Drinking Water Quality and Quantity Concerns On and Near the Farm

Lesson: 8

National Science Education Standards for Grades 9-12

Content Standard F: Science in Personal and Social Perspectives: Natural Resources

- *Human populations use resources in the environment in order to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations.*
- *The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.*

Content Standard F: Science in Personal and Social Perspectives: Environmental Quality

- *Many factors influence environmental quality. Factors that students might investigate include: population growth; resource use; population distribution; overconsumption; the capacity of technology to solve problems, poverty, the role of economic, political and religious views; and different ways humans view the earth.*

Content Standard F: Science in Personal and Social Perspectives: Science and Technology in Local, National and Global Challenges

- *Humans have a major effect on other species. For example, the influence of humans on other organisms occurs through land use—which decreases space available to other species—and pollution--which changes the chemical composition of air, soil and water.*

Student Learning Objectives

8.1 Describe groundwater dynamics that impact water contamination and availability.

8.2 Determine how much local groundwater and surface water is used proportionally by user type.

8.3 Describe the potential for rural land uses to affect the availability of drinking water sources.

Teacher Info Table Time

Instruction time for this lesson: 90 minutes (45 minutes more if you choose to do the "Predicting Groundwater Flow" activity at the end of Objective 8.1)

Resources, Tools, Equipment and Supplies

8.1. Describe groundwater dynamics that impact water contamination and availability.

Resources

- Worksheet SW.8.1.AS – Groundwater Flows; one copy for each student
- Slide SW.8.1.TM.A – Groundwater Contaminant Plume: Gasoline
- Slide SW.8.1.TM.B – Groundwater Contaminant Plume: Fertilizer
- *Underground Storage Tanks*, U.S. EPA, http://www.epa.gov/oust/index.htm

Equipment
Computer
LCD projector
Screen

Supplies
Pencils

Resources, Tools, Equipment and Supplies

8.2. Determine how much local groundwater and surface water is used proportionally by user type.

Resources

- Worksheet SW.8.2.AS – Local Source Water; one copy for each student
- Groundwater Data for the Nation, USGS, http://waterdata.usgs.gov/nwis/gw
- U.S. Groundwater Information, USGS, http://water.usgs.gov/ogw/

Equipment

Students will need access to computer with Internet connection and Excel software

Supplies

Pie chart blanks or materials to create a pie chart (protractor, ruler and paper)

Colored pencils or markers

8.3. Describe the potential for land uses to affect the availability of drinking water sources.

Resources

- USGS Fact Sheet, *Ground-Water Depletion Across the Nation*: http://pubs.usgs.gov/fs/fs-103-03/JBartolinoFS(2.13.04).pdf; one copy for each student

Equipment

Students will need access to computer with Internet connection and Excel software

Key Terms

Aquaculture
Domestic
Flowpath
Industrial
Irrigation
Interaquifer leakage
Karst
Livestock
Mining
Plume
Public Supply
Solution opening
Subsidence
Thermoelectric
Unsaturated zone

SUMMARY OF CONTENT AND TEACHING STRATEGIES:

Groundwater Flows[1]

Groundwater traveling in shallow flowpaths has been in the groundwater system only a few days, weeks, months, years or decades; most of the groundwater that we use is supplied by these shallow flowpaths. Deeper in the aquifer where the groundwater flowpaths are much longer, water may be in the groundwater system decades or maybe even hundreds of years. Even though water may be very old, it is important to understand that very few wells tap water that has been underground since glacial times.

Most people do not realize that groundwater is always moving. It moves very slowly through the small pores or cracks found in the soil and bedrock. Two factors that affect the rate at which groundwater move are:

1) the size of the pore spaces

2) how well the pores or cracks within an aquifer are connected.

The larger the spaces and the better connected those spaces are, the faster water will move. Typically groundwater may only move a few inches to a few feet per day, although in areas where there is fractured bedrock, groundwater may move much quicker.

