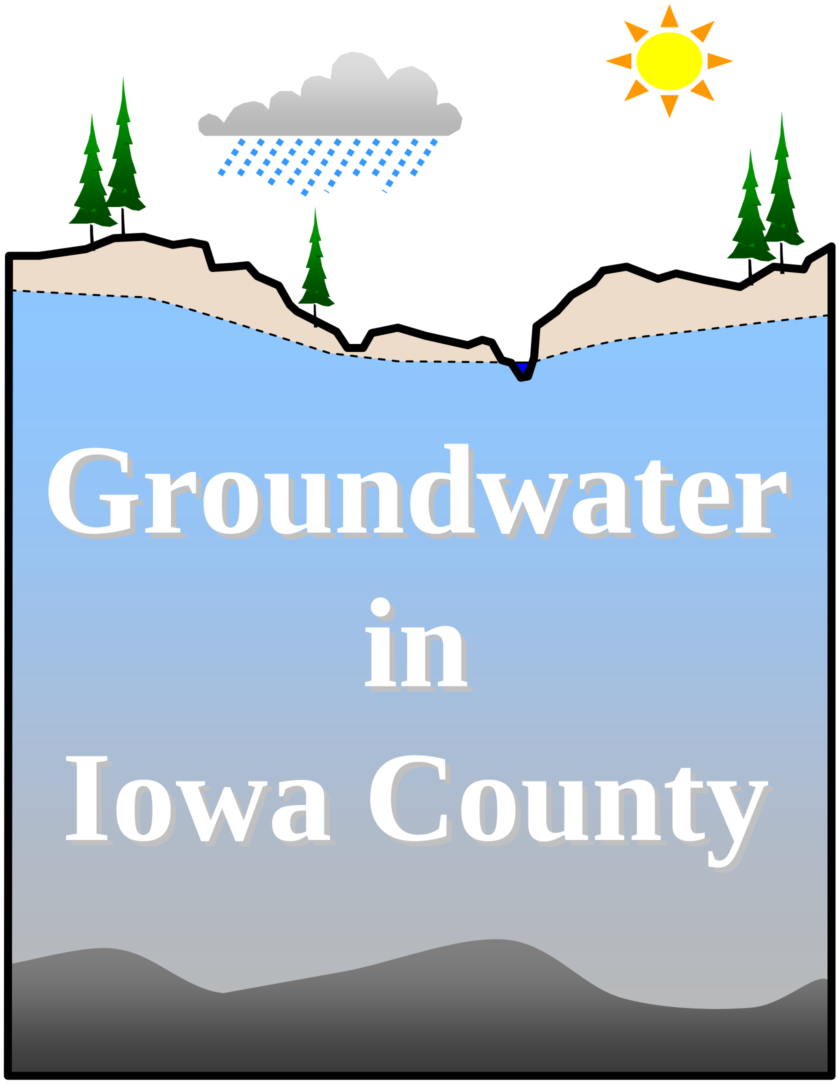

Groundwater in Iowa County

A Citizen's Guide

UW Extension

Center for Watershed Science and Education

Groundwater in Iowa County
A Citizen's Guide

Kevin Masarik
Paul Ohlrogge
David Mechenich

UW Extension Iowa County
University of Wisconsin-Extension
Center for Watershed Science and Education/UW-Stevens Point

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INTRODUCTION

A clean and dependable supply of water is necessary to maintain a high quality of life and strong economy in Iowa County. Groundwater is particularly important since it serves as the primary source of water for the residents and many industries in Iowa County. Because we cannot see groundwater it is important that we pay extra attention to this resource if we are to ensure that the quantity and quality of groundwater is maintained for our future needs.

The luxury of quality drinking water is something that many of us commonly take for granted. Municipal and other public water supplies are subject to strict guidelines and water quality testing to ensure that the water meets current drinking water standards and is safe to drink. However, there are also over 800,000 private wells which serve as the primary water supply for a large number of people throughout Wisconsin, which are not required to be tested or treated. Determining the safety of private water supplies is the responsibility of the individual homeowner.

Groundwater is vulnerable and if it is not carefully monitored, managed, and protected has the potential to be depleted or degraded. While much has been done to protect our groundwater supply we increasingly face the question of how to improve groundwater quality. Wide-spread land-use activities have resulted in elevated concentrations of contaminants such as nitrate and pesticides throughout the state, including Iowa County. Cleaning up groundwater after it is contaminated has proven difficult and expensive; therefore it is beneficial to prevent groundwater from becoming contaminated in the first place.

As a way to address the concerns of Iowa County residents regarding the quality of their drinking water supply, the Iowa County UW-Extension office in cooperation with the Center for Watershed Science and Education in Stevens Point conducted a number of drinking water testing programs throughout the county. These programs offered community members an opportunity to learn about their individual water quality as well as groundwater basics and the overall groundwater quality in Iowa County.

The results from nearly 800 private well tests have been used to generate this report on the water quality of Iowa County. The major benefit of these programs is that residents of Iowa County are better informed on groundwater and the issues that surround it. This report is intended to summarize what was learned and to further educate residents and local leaders on important groundwater issues so they can best manage Iowa County's groundwater resource for the future. Those residents of Iowa County who participated in the well water testing program deserve special thanks, without them this report would not have been possible.

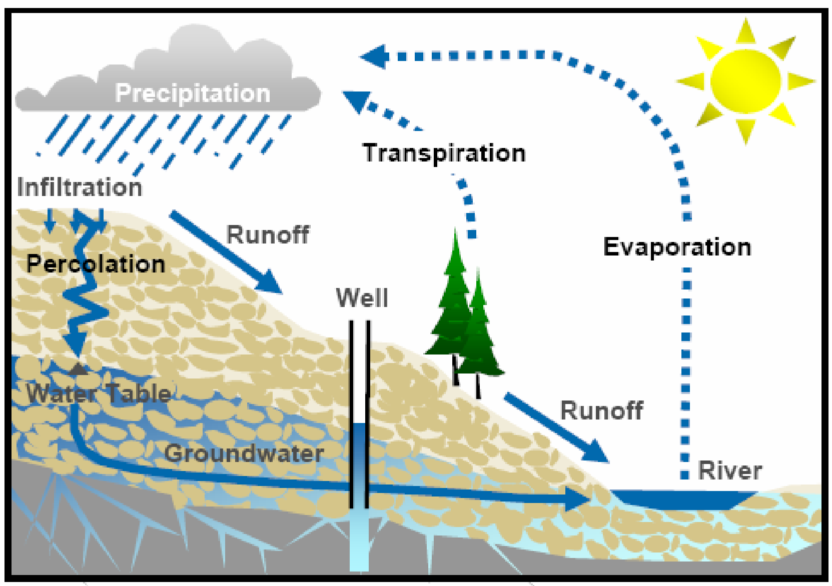
What is Groundwater?

Groundwater is the water contained in the empty spaces between soil particles and rock materials below the surface of the earth. If you dig a hole and find the **saturated zone**, the point at which all of the empty spaces between the soil and rock are filled with water, you have hit the **water table**. The saturated areas below the water table make up our groundwater resources.

Groundwater is not the mysterious subject that some people believe it to be. Wisconsin's groundwater is related to all other water on earth through a process called the **hydrologic cycle**, or the water cycle. In the water cycle, water is transported from the earth by the processes of **evaporation** and **transpiration** to form clouds and eventually falls back to the earth as precipitation. Some precipitation runs off into surface water. Some soaks into the ground to be used by plants. Water that soaks past the plant root zone to the saturation zone becomes groundwater. Some of this water is pumped out by a pumping well and is used by humans in our everyday activities.

Groundwater that supplies Wisconsin's **wells** does not flow in underground rivers. Rather, the **aquifers**, water bearing geological formations that transmit and store water, are more appropriately thought of as underground "sponges". Major aquifers in Iowa County include sand and gravel; limestone, dolomite and sandstone bedrock.

Figure 1
The hydrologic cycle.



What many people do not realize is 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: 1) the size of the pore spaces and 2) how well the pores or cracks within the groundwater aquifer are connected to one another. 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!

In Wisconsin's shallow aquifers, groundwater flows only short distances, a few thousand feet to a few miles, from **recharge areas** located higher up on the landscape to **discharge areas** located at lower areas on the landscape.

Examples of discharge areas include streams, rivers, lakes and wetlands. Groundwater traveling in these shallow flowpaths has been in the groundwater system only a few years or decades. 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 our groundwater does not come from Canada, and few very deep wells tap water that has been underground since glacial times.

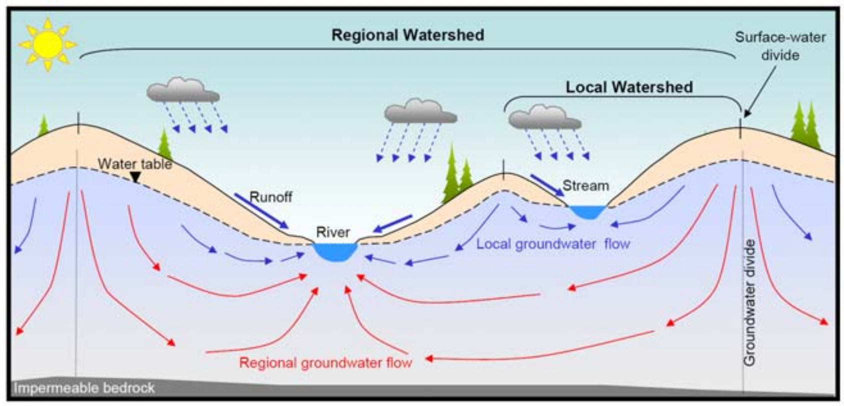


Figure 2
Local groundwater flows to nearby streams while regional groundwater flows longer distances to major rivers.

Since groundwater generally discharges to the landscape at surface water bodies, we use the concept of a **watershed** to determine the area of recharge for lakes and rivers. Any precipitation that falls within the watershed boundary will eventually find its way to that particular water body, some through direct runoff over the land surface and much of it through infiltration and groundwater flow. Small streams such as Otter Creek, for example, will have a small watershed boundary. Major rivers like the Wisconsin River have watershed boundaries which include many smaller watersheds. You will see from looking at Fig. 3, the Wisconsin River receives surface water from smaller tributary streams, as well as regional groundwater flow.

