answers without a lot of guidance from the teacher. However, if students are still struggling, you may have them each write a suggested answer and then share it with the rest of the group before writing their final answer.

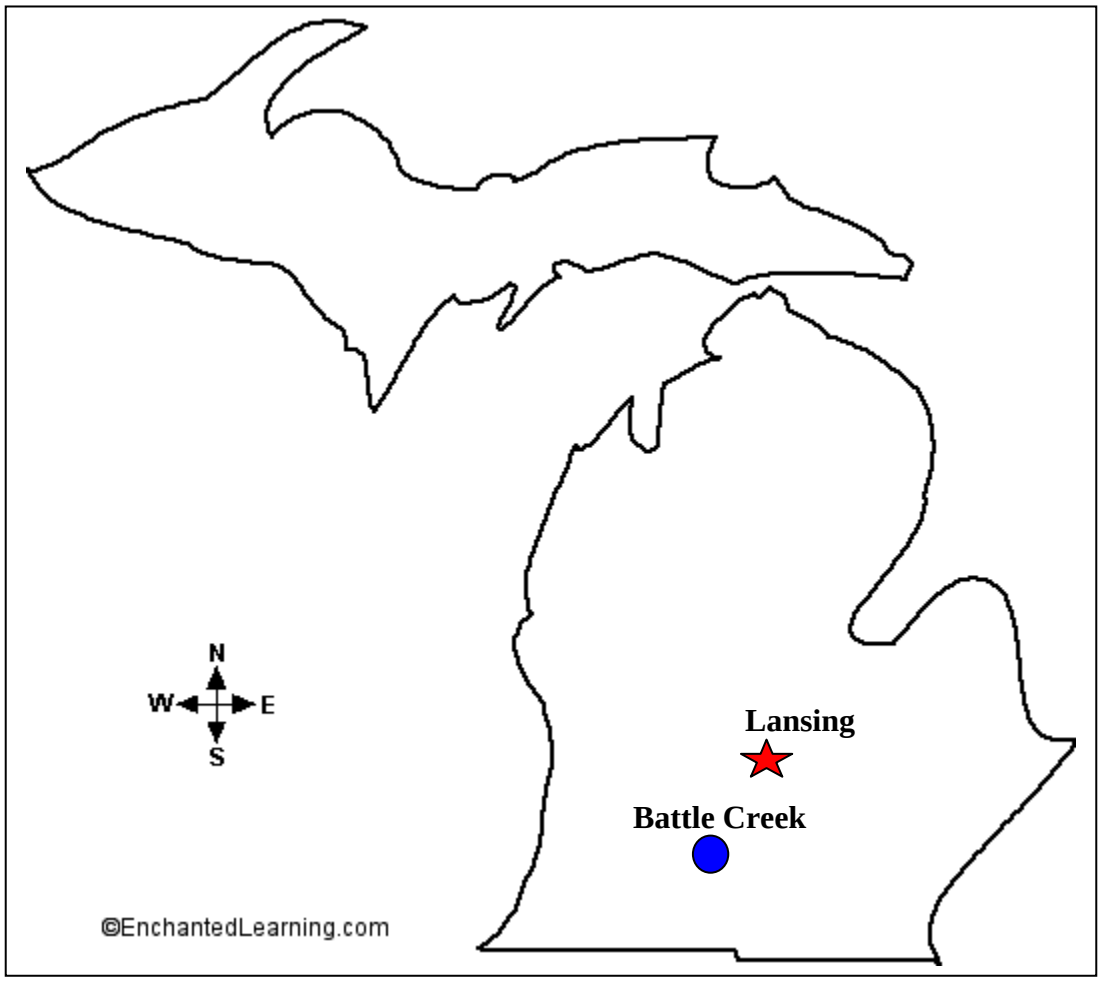
Embedded Assessment:

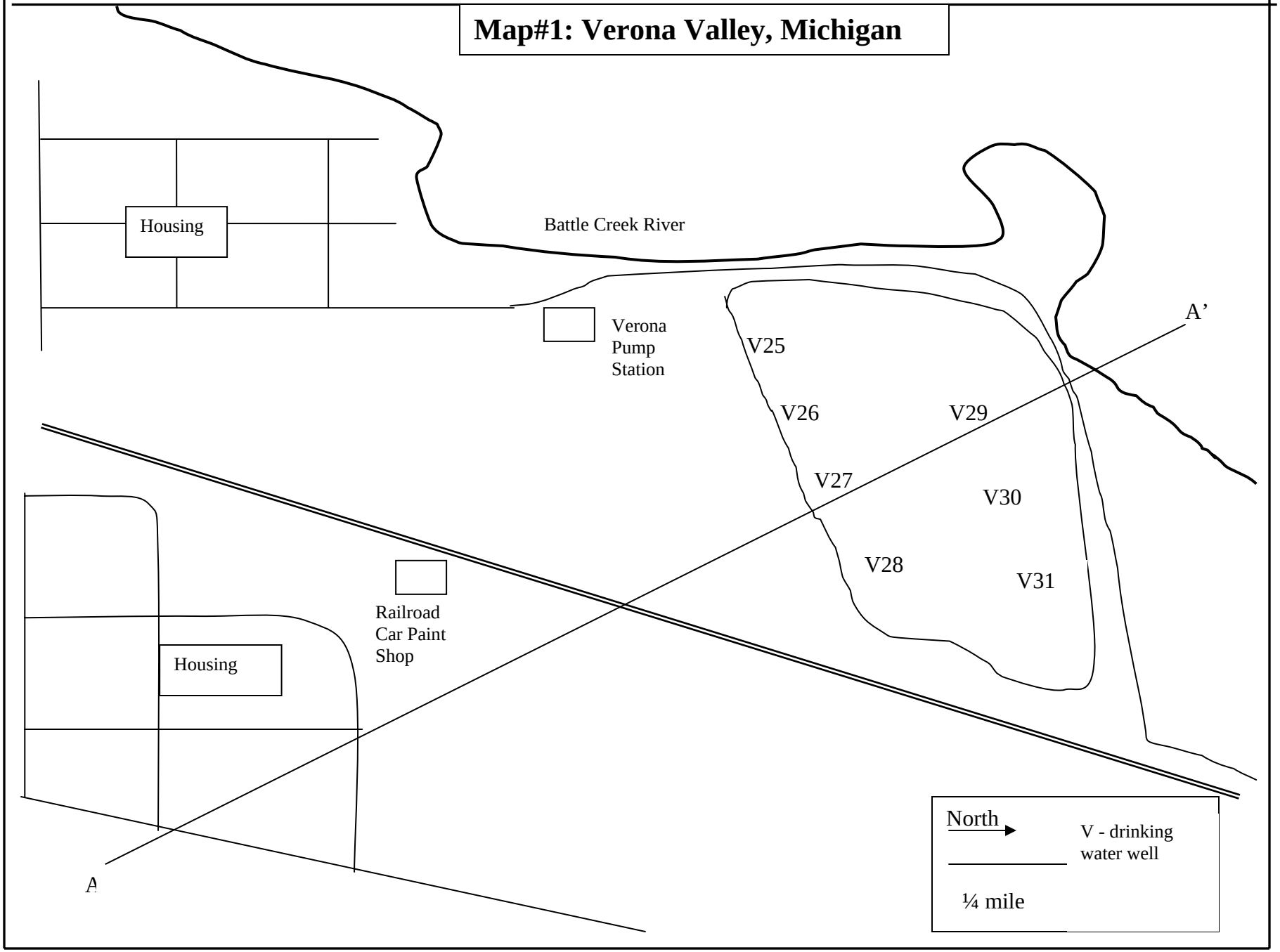
1) As students work on their solutions in groups, you can track the kind of discussions they are having by circulating among the groups and asking to see what they have produced so far. If students haven't produced anything, question them as to what the stumbling

blocks are to a solution. This can be an opportunity to point out that even scientists with a great deal of knowledge and experience may take years to arrive at workable solutions.

