Training About Protecting the Source (TAPS)

A Manual for Hands-on Source Water Protection Education

Second Edition
A publication of the Groundwater Foundation

GROUNDWATER FOUNDATION
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Training About Protecting the Source (TAPS) Manual

Table of Contents

3	Introduction
3	Definition and explanation of source water protection
4	Groundwater basics
5	Overall Activity Description
	Individual Activity Instructions
6	Improperly abandoned wells
8	Sinkholes or land erosion
10	Over-applied fertilizer
12	Leaking underground storage tank
14	Improperly operated landfills
16	Improperly Grouted Hydraulic Fracturing Wells
18	Correlation to Next Generation Science Standards
19	Potential sources of contamination
20	Role of human actions in the protection of groundwater
22	Evaluation
23	Glossary
26	Appendices

About and Definition

ABOUT THE TRAINING ABOUT PROTECTING THE SOURCE (TAPS) MANUAL

The source of what? The source of our drinking water.

Source water is water from streams, rivers, lakes, or underground aquifers that is used to provide drinking water for human consumption for both public and private supplies.

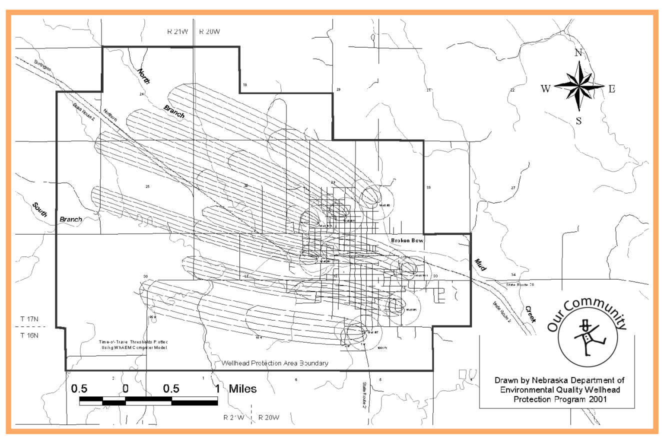
All of us need water, and as such, all of us play a role in protecting it. In order to protect source water, we must first understand it. The Groundwater Foundation developed this manual and its activities to allow you, your students, your community, and your neighbors to appreciate and value the water that is so vital to our existence.

DEFINITION AND EXPLANATION OF SOURCE WATER PROTECTION

Source water is our drinking water. It may be comprised of surface water, groundwater, or a combination of both. For public supply, source water must often be treated prior to entering the home or business for drinking purposes to meet minimum water quality standards and to provide high quality, safe water to consumers. The cost of this treatment, as well as the risk to public health, can be lessened by protecting source water from contamination. The U.S. Environmental Protection Agency (EPA), other federal agencies, states, local communities, businesses, and citizens all play a role in protecting drinking water.

Source water protection is a process that enables citizens to protect local groundwater supplies which serve as a source for drinking water.

Wellhead protection is one tool utilized by communities to protect groundwater used as a source of drinking water.

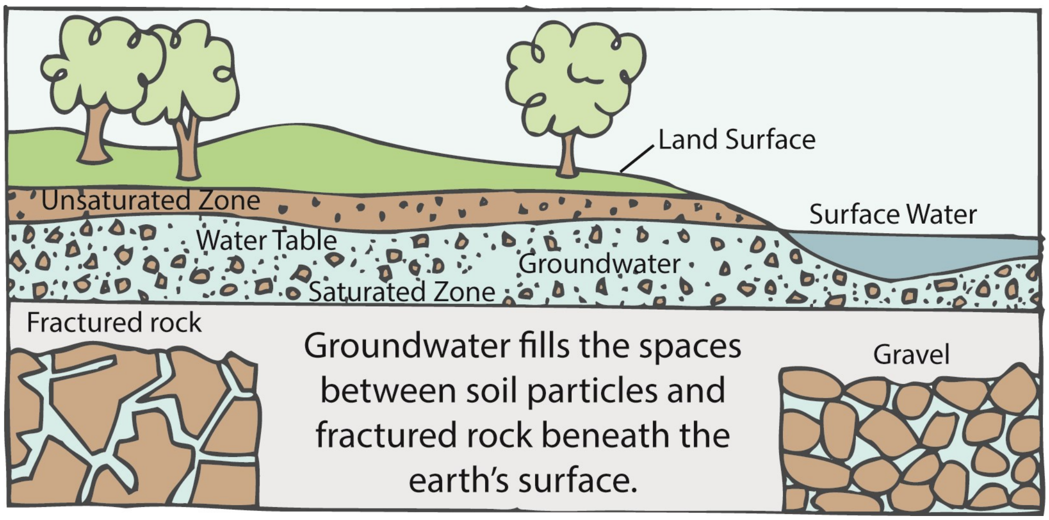


Introduction to Groundwater

Groundwater is an important source of water. Over 50 percent of Americans, including almost everyone who lives in rural areas, rely on groundwater for part or all of their drinking water.

