

Improving Your Private Well Water Quality

Kevin Masarik

While most private wells in Wisconsin provide water that is safe and good quality, many private well owners may have one or more water quality problems. Some are quite noticeable. Others, particularly those that are health-related, often require testing to detect them. The search for ways to improve water quality can be challenging. This publication describes options for improving private residential well water quality, including water treatment methods.

What's in your water?

Groundwater, the source of water for private wells, is never simply a pure combination of hydrogen and oxygen atoms (H₂O). It naturally contains many impurities, reflecting the composition of the soils, sand, gravel and rock through which it travels. Groundwater contains: 1) dissolved minerals such as iron, calcium, magnesium, bicarbonate, chloride, and sulfate; 2) gases such as carbon dioxide, oxygen and nitrogen; and 3) dissolved organic compounds. As a result of human activity, groundwater can also contain contaminants such as pesticides, nitrate and volatile organic chemicals (VOCs).

Typical concentrations of most impurities are not considered harmful to health, but private well owners may find some of the non-health-related problems objectionable. Too much iron, for example, can discolor laundry or stain fixtures; too much calcium can cause scale to build up in water heaters and plumbing. Improving water quality is more serious if the water contains substances that pose a health concern such as bacteria, viruses, nitrate, metals such as lead or arsenic, pesticides or VOCs.

While private well owners are under no obligation to correct water quality problems, safe drinking water standards are good guidelines for homeowners to determine whether their private well water is safe to drink.

What to do if you have water quality problems

What are the best options available to homeowners who have water quality problems? If your water is persistently contaminated with substances that pose a health concern or the water is extremely objectionable, consider the following options before resorting to water treatment.

Eliminate sources of contamination

When water quality problems are due to human activities, the ideal solution is to eliminate the contamination source. Sometimes the source is local, such as a septic system, an unused well, fertilizers or pesticides, sink holes, a chemical spill, leaking storage tank, or seepage from a barnyard. If you are able to, eliminate the source and water quality should eventually improve through filtration, breakdown of the contaminants, dilution and movement of the contaminants away from your well. Depending on the local geology and type of pollutant, however, the improvement may take far too long—years or decades—and an additional solution may still be required to provide a safe source of water.

Repair or replace the existing system

Correct construction faults. Making sure that your well has a vermin-proof cap and diverting surface water drainage away from the well may both help in some cases. Persistent bacterial contamination or cloudy water may indicate problems such as a cracked casing, poor grout and seals, or rock fractures that allow rapid movement of surface water into the well. Your plumber, well installer, county sanitarian or Wisconsin Department of Natural Resources water supply specialist can help diagnose and correct such problems.

Install a new private well or reconstruct an existing well.

Constructing a new well or reconstructing an existing one may improve drinking water quality when problems are related to land use or limited to a certain part of an aquifer. You may have to change the well location. More likely, you will need to drill and case the existing well to a different depth where the aquifer is less contaminated, or drill into a different, uncontaminated aquifer. It is important to point out that installing a new well does not guarantee better water quality. While you solve one water quality problem, you may exchange it for another. Deeper wells, for instance, may be less influenced by local land-use activities but are more likely to contain higher concentrations of substances such as iron and manganese, which can cause aesthetic problems.

Connect to a public water supply

In some cases, connecting to a public water system is less expensive in the long run than installing a new well. Public wells generally are located and drilled in aquifers where contamination is less likely. New municipal wells must submit a wellhead protection plan to protect the well's recharge area. In addition, municipal water supplies are required to be regularly tested and to meet state and federal water quality standards.

Develop a community water system

If a cluster of private wells develops water quality problems, homeowners may find it less expensive to drill a single new well for all the homes rather than have each homeowner pursue an individual solution. This option should contain some sort of legal arrangement among homeowners in case of property transfer, well testing or problems that require maintenance.

Install a water treatment system

It is important that homeowners realize that no single water treatment system is capable of treating all water quality problems, and that all systems have limitations. You need to match the treatment system to the specific water quality problem(s) you want to remove. Before buying a treatment system, have a chemical analysis of your water performed at a state certified laboratory and then ask several dealers for estimates on systems to remove the *type* and *amount* of contaminant(s) found in your water.

Proper care and routine maintenance are critical to ensuring the device continues to work properly. Weigh all the costs, including that of electricity to operate the device and maintenance costs associated with upkeep or replacement of filters. Remember that the claims of manufacturers and dealers may not always accurately describe what the system will do.

