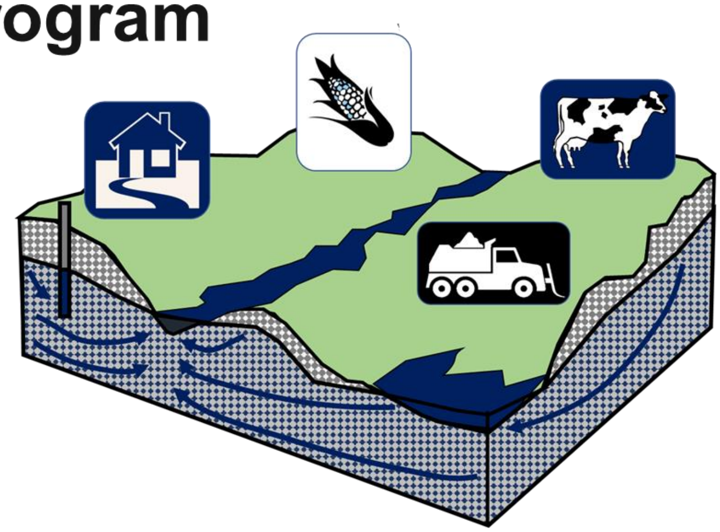
Green County Well Water Monitoring Program

Year 3



Green County Well Water Monitoring Annual Report

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June, 2022

Abstract
Groundwater is the principal water supply for Green County municipalities, industries, and rural residents. While municipal water supplies are regularly monitored and required to meet drinking water standards, private well owners must make decisions regarding when and what to test for and what to do if there is a problem. In an effort to 1) understand changes to well water quality over time, 2) effectively target management, and 3) focus public health outreach efforts related to groundwater and private well owners, Green County undertook steps to initiate a 5-year project to monitor well water quality.

In July 2019, Green County began collaborating with the UW-Stevens Point & University of Wisconsin – Madison, Division of Extension's Center for Watershed Science and Education to test a subset of Green County private wells as part of a long-term monitoring network. The following county departments are assisting with the project: Extension Green County, Green County Health Department, Green County Land & Water Conservation Department, Green County Land Information Office, and Green County Land Use & Zoning Department.

Criteria were developed and used to select a network of wells that are representative of Green County's diverse soils, geology, land-use, and well construction. A total of 342 participants successfully submitted samples for Year 1, 323 samples were analyzed in Year 2, and 307 samples were analyzed in Year 3 of the project. All samples were analyzed for nitrate-nitrogen, chloride, pH, alkalinity, total hardness, and conductivity at the state-certified Water and Environmental Analysis Lab. The goal is for at least 240 wells to submit samples in all 5 years of the study. At the current rate of attrition in sample participants, the project is on track to meet that goal.

An interactive dashboard is available online at to provide additional information and access to results: http://68.183.123.75/wisconsinwater/County-Apps/Green/

Year 3 Well Water Quality Summary
Green County's groundwater can generally be characterized as slightly basic (pH = 8.1), hard water (mean = 346 mg/L as $CaCO_3$), with high alkalinity (307 mg/L as $CaCO_3$). These aesthetic characteristics of the water are largely influenced by the geologic materials groundwater is stored and transported in; lower values of pH, alkalinity, and total hardness are sometimes found in wells near the Sugar River where wells may be shallower and access the sand/gravel aquifer versus bedrock.

Nitrate is a common health-related contaminant found in Green County's groundwater (mean = 5.8 mg/L nitrate-nitrogen). Nineteen percent of wells tested greater than the 10 mg/L drinking water standard; approximately 73% of wells tested measured greater than 2 mg/L, which provides evidence that land-use activities are impacting water quality in much of the county.

Chloride provides additional insight into the effects of land-use on water quality; background levels of chloride in groundwater are typically less than 10 mg/L. Sixty-three percent of wells measured chloride greater than 10 mg/L; the mean chloride concentration in Green County was 18.9 mg/L.

The county-wide nitrate average from year to year has remained relatively consistent over the three years. This study provides an important benchmark of well water quality in Green County. Additional work will be done in years 4-5 to investigate the main factors affecting well water quality. Year 3 results add to the previous two years of data to create a foundation for understanding how or if groundwater is changing over time.

Green County Groundwater Well Water Monitoring
Year 3 - Annual Report

July 1, 2021 – June 30, 2022

Project Background

On May 8, 2018 the Green County Board voted to accept the Green County Livestock Facility Study Group's recommendations for consideration. As a result of the recommendations from the Green County Livestock Facility Study Group, Green County started a five-year groundwater quality trend data project, with 2020 being the first year of testing. It is one of the first counties in Wisconsin (and nationally) to use the process it is using. This is an opportunity to learn more about groundwater in Green County. This multiyear process is specifically designed to get good data in order to better understand water quality in Green County.

Tracking groundwater quality trend data will help local officials and Green County residents make data-drive decisions when managing groundwater quality. Currently, little information exists that allows for an understanding of how groundwater quality has changed over time in Green County. Establishing a network of private well owners to perform annual testing over an extended period of time will help inform residents and local leaders whether groundwater quality is getting better, worse, or staying the same.

Initial Well Selection and Recruitment

A total of 778 wells were selected as part of the initial recruitment (Figure 1). This assumed a response rate of approximately 35%. Wells were selected utilizing a variety of datasets that included the Wisconsin Parcel Data Layer, Well Construction Records, Center for Watershed Science and Education Well Water Data, and others.

For the initial recruitment list, an attempt was made to locate and at least one well owner per section with a Wisconsin Unique Well Number and could be matched to a landowner from the parcel data layer. All things being equal, preference was given to those landowners that participated in previous Extension well testing efforts. Most wells on the list have well depth, well casing, and water table information. Of the landowners that were contacted, 114 submitted a previous sample through Extension programming. Recruitment materials consisted of a recruitment letter describing why the landowner was being contacted along with additional information about the project. Landowners were asked to respond using a pre-paid postcard. Recruitment materials were mailed in early November.

A total of 388 landowners indicated their willingness to participate in the well monitoring program (Figure 2). This is a success rate of 49.8%, higher than our initial estimate of 35%. Anticipating a drop in participation over the 5 year period, we attempted to sample all 388 wells in hopes that we still have a minimum of 240 well samples by the end of the final year of the project. Each year kits are mailed to all of the participants from the previous year.

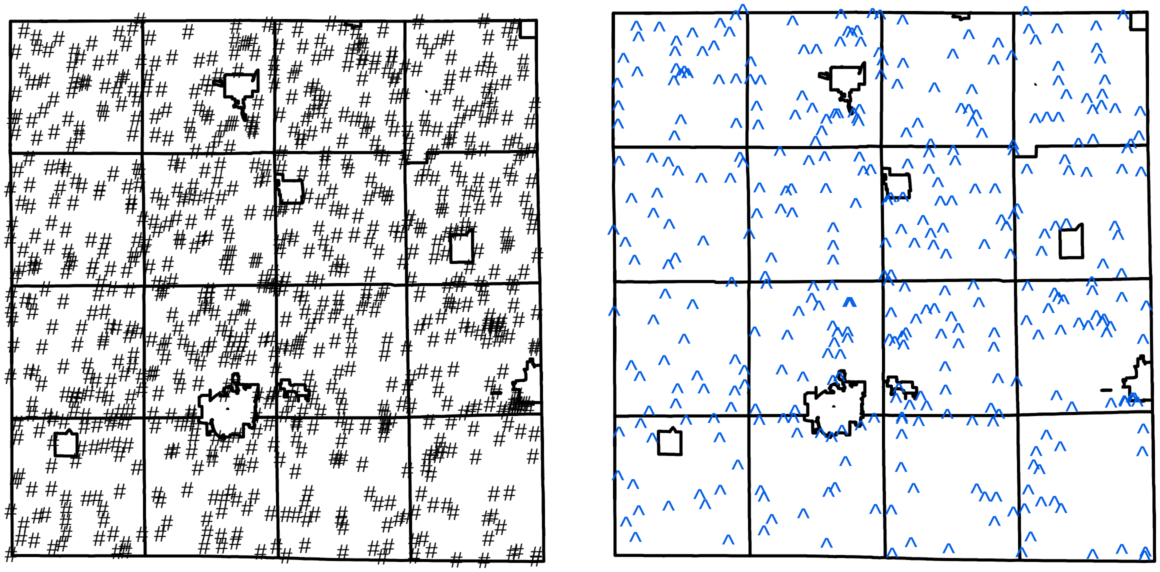


Figure 1. Black symbols represent 770 well parcels that were mailed recruitment materials. The blue symbols indicate the location of well parcels (388 / 49.8%) that indicated an interest in participating.