Groundwater is the hidden resource. Groundwater can be equated to water within a saturated sponge and it moves slowly through the pores and cracks in the earth and replenished locally. Most fresh water readily available for human use is groundwater.

Groundwater can be found almost everywhere. Groundwater in aquifers is brought to the



surface naturally through a spring or can be discharged into lakes and streams. Groundwater can also be extracted through wells drilled into an aquifer. A well is a pipe in the ground that fills with groundwater. This water can be brought to the surface by a pump.

Groundwater supplies are replenished, or recharged, by precipitation and snow melt. In some areas of the world, people face serious water shortages because groundwater is extracted faster than it is naturally replenished. Although most of our groundwater supplies are clean, they are vulnerable to contamination from natural and man-made sources.

In areas where material above the aquifer is permeable, meaning water can move through it, pollutants can readily sink into groundwater supplies. Groundwater can be polluted by landfills, septic tanks, leaky underground gas tanks, overuse of fertilizers and pesticides, and improperly grouted hydraulic fracturing, among others. If groundwater becomes polluted, it will no longer be safe to drink. Because of its importance as a source of drinking water, learning how to protect groundwater is essential.

Overall Activity Description

The TAPS activities use the Groundwater Foundation's Awesome Aquifer Kit (www.awesomeaquifer.com) to demonstrate various aspects of potential groundwater contamination. Activities in this manual can also be implemented utilizing your own materials.

The following activities build upon the activities that are included in the Awesome Aquifer curricula. It's best to introduce students to basic groundwater concepts prior to introducing the source water protection aspects of TAPS.

TAPS can be presented in various ways:

1. Divide students into small groups of three to four. Assign each group to one of the five TAPS activities. Students follow the instructions and develop a model of the concepts displayed in the activity. Once the students have developed their model and understand the relationships between the concepts involved, they present the activity to the rest of the class and share what they've learned. This method of learning and then teaching others about what you have learned has been found to be a very effective way of allowing students to really understand the concepts.

2. Each student or student group works through each activity. Activities build upon each other and all the students work through the concepts consecutively.

The Awesome Aquifer Kit is an all-in-one aquifer model-building kit. Find out more and how to get yours at AwesomeAquifer.com.

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Improperly Abandoned Wells

Introduction: It is not uncommon to find old wells which are either out or service or no longer usable. These are called abandoned wells. While some abandoned or forgotten wells can pose risks to the physical safety of people, livestock, or equipment, abandoned wells can also become a direct channel for pollutants such as fertilizers, pesticides, and other chemicals to flow directly into groundwater, which may be your source of drinking water. It is required that these wells be sealed, or decommissioned according to state guidelines.

Duration: 15 minutes

Objectives: Demonstrate how an abandoned well can contribute to groundwater contamination.

Activity Supplies:

- Awesome Aquifer Kit
    - Plastic box
    - Gravel
    - Plastic tube
    - Clay
    - Nylon
    - Rubber band
    - Food coloring
- Aluminum Foil (heavy duty recommended
- Pencil
- 16 oz cup of water

Activity Steps:

1. Read through all the instructions first before you begin to build the model. Make sure you have all the needed materials and supplies.
2. Prepare your materials by filling the plastic box with gravel until it is about ¼-½ full and, if you choose, lightly dyeing the cup of water blue.
3. Add 1/5-1/4 of the water to the box. Do not fill water to the top of the gravel. (This will represent an aquifer.)

Activity Steps *(continued)*:

4. Create an impermeable, or confining, layer using the foil. This should be approximately the length and width as the inside of container. You can use the lid of the Awesome Aquifer kit as a pattern. Use heavy duty foil or make a double layer of foil.
5. Once you have a piece of foil that fits inside the container, make a mark on the foil about two inches towards the center from one of the short sides of the box. Place the foil on top of the gravel being careful not to puncture the foil.
6. Roll the clay into a long, skinny roll and use it to seal the edges of the foil to the box. You have now created a confined aquifer.
7. Model a well with the plastic tubing by covering one end of the tube with the nylon, securing it with a rubber band.
8. Insert the well (well screen/nylon end first) at the spot marked earlier on the foil. You can use a pencil or pen to puncture the foil in order to get your well inserted.
9. Add more gravel on top of the foil and around the well until the container is about ½-¾ full.
10. Apply colored water to the gravel surface evenly. Make sure to pour the same amount all over the surface and the well.
11. Observe where the colored water travels.

