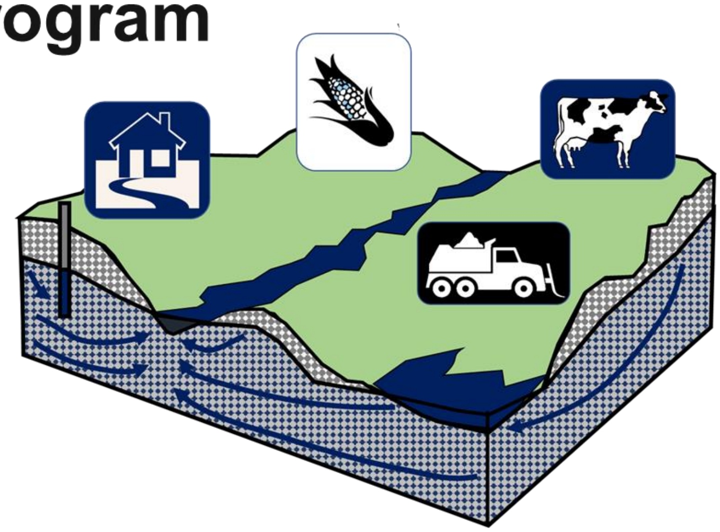
Green County Well Water Monitoring Program

Year 4



Green County Well Water Monitoring Annual Report
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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, and 294 samples in Year 4. 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 4 Well Water Quality Summary

Green County's groundwater can generally be characterized as slightly basic (pH = 7.9), hard water (mean = 344 mg/L as $CaCO_3$), with high alkalinity (298 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 = 5.5 mg/L nitrate-nitrogen). Sixteen percent of wells tested greater than the 10 mg/L drinking water standard; approximately 74% 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 four year period. 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 4 results add to the previous three years of data to create a foundation for understanding how or if groundwater is changing over time.

Green County Groundwater Well Water Monitoring
Year 4 - Annual Report

July 1, 2022 – June 30, 2023

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 participants from the previous year.

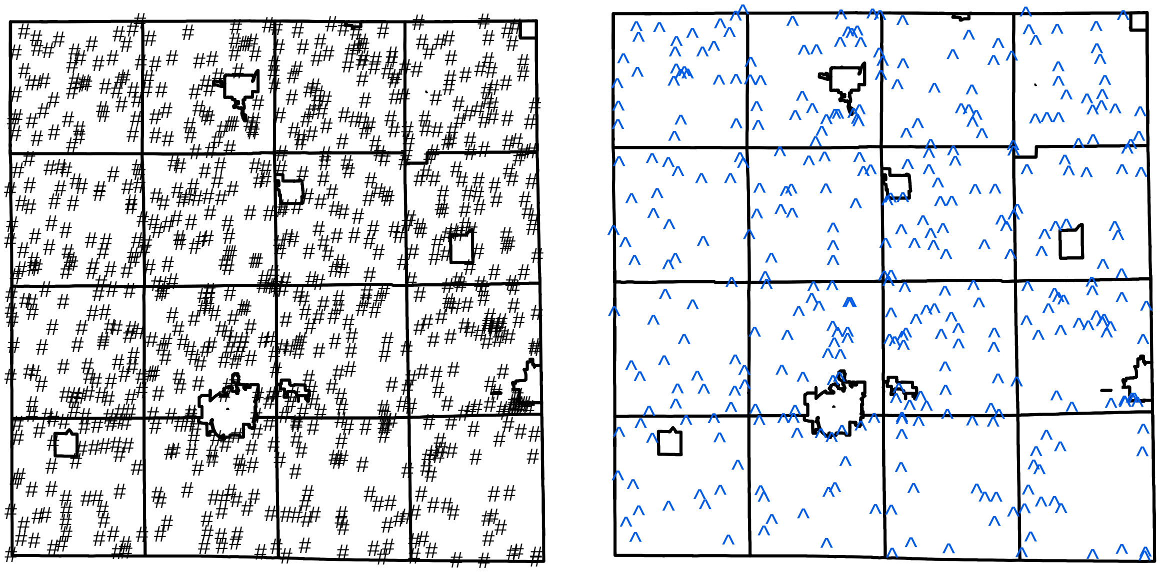


Figure 1. Black symbols represent 770 well parcels that were mailed recruitment materials. The blue symbols indicate the location of well parcels (388 / 49.8%) that indicated an interest in participating.

Year 4 - Well Sampling

Sampling kits were mailed in mid-October to the 307 participants that participated in Year 1,2, and 3. 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
2022 (Year 4) - 294 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 4 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 of 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)

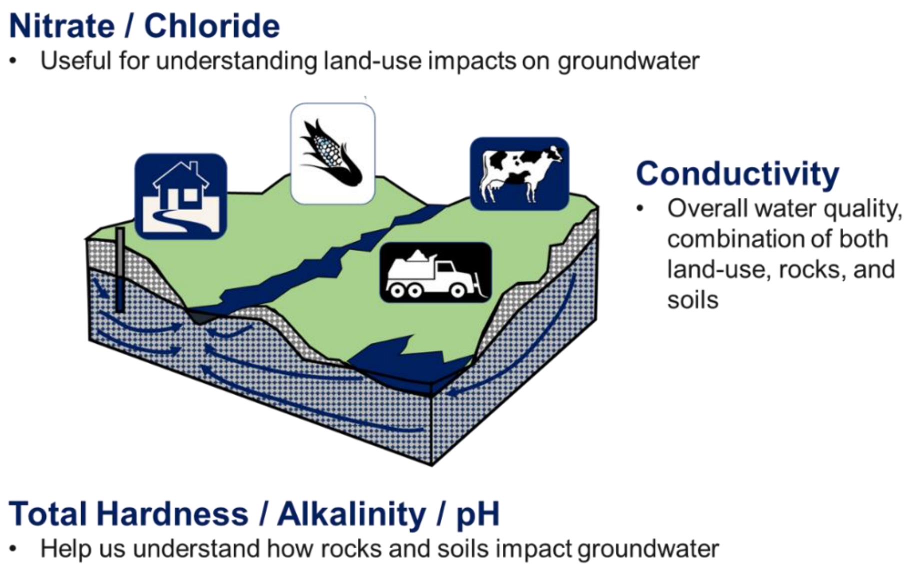


Table 1. Summary statistics for Year 4 of the Green County Well Water Monitoring Project.

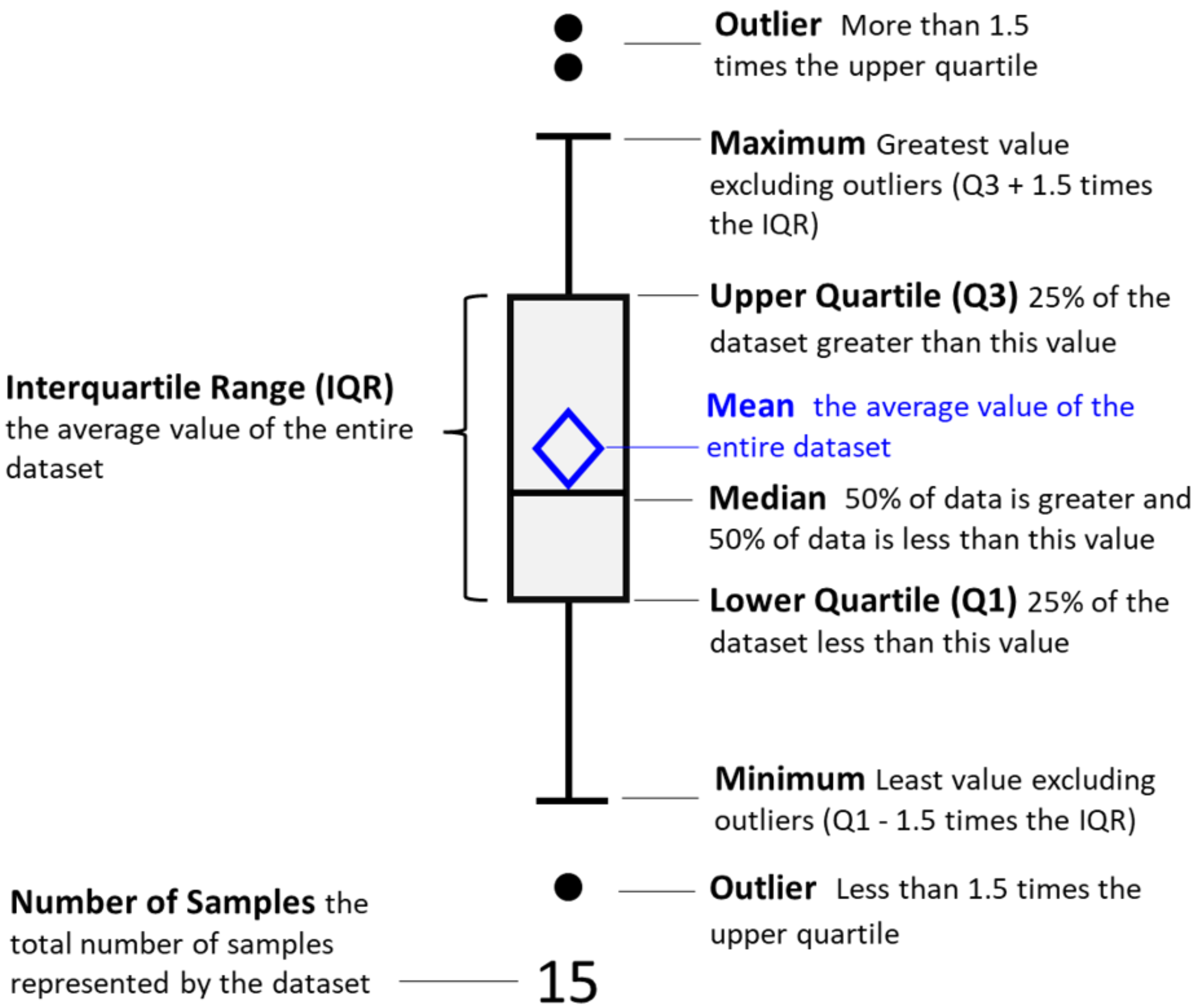
	Total Hardness*	Alkalinity	Conductivity	pH	Nitrate-Nitrogen	Chloride
	mg/L as $CaCO_3$	mg/L as $CaCO_3$	umhos/cm		mg/L	mg/L
Minimum	52	25	103	6.5	<0.1	0.6
Mean	344.4	298.4	656.7	7.9	5.5	18.9
Median	353	306	658.5	7.93	4.85	14.1
Maximum	539	455	1051	8.24	23.7	169
# of samples	278	294	294	294	294	294

*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 $CaCO_3$*

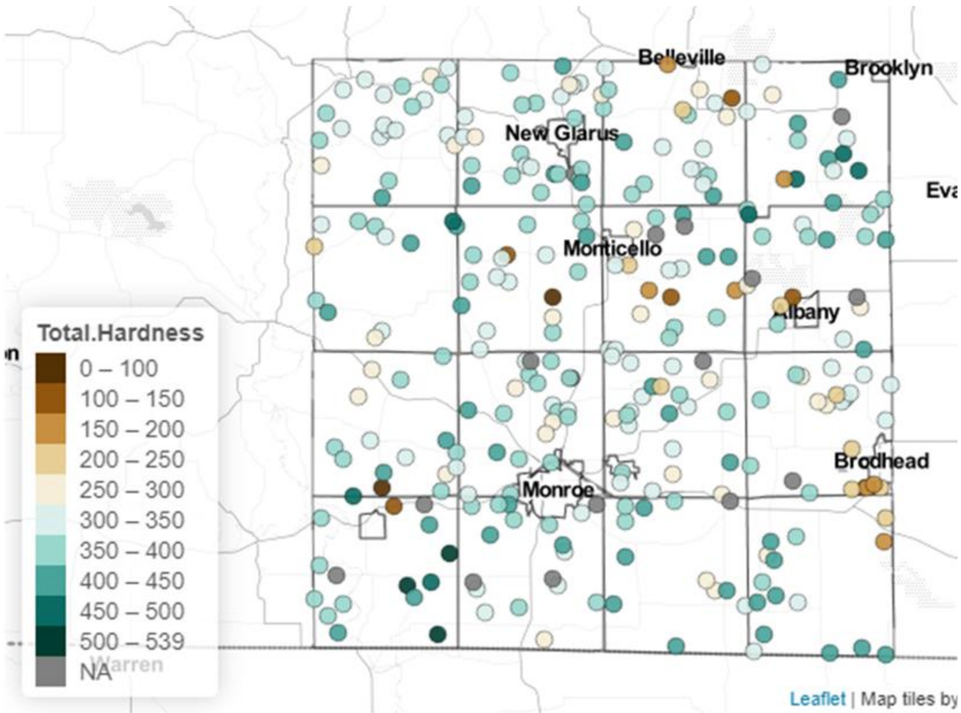
Soft Water:
Water with a total hardness concentration less than 150 mg/L is considered soft. Water with too little hardness is often associated with corrosive water, which can be problematic for households with copper plumbing or other metal components of a plumbing system. Please note: Total Hardness 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 4 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	43	15%
301 – 400	162	55%
Greater than 400	58	20%

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

Figure 4a. Boxplots of countywide total hardness for Year 1 (2019), Year 2 (2020), Year 3 (2021), and Year 4 (2022) of the project. Includes only wells that sampled in all 4 years.

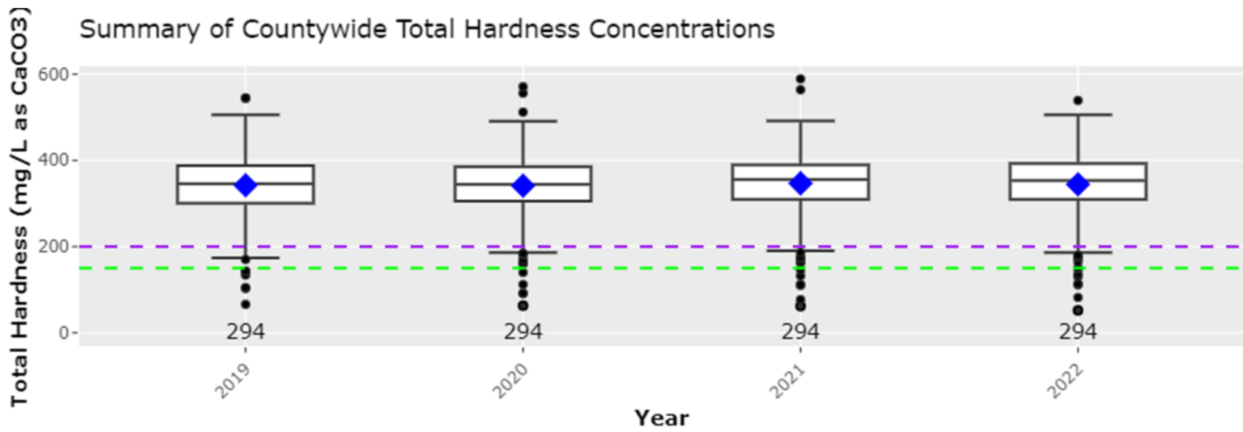
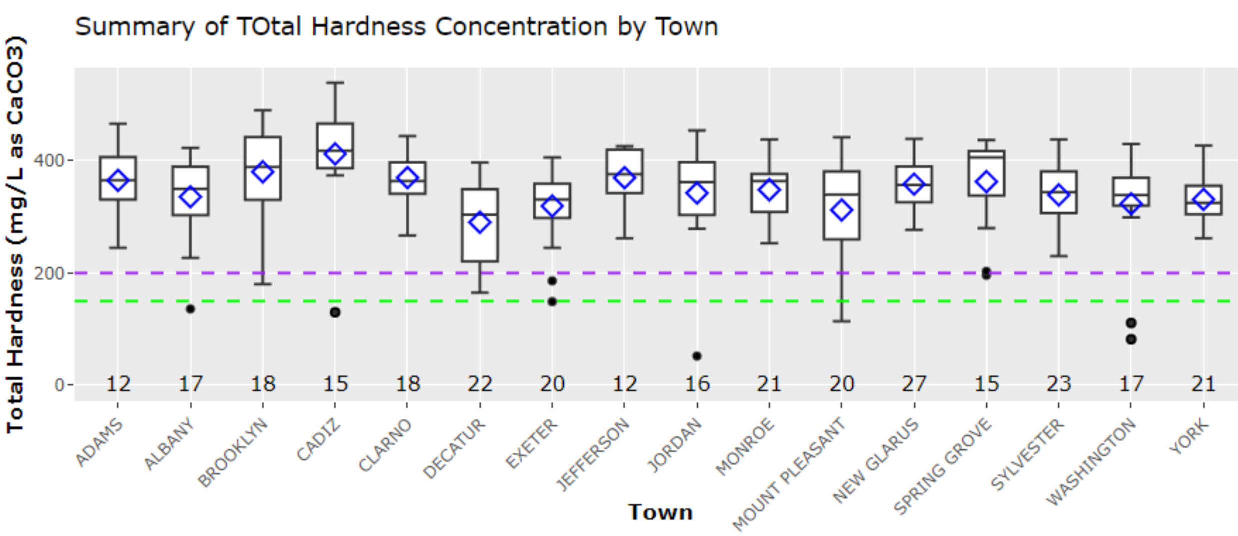


Figure 4b. Boxplots of total hardness by town for Year 4.



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.

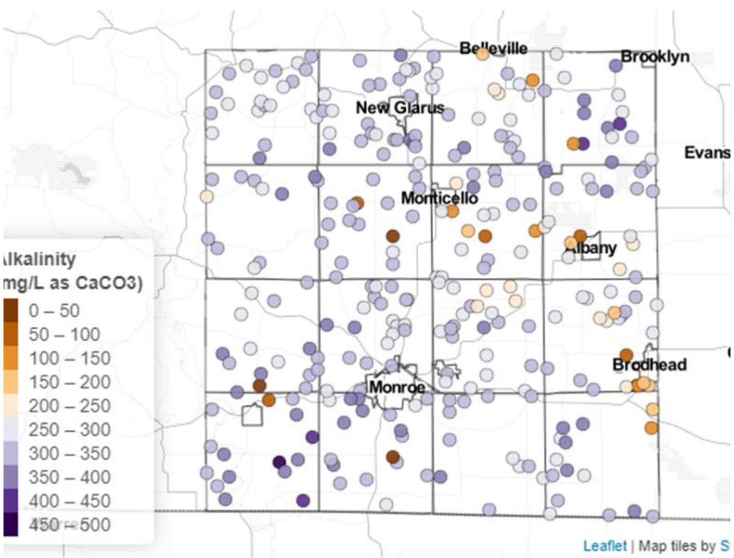
Why Test for Alkalinity

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 4 of the Green County Well Water Monitoring Project.



Alkalinity (mg/L CaCO3)	# Samples	Percent
Less than 50	3	1%
51 – 100	5	2%
101 – 200	14	5%
201 – 300	105	36%
301 – 400	163	55%
Greater than 400	4	1%

Figure 6a. Boxplots of countywide alkalinity for Year 1 (2019), Year 2 (2020), Year 3 (2021), and Year 4 (2022) of the project. Includes only wells that sampled in all 4 years.

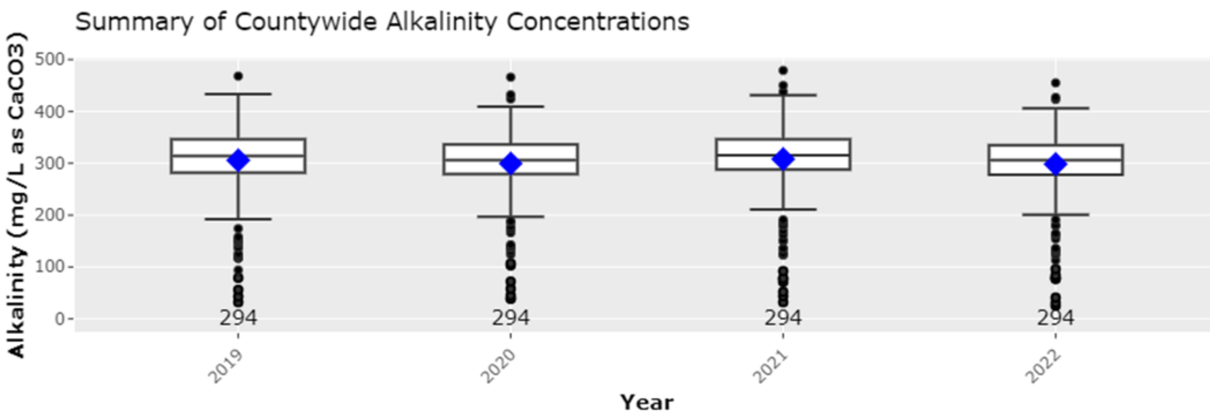
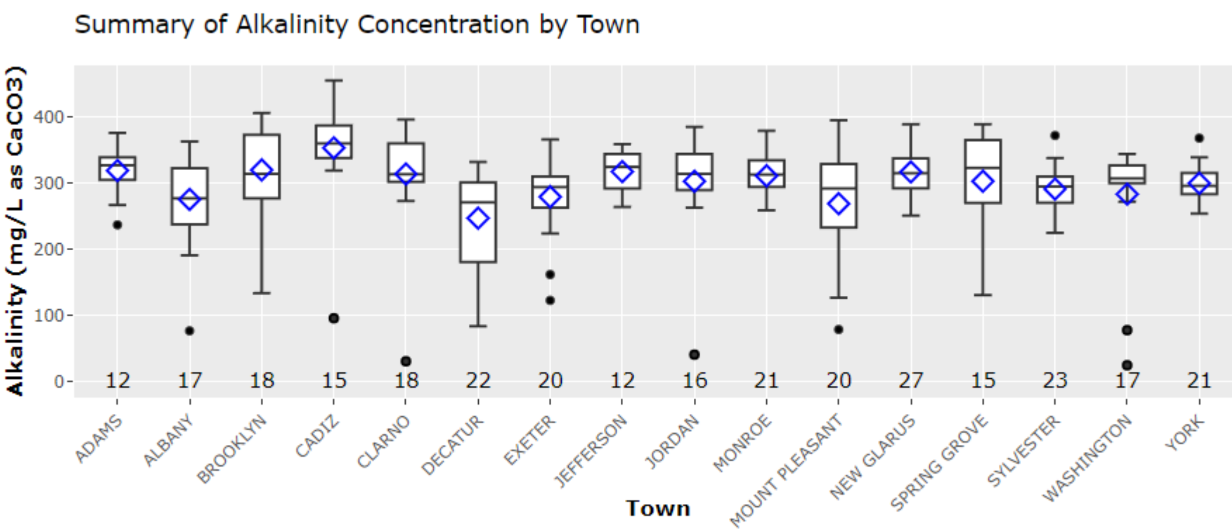


Figure 6b. Boxplots of alkalinity by town for Year 4.



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.

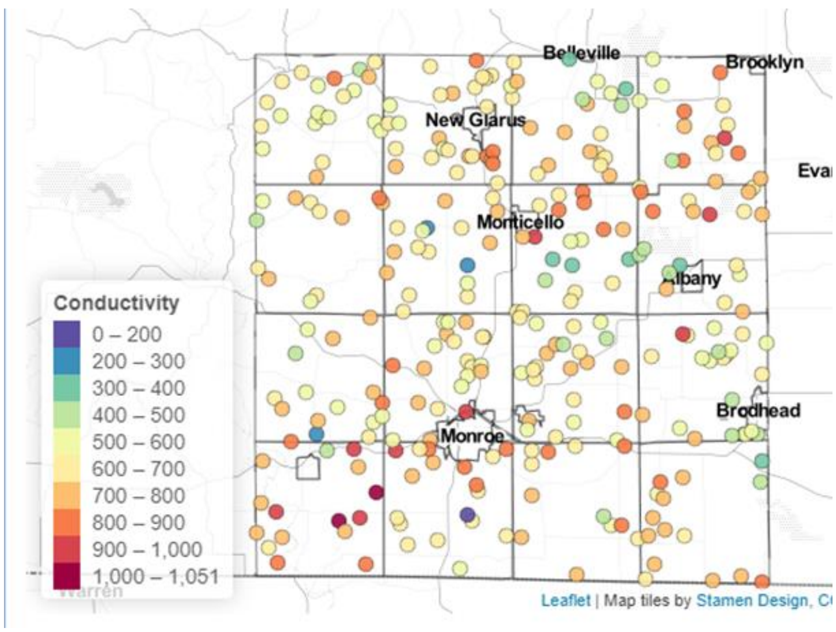
Why Test for Conductivity

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 4 of the Green County Well Water Monitoring Project.



Conductivity (umhos/cm)	Number of Samples	Percent
Less than 100	0	0%
101 – 250	3	1%
251 – 500	27	9%
501 – 750	198	67%
751 – 1000	64	22%
Greater than 1000	2	<1%

Figure 8a. Boxplots of countywide conductivity for Year 1 (2019), Year 2 (2020), Year 3 (2021), and Year 4 (2022) of the project. Includes only wells that sampled in all 4 years.

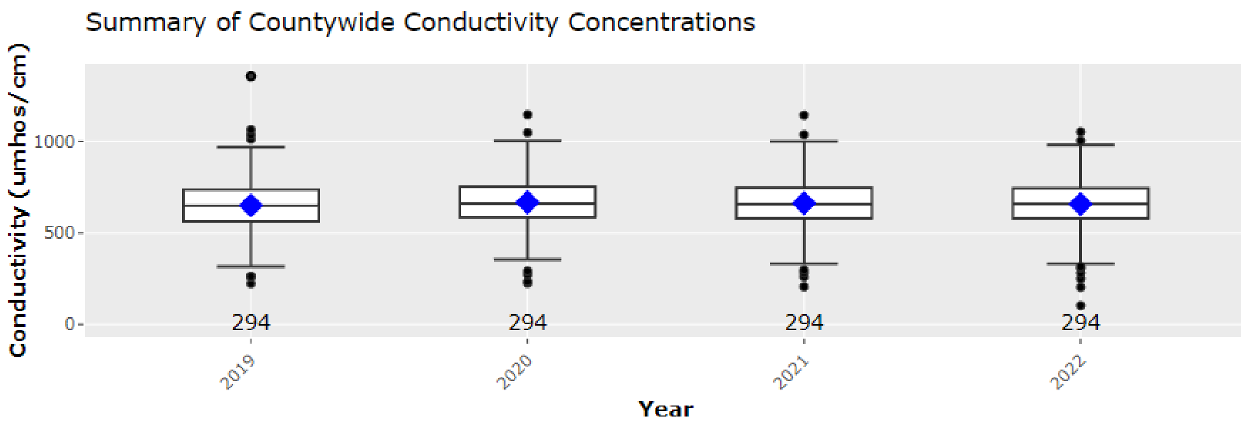
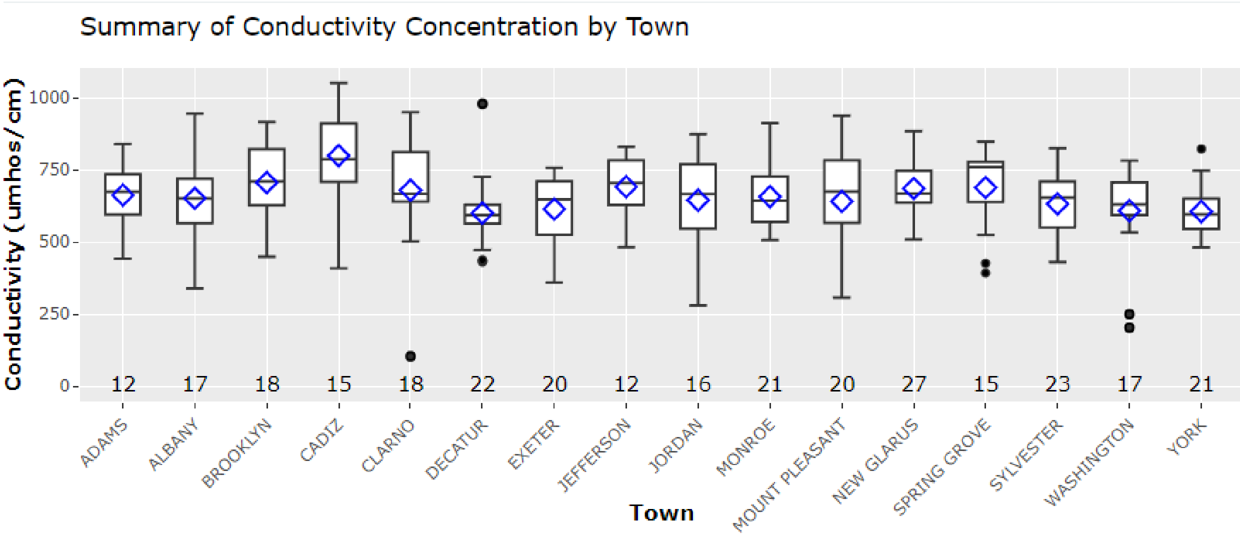


Figure 8b. Boxplots of conductivity by town for Year 4.



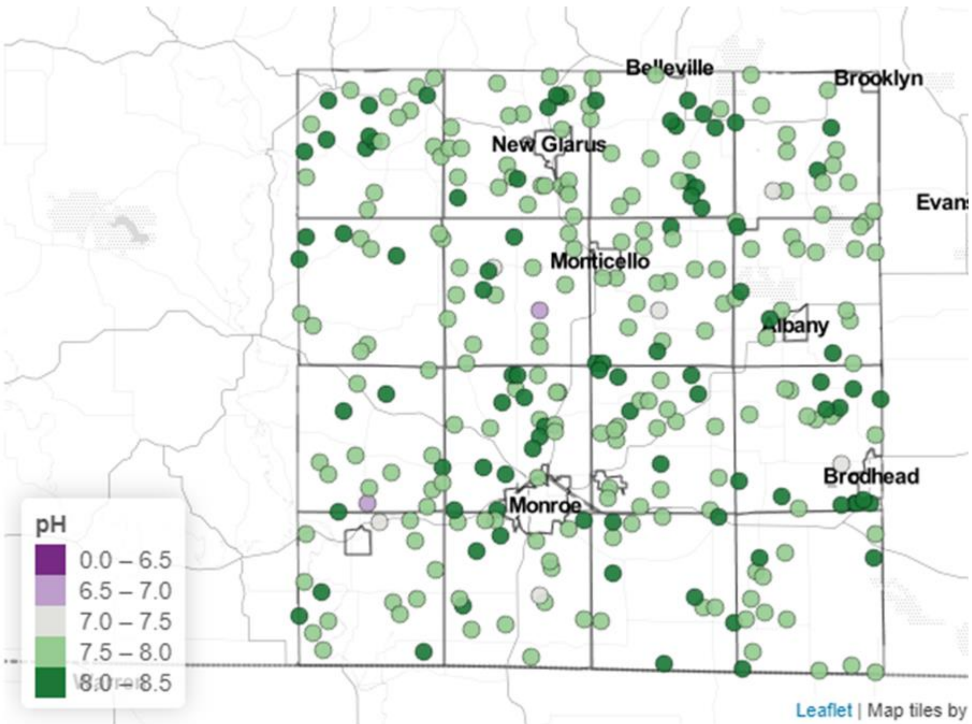
pH

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 4 of the Green County Well Water Monitoring Project.



pH	Number of Samples	Percent
6.00 – 7.00	2	<1%
7.01 – 8.00	208	71%
8.01 – 9.00	84	29%

Figure 10a. Boxplots of countywide conductivity for Year 1 (2019), Year 2 (2020), Year 3 (2021), and Year 4 (2022) of the project. Includes only wells that sampled in all 4 years.

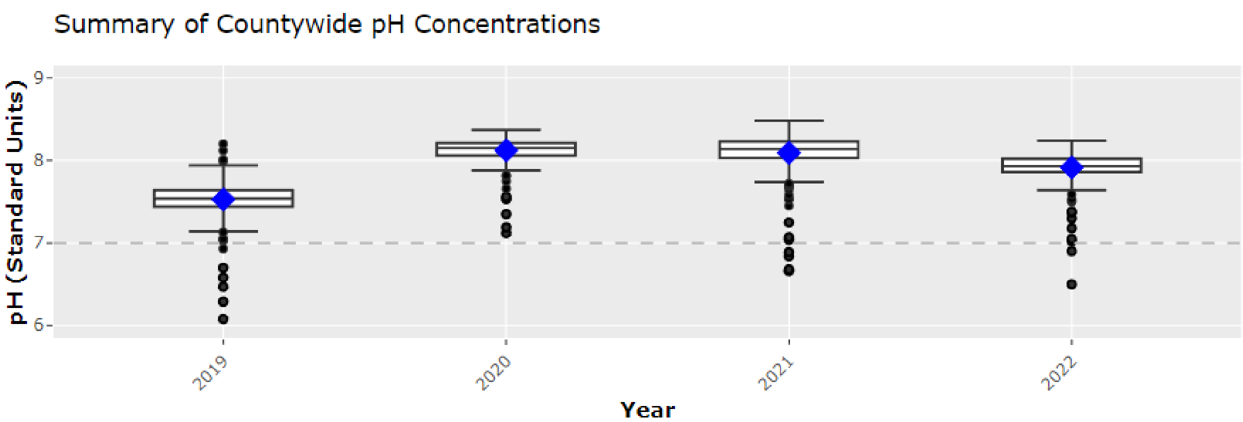
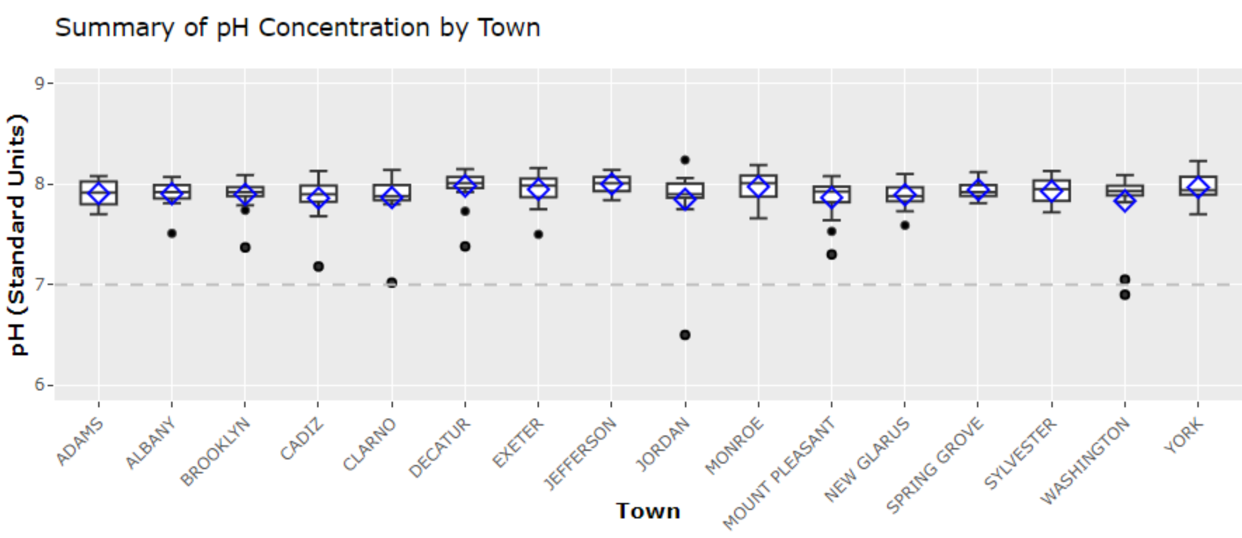


Figure 10b. Boxplots of pH by town for Year 4.



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).

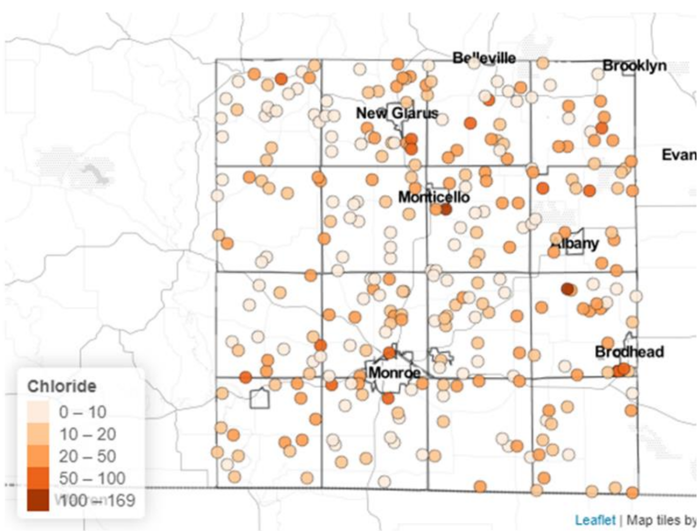
Interpreting Chloride Concentrations

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 4 of the Green County Well Water Monitoring Project.



Chloride (mg/L)	Number of Samples	Percent
Less than 10 mg/L	111	38%
11 – 50	165	56%
51 – 100	16	5%
101 – 200	2	<1%
Greater than 200	0	0

Figure 12a. Boxplots of countywide chloride for Year 1 (2019), Year 2 (2020), Year 3 (2021), and Year 4 (2022) of the project. Includes only wells that sampled in all 4 years.

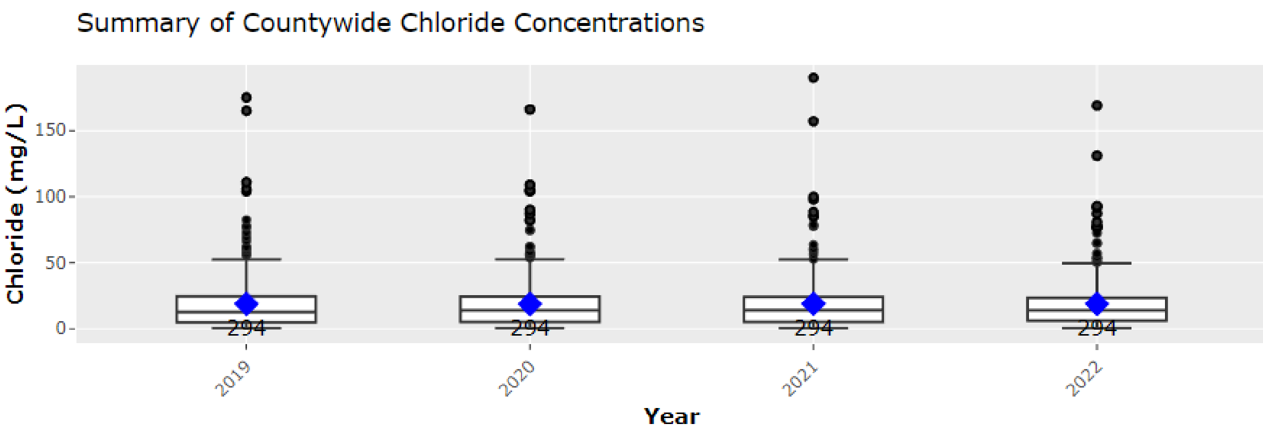
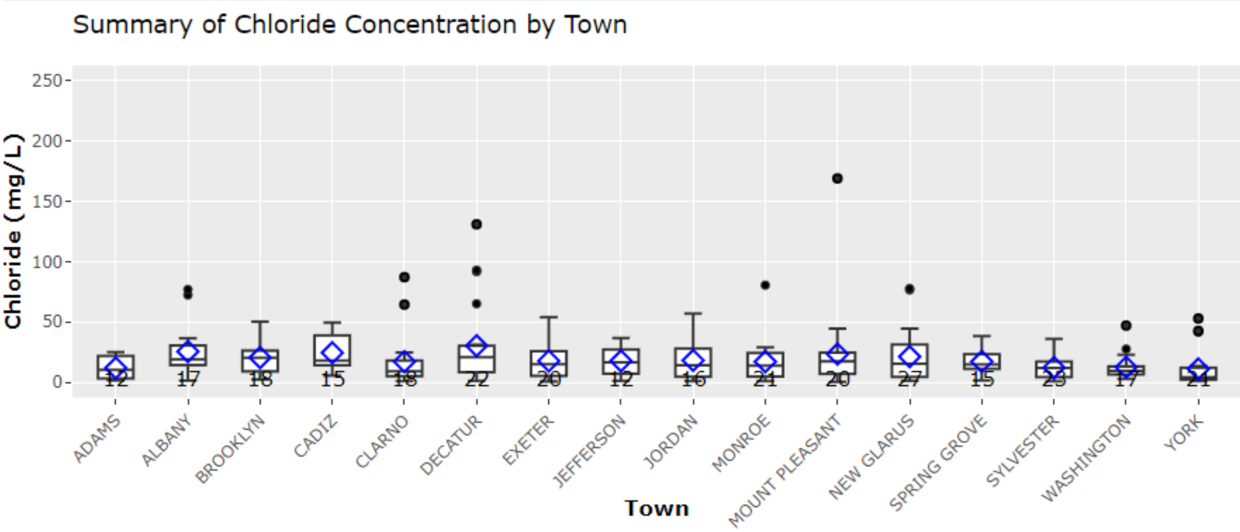


Figure 12b. Boxplots of chloride by town for Year 4.



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.

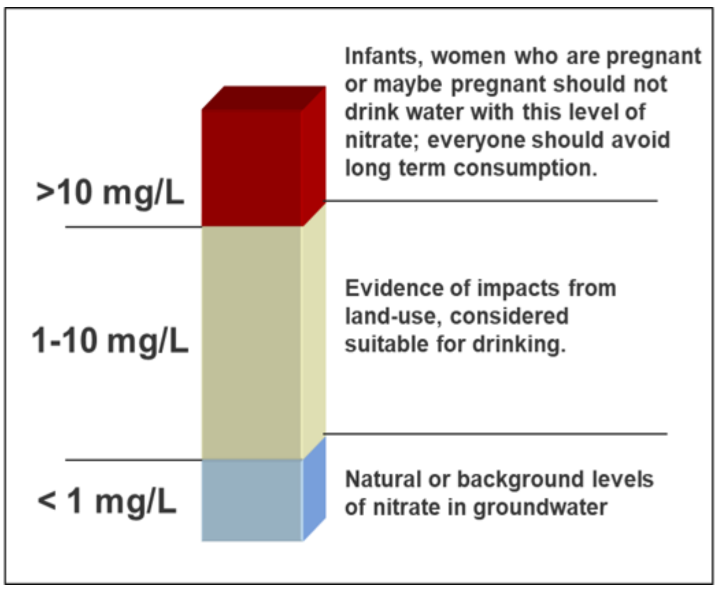
Why Test for Nitrate

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

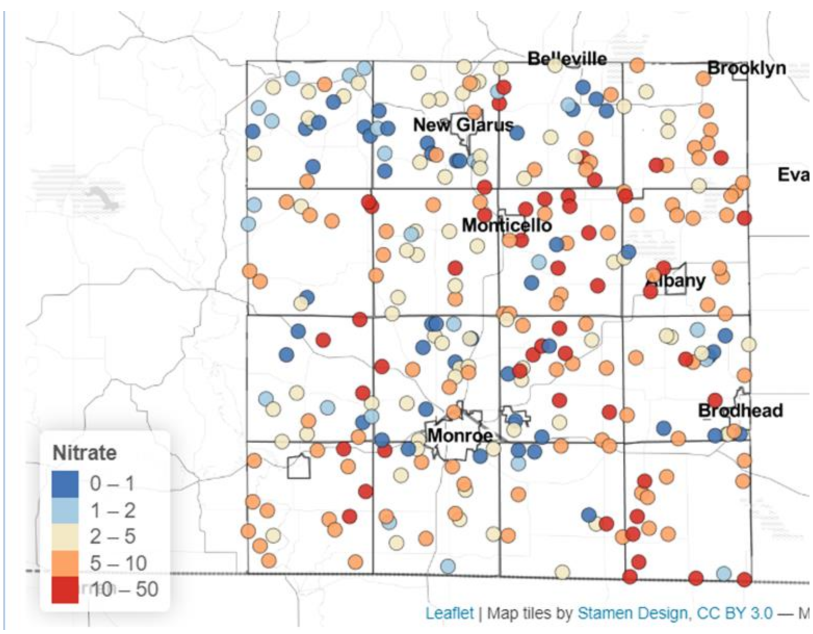
Sources of Nitrate

- 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 4 of the Green County Well Water Monitoring Project.



Nitrate-Nitrogen (mg/L)	Number of Samples	Percent
Less than 0.1	32	11%
0.1 – 2.0	43	15%
2.1 – 5.0	75	26%
5.1 – 10.0	97	33%
10.1 – 20.0	45	15%
Greater than 20.0	2	<1%

Figure 14a. Boxplots of countywide nitrate-nitrogen for Year 1 (2019), Year 2 (2020), Year 3 (2021), and Year 4 (2022) of the project. Includes only wells that sampled in all 4 years.

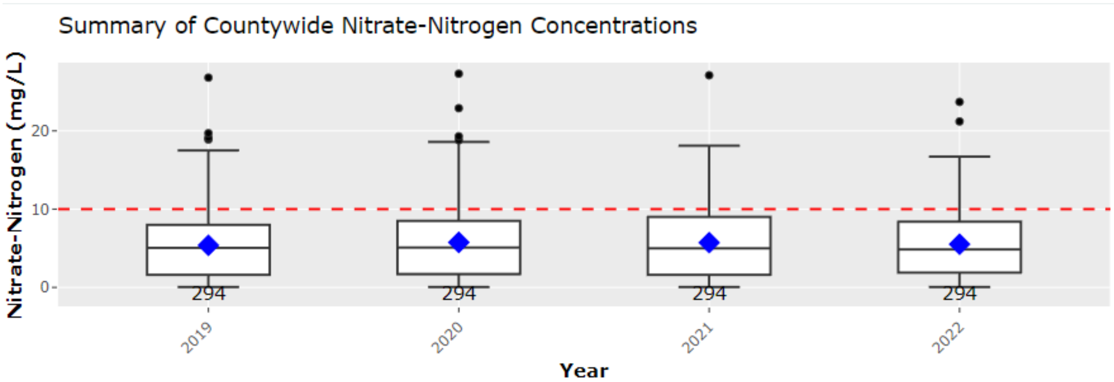
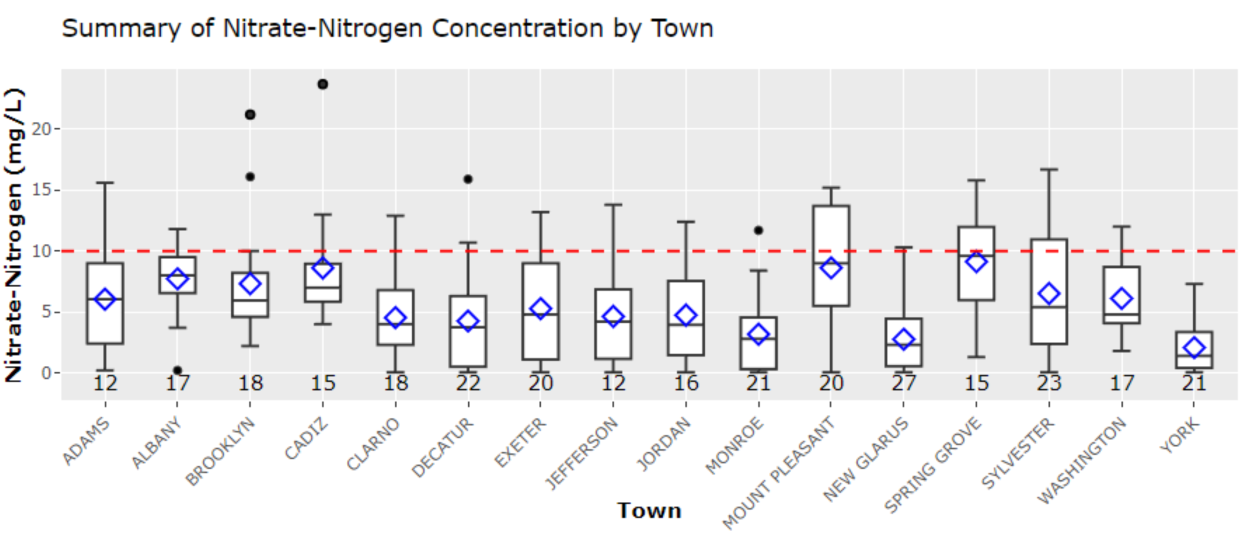


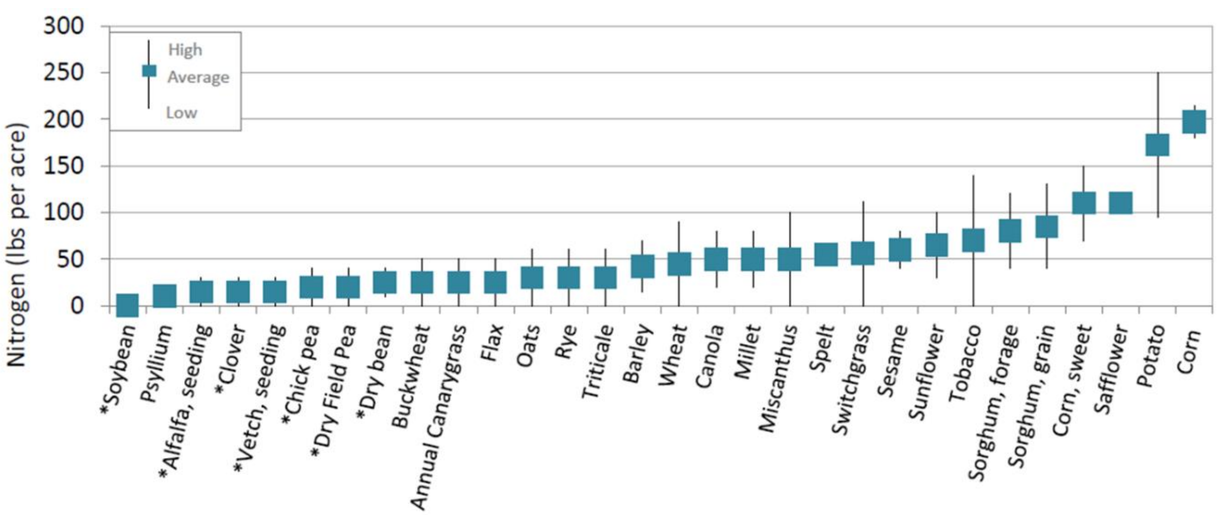
Figure 14b. Boxplots of nitrate-nitrogen by town for Year 3.



Agriculture and nitrate

Within agricultural systems there are various factors that influence the amount of nitrate that gets into groundwater. While significant amounts of nitrogen are taken up by crops, not all nitrogen applied as fertilizer/manure is removed via the harvested portion of the plant. Heavy rains during the growing season can push nitrate past the reach of plant roots. Meanwhile, any nitrate left over in the soil at harvest time is likely to leach into groundwater with autumn rains and/or spring snow melt.

Figure 15. Nitrogen fertilizer recommendations (in pounds per acre) for various crops growing in Wisconsin. Asterisk (*) indicates legumes. (Source: Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. A2809. Laboski and Peters, 2012. University of Wisconsin-Madison).



Nitrate leaching is largely a function of nitrogen fertilizer/manure inputs and the amount of nitrogen removed via harvested material. As a result, nitrate leaching estimates can be made when you know how much fertilizer was applied and the yield that was obtained on that field (Meisinger and Randall, 1991).

This budget approach often reveals that even fields with nutrient management plans are capable of leaching nitrate-nitrogen that is in excess of what is considered suitable for drinking water (i.e. 10 mg/L). Depending on the soil type and other factors, it's estimated that 20-50% of the nitrogen applied as fertilizer may leach past the root zone into groundwater (Shrethsa et al., 2023). Applying fertilizer at the right rate, time, source, place will maximize profitability and minimize excessive losses of nitrogen to groundwater; however additional practices are often necessary if looking to improve water quality in areas with susceptible soils and geology.

Figure 16. Illustration of the relationship between crop type, the susceptibility of groundwater to contaminants such as nitrate, and the amount of nitrate that leaches under various scenarios. The plane represents the baseline level of nitrate leaching expected as the result of what are generally considered to be acceptable management practices.

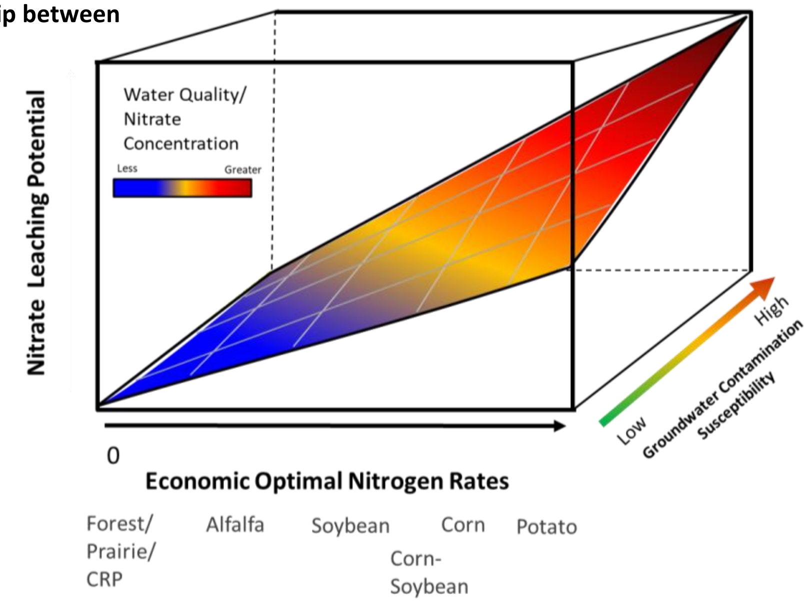
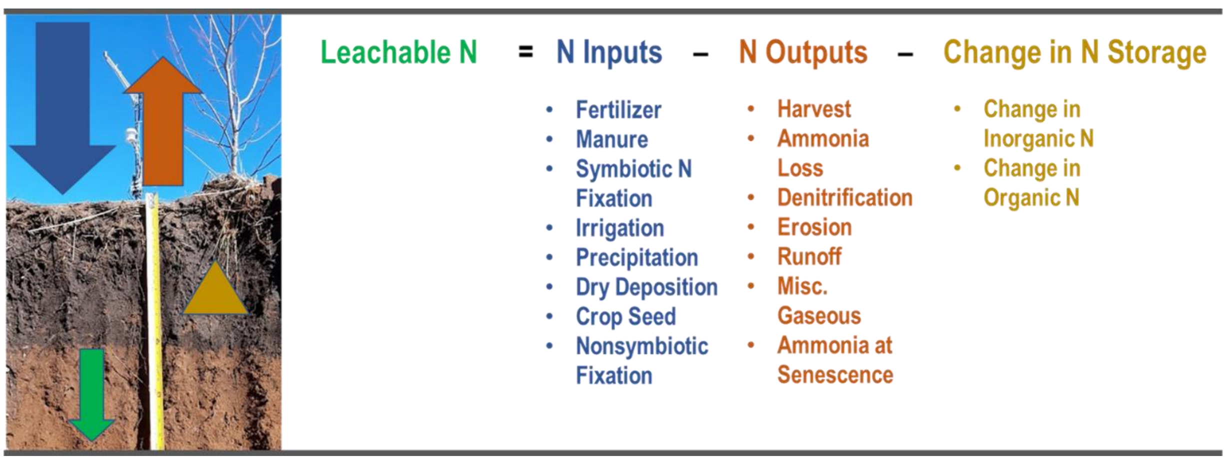


Figure 17. Potential leachable N (nitrate) can be calculated using a nitrogen budget approach. If various inputs are known and a reasonable estimate of yield can be made, estimating leachable nitrogen can be performed.



Minimizing nitrate leaching to groundwater fundamentally requires that we think about how best to maintain nitrogen in the top one to two feet of soil where plants are most likely to capture it. If nitrate in groundwater is an issue, improvements to groundwater quality below agricultural systems will only be observed when the following are achieved: 1) increasing yield with the same amount of nitrogen, 2) achieve the same yield with less nitrogen, 3) increase long-term soil organic matter levels which helps to store organic nitrogen in the soil and also increase water holding capacity, 4) temporary storage of nitrogen by cover crops that can be used to reduce nitrogen inputs to the next year’s crop.

While significant nitrate can be lost during the growing season, particularly during wet years, leaching post-harvest through the following planting season may represent the majority of leaching losses during moderate to dry years (Masarik et al., 2014). Therefore, multiple strategies that reduce nitrogen fertilizer inputs, make nitrogen available when the plant needs it most, combined with additional activities that encourage active root systems or minimize decomposition during the fall and spring should all be explored.

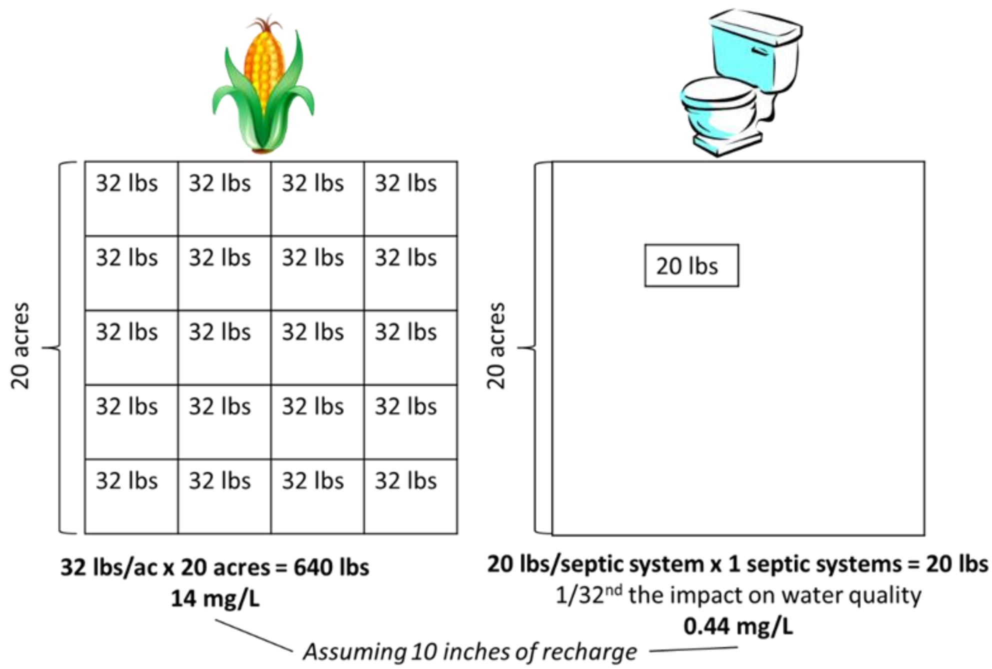
The following ideas are actionable activities that will help to reduce nitrate concentrations in groundwater and nearby wells:

- 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 unprofitable parts of fields out of production.
- Diversify cropping systems to include less nitrogen intensive crops in the rotation (see Figure 15 for list of crops and nitrogen recommendations).
- Explore and experiment with the use of cover crops, intercropping, perennial cropping systems, or managed grazing to reduce nitrate losses to groundwater. Perennial cover, particularly diverse cover with multilayered root systems will have the greatest potential to reduce nitrate losses.

Septic systems and nitrate

Septic systems are designed to deactivate pathogens from wastewater and filter out other potential pollutants such as phosphorus, however other dissolved constituents like nitrate/chloride pass easily through drainfields into groundwater below. It is important to point out here that even properly functioning septic systems are contributors of nitrate to groundwater, although in traditional rural development the degree of influence is much less than agricultural systems.

Figure 18. Illustration of nitrogen leaching estimates for a twenty-acre agricultural field of corn (left) versus a twenty-acre parcel with one septic system drainfield for a 3 person household (right).



We can use a nitrogen budget approach to again understand why this might be the case. On average a septic system would be expected to leach between 16-20 pounds of nitrogen per year (EPA 625/R-00/008). If we compare this to an agricultural field that leaches 32 pounds per acre (Masarik, 2014) they may not seem that different. However, traditional rural development often has one septic system on a large parcel where the impact of nitrate leaching is offset by the rest of the property acreage (Figure 18). In some instances the impacts may be more evident; for instance if a well is directly downgradient of a septic drainfield or there are large numbers of drainfields in close proximity to one another.

When the density of septic systems in a small area increases, there is a greater potential for higher nitrate concentrations as the result of increased nitrate loss. The smaller the lot size the greater potential impact that will result from septic systems in close proximity to one another, not only with respect to nitrate but also other compounds associated with household wastewater (ex. pharmaceuticals, personal care products, PFAS, etc.). For the example in Figure 18, we'd estimate that lot sizes of 0.6 acres in a 20 acre development with septic systems would essentially have the same impact as a 20 acre agricultural field leaching 32 lbs of nitrogen per acre.

Figure 19. (Right) Picture of subdivision with homes served by private wells and septic system drainfields. Groundwater flow direction is from upper-left to lower-right. Orange shapes illustrate hypothetical plumes paths downgradient of drainfields.

Nitrate Trends

The goal of this project is to help understand trends or changes in groundwater quality over time. Four years is the minimum necessary to begin answering the question of trends. Information on trends can be found in the figures below, including a map showing individual wells that detected significant trends. There were 13% (39 wells) that detected increasing trends, 9% (26 wells) that detected decreasing trends, and 78% (229 wells) that did not detect a trend.

These statistics will likely change with more years of data. Because a well has an increasing trend it does not mean that it will increase indefinitely. Areas with more wells increasing should receive special attention, particularly for wells that are approaching the standard of 10 mg/L. Wells without trends that are above the standard should still be considered areas of concern. These data provide some timely feed back on the question of where and to what degree groundwater quality is changing in Green County.

Future work will try to investigate whether there are common factors which explain increases or decreases; and the role of weather variability for helping explain changes over time.

Figure 15. 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.

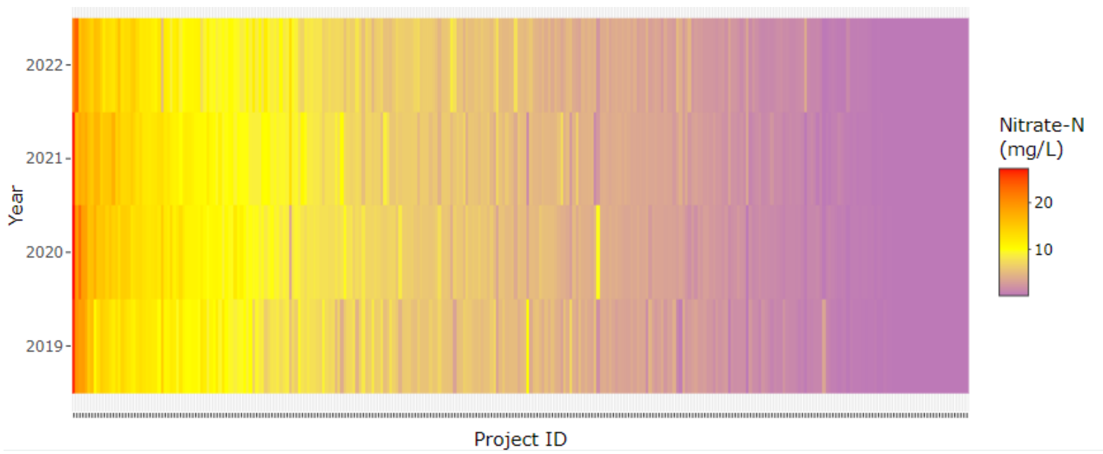
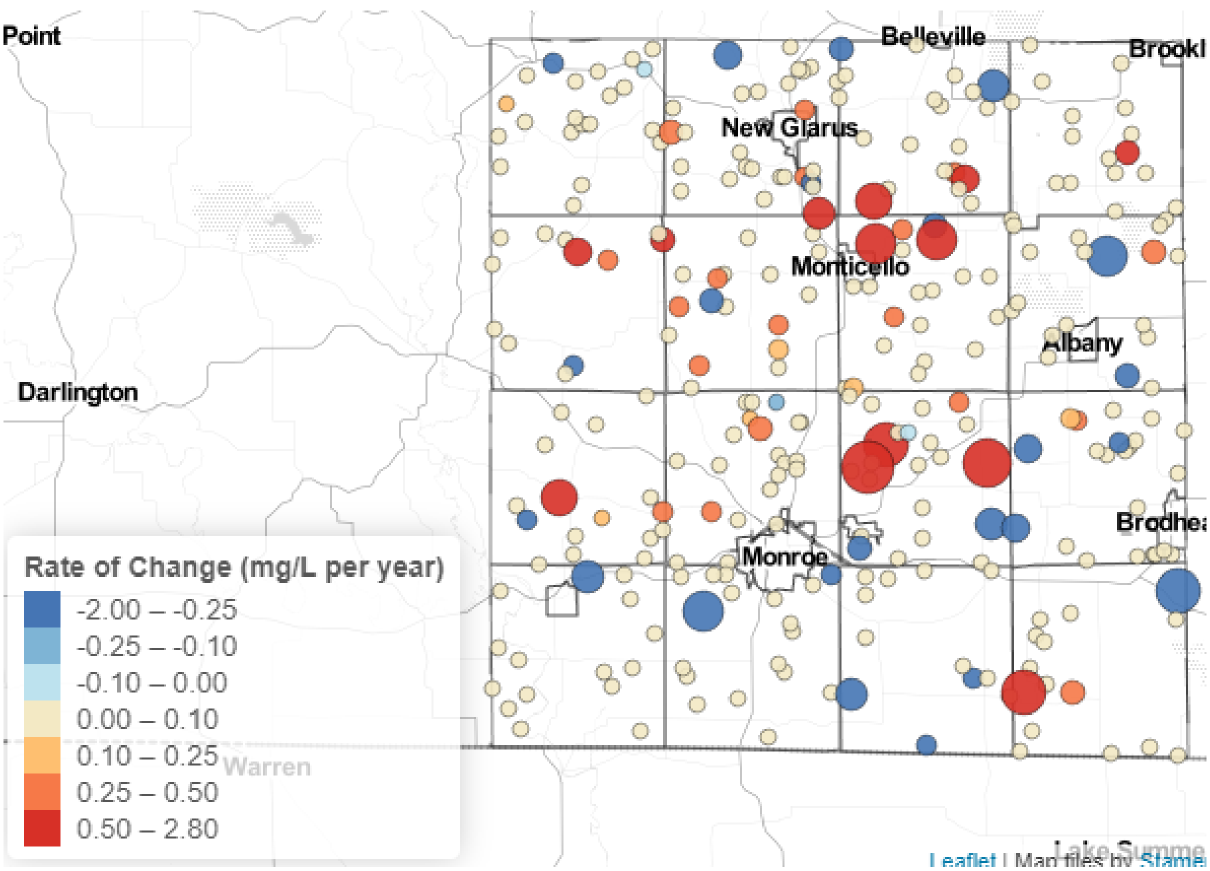


Figure 16. Nitrate-nitrogen trends



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.

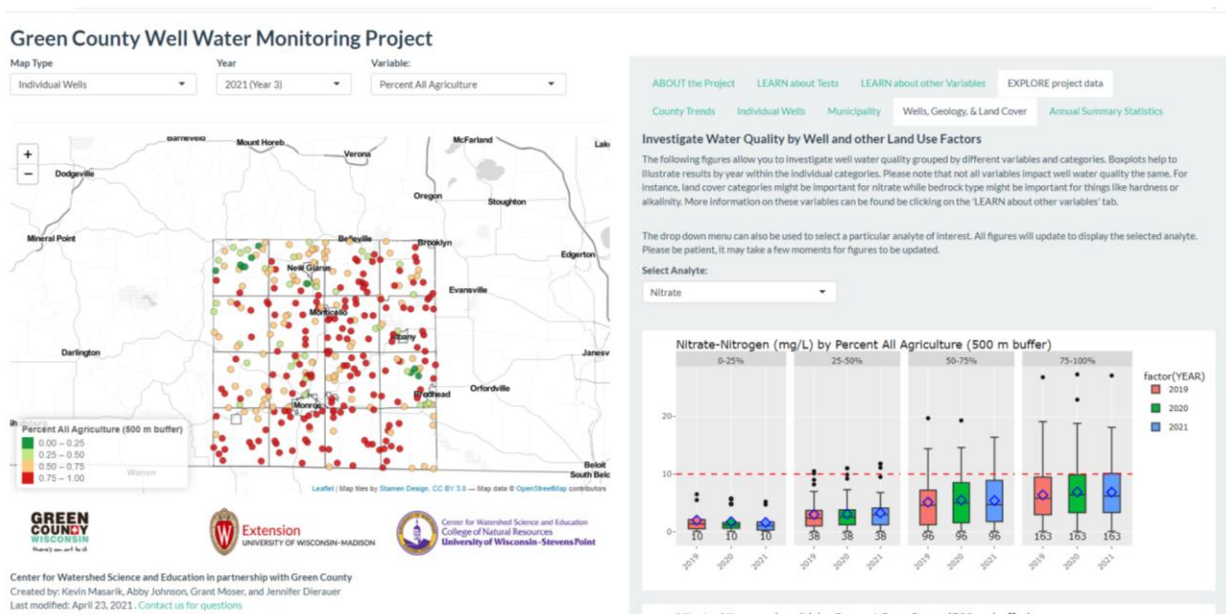
Features include:

- 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

Access the dashboard here:

- http://68.183.123.75/wisconsinwater/County-Apps/Green/

Figure 17. 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 2023, with the goal of having participants send samples back to the laboratory by December 1, 2023. 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.