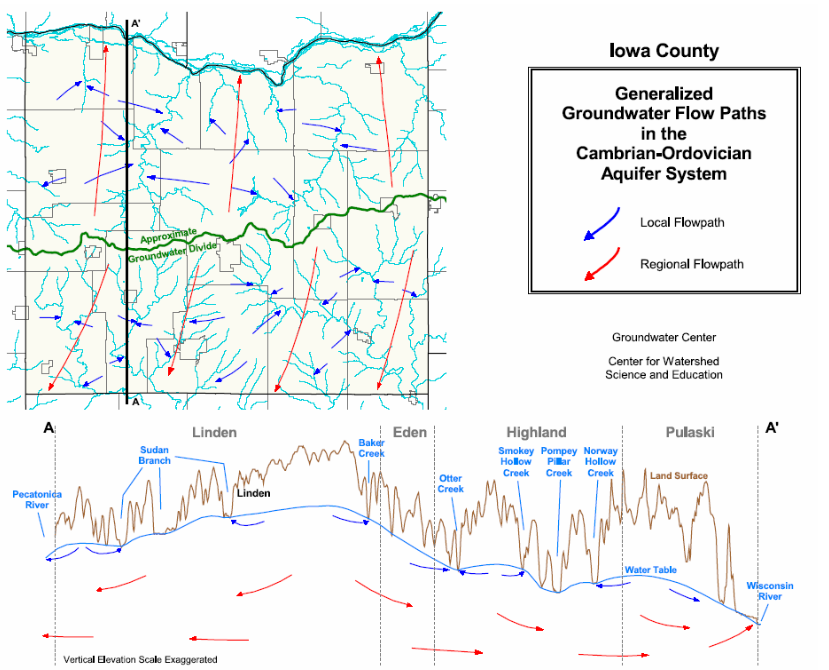


Figure 3
Generalized diagram of groundwater flow.

Groundwater and surface water divides are used to determine the boundaries of a watershed. Iowa County actually has a major **groundwater divide** running from east to west through the middle of the county. Groundwater divides are often similar to surface water divides. You will notice by looking at a map of Iowa County that all of the streams north of the divide flow into the Wisconsin River and are part of the Wisconsin River Watershed, while all of the streams south of the divide are part of the Pecatonica River Basin and will eventually flow into the Pecatonica River.

Because the groundwater used by most Iowa County residents is locally recharged, it is greatly affected by local geological conditions and local land use. Water is often referred to as the universal solvent because it can dissolve many different materials, some which may be harmful, and may be found in groundwater. People may be surprised that groundwater quality problems do exist in Iowa County. Some of the problems occur naturally from the contact of water with soil and rock; others are introduced by human activity.

While local geology plays an important role in determining how susceptible groundwater is to human contamination, it is important to keep in mind that what we do on top of the land and how carefully we do it ultimately determines whether or not groundwater becomes contaminated. Many everyday activities have the potential to impact our groundwater below.

Geology and Soils of Iowa County

In order to understand some of the key factors affecting groundwater, it is important to know about the local **geology** and soils. Geologic materials and soils both influence groundwater. Different geological formations have different chemical and physical properties which greatly affect groundwater chemistry as well as the storage and transport of groundwater.

You may have noticed traveling around the state that Southwestern Wisconsin which includes Iowa County, looks very different than the rest of the state. This is because Iowa County is located in what is referred to as the driftless region of Wisconsin. While much of the state was at one time or another covered by huge glaciers and has been greatly transformed by glaciation, the driftless region is an area of Wisconsin that was left untouched by glacial advances. Because the driftless region is not covered by glacial deposits, we are able to see the effects that hundreds of thousands of years of erosion and weathering have had on the landscape following the periods when ancient oceans once occupied Iowa County and much of Wisconsin.

Figure 4
Generalized cross section of Iowa County geology.

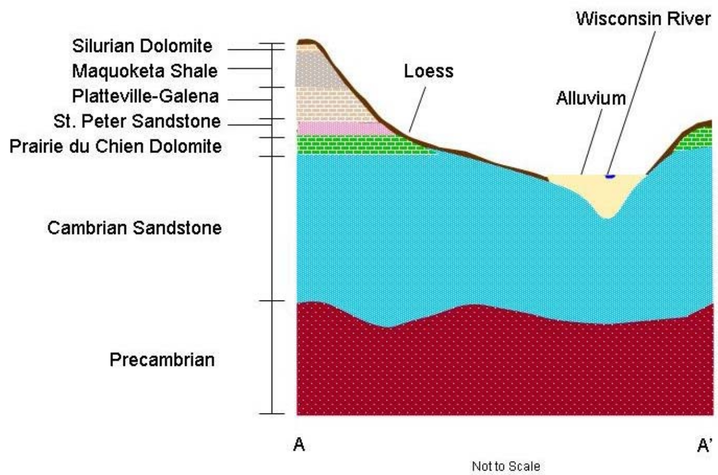
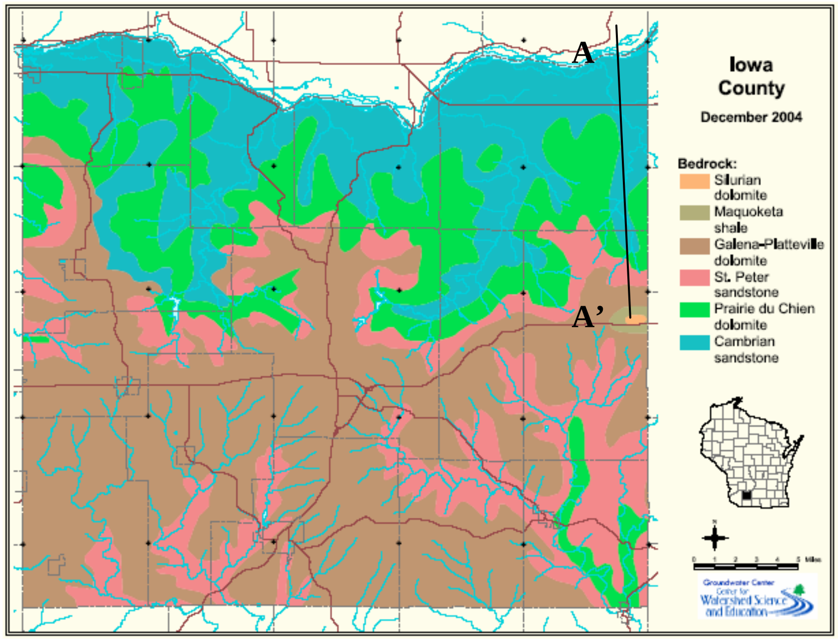


Figure 5
Bedrock geology of Iowa County



The geology of Wisconsin is very similar to a layered cake, with each layer of the cake representing a different geological material and different geologic period. In order to learn about the different aquifers that are found in Iowa County, we will work our way forward through time starting with the deepest and oldest layer formed during the Precambrian time period.

Precambrian Era

The Precambrian layer consists of granites and gneiss rocks which are igneous and metamorphic rock types formed originally from volcanic activity and igneous intrusions approximately 2.8 billion years ago. Some of these igneous granites that were originally formed were later metamorphosed into gneisses under intense heat and pressure from subsequent geologic activity.

In general, these rocks do not store much water and do not transmit water readily. This layer is located very deep below the ground and is generally considered a poor aquifer; as a result, wells in Iowa County do not extend down into the Precambrian layer.

Cambrian Era

Located above the Precambrian layer are the Cambrian sandstones. Cambrian sandstones were deposited beginning around 500 million years ago when a large sea once covered Iowa County and much of Wisconsin. As upland areas eroded, the weathered materials were deposited into the sea and over time these collections of sand grains on the ocean floor became loosely cemented together.

Actual rocks from this formation are highly weatherable and often crumble when holding in your hand. Sandstone is also quite porous and allows a substantial amount of water to be stored and transmitted through the small interconnected pore spaces between the cemented sand grains. Pouring water into sandstone is much like pouring water into a very rigid sponge. Because of its water transmitting properties, sandstone makes an excellent aquifer.

Ordovician Era

Prairie du Chien Formation

Overlying the Cambrian sandstones we find a formation of the Prairie du Chien dolomite which began forming approximately 490 million years ago when sea levels rose and once again occupied Wisconsin. Dolomite is a sedimentary rock consisting of calcium magnesium carbonate. Much of this formation was initially deposited as limestone (calcium carbonate) from the seas that occupied the area. It is thought that sea water rich in magnesium displaced some of the calcium in the limestone forming the much more weather resistant dolomite that we find in Iowa County.

Dolomite is soluble in slightly acidic water and over time solution fractures have developed as water travels through the cracks in the dolomite. This enlarging of fractures by the weathering of dolomitic rock has turned the Prairie du Chien into a productive aquifer as water is able to move through solution fractures in the dolomite. Water in this aquifer has the potential to move quite quickly where the fractures are large and well connected.

St. Peter Formation

Approximately 480 million years ago, sea levels lowered and much of the area was once again exposed to weathering. Quartz sand was redeposited from river and wind erosion that cut into the Cambrian formations formed a mere 10 million years earlier, forming a blanket of sand that was eventually cemented together and is now referred to as St. Peter Sandstone. For aquifer properties see Cambrian era.

Platteville – Galena Formation

Another rise in sea level is responsible for the deposition of material that created the limestone formation on top of the St. Peters Sandstone. As was the case with the Prairie du Chien Dolomite, much of the deposited limestone was converted into dolomite when magnesium from enriched seawater replaced some of the calcium in the limestone. Except for a small outcrop in the far eastern part of the county, the Platteville – Galena Dolomite caps most of the ridges and hilltops in Iowa County. Although a number of streams and rivers in Iowa County have cut through this dolomite layer, much of the formation has withstood the erosive power of water and serves as a protective layer for the geologic formations below. Millions of years from now, this layer may also completely erode away.

Aquifer properties of the Platteville – Galena dolomite are similar to those of the Prairie du Chien formation. Most of the water movement and water storage capabilities are a result of fractures in the dolomite rock. Because of the potential for rapid water movement through this material, areas with shallow soil covering the Platteville – Galena Formation or the Prairie du Chien Formation may be more susceptible to contamination from land-use activities.

Maquoketa and Silurian Formations

The Maquoketa formation consists of a sedimentary rock called shale. The shale was formed approximately 440 million years ago by the erosion of a mountain chain in what is now the Eastern United States. The erosion supplied fine clay which was deposited on the sea floor and eventually cemented together to form shale. Because shale is very weatherable, it very seldomly survives the weathering process. There is only a very small area of Maquoketa shale in Iowa County, located on the eastern border. This shale layer underlies a much more weather resistant formation of Silurian Dolomite which has protected it from completely eroding away. This small area of Silurian Dolomite was formed approximately 430 million years ago when an ocean once covered the entire North American Continent.

There is simply not enough of these two formation to be considered important as aquifers in Iowa County. In fact the Maquoketa Formation is not really an aquifer at all since it has a very limited ability to transmit water. Although it is quite porous, the pores and cracks in this material are not well connected and don't allow water to move through it easily. This shale layer is often referred to as an **aquitard**. An aquitard is a formation or a layer of material with physical properties that impede water movement.

Quaternary Period

Unconsolidated Materials

On top of the geologic formations that underlay Iowa County are the unconsolidated materials that have been deposited over the years. Much of the county is overlain by a blanket of wind blown silt and sand referred to as loess. The loess is the parent material for many of Iowa County's soils. Soils are important because they act as a natural filter of water as it percolates into the ground. Soils have the ability to attenuate many contaminants. While soil cannot remove all pollutants it does provide a certain amount of protection. As a result, areas where soils are thin or absent tend to have a greater likelihood of groundwater contamination. Soil texture is also considered when determining areas of contaminant susceptibility. Coarse sandy soils offer less protection from contamination than fine clay soils.