In addition, some systems may require pre-treatment of the water for the device to function properly. You can often lease a unit initially to determine whether it performs properly. Wisconsin has established a product approval program for home water treatment devices. Be certain that the unit you purchase or lease has been approved by the Wisconsin Department of Commerce. If you are not sure, request a copy of the approval letter from the installer or manufacturer.

Understanding water treatment technology

Water treatment devices generally fall into two categories: **point-of-use** and **point-of-entry**. Point-of-use devices are for problems limited to specific uses, such as drinking, since the cost to treat all the water in the house is generally prohibitive. Point-of-entry devices are capable of treating all of the water that is distributed throughout the house. The following is a brief overview of some common water

treatment technologies, how they work and the water quality problems they are designed to treat.



Aeration

Aeration introduces air into water to reduce the concentration of certain dissolved gas contaminants like VOCs, hydrogen sulfide and radon. When air is injected into the water the dissolved gas is released into the atmosphere; the contaminant must be vented to the outside atmosphere to prevent exposure to hazardous substances. Aeration is also a method of oxidation and can be used in conjunction with a particle filter to treat iron and manganese problems (see also "Oxidation").

Activated carbon

Activated carbon or charcoal filters are very popular. The carbon particles contain countless miniscule pores and channels. As water passes through the channels, particles and some types of contaminants are trapped or sorbed by the carbon. Carbon filters remove many general taste and odor problems. They can also be effective at removing some health-related organic and inorganic compounds, including certain pesticides. They do not effectively remove contaminants such as arsenic, nitrate or bacteria.

Activated carbon filters are very versatile and come in many sizes and designs; the design greatly influences how well they work and how much water they can treat before they need to be replaced. Some units fit on kitchen faucets and treat a relatively small amount of water before their effectiveness is reduced. Thus, you must change such filters frequently. Units that fit under the sink are designed to treat larger quantities of water. Still others are designed to treat all water coming into the home.

Carbon filters present three problems. First, while you will notice when the filter stops removing an odor-producing compound, such as hydrogen sulfide, other contaminants are not as easily detected. As a result, you can't always be certain when a carbon filter is working effectively without testing it. Second, drinking water that passes through a filter that has been used for too long can end up being worse than drinking unfiltered water. Water flowing through such a filter can harbor high concentrations of contaminants that remain caught in the filter. Finally, if the filter is not used for a period of time, bacteria may develop. Always follow the manufacturer's instructions for operation and maintenance.

Anion exchange

Anion exchange units are generally used to remove nitrate but also remove sulfate, fluoride, bicarbonate and other negatively charged ions called anions. Anion exchange units remove anions such as nitrate or bicarbonate from the water and replace them with chloride. Removing bicarbonate makes water more corrosive (acidic). If sulfate levels are moderate to high, the unit's ability to remove nitrate may be reduced, making frequent monitoring a necessity.

Disinfection techniques

Disinfection devices are designed to kill and/or remove bacteria or viruses. When dealing with bacteria, it is important to use the most effective method for producing safe water. For wells with reoccurring bacteria problems, reconstruction or a new well are the first alternatives—unless it is determined that these options are not likely to correct the problem. If you are installing a treatment device to treat a bacteriologically unsafe water supply, you must have prior approval from the Department of Natural Resources, Bureau of Drinking Water and Groundwater. Only chlorination and UV treatment have been approved to treat water in private wells that are unsafe due to bacteria.

Chlorination. Households can disinfect water by adding chlorine or hypochlorite (similar to household bleach) through chemical injection. Chlorination requires a proper design that meters the chemical dose and contact time of the disinfection agent with the water. A major problem with chlorination is the potential for hazardous organic chemicals to form when the chlorine reacts with organic molecules in groundwater. Chlorination doesn't remove nitrates or many other compounds, but may oxidize and remove some of the color and odor problems associated with iron and hydrogen sulfide. Using an activated carbon filter after chlorination will remove excess chlorine and many of the chlorine byproducts that form.

Ultraviolet (UV) light. Disinfects without the use of chemicals. Kills bacteria, viruses and some cysts on contact with water. The effectiveness of UV light in killing microorganisms is directly related to the light's intensity and exposure time. Depending on the quality of the water, pretreatment is often necessary. Things that block light such as tannins, suspended sediment and turbidity need to be removed prior to UV disinfection. A water softener may be required to prevent scale buildup on the lamp. UV lights lose intensity over time and lamps generally need to be replaced regularly.