Discussion:

What might the colored water represent? (Potential contaminants such as gasoline, oil, road salt, chemicals, fertilizers, pesticides, etc.)

What happened when you poured the colored water which represents a contaminant on the surface? (It soaks into the ground above and below the impermeable layer.)

Why is the result a problem? (It contaminated the aquifer/groundwater which may be used for drinking)

What could have been done to prevent this from happening? (Cap the well, also make sure the well is not located close to hazardous activity.)

Sinkholes

Introduction: A sinkhole is a depression that is formed as underlying limestone or a similarly soft rock is dissolved by groundwater. Typically, sinkholes form slowly so that the top layer of land stays intact for a while after the rock below dissolves. Sinkholes vary greatly in area and depth and can be small and shallow or they may be very large. Sinkholes form a direct path to groundwater through which contaminants can easily enter.

Duration: 15 minutes

Objectives: Demonstrates how sinkholes form, allowing first-hand understanding of the challenges that go along with the occurrence of a sinkhole.

Activity Supplies:

- Awesome Aquifer Kit
    - Plastic box
    - Gravel
- Sugar Cubes (at least 12 per model)
- Small plastic toy animal or house (optional)
- 16 oz cup of water, slightly above room temp

Activity Steps:

1. Read through all the instructions first before you begin to build the model. Make sure you have all the needed materials and supplies.
2. Fill the plastic box with gravel until it is about ¼ full.
3. Add water about ½ of the way up the gravel. Do not fill water to the top of the gravel. (This will represent an aquifer.)
4. Place sugar cubes on the gravel, next to one side of the plastic box. The sugar cubes should be at least three cubes across, two cubes wide, and two layers deep. The sugar cubes simulate layers of limestone.
5. Add more gravel on top to cover the sugar cubes completely. You can either create a hill over the sugar cubes or continue to add gravel so that surface of the model is level.
6. If you have a small plastic toy animal or house, place it on top of the gravel directly above the sugar cubes.
7. Pour or spray water (preferably warm water) over the buried sugar cubes to simulate rain. Watch and wait.

Discussion:

What happened when the sugar cubes melted? (the gravel and small toy sunk down)

What did this represent? (the formation of a sink hole.)

What did the sugar cubes represent? (a limestone or other easily dissolved geological layer)

Why do sinkholes occur? (Too much pumping, land stressed due to development, land use, or construction)

Over-Application of Fertilizer

Introduction: Fertilizers promote plant growth and green lawns by helping plants meet their nutrient needs, primarily for nitrogen, phosphorus, and potassium. Plants, however, are limited in the amount they can absorb and use. Fertilizers applied in excess can soak down into the groundwater or run off into surface water bodies. This pollution of surface and groundwater can impact our drinking water supplies.

Duration: 15 minutes

Objectives:

Demonstrates the impacts of excessive fertilizer use to groundwater supplies.

Activity Supplies:

- Awesome Aquifer Kit
    - Plastic box
    - Gravel
    - Plastic tube
    - Hand pump or syringe
    - Nylon
    - Rubber band
- Powdered drink mix (i.e. KoolAid)
- 16 oz cup of water

Activity Steps:

1. Read through all the instructions first before you begin to build the model. Make sure you have all the needed materials and supplies.
2. Fill the plastic box with gravel until it is about ¼ full.
3. Add water so that half of the rocks are covered. (This will represent an aquifer.)
4. Create a well by covering the end of the plastic tube with nylon, securing it with a rubber band.
5. Insert the well, with the well screen on the bottom, near one corner of the plastic box. Push the well down so that it reaches the bottom of the model.
6. Add more gravel until the box is about ½-¾ full. The surface of the gravel should be fairly level across the box.

Activity Steps *(continued)*:

7. Sprinkle ½ a packet, about 1 tablespoon, of powdered drink mix (i.e. Kool-Aid) on the surface of the gravel to simulate fertilizer.
8. Pour water on the surface of the gravel to simulate rain.
9. Make observations
10. Pump the well by inserting the tip of the syringe into the well (plastic tube) or attaching and pumping the hand pump.
11. Observe what happens to the fertilizer and water when the well is pumped.

Discussion:

What happens to the fertilizer when it rains? Can you see it infiltrate the ground? (Soaks into the earth and potentially into the groundwater.)

What happens when the well is pumped? (The fertilizer moves towards the well.)

What color is the water that is pumped out? Does it change as the well is pumped? (The water may be clear at first and will eventually change to the color of the powdered drink mix.)