Although the area is referred to as the driftless region, a small part of Iowa County was affected by Wisconsin's glacial history. The thick sandy deposits along the Wisconsin River Valley on the northern edge of Iowa County are a result of a large outwash river fed by the melting glaciers. The river, which would have been much higher than it is today, eroded the Cambrian Sandstones along the river banks and redeposited the sand along the streambed. Sediment deposited by rivers is often called **alluvium**. Some of these deposits of well sorted sand are hundreds of feet thick.

You can imagine that water infiltrates these sandy deposits very quickly. Groundwater can also be extracted very quickly and as a result this area of Iowa County is a very productive irrigated agricultural region. **Irrigation wells** are able to pump out large amounts of water to supply water to crops such as potatoes.

For the same reasons that it is conducive for irrigation, this sandy region along the Wisconsin River is also very susceptible to contamination from land-use. The sand which allows water to drain through very quickly, also allows chemicals such as fertilizers and pesticides to reach groundwater quickly as well.

For more detailed information on the geology of Wisconsin look for the following resource:

Dott, R.H., and J.W. Attig. 2004. Roadside Geology of Wisconsin. Missoula: Mountain Press Publishing Company.

Where Does Our Drinking Water Come From?

Chances are if you drink water out of a faucet in Iowa County you are drinking groundwater. Wells are what we use to extract water from the ground. There are private wells which typically serve one home and there are large **municipal wells** which provide water for whole cities.

Municipal wells are required to be regularly tested to ensure that the water being supplied meets all the drinking water standards for public water supply systems. If water quality problems do exist, the water is required to be treated before it is distributed to individual homes.

Private wells on the other hand are not required to be regularly tested. It is up to the individual homeowner to determine what tests to perform and how often. If water quality problems are detected, the homeowner is not required to treat the water. It is solely the responsibility of the homeowner to decide whether to correct the problem or continue drinking the water.

Wells aren't much more than a hole drilled into the soil and rock below. Wells must be drilled deep enough to extend past the water table into the groundwater aquifer below. As water is pumped or removed from the well, water contained in the adjacent rock or unconsolidated material replaces the water that was removed from the well.

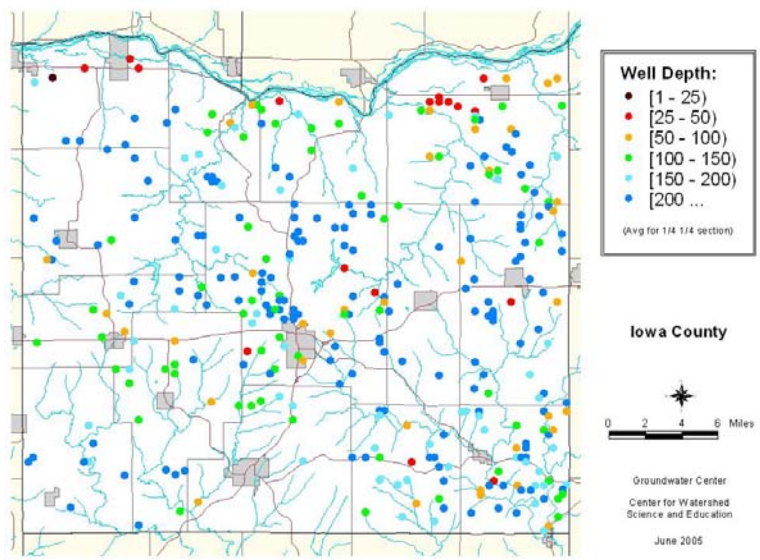
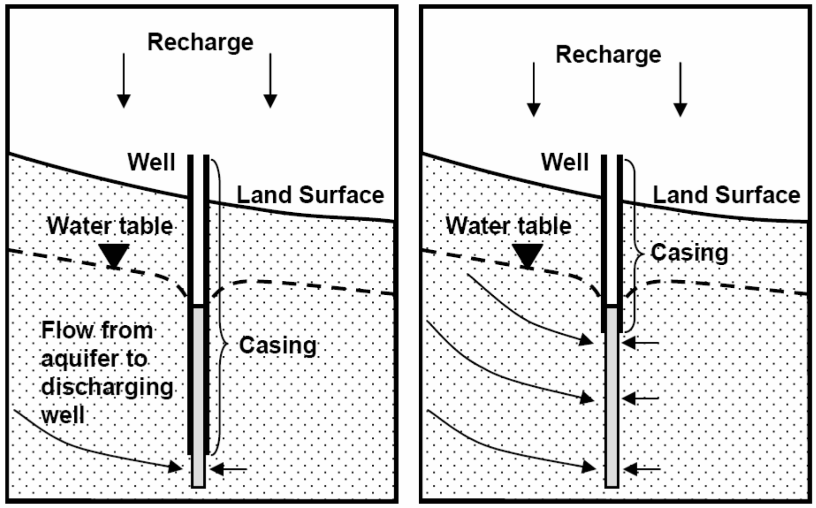


Figure 6
Depth of private wells as reported by drinking water program participants.

Well casing is the metal lining that helps to seal the well off from the surface and prevents unconsolidated material from falling into the well. A properly installed casing is important in maintaining the physical and sanitary conditions necessary to provide a dependable and safe supply of drinking water. Casing also plays an important role in determining where a well receives its water from. Wells that are cased just below the water table receive water that recharged recently and are more likely to be affected by local land-use activities than are deeper wells.

Generally, the deeper the water is found below the water table, the older the water tends to be. In areas where groundwater has been affected by human activities, older groundwater tends to show less signs of being impacted than shallower groundwater. However, all groundwater originates as precipitation infiltrating into the ground. Eventually even very deep groundwater that does not show signs of being impacted today may show signs of degradation in water quality over time as newer water replaces older water within the aquifer.

Figure 7
Casing plays an important role in determining which area of the aquifer a well draws water from.

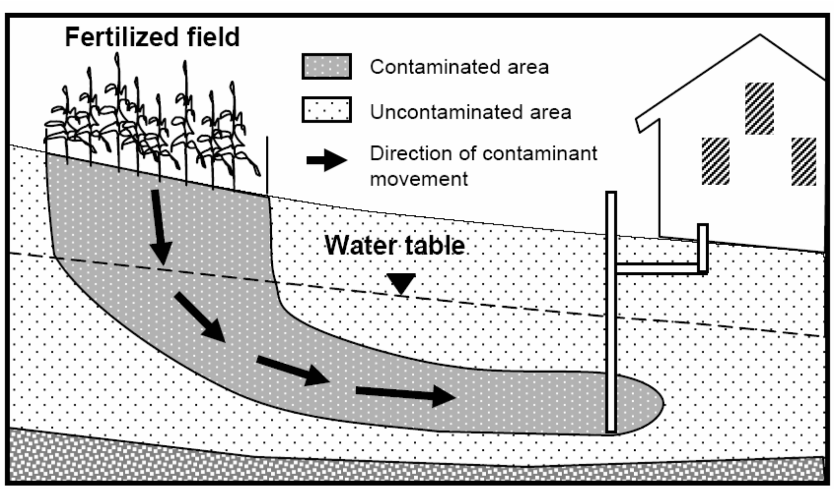


A well that pumps continuously often will often lower the water table surrounding the well. This is what is referred to as a **cone of depression**. The cone of depression created by residential wells is minimal when compared to municipal or **high capacity wells**. Depending on how much water is being pumped and the well location, under certain circumstances wells have the potential to impact surface water bodies. A high capacity well located in close proximity to the headwaters of a small stream, for example, could reduce the amount of groundwater discharge to the stream, thereby decreasing the total streamflow. It is important when citing new high capacity wells that they will not negatively impact nearby surface waters.

What's in Groundwater?

Water under natural conditions is never just H_2O or pure hydrogen and oxygen atoms. Water is often referred to as the universal solvent because it has the ability to dissolve many different types of materials. Just because water is not pure water does not necessarily mean that it is contaminated. Groundwater will naturally have certain solutes in it depending on what type of soils and minerals the water has come in contact with. Things like calcium and magnesium which are readily found in groundwater can actually be beneficial to health. On the other hand, naturally occurring arsenic in groundwater is considered to be a contaminant since drinking water that contains arsenic can negatively impact people's health.

Figure 8
Everyday activities such as fertilizer use can impact groundwater.



Humans also have a significant impact on what is in our groundwater. While many people know that a leaking landfill or a chemical spill are sources of contamination, everyday activities such as fertilizing your lawn or salting roads can also contaminate groundwater supplies. Depending on what land-uses are allowed to take place and how careful we are about carrying out these activities, some chemicals can eventually find their way into our groundwater supplies. Because groundwater travels very slowly, we may not realize that we have contaminated our groundwater supply until it is too late. Once groundwater becomes contaminated, it is very difficult to clean up. Since the groundwater being supplied to wells is often years or even decades old, eliminating the contamination source today may not improve quality for years to come.

Table 1
Potential sources of groundwater contamination. (Born et al., 1987)

PLACE OF ORIGIN	POTENTIAL POLLUTION SOURCES			
	Municipal	Industrial	Agricultural	Other
	Waste Related			
At or near the land surface	Sludge and wastewater disposal (N)		Feedlots (P)	Septage disposal (N)
			Manure storage (P) and spreading (N)	Junkyards (P)
			Whey spreading (N)	
Below the land surface	Landfills (P)		Manure Pits (P)	Septic systems (P)
	Wastewater impoundments (P)			Holding Tanks (P)
	Seepage cells (P)			
	Sanitary sewers (L)			
	Non-waste related			
At or near the land surface	Salt piles (P)	Above and on the ground storage of chemicals (P)		Highway deicing (L)
		Stockpiles (P)	Irrigation (N)	Lawn fertilizers (N)
		Tailing piles (P)	Fertilizers (N)	
		Spills (P)	Pesticides (N)	
			Silage (P)	
Below the land surface		Underground tanks (P)		Improperly constructed and abandoned wells (P)
		Pipelines (L)		Overpumping (induced pollution) (P)

P=point source
N=nonpoint source
L=line source

Drinking Water and Health

While the majority of wells in Wisconsin provide a clean and dependable supply of drinking water, there are a number of contaminants found in private and municipal wells that can negatively impact health. Contaminants in drinking water are always a cause for concern. Health effects related to contaminants in drinking water can be divided into two categories; those that cause acute effects and those that cause chronic effects.

Acute effects are usually seen within a short time after exposure to a substance. Bacterial contamination is an example of a contaminant that causes acute effects. People who consume water contaminated with bacteria usually develop symptoms shortly after ingesting the water. Copper is another example of a contaminant that can cause acute health effects. While some copper is necessary, too much in drinking water can cause abdominal pains.