Year 3 - Well Sampling

Sampling kits were mailed in mid-October to the 323 participants that participate in Year 1 and 2. Each kit included a sample bottle, sampling instructions, and a pre-paid mailer for participants to enclose materials in. Participants were instructed to sample an untreated faucet, if they were not sure they were asked to collect the sample from their cold-water kitchen faucet which is generally untreated in most households. Following sample collection, participants were asked to take the pre-paid mailer to a Postal Service counter.

A total of 307 samples were received by January 1, 2022 and analyzed for nitrate-nitrogen, chloride, alkalinity, pH, total hardness, and conductivity. Samples were analyzed by the Water and Environmental Analysis Laboratory which is state-certified to perform the analyses of interest.

2019 (Year 1) – 348 well owners participated
2020 (Year 2) – 323 well owners participated
2021 (Year 3) – 307 well owners participated

Results and Summary Report

Analyses were completed and results mailed out to participants in early February. Each participant received a copy of their individual test results along with an interpretive guide and overall summary of the results. A virtual webinar was held on February 28, 2022 for project participants. The webinar provided an overview of the project, described the various tests that were performed. The webinar was video recorded and is available on the Extension Green County website.

Year 3 Project Results

The following information summarizes the Year 3 test results and provides an overview of each of the tests performed in Green County. We will continue to analyze the data and provide additional details in years 4-5 about what we are learning.

Nitrate is an important to test for because it is a health-related contaminant. The other tests deal with other important characteristics well water, such as how hard or corrosive it is. Nitrate and chloride also can be useful for understanding how land use is impacting groundwater. Meanwhile, hardness, alkalinity, pH, and conductivity tell us other important information such as how rocks and soil affect well water quality.

Figure 2. Each of the tests performed help us better understand influences on well water quality in Green County. (figure modified from Merritts et al., 2014)

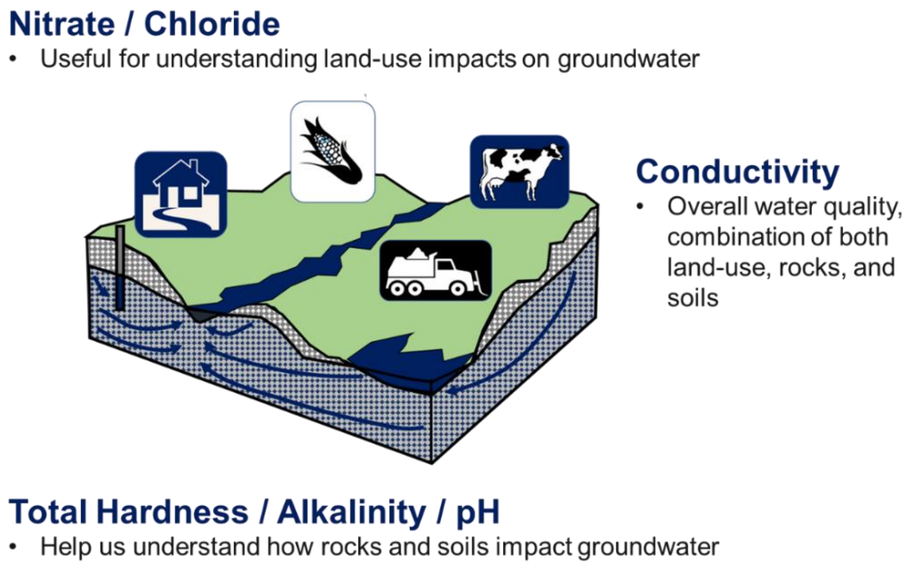


Table 1. Summary statistics for Year 2 of the Green County Well Water Monitoring Project.

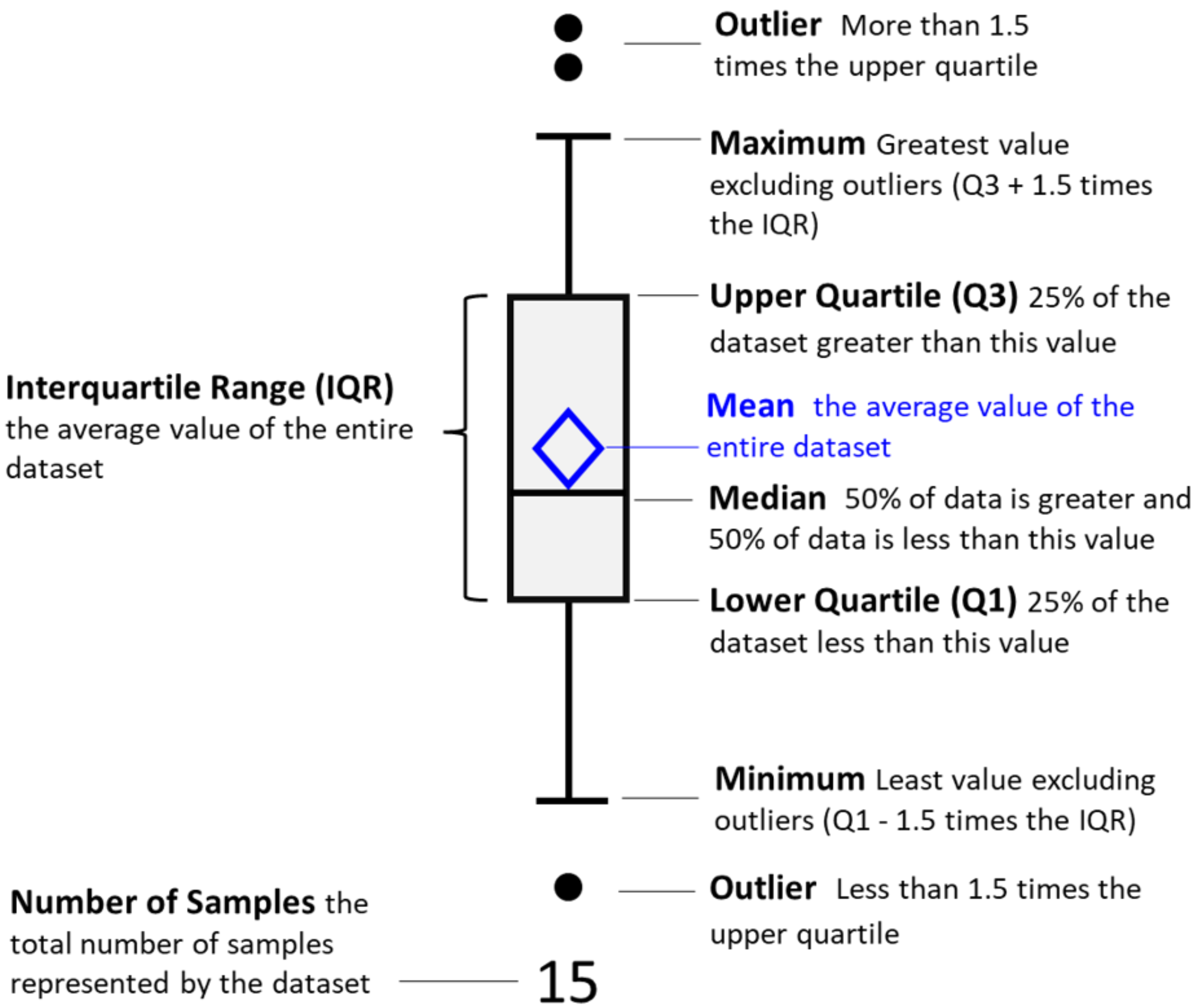
	Total Hardness*	Alkalinity	Conductivity	pH	Nitrate-Nitrogen	Chloride
	mg/L as $CaCO_3$	mg/L as $CaCO_3$	umhos/cm		mg/L	mg/L
Minimum	62	32	206	6.66	<0.1	0.6
Mean	346.3	307.2	661.1	8.1	5.8	18.9
Median	356	315	655	8.14	5	15
Maximum	589	479	1142	8.48	27.1	190
# of samples	291	307	307	307	307	307

*Softened samples removed from summary statistics for Total Hardness.

Well Water Quality by Year

The overall goal of the project is to assess well water quality over time with an interest in detecting changes or trends. While trends in individual wells may be easier to detect, changes in county-wide level statistics are less likely to show significant differences from one year to the next.

Boxplots throughout the report summarize county-wide project results for select analytes by year for those wells that have sampled in all three years.



Overall, countywide well water quality among participants in Year 3 is similar to Year 1 and 2 results. There were 16 less participants in Year 3 than participated in Year 2, representing 88% of the Year 1 participants.

Total Hardness

The total hardness test measures the amount of calcium and mangnesium in water. Calcium and magnesium are essential nutrients, which generally come from naturally sources of these elements in rock and soils. The amount present in drinking water is generally not a significant source of these nutrients compared with a health diet. While there are no health standards associated with total hardness in your water, too much or too little hardness can be associated with various aesthetic issues that can impact plumbing and other functions.