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Leaking Underground Storage Tank

Introduction: An underground storage tank system (UST) is a tank and any underground piping connected to the tank that has at least 10 percent of its combined volume underground. Underground storage tanks can contain fuels, chemicals, and wastes. According to the US Environmental Protection Agency there are over 550,000 underground storage tanks that store fuels or other hazardous substances. These tanks may leak and when they do, they can contaminate surrounding soil, groundwater, surface waters, and even affect indoor air quality.

Duration: 15 minutes

Objectives: Demonstrates how leaking underground storage tanks impact groundwater supplies.

Activity Supplies:

- Awesome Aquifer Kit
    - Plastic box
    - Gravel
    - Plastic tube
    - Hand pump or syringe
    - Nylon
    - Rubber band
    - Food coloring
- Film canister or other small plastic container (ballon/small cup with plastic wrap lid/etc.)
- Thumb tack
- Pencil
- 16 oz cup of water

Activity Steps:

1. Read through all the instructions first before you begin to build the model. Make sure you have all the needed materials and supplies.
2. Fill the plastic box with gravel until it is about ¼ full.
3. Add water so that half of the rocks are covered. (This will represent an aquifer.)
4. Create a well by covering the end of the plastic tube with nylon, securing it with a rubber band.

Activity Steps *(continued)*:

5. Insert the well, with the well screen on the bottom, near one corner of the plastic box. Push the well down so that it reaches the bottom of the model.
6. Add more gravel until the box is about ½-¾ full. The surface of the gravel should be fairly level across the box.
7. Dye about xx oz of water with the food coloring and use it to fill the film canister (or other small container). Seal the cannister when full.
8. Using a tack, carefully poke holes in one end of the film canister or container.
9. Dig a small hole in the gravel on the opposite side of the model from the well. Place the canister/ container inside the hole. The end of the cannister with the holes poked in it should be facing down. Cover the cannister, either partially or entirely, as long as at least 10% of it is underground.
10. Pour water on the surface of the gravel to simulate rain.
11. Observe what happens to the colored water inside the storage tank after it rained.
12. Pump the well by inserting the tip of the syringe into the well (plastic tube) or attaching and pumping the hand pump.

Discussion:

What happens when it rained? (The rain washed the colored water leaking from the film canister into the groundwater.)

How does the contaminant react? (The contaminant infiltrated down into the groundwater.)

What happens when you pump the well? (The contamination moved towards the well eventually being pumped out.)

Why are leaking underground storage tanks a potential problem? (They are out of sight and may be forgotten about and could lead to groundwater contamination.)

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Improperly Operated Landfills

Introduction: A municipal solid waste landfill (MSWLF) is an area of land that typically receives household waste and sometimes can receive other types of nonhazardous waste, such as commercial solid waste, nonhazardous sludge, and industrial nonhazardous solid waste. According to the EPA, there are approximately 2,000 MSWLFs in the U.S. that are managed by the states in which they are located. When rain, snow, or runoff water soaks into and through a landfill, it can dissolve some of the landfill's contents and, in an improperly constructed or operated landfill, carry it on down to the groundwater. This mixture of recharge and particles from the landfill's contents is called leachate. As the amount of waste increases, the potential for leachate to enter the groundwater increases.

Duration: 30 minutes

Objectives: Demonstrates how leachate from an improperly constructed or operated landfill can affect groundwater in the area around a landfill.

Activity Supplies:

- Awesome Aquifer Kit
    - Plastic box
    - Gravel
    - Plastic tube
    - Hand pump or syringe
    - Nylon
    - Rubber band
- 2 inch square piece of dyed paper towel (prepped at least 24 hours in advance)
    - Dip a paper towel in/or spray with slightly diluted food coloring (2 drops of dye per ounce of water)
    - Allowed to dry completely.
- 16 oz cup of water

Activity Steps:

1. Read through all the instructions first before you begin to build the model. Make sure you have all the needed materials and supplies.
2. Fill the plastic box with gravel until it is about ½ full.
3. Add water so that half of the rocks are covered. (This will represent an aquifer.)

Activity Steps *(continued)*:

4. Create a well by covering the end of the plastic tube with nylon, securing it with a rubber band.
5. Insert the well, with the well screen on the bottom, near one corner of the plastic box. Push the well down so that it reaches the bottom of the model.
6. Take the colored piece of paper towel, scrunch it up, and bury it on the opposite side of the model from the well location and near the outside of the box. (This is your landfill.)
7. Pour water on the surface of the gravel to simulate rain.
8. Observe what happens to the landfill and groundwater after it rained.
9. Pump the well by inserting the tip of the syringe into the well (plastic tube) or attaching and pumping the hand pump.