Groundwater consumers are more at risk if the flow is fast and takes a direct path to the consumer. High risk groundwater passes through the largest openings in the subsurface such as caves, caverns, solution-enlarged fractures or fractures. Where limestone has been dissolved by acid groundwater to form caves or solution-enlarged fractures, this is recognized as karst limestone, the most vulnerable groundwater aquifer type. Where flow is in fractured rocks other than limestone, consumers are more at risk but less than in karst. When flow is slower and less direct (for example because it circulates around the grains in a sandstone), then the aquifer is least vulnerable.

In areas where there are shallow aquifers, groundwater may flow only short distances, a few thousand feet to a few miles. It flows from recharge areas, areas where water infiltrates into the ground, to discharge areas, which are lower points on the landscape where groundwater intersects the land surface and water exits the ground. Examples of discharge areas include springs, streams, rivers, lakes and wetlands.

1 From Dodge County Groundwater: A Community Resource, UW Extension, http://www.uwsp.edu/cnr/watersheds/Reports_Publications/Reports/dodge_gw.pdf

Groundwater Flow and Contamination[2]

To begin addressing drinking water contamination and conservation adequately, we must understand how surface waters and groundwaters interrelate. Groundwater and surface water are interconnected and can be fully understood and intelligently managed only when that fact is acknowledged. If there is a water supply well near a source of contamination, that well runs the risk of becoming contaminated. If there is a nearby river or stream, that water body may also become polluted by the groundwater.

How does groundwater become contaminated?

Depending on its physical, chemical and biological properties, a contaminant that has been released into the environment may move within an aquifer in the same manner that groundwater moves. (Some contaminants, such as bacterial or viral pathogens, because of their physical or chemical properties, do not always follow groundwater flow and can arrive at a well more quickly than the average groundwater flow.) It is possible to predict, to some degree, the transport within an aquifer of those substances that move along with groundwater flow. For example, both water and certain contaminants flow in the direction of the topography from recharge areas to discharge areas. Soils that are porous and permeable tend to transmit water and certain types of contaminants with relative ease to an aquifer below.

Just as groundwater generally moves slowly, so do contaminants in groundwater. Because of this slow movement, contaminants tend to remain concentrated in the form of a plume (see Figure SW.8.1.TM.A and SW.8.1.TM.A on page 21 and 22) that flows along the same path as the groundwater. The size and speed of the plume depend on the amount and type of contaminant, its solubility and density, and the velocity of the surrounding groundwater.

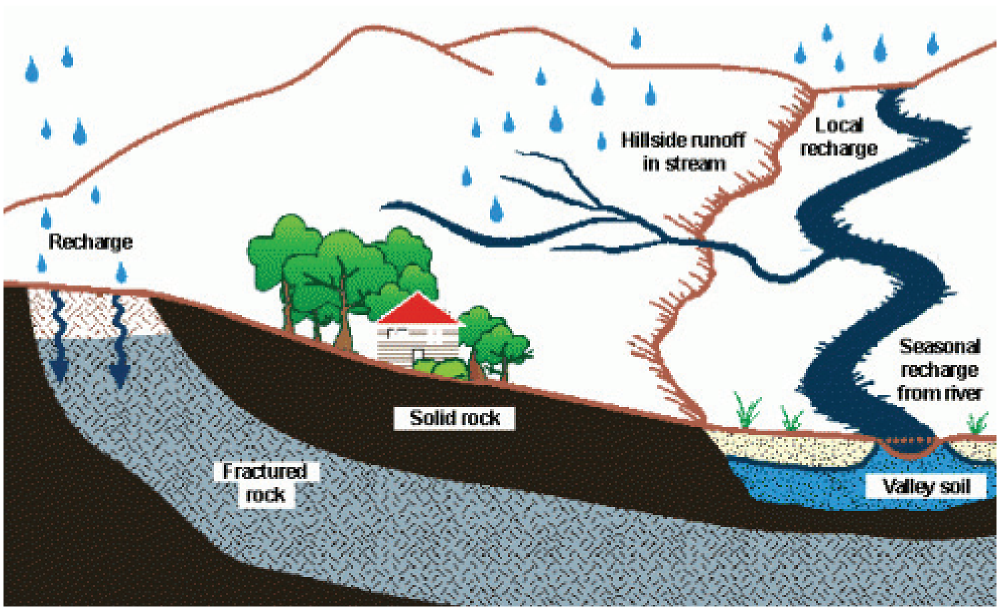
Groundwater and contaminants can move rapidly through fractures and solution openings in rocks. Fractured rock and karst present a unique problem in locating and controlling contaminants because the fractures are generally randomly spaced and do not follow the contours of the land surface or the hydraulic gradient. Contaminants can also move into the groundwater system through macropores—root systems, animal burrows, abandoned wells, and other systems of holes and cracks that supply pathways for contaminants.