Results from the project suggest that Green County well water generally contains moderate amounts of hardness. Hardness values are such that water softeners are expected to be fairly common to treat against negative aesthetic effects associated with hardness. Lower values associated with soft water were most commonly detected in sand/gravel wells located near the Sugar River.

Why Test for Total Hardness

Because total hardness is related to the rocks and soils that water flows through on its way to a well, we would expect total hardness concentrations to be fairly stable from year to year. Any changes observed in total hardness concentrations may help us better understand the influence of climate variability on well water quality on an individual well. Because hardness concentrations have been shown to increase when nitrate and/or chloride increase, the total hardness test is a good complement to other tests.

Interpreting Total Hardness Concentrations

Hard Water:

Water with a total hardness value greater than 200 mgL is considered hard water. Hard water can cause lime buildup (scaling) in pipes and water heaters. Elements responsible for water hardness can also react with soap decreasing its cleaning ability, can cause buildup of soap scum, and/or graying of white laundry over time. Some people that use hard water for showering may notice problems with dry skin.

If you are experiencing problems with hard water: Consider softening water using a water softener. Water softeners remove calcium and magnesium and replace those elements with a different cation (usually sodium). Many people choose not to soften the cold-water tap used for drinking/cooking and the outdoor faucet used for yard watering. *Note: the water softening industry measures hardness in grains per gallon. 1 grain per gallon = 17.1 mg/L as $CaCO_3$*

Soft Water:

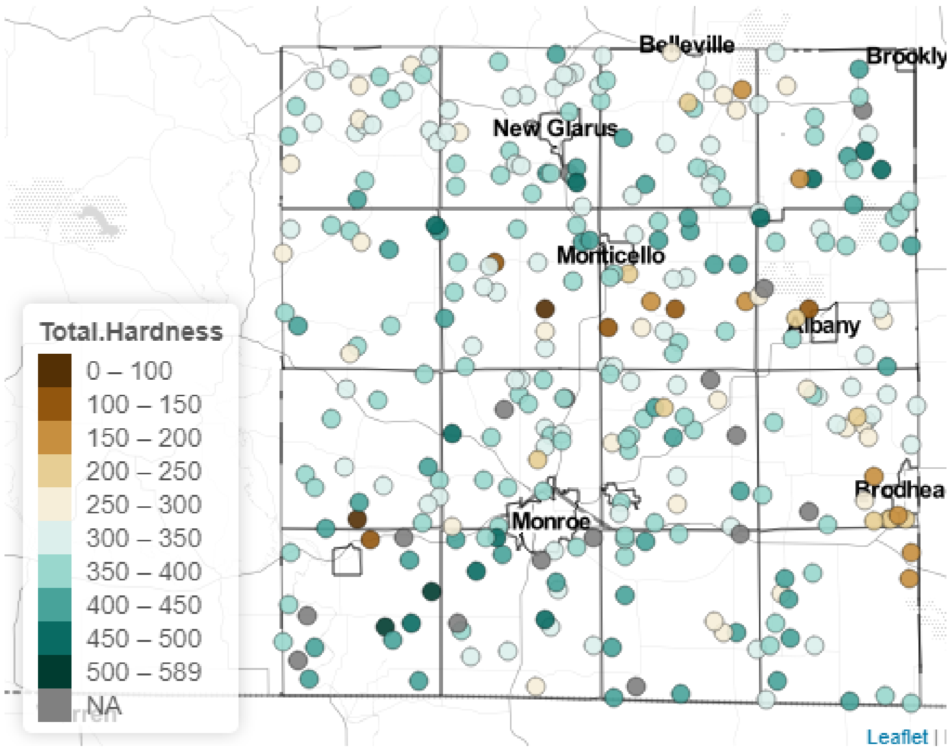
Water with a total hardness concentration less than 150 mg/L is considered soft. Water with too little hardness is often associated with corrosive water, which can be problematic for households with copper plumbing or other metal components of a plumbing system. Please note: Total Hardness values less than 50 would be rare for Green County, if your water reported less than 50 mg/L of Total Hardness it likely represents softened or partially softened water.

If you are experiencing problems with soft water or corrosion of household plumbing: You may want to consider a water treatment device (called a neutralizer) designed to make water less corrosive. Newer homes with plastic plumbing generally don't need to be as concerned with corrosive water with respect to the plumbing.

Ideal:
Water with total hardness between 150-200 mg/L is generally an ideal range of water hardness because there are enough ions to protect against corrosion, but not too many that they contribute to scale formation. While it is a personal preference, households with hardness in this range generally don't require additional treatment.

Sources of Total Hardness
Primarily dissolved carbonate minerals from soil and rock materials. When carbonate minerals dissolve, they increase the amount of calcium and magnesium ions in water.

Figure 3. Total hardness results for Year 3 of the Green County Well Water Monitoring Project. (NA indicates softened or partially softened samples.



Total Hardness (mg/L CaCO3)	# Samples	Percent
Less than 50	16	5%
51 – 100	2	<1%
101 – 200	13	4%
201 – 300	40	13%
301 – 400	178	58%
Greater than 400	58	19%

*Samples with less than 50 mg/L are likely softened or partially softened

Figure 4a. Boxplots of countywide total hardness for Year 1 (2019) and Year 2 (2020) and Year 3 of the project. Includes only wells that sampled in all 3 years.

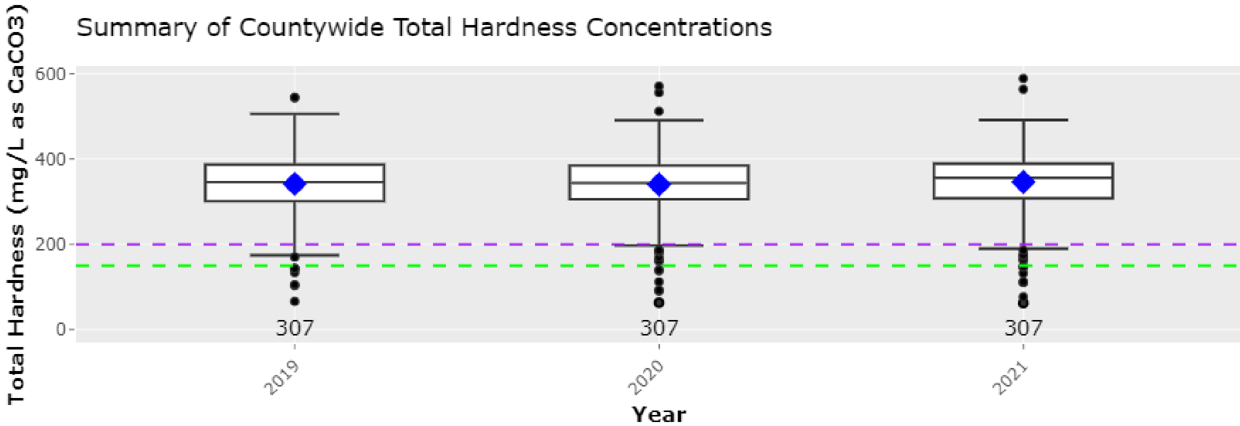
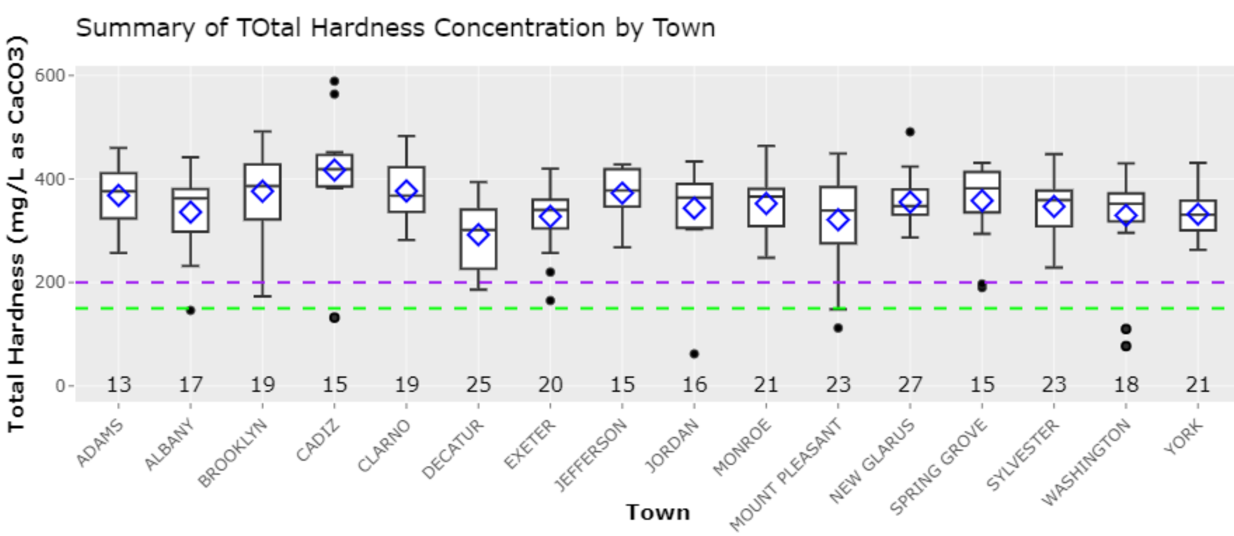


Figure 4b. Boxplots of total hardness by town for Year 3.