Chronic effects result from exposure to a substance over a long period of time; this could be weeks or many years. Drinking water that contains contaminants like pesticides, arsenic and lead increases the likelihood of developing certain types of cancer or other long-term health effects.

When dealing with substances that cause chronic health effects, it can be difficult to determine how much of a substance is too much. For those contaminants that cause chronic health effects such as cancer, it is assumed that at any dose some adverse health effects may be possible. Standards are developed to provide a reasonably low risk of developing any adverse health effects; risk levels usually range from one additional case of cancer in ten thousand people to one in a million. As with other health related issues, certain individuals may be more at risk than others. While standards exist for some of the more common chemicals found in groundwater there are many others for which standards have not yet been decided on. To complicate matters further, little is known regarding multiple contaminants in water and the combined effect that they may have on people's health.

Municipal wells are required to meet safe drinking water standards before they distribute water to the individual homes in the community. Water from municipal systems provides reasonable assurance that drinking the water will not result in any acute or chronic health effects. For private well owners it is up to the individual to determine what the risks are and whether those risks are great enough to find an alternative source of drinking water.

Private Well Data from Iowa County

Interpreting water quality information can often be difficult. While water testing is encouraged by all private well users, individuals are often unable to understand what water test results mean in terms of drinking water safety, aesthetics and effects on household plumbing. In order to truly understand results people must be informed on what they are testing for and why; in addition people must have standards to compare their water test results against. The following information was collected from over 800 private well samples and has been summarized to inform people on the common tests performed on private wells. Interpretation information has also been included to help people determine if their water is safe to drink and identify other potential problems.

Tests Important to Health

Coliform Bacteria

Testing for coliform bacteria helps to determine if a private well is bacterialogically safe. There are many different types of bacteria. Coliform bacteria are very common microorganisms found in surface water, soil and in human and animal waste. All wells that supply drinking water should be absent of bacteria including coliform bacteria. Coliform bacteria do not usually cause disease themselves, however; their presence indicates a potential pathway for fecal coliform and other pathogenic (waterborne disease-causing) organisms such as *E. coli* to enter the well. If human or animal wastes are contaminating the water, gastrointestinal diseases, hepatitis, or other waterborne diseases may result.

In most cases a properly constructed well will prevent bacteria and other disease causing organisms from entering a well. Soils are usually able to filter bacteria out of water before it reaches the saturated zone. Unfortunately in areas where there are thin soils or fractured bedrock, which is commonly the case in many areas of Iowa County, bacteria can more easily contaminate the groundwater aquifer. Under these conditions even a properly constructed well may become contaminated with bacteria. Installing wells according to recommended distances from septic systems, animal feedlots and manure pits should help in avoiding potential bacteria problems. Also, ensuring that pets are not allowed in the area directly surrounding the well is a good precaution.

Bacteria can also enter wells through sanitary defects. One of the most common sanitary defects is related to the well cap. Wells should have a vermin proof cap which covers the top of the well. If the well cap is loose or absent, insects or small animals can enter and can contaminate the well with bacteria. Bad or loose connections to the well may also allow bacteria an opportunity to enter the well.

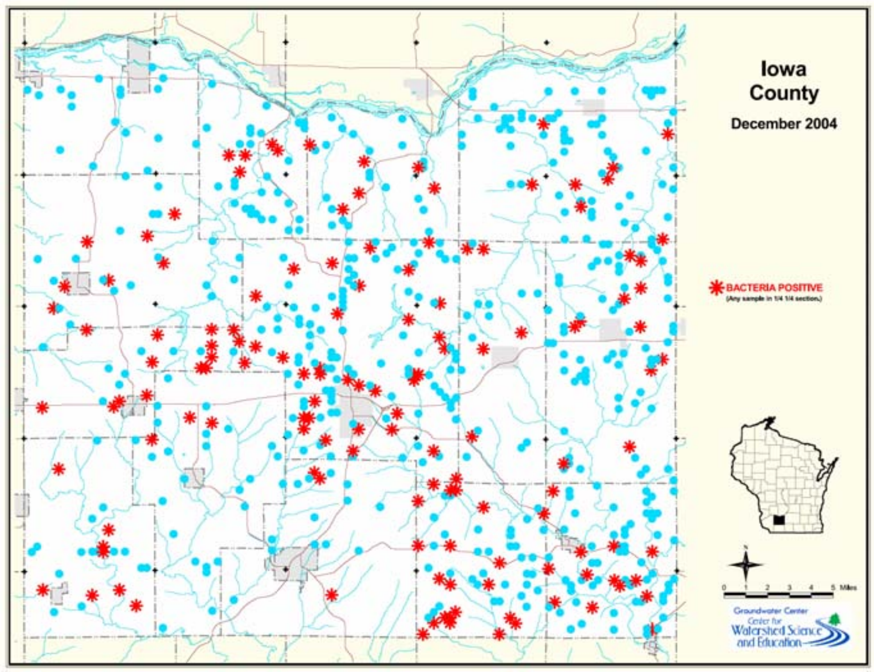


Figure 9
Twenty-four percent of all wells tested positive for coliform bacteria.

Other sanitary defects may have to do with the well casing. Over time the casing may corrode or crack, allowing water to enter into the well close to the surface before bacteria can be filtered out. Similarly, grouting is supposed to fill any gaps between the casing and the surrounding soil or material. A poorly grouted well may allow water from the surface to run down the sides of the well casing directly into the well.

Once the cause of the bacteria contamination is identified and corrected, the well must be sanitized to ensure that the water will be safe to drink in the future. A simple chlorination procedure sometimes called shocking the well is used to destroy the bacteria and sanitize the well. Sometimes the cause of bacterial contamination is never identified but can be corrected by disinfecting the well. Private well owners are encouraged to perform a bacteria test on their well annually or if they notice a sudden change in the taste or odor of the water.

Nitrate-Nitrogen

Nitrate-nitrogen in groundwater commonly results from the use of agricultural and lawn fertilizer, animal waste, septic systems, or decomposing organic matter. It is a widespread groundwater contaminant in Wisconsin especially in agricultural regions because it does not adsorb to soil particles and moves very readily with water as it percolates down through the soil profile into groundwater. Applying more nitrogen fertilizer than a plant needs often leads to nutrient leaching into groundwater as nitrate. Even when applying just the right amount, nitrate often leaches to groundwater under wet conditions when water carries nitrate past the root zone of plants quicker than the plants are able to take it up.

While nitrate in groundwater is considered a **pollutant** to certain sectors of society, it also represents an economic loss for those farmers who continue to apply fertilizer in excess of what crops can take up in any given year. Any nitrate that is detected in groundwater below an agricultural field represents fertilizer that has not been utilized by crops. As the price of fertilizers and energy continue to increase, tailoring fertilizer applications to meet the needs of the crop and eliminate leaching losses will become increasingly important as a way to improve profitability.

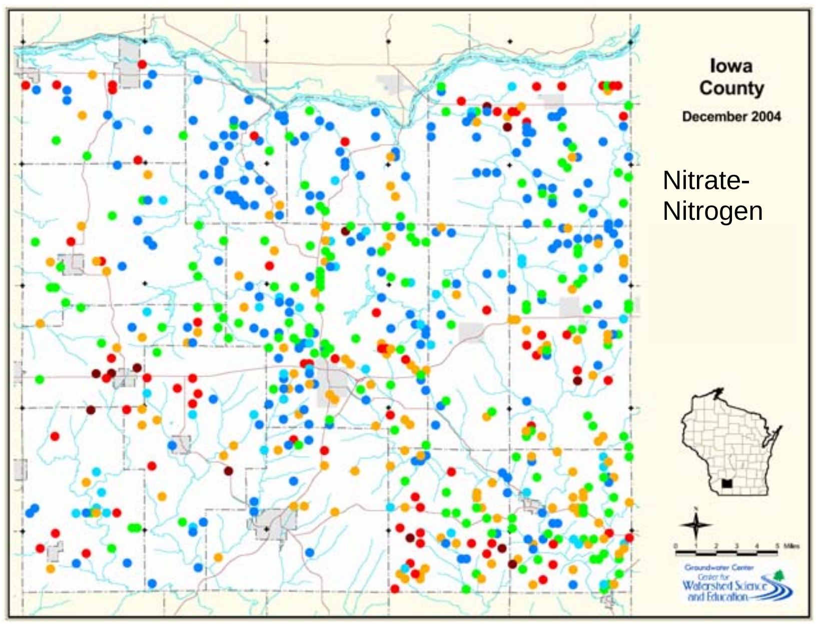
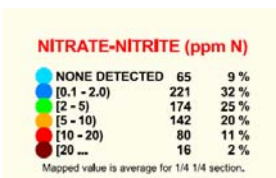


Figure 10
Concentration of nitrate-nitrogen in private wells tested through Iowa County water testing program.



The natural level of nitrate in Wisconsin's groundwater is typically less than 2.0 mg/L. Concentrations greater than 2.0 mg/L suggest that groundwater is impacted by surrounding land-use activities. Because nitrate is very soluble in water, it is considered a good indication that groundwater is susceptible to other forms of pollutants as well. Areas that have elevated levels of nitrate may also consider testing the groundwater for pesticides if there is agriculture nearby.

There are certain health implications related to drinking water with high nitrate. The US EPA set the safe drinking water limit of nitrate-nitrogen in drinking water at 10.0 mg/L. According to the water test data for Iowa County, 13% of the wells tested exceeded the safe drinking water standard for nitrate-nitrogen. Studies suggest that infants less than six months of age that drink water (or formula made with water) containing more than the standard for nitrate-nitrogen are susceptible to methemoglobinemia. This disease interferes with the blood's ability to carry oxygen. Studies also suggest that high nitrate water may be linked to birth defects and miscarriages, so pregnant women and infants should avoid drinking water that is high in nitrate.

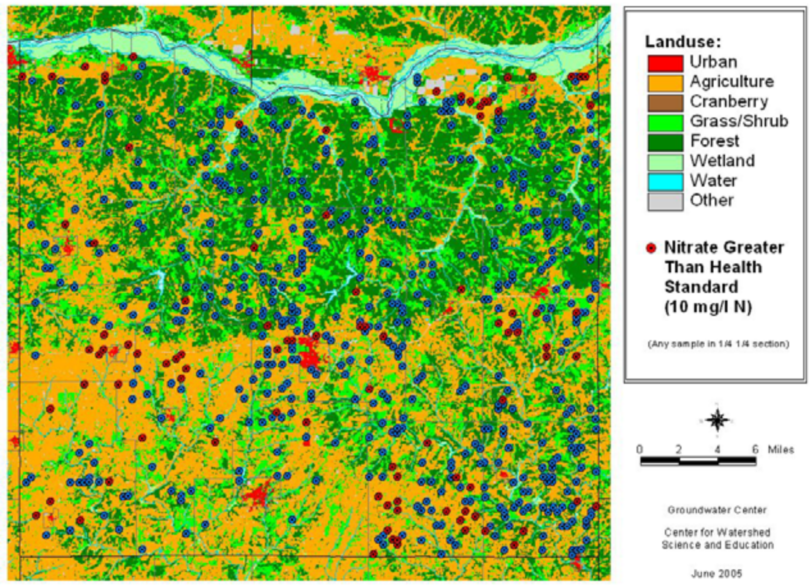


Figure 11
Many of the wells that exceeded the nitrate standard were located in agricultural areas.