Discussion:

What happens to the landfill when it begins to rain? (The landfill's contents – paper towel- begins to get wet and the color leaches out of the "waste" into the soil, eventually soaking down into the groundwater)

What happens when the well begins to pump? (The contamination moves towards the well.)

How could the contamination been prevented? Model this. (Properly line and manage the landfill and keep potentially hazardous materials out of the landfill.)

What else can be done to prevent this problem? (Recycle, properly dispose of hazardous waste such as pharmaceuticals, paint, oil, cleaners, computers, batteries.)

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Improperly Grouted Hydraulic Fracturing Wells

Introduction: Hydraulic fracturing, commonly referred to as "fracking", breaks up the ground deep beneath the surface in order to allow companies to more easily access oil and gas. The technique uses a mixture, or slurry, of water, chemicals, and sand and pumps it into the ground at a very high pressure. Fracking fluids can contain a variety of toxic chemicals such as diesel fuel, acids, and acetone. Federal regulations

Duration: 30 minutes

Objectives: Demonstrates how improper well construction and management in hydraulic fracturing sites can affect groundwater.

Activity Supplies:

- Awesome Aquifer Kit
    - Plastic box
    - Gravel
    - Plastic tube
    - Hand pump or syringe
    - Nylon
    - Rubber band
- Plastic, bendable straw
- Pushpin, thumbtack, or scissors.
- 16 oz cup of water
- Approximately 30 ml of intensely colored water (at least 2 drops in the 30 ml)

Activity Steps:

1. Read through all the instructions first before you begin to build the model. Make sure you have all the needed materials and supplies.
2. Prepare your plastic straw by poking or cutting several holes on the long side.
3. Fill the plastic box with gravel until it is about ¼ full.
4. Create a hydraulic fracturing injection well by securely attaching the straw to the plastic tube with a rubber band. Secure the well screen (piece of nylon) to the end of the straw with an additional piece of rubber band.
5. Place your hydraulic fracturing injection well on top of the gravel. Add more gravel until the box is about ½ full.

Activity Steps *(continued)*:

6. Add water so that half of the rocks are covered. (This will represent an aquifer.)
7. Fill the syringe full of the intensely dyed water, which represents fracking fluid. Attach the full syringe to the well.
8. Pump the fluid into your aquifer by pushing on the plunger. Observe what happens to the fracking well and the water around it.

Discussion:

What happened to the hydraulic fracturing well? (slurry leaks out at seams)

Design a solution to any problems or challenges that arose from the injection well using classroom materials. What materials could be used to solve these problems on a real hydraulic fracturing site? (lower injection pressure, modeling clay around seam between straw and tubing)

Correlation to Next Generation Science Standards

Within the Next Generation Science Standards (NGSS), there are three distinct and equally important dimensions to learning science. Cross-Cutting Concepts, Disciplinary Core Ideas, and Science and Engineering Practices are combined to form each standard—or performance expectation—and each dimension works with the other two to help students build a cohesive understanding of science over time.

Forty-four states, including the District of Columbia, have either directly accepted NGSS or adapted the NGSS framework into their own state standards. To learn more about NGSS, visit: www.nextgenscience.org

ALL ACTIVITIES

MS-ESS3-3
HS-ESS3-1
HS-ESS3-2

SINKHOLES

MS-ESS3-2

IMPROPERLY GROUTED HYDRAULIC FRACTURING

MS-ESS3-1

IMPROPERLY ABANDONDED WELLS

MS-ESS3-4

OVER APPLICATION OF FERTILIZER

MS-ESS3-4

Potential Sources of Contamination

Groundwater contamination occurs when manmade or naturally occurring products and materials such as motor oil, gasoline, solvents, oil-based paints, paint thinner, cleaning chemicals, medicines, fertilizers, pesticides, and road salts get into the aquifer and cause the water it to become unsafe for human consumption. Some of the major sources of these products, are leaking storage tanks, improperly managed septic systems, hazardous waste sites, improperly constructed or operating landfills, and improperly abandoned wells.

Place of Origin	Potential Groundwater Contamination Source			
	Municipal	Industrial	Agricultural	Individual
At or near the land surface	Municipal waste Salt for de-icing streets Streets and parking lot runoff	Chemicals: storage and spills Fuels: storage and spills	Chemicals: storage and spills Fertilizers Livestock waste Pesticides	Fertilizers Home cleaners Detergents Motor oil Paints Pesticides
Below the land surface	Landfills Leaky sewer lines	Pipelines Underground storage tanks	Underground storage tanks Wells: poorly constructed or improperly abandoned	Septic systems Wells: poorly constructed or improperly abandoned

Role of Human Actions in the Protection of Groundwater

Once contaminated, an aquifer can be difficult and expensive to clean up. Prevention of groundwater contamination is simpler and less expensive than remediation. The protection of groundwater quality depends upon everyone's efforts. Here are examples of ways you can help protect groundwater.