Alkalinity

Alkalinity measures the ability of water to neutralize acids. Alkalinity is associated with carbonate minerals and is commonly found in areas where groundwater is stored or transported in carbonate rock which occur in parts of Green County. Well water in Green County was generally found to contain moderate- high amounts of alkalinity. Lower values occurred in sand/gravel wells near the Sugar River.

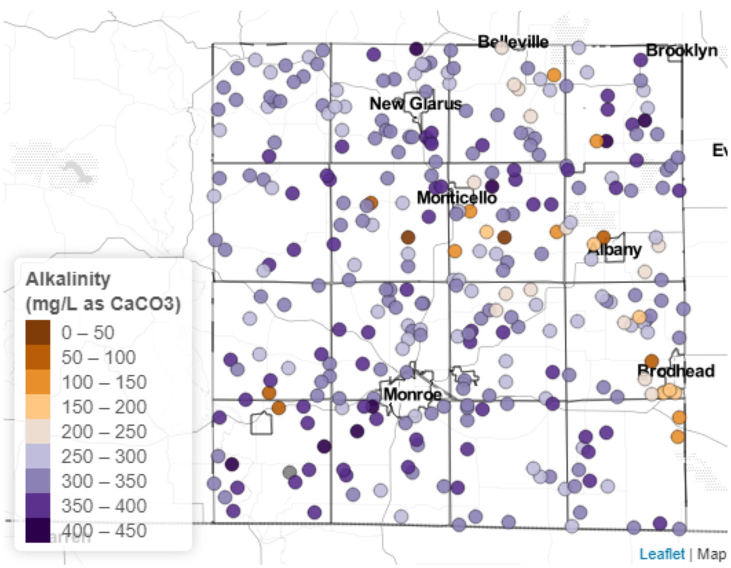
Why Test for Alkalinity

Because alkalinity is related to the rocks and soils that water flows through on its way to a well, we would expect alkalinity concentrations to be relatively stable from year to year. Any changes observed in alkalinity concentrations may help us better understand the influence of climate variability on well water quality from year to year, or make sense of broader water quality results from Green County. Particularly in wells that are uninfluenced by human activity, Alkalinity concentrations may help us better understand which aquifers wells may be accessing groundwater from.

Interpreting Alkalinity Concentrations

There are no health concerns associated with having alkalinity in water. Alkalinity should be roughly 75-100% of the total hardness value in an unsoftened sample. Water with low levels of alkalinity (less than 150 mg/L) is more likely to be corrosive. High alkalinity water (greater than 200 mg/L), may contribute to scale formation. If total hardness is half or less than the alkalinity result, it likely indicates that your water has passed through a water softener. If alkalinity is significantly less than total hardness, it be related to elevated levels of chloride or nitrate in your water sample.

Figure 5. Alkalinity results for Year 3 of the Green County Well Water Monitoring Project.



Alkalinity (mg/L CaCO3)	# Samples	Percent
Less than 50	2	<1%
51 – 100	5	2%
101 – 200	14	5%
201 – 300	84	27%
301 – 400	194	63%
Greater than 400	8	3%

Figure 6a. Boxplots of countywide alkalinity for Year 1 (2019) and Year 2 (2020) and Year 3 of the project. Includes only wells that sampled in all 3 years.

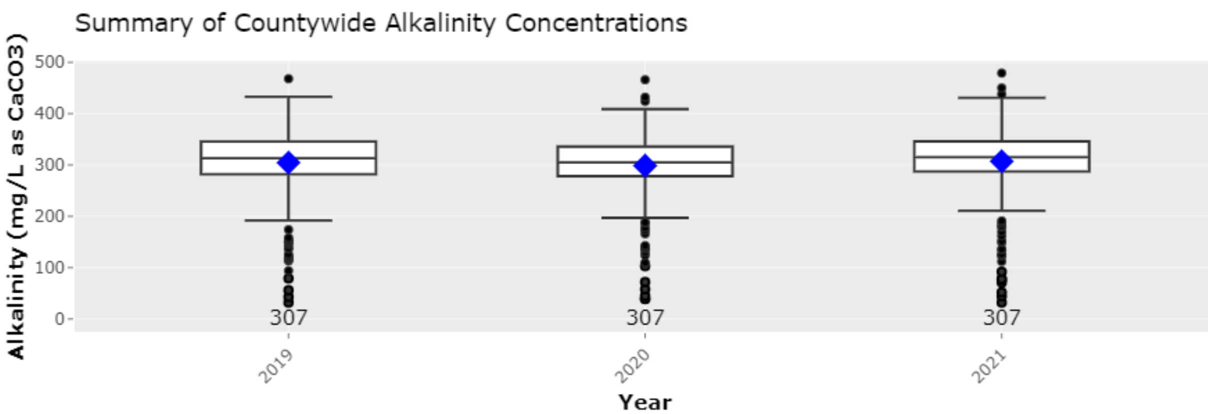
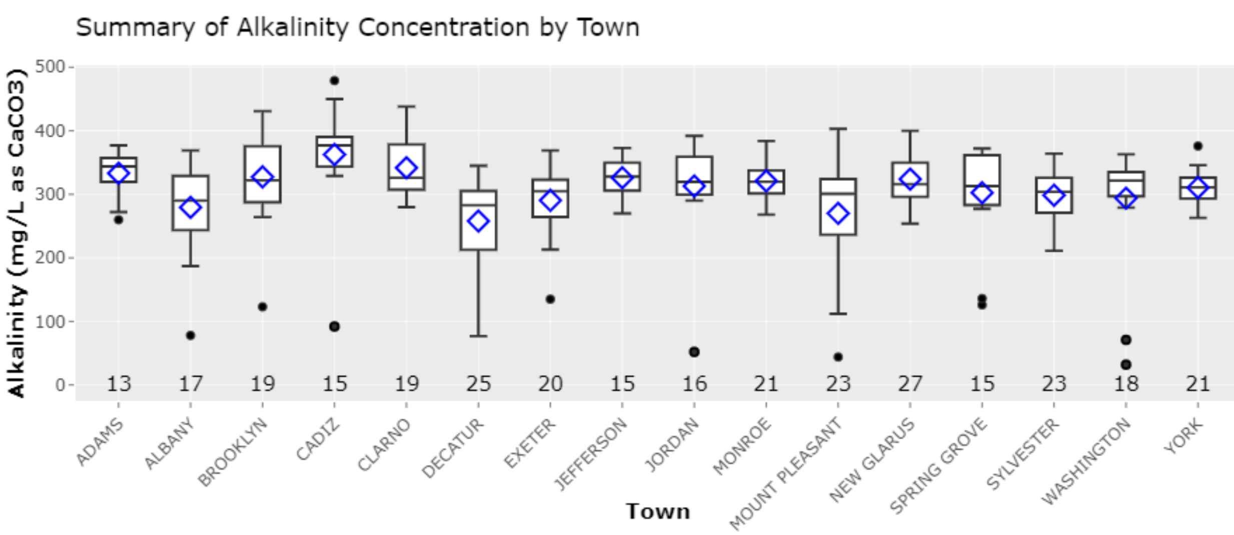


Figure 6b. Boxplots of alkalinity by town for Year 3.



Conductivity

Conductivity measures the amount of dissolved substances (or ions) in water; but does not give an indication of which minerals are present. Conductivity is a measure of both naturally occurring ions such as calcium, magnesium, and alkalinity; as well as ions that are often associated with human influences such as nitrate and chloride. Changes in conductivity over time may indicate changes in your overall water quality.