In Iowa County, the wells that reported the highest concentrations of nitrate tended to be located primarily in agricultural regions where nitrogen fertilizers and livestock are often the source.

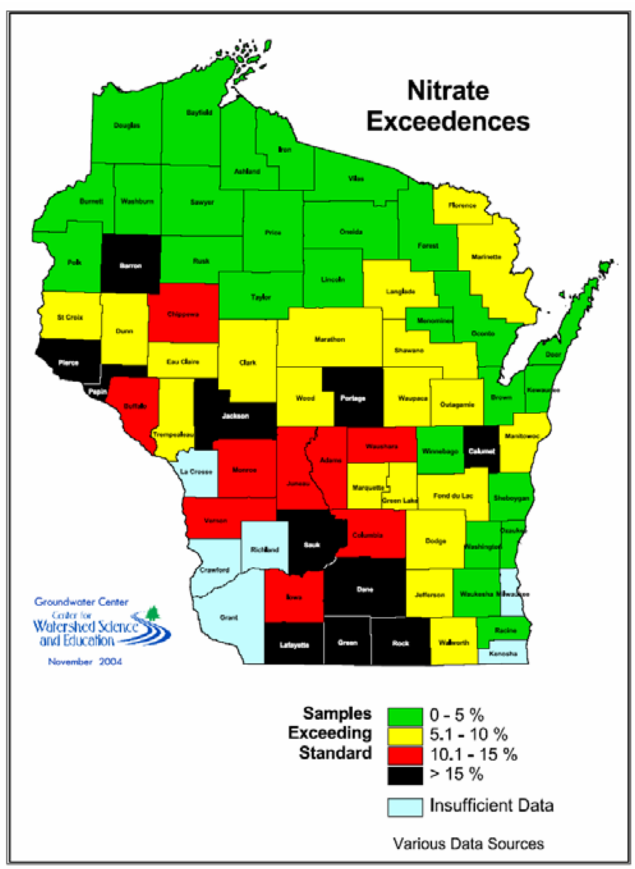


Figure 12
Southwestern Wisconsin counties, including Iowa County, typically have a greater number of wells that exceed the nitrate standard than many other counties in the state.

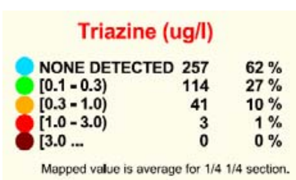
The county wide average nitrate-nitrogen concentration is between 5 and 10 mg/L. While this is below the drinking water standard it does show that many wells in Iowa County are being affected by local land uses. This is similar to surrounding counties; however it is higher than many other counties throughout Wisconsin.

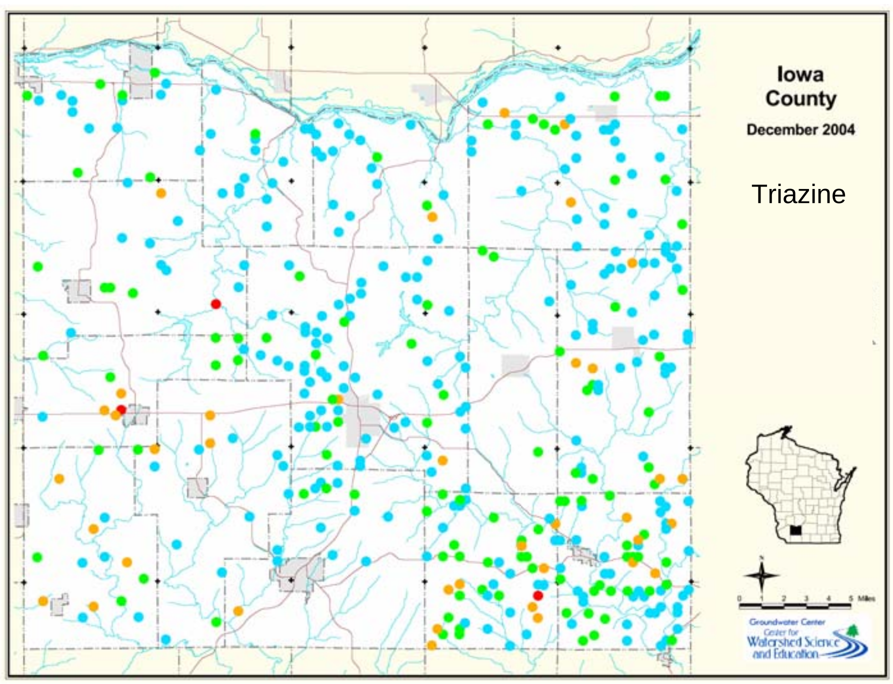
Pesticides

A pesticide is any substance used to control or repel a pest or prevent the damage that pests may cause. The term pesticide includes insecticides, herbicides, fungicides and other substances used to control pests. When pesticides are spilled, disposed of, or applied on the soil, some amount can be carried into the surrounding surface water or groundwater. These products move with water and can eventually enter groundwater and nearby drinking water wells. The occurrence of pesticides in groundwater is more common in agricultural regions.

While the long-term or chronic health effects of drinking water that contain pesticides are not completely understood, certain pesticides may cause an increased risk of developing certain diseases, including cancer. Because of the number of pesticides on the market, health standards for safe amounts in drinking water have not been established for all pesticides. This is further complicated by the fact that pesticides can break down into many other chemicals which may also adversely impact health. Little is known about the health effects of drinking water containing a combination of pesticides and pesticide breakdown products. As a result, limiting the amount of pesticides that end up in groundwater is the best way to ensure safe drinking water for the future.

Figure 13
Triazine screen results from private well tests.





Based on Department of Agriculture, Trade and Consumer Protection survey, the most frequently detected pesticides in Wisconsin groundwater are alachlor, metolachlor, atrazine, metribuzin, and cyanazine. These are the most commonly detected, but there may be others depending on what types of pesticides have been applied. The safe drinking water standard for alachlor is

2 ppb (parts per billion) while atrazine is 3 ppb. There are currently no drinking water standards for metolachlor, metribuzin and cyanazine.

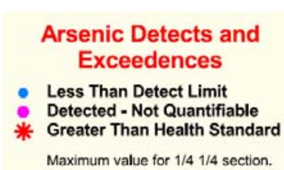
Well test results from Iowa County show certain areas where the groundwater contains measurable amounts of triazine in the groundwater. These results are based on the triazine screen tests performed during the water testing programs. While none of the tests are over the 3 ppb standard for atrazine, this test is only a screening tool and often underestimates the amount of atrazine and its breakdown components. However, it does show that groundwater in agricultural regions in Iowa County are susceptible to contamination from localized pesticide use. Care should be taken by individuals when deciding on the types and application rates of pesticides and strategies should be developed within the county to minimize the potential impacts of pesticide use on groundwater quality.

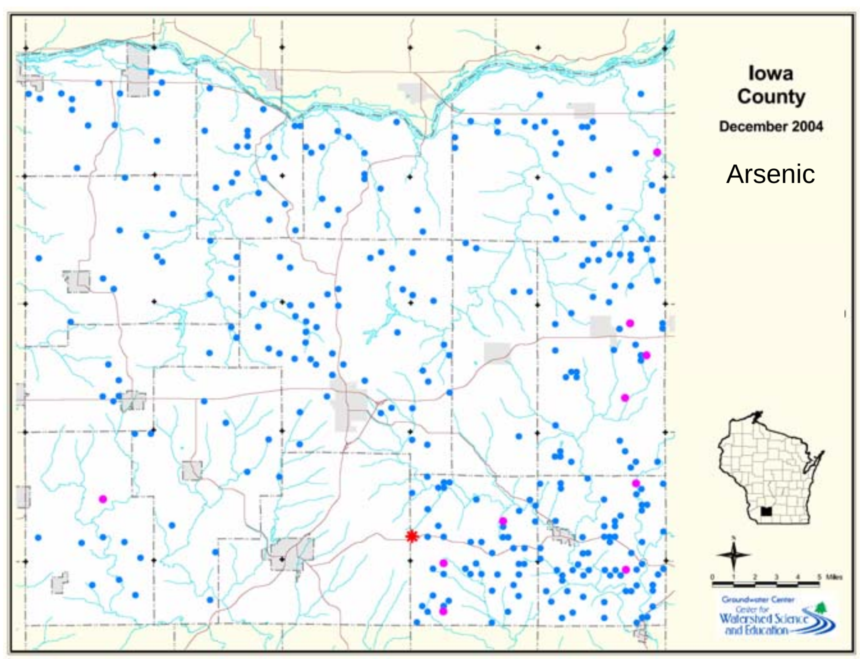
Arsenic

Arsenic occurs at low levels in soil and bedrock, but has been found at levels above the drinking water standard in some Wisconsin wells. Wells with high concentrations of iron may be more likely to contain arsenic bearing minerals. Studies show that even low levels of arsenic can increase the chances of developing cancer of the skin, liver, kidney or bladder.

The drinking water standard for arsenic is 0.010 mg/L (10 parts per billion). While the chance of finding elevated levels of arsenic appear to be greatest in northeastern Wisconsin, problems have been detected in other areas of the state as well, including Iowa County. Because little is known about the extent of the arsenic throughout the state, all residents are encouraged to test for arsenic at least once.

Figure 14
Arsenic has been detected in some Iowa County wells, one was greater than the safe drinking water standard of 10 parts per billion.





Lead

Lead is a toxic metal which until 1985 was commonly used in the construction of most household plumbing systems in Wisconsin. Under natural conditions groundwater has little to no measurable lead. However, water that sits in lead pipes or pipes containing lead solder has the potential to dissolve lead and increase the concentration of lead in drinking water to unsafe levels. Corrosive water increases the likelihood of experiencing elevated lead levels.

Table 2
Concentrations of lead measured in Iowa County wells tested.

Lead (mg/L)	# of Wells	%
None Detected	235	55
[0.002 - 0.015)	143	34
[0.015 - 0.05)	39	9
[> 0.05)	9	2

The safe drinking water standard for lead is 0.015 mg/L (or 15 parts per billion) of lead. Lead can be especially harmful to young children. Drinking water that contains elevated lead levels has been shown to cause brain and nerve damage as well as kidney damage. One way to reduce lead levels in drinking water is to run the faucet for a couple of minutes to flush out water that has sat in pipes for extended periods of time. Treatment systems can also be purchased which reduce the amount of lead in the water.