AT HOME

- Follow specific chemical, fuel, and hazardous waste storage and disposal instructions. (i.e. don't dump chemicals down the drain or on the ground.)
- Take waste products to a hazardous waste collection site if possible.
- Substitute less hazardous products for use at home when possible.
- Recycle whenever possible to minimize the impact of solid-waste disposal sites.
- Keep your septic system well maintained.
- Have abandoned wells properly decommissioned.
- Manage proper fertilizer applications.

AT WORK

- Follow specific chemical, fuel, and hazardous waste storage and disposal instructions. (i.e. don't dump chemicals down the drain or on the ground.)
- Properly use and maintain onsite septic systems.
- Monitor underground fuel and chemical tanks; if possible, replace to above ground storage.
- Reduce or substitute use of potentially harmful chemicals.
- Use de-icing salt and pesticides sparingly.

You can do your part to reduce threats to source water quality by taking appropriate action at home and at work, and making sure others do the same.

ON THE FARM

Polluted runoff is one of the biggest threats to source water supplies.

- Follow specific chemical, fuel, and hazardous waste storage and disposal instructions. (i.e. don't dump chemicals down the drain or on the ground.)
- Take waste products to a hazardous waste collection site if possible.
- Properly use and maintain onsite septic systems.
- Monitor underground fuel and chemical tanks; if possible, replace above to above ground storage.
- Reduce or substitute use of harmful chemicals.
- Use pesticides sparingly.
- Manage proper fertilizer applications
- Ensure wells are properly constructed and abandon wells properly decommissioned.
- Locate wells up slope and away from sources of contamination.
- Fill sprayers away from wells or other sources of water.
- Ensure proper siting and maintenance of animal enclosures.

IN TOWN

- Ensure that land use plans and regulations protect water supply aquifers and well fields.
- Support protection legislation and programs.
- Inform and educate the community about groundwater.
- Monitor and inspect well fields and recharge areas.
- Conduct household hazardous waste collections.
- Ensure that town facilities practice good pollution prevention.
- Participate in Groundwater Guardian or Groundwater Guardian Green Sites.

Evaluation

Evaluation of this project can be done in a variety of ways. One of the easiest is educator assessment based on the demonstration of the models.

To see if the whole class has grasped the concepts of each model, pre and post testing can be useful. A sample quiz and other and post activity evaluation options are included in this manual's appendix.

Students present an individual TAPS activity to the larger group. This is one option for evaluating the TAPS project.

Glossary

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

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

Contaminant: Any substance that when added to water (or another substance) makes it impure and unfit for consumption or an intended use.

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

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

Discharge area: The area or zone where groundwater emerges from the aquifer. The outflow maybe into a stream, lake, spring, wetland, etc.

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

Erosion: The wearing down or washing away of the soil and land surface by the action of water, wind, or ice.

Filtering: The soil's ability to attenuate substances by retaining chemicals or dissolved substances on the soil particle surface, transforming chemicals through microbial biological processing, retarding movement, and capturing solid particles.

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

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

Hydraulic Fracturing: a well stimulation technique involving the fracturing of bedrock formations by a pressurized liquid. The process involves the high-pressure injection of 'fracking fluid' (primarily water, with thickening agents) into a well to create cracks in the deep-rock formations through which natural gas and oil can flow more easily.

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

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

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

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

Karst: A geologic formation of irregular limestone deposits that dissolve forming sink holes, underground streams, and caverns.

Leachate: Liquids that have percolated through a soil and that carry substances in solution or suspension.

Leaching: The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals, or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

Liquid: The part of the hydrologic cycle in which molecules move freely among themselves but do not separate like those in a vapor/gaseous state.

Nonpoint source (NPS) pollution: Pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land use activities which are carried to lakes and streams by surface runoff. Nonpoint source pollution is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants, such as nutrients and pesticides.

Percolation: (1) The movement of water through the openings in rock or soil. (2) The entrance of a portion of the streamflow into the channel materials to contribute to groundwater replenishment.

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

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

Plume: In groundwater a plume is an underground pattern of contaminant concentrations created by the movement of groundwater beneath a contaminant source. Contaminants spread mostly laterally in the direction of groundwater movement. The source site has the highest concentration, and the concentration decreases away from the source.

Point source pollution: Pollutants discharged from any identifiable point, including pipes, ditches, channels, sewers, tunnels, and containers of various types.