2 From Getting Up to Speed: Groundwater Contamination, EPA, http://www.epa.gov/ne/students/pdfs/gwc1.pdf

In areas surrounding pumping wells, the potential for contamination increases because water from the zone of contribution, a land area larger than the original recharge area, is drawn into the well and the surrounding aquifer. Many drinking water wells actually draw water from nearby streams, lakes or rivers. Contaminants present in these surface waters can contribute contamination to the groundwater system. Some wells rely on artificial recharge to increase the amount of water infiltrating an aquifer, often using water from storm runoff, irrigation, industrial processes or treated sewage. In several cases, this practice has resulted in increased concentrations of nitrates, metals, microbes or synthetic chemicals in the water.

Under certain conditions, pumping can also cause the groundwater (and associated contaminants) from another aquifer to enter the one being pumped. This phenomenon is called interaquifer leakage. Thus, properly identifying and protecting the areas affected by well pumping is important to maintain groundwater quality.

Generally for low risk aquifers such as sand and sandstone, the greater the distance between a source of contamination and a groundwater source, the more likely that natural processes will reduce the impacts of contamination. Processes such as oxidation, biological degradation (which sometimes renders some contaminants less toxic) and adsorption (binding of materials to soil particles) may take place in the soil layers of the unsaturated zone and reduce the concentration of a contaminant before it reaches groundwater. Even contaminants that reach groundwater directly, without passing through the unsaturated zone, can become less concentrated by dilution (mixing) with the groundwater. However, groundwater usually moves slowly, and contaminants generally undergo less dilution than when in surface water.



Cite as llustration adapted from "What is Groundwater? by Lyle Raymond, Jr. (© Cornell Cooperative Extension, Cornell University, July 1988).

Land Use and Groundwater Availability

A. Land use effects on drinking water: Each time the use of a land area changes, it can affect the hydrologic makeup of the landscape, and affect surface and groundwater.

 1. Developed land use (residential, commercial and industrial)
    a. Septic systems- may contaminate surface and groundwater by infiltration and percolation to groundwater or runoff. Septic systems are used by homes, offices or other buildings that are not connected to a city sewer system. Septic systems are designed to slowly drain away human waste underground at a slow, harmless rate. An improperly designed, located, constructed, or maintained septic system can leak bacteria, viruses, household chemicals, and other contaminants into the groundwater causing serious problems. (http://groundwater.org/gi/sourcesofgwcontan.html)
    b. Animal waste – watershed runoff or direct contact can introduce wastes into drinking water supplies
    c. Pesticide herbicide application – runoff to surface waters due to rainfall on gardens, lawns, and farms
    d. Fertilizer application – runoff to surface water and infiltration and percolation to groundwater
    e. Storm water runoff – gasoline, oil, automotive fluids, sediment and hazardous waters can enter drinking water and cause gastrointestinal illness, reproductive and developmental effects, and increased cancer risk
    f. Vehicle washing – oil, degreasers, antifreeze may enter drinking water supply through rinse water
    g. Cropland (agriculture) – nutrients from fertilizer, pesticide runoff
    h. Livestock and poultry facilities – sources of nutrients, pathogens and pharmaceuticals from manure, antibiotic-resistant bacteria, litter and dust
    i. Forest land – sediment and attached petroleum materials related to harvesting
    j. Roads – runoff of road salts, oil products, rubber, metal filings (steel, chromium, aluminum, etc.)
    k. Examples of other land-uses that have the potential to directly or indirectly impact the quantity or quality of both groundwater and surface water:
       i. Recreation areas (ski slopes, hiking trails, golf courses, etc.)
       ii. Parking lots