Copper

Copper is a reddish metal that occurs naturally in rock, soil, water, and air, however the source of copper in drinking water is most often due to plumbing. Copper pipes are commonly used in household plumbing. Much like lead, when water sits in copper pipes for extended periods of time it has the potential to dissolve copper pipes and increase copper levels in water. Corrosive water increases the likelihood that you will experience elevated copper levels in drinking water. Blue-green staining in sinks and bathtubs is a good indicator that copper corrosion is taking place.

Table 3
Copper concentrations measured through the well testing program in Iowa County.

Copper (mg/L)	# of Wells	%
None Detected	10	2
[0.001 - 0.13)	236	56
[0.13 - 1.3)	158	38
[> 1.3)	17	4

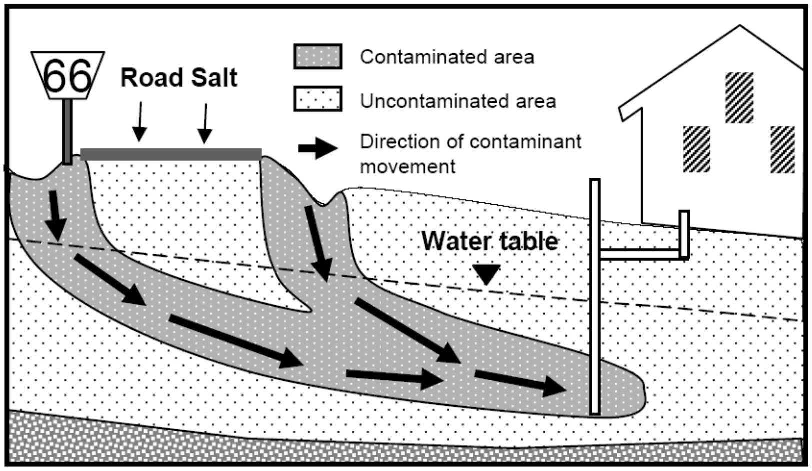
Small amounts of copper should not cause problems, however too much copper in our diets can be potentially harmful. The safe drinking water standard for copper is 1.3 mg/L of copper. Immediate effects from drinking water with high levels of copper may include vomiting, diarrhea, stomach cramps, and nausea. Long-term exposure of high levels of copper may cause kidney and liver damage. To reduce copper levels in drinking water run the faucet to flush out water that has sat in pipes for extended periods of time. Treatment systems are also available that will reduce the amount of copper in drinking water.

Other Important Water Quality Tests

Chloride

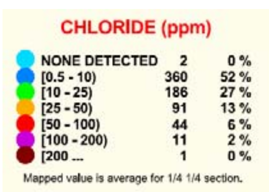
In most areas of Wisconsin, chloride in groundwater is naturally less than 10 mg/L. Higher concentrations usually indicate contamination by septic systems, road salt, fertilizer, animal waste or other wastes. Chloride is not toxic, but some people can detect a salty taste at 250 mg/L. High chloride may also speed up corrosion in plumbing (just as road salt does to your car).

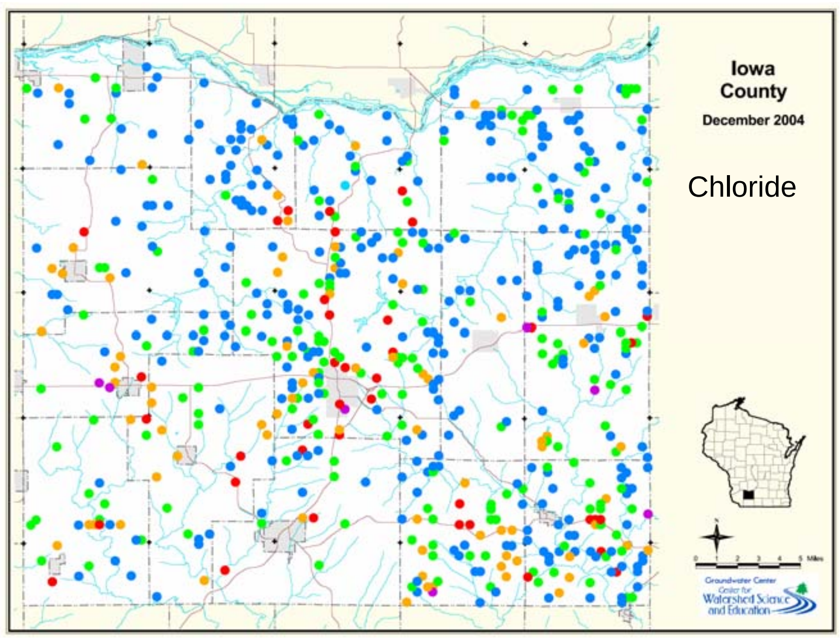
Figure 15
Road salt is a common source of chloride in groundwater.



Chloride is considered an indicator of other potential water quality problems. Levels of chloride that are above what is typical under natural conditions indicate that groundwater is being affected and extra care should be taken to ensure that land-use activities do not further degrade water quality.

Figure 16
Chloride concentrations measured in Iowa County private wells.





In Iowa County 52% of the well tests showed natural levels of chloride in groundwater while another 27% were only slightly elevated. The remaining 21% of wells which tested above 25 mg/L (ppm) of chloride tended to be located near major roadways where road salt is commonly applied or in agricultural regions where fertilizer and animal wastes are often used. Residential septic systems may also be responsible for some of the elevated levels of chloride in groundwater.

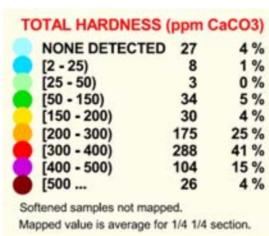
Total Hardness

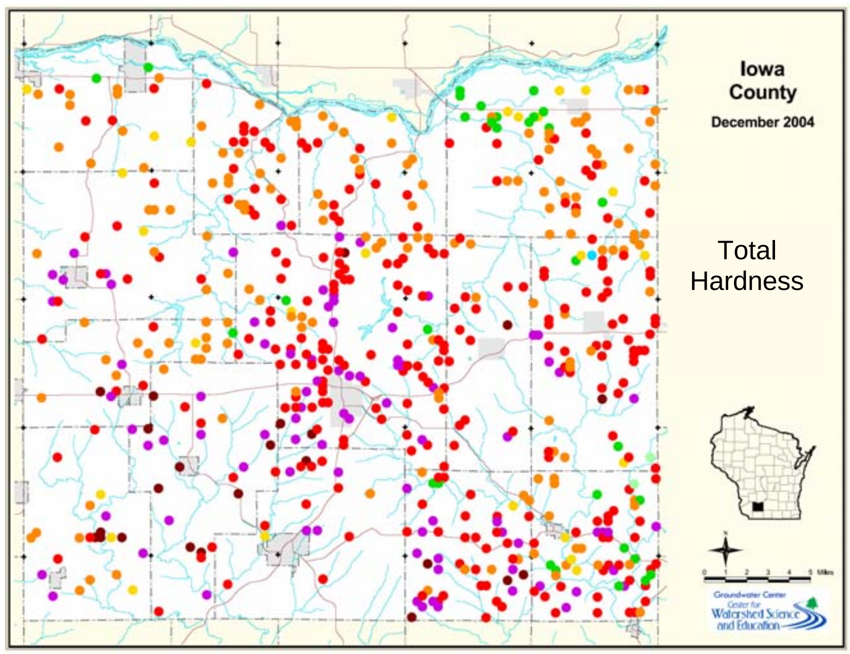
Water hardness results when minerals, generally calcium and magnesium, dissolve naturally into groundwater from soil or limestone and dolomite rocks. There are no drinking water standards for hardness; however, high hardness is usually undesirable because it can cause lime buildup (scaling) in pipes and also in water heaters which over time will decrease water heater efficiency. In addition, calcium and magnesium react with soap to form a “scum”, decreasing the cleaning ability of the soap and increasing bathtub rings and graying of white laundry.

The ideal range for total hardness is typically between 150 and 200 mg/L or ppm $CaCO_3$. Water that is naturally low in calcium and magnesium (often referred to as soft water) may be corrosive. Soft water is water that contains less than 150 mg/L of total hardness as $CaCO_3$. Water that contains more than 200 mg/L $CaCO_3$ is considered hard. Water softeners are commonly used to reduce problems associated with hard water. The water softening industry measures hardness in grains per gallon. 1 grain/gallon = 17.1 mg/L $CaCO_3$.

Dolomite, a type of carbonate mineral, is very common throughout Iowa County. Water that comes in contact with this type of rock has high amounts of calcium and magnesium, creating hard water conditions for many wells in the county. The exception to this is the northern edge of Iowa County along the Wisconsin River. Many of the wells in this area obtain water from the sand aquifer. Because sand is primarily composed of silica and very little carbonate exists in the sand aquifer, water in this aquifer generally does not contain as much calcium and magnesium.

Figure 17
Map of total hardness for Iowa County private well samples.





pH

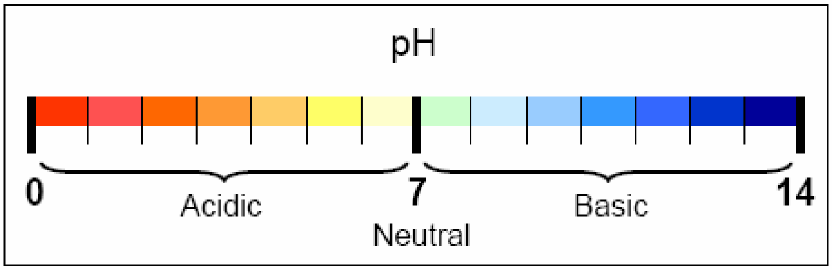
The pH is a measure of the hydrogen ion (acid) concentration in water. A pH of 7 is neutral. Values above 7 are alkaline or basic; those below 7 are acidic. In Wisconsin pH is commonly found between 6.0 and 9.0.

Table 4
The pH values recorded for Iowa County well tests.

pH	# of Wells	%
[6.0 - 6.5)	6	1
[6.5 - 7.0)	15	2
[7.0 - 7.5)	90	12
[7.5 - 8.0)	518	66
[8.0 - 8.5)	148	19

Low values are most often caused by the lack of carbonate minerals such as limestone and dolomite in the aquifer. Some contaminant sources such as landfills or mine drainage may also lower pH.

Figure 18
The pH scale.



A change of 1 pH unit is a 10-fold change in acid level. Acidic water is often corrosive and can react with plumbing. The lower the pH value the more corrosive the water will be. It may be important to note that pH values are often slightly higher in the laboratory than at your well, because carbon dioxide gas (CO_2) leaves water when it is exposed to air. If corrosion is a problem, neutralizing filters can often be installed to counteract the effects of acidic water.

Alkalinity

Alkalinity is the measure of water's ability to neutralize acid, and so is related to pH. Like total hardness, it results from the dissolution of carbonate minerals such as limestone and dolomite. Water that is low in alkalinity is more likely to be corrosive.

Table 5
The alkalinity test results from Iowa County well testing participants.