Distillation

Distillation units, or stills, boil water to make steam which is cooled (condensed) and collected as purified water. Most distillation units are batch operation where water is poured in, distilled and stored for later use, but some may operate continuously. Distillation can remove more contaminants than any other single type of treatment, including metals, nitrate and many organic contaminants.

Distillation does have several drawbacks. One is that the process also removes minerals such as calcium and magnesium and can leave water with a bland taste. Secondly, most stills are point-of-use devices because they are only able to treat small amounts of water for drinking and cooking. Third, some stills allow contaminants with a boiling point lower than water—certain pesticides and volatile solvents, for example—to vaporize with the water and recondense with the treated water. A unit called a fractional distiller avoids this problem, but not all distillers are this type.

Maintenance can also be a problem, depending on the unit's design. Minerals and other contaminants can accumulate in the boiling chamber, interfering with operation. Hard water can quickly clog a distiller. You can clean some units easily by hand, while others are difficult to clean or require washing with a strong acid. Some units also use large amounts of electrical energy. Distilled water is corrosive and must be stored or transported in plastic, glass or stainless steel to prevent it from dissolving unwanted contaminants.

Neutralizers

Neutralizers treat corrosive (acidic) water by increasing the alkalinity and pH which decreases water acidity. Passing the water through granular calcite (marble, calcium carbonate or lime) is the most common method although some other materials may also be used. Adding calcite may cause scale buildup particularly in the hot water heater.

If your water is very acidic or if you need a high flow rate, you may need a system that adds soda ash (sodium carbonate) or caustic soda (sodium hydroxide). These chemicals increase the water's sodium content, which may be less desirable than the increase in calcium that results from use of calcite or lime.



Oxidation

Many aesthetic problems associated with taste, odor or color in water are related to reducing conditions within the aquifer. Reducing conditions are a result of low oxygen concentrations in the ground-water which cause some elements in soil and bedrock such as iron and manganese to become soluble. By introducing oxygen into the water with a treatment device as water enters the home, the iron and manganese become insoluble and form precipitates that can be filtered out of the water. This eliminates taste and color problems associated with these two elements.

Chemical oxidation. Although not widely used, chemical injection of strong oxidizers like chlorine, hydrogen peroxide or ozone can be used to oxidize dissolved iron and manganese, causing it to precipitate, or separate, out of the solution. A particle filter will need to be installed after the chemical injection unit to trap the particulate iron and manganese. These oxidizers can also be used for odor problems related to hydrogen sulfide.

The chemicals used in this method can be hazardous to work with. If you are thinking about this type of treatment, also consider the problems associated with storing and handling large amounts of chemicals. Any chemicals that are used must be approved as food grade since they will be injected into a potable water supply. Any chemical injection system must be approved by the Department of Commerce. In the case of chlorine injection, it may also be necessary to use an activated carbon filter to remove any hazardous chlorine byproducts.

Iron filters. Iron filters are the most common form of oxidation treatment and have been used successfully for a number of years. Natural green-sand or artificial resins coated with manganese dioxide can remove iron, manganese and hydrogen sulfide from water. The manganese dioxide surface oxidizes the iron, which the sand or resin then filters out. You must periodically backwash and add potassium permanganate to rejuvenate the device. Iron filters are particularly useful if you don't want to soften water and/or the iron concentration is between 3 and 10 mg/L. Frequency of maintenance depends on the amount of iron in the water and water usage.

Particle filter

Particle filters are used in home water treatment to remove sediment or compounds like iron and manganese precipitates. Particles become trapped on the surface of or within the filter. The size of the filter's pores, or the spaces between the granules or fiber, determine what particles the filter can capture. You may have to replace filters frequently depending on how much sediment or other material you are removing. Pretreatment may be necessary for removing iron and manganese if it is in the reduced form. If iron or sulfur bacteria are also present, particle filters may become frequently clogged.

Pellet chlorinator

Pellet chlorinators are designed to periodically inject a solid chlorine pellet into the well. They can be used to control aesthetic problems associated with severe iron/sulfur bacteria problems. Pellet chlorinators are not an approved treatment technology for water that is unsafe due to bacteria. Prior DNR approval is required to install a pellet chlorinator on a well. If you install a pellet chlorinator, you may also want to install a carbon filter to remove any residual chlorine from the water.