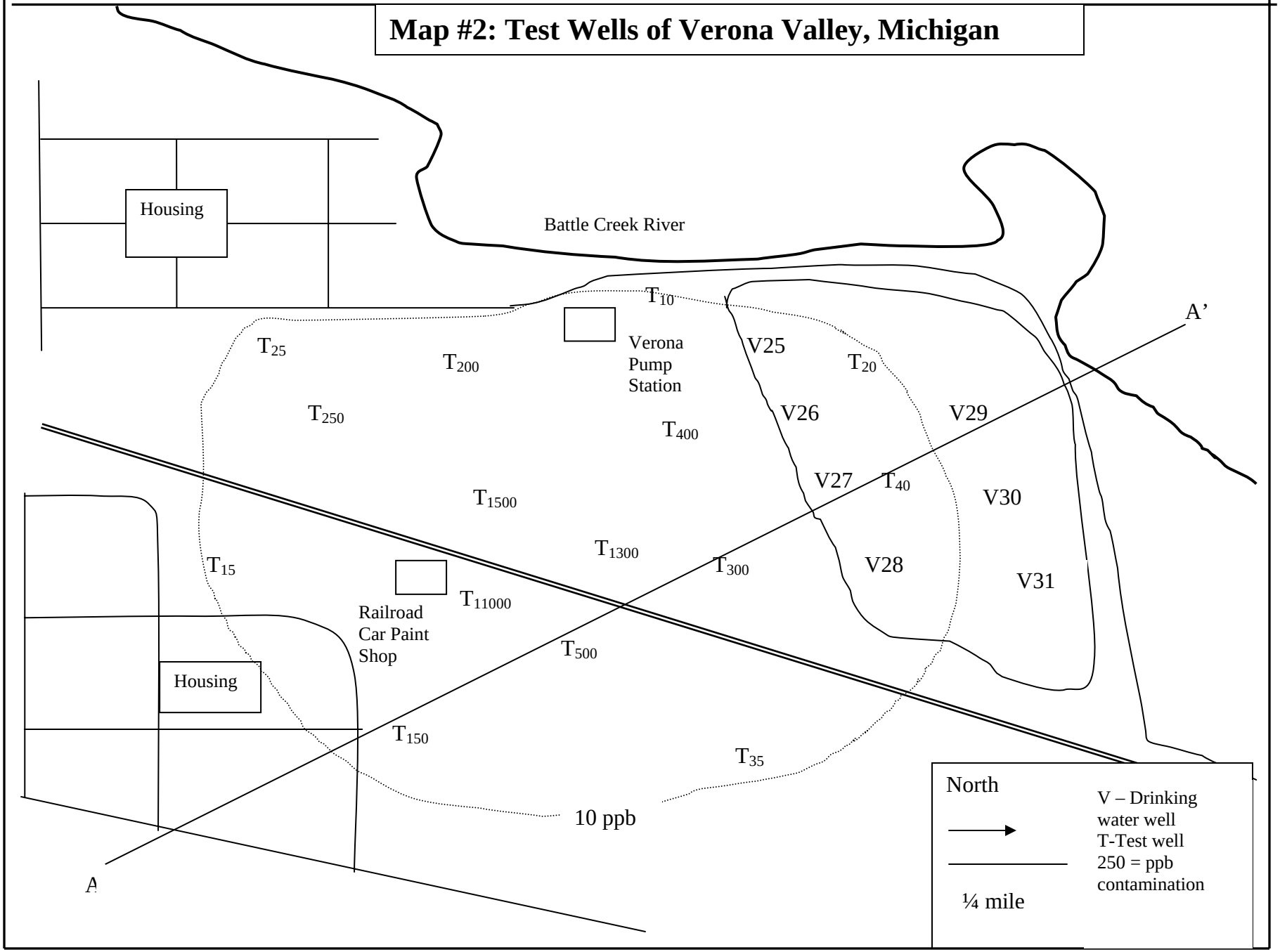
2) If necessary, you may need to refer students to the maps and cross-sections used in activity 5.7 to help them visualize how the different solutions might be applied at Verona Wells.
3) During the reading, you may choose to ask some students to summarize what they just read to either you or their group members. Then, group members can provide additional details to help each other understand the technical aspects of the reading.
4) The last three questions are synthesis and reflection questions. Guide students to put themselves in the shoes of the people who actually live in Verona Valley and help students see that what happened in Verona Valley is neither an isolated nor a unique situation.