2. Water usage types
    a. Irrigation: Used for growing crops, frost protection, chemical applications and maintain areas such as parks and golf courses
    b. Public supply: Used for domestic, commercial, industrial, thermoelectric or public-use (including recreational)
    c. Industrial: Used for fabrication, processing, washing and cooling. Some industries producing chemical products, food and paper products
    d. Habitat for fish and wildlife

3. Water usage amounts
    a. Thermoelectric: Accounts for about half of total water usage
    b. Irrigation: Accounts for about a third of water usage and is the largest use of fresh water in the United States
    c. Public supply: Accounts for about 11 percent of water use.
    d. Industrial: Use has declined 24 percent since 1985 and in 2000 was at the lowest level since reporting began in 1950

INTEREST APPROACH:

Drawing on their groundwater activities in Lesson 2, students will add new components to their thinking about groundwater – movement and change. Groundwater quality and quantity are in continual flux, changed by both natural and human activity. Students will explore these characteristics in lesson activities. Locating water use data for their own counties will give the students a sense of ownership in the concepts they are acquiring.

A suggestion for getting started:

Start the class off by reading the following scenario to the students:

Imagine it is the middle of summer; you have just come home from a game of basketball with your friends. The only thing you want is a nice cold glass of water. You turn on the faucet and what comes out shocks you. Nothing! Nothing comes out! You try the bathroom and the water isn't working there either. What's going on?

Allow the students to use their creativity to create their own ending to the scenario. Give them two minutes to write their stories in their journals. Once students have created their endings, ask for volunteers to share their ideas with the class.

OBJECTIVE BY OBJECTIVE:

Activity Outline and Teacher Support Information:

Lesson 8, “Drinking Water Quality and Quantity Concerns On or Near the Farm”, brings the science of Lesson 6 to a personal level, giving students local county information to evaluate and compare to their knowledge base. Students will explore rural water users and groundwater dynamics to recognize contaminant plumes.

8.1. Describe groundwater dynamics that impact water contamination and availability.

Ask students to brainstorm ideas about what might affect groundwater availability in rural areas? There are use issues caused by too many users and not enough infiltration. Drought can cause drinking water quantity problems. Contamination caused by humans or natural events (floods, hurricanes, etc.,) can cause drinking water availability issues as well. Even invasive plants can rob the soil of moisture and reduce groundwater recharge. In this activity we’ll examine how contamination can move with groundwater to contaminate wells.

Hand out worksheet SW.8.1.AS and point out the diagram of a regional watershed. Give students a minute to look at the diagram. Ask them not to focus on the labels for a minute, but just on the lines in the diagram. What do all the lines with arrows suggest? – They suggest <u>movement</u>.

Students have already discussed water movement in a watershed in a previous lesson. In this activity they’re going to focus on water movement underground.

Ask the students to read the content of the worksheet. Where in the diagram does it illustrate the discharge of groundwater into surface water resources? Have students circle those areas on their diagrams.

Ask students to imagine that this regional watershed is a local agricultural area. What agricultural activities might occur there? Think about how farmers use water in those activities. What other water users might there be in this watershed (homeowners, gas stations, strip mall, golf course, etc.)?

Students should:

1. Draw some of these water users into their watershed using simple geometric shapes for houses, gas stations, etc.
2. Draw a line from the user straight into the ground to indicate a well. Remember, different users may have wells of different depths depending on the geology of the aquifer.

3. Imagine an underground gasoline storage tank was leaking near one of the surface water divides on either side of the diagram. Draw the location of that leaking underground storage tank in your diagram. How might that contamination affect the water users you've created in the watershed?

Just as groundwater generally moves slowly, so do contaminants in groundwater. Because of this slow movement, contaminants tend to remain concentrated in the form of a plume that flows along the same path as the groundwater. The size and speed of the plume depend on the amount and type of contaminant, its solubility and density, and the velocity of the surrounding groundwater. Draw a plume or area of contamination spreading from your underground storage tank. Will that plume remain in the same place forever? Why or why not? If not, in which direction will it move? How quickly will it move? Would it just affect wells that are very near the leak or might it affect wells in other areas of the watershed? Elicit student responses.

Display slides SW.8.1.TM.A and SW.8.1.TM.B. Ask students to compare their drawings of the contaminant plume with those in slide. Did they show the plume moving in the same direction as the groundwater? If not, ask them to correct their drawings to make them more accurate.