Pollution: An alteration in the character or quality of the environment, or any of its components, that renders it less suited for certain uses. The alteration of the physical, chemical, or biological properties of water by the introduction of any substance that renders the water harmful to use.

Precipitation: The part of the hydrologic cycle when water falls, in a liquid or solid state, from the atmosphere to Earth (rain, snow, sleet).

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

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

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

Runoff: Precipitation that flows over land to surface streams, rivers, and lakes.

Septic system: Used to treat household sewage and wastewater by allowing the solids to decompose and settle in a tank, then letting the liquid be absorbed by the soil in a drainage field. Septic systems are used when a sewer line is not available to carry wastes to a sewage treatment plan. Also called an onsite wastewater treatment system.

Soil: The top layer of the Earth's surface, containing unconsolidated rock and mineral particles mixed with organic material.

Source water assessment: A process in which the land area that impacts a public drinking water source is delineated, possible sources of contaminants that could impact that drinking water source are identified, and a determination of the likelihood that the contaminants will reach the drinking water source is made. The federal Safe Drinking Water Act requires states to provide each public water system with a source water assessment. Public water systems are then required to make the assessments available to the public. A community may verify, refine or expand the list of potential contaminants. See source water protection.

Source water protection: Voluntary action taken to prevent the pollution of drinking water sources, including groundwater, lakes, rivers, and streams. Source water protection is developing and implementing a plan to manage land uses and potential contaminants. To be effective, source water protection should be directed to major threats to the drinking water source identified in the source water assessment. As part of the source water protection plan, a contingency plan for use in the event of an emergency is developed. Source water protection for groundwater is also called wellhead protection. See source water assessment.

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

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

Water quality: The chemical, physical, and biological characteristics of water with respect to its suitability for a particular use.

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

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

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

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

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

Withdrawal: Water removed from a surface or groundwater source for use.

Appendices—Sample Quiz

1. T/F: Groundwater is the water located between the particles of soil and rock spaces.
    a. True
    b. False

2. A measure of how acidic or alkaline water is called ________.
    a. pH
    b. turbidity
    c. eutrophication
    d. pollution

3. Pollution discharged from one specific location is called:
    a. Leachate
    b. Microbial Load
    c. Point Source
    d. Plume

4. Permeable materials allow water to easily flow through them. Which of the following is the most permeable material?
    a. sediment with large pore spaces that connect together
    b. sediment with small pore spaces that connect together
    c. sediment with large pore spaces that do not connect together
    d. sediment with small pore spaced that do not connect together

5. What is a porous rock layer underground that is a reservoir for water?
    a. stream
    b. groundwater
    c. aquifer
    d. surface water

6. Well Closure is defined as:
    a. The lid at the top of a well which can be opened and closed as needed
    b. The location of a specific well
    c. The process of sealing a well that is no longer being used to prevent groundwater contamination and harm to people and animals
    d. A protected surface and subsurface zone surrounding a well or well field

7. Define a Watershed.

8. Groundwater reservoirs are recharged primarily by ________.
   a. rain
   b. wells
   c. rivers

9. T/F: Contaminated groundwater can not affect surface waters.
   a. True
   b. False

10. Choose the best definition for: Area of Influence
   a. An area in which productive wells are drilled.
   b. A protected surface and subsurface zone surrounding a well or well field supplying a public water system to keep contaminants from reaching the well water
   c. The land surface overlying the cone of depression
   d. The zone around a well in a confined aquifer that is normally saturated but becomes unsaturated as a well is pumped

Appendices—Sample Quiz {Answers}

1. T/F: Groundwater is the water located between the particles of soil and rock spaces.
    - **a. True**
    - b. False

2. A measure of how acidic or alkaline water is called ________.
    - **a. pH**
    - b. turbidity
    - c. eutrophication
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    - **d. The process of sealing a well that is no longer being used to prevent groundwater contamination and harm to people and animals**

7. Define a Watershed.

The land area from which surface runoff drains into a stream, channel, lake, reservoir, or other body of water.