Battle Creek Location Map

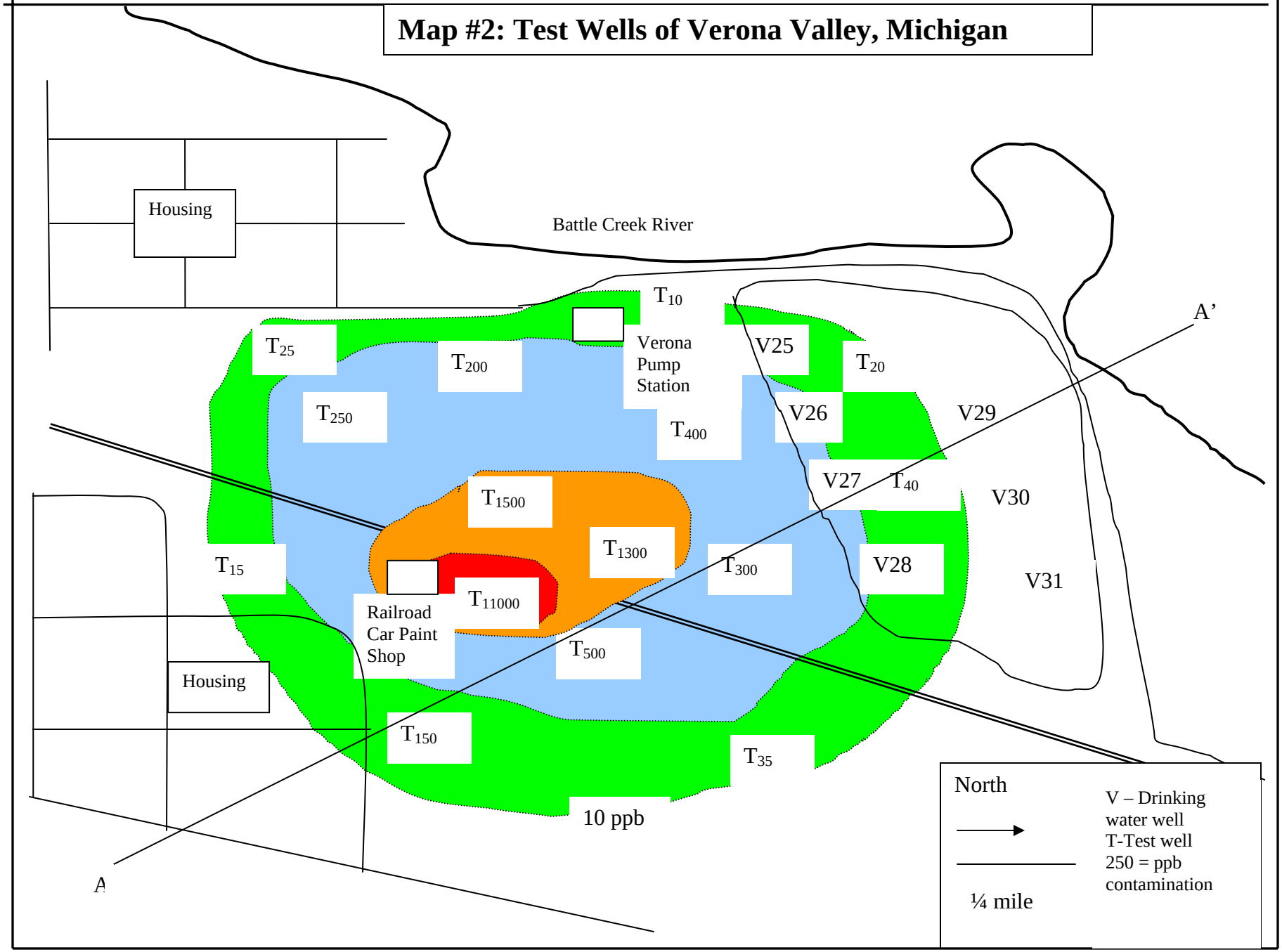


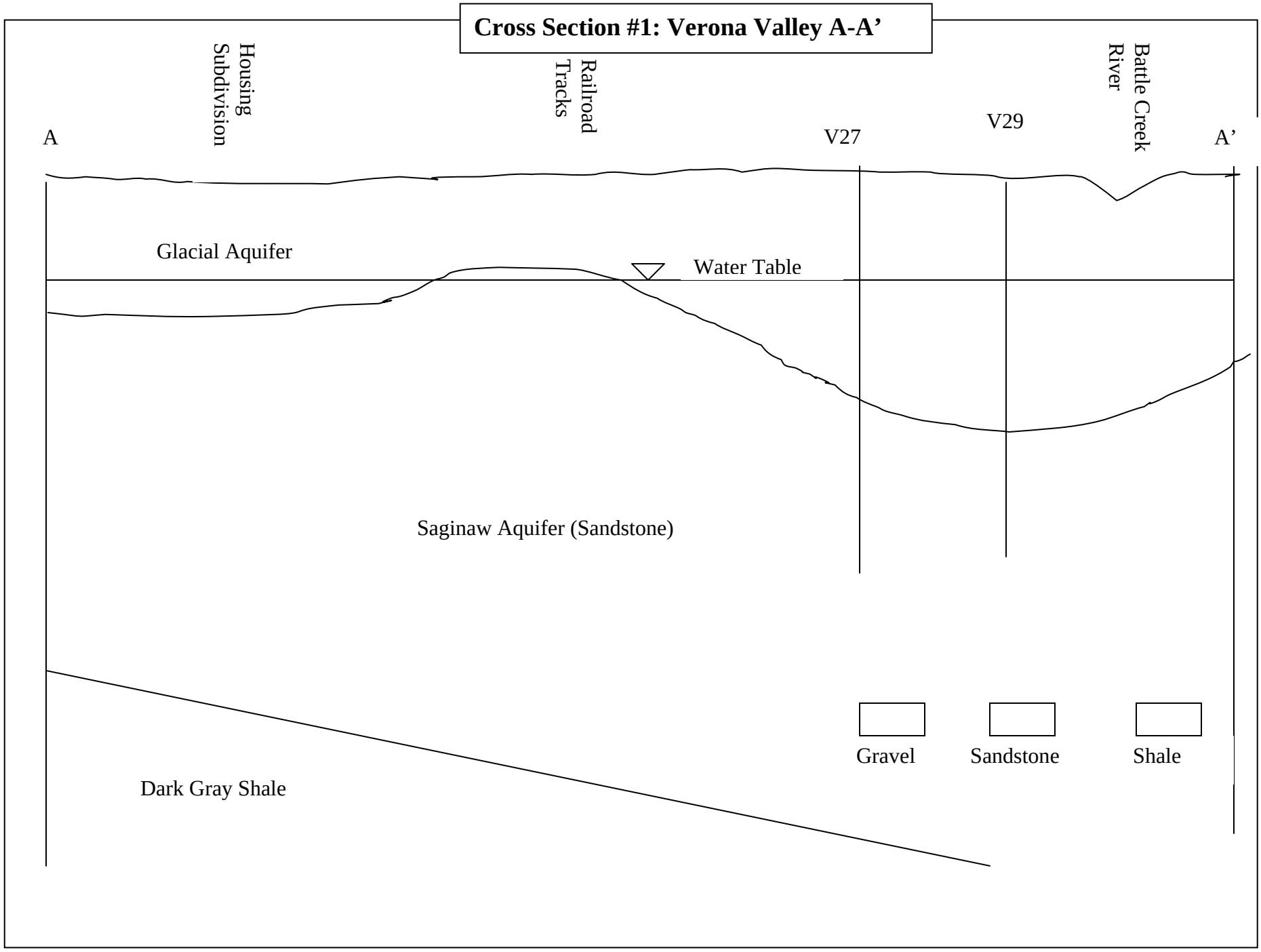

Map#1: Verona Valley, Michigan
Housing
Battle Creek River
Verona
Pump
Station
A'
V25
V26
V29
V27
V30
V28
V31
Railroad
Car Paint
Shop
Housing
A
North
V - drinking
water well
¼ mile

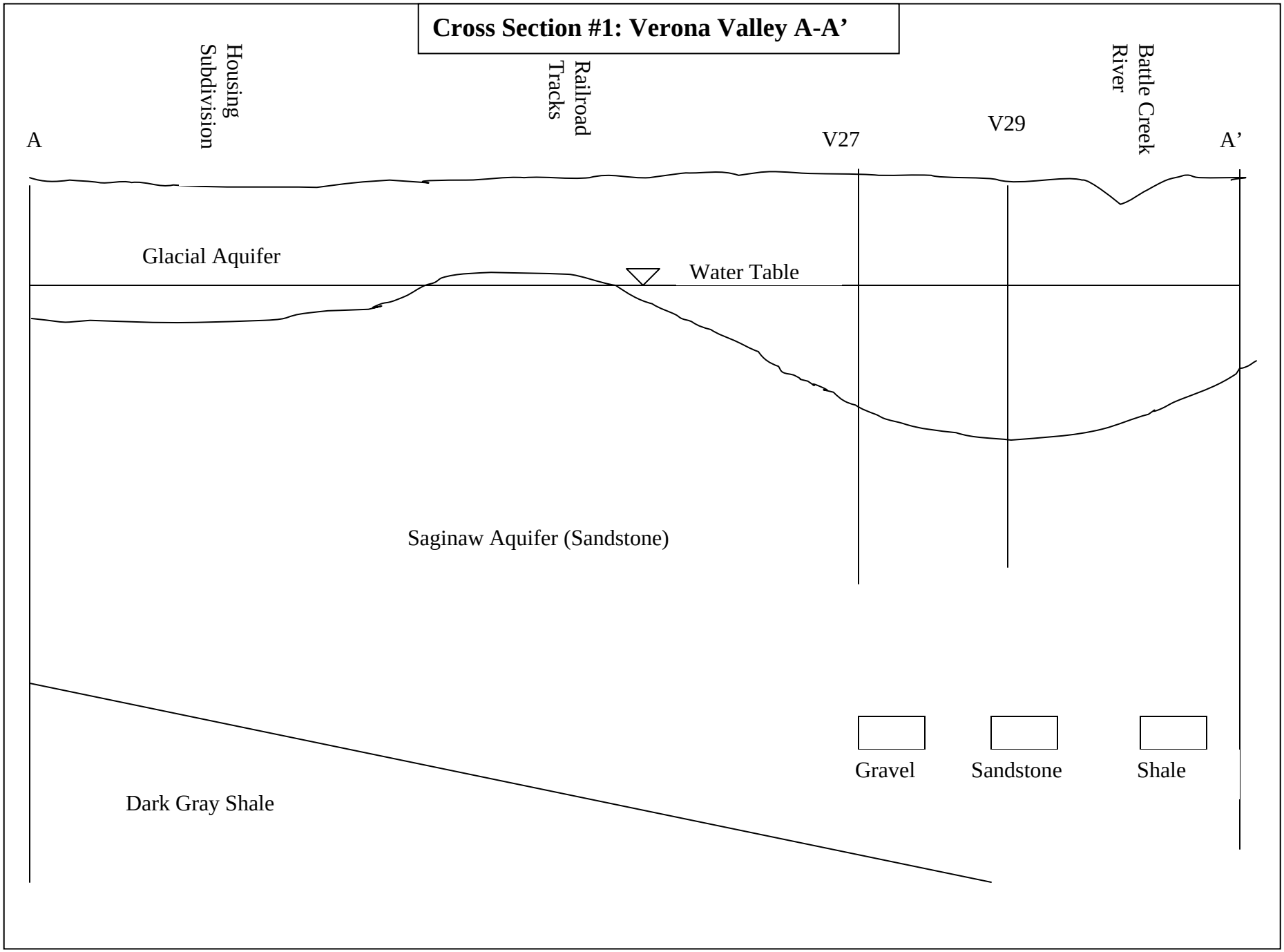
Map #2: Test Wells of Verona Valley, Michigan



Map #2: Test Wells of Verona Valley, Michigan




Cross Section #1: Verona Valley A-A'
Housing Subdivision
Railroad Tracks
Battle Creek River
A
V27
V29
A'
Glacial Aquifer
Water Table
Saginaw Aquifer (Sandstone)
Gravel
Sandstone
Shale
Dark Gray Shale


Cross Section #1: Verona Valley A-A'
Housing Subdivision
Railroad Tracks
Battle Creek River
A
V27
V29
A'
Glacial Aquifer
Water Table
Saginaw Aquifer (Sandstone)
Gravel
Sandstone
Shale
Dark Gray Shale

Name:_____Hour: _____

Lesson #5: Groundwater Pollution

Activity 5.2 - Groundwater Pollution Models

Purpose:
In this activity you will simulate different causes and effects of groundwater pollution using the groundwater models your group constructed previously. You will be asked to predict what will happen after you pollute your model using a particular method, as well as to carefully examine and describe what actually happened.