Reverse osmosis

Reverse osmosis (RO) removes contaminants by forcing water through a membrane with microscopically small holes that allows water molecules, but not large compounds and microorganisms, to pass through. Water flushes away the contaminants captured by the membrane. Because they can only treat small amounts of water at a time, RO systems generally serve as point-of-use devices to purify water for drinking and cooking. In addition to the membrane, RO systems frequently include a sediment filter and carbon filter along with a storage tank to store treated water. Pressure and temperature will greatly affect the device's effectiveness.

Although they cannot remove 100% of chemicals in the water, RO units can remove more kinds of contaminants than any other single method except distillation. The RO process can remove organic chemicals, including some pesticides, but will not remove others which is why many RO systems also include an activated carbon filter (see "activated carbon"). RO units also waste large amounts of water. Only about 10% to 30% of the water entering the unit is recovered as treated water; the remainder is discharged as waste along with the contaminants. The membrane can also develop problems from precipitate buildup and scaling. To overcome this problem, pretreatment of water ahead of the reverse osmosis unit is sometimes necessary. The membranes are made of a variety of materials that differ in their effectiveness for different chemicals. Change the filters per manufacturer's recommendations or annually.

Water softeners

Water softeners are a very popular form of water treatment, since hard water is prevalent in Wisconsin. Calcium and magnesium from natural mineral sources cause hardness. Hard water can interfere with the cleaning action of soaps and detergents. Hard water is not a health concern and while some calcium can help prevent corrosion of plumbing, too much can cause scale buildup, particularly in hot water pipes, water heaters and fixtures.

Home water softeners use a synthetic resin or natural zeolite material that exerts a strong attraction on calcium, magnesium and other positively charged metal ions called cations. The resin is first saturated with charged ions of sodium from a salt (usually sodium chloride) solution. As water passes through the resin, the sodium exchanges with calcium and magnesium. Some softeners may also remove a limited amount of iron and manganese if they are in a soluble (reduced) form. When the resin's capacity to remove calcium and magnesium is filled, it must be recharged.

There are some disadvantages of water softeners. One is that they remove calcium and magnesium and substitute sodium if using sodium chloride salt. Sodium may have health implications for individuals on low sodium diets. If you must drink softened water, potassium chloride can be used in place of sodium chloride if you are concerned about limiting your sodium intake. Many people choose not to soften the faucet where they get their water for drinking and cooking.

Softening of outdoor water faucets is unnecessary.

A few words of caution

If you have a health-related water quality problem, it is best to obtain a safe water supply before resorting to water treatment systems. If water treatment appears to be your only option, read this publication carefully to understand the limitations of the options. No system is foolproof and all require maintenance and/or monitoring to be sure they are working properly. Request written assurance from the supplier as to what contaminants the device is capable of removing, the unit's removal effectiveness, life expectancy of the unit, and annual maintenance and operating costs.

Diagnosing your water quality

The following table illustrates some of the symptoms, causes and treatment options for the most common water quality problems in Wisconsin.