Alkalinity (mg $CaCO_3$/L)	# of Wells	%
[2 - 25)	7	1
[25 - 50)	6	1
[50 - 150)	52	7
[150 - 200)	34	4
[200 - 300)	332	43
[300 - 400)	333	43
[400 - 500)	12	2

Conductivity

Conductivity (specific conductance) is a measure of the ability of water to conduct an electrical current. Conductivity is a test of overall water quality and is not a health concern. It is related to the amount of dissolved ions in water, the more dissolved ions in the water the greater the conductivity.

Table 6
Conductivity ranges for Iowa County well tests.

Conductivity (umhos/cm)	# of Wells	%
[100 - 200)	14	2
[200 - 500)	194	25
[500 - 800)	432	55
[800 - 1000)	95	12
[> 1000)	40	5

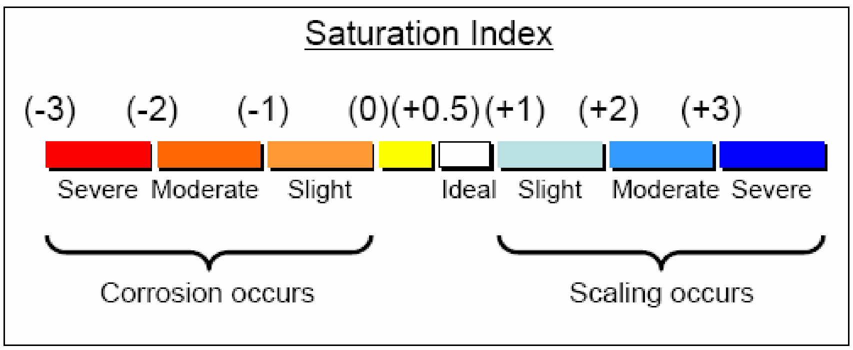
Typically calcium and magnesium represent the majority of dissolved ions in solution. As a result, conductivity (measured in μmhos/cm at 25^{o} C) is about twice the hardness (mg/L $CaCO_3$) in most uncontaminated waters in Wisconsin. If the conductivity is much greater than twice the hardness, it may indicate the presence of contaminants such as sodium, chloride, nitrate, or sulfate, which may be human-influenced or natural. Changes in conductivity over time may indicate changes in water quality.

Saturation Index

The saturation index is a measurement used to determine the tendency of lime (calcium carbonate) to precipitate (form a solid and settle out) from water or for the water to corrode household plumbing. It is calculated from pH, alkalinity, calcium hardness and conductivity data. Water with a low pH, low alkalinity, and low hardness value will result in corrosive water. Water that is high in pH, alkalinity and hardness will likely produce scale.

Water is a good solvent, and will attack unprotected metal plumbing. Lead, copper and zinc from pipes and solder joints may then leach (dissolve) into drinking water. Symptoms of corrosive water include pinhole leaks in copper pipes or green stains on plumbing fixtures. Lime precipitate (scale) is a natural protection against corrosion. Too much scale, however, will plug pipes and water heaters, decreasing their efficiency. Water softeners prevent scale buildup, but also decrease any protection from corrosion the unsoftened water may have provided.

Figure 19
The saturation index helps determine whether water is corrosive or scale forming.



Values between 0 and 1 units are considered the most desirable because at this level the water is fairly balanced. Water with a value less than 0 will be more likely to corrode plumbing. Water with a saturation index greater than 1 will be more likely to form scale.

Table 7
The saturation index reported for Iowa County well tests.

SI (Saturation Index)	# of Wells	%
[< (-3))	6	1
[(-3) - (-2))	6	1
[(-2) - (-1))	33	4
[(-1) - 0)	38	5
[0 - 1)	609	78
[> 1)	87	11

Iron

Iron is a naturally occurring mineral that is commonly found in groundwater. Increased iron concentrations are typically found in areas with acid waters or water that is low in oxygen. While there are no known health effects caused by drinking water that contains iron, concentrations greater than 0.3 mg/L are associated with aesthetic problems relating to taste, odor and color.

Table 8
Iron concentrations in Iowa County recorded during water testing.

Iron (mg/L)	# of Wells	%
None Detected	53	13
[0.002 - 0.3)	336	80
[0.3 - 1.0)	18	4
[> 1.0)	14	3

Reddish-orange staining of bathroom fixtures and laundry can often be attributed to high levels of iron in the water. Low levels of iron can often be treated with a household water softener which also eliminates problems associated with hard water. Iron removal can also be accomplished using aeration techniques or a permanganate water treatment system.

Taste and odor problems can be magnified by the presence of iron bacteria, which thrive in wells that have a high concentration of iron. Homes that have iron bacteria often first notice that the water smells like raw sewage or rotten eggs. People also report slimy water or report an oily sheen on water that is allowed to sit. While the presence of iron bacteria is not considered to be a health issue, it can be a nuisance and is difficult to get rid of. Periodic disinfection of the well is often used to control the problems associated with iron bacteria.

Manganese

Similar to iron in groundwater, manganese is naturally occurring and is found in areas where water is low in oxygen such as areas of wet or organic soils. Although not considered to be a health issue at concentrations typically found in groundwater, manganese can be a nuisance for aesthetic reasons.

Table 9
Manganese concentrations in Iowa County well samples.

Manganese (mg/L)	# of Wells	%
None Detected	206	49
[0.001 - 0.05)	189	45
[0.05 - 0.2)	21	5
[0.2 - 1.0)	3	1

The aesthetic limit of manganese in water is set at 0.05 mg/L. This is because of the tendency for manganese to form black precipitates which can cause staining of plumbing fixtures. While it can be difficult to remove manganese using water treatment, iron treatment systems can often be used to control some of the problems associated with elevated levels of manganese.

Treatment of Water Quality Problems

It may be surprising to hear that private well owners with water quality concerns are still allowed to use their wells, even if the water does not meet safe drinking water standards. Even though private well owners are not required to correct water quality problems, many people do choose water treatment or find alternative sources of water to avoid drinking unsafe water. The following are available when deciding on a solution to water quality problems:

Drilling a New Well

In situations where water quality problems can be attributed to well construction faults, drilling a new well or correcting the fault is the preferred solution. Replacing the well may also be an option for water quality problems caused by land-use activity such as high nitrate or pesticides.

When a change in water quality is desired, changing the well depth is often more critical than the location of the new well on a particular piece of property. However, it is worth mentioning that drilling a new well does not guarantee better water quality. While deeper wells often tap into older water that is less impacted by surface activities, other problems such as high iron or increased levels of hardness may be more likely. In addition, water quality changes over time and while nitrate and pesticide concentrations may be low initially, there is no guarantee that they will not increase as newer water replaces older groundwater in the aquifer.

When drilling a new well, always consult with neighbors who have private wells. Look for similarities in well construction among those individuals who are satisfied with their water quality. Also, well drillers may have recommendations based on knowledge of local conditions and may be able to provide guidance.

Water Treatment

Water treatment is often very successful at removing health related contaminant as well as reducing aesthetic concerns associated with water quality. When deciding if water treatment is the best option, always consider the cost of the device, annual maintenance, as well as energy costs to operate the device. It is also important to remember that routine maintenance is necessary to ensure that the water treatment device is working properly.

No one water treatment device designed today is capable of solving all water quality problems. The type that you purchase depends on the particular concern and the amount of contaminant in your water. Before purchasing a water treatment device, always test water at a certified laboratory. Know the types and amounts of contaminants that you are looking to remove. Check before you buy anything to make sure the device is capable of removing the particular contaminant of concern as well as the amount that is in your water.

Water treatment systems can be divided into two categories; point-of-entry systems and point-of-use. **Point-of-entry** systems are able to treat water throughout the entire house and are typically used to treat aesthetic concerns associated with water quality. Water softeners are a common example of a point-of-entry system. **Point-of-use** systems only treat water at the faucet where you get your drinking water from and are usually used to remove health related contaminants from drinking water. Reverse osmosis units and distillation units are examples of a point-of-use system which can be used to reduce levels of nitrate and arsenic.

Bottled Water

People often assume that because they are buying water from the store that it is purer or better than the water that is coming from their private well. The well tests from the over 800 private wells in Iowa County reveal that many private wells in Iowa County provide water that is just as good if not better than bottled water that is sold in stores. However, for those people who have water quality problems, drinking bottled water may be an option to avoid drinking unsafe drinking water. When purchasing bottled water choose a company that is able to provide details regarding the source of the water, how the water was treated, as well as the water test information. Many types of bottled water are treated using reverse osmosis or distillation units like those available for residential homes.

Eliminate the Contamination Source

The ideal solution to water quality problems caused by human activity is to eliminate the contamination source. In cases where the source of contamination is obvious, such as a failing septic system or a leaking underground storage tank, it may be easy to eliminate the source. However, identifying contamination sources can often be difficult or challenging, especially when dealing with non-point pollutants like nitrate. In addition, eliminating the contamination source may not result in a change in water quality for a long time since it may take years for newer uncontaminated water to replace the contaminated groundwater within the aquifer. While improving land-uses to eliminate groundwater contamination should be a goal of everyone in the community, it is important realize that short term solutions often have to be implemented as well to avoid drinking unsafe drinking water.

Groundwater Management

The ultimate goal of groundwater management is to protect, maintain, and improve the quality and quantity of groundwater. The responsibility of regulating pollution sources is often handled by state agencies. In situations where the state has not preempted local authority, local regulations that control the location of land-uses, the types of permitted activities, and regulate densities can be important tools for managing groundwater (Born et al., 1987). Because many local factors influence groundwater, it is important that local governments realize the role they have in managing this resource for the future. The emphasis of groundwater management should be placed on conservation and prevention, not remediation after groundwater becomes contaminated.

Ensuring success requires local communities to clearly identify goals that will protect groundwater. While not a comprehensive list, an effective local groundwater management strategy will include similar goals to the following:

- Encourage wise land-use decisions that will prevent adverse effects to groundwater quality or quantity.
- Protect municipal and/or private water supplies from contamination.
- Educate community members about the local groundwater resource, its use, the value, current and potential problems, as well as possible solutions.
- Establish and maintain a data collection, monitoring and analysis program.
- Coordination and cooperation between state agencies, local government, and citizens.

All of the previously stated goals will improve the chances of developing a successful comprehensive groundwater management strategy (Born et al.

1987). Because land-use activities can have a profound impact on groundwater quality, the making of sound land-use decisions by local governments is critical to protecting groundwater and drinking water supplies from contamination. Increased knowledge about the properties and importance of groundwater, will hopefully lead to wiser decision making by local governments and less opposition from within the community if the decisions are controversial. Maintenance of a data monitoring program allows local governments to track changes in groundwater quality or quantity, and identify areas of concern. Lastly, because the authority for managing groundwater is not held by one agency, coordination and cooperation between state agencies, local governments, and citizens is vital to maximizing efficiency and achieving the ultimate goal of protecting groundwater.