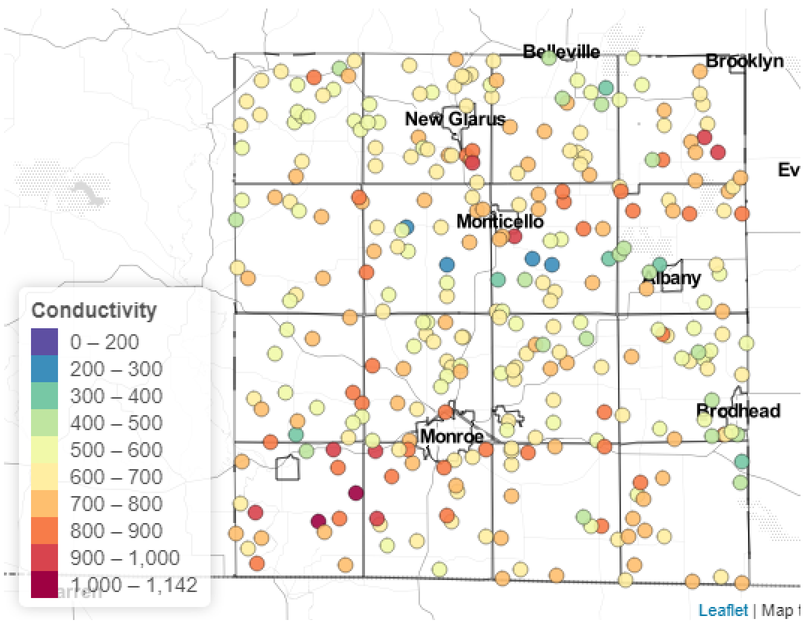
Why Test for Conductivity

Conductivity is relatively easy to measure for and sensors for conductivity are reliable. Information learned from changes in conductivity during this project may be useful for designing future monitoring strategies for Green County or even individual households to inexpensively track changes in well water quality continuously on their own.

Acceptable results:

There is no health standard associated with conductivity. A normal conductivity value measured in umhos/cm is roughly twice the total hardness as mg/L $CaCO_3$ in unsoftened water samples. If conductivity is significantly greater than twice the hardness, it may indicate the presence of other human-influenced or naturally occurring ions such as chloride, nitrate, or sulfate.

Figure 7. Conductivity results for Year 3 of the Green County Well Water Monitoring Project.



Conductivity (umhos/cm)	Number of Samples	Percent
Less than 100	0	0%
101 – 250	1	<1%
251 – 500	29	9%
501 – 750	203	66%
751 – 1000	72	23%
Greater than 1000	2	<1%

Figure 8a. Boxplots of countywide conductivity for Year 1 (2019) and Year 2 (2020) and Year 3 of the project. Includes only wells that sampled in all 3 years.

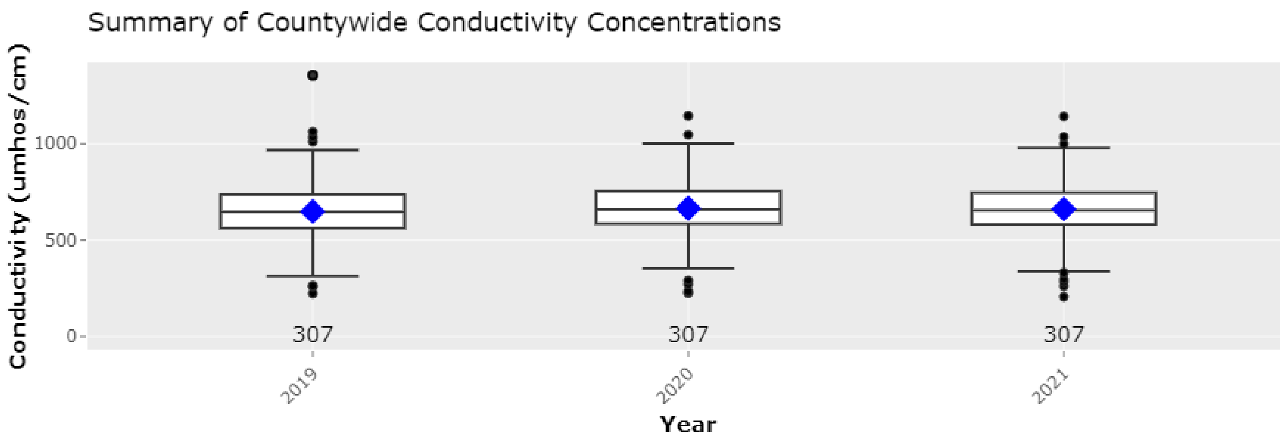
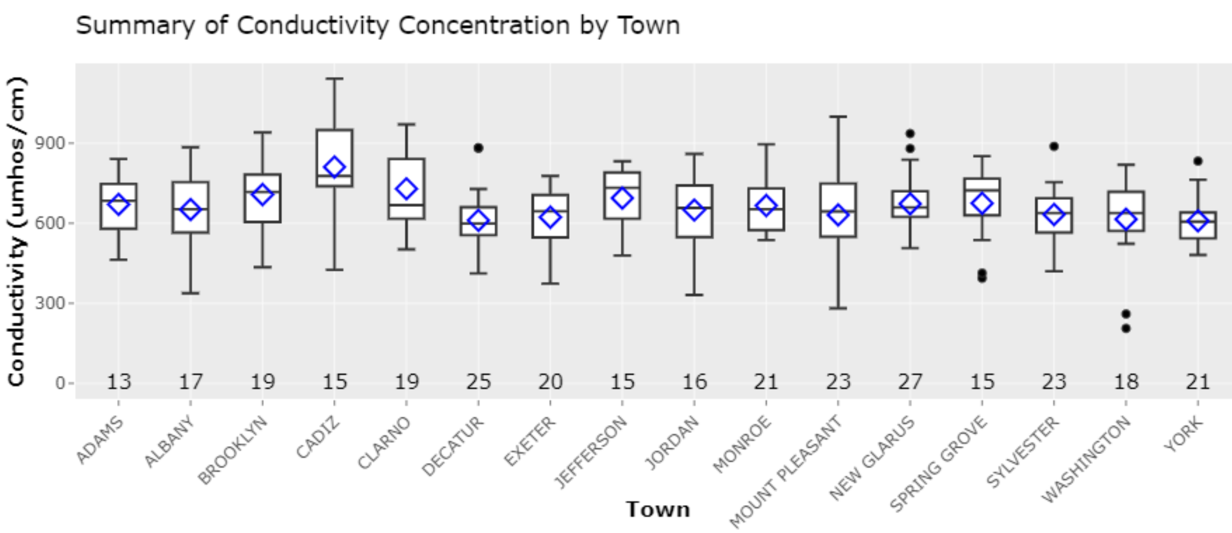


Figure 8. Boxplots of conductivity by town for Year 3.



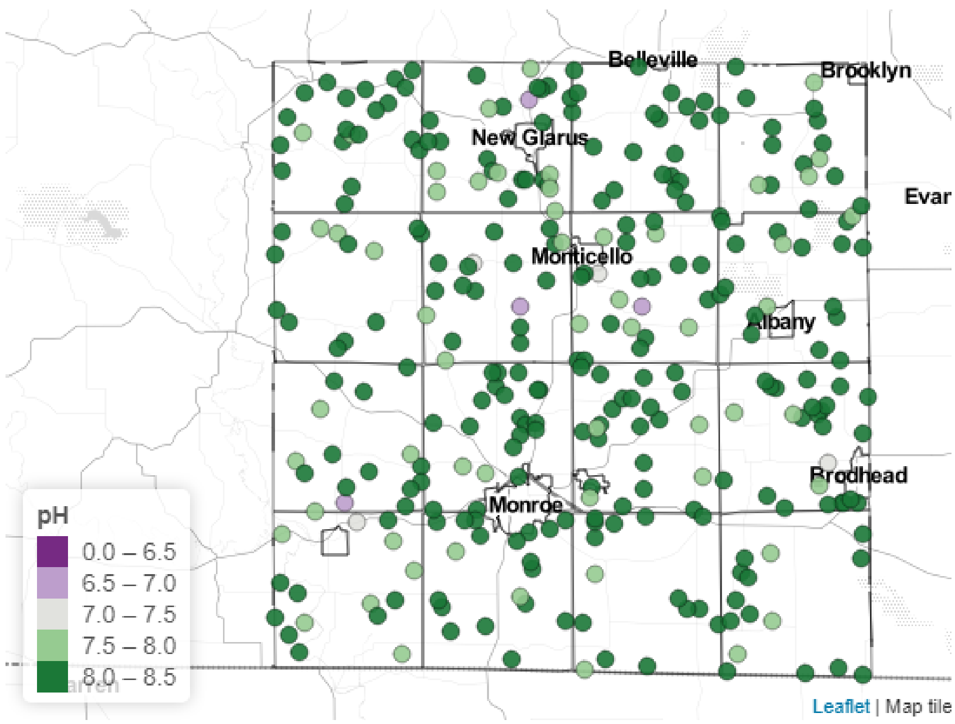
pH

The pH test measures the concentration of hydrogen ions in a solution. The concentration of hydrogen determines if a solution is acidic or basic. The lower the pH, the more corrosive water will be. The pH of well water in Green County is basic, with 86% of wells indicating a pH between 8-9.

Acceptable results:
There is no health standard for pH but corrosive water (pH less than 7) is more likely to contain elevated levels of copper or lead if these materials are in your household plumbing. Typical groundwater pH values in Wisconsin range from 6.0 to 9.0.