Symptoms, causes and treatment options for water quality problems

Concern	Symptoms /problems	Cause/source	Possible treatment methods	Additional information
Arsenic*	Has no color, taste, or odor; detecting this problem requires testing.	Occurs naturally in soil and aquifer minerals.	In some areas new well construction or reconstruction has been successful at reducing arsenic concentrations; otherwise distillation, reverse osmosis, or anion exchange.	The arsenic standard is 0.010 mg/L. If you detect arsenic in your water, it is recommended that you retest your well each year. Since water treatment is less effective for some forms of arsenic, it is important to test before and after treatment to ensure that the device is working properly.
Coliform bacteria *	Detecting this problem requires testing. A sudden change in taste, color or odor may indicate a problem with coliform bacteria. Intestinal illnesses may occur if harmful bacteria like E. coli are also present.	Well construction and/or plumbing defects; wells installed in fractured bedrock that allow bacteria from surface water or wastes to seep into groundwater.	Correct any well construction faults, then follow DNR recommended procedure for disinfection. For recurring bacteria problems it may be necessary to install a new well or reconstruct the existing one. If this fails, chlorination or UV treatment may be used only with prior DNR approval.	A sanitary well should not contain coliform bacteria. The presence of coliform bacteria indicates a pathway for harmful pathogens such as E. coli to enter the well. While coliform bacteria are generally not considered harmful they are an indication of unsanitary conditions that should be investigated and corrected.
Chlorine	Water smells like chlorine.	Result of pellet chlorinator or well disinfection process.	Activated carbon.	If caused by one-time well disinfection, the chlorine will dissipate over time.
Cloudiness	Cloudy or gritty water; water pipes, filters and water heater may be plugged up.	Fine sand, silt and clay passing through the well screen. Precipitates or gases forming in the water due to changes in temperature or pressure.	Repair or replace well screen. Install a physical filter system or soften the water to prevent precipitation of scale.	Cloudy or gritty water may occur as a result of blasting or construction activities. If cloudy water routinely occurs after rainfall and snowmelt, rock fractures may be allowing rapid water movement of surface water into the well or well may have a leaky casing; also be aware of possible bacterial contamination.
Copper*	Blue green stains on sinks and other bathroom fixtures. Detecting this problem may require testing.	Copper is a common material in household plumbing. Corrosive water that comes in contact with copper pipes will often cause elevated levels of copper in water.	Install a neutralizing filter if water is corrosive to prevent copper dissolution; or use reverse osmosis or distillation to reduce copper concentration.	The copper standard is 1.3 mg/L. Because elevated copper levels are generally a result of water sitting in contact with household plumbing, allow water to run for a period of time before drinking. This will often lower concentration to a safe level.
Corrosive Water	Blue green stains on bathroom fixtures. Pinhole leaks in pipes.	Acidic water or water with very low hardness that reacts with household plumbing.	Install a neutralizing filter if the problem is attributable to low pH; or install plumbing made of materials that resist corrosion.	Corrosion may also increase the amounts of health-related contaminants such as copper and lead. (See Copper and Lead for more details).

* Indicates a contaminant with potential health implications.

Symptoms, causes and treatment options for water quality problems, *continued*

Concern	Symptoms /problems	Cause/source	Possible treatment methods	Additional information
Chloride	Blackening and pitting of stainless steel.	Very high chloride levels from leaching of road salt, fertilizers, septic systems or landfills.	Use chloride resistant metals or anion exchange.	Naturally occurring chloride levels are generally less than 20 mg/L, although elevated chloride levels can occur naturally in some parts of the state. Excessive hardness and sulfate may indicate a natural source of chloride.
Fluoride*	Yellowish mottled teeth; tests showing elevated levels of fluoride.	Fluoride that leaches from natural mineral sources or industrial wastes.	Activated carbon, distillation, anion exchange or reverse osmosis.	Fluoride less than 2 mg/L helps prevent tooth decay in children; levels greater than 2 mg/L may cause mottling of teeth.
Hardness	Formation of scale, particularly within the water heater; scale deposits on faucets or utensils, soap scum.	Dissolved calcium and magnesium from soil and aquifer minerals containing limestone or dolomite.	Ion exchange (water softener).	Water is considered hard when hardness greater than 150 mg/L as CaCO ₃ . Hard water is generally higher in alkalinity and less corrosive than soft water. Scale formation in water heater can decrease water heater efficiency.
Hydrogen Sulfide	Water smells like rotten eggs.	Hydrogen sulfide, a reduced form of sulfur. Source may be naturally occurring if water has passed through organic matter. May be caused by reaction with anode rod in water heater or produced by a sulfate reducing bacteria (see also Iron and/ or Sulfur Bacteria).	If only present in hot water, first try replacing the magnesium anode rod in the hot water heater with one made of aluminum or other metal; otherwise use aeration or oxidation.	This is the most common odor and is more noticeable in hot water. It causes no harmful health effects at low levels, but may cause air quality problems.
Iron and/or Manganese (reduced)	Water clear when drawn but red-brown (iron) or black particles (manganese) appear as water stands; red-brown or black stains on fixtures or laundry.	Acidic or reduced groundwater can dissolve naturally occurring iron or manganese from soil or bedrock. Color caused by reduced iron or manganese precipitating out of solution as water comes in contact with oxygen.	Water softener (hard water and low iron levels); iron filter (<15 mg/L iron + manganese); chemical oxidation or aeration and physical filter (>10 mg/L iron).	Iron is a major aesthetic problem in many parts of the state. The secondary drinking water standards of 0.3 mg/L for iron and 0.05 mg/L manganese are based on aesthetic effects in water.
Iron and/or Manganese (oxidized)	Water contains red-brown (iron) or black (manganese) particles when drawn.	Oxidized iron or manganese due to exposure of water to air prior to faucet; iron particles from corrosion of old pipes or equipment.	Particle filter.	same as for oxidized

* Indicates a contaminant with potential health implications.