Why should communities be aware of the direction of groundwater flow? By knowing the direction of groundwater flow, communities can map out the land area that recharges their public water supply wells, streams, rivers, lakes, or estuaries. They can then take steps to ensure that land use activities in the recharge area will not pose a threat to the quality of the groundwater and the resources dependent on it. Since contaminants generally move in the direction of groundwater flow, communities can also predict how contaminants might move through the local groundwater system. State geologists (www.stategeologists.org) may have information or may be conducting applicable studies that can help communities assess groundwater movement. State source water protection programs have identified the areas around public water systems that could impact drinking waste quality, and many communities have developed source water protection plans.

If time allows, students can participate in the "Predicting Groundwater Flow" activity provided on p. B-107 of EPA's "Getting Up to Speed, The Water Cycle and Water Conservation": http://www.epa.gov/region1/students/pdfs/gndw_712.pdf. This 45 minute activity provides a basic understanding of how to predict the direction of groundwater flow, as well as an understanding of the interrelated nature of ground and surface waters.

8.2. Determine local groundwater and surface water is used proportionally by user type.

In the previous activity students created a list of water users in a local rural community. In this activity they will examine data to determine with more accuracy who is using water in their community.
Students will access their own county's water use data at the US Geological Survey website, "Estimated Use of Water in the United States County-Level Data": http://water.usgs.gov/watuse/ data/2000/index.html.

Using worksheet SW.8.2.AS, have students research local source water use in their county and create a pie chart of user categories. They will compare groundwater use to surface water use.

If the watershed studied in Lesson 1 crossed the borders of more than one county, split the class up so some are checking those county use statistics as well. Compare the pie charts of both counties. How are they alike? How are they different?

8.3. Describe the potential for land uses to affect the availability of drinking water sources.

Groundwater use has many societal benefits. It is the source of drinking water for about half the nation and nearly all of the rural population, and it provides more than 50 billion gallons per day in support of the nation's agricultural economy. Groundwater depletion, a term often defined as long-term water-level declines caused by sustained ground-water pumping, is a key issue associated with groundwater use. Many areas of the United States are experiencing ground-water depletion.[3] Land use and weather variability can also affect availability of surface water.

Make a copy of the USGS Fact Sheet, "Ground-Water Depletion Across the Nation" (http://pubs.usgs.gov/fs/fs-103-03/JBartolinoFS(2.13.04).pdf) for each student. Students will read the fact sheet to learn about the causes and effects of groundwater depletion nationally. Then, working in small groups, they will search for information about issues related to groundwater availability in their county or state. Encourage them to use the Internet and library resources for their research. They might also want to check with local water experts (state and county agencies, environmental groups, university researchers). Groups will report their findings to the class. Ask them to identify which of the local issues are agriculturally related.

3 Adapted from Ground-Water Depletion Across the Nation, USGS Fact Sheet-103-03, http://pubs.usgs.gov/fs/fs-103-03/JBartolinoFS(2.13.04).pdf

REVIEW / SUMMARY:

In your journal, describe how understanding groundwater movement can help communities assess contaminant threats.

EVALUATION AND ANSWERS:

SW.8.ASSESS

8.1. Review your diagram drawing of the leaky underground storage tank from activity in Lesson 5. Name three factors you would need to know about the contaminants and the groundwater to make this an accurate model of groundwater movement in this particular location.

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8.2. List the water user type in your county that uses the most groundwater in a day and the most surface water in a day.

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8.3. Name two effects of groundwater depletion (national).