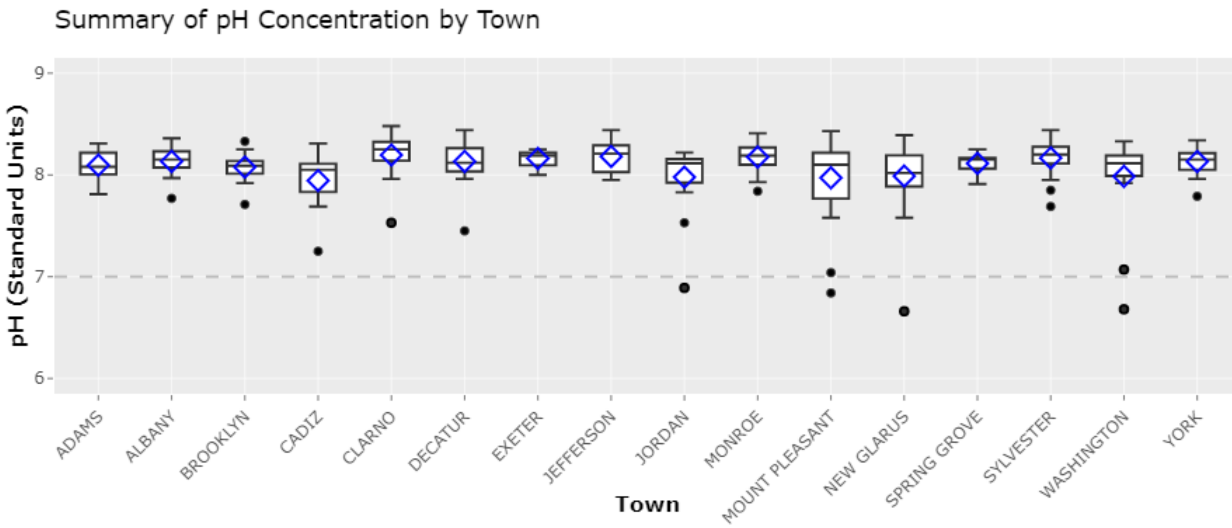
Sources: Low values are most often caused by lack of carbonate minerals in the aquifer.

Figure 9. The pH results for Year 3 of the Green County Well Water Monitoring Project.



pH	Number of Samples	Percent
6.00 – 7.00	4	1%
7.01 – 8.00	62	20%
8.01 – 9.00	241	79%

Figure 10. Boxplots of pH by town for Year 3.



Chloride

In most areas of Wisconsin, chloride concentrations are naturally low (usually less than 15 mg/L). Higher concentrations may serve as an indication that the groundwater supplied to your well has been impacted by various human activities. Fifty-nine percent of wells tested as part of the Green County Well Water Monitoring Project suggest evidence that land-use has impacted the well water quality.

Why Test for Chloride

Chloride is a test that allows us to understand the influence of human activities on well water quality. Measuring chloride concentrations in well water will also allow us to better understand whether well water quality is getting better, worse, or staying the same with respect to certain land-uses (see Sources).

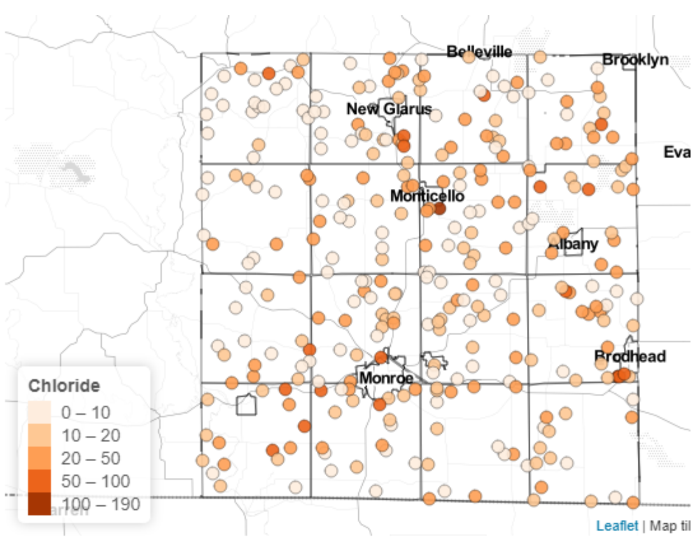
Interpreting Chloride Concentrations

Chloride is not toxic at typical concentrations found in groundwater. Unusually high concentrations of chloride (greater than 150 mg/L) are often associated with road salt and may be related to nearby parking lots or road culverts where meltwater from winter deicing activities often accumulates. Water with concentrations greater than 250 mg/L are likely to contain elevated sodium and are sometimes associated with a salty taste; water is also more likely to be corrosive to certain metals.

Sources of Chloride

- Agricultural Fertilizers (chloride is a companion ion of potash fertilizers
- Manure and other biosolids
- Septic Systems
- Road Salt

Figure 11. Chloride results for Year 3 of the Green County Well Water Monitoring Project.



Chloride (mg/L)	Number of Samples	Percent
Less than 10 mg/L	114	37%
11 – 50	174	57%
51 – 100	17	6%
101 – 200	2	<1%
Greater than 200	0	0

Figure 12a. Boxplots of countywide chloride for Year 1 (2019) and Year 2 (2020) and Year 3 of the project. Includes only wells that sampled in all 3 years.

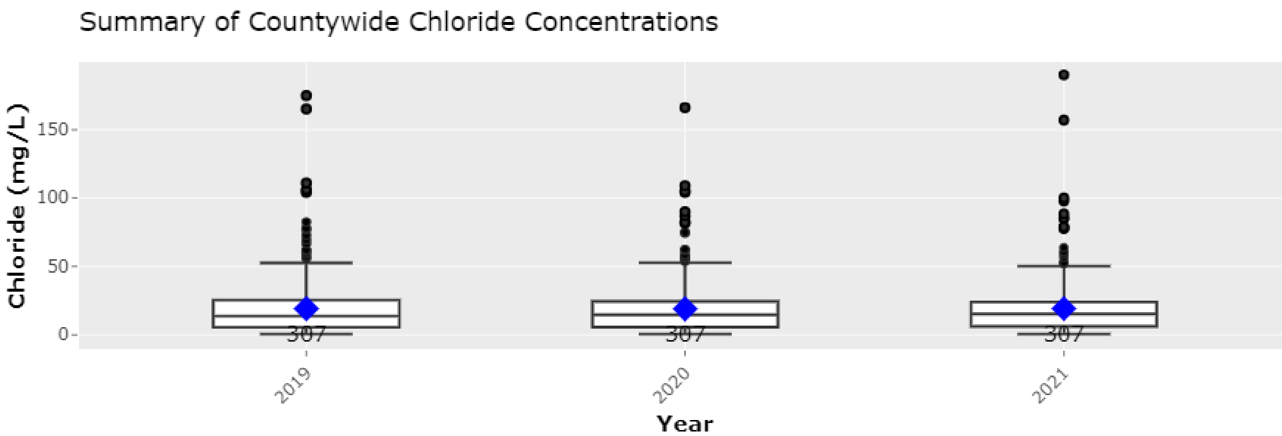
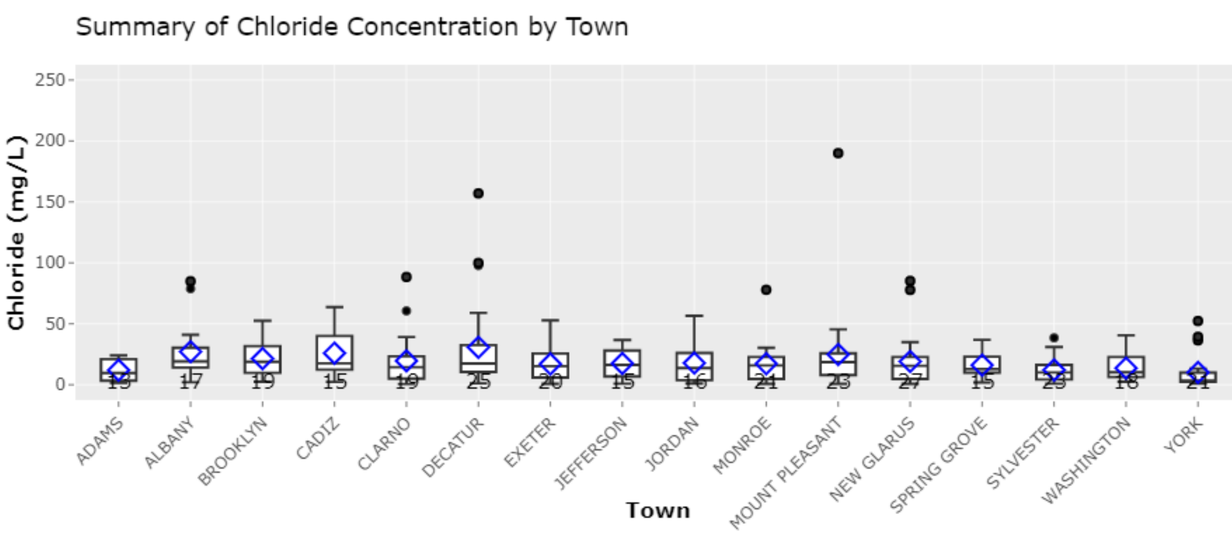


Figure 12b. Boxplots of chloride by town for Year 3.