Conclusion

Even though it's often buried deep underground and we can't see it, groundwater is one of Iowa County's most valuable natural resources. A clean and dependable supply of groundwater provides safe drinking water, supports a healthy economy, and maintains our lakes, rivers and streams. Unless people are willing to sacrifice any of these things, the community must be committed to managing our groundwater resources wisely.

Groundwater is a local resource and is replenished by the rain and snow that infiltrate the soil. Many everyday activities that we do on the land surface have the potential to impact the quality and quantity of our groundwater resources below. While there are some naturally occurring contaminants, most of the unwanted chemicals in groundwater are a direct result of human activity. These activities can also affect nearby surface waters as well, since groundwater flows to the rivers and lakes in Iowa County.

The drinking water programs held between 2000 and 2005, in which over 800 households had their private wells tested help us to create a better picture of current groundwater quality in Iowa County. Iowa County groundwater is generally characterized by having high hardness, a pH greater than 7.0, and high alkalinity. While the testing showed many private well provide drinking water that meets or exceeds drinking water standards, test results revealed that groundwater quality is degraded in parts of Iowa County.

Private well testing indicated that nearly 60% of all wells tested had concentrations of nitrate-nitrogen above 2 mg/L, an indication that groundwater is being impacted by local land-uses. Thirteen percent of all wells tested greater than the safe drinking water standard for nitrate-nitrogen. In addition, nearly one-quarter of the wells tested positive for coliform bacteria and 38% of wells reported detectable levels of triazine, the most commonly applied corn herbicide in Wisconsin.

Once groundwater becomes contaminated it is very difficult and costly to clean up, therefore preventing groundwater contamination should be the goal of everyone in Iowa County. As a result, local governments looking to manage groundwater will need to make wise choices when it comes to future land-use decisions. Local governments can only do so much however; everyone in Iowa County will also need to make wise personal decisions when it comes to their individual actions that involve using groundwater or making land-use decisions on their own property that will potentially affect this underground resource. Groundwater is a perfect example of a community resource and every one of us has a critical part to play in protecting groundwater for future generations.

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Yanggen, D.A., and B. Webendorfer. 1991. Groundwater Protection Through Local Land-Use Controls. Wisconsin Geological and Natural History Survey. Special Report No 11, 91 p.

Born, S.M., D.A. Yanggen, and A. Zaporozec. 1987. A Guide to Groundwater Quality Planning and Management for Local Governments. Wisconsin Geological and Natural History Survey. Special Report No 9, 48 p.

Glossary

alluvium Sediment deposited by flowing water, as in riverbeds, or floodplains.

aquifer Water bearing geological formations that transmit and store water.

aquitard A layer or section of the aquifer that impedes water movement.

cone of depression When pumping water from a well, the water level adjacent to the well is lowered creating a cone where water has been pulled from the aquifer.

discharge area Area where groundwater is discharged or returned to the earth's surface through springs, seeps, or baseflow.

evaporation Process by which water changes from a liquid to a gas.

geology The scientific study of the origin, history, and structure of the earth.

groundwater Water contained in the empty spaces between soil particles and rock materials below the surface of the earth.

high capacity well A well that pumps more than 100,000 gallons of water per day.

hydrologic cycle Also referred to as the water cycle, explains how water is constantly in a state of movement through the environment.

irrigation well A well that pumps water for the sole purpose of watering crops.

point-of-entry A whole house water treatment system; treats water as it enters the house.

point-of-use A water treatment system that treats a small amount of water at a particular faucet, typically supplies enough water only for drinking and cooking.

pollutant A waste material that contaminates soil, air, or water.

recharge area Area on the land surface where precipitation is able to infiltrate into the soil and percolate down to the saturated zone of an aquifer.

transpiration The emission of water vapor through the leaves of plants.

water table Level below the surface of the earth where groundwater exists; separates the saturated zone from the unsaturated zone.

watershed Area of land that contributes water to a water body through surface water runoff or groundwater.

well A vertical excavation that extends into a liquid bearing formation. In Wisconsin, wells are drilled to obtain water, monitor water quality, and monitor water levels.

well casing Metal lining along the inside of a well that prevents unconsolidated material from falling into the well; also controls the part of the aquifer a well receives water from.

Additional Groundwater Resources

The following resources contain useful information designed for the general public to learn more about current groundwater issues and gain a better understanding of common drinking water concerns. Many resources are available in hardcopy form; some are also available online on the respective agency webpage.

- For copies of **WI Department of Natural Resources (DNR)** publications please call (**608)266-0821** or visit http://www.dnr.state.wi.us/org/water/dwg/pubbro.htm.
- For copies of **UW-Extension (UWEX)** publications please call (**877)947-7827** or visit http://www.uwex.edu/ces/.
- The **Wisconsin Geological and Natural History Survey (WGNHS)** has many excellent geology and groundwater resources including maps available from their office. If interested call (**608)263-7389** or for a complete listing visit their website at http://www.uwex.edu/wgnhs/pubs.htm.

Teaching Resources

- **Wisconsin's Groundwater Study Guide.** A curriculum development guide primarily for 6th to 9th grade earth science teachers. Adaptable to older and younger students and informal education settings. For a copy call (**877)268-WELL** or visit http://dnr.wi.gov/org/water/dwg/gw/educate.htm.
- **Groundwater Flow Demonstration Model**. Over the years this two dimensional model has effectively demonstrated basic groundwater concepts to both children and adult audiences. Offering a glimpse underground, concepts such as groundwater flowpaths, leaking landfills, cones of depression, and groundwater surface water connections are brought to life. For information on ordering a model call (**715)346-4613** or to borrow a model call (**715)346-4276** for a list of available models.

Groundwater Publications

- **Groundwater: Protecting Wisconsin's Buried Treasure.** DNR. PUB-DG-055-99. An easy to read full-color magazine designed to help people learn more about their groundwater resources, what it is used for, common threats, and groundwater protection.
- **Answers to Your Questions about Groundwater**. DNR. PUB DG-049 2003. Answers to many of the common concerns and misconceptions that the average person has about groundwater.
- **Better Homes and Groundwater**. DNR. PUB-DG-070 2004. Easy to do activities to perform in our own backyards to improve and protect the quality of our groundwater resources.
- **Answers to Your Questions on Well Abandonment**. DNR. PUBL-DG-016 2004. This brochure explains the importance of abandoning unused wells to protect groundwater quality and covers procedures for abandoning wells properly.
- **Wellhead Protection: An ounce of prevention…** DNR. PUB-DG-0039 99REV. Brief description of the importance of wellhead protection and initial steps for protecting community water supplies.
- **A Growing Thirst for Groundwater**. DNR. 2004. This article in WI Natural Resources Magazine looks at the rising issue of groundwater quantity in Wisconsin. It also identifies steps which have recently been taken to ensure that there is enough groundwater for our homes and businesses, as well as our state's lakes, rivers, and wetlands. http://www.wnrmag.com/stories/2004/jun04/ground.htm
- **GCC Directory of Groundwater Databases**. DNR. PUB-DG-048 1998. This document from the Wisconsin Groundwater Coordinating Council provides a listing of groundwater related information maintained in computerized and non-computerized databases.

Groundwater Policy

- **Wisconsin Groundwater Coordinating Council Report to the Legislature.** GCC. The Groundwater Coordinating Council is required by s. 15.347, Wis. Stats., to prepare a report which "summarizes the operations and activities of the council..., describes the state of the groundwater resource and its management and sets forth the recommendations of the council.
  Download at http://www.dnr.state.wi.us/org/water/dwg/gcc/Pubdwnld.htm
- GCC Comprehensive Planning and Groundwater Fact Sheets.
  Download at http://www.dnr.state.wi.us/org/water/dwg/gcc/Pubdwnld.htm
  - **Groundwater and its Role in Comprehensive Planning.** GCC. Fact Sheet 1. 2002. This informational sheet provides an basic explanation of what groundwater is and why it is an important consideration when preparing comprehensive plans for local governments.

- **Resources to Help You Protect Your Drinking Water Supply.** GCC. Fact Sheet 2. 2002. This informational sheet identifies state resources available to help communities protect drinking water supplies.
- **Residential Development and Groundwater Resources.** GCC. Fact Sheet 3. 2002. This informational sheet identifies potential considerations of the effects of residential development on groundwater resources and also offers suggestions on how to minimize those impacts.

Drinking Water Publications

- **You and Your Well**. DNR. PUB-DG-002 2003. Basic information and requirements for a properly constructed well.
- **Do Deeper Wells Mean Better Water?** UWEX. G3652. This brochure explores different well construction terminology and explains how well depth can affect water quality.
- **Tests for Drinking Water from Private Wells**. DNR. PUBL-DG-023-04REV. Advises private well owners on the tests and frequency that should be performed on their well to ensure safe drinking water.
- **Choosing a Water Treatment Device**. UWEX. G3558-5. Describes the most common water treatment devices for home use and lists contaminants that each is capable of removing.
- **Bacteriological Contamination of Drinking Water**. DNR. PUB-DG-003-2000. Explains how wells become contaminated with bacteria, how to test for it, and how eliminate bacteria in your well.
- **Lead in Drinking Water**. DNR. PUB-DG-015 2003.
- **Copper in Drinking Water**. DNR. PUB-DG-027 2003.
- **Arsenic in Drinking Water**. DNR. PUB-DG-062 00.
- **Pesticides in Drinking Water**. DNR. PUB-DG-007 2002
- **Radium in Drinking Water**. DNR. PUB-DG-008 2002
- **Nitrate in Drinking Water**. DNR. PUB-DG-001 2004
- **Volatile Organics in Drinking Water**. DNR. PUB-DG-009 00
- **Iron in Drinking Water**. DNR. PUB-DG-035 01REV
- **Radon in Private Well Water**. DNR. PUB-DG-036 2004
- **Iron Bacteria Problems in Wells**. DNR. PUBL DG-004 01 Rev
- **Sulfur Bacteria Problems in Wells**. DNR. PUBL-DG-005 99 Rev

Useful Websites

Iowa County. Government information source for Iowa County listing services offered through county government and contact information. http://www.iowacounty.org/

Groundwater Center. Helping citizens and governments manage the groundwater in Wisconsin wisely, through education, public information, applied research, and technical assistance. http://www.uwsp.edu/cnr/gndwater/

Wisconsin Geological and Natural History Survey. Provide objective scientific information about the geology, mineral resources, water resources, soil, and biology of Wisconsin. Communicate the results of our activities through publications, technical talks, and responses to inquiries from the public. http://www.uwex.edu/wgnhs/index.html

Wisconsin Department of Natural Resources

- **Drinking and Groundwater Section.** Working to safeguard Wisconsin drinking water and groundwater now and in the future. http://www.dnr.state.wi.us/org/water/dwg/
- **Bureau for Remediation and Redevelopment Tracking System.** Allows you to find information on incidents that contaminated soil or groundwater in your area. http://botw.dnr.state.wi.us/botw/Welcome.do