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Answers to SW.8.ASSESS

8.1. Contaminant: Amount, type, solubility, density
Groundwater: velocity

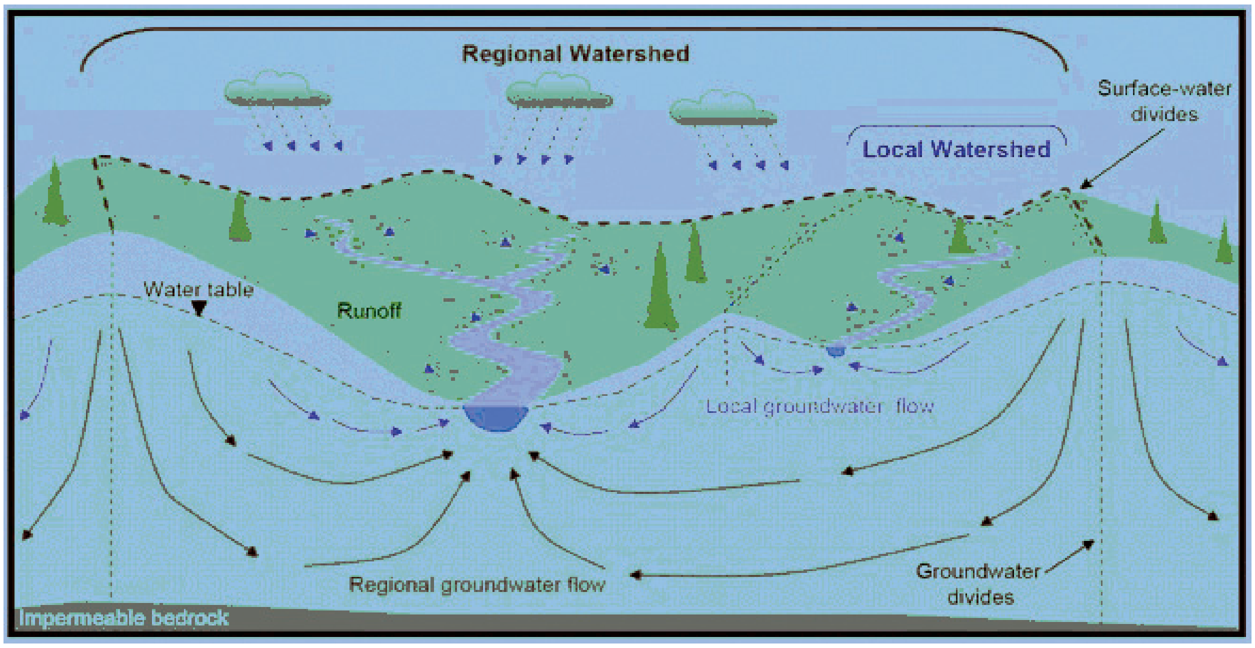
8.2. Will vary by county. Check students' pie charts for answers.

8.3 Acceptable answers: Water well problems, reduced surface water flows, subsidence, deterioration of water quality.

ACTIVITY WORKSHEET(S) – AS NEEDED:

SW.8.1.AS

Groundwater Flows[4]



Most people do not realize that groundwater is always moving. It moves very slowly through the small pores or cracks found in the soil and bedrock. Two factors that affect the rate at which groundwater moves are: the size of the pore spaces and how well the pores or cracks within an aquifer are connected. The larger the spaces and the better connected those spaces are, the faster water will move. Typically groundwater may only move a few inches to a few feet per day, although in areas where there is fractured bedrock, groundwater may move much quicker.

In areas where there are shallow aquifers, groundwater may flow only short distances, a few thousand feet to a few miles. It flows from recharge areas, areas where water infiltrates into the ground, to discharge areas, which are lower points on the landscape where groundwater intersects the land surface and water exits the ground. Examples of discharge areas include streams, rivers, lakes and wetlands.

4 From Dodge County Groundwater: A Community Resource, UW Extension, http://www.uwsp.edu/cnr/watersheds/Reports_Publications/Reports/dodge_gw.pdf

SW.8.1.AS *(continued)*

Groundwater traveling in shallow flowpaths has been in the groundwater system only a few years or decades; most of the groundwater that we use is supplied by these shallow flowpaths. Deeper in the aquifer where the groundwater flowpaths are much longer, water may be in the groundwater system decades or maybe even hundreds of years. Even though water may be very old, it is important to understand that few very deep wells tap water that has been underground since glacial times.

SW.8.2.AS

Local Source Water Worksheet

The purpose of this activity is for you to create two pie charts that indicate surface and groundwater use in your county by different users. You will use data from a 2000 U.S. Geological Survey (USGS) web site to create your charts. You will need an Internet connection, Excel software and this worksheet to proceed. Follow the steps below:

Go to the “USGS Use of Water in the United States County-Level Data”: http://water.usgs.gov/watuse/data/2000/index.html.