Nitrate-nitrogen

This test measures the amount of nitrate-nitrogen in a well. Nitrate is a form of nitrogen, commonly found in agricultural and lawn fertilizer, that easily dissolves in water. It is also formed when waste materials such as manure or septic effluent decompose. The natural level of nitrate-nitrogen in Wisconsin's groundwater is less than 1 mg/L. Levels greater than this suggest groundwater has been impacted by various land-use practices.

There is a health-based drinking water standard of 10 mg/L of nitrate-nitrogen. Fifteen percent of wells tested as part of the Green County Well Water Monitoring Project indicated nitrate at levels above what is considered safe for drinking water. Statewide approximately 9% of all private wells contain nitrate-nitrogen above 10 mg/L. Seventy-two percent of wells tested in this project suggest evidence of land-use impacts to well water quality.

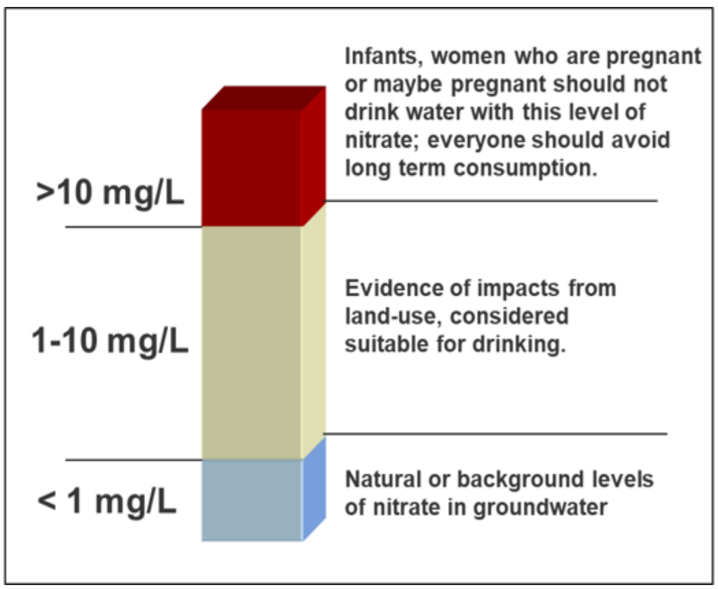
Why Test for Nitrate

Nitrate is an important test for determining the safety of well water for drinking. Nitrate is a test that allows us to understand the influence of human activities on well water quality. Because it moves can come from a variety of sources and moves easily through soil, it serves as a useful indicator of certain land-use activities. An annual nitrate test is useful for understanding whether water quality is getting better, worse, or staying the same with respect to certain land-uses (see Sources).

Health Effects of Nitrate in Drinking Water

Nitrate-nitrogen levels greater than 10 mg/L may result in the following potential health concerns:

- **Infants less than 6 months old –** blue baby syndrome or methemoglobinemia is a condition that can be fatal if left untreated
- **Women who are or may become pregnant –** may cause birth defects
- **Everyone –** may cause thyroid disease and increase the risk for certain types of cancer



Infants less than 6 months old and women who are or may become pregnant should not drink water or consume formula made with water containing more than 10 mg/L of nitrate-nitrogen. Everyone should avoid long-term consumption of water with greater than 10 mg/L of nitrate-nitrogen.

Ways to reduce nitrate in your drinking water

Sometimes drilling a new well or reconstructing an existing well may provide water with less nitrate. If this is not possible, or you need an alternative solution because of time or cost, another way to reduce nitrate is to install a water treatment device approved for removal of nitrate. Please note that if using treatment for nitrate, routine testing is necessary to make sure its functioning properly.

Treatment for Nitrate

Point-of-use devices treat enough water for drinking and cooking needs

- Reverse Osmosis
- Distillation

Point-of-entry systems treat all water distributed throughout the house

- Anion Exchange

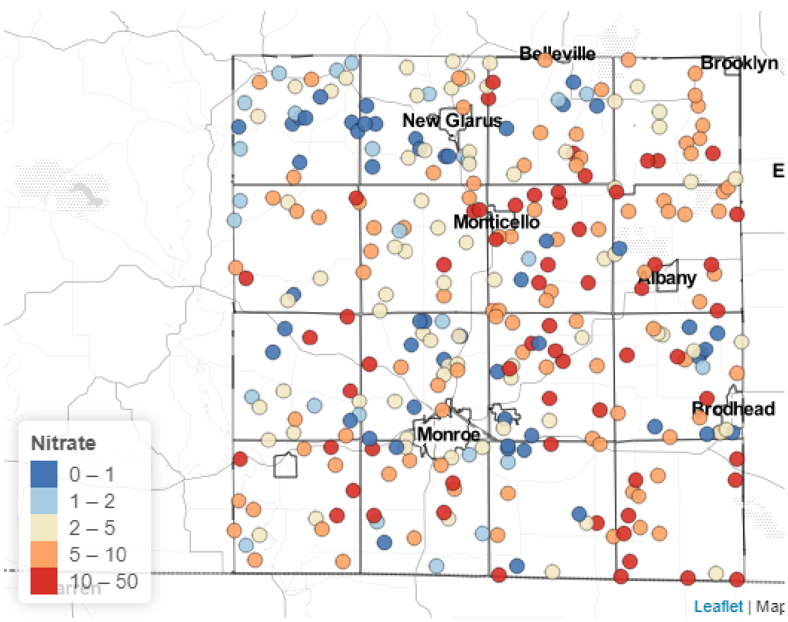
Sources of Nitrate

- Agricultural Fertilizers
- Manure and other biosolids
- Septic Systems
- Lawn Fertilizers

Strategies to reduce nitrate in groundwater

- Applying fertilizer at the right rate, time, source, place will maximize profitability and minimize excessive losses of nitrogen to groundwater; additional practices may be needed to improve water quality in areas with susceptible soils and geology
- You may not need as much nitrogen fertilizer as you think, conduct your own on-farm rate trials to develop customized fertilizer response curves for your farm
- Utilize conservation incentive programs to take marginal land or underperforming parts of fields out of production
- Diversify cropping systems to include less nitrogen intensive crops in the rotation
- Explore and experiment with the use of cover crops, perennial cropping systems, or managed grazing to reduce nitrate losses to groundwater

Figure 13. Nitrate-nitrogen results for Year 3 of the Green County Well Water Monitoring Project.



Nitrate-Nitrogen (mg/L)	Number of Samples	Percent
Less than 0.1	33	11%
0.1 – 2.0	50	16%
2.1 – 5.0	72	23%
5.1 – 10.0	93	30%
10.1 – 20.0	58	19%
Greater than 20.0	1	<1%

Figure 14a. Boxplots of countywide nitrate-nitrogen for Year 1 (2019) and Year 2 (2020) and Year 3 of the project. Includes only wells that sampled in all 3 years.

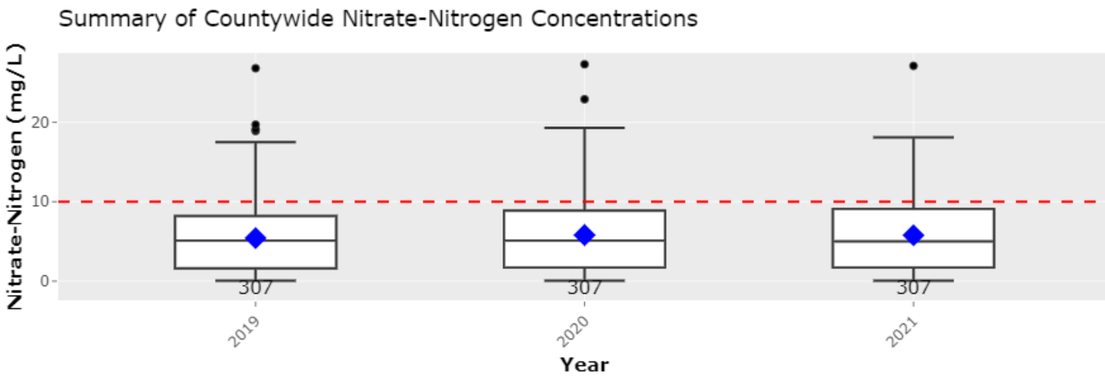


Figure 15b. Boxplots of nitrate-nitrogen by town for Year 3.