1. Return to your groups from the previous groundwater model lesson.

2. Select one of the following examples to study. If you have your own groundwater pollution example, you may use it instead, with approval from your teacher.

   A. *Example #1: Fertilizer/Pesticides on Agricultural Fields* - Use colored powdered drink mix to simulate contaminant. Observe the path of the contamination in the model.

   B. *Example #2: Landfill* - Bury a paper towel soaked in colored water. Observe the path of the contamination in the model.

   C. *Example #3: Leaking Underground Storage Tank (Gasoline Station)* - Bury a film canister punctured with holes and filled with colored water. Observe the path of the contamination in the model.

   D. *Example #4: Abandoned Well* - Insert a straw with holes into the model to represent an abandoned well. Pour colored water into the straw to represent pollution. Observe the path of the contamination in the model.

   E. *Example #5: Lagoon or Surface Contamination Model* - Place a paper cup with holes in the bottom on surface of the model. Pour colored water into the cup to simulate pollution leaking out of the old barrels at the paint shop. Observe the path of the contamination in the model.

Name:_____Hour: _____

Use the space below if you need to draw a diagram or to write some pros and cons of each example as you discuss this decision with your group:

3. Which scenario did your group finally decide upon? _____

4. Predict what will happen when you run the simulation your group has chosen. Why do you think this will happen?

What the group member said about what will happen	**Initials**
Example: "I think the colored water will go straight down until it gets to a layer it can't get through. Then it might go to the side or it might stop."	*MP*

Name:_____Hour: _____

5. Draw a picture of what your model looks like now, before you run the simulation. Be sure to include and label the important parts of the groundwater system (aquifers, layers, etc.)

6. Obtain the necessary materials to run your simulation.

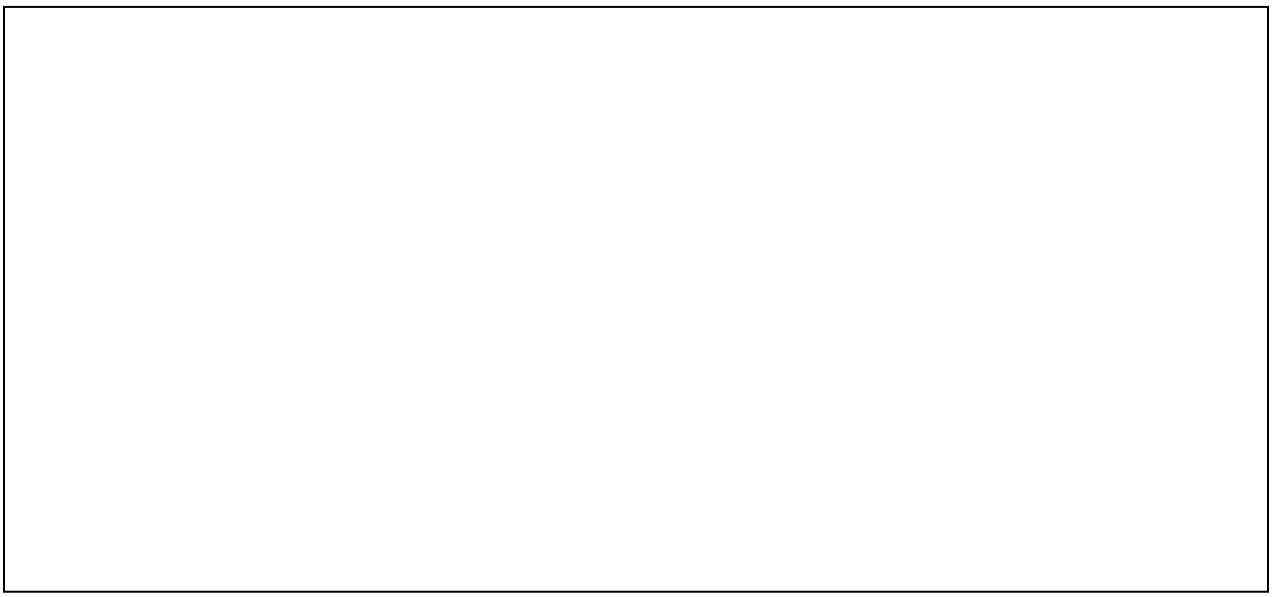
7. Set up your groundwater pollution scenario.

8. Use the rain cup (cup with holes in the bottom) to sprinkle water onto the model and watch what happens. It's important not to flood it, so pour enough water onto your model to make the contamination spread, but not too much!

9. Describe what happened.

Name:_____Hour: _____

10. Draw a picture of what your model looks like now. Use colored pencils to show the contamination.



11. Group Work
    A. Write down one thing your group did well today

    _____

    _____

    B. Write down one thing your group should work on for tomorrow

    _____

    _____

Name:_____Hour: _____

Lesson #5: Groundwater Pollution

Activity 5.3 – Discussion of Clean-Up Methods

Purpose: In this activity, your teacher will lead you in a discussion of what to do with your models now that they are polluted. You are to devise a plan for cleaning them up, and you will implement that plan in the activity following this one.

After you complete this worksheet, all of the members of your group will present your findings from this activity to the whole class.

1. Within your group, develop a plan for cleaning up the pollution. Describe your plan here. Be sure to explain the steps you will take to remove the pollution and what you will do with any contaminated water that you might pump out and any contaminated sediment (sand or gravel) that you might remove from the area.

   _____

   _____

   _____

   _____

   _____

   _____

2. Write some of the things you and your group members said to justify your final decision. If you disagreed with the other members of your group, you can write that in, too:

What the group member said to justify or argue against a particular choice	**Initials**
Example: "Let's add a lot of water, because it will dilute everything, and it's a cheap way of solving the problem."	*MP*

Name:_____ Hour: _____

3. Do you think this plan would be feasible (possible) in real life? Why or why not?

Name:_____Hour: _____

Lesson #5: Groundwater Pollution

Activity 5.4 – Clean-Up of the Models

Purpose: In this activity your group will implement your plan for cleaning the pollution from your models.

1. Obtain the materials to implement your plan.

2. Use your plan to clean-up your model as best you can.

3. Did your plan work? _____ As a group, decide why your plan did or did not work.

   _____

   _____

   _____

   _____

4. Did you try something that you did not plan to do? _____If so, what did you try and why? Be sure to say if your modified plan worked any better.

   _____

   _____

   _____

5. In your group, discuss how your clean-up model is similar to and different from what might happen in real life?

	My Ideas	Other Ideas (from people in my group)
Similar		
Different		

Name:_____Hour: _____

6. Can you imagine this happening in real life? Should people care about pollution? Why or why not? Write what you think (in other words, this is an individual question, not a group question).

_____

_____

_____

_____

_____

7. How could we prevent this sort of pollution and clean-up problem from happening in the first place?

_____

_____

_____

_____

_____

Name:_____Hour: _____

Lesson #5: Groundwater Pollution

Activity 5.5 – Small Group Presentations of Clean-Up Approaches

Purpose: In this activity, each member of your group will have a chance to practice your presentation skills by communicating the group's findings to the rest of the class.

Directions:

1) Your group will present your model, your clean-up plan, and your results to the rest of the class. Each person in your group will help with the presentation.

2) As a group, decide what each of you will say about your model. Your presentation should include the following information:
   A) A description of the pollution example your group chose.
   B) A description of how the pollution moved through the model. In other words, answer the question,"What happened to the pollution?"
   C) A description of the clean-up plan.
   D) An explanation of whether or not the clean-up plan worked and why.

Tips for presenters

It's hard not to notice successful people giving presentations all the time in our society, whether it's sports stars talking to the press after a great game, actors and actresses giving their Oscar speeches, or talented comedians working their magic.

Regular people in regular jobs also present to their co-workers more often than you might think, and it often makes a difference in their careers. Here are some guidelines for making a good presentation:

4) Establish eye contact with many members of the audience.

5) Rehearse what you're going to say before you get up to present – this will make both you and your audience more comfortable. Practicing your opening line a few times will lead you into the rest of the presentation.

6) In a scientific presentation, it can be especially helpful to use drawings, physical models, or other visual aids to engage your audience. Make sure your drawings or models are large enough for the audience to see your ideas.