Get your county code: Scroll down the page to the “Data Files” section. In the second paragraph, find the link to the “Index of County FIPS Codes.” A list of state names will appear. Click on your state for the list of county codes. Write your county name and code below.

My county name is: ______________________

My county FIPS code is: ________________

Using the back arrow in your browser, return to the “Data Files” section of the USGS site. Click on your state’s county data files link. An Excel file with your county’s data will open. Find your county FIPS code in column C. Highlight that row to help collect the data more accurately. Collect the information listed in Table 1 on the next page.

Make two pie charts, one for groundwater use and one for surface water use. Categories in each chart should be:

Public water supply

Domestic (private well) water supply

Industrial

Irrigation

Aquaculture

Livestock

Mining

Thermoelectric power

SW.8.2.AS *(continued)*

Table 1: My County's Water Use Data			
Column	**FIPS Code**	**Code explanation**	**Value**
E	TP-TotPop	Total population of county, in thousands	
F	PS-TOPop	Public supply, total population served, in thousands	
G	PS-WGWFr	Public supply, groundwater withdrawals, fresh, in Mgal/d	
H	PS-WSWFr	Public supply, surface water withdrawals, fresh, in Mgal/d	
I	PS-WFrTo	Public supply, total withdrawals, fresh, in Mgal/d	
J	DO-SSPop	Domestic, self-supplied population, in thousands	
K	DO-WGWFr	Domestic, groundwater self-supplied withdrawals, fresh, in Mgal/d	
L	DO-WSWFr	Domestic, surface water self-supplied withdrawals, fresh, in Mgal/d	
M	DO-WFrTo	Domestic, total self-supplied withdrawals, fresh, in Mgal/d	
P	IN-WGWTo	Industrial, groundwater self-supplied withdrawals, total, in Mgal/d	
S	IN-WSWTo	Industrial, surface water self-supplied withdrawals, total, in Mgal/d	
Z	IT-IrTot	Irrigation, acres irrigated, total, in thousands	
AA	IT-WGWFr	Irrigation, groundwater withdrawals, fresh, in Mgal/d	
AB	IT-WSWFr	Irrigation, surface water withdrawals, fresh, in Mgal/d	
AD	LA-WGWFr	Aquaculture, groundwater withdrawals, fresh, in Mgal/d	