Concern	Symptoms /problems	Cause/source	Possible treatment methods	Additional information
Iron and/or Sulfur Bacteria	Odors, oily film on water and gelatinous growth in water tanks or toilets, corrosion of plumbing equipment.	Naturally occurring bacteria that produce slime build-up in well screens, pipes and plumbing.	Periodic chlorination of the well using DNR recommended procedure can often help control the problem; for severe problems pellet chlorinator (prior DNR approval is required). If the problems are caused by sulfate-reducing bacteria, removing or replacing the magnesium anode in the hot water heater may also help.	These bacteria are not a health concern but are often a nuisance. It is difficult to totally eliminate iron and/or sulfur bacteria; therefore prevention is the best safeguard. All precautions should be taken during the drilling process to prevent the introduction of these bacteria or organic material that can nourish them.
Lead*	Has no color, taste or odor; detecting this problem requires testing.	Before 1985 lead solder was a common component of household plumbing systems. Bathroom fixtures may also be a source, if they are made of brass and bronze.	Install a neutralizing filter if water is corrosive to prevent lead dissolution; or use reverse osmosis or distillation to reduce lead concentration.	The lead standard is 0.015 mg/L. Because the source of the lead is generally the household plumbing, allow water to run for a period of time before drinking. This will often lower concentration to a safe level.
Nitrate*	Has no color, taste or odor; detecting this problem requires testing.	Nitrogen from fertilizers, manure storage, waste spreading, septic systems or the breakdown of organic matter and wastes.	Anion exchange, distillation, reverse osmosis.	Infants less than 6 months of age and women who are pregnant should avoid drinking water that contains more than 10 mg/L of nitrate-nitrogen. The presence of nitrate above 2 mg/L generally indicates water is being impacted by local land-use and may also indicate other potential contaminants.
Organic Matter	Water smells musty or earthy.	Compounds from decomposition of natural organic matter entering the water supply.	Activated carbon, oxidation	
Tannins	Yellowish cast to water even after softening and/or filtering.	Tannins are picked up when water passes through soils with high organic matter content or decaying vegetation.	Anion exchange, oxidation	
Pesticides*	Has no color, taste or odor; detecting this problem requires testing.	Leaching of pesticides from places where they have been applied, spilled or stored.	Activated carbon, distillation. Reverse osmosis may be effective for some pesticides.	You may suspect this problem if pesticides are used or handled near your water supply.
Radioactivity*	Has no color, taste or odor; detecting this problem requires testing.	Naturally occurring radon and/or radium in some granite and sandstone aquifers.	Aeration to remove radon. Distillation, reverse osmosis or water softener for radium.	More likely to be a problem in wells drilled in the deep sandstone of Wisconsin's eastern aquifer or the crystalline granite aquifer of north central part of the state.
Volatile Organic Compounds* (VOCs)	Water smells like gasoline or chemical solvents. At low levels may require testing.	Gasoline, solvents, or cleaning agents from chemical spills, pump oils, improper waste disposal, leaking underground storage tanks and other sources.	Activated carbon, vented distillation or aeration.	Owners whose wells have VOCs above health advisory levels should contact the DNR for assistance. They may be eligible for well compensation funds to help with the cost of a new well.

* Indicates a contaminant with potential health implications.

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Adapted from *Improving Your Drinking Water Quality* (G3378) by Byron Shaw and Jim Peterson.

Author: Kevin Masarik is a groundwater educator with the Central Wisconsin Groundwater Center at the College of Natural Resources, University of Wisconsin-Stevens Point.

Reviewers: Paul McGinley is a professor of water resources at the College of Natural Resources, University of Wisconsin-Stevens Point. Bob Schaefer is a private water supply specialist with the Wisconsin Department of Natural Resources. Peggy Compton is a basin educator and Paul Ohlrogge is a CNRED educator with the University of Wisconsin-

Extension. This information was also reviewed by the members of the Education Subcommittee of the Groundwater Coordinating Council.

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