Name:_____Hour: _____

3. Write out what your presenters should say. As a whole, each presentation should cover at least these points:
    1. Presenter #1: A description of the pollution scenario your group was modeling.
    2. Presenter #2: A description of how the pollution moved through the model. In other words, answer the question, “What happened to the pollution?
    3. Presenter #3: A description of the clean-up plan.
    4. Presenter #4: An explanation of whether or not the clean-up plan worked and why.
    5. Presenter #5: A summary of the above. (If there aren’t five members in your group, one of you should do this.)

1. (Presenter #1): _____

_____

_____

_____

2. (Presenter #2): _____

_____

_____

_____

3. (Presenter #3): _____

_____

_____

_____

4. (Presenter #4): _____

_____

_____

_____

5. (Presenter #5): _____

_____

_____

_____

Tip: Don’t forget to thank your audience for listening!

Name:_____Hour: _____

4. While other groups are presenting, fill in the following table.

Group Number	**Scenario - What were they modeling?**	**Clean Up - How did they try to clean up the pollution?**	**How realistic was the model & why?**
The line below is an example			
Group 7	Abandoned Well	Capped the well. Drilled wells to pump out contamination.	This model did not treat the contaminated water that was pumped out.

5. How well do you feel your group did presenting today? Explain.

_____

_____

Name:_____Hour: _____

Lesson #5: Groundwater Pollution

Activity 5.6 – Introduction to Verona Well Field

Purpose: In 1981, the City of Battle Creek realized that it had a very big pollution problem associated with its wells. Read these articles to find out what the problem was.

Directions:

1. Listen to your teacher's introduction to the Verona Well Field pollution case
2. Read and discuss the questions that follow the article and the letter to the editor. Discuss your answer as a group. Record your answers on this worksheet.

Tainted Water in Tiny Michigan Township

BATTLE CREEK, MICHIGAN – Bill Pritchard's neighborhood in Pennfield Township has always been close-knit. Many of the 500 or so residents have owned their small, older homes for a good number of years. About a third are retired. Most people in the area, called the Verona Valley, just north of Battle Creek, don't hesitate to drop in on each other unannounced.

Circumstances, however, have pulled the residents even closer. Most now bathe not in their own bathtubs, but in two common bathhouses – actually converted trailers – set up last month in a nearby field, or in the showers of a local school. Or, they wash in their homes with bottled water, delivered once a month.

Why? In 1981, when the Michigan Department of Natural Resources tested the well water in the area, it found that more than 20 toxic chemicals, including six suspected of causing cancer, were in the water the residents were drinking.

Like many residents affected by the groundwater pollution, Pritchard, 28, a former government clerk and Verona Valley resident for six years, has come to know intimately such chemicals as TCE.

Pritchard knows them partly because he prints a neighborhood newsletter, *Common Problems*, dealing with the pollution problem. The newsletter details a chemical of the week and also includes news, editorials, and announcements of upcoming environmental meetings. Recently the chemical of the week, which Pritchard may have ingested, was tri-chloro-ethylene: "TCE is toxic, mutagenic carcinogenic and known to cause central nervous system disturbance in humans as well as cause visual, hearing, and respiratory problems."

The city's water comes from the Verona Pumping Station, which sits at the edge of the contaminated neighborhood. It once pumped water from 30 wells, but 10 have been shut down because they were found to have tainted water. Of the 20 remaining wells, 10 have since been found to contain volatile organic chemicals, but the water demand is such that the city and township must still pump water from them. More than 30,000 Battle Creek residents get their water from the station.

(Adapted from a Detroit Free Press article written by Roddy Ray, published August 22, 1983)

Name:_____Hour: _____

A reconstructed letter to the editor from a Verona resident

To the Editor:

I am writing to express my outrage at the situation with the drinking water pollution that affects all of the homes in Verona, Michigan. Not only does the water here taste so bad that we cannot use it for drinking, cooking or even taking a bath, but it has caused serious health problems to many members of this community. For me, the problems are life-threatening–two of my teeth are crumbling, my thyroid doesn't work anymore, and I have liver failure. I'm not the only one with health problems. Several people are now suffering from cancer and plenty of people in my neighborhood are feeling the effects of this water pollution.

How did this problem get started in the first place? The government says that the so-called Environmental Protection Agency is supposed to protect the average Joe from stuff like this, so where were they when our water became polluted? Why do my taxes go to the federal government that doesn't step in when it should? Or maybe they did and it was *local* officials who didn't take the warning signs seriously? I mean, if there are companies that let pollution spill onto the ground over and over, and then the chemicals get into the groundwater, and they continue doing it even after the government warns them – well, you can see why a lot of us are angry.

I've done some reading on the subject, and there are those who say that it's the working class that gets the raw end of the deal. We're the ones who get saddled with the mess, and not just here in Battle Creek and Verona. I'd say it's time someone found out exactly who caused this problem, how far the pollution has gotten, and spend whatever money it takes to clean it up. If you don't agree with me, I invite you to check out my doctor's bills while sipping on a glass of water from my kitchen faucet.

Sincerely,

Erin Vontovich

June 14, 1985

Name:_____Hour: _____

3. Talk about these questions as a group. Write down your own answer after you have heard other people's ideas.

A. How has the pollution of the groundwater changed the lives of the people in Verona Valley? How long has this been going on?

_____
_____
_____
_____

B. Do you know of similar cases where ground water pollution has affected people's lives? How do news stories like this make you feel?

_____
_____
_____
_____

4. Complete the following question as a group:

Imagine that you are a reporter who has been given the job of interviewing people who live in Verona Valley and writing a news story about their pollution problem. Each member of your group should write a question for the residents who were drinking the polluted water. Each of the questions should be designed to obtain information that would help people who don't live there to better understand the pollution problem in Verona Valley.

Question for Verona Valley resident	**Initials**
What government agencies have been involved in helping community members deal with the problem? What have they done?	

Name:_____Hour: _____

Lesson #5: Groundwater Pollution

Activity 5.7 – Verona Wells: Mapping the Problem

Purpose: There was a serious pollution problem in the Verona Valley, but the residents and the government weren't sure where it was coming from, how bad it was, and who was being affected. Your task now is to put yourself in the shoes of the scientists who had to find out as much as possible about the source of the pollution and how much of it there was in different areas.

2) Your teacher will give you two maps that show you the area in the Verona Valley in which the pollution was found. One is a surface map (Surface Map #1) that shows you what you would see from an airplane. The other is a cross section (Cross Section #1) that matches it from a different perspective. Mark each point of interest on the two with the appropriate letter A-F as your teacher points them out to you on the overhead:

   A. Housing subdivision
   B. Railroad Car Paint Shop
   C. Railroad Tracks
   D. Verona Pump Station
   E. Drinking Water Wells
   F. Battle Creek River

   It's true that these points of interest are not the *only* things you would see from the airplane or in a photographic cross-section, but scientists, like detectives, have to focus on what is most likely to be important in figuring out the situation. Please discuss in your group why each of the points of interest above might be important to think about as you try to think like a scientist to figure out where the source of the chemicals that are causing the pollution.

Name:_____Hour: _____

Point of interest	**What the group member said about the importance of the point of interest**	**Initials**
Housing subdivision	*Example:* "It could be that the people who live there are dumping their oil or paint on the ground and it's getting into the groundwater."	*PZ*
Railroad Car Paint Shop		
Railroad Tracks		
Verona Pump Station		
Drinking Water Wells		
Battle Creek River		

3) You should now take a few minutes to brainstorm with your group and report back to the class on this question: What would you need to do, as scientists, to find out more about where the pollution is located underground and how concentrated it is?

_____

_____

_____

4) Your teacher will now give you two additional maps. One is another surface map that shows what the scientists did to get more information that they predicted would be valuable.

Name:_____Hour: _____

Surface Map #2

On Surface Map #2, you can see additional marks on the map from what you saw on Surface Map #1. These marks (the T stands for "testing well") indicate the position of new wells the scientists drilled. The numbers next to the marks indicate the amount of pollution in the water samples they tested from those wells. For example, if you see a mark that says T200, it means that the level of pollution in that sample was 200 parts pollution per billion parts water. If you see a mark that says T1000, that sample had 5 times more pollution.