8. Groundwater reservoirs are recharged primarily by ________.

   a. rain
   b. wells
   c. rivers

9. T/F: Contaminated groundwater can not affect surface waters.

   a. True
   b. False

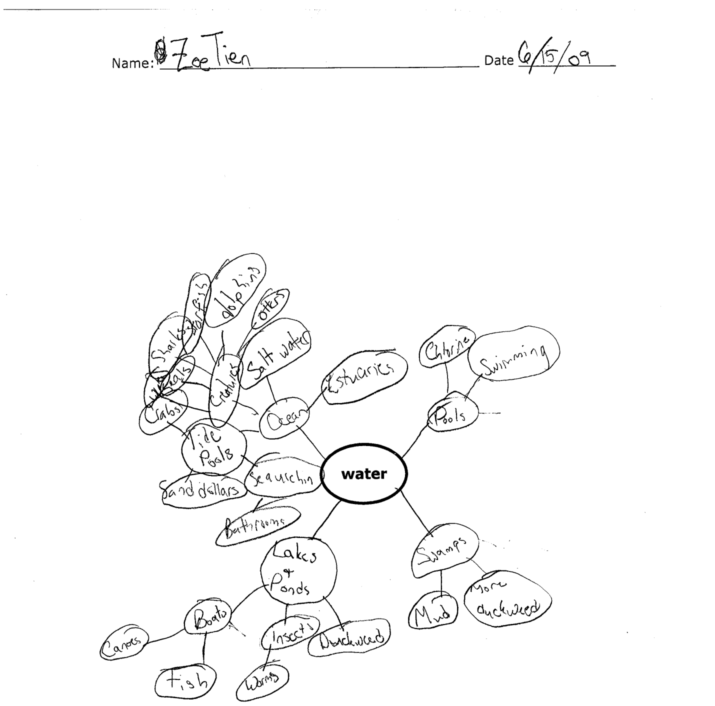
10. Choose the best definition for: Area of Influence

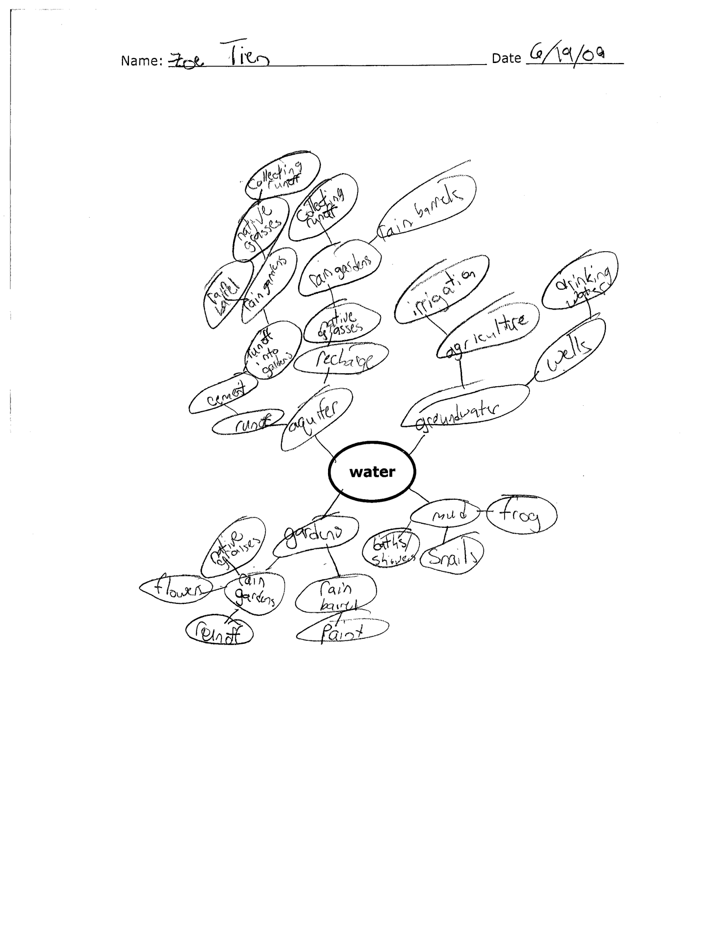
   a. An area in which productive wells are drilled.
   b. A protected surface and subsurface zone surrounding a well or well field supplying a public water system to keep contaminants from reaching the well water
   c. The land surface overlying the cone of depression
   d. The zone around a well in a confined aquifer that is normally saturated but becomes unsaturated as a well is pumped

Appendices—Brain Web {Sample}

Brain webs, or brainstorming webs, are a creative way to evaluate how much students have learned about groundwater. A brain web begins with a core concept and grows as details, ideas, and further concepts emerge. Students can use vocabulary, pictures or diagrams, a variety of colors, and a large blank canvas or paper to lay out what they've learned. Brain webs can help students visualize relationships, compare ideas, and organize thoughts and conclusions.

Below is an example of a brain web about the water cycle.





Training About Protecting the Source: Hands-on Water Education

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Founded in 1985, the Groundwater Foundation is a 501(c)(3) nonprofit organization operated by the National Ground Water Association that connects people, businesses, and communities through local groundwater education and action, making us all part of the solution for clean, sustainable groundwater.

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