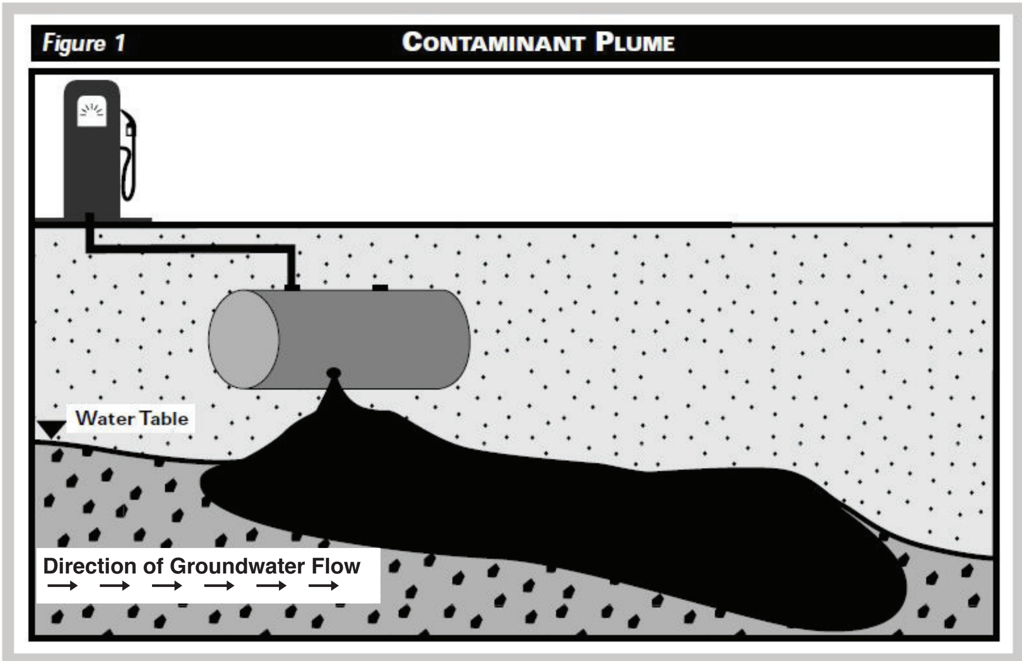
SW.8.2.AS *(continued)*

Table 1: My County's Water Use Data			
Column	**FIPS Code**	**Code explanation**	**Value**
AE	LA-WSWFr	Aquaculture, surface water withdrawals, fresh, in Mgal/d	
AG	LS-WGWFr	Livestock, groundwater withdrawals, fresh, in Mgal/d	
AH	LS-WSWFr	Livestock, surface water withdrawals, fresh, in Mgal/d	
AL	MI-WGWTo	Mining, groundwater withdrawals, total, in Mgal/d	
AO	MI-WSWTo	Mining, surface water withdrawals, total, in Mgal/d	
AS	PT-WGWFr	Thermoelectric power, groundwater withdrawals, fresh, in Mgal/d	
AV	PT-WSWTo	Thermoelectric power, surface water withdrawals, total, in Mgal/d	
BL	TO-WGWTo	Total, groundwater withdrawals, total, in Mgal/d	
BO	TO-WSWTo	Total, surface water withdrawals, total, in Mgal/d	
BR	TO-WTotl	Total withdrawals, total, in Mgal/d	

POWERPOINT SLIDES – AS NEEDED:

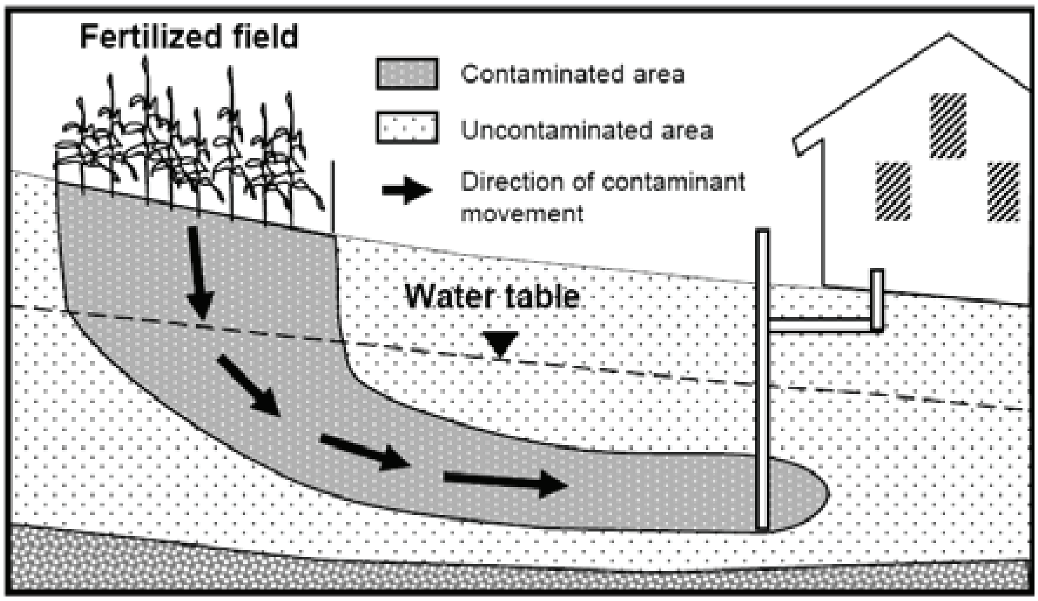
SW.8.1.TM.A

Groundwater Contaminant Plume: Gasoline



SW.8.1.TM.B

Groundwater Contaminant Plume: Fertilizer[5]



5 Dodge county Groundwater: A Community Resource, UW Extension: http://www.uwsp.edu/cnr/watersheds/Reports_Publications/Reports/dodge_gw.pdf