There's something else that's new on Surface Map #2: the curved line that surrounds all of the drinking wells and the testing wells. This line is called an "iso-concentration line." "Iso" means "same," and what this line shows is where the water samples all had the same amount of pollution. The water samples taken from wells on the inside of that line had more pollution, and the water samples taken from wells outside the line had less pollution.

In other words, an iso-concentration line outlines the level of contamination in a particular area. Samples with more than 10 ppb are of concern because of the accumulated health affects from drinking this water.

5) As your teacher draws in the iso-concentration lines, follow along on your own maps.

6) Color in the areas between the iso-concentration lines with color. Below is a table that shows which colors to use:

Concentration Level	**How much of the pollutant does each liter of water contain?**	**How much in a bathtub full (about 200 liters, or 53 gallons)**	**Color**
Greater than 10,000 parts per billion	More than 10 mg	More than 2000 mg	Red
1,000 – 10,000 parts per billion	1 – 10 mg	200 – 2000 mg	Orange
100 – 1,000 parts per billion	0.1 – 1 mg	20 –200 mg	Blue
100 – 10 parts per billion	0.01 – 0.1 mg	2 – 20 mg	Green

Name:_____Hour: _____

7) Answer the following questions in your group. Write down your group answer.
   A. What do the points on the maps with numbers (for example: **T200**) show you?

_____

_____

_____

   B. How were these points created – what did the scientists do to obtain these numbers?

_____

_____

_____

8) Look at Cross-Section #1. Locate the aquifers, the Battle Creek River, and the Verona Wells.
9) Look at Cross-Section #2. Notice the iso-concentration lines are already drawn on this cross-section. Color in the areas between the lines using the same colors you used on Map #2.
10) Using the data from the map and the cross-section, what patterns do you see?

_____

_____

11) In your group or as a class, answer the following questions.
   A. Where did the pollution come from?

_____

_____

   B. Which way is the pollution moving?

_____

_____

   C. How did the pollution get to the wells?

_____

_____

Name:_____Hour: _____

12) Now that you have seen how some of the important evidence was gathered, please work with your group to fill in the chart to show what you have concluded so far. You may wish to divide up the points of interest so that each person determines the answers for one location. Then, share your information among your group members.

Point of interest	**Contaminated? At what level?**	**How do you know? (Evidence)**	**Initials**
Housing subdivision			
Railroad Car Paint Shop			
Railroad Tracks			
Verona Pump Station			
Drinking Water Wells			
Battle Creek River			

13) How do you think the pollution got to the Verona Well Field Drinking Wells? What is your evidence? Work as a group to come up with an answer.

Source of Pollution	Evidence

14) Grade your work in your group and your group work today

	Grade (A – F)	Reason
My work in the group		
Our group work overall		

Name:_____Hour: _____

Lesson #5: Groundwater Pollution

Activity 5.8 – Groundwater Pollution: Cleaning It Up

Purpose: The residents of Verona Valley now have clean water. However, cleaning it up wasn't easy and there are still some ongoing problems.

Directions:

1. Now that you have seen the extent of the pollution problem in the Verona Valley, it's time to think about how you would go about cleaning it up. Working with your group, think about the ways you cleaned your groundwater models, and how what you found during that activity applies in this case. Remember: you don't have to get every single drop of pollution out of the ground, but the residents are counting on you to make their water safe again!

2. Here is a reminder of some of the clean-up methods you used with your own models:

   A. Pumping
   B. Dig up and remove the contaminated soil.
   C. Bio-remediation - introducing bacteria that can eat up the contaminants
   D. Natural processes - These processes happen naturally, without participation from humans. However, they take place very, very slowly.
   E. Dilution - contamination eventually spreads far enough that concentrations of the contamination are no longer a problem.
   F. Degradation - some chemicals will break down into other chemicals. Sometimes, these new chemicals are less harmful than the original chemical, but not always.
   G. Bio-remediation - much slower than if human induced because the bacteria take a while to find the contamination, if ever.

   Questions to consider as you come up with a solution:

   - *Can a combination of methods give you better results?*
   - *What would be the best choices of methods?*
   - *Why do you think so? What do the others (in the group) think about this?*

Your group solution:

_____

_____

_____

_____

_____

Name:_____Hour: _____

_____

_____

_____

_____

_____

_____

_____

2. Use the space below to draw a diagram that shows the most important aspects of your solution:

3. As a group, explain why your plan would work. Record the initials of each person who contributes to the conversation.

Reasons why this solution could work:	**Initials**

When your teacher tells you it's OK to do so,
Turn the page to find out how the
Verona pollution was actually cleaned-up

Name:_____Hour: _____

Verona Pollution Clean Up – What Actually Happened

Cleaning up the Verona Well Fields has not been easy. The pollution from the Railroad Paint Shop spread a long way before being discovered. There were many different companies and government agencies involved in figuring out how much pollution there was, where it came from, and who was responsible for it. Often, the companies, agencies, and Battle Creek citizens did not agree about what to do. The companies did not want to pay to clean up the mess. The citizens wanted their water to be clean and safe. Sometimes, the citizens did not feel that the government was moving quickly enough to clean up the water.

Question: List three groups that might have different perspectives on how to clean-up the Verona Well Fields:

1. _____
2. _____
3. _____

The Michigan Department of Natural Resources (MDNR) discovered the contamination in 1981. By then, the contamination had spread from the Railroad Paint Shop to the Verona Well Field. These wells supply the public drinking water for the city of Battle Creek. Some people feel that the MDNR should have discovered the pollution earlier. As early as1978 the company that owned the paint shop had been cited for not following state law procedures for transporting and handling hazardous wastes.

Once the contamination was discovered, the city started supplying people with bottled water. Then, in 1984, the United States Environmental Protection Agency (EPA) developed what was supposed to be a temporary plan to protect the well field. The plan was to turn the first 12 city wells, the wells closest to the pollution source, from drinking water wells into *blocking wells*. The water from the blocking wells is pumped out of the ground, treated, and dumped into the Battle Creek River. These blocking wells acted like an underground fence to keep the pollution from spreading to the drinking water wells that are located behind the blocking wells. This solution worked so well that it is still in use today. However, the blocking wells have to be continually monitored because if any of the pumps stop working or if the drinking wells pump more water than the blocking wells, the pollution could still seep past the blocking wells and contaminate the drinking water supply of Battle Creek.

Draw a cross-section picture below of how you think the blocking wells work.

Name:_____Hour: _____

In addition to the blocking wells, there were several other solutions. First, in 1989, a judge ordered the company that owned the paint shop, Thomas Solvent Company, to begin cleaning up their property. The court ordered Thomas Solvent Company to drain and inspect all of its underground storage tanks and prohibited the company from storing any more hazardous chemicals.

Second, the EPA also ordered Thomas Solvent Company to clean up a 3-foot deep layer of contaminated soil from the site. This was very difficult because there were at least 11 toxic chemicals in the soil, six of which are known or suspected to cause cancer. Many of these chemicals can actually vaporize and move from the soil into the air when they are disturbed. The clean-up company had to use a special expensive system, called a *soil vapor extraction system*, to protect the air while they removed the contaminated soil.

Third, the Michigan Department of Natural Resources required that the Thomas Solvent Company install a *purge-well treatment system*. The purge-well treatment system involved drilling wells near the contamination site, pumping the contaminated groundwater out of the wells, and treating the contaminated water.

List three other solutions, besides the blocking wells, used to clean-up Verona Wells. Also explain the purpose of each solution (what did it do, or why was it necessary).

1. _____

2. _____

3. _____

The total cost of the clean up was estimated in 1989 to be $2 million dollars. However, by 2002, over $17 million dollars had been spent on clean up of the site. The Thomas Solvent Company paid some of this cost, but a large part of it was paid for with state and federal tax dollars.

Today monitoring efforts continue. The city no longer supplies bottled water to its citizens. The blocking wells still operate. However, some people are not satisfied that the blocking wells will always work and are still concerned about contamination spreading to the city drinking wells. The State of Michigan estimates that monitoring and maintenance of the clean-up operation will continue for at least another 35 years, the cost to the state is another $35 million dollars.

4. In your groups, discuss the following questions. Write down your own answer to each question after you have discussed it with your group.
   A. Do you think that the EPA and the Department of Natural Resources acted effectively in this situation? Why or why not?