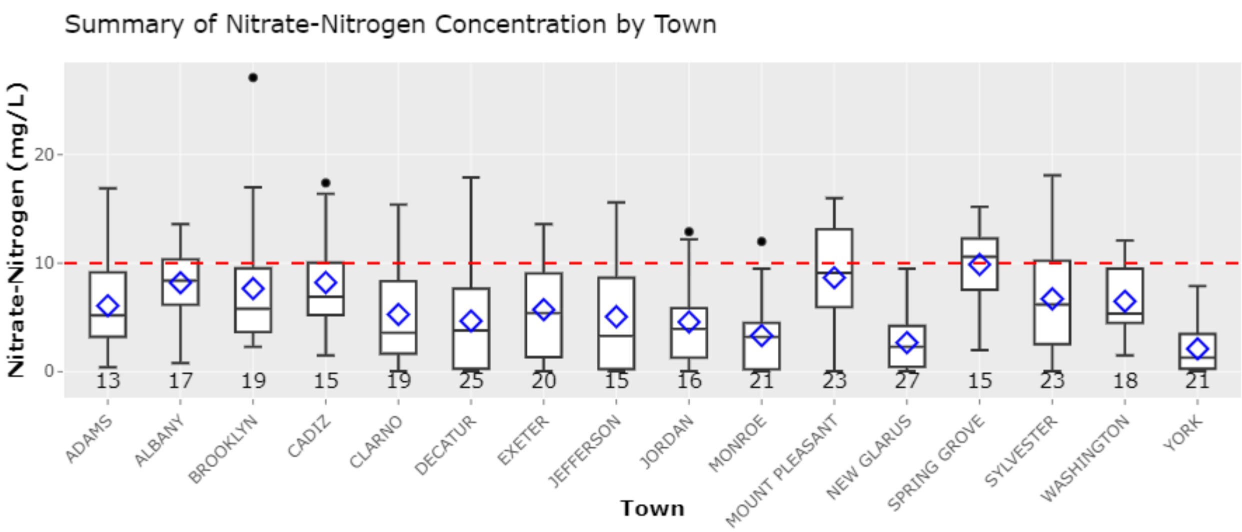
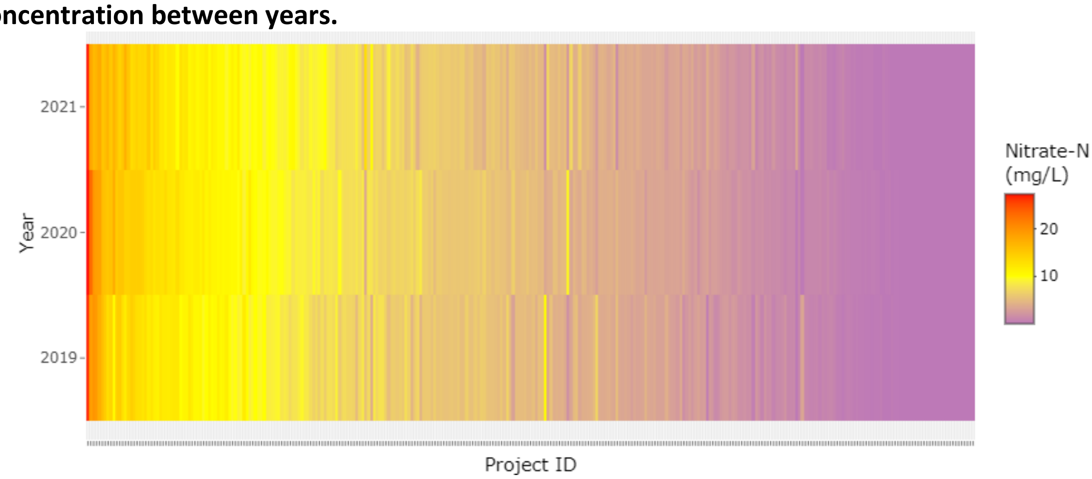


Figure 16. Heat map showing nitrate-nitrogen concentrations of the wells that have tested every year for the study. The results are arranged by the average nitrate concentration and show the variability of concentration between years.



Project Website

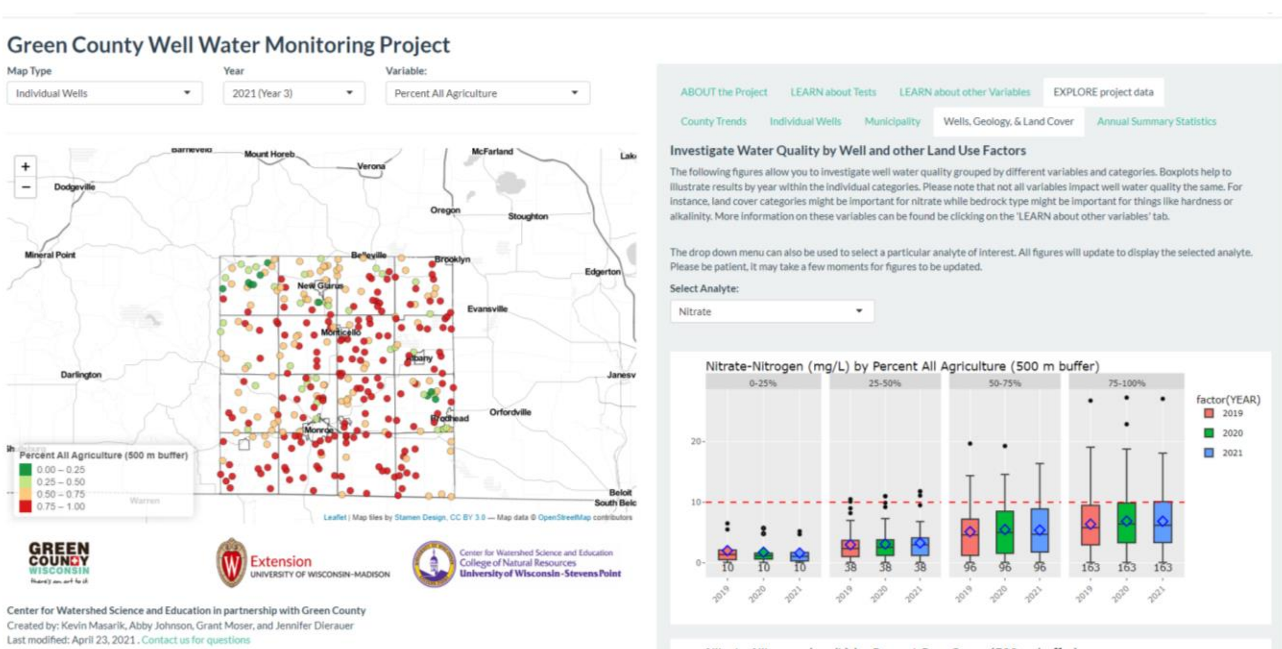
A website has been developed to communicate project results. The website provides interactive data visualization of project results and will contain the most up to date information. It will be updated annually as each year's samples are processed. Additional tools or data visualizations will be added as various tasks are completed.

Features include:

- Maps of each analyte for individual wells for each year
- Maps of other important well variables; such as geology, land cover within 500 meter buffer of well, soil drainage classification, well casing depth, etc.
- Maps of each analyte by Town for each year
- Observe changes in analyte concentrations for individual wells
- View summary statistics by municipality
- County-wide summary of all analytes for each year
- Summary box-plots by other important well variables

The website can be accessed by visiting: shiny.theopenwaterlog.com/wellwater_greencounty/

Figure 15. Screen capture of Green County Well Water Monitoring Project interactive website.



What is the timeline for Year 4 of the project?

Sampling kits for Year 4 of the project will be mailed out October 2022, with the goal of having participants send samples back to the laboratory by December 1, 2022. Once samples are returned to the lab, we anticipate 1-2 months before sample results will be made available to project participants.

Following notification of results to project participants, we will host an educational session to communicate with project participants regarding results. The annual report for Year is anticipated to be completed around June 30, 2023.

Additional next steps

The focus of Year 3 has been on well water sampling and the addition of new functionality into the online data visualization tool. Beginning in Year 4 we plan to:

- Investigate trends/changes in water quality from year to year in individual wells.
- Develop statistical models to better predict water quality risk for wells in Green County. Because a subset of the thousands of wells in Green County are being tested as part of this project, statistical models will assist us in identifying other wells that are most at risk for having elevated levels of nitrate.
- Multiple years of data from the same well will allow us to understand changes in well water quality from year to year. This type of data analysis will aid in our understanding of changes to well water quality over time and whether groundwater quality is getting better, worse, or staying the same. If well water quality is changing, we will be able to assess what factors may be responsible for those changes.

Questions regarding this information please contact:

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