FINAL TOWNSHIP TESTING NITRATE REPORT: WINONA COUNTY 2016-2017

April 2018

Minnesota Department of Agriculture

Pesticide and Fertilizer Management Division

ACKNOWLEDGEMENTS

MDA PRIMARY AUTHOR

Ben Bruening, Kim Kaiser, and Nikol Ross

MDA CONTRIBUTORS AND REVIEWERS

Larry Gunderson, Bruce Montgomery and Jen Schaust

LOCAL COUNTY PARTNERS

Winona Soil and Water Conservation District

FUNDING

Project dollars provided by the Clean Water Fund (from the Clean Water, Land and Legacy Amendment).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Nitrate is a naturally occurring, water soluble molecule that is made up of nitrogen and oxygen. Although nitrate occurs naturally, it can also originate from sources such as fertilizer, animal manure, and human waste. Nitrate is a concern because it can be a risk to human health at elevated levels. The Minnesota Department of Health (MDH) has established a Health Risk Limit (HRL) of 10 mg/L nitrate as nitrogen (nitrate-N) for private drinking water wells in Minnesota.

In response to health concerns over nitrate-N in drinking water the Minnesota Department of Agriculture (MDA) developed the Nitrogen Fertilizer Management Plan (NFMP). The NFMP outlines a statewide plan to assess vulnerable areas for nitrate in groundwater known as the Township Testing Program.

The primary goal of the Township Testing Program is to identify areas that have high nitrate concentrations in their groundwater. The program also informs residents about the health risk of their well water. Areas were selected based on historically elevated nitrate conditions, aquifer vulnerability and row crop production. The MDA plans to offer nitrate-N tests to more than 70,000 private well owners in over 300 townships by 2019. This will be one of the largest nitrate testing efforts ever conducted and completed.

In 2016-2017, private wells in the Winona County study area (13 townships) were sampled for nitrate-N. Samples were collected from private wells using homeowner collection and mail-in methods. These initial samples were collected from 940 wells representing an average response rate of 40 percent of homeowners. Well log information was obtained when available and correlated with nitrate-N results. Initial well dataset results showed that across the study area, 19.1 percent of private wells sampled were at or above the health standard of 10 mg/L for nitrate-N. Based on the initial results, it is estimated that over 1,300 residents could be consuming well water with nitrate-N at or over the HRL.

The MDA completed follow-up sampling and well site visits at 285 wells in 2017. A follow-up sampling was offered to all homeowners with wells that had a detectable nitrate-N result.

A well site visit was conducted to identify wells that were unsuitable for final analysis. The final well dataset is intended to only include private drinking water wells potentially impacted by applied commercial agricultural fertilizer. Therefore, wells with construction issues or nearby potential point sources of nitrogen were removed from the final well dataset. Point sources of nitrogen can include: feedlots, subsurface sewage treatment systems, fertilizer spills, and bulk storage of fertilizer. A total of 209 (22 percent) wells were determined to be unsuitable and were removed from the dataset. The final well dataset had a total of 731 wells.

The final well dataset was analyzed to determine the percentage of wells at or over the HRL of 10 mg/L nitrate-N. When analyzed at the township scale the percent of wells at or over the HRL ranged from 0 to 42.9 percent. Four of the thirteen townships sampled in Winona County are showing significant problems with 10 percent of wells at or over the HRL.

INTRODUCTION

The Minnesota Department of Agriculture (MDA) is the lead agency for nitrogen fertilizer use and management. The Nitrogen Fertilizer Management Plan (NFMP) is the state's blueprint for prevention or minimization of the impacts of nitrogen fertilizer on groundwater. The MDA revised the NFMP in 2015. Updating the NFMP provided an opportunity to restructure county and state strategies for reducing nitrate contamination of groundwater, with more specific, localized accountability for nitrate contamination from agriculture. The NFMP outlines how the MDA addresses elevated nitrate levels in groundwater. The NFMP has four components: prevention, monitoring, assessment and mitigation.

The goal of nitrate monitoring and assessment is to develop a comprehensive understanding of the severity, magnitude, and long term trends of nitrate in groundwater as measured in public and private wells. The MDA established the Township Testing Program to determine current nitrate concentrations in private wells on a township scale. This program is designed to quickly assess a township in a short time window. Monitoring focuses on areas of the state where groundwater nitrate contamination is more likely to occur. This is based initially on geologically vulnerable areas where appreciable acres of agricultural crops are grown. Statewide the MDA plans to offer nitrate-N tests to more than 70,000 private well owners in over 300 townships by 2019. As of April 2018, 242 townships in 24 counties have completed the initial sampling with the goal of providing nitrate testing in approximately 300 vulnerable townships by 2019.

In 2016, 13 townships in Winona County were selected to participate in the Township Testing Program (Figure 1). Areas were chosen based on several criteria. Criteria used includes: professional knowledge shared by the local soil and water conservation district (SWCD) or county environmental department, past high nitrate as nitrogen (nitrate-N) results, vulnerable groundwater, and the amount of row crop production. Initial water samples were collected from private wells by homeowners and mailed to a laboratory. Sample results were mailed by the laboratory to the participating homeowners. The sampling, analysis, and results were provided at no cost to participating homeowners and paid for by the Clean Water Fund.

Well owners with detectable nitrate-N results were offered a no cost pesticide sample and a follow-up nitrate-N sample collected by MDA staff. The MDA began evaluating pesticide presence and concentrations in private water wells at the direction of the Minnesota Legislature. The follow-up nitrate-N and pesticide sampling in Winona County occurred during the summer and fall of 2017. The follow-up included a well site visit (when possible) in order to rule out well construction issues and to identify potential point sources of nitrogen (Appendix B).

Wells that had questionable construction integrity or were near a point source of nitrogen were removed from the final well dataset. After the unsuitable wells were removed, the nitrate-N concentrations of well water were assessed for each area.

For further information on the NFMP and Township Testing Program, please visit the following webpages:
www.mda.state.mn.us/nfmp
www.mda.state.mn.us/townshiptesting