_____

_____

_____

Name:_____Hour: _____

B. Would you be satisfied with the solution if you lived in the Verona Valley? Why or why not?

_____

_____

_____

_____

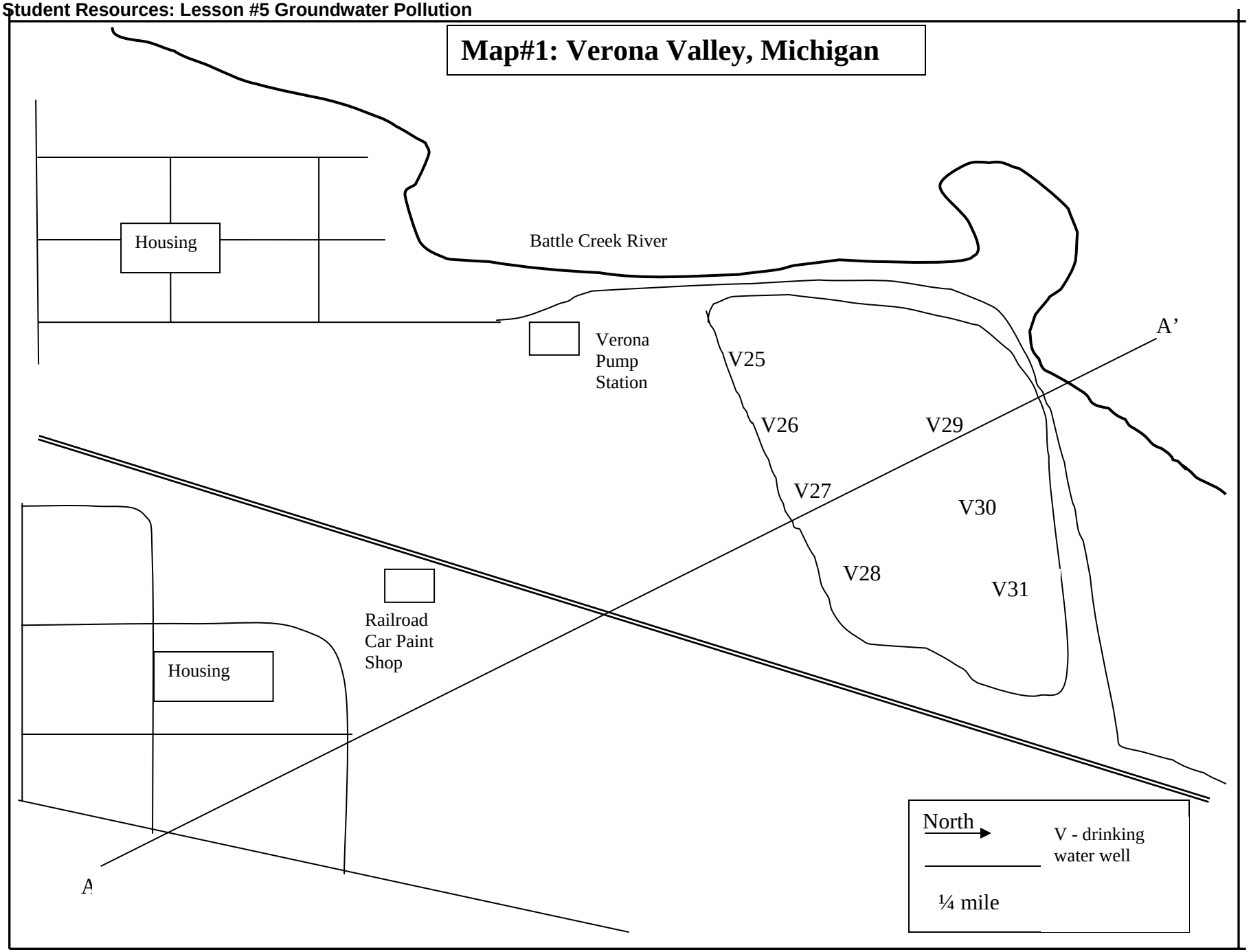
C. Many people may think that what happened in Verona Valley only matters to people who live there. However, a very similar situation exists in Lansing at the Motor Wheel Plant Site. You teacher will provide you with some details of the situation. How do you think what happened in Verona Valley might be relevant to people who live in Lansing?

_____

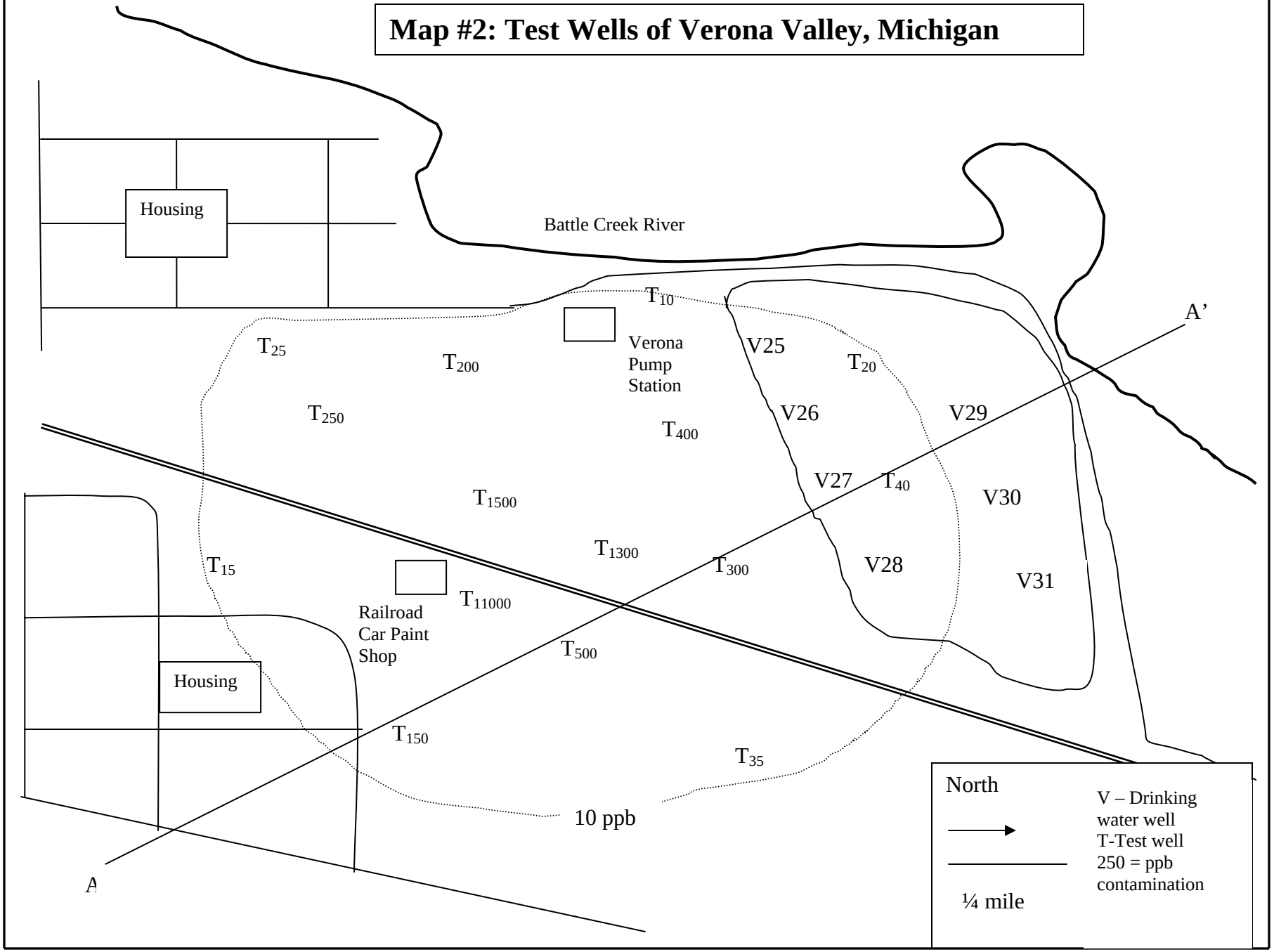
_____

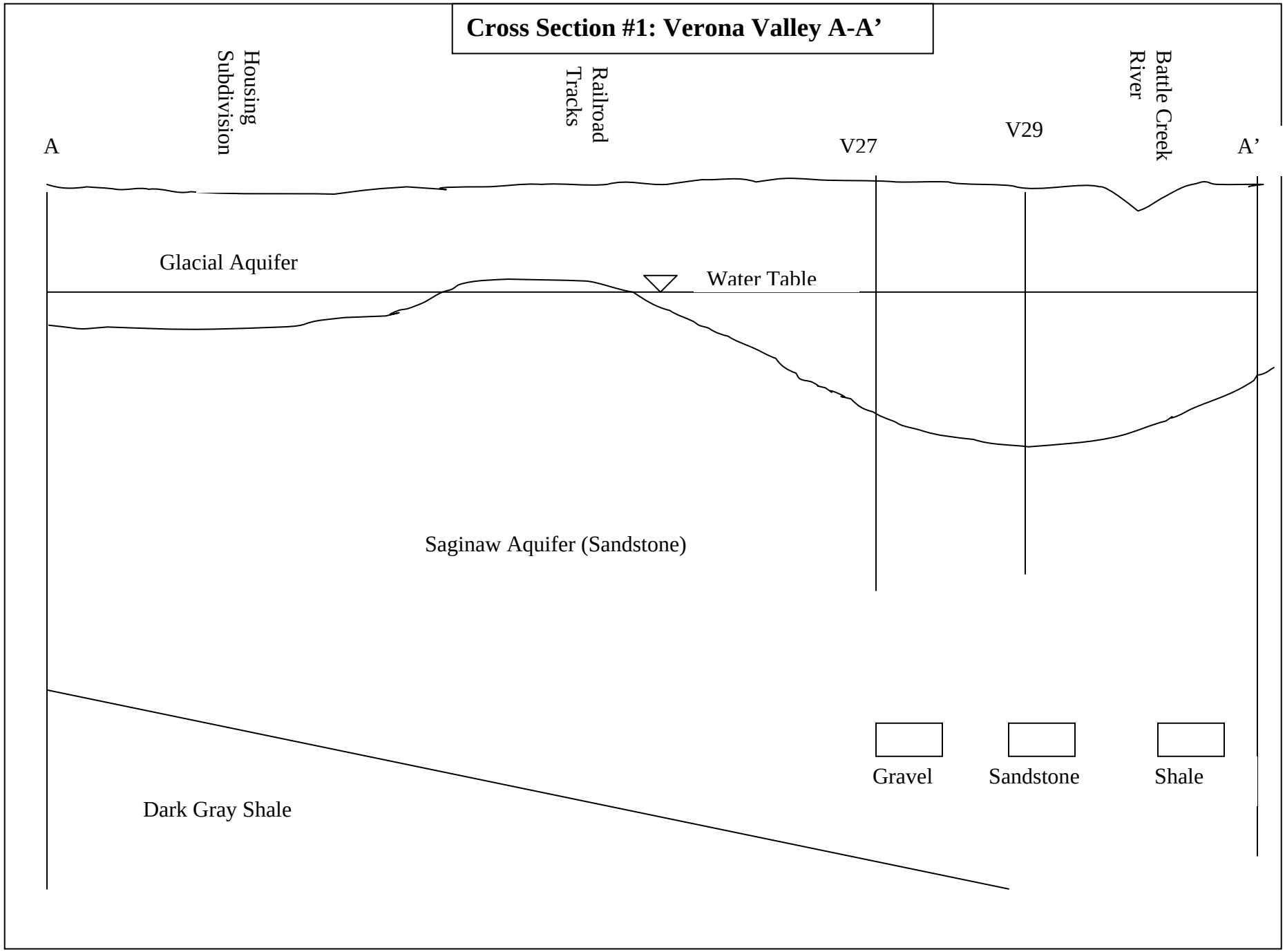
_____

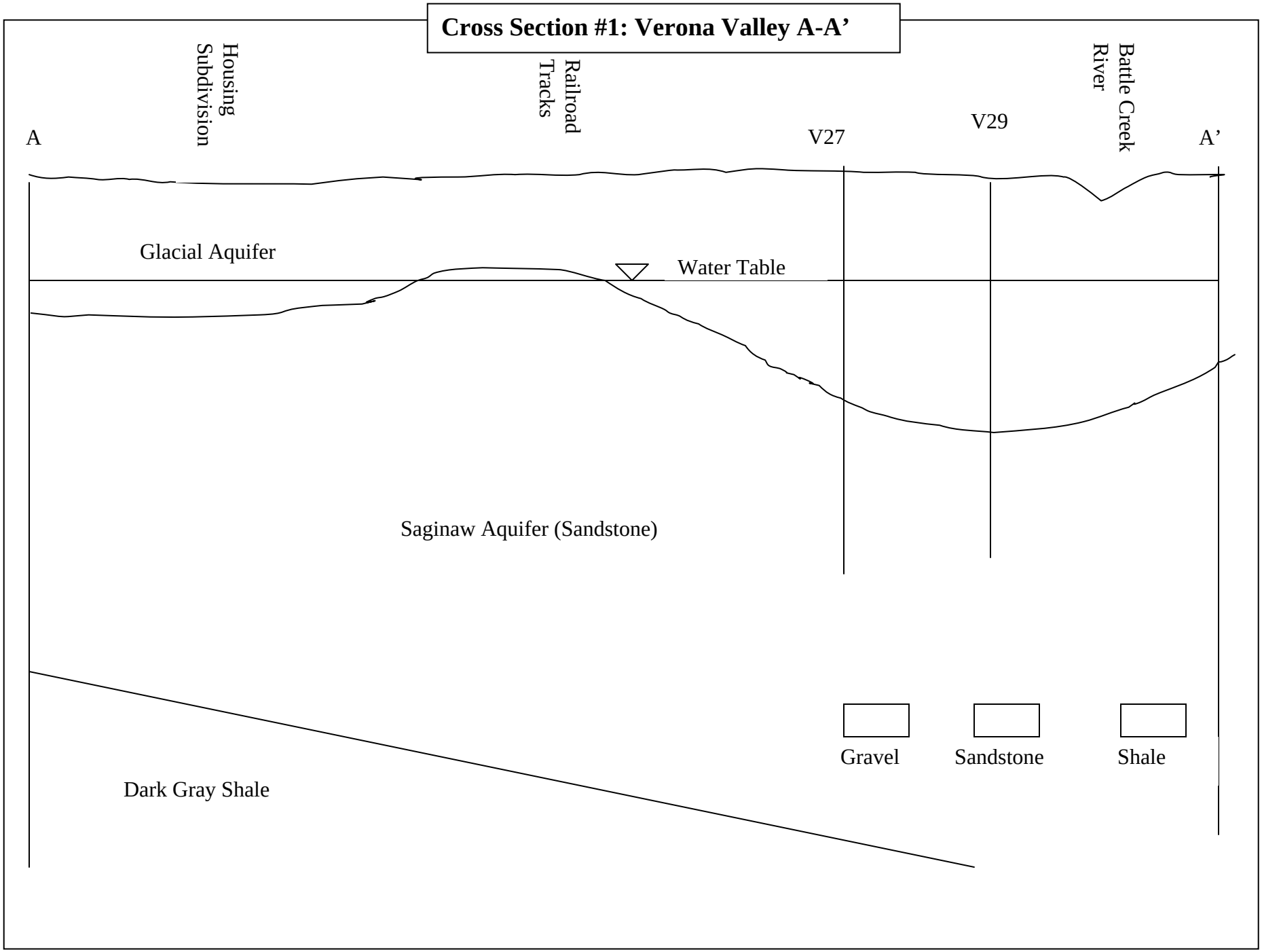
_____


Map#1: Verona Valley, Michigan
Housing
Battle Creek River
Verona
Pump
Station
A'
V25
V26
V29
V27
V30
V28
V31
Railroad
Car Paint
Shop
Housing
A
North
V - drinking
water well
¼ mile

Map #2: Test Wells of Verona Valley, Michigan




Cross Section #1: Verona Valley A-A'
Housing Subdivision
Railroad Tracks
Battle Creek River
A
V27
V29
A'
Glacial Aquifer
Water Table
Saginaw Aquifer (Sandstone)
Gravel
Sandstone
Shale
Dark Gray Shale


Cross Section #1: Verona Valley A-A'
Housing Subdivision
Railroad Tracks
Battle Creek River
A
V27
V29
A'
Glacial Aquifer
Water Table
Saginaw Aquifer (Sandstone)
Gravel
Sandstone
Shale
Dark Gray Shale