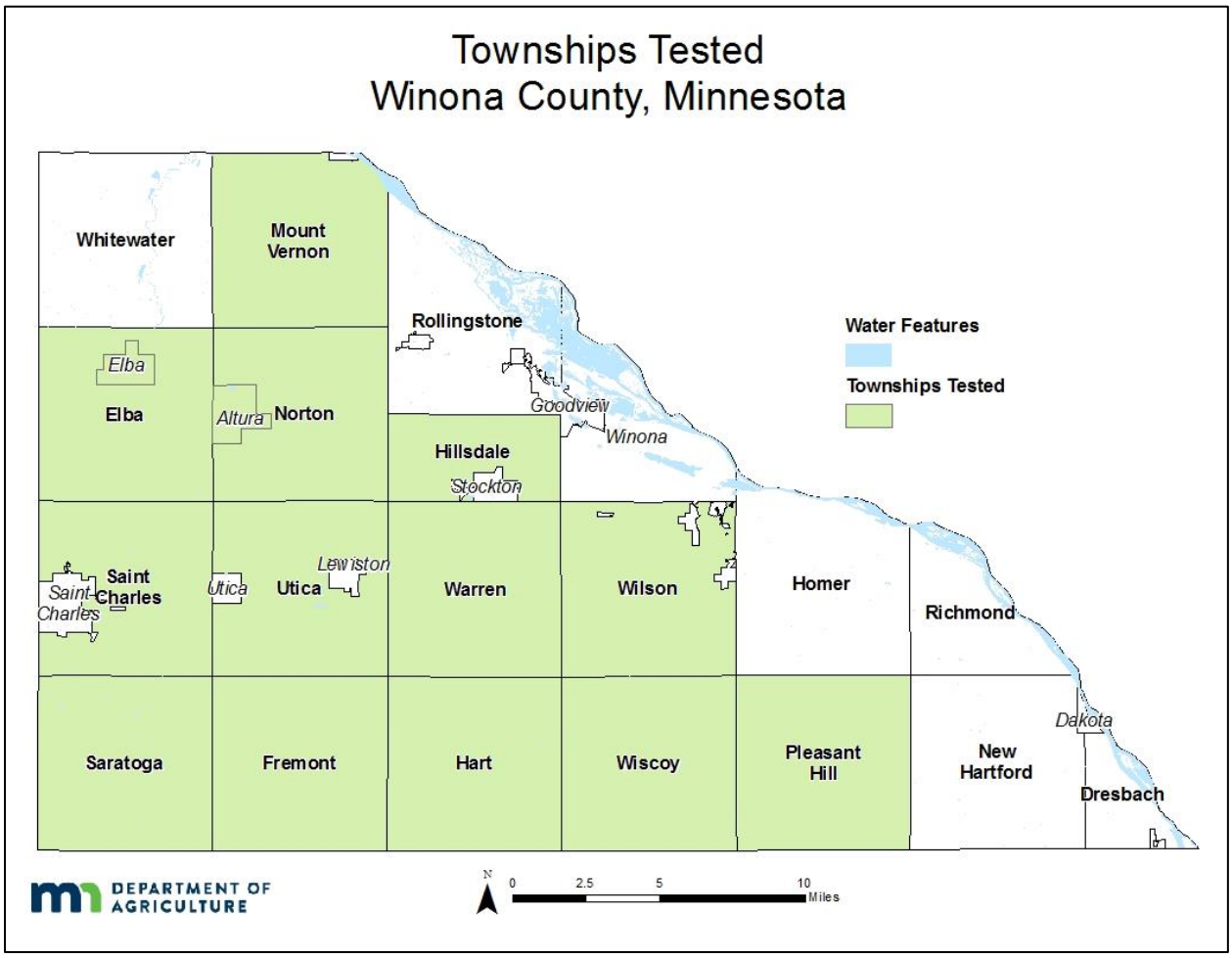


Figure 1. Townships Tested in Winona County

BACKGROUND

In many rural areas of Minnesota, nitrate is one of the most common contaminants in groundwater, and in some localized areas, a significant number of wells have high nitrate levels.

Nitrate is a naturally occurring, water soluble molecule that is made up of nitrogen and oxygen. Although nitrate occurs naturally, it can also originate from other sources such as fertilizer, animal manure, and human waste. Nitrate is a concern because it can have a negative effect on human health at elevated levels. The United States Environmental Protection Agency has established a drinking water Maximum Contaminant Level (MCL) of 10 mg/L for nitrate-N (US EPA, 2009) in municipal water systems. The Minnesota Department of Health (MDH) has also established a Health Risk Limit (HRL) of 10 mg/L nitrate-N for private drinking water wells in Minnesota.

Nitrogen present in groundwater can be found in the forms of nitrite and nitrate. In the environment, nitrite generally converts to nitrate, which means nitrite occurs very rarely in groundwater. The nitrite concentration is commonly less than the reporting level of 0.01 mg/L, resulting in a negligible contribution to the nitrate plus nitrite concentration (Nolan and Stoner, 2000). Therefore, analytical methods generally combine nitrate plus nitrite together. Measurements of nitrate plus nitrite as nitrogen and measurements of nitrate as nitrogen will hereafter be referred to as “nitrate”.

NITRATE FATE AND TRANSPORT

Nitrate is considered a conservative anion and is highly mobile in many shallow coarse-textured groundwater systems. Once in groundwater, nitrate is often considered very stable and can move large distances from its source. However, in some settings nitrate in groundwater may be converted to nitrogen gas in the absence of oxygen and the presence of organic carbon, through a natural process called denitrification. Denitrification occurs when oxygen levels are depleted and nitrate becomes the primary oxygen source for microorganisms (Rivett et al., 2008).

In karst environments, macropores and preferential flow pathways in the geology allow for nitrate-contaminated surface leachate to quickly reach aquifers (Bakalowicz, 2005). Because the time it takes for contaminated water to leach to aquifers is so short in karst systems, there is limited opportunity for denitrification (Katz, 2012). As a result, areas with karst geology and intensive row crop agriculture, like Winona County, are particularly vulnerable to groundwater nitrate contamination (Nolan, 2001, Panno et al., 2001). However, geochemical conditions can be highly variable within an aquifer or region and can also change over time (MPCA, 1998).

GEOLOGY AND HYDROGEOLOGY

Geology in Winona County consists of relatively thin interspersed layers of sandstone, siltstone, and carbonate rock deposited by shallow seas from about 500 to 450 million years ago (Setterholm, 2014). The county is located in the driftless region, which unlike the rest of the

state was not glaciated during the last glacial event, therefore its hilly topography remains intact.

Geology varies with the topography. Bedrock of uplands, which make up most of the central and western portions of the county, is characterized by crystalline dolostone and limestone bedrock overlying coarse-grained sandstone aquifers, with a layer of siltstone below the coarse-grained sandstone (Setterholm, 2014). This bedrock is typically covered only by a thin layer (generally less than 50 feet) of loess or clay to sand alluvium. In valleys, which are present primarily along the northern, eastern and southern edges of the county, the crystalline layers and varying amounts of the coarse grained sandstone have eroded away, leaving either the coarse-grained sandstone or siltstone as bedrock. Covering the bedrock in valleys is a thin layer of clay to sand alluvium with coarser rocks and boulders mixed in on hillsides (Setterholm, 2014).

The sandstone aquifers located directly beneath the dolostone and limestone bedrock of the uplands are particularly susceptible to contamination. This is because limestone and dolostone are susceptible to dissolution, which causes the formation of macropores and preferential flow channels, known as karst conduits (Runkel et. al 2003, Bakalowicz, 2005). These karst conduits allow for contaminated water from the surface to quickly flow through the limestone and dolostone into the underlying sandstone aquifers (Runkel et al 2003). Deeper sandstone aquifers, such as the Mt. Simon, tend to be more resistant to contamination as they are protected by the St. Lawrence and Eau Claire siltstone confining layers (Runkel et al., 2003, Setterholm, 2014).

Statewide geomorphological mapping conducted by the Minnesota Department of Natural Resources (MDNR), the Minnesota Geological Survey (MGS) and the University of Minnesota at Duluth (MDNR, MGS, and UMD, 1997) indicates the extent of alluvium and bedrock dominated surficial geology in Winona County as presented in Figure 2.

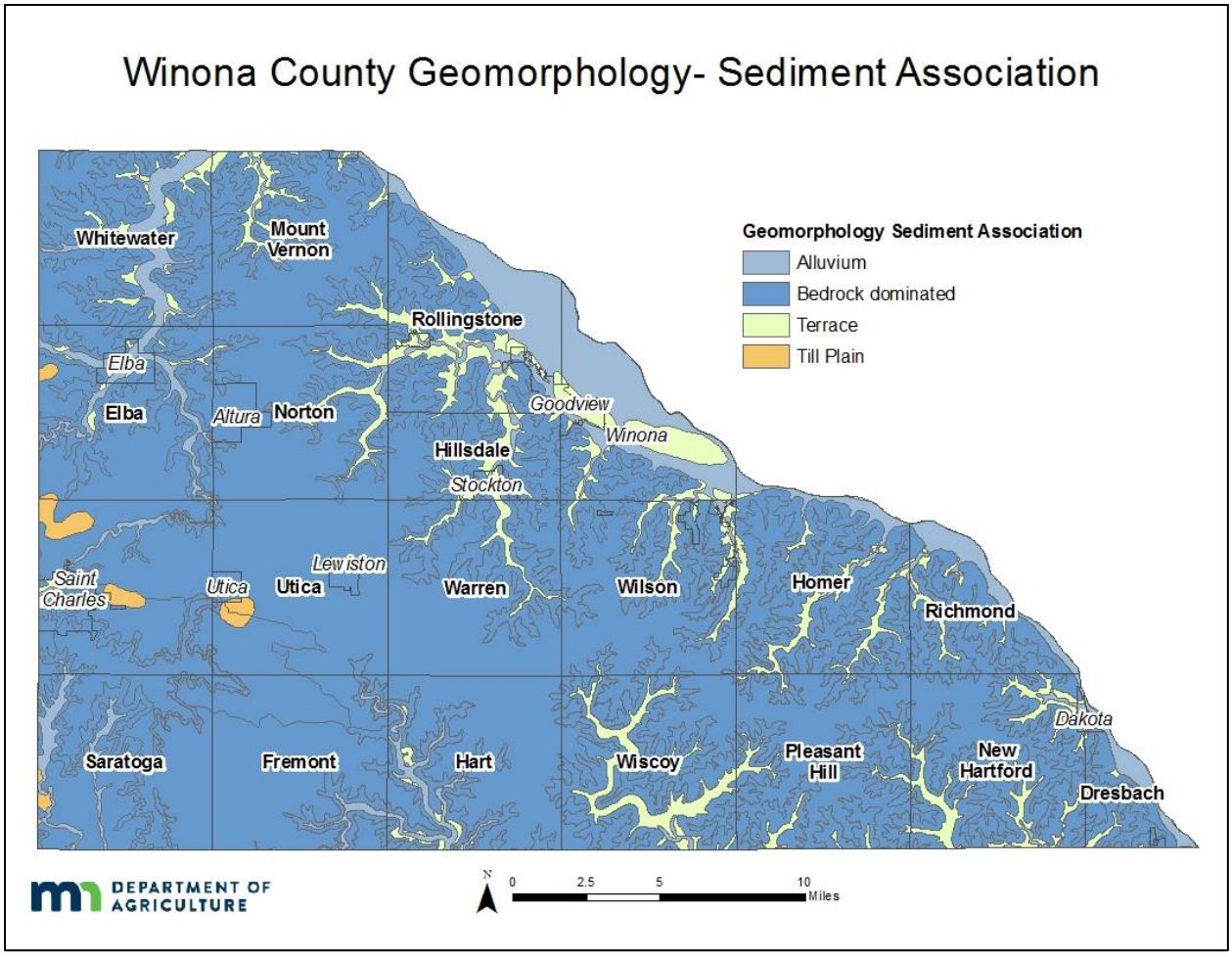


Figure 2. Statewide Geomorphology Layer, Sediment Association in Winona County (DNR, MGS, UMD, 1997)

NITROGEN POINT SOURCES

The focus of the Township Testing Program is to assess nitrogen contamination in groundwater as a result of commercial nitrogen fertilizer applied to cropland. Any wells potentially impacted by point sources were removed from the final well dataset. Potential point sources such as subsurface sewage treatment systems (more commonly known as septic systems), feedlots, fertilizer spills, and bulk storage of fertilizer are considered in this section. Below is a brief overview of these sources in Winona County. Further details are in Appendix B.

SUBSURFACE SEWAGE TREATMENT SYSTEM

Subsurface Sewage treatment systems (SSTS) can be a potential source for contaminates in groundwater such as nitrate and fecal material (MDH, 2014). A total of 4,905 SSTS were reported in Winona County for 2016. Over a recent 13 year period (2002-2016), 1,429

construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Winona County, 29 percent are newer than 2002 or have been repaired since 2002 (MPCA, 2017a). When new SSTS's are installed they are required to be in compliance with the rules at the time of installation. Newer systems meet modern SSTS regulations and must comply with the current well code; which requires a 50 foot horizontal separation from the well (MDH, 2014).

FEEDLOT

Manure produced on a feedlot can be a potential source of nitrogen pollution if improperly stored or spread. In the Winona County study area there are a total of 668 active feedlots. Of these, 229 are permitted to house more than 100 animal units (AU) and 68 are permitted to house more than 300 AU (Appendix B; Figure 7). The majority of feedlots in the study area are comprised of dairy and beef cattle.

FERTILIZER STORAGE LOCATION

Bulk fertilizer storage locations are potential point sources of nitrogen because they store large concentrations of nitrogen based chemicals. Licenses are required for individuals and companies that store large quantities of fertilizer. The Winona County study area has a total of 7 fertilizer storage licenses with 3 located in Utica Township, 2 in St. Charles Township, and 1 in Norton Township (Appendix B; Table 11).

FERTILIZER SPILLS AND INVESTIGATIONS

A total of 9 historic fertilizer spills and investigations occurred in the Winona County study area. The majority of these were incident investigations (Appendix B; Table 12).

TOWNSHIP TESTING METHODS

VULNERABLE TOWNSHIPS

Well water sampling is focused on areas that are considered vulnerable to groundwater contamination by commercial nitrogen fertilizer. Typically townships and cities are selected for sampling if more than 30 percent of the underlying geology is considered vulnerable and more than 20 percent of the land cover is row crop agriculture. These are not rigid criteria, but are instead used as a starting point for creating an initial plan. A map depicting the areas that meet this preliminary criteria is shown in Figure 3. Additional factors such as previous nitrate results and local knowledge of groundwater conditions were, and continue to be, used to prioritize townships for testing.

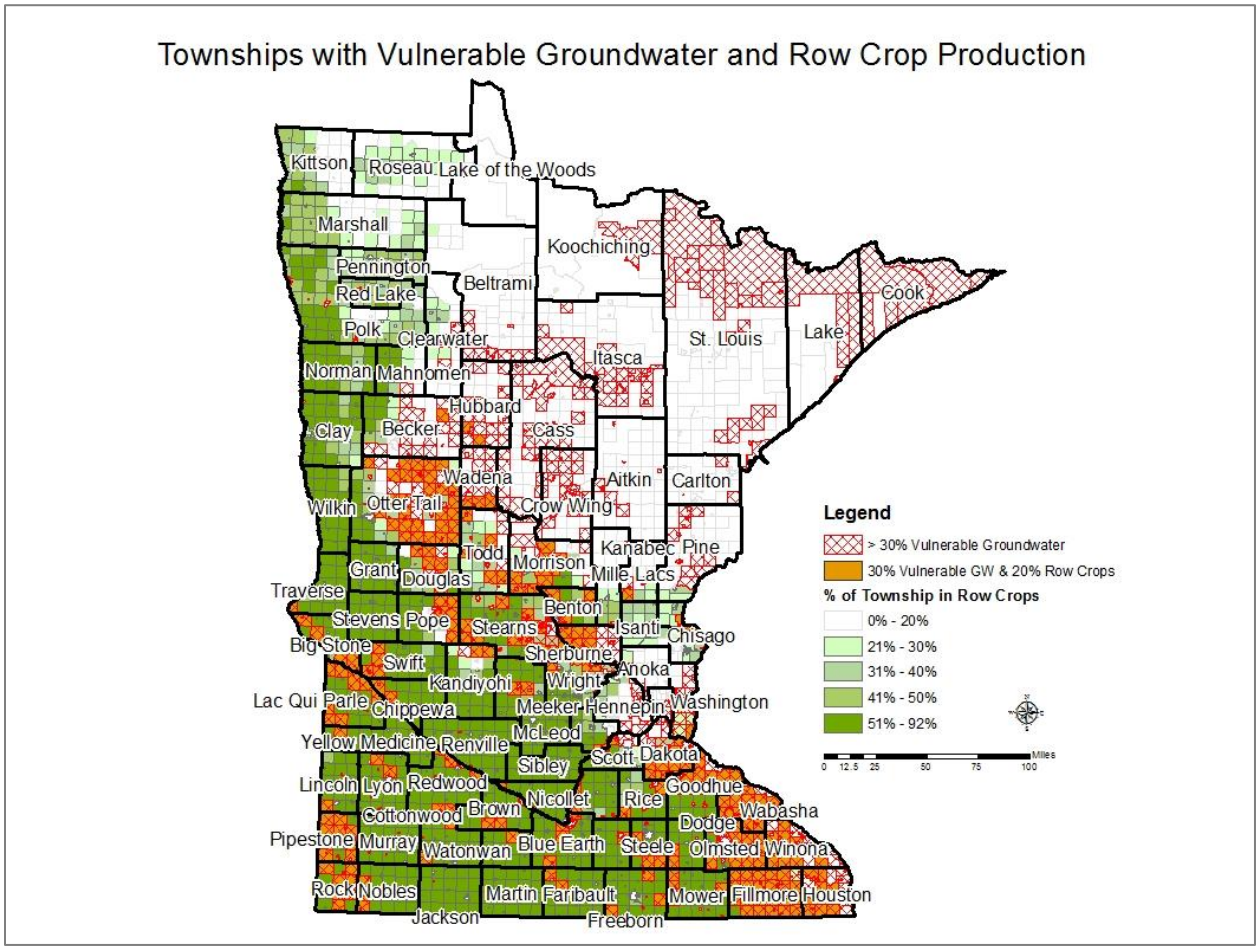


Figure 3. Minnesota Townships with Vulnerable Groundwater and Row Crop Production

Aquifer sensitivity ratings from the Minnesota Department of Natural Resources were used to estimate the percentage of geology vulnerable to groundwater contamination. The same

geologic mapping project presented in Figure 2 was used to classify the state into aquifer sensitivity ratings. There are three ratings for aquifer sensitivity: low, medium and high. Sensitivity ratings are described in Table 1. The ratings are based upon guidance from the Geologic Sensitivity Project Workshop's report "Criteria and Guidelines for Assessing Geologic Sensitivity in Ground Water Resources in Minnesota" (MDNR, 1991). A map of Winona County depicting the aquifer vulnerabilities is shown below in Figure 4. Winona only has regions with high and low aquifer sensitivity, there are no areas classified as having medium sensitivity.

Table 1. Vulnerability Ratings Based on the Geomorphology of Minnesota, Sediment Association Layer

Sediment Association	Sensitivity/Vulnerability Rating
Alluvium, Outwash, Ice Contact, Terrace, Bedrock: Igneous, Metamorphic, and Sedimentary	High
Supraglacial Drift Complex, Peat, Lacustrine	Medium
Till Plain	Low

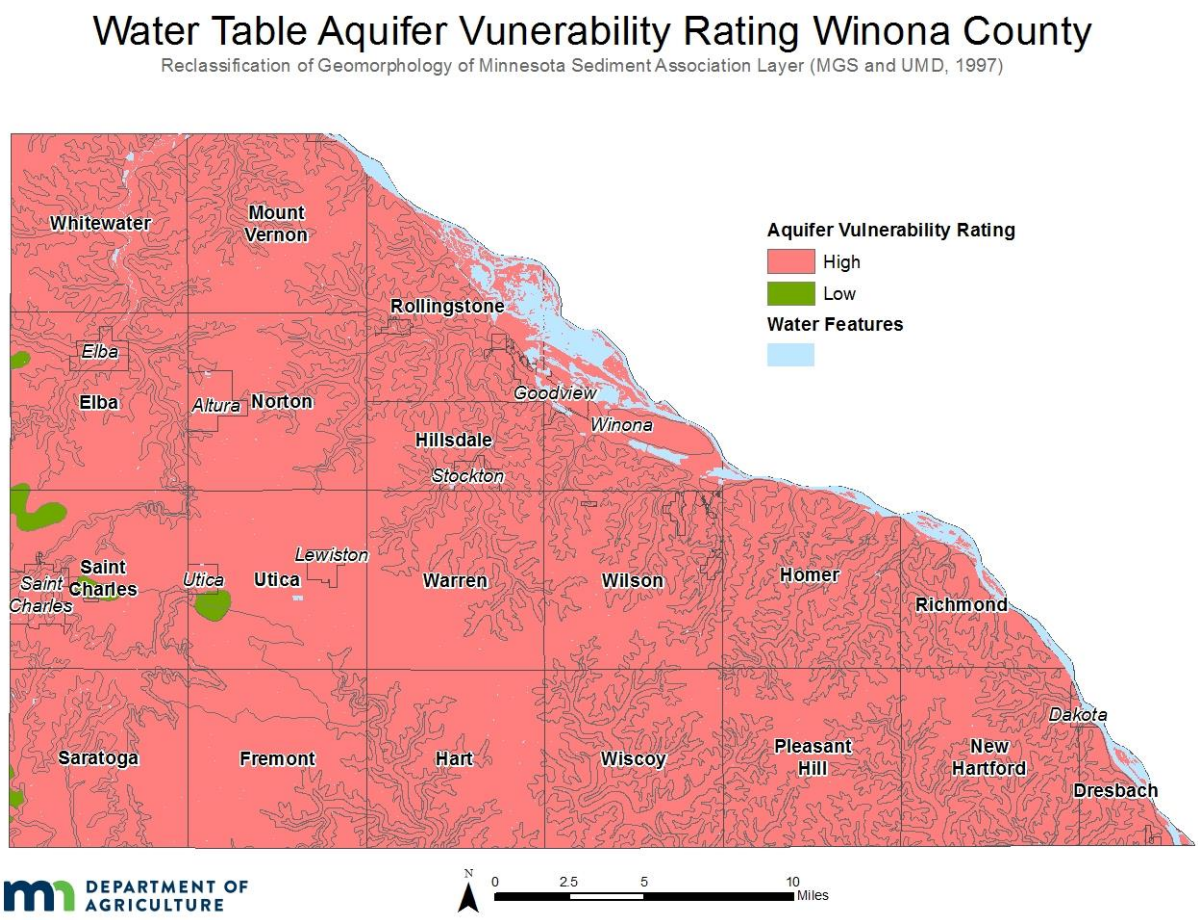


Figure 4. Water Table Aquifer Vulnerability Rating in Winona County

The National Agriculture Statistics Service data (USDA NASS, 2013) on cropland was used to determine the percentage of row crop agriculture. A map and table depicting the extent of the cropland in Winona County can be found in Appendix C (Figure 9, Table 14). On average 31 percent of the land cover was row crop agriculture.

PRIVATE WELL SAMPLING - NITRATE

The testing is done in two steps in each township: “initial” sampling and “follow-up” sampling. The initial nitrate sampling was conducted in 2016. In the initial sampling, all private well owners in the selected townships are sent a nitrate test kit. These kits include instructions on how to collect a water sample, a sample bottle, a voluntary survey, and a prepaid mailer. Each homeowner was mailed the nitrate result for their well along with an explanatory nitrate brochure (Appendix D). Well water samples were collected by 940 homeowners using the mail-in kit (Table 2). These 940 samples are considered the “initial well dataset”. Overall, 40 percent

of the homeowners in these townships responded to the free nitrate test offered by the Minnesota Department of Agriculture (MDA).

All of the homeowners with a nitrate detection from the initial sampling were asked to participate in a follow-up well site visit and sampling. The well site visit and follow-up sampling was conducted in 2017 by MDA staff. A total of 285 follow-up samples were analyzed (Table 2).

Table 2. Homeowner Participation in Initial and Follow-Up Well Water Sampling, Winona County

Township	Kits Sent	Return Rate for Kits	Initial Well Dataset	Well Site Visits & Follow-up Sampling Conducted
Elba	139	44.6%	62	23
Fremont	119	35.3%	42	11
Hart	120	40.0%	48	15
Hillsdale	107	48.6%	52	8
Mt. Vernon	95	34.7%	33	12
Norton	193	41.5%	80	24
Pleasant Hill	214	27.1%	58	18
St. Charles	198	42.9%	85	28
Saratoga	189	29.6%	56	13
Utica	198	43.4%	86	29
Warren	210	43.8%	92	41
Wilson	441	44.4%	196	51
Wiscoy	144	34.7%	50	12
Total	2369	39.7%	940	285

Each follow-up visit was conducted at the well site by a trained MDA hydrologist. Well water was purged from the well for 15 minutes before a sample was collected to ensure a fresh water sample. Additionally, precautions were taken to ensure no cross-contamination occurred. A more thorough explanation of the sampling process is described in the sampling and analysis plan (MDA, 2016). As part of the follow-up sampling, homeowners were offered a no cost pesticide test. As pesticide results are finalized, they will be posted online in a separate report (www.mda.state.mn.us/pwps).

The well site visit was used to collect information on potential nitrogen point sources, well characteristics (construction type, depth, and age) and the integrity of the well construction.

Well site visit information was recorded on the Private Well Field Log & Well Survey Form (Appendix A).

WELL ASSESSMENT

All wells testing higher than 5 mg/L were carefully examined for well construction, potential point sources and other potential concerns.

Using the following criteria, a total of 209 wells were removed to create the final well dataset. See Appendix E (Table 16 and 17) for a summary of the removed wells.

HAND DUG

All hand dug wells were excluded from the dataset, regardless of the nitrate concentration. Hand dug wells do not meet well code and are more susceptible to local surface runoff contamination. Hand dug wells are often very shallow, typically just intercepting the water table, and therefore are much more sensitive to local surface runoff contamination (feedlot runoff), point source pollution (septic system effluent), or chemical spills.

POINT SOURCE

Well code in Minnesota requires wells to be at least 50 feet away from most possible nitrogen point sources such as SSTS (septic tanks and drain fields), animal feedlots, etc. High nitrate-N wells that did not maintain the proper distance from these point sources were removed from the final well dataset. Information gathered from well site visits was used to assess these distances. If a well was not visited by MDA staff, the well survey information provided by the homeowner and aerial imagery was reviewed.

WELL CONSTRUCTION PROBLEM

The well site visits allowed the MDA staff to note the well construction of each well. Some wells had noticeable well construction problems. For instance, a few wells were missing bolts from the cap, making the groundwater susceptible to pollution. Other examples include wells buried underground, cistern wells or wells with cracked casing. Wells with significant problems such as these were excluded from the final well dataset.

CISTERNS

Cisterns are buried or above-ground tanks used for the storage of water. In these systems, water is pumped from a well into the cistern, where it is then drawn for use (Hardie, 2018).

Cistern systems were built in American rural areas, such as Winona County, until the 1940's to store water pumped by windmills or gasoline pumps before rural electrical infrastructure was developed (Peterson, 2008). Cisterns provided water reserves for times when the limited and weather-dependent pumping capabilities of a windmill or gasoline pump could not keep up with the demands of the household and/or farm (Wood et al., 1977).

The vast majority of windmill and gasoline pumping systems have since been replaced with electric pumps, but in some cases the cisterns remain and are still used to store water pumped with electric pumps. Cisterns are vulnerable to leaks and contamination due to underground cracking, damaged lids, fill ports, or vents (Alberta Health Services, 2016), so we removed wells from the final dataset if the sample was drawn from a cistern.

IRRIGATION WELL

If the water sample from the initial homeowner sample was likely collected from an irrigation well, it was removed from the dataset. This study is focused on wells that supply drinking water.

UNSURE OF WATER SOURCE

Also, if the water source of the sample was uncertain, then data pertaining to this sample was removed.

SITE VISIT COMPLETED - WELL NOT FOUND & CONSTRUCTED BEFORE 1975 & NO WELL ID

Old wells with no validation on the condition of well construction were removed from the dataset. These wells were installed before the well code was developed in Minnesota (mid-1975), did not have a well log, and MDA staff could not locate the well during a site visit.

NO SITE VISIT & CONSTRUCTED BEFORE 1975 & NO WELL ID

Additionally if there was no site visit conducted, and the well is an older well (pre-1975) the well would not be used in the final analysis.

NO SITE VISIT & INSUFFICIENT DATA & NO WELL ID

Wells that were clearly lacking necessary background information were also removed from the dataset. These wells did not have an associated well log, were not visited by MDA staff, and the homeowner did not fill out the initial well survey or the address could not be found.

DUPLICATE / EXTRA KIT

Wells that were later found to be duplicates were removed from the final well dataset.

INITIAL RESULTS

INITIAL WELL DATASET

Approximately 940 well owners returned water samples for analysis across the six townships (Figure 5). These wells represent the initial well dataset.

The following paragraphs provide a brief discussion of the statistics presented in Table 3.

The minimum values of nitrate-N for all townships were less than the detection limit (<DL) which is 0.25 mg/L. The maximum values ranged from 9.4 to 43.8 mg/L, with Fremont Township having the highest result. Median values range from <0.25 to 11.4 mg/L, with Fremont Township having the highest median value. The 90th percentiles range from 6.3 to 20.1 mg/L, with Utica Township having the highest 90th percentile.

Initial results from the sampling showed that in Elba, Fremont, Hart, Mt. Vernon, Norton, St. Charles, Saratoga, Utica, and Warren Townships, ten percent or more of the wells were at or over 10 mg/L nitrate-N. Data from the Township Testing Program (MDA) and a United States Geological Survey report (Warner, 2010) suggests that private well water in Elba, Fremont, Hart, Mt. Vernon, Norton, St. Charles, Saratoga, Utica, and Warren Townships are more heavily impacted by nitrate than other areas of the upper United States. Both the USGS report and MDA Township Testing studies indicate that nitrate concentrations can vary considerably over short distances.

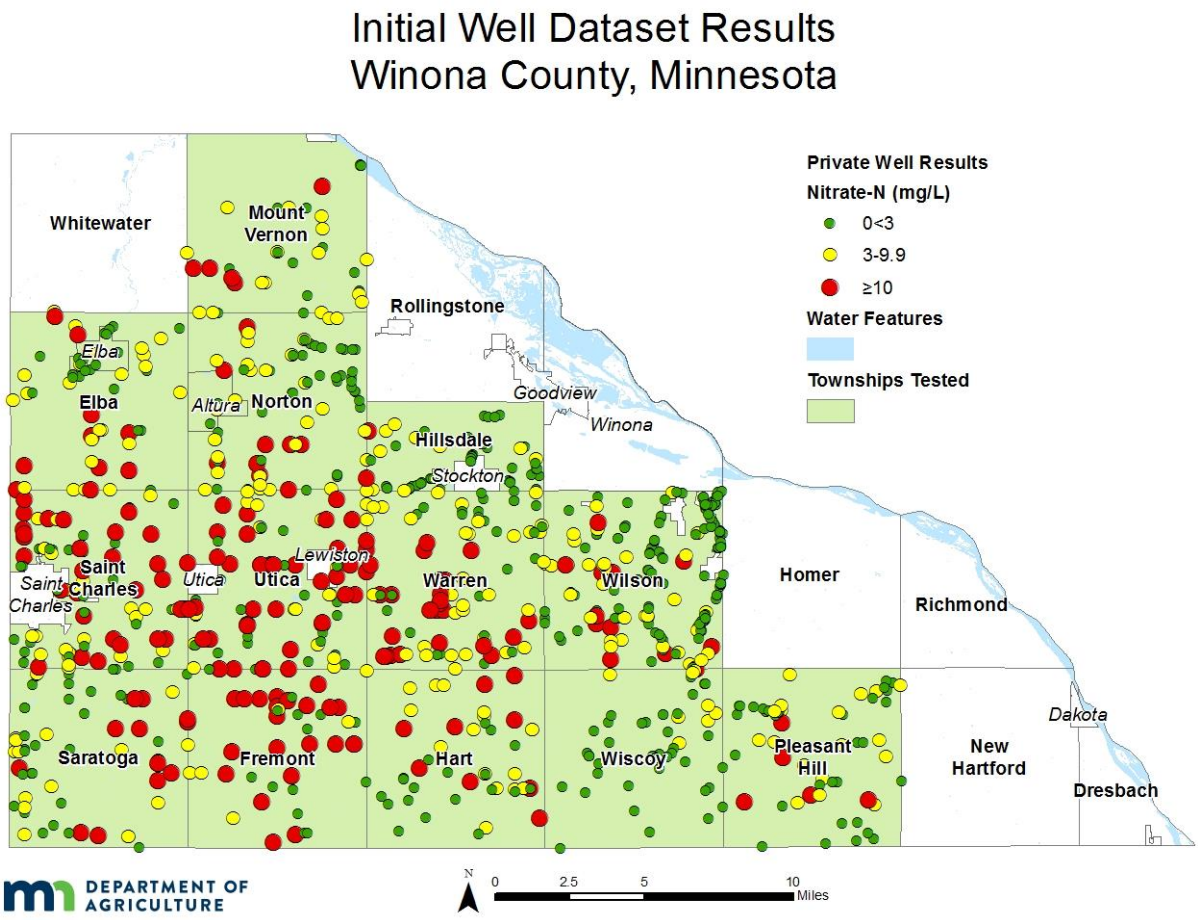


Figure 5. Well locations and Nitrate Results from Initial Dataset in Winona County

Table 3. Winona County Township Testing Summary Statistics for Initial Well Dataset

Township	Total Wells	Values			Percentiles					Number of Wells					Percent of Wells				
		Min	Max	Mean	50th (Median)	75th	90th	95th	99th	<3	3<10	≥5	≥7	≥10	<3	3<10	≥5	≥7	≥10
		Nitrate-N mg/L or parts per million (ppm)																	
Elba	62	<0.25	20.4	4.5	3.4	7.4	11.1	13.8	19.9	28	24	19	16	10	45.2%	38.7%	30.6%	25.8%	16.1%
Fremont	42	<0.25	43.8	10.6	11.4	15.4	18.7	27.0	43.8	13	6	29	28	23	31.0%	14.3%	69.0%	66.7%	54.8%
Hart	48	<0.25	32.7	5.7	4.4	9.3	13.7	17.4	32.7	22	17	21	17	9	45.8%	35.4%	43.8%	35.4%	18.8%
Hillsdale	52	<0.25	12.9	1.7	<0.25	1.7	8.3	9.4	12.9	43	8	8	6	1	82.7%	15.4%	15.4%	11.5%	1.9%
Mt. Vernon	33	<0.25	14.4	4.5	3.5	7.7	10.9	11.7	14.4	14	14	14	11	5	42.4%	42.4%	42.4%	33.3%	15.2%
Norton	80	<0.25	23.1	4.3	2.8	7.0	11.0	13.0	21.4	41	30	32	20	9	51.3%	37.5%	40.0%	25.0%	11.3%
Pleasant Hill	58	<0.25	18.6	3.4	2.2	5.7	9.4	11.8	18.3	33	20	16	9	5	56.9%	34.5%	27.6%	15.5%	8.6%
St. Charles	85	<0.25	34.8	7.0	4.7	13.1	17.7	18.9	29.4	33	23	40	34	29	38.8%	27.1%	47.1%	40.0%	34.1%
Saratoga	56	<0.25	25.8	5.1	2.3	9.2	13.8	15.8	25.4	29	16	24	17	11	51.8%	28.6%	42.9%	30.4%	19.6%
Utica	86	<0.25	27.9	8.9	8.6	15.4	20.1	21.0	27.1	30	16	53	47	40	34.9%	18.6%	61.6%	54.7%	46.5%
Warren	92	<0.25	29.3	6.8	5.2	10.6	16.0	18.0	26.6	30	36	50	34	26	32.6%	39.1%	54.3%	37.0%	28.3%
Wilson	196	<0.25	34.8	2.2	0.3	2.7	6.5	10.4	24.8	151	33	25	18	12	77.0%	16.8%	12.8%	9.2%	6.1%
Wiscoy	50	<0.25	9.4	1.5	<0.25	2.0	6.3	7.1	9.4	41	9	7	3	0	82.0%	18.0%	14.0%	6.0%	0.0%
Total	940	<0.25	43.8	4.9	2.1	7.8	14.3	17.4	25.7	508	252	338	260	180	54.0%	26.8%	36.0%	27.7%	19.1%

ESTIMATES OF POPULATION AT RISK

The human population at risk of consuming well water at or over the HRL of 10 mg/L nitrate was estimated based on the sampled wells. An estimated 1,324 people in Winona County's study area have drinking water over the nitrate HRL (Table 4). Nitrate contamination is a significant problem across much of Winona County. Additional public awareness and education programming will need to take place in many of the townships.

Table 4. Estimated Population with Water Wells Over 10mg/L Nitrate-N, Winona County

Township	Estimated Households on Private Wells*	Estimated Population on Private Wells*	Estimated Population ≥10 mg/L Nitrate-N**
Elba***	176	456	73
Fremont	123	331	181
Hart	116	333	63
Hillsdale	325	885	17
Mt. Vernon	107	260	40
Norton****	182	468	53
Pleasant Hill	207	527	45
St. Charles	197	610	208
Saratoga	186	587	115
Utica	202	603	280
Warren	224	636	180
Wilson	427	1118	68
Wiscoy	150	363	0
Total	2,622	7,177	1,324

* Data collected from the Minnesota State Demographic Center, 2017

** Estimates based off of the 2016 estimated households per township gathered from Minnesota State Demographic Center and percentage of wells at or over the HRL from the initial well dataset

***Includes Elba city in population estimates

**** Does not include Altura city in population estimates since Altura city has a municipal water system within the city

WELL SETTING AND CONSTRUCTION

MINNESOTA WELL INDEX AND WELL LOGS

The Minnesota Well Index (MWI) (formerly known as the "County Well Index") is a database system developed by the Minnesota Geological Survey (MGS) and the Minnesota Department of Health (MDH) for the storage, retrieval, and editing of water-well information. The database contains basic information on well records (e.g. location, depth, static water level) for wells drilled in Minnesota.

The database also contains information on the well log and the well construction for many private drinking water wells. The MWI is the most comprehensive Minnesota well database available, but contains only information for wells in which a well log is available. Most of the records in MWI are for wells drilled after 1974, when water-well construction code required well drillers to submit records to the MDH. The MWI does contain data for some records obtained by the MGS through the cooperation of drillers and local government agencies for wells drilled before 1974 (MGS, n.d.-b).

In some cases, well owners were able to provide Unique Well Identification Numbers for their wells. When the correct Unique IDs are provided, a well log can be used to identify the aquifer that the well withdraws water from. The well logs were obtained from the MWI for 202 documented wells (Table 5). Approximately 21.5 percent of the sampled wells had corresponding well logs. Thus, the data gathered on aquifers represents a portion of the total sampled wells. The majority of the wells did not have well log or aquifer information.

According to the well log data, the most commonly utilized aquifers for the sampled wells were from the Wonewoc, Tunnel City, Jordan, and Prairie du Chien. This majority reflects the overall findings for all documented wells in the focus area (Appendix F, Table 18). The wells in these aquifers are relatively deep, averaging 318 feet.

Below is a brief description of the aquifers characterized in Table 5.

The Quaternary aquifers represent the youngest geological aquifer formation identified in Winona County. The Quaternary Water Table (QWTA) wells are defined as having less than ten feet of confining material (clay) between the land surface and the well screen (MPCA, 1998). When there is less than ten feet of clay, it allows surface contaminants to travel more quickly to the water table aquifers. In general, shallower wells completed in the QWTA may be more susceptible to nitrate contamination. There are few QWTA wells documented in the MWI for Winona County which can be attributed to the lack of glacial sediments, typically less than 50 feet deep throughout the county.

The Paleozoic (Pre-Cretaceous) aquifers are dominated by carbonates, sandstone and shale. Upper parts of this formation were eroded during the later Quaternary glaciation (Lusardi, 2013). Most wells in Winona are likely completed in Paleozoic aquifers whether they have well logs or not since there is less than 50 feet of glacial material overlying the bedrock in most of the county.

The Prairie du Chien aquifer is the upper most widely used Paleozoic aquifer made up of carbonate rock (limestone and dolostone). In the area between Charles Township and New Hartford Township there is less than 30 feet unconsolidated deposits overlying the Prairie du Chien formation which allows water and contaminants to travel more quickly into the aquifer. Many of the older wells especially in the western part of the county have been completed in the Prairie du Chien and is known to have wells with nitrate ranging from 3 mg/L to 10 mg/L or more (Kanivetsky, 1984). The Jordan aquifer is comprised of sandstone lies just beneath the Prairie du Chien. The Tunnel City Group and the Wonewoc aquifers are also comprised of sandstone, but have the added benefit of sitting below the St. Lawrence Formation which is considered an aquitard.

Most (164) of the 180 total samples that were over 10 mg/L came from wells without a well log or aquifer information. The known Prairie du Chien wells had eight samples over 10 mg/L, which was 44 percent of the wells in that aquifer. The Jordan aquifer had six wells (nine percent) over 10 mg/L, while the Wonewoc aquifer had only two wells (four percent) over 10 mg/L. It is the likely that most of the wells without well or aquifer information are completed in the Prairie du Chien and the Jordan and also likely to be older and possibly not up to the most recent well codes.

Table 5. Nitrate Concentrations within Sampled Groundwater Aquifers

Aquifer Group	Average Depth	Total Wells	Values				Percentile	Number of Wells			Percent of Wells		
			Min	Max	Mean	Median	90th	<3	3<10	≥10	<3	3<10	≥10
			Nitrate-N mg/L or parts per million (ppm)										
QWTA*	65	2	<DL	4.1	2.1	2.1	4.1	1	1	0	50.0%	50.0%	0.0%
Prairie du Chien	280	18	<DL	25.7	9.2	8.8	19.3	5	5	8	27.8%	27.8%	44.4%
Jordan	389	63	<DL	15.9	3.4	1.0	9.9	36	21	6	57.1%	33.3%	9.5%
St. Lawrence	407	2	<DL	<DL	<DL	<DL	<DL	2	0	0	100.0%	0.0%	0.0%
Tunnel City	376	64	<DL	8.5	0.9	<DL	3.5	55	9	0	85.9%	14.1%	0.0%
Wonewoc	318	49	<DL	23.4	1.2	<DL	1.7	47	0	2	95.9%	0.0%	4.1%
Mt. Simon	244	3	<DL	<DL	<DL	<DL	<DL	3	0	0	100.0%	0.0%	0.0%
Indeterminate	300	1	5.1	5.1	5.1	5.1	NA	0	1	0	0.0%	100.0%	0.0%
Not Available	NA	738	<DL	43.8	5.5	3.1	15.0	359	215	164	48.6%	29.1%	22.2%
Total	318	940	<DL	43.8	4.9	2.1	14.3	508	252	180	54.0%	26.8%	19.1%

*Quaternary Water Table Aquifer

WELL OWNER SURVEY

The private well owner survey, sent out with the sampling kit, provided additional information about private wells that were sampled. The survey included questions about the well construction, depth and age, and questions about nearby land use. A blank survey can be found in Appendix G. It is important to note that well information was provided by the well owners and may be approximate or potentially erroneous. The following section is a summary of information gathered from the well owner survey (complete well survey results are located in Appendix H at the end of this document, Tables 19-32).

The majority of wells in each township are located on rural or "country" property. There were no properties located on lakes and very few (2 percent) in sub-divisions.

Approximately 85 percent of sampled wells are of drilled construction and less than one percent are sand-point wells. Sand point (drive-point) wells are typically completed at shallower depths than drilled wells. Sand point wells are also usually installed in areas where sand is the dominant geologic material and where there are no thick confining units such as clay. This makes sand point wells more vulnerable to contamination from the surface. There were only two hand dug wells sampled in the townships. As previously mentioned, hand dug wells are shallow and more sensitive to local surface runoff contamination than deeper drilled wells.

Approximately half the homeowners responded that their wells are greater than 100 feet deep. However, 37 percent of homeowners didn't know the depth of their well.

Only eight percent of wells have been tested for nitrate within the last year. Whereas 58 percent had not tested their well within the last ten years, hadn't ever tested their well or were unsure if they had tested it. Therefore, the results most homeowners receive from this study will provide them with new information. The Minnesota Department of Health recommends that homeowners test their wells for nitrate every 2 to 3 years.

POTENTIAL NITRATE SOURCE DISTANCES

The following response summary relates to isolation distances of potential point sources of nitrate that may contaminate wells. This information was obtained from the well surveys completed by the homeowner (complete well survey results are located in Appendix H at the end of this document, Tables 19-32).

- On average, farming takes place on 48 percent of the properties.
- Agricultural fields are closer than 300 feet from wells at 52 percent of the properties.
- Twenty-six percent of the well owners across all the townships responded that they have livestock (greater than ten head of cattle or other equivalent) on their property.
- The majority of wells (58 percent) are over 300 feet from an active or inactive feedlot.

- Very few well owners (less than two percent) across all townships store more than 500 pounds of fertilizer on their property.
- A small minority of wells (five percent) are less than 50 feet away from septic systems.

FINAL RESULTS

FINAL WELL DATASET

A total of 940 well water samples were collected by homeowners across 13 townships. A total of 209 (22 percent) wells were found to be unsuitable and were removed to create the final well dataset. The final analysis was conducted on the remaining 731 wells (Table 6). The wells in the final well dataset represent drinking water wells potentially impacted by applied commercial agricultural fertilizer.

WELL WATER NITROGEN ANALYSIS

The final analysis was based on the number of wells at or over the nitrate-N HRL of 10 mg/L.

Table 6 shows the results for all townships sampled. The percent of wells at or over the HRL ranged from 0.0 to 42.9 percent.

Table 6. Initial and Final Well Dataset Results, Winona County

Township	Initial Well Dataset	Final Well Dataset	Final Number of Wells ≥10 mg/L Nitrate-N	Final Percentage of Wells ≥10 mg/L Nitrate-N
Elba	62	52	3	5.8%
Fremont	42	28	12	42.9%
Hart	48	31	2	6.5%
Hillsdale	52	44	0	0.0%
Mt. Vernon	33	24	0	0.0%
Norton	80	62	3	4.8%
Pleasant Hill	58	50	2	4.0%
St. Charles	85	62	9	14.5%
Saratoga	56	40	2	5.0%
Utica	86	51	10	19.6%
Warren	92	62	7	11.3%
Wilson	196	179	3	1.7%
Wiscoy	50	46	0	0.0%
Total	940	731	52	7.1%

The individual nitrate results from this final well dataset are displayed spatially in Figure 6. Due to the inconsistencies with geocoding the locations, the accuracy of the points is variable.

The final well dataset summary statistics are shown in Table 7. The minimum values were all below the detection limit. The maximum values ranged from 5.1 to 32.7 mg/L nitrate-N, with Hart Township having the highest result. The 90th percentile ranged from 2.0 to 16.2 mg/L nitrate-N, with Hillsdale Township having the lowest result and Fremont Township having the highest result.

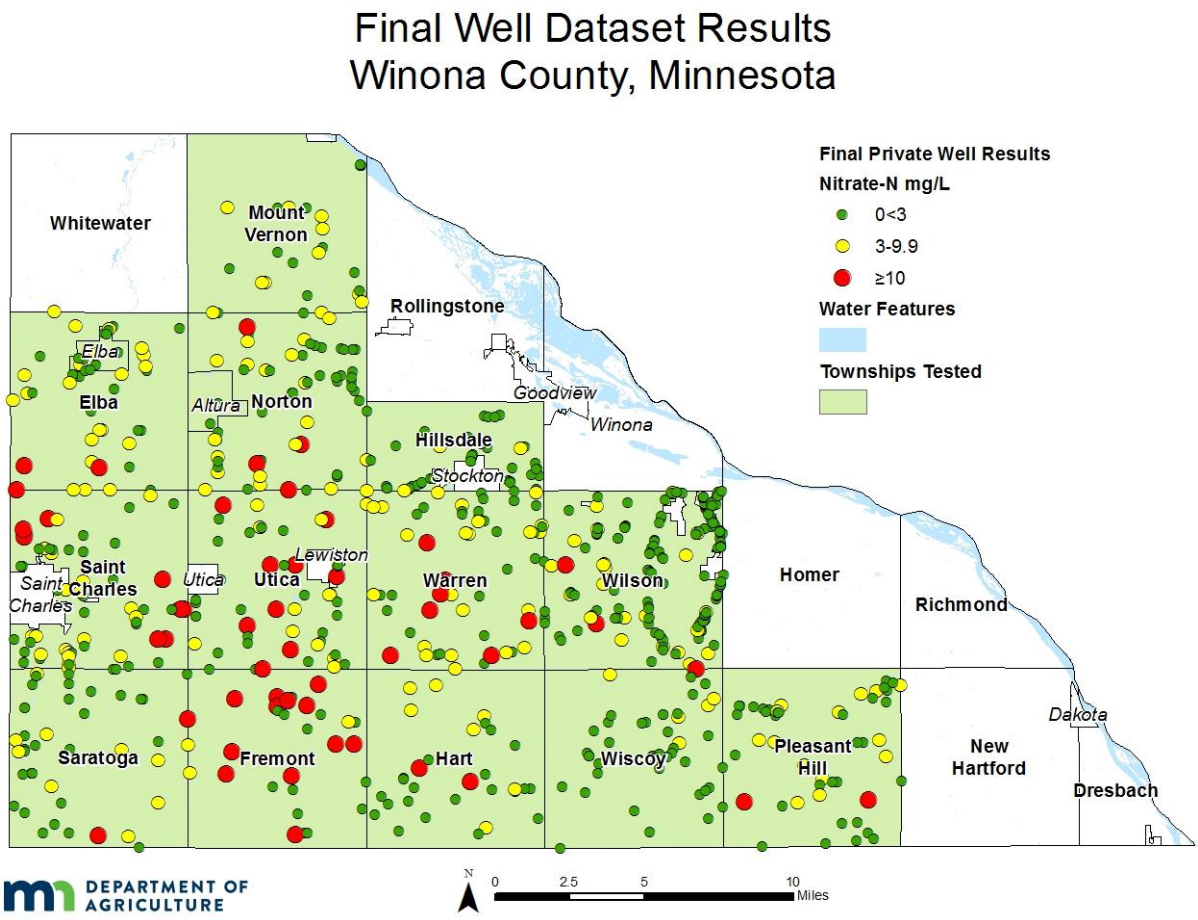


Figure 6. Well Locations and Nitrate Results from Final Well Dataset in Winona County

Table 7. Winona County Township Testing Summary Statistics for Final Well Dataset

Township	Total Wells	Values			Percentiles					Number of Wells					Percent of Wells				
		Min	Max	Mean	(50th) Median	75th	90th	95th	99th	<3	3<10	≥5	≥7	≥10	<3	3<10	≥5	≥7	≥10
		Nitrate-N mg/L or parts per million (ppm)																	
Elba	52	<0.25	20.4	3.2	2.2	4.7	7.9	10.3	20.2	28	21	9	7	3	53.8%	40.4%	17.3%	13.5%	5.8%
Fremont	28	<0.25	29.1	7.8	7.5	13.8	16.2	25.9	29.1	13	3	15	14	12	46.4%	10.7%	53.6%	50.0%	42.9%
Hart	31	<0.25	32.7	2.9	0.3	4.2	5.8	13.6	32.7	22	7	4	2	2	71.0%	22.6%	12.9%	6.5%	6.5%
Hillsdale	44	<0.25	5.1	0.6	<0.25	0.7	2.0	3.1	5.1	42	2	1	0	0	95.5%	4.5%	2.3%	0.0%	0.0%
Mt. Vernon	24	<0.25	8.9	2.7	1.9	4.2	7.6	8.3	8.9	14	10	5	5	0	58.3%	41.7%	20.8%	20.8%	0.0%
Norton	62	<0.25	14.7	2.8	1.7	5.0	7.6	9.5	14.5	40	19	15	9	3	64.5%	30.6%	24.2%	14.5%	4.8%
Pleasant Hill	50	<0.25	14.4	2.6	1.6	3.5	7.6	9.6	14.4	33	15	8	5	2	66.0%	30.0%	16.0%	10.0%	4.0%
St. Charles	62	<0.25	19.5	4.1	1.0	6.3	14.3	17.4	19.2	33	20	17	12	9	53.2%	32.3%	27.4%	19.4%	14.5%
Saratoga	40	<0.25	16.5	2.4	<0.25	4.1	7.1	11.8	16.5	29	9	8	4	2	72.5%	22.5%	20.0%	10.0%	5.0%
Utica	51	<0.25	27.9	4.5	0.3	8.3	13.6	16.1	27.8	30	11	18	14	10	58.8%	21.6%	35.3%	27.5%	19.6%
Warren	62	<0.25	18.6	4.2	3.4	6.0	11.0	14.1	18.2	30	25	20	13	7	48.4%	40.3%	32.3%	21.0%	11.3%
Wilson	179	<0.25	12.1	1.2	<0.25	1.6	3.7	5.4	11.5	150	26	9	6	3	83.8%	14.5%	5.0%	3.4%	1.7%
Wiscoy	46	<0.25	6.9	0.9	<0.25	1.0	3.1	5.4	6.9	41	5	3	0	0	89.1%	10.9%	6.5%	0.0%	0.0%
Total	731	<0.25	32.7	2.7	0.7	3.8	7.9	12.7	18.7	505	173	131	90	52	69.1%	23.7%	17.9%	12.3%	7.1%

The 50th percentile (75th, 90th, 95th, and 99th, respectively) is the value below which 50 percent (75%, 90%, 95% and 99%) of the observed values fall

As discussed previously, the areas selected were deemed most vulnerable to nitrate contamination of groundwater. Table 8 compares the final results to the percent of vulnerable geology (MDNR, 1991) and row crop production (USDA NASS, 2013) in each township. The percent land area considered vulnerable geology and in row crop production was estimated using a geographic information system known as ArcGIS.

Table 8. Township Nitrate Results to Vulnerable Geology and Row Crop Production, Winona County

Township	Final Well Dataset	Percent in Row Crop Production*	Percent in Vulnerable Geology	Percent ≥7 mg/L	Percent ≥10 mg/L
				Nitrate-N mg/L or parts per million (ppm)	
Elba	52	28%	33%	13.5%	5.8%
Fremont	28	54%	36%	50.0%	42.9%
Hart	31	48%	36%	6.5%	6.5%
Hillsdale	44	25%	16%	0.0%	0.0%
Mt. Vernon	24	26%	35%	20.8%	0.0%
Norton	62	36%	33%	14.5%	4.8%
Pleasant Hill	50	22%	36%	10.0%	4.0%
St. Charles	62	56%	30%	19.4%	14.5%
Saratoga	40	58%	35%	10.0%	5.0%
Utica	51	63%	33%	27.5%	19.6%
Warren	62	40%	36%	21.0%	11.3%
Wilson	179	24%	34%	3.4%	1.7%
Wiscoy	46	19%	36%	0.0%	0.0%
Total	731	38%**	33%**	12.3%	7.1%

*Data retrieved from USDA NASS Cropland Data Layer, 2013 **Represents an average value

WELL AND WATER CHARACTERISTICS FOR FINAL WELL DATASET

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells in the Winona County final well dataset. The well logs provided information on the well age, depth, and construction type (MDH Minnesota Well Index Database; https://apps.health.state.mn.us/cwi/). The well construction was provided by some homeowners if a well log was not available. The well characteristics are described below and a more comprehensive view is provided in Appendix I (Tables 34-36).

- The majority of wells in the final well data set were drilled (88 percent), and only 16 (2 percent) were sand point wells
- The median depth of wells (with well logs) was 359 feet, and the shallowest was 60 feet
- The median year the wells (with well logs) were constructed in was 2000

WELL WATER PARAMETERS

The Minnesota Department of Agriculture (MDA) staff conducted the follow-up sampling. Field measurements of the well water parameters were recorded on the first page of the Private Well Field Log & Well Survey Form (Appendix J). The measurements included temperature, pH, specific conductivity, and dissolved oxygen. The well was purged for 15 minutes, so that the measurements stabilized, ensuring a fresh sample of water was collected. The stabilized readings are described below and a more comprehensive view is available in Appendix K (Table 36-39).

- The temperatures ranged from 9.9 °C to 15.2 °C
- The median specific conductivity was 575 µS/cm, and was as high as 1458 µS/cm
- The water from the wells had a median pH of 7.6
- The dissolved oxygen readings ranged from 1.0 mg/L to 16.4 mg/L

Water temperature can affect many aspects of water chemistry. Warmer water can facilitate quicker chemical reactions, and dissolve surrounding rocks faster; while cooler water can hold more dissolved gases such as oxygen (USGS, 2016).

Specific conductance is the measure of the ability of a material to conduct an electrical current at 25°C. Thus the more ions present in the water, the higher the specific conductance measurement (Hem, 1985). Rainwater and freshwater range between 2 to 100 µS/cm. Groundwater is between 50 to 50,000 µS/cm (Sanders, 1998).

The United States Environmental Protection Agency has set a secondary pH standard of 6.5-8.5 in drinking water. These are non-mandatory standards that are set for reasons not related to health, such as taste and color (40 C.F.R. §143).

Dissolved oxygen concentrations are important for understanding the fate of nitrate in groundwater. When dissolved oxygen concentrations are low (<0.5 mg/L) (Dubrovsky et al., 2010), bacteria will use electrons on the nitrate molecule to convert nitrate into nitrogen gas (N_2). Thus nitrate can be removed from groundwater through the process known as bacterial denitrification (Knowles, 1982).

SUMMARY

The focus of this study was to assess nitrate concentrations in groundwater impacted by row crop production in selected townships in Winona County. In order to prioritize testing, Minnesota Department of Agriculture (MDA) looked at townships with significant row crop production and vulnerable geology. Approximately 31 percent of the land cover is row crop agriculture.

Thirteen townships were sampled covering about 279,000 acres. The initial (homeowner collected) nitrate sampling resulted in 940 samples. The 940 households that participated represent approximately 40 percent of the population on private wells. Well owners with measureable nitrate results were offered a follow-up nitrate sample and a pesticide sample. The MDA resampled and visited 285 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 209 (22 percent) wells were found to be unsuitable and were removed from the initial well dataset of 940 wells. The remaining 731 wells were wells believed to be impacted by nitrogen fertilizer and were included in the final well dataset.

A majority of wells were drilled; less than 2 percent were sand points. The majority of wells were over 100 feet deep.

In four of the thirteen townships tested in Winona County, more than 10 percent of the wells were at or over the nitrate Health Risk Limit of 10 mg/L. The percent of wells at or over the nitrate Health Risk Limit in each township ranged from 0.0 to 42.9 percent.

REFERENCES

Alberta Heath Services. (2016). *How to Clean and Disinfect a Cistern*. Retrieved from: https://myhealth.alberta.ca/Alberta/Pages/How-to-clean-and-disinfect-a-cistern.aspx.

Bakalowicz, M., (2005). Karst Groundwater: A challenge for new resources. *Hydrogeology*, *13*,148-160. https://doi.org/10.1007/s10040-004-0402-9.

Dubrovsky, N., Burow, K.R., Clark, G.M., Gronberg, J.M., Hamilton, P.A.., Hitt, K.J., Mueller, D.K., Munn, M.D., Nolan, B.T., Puckett, L.J., Rupert, M.G., Short, T.M., Spahr, N.E., Sprague, L.A., & Wilber, W.G. (2010). *The Quality of Our Nation's Water: Nutrients in the Nation's Streams and* Groundwater, *1992-2004* (U.S. Geological Survey Fact Sheet 2010-3078). U.S. Geological Survey. Retrieved from https://pubs.usgs.gov/fs/2010/3078/.

Hardie, C. (2018). Windmills are country icons*. La Crosse Tribune.* Retrieved from: http://lacrossetribune.com/news/local/chris-hardie-windmills-are-country-icons/article_66658319-5f2f-52a0-b964-8ba668026250.html.

Hem, J.D. (1985). *Study and interpretation of the chemical characteristics of natural water*. (Water Supply Paper 2254*)*. Alexandria, VA: U.S. Department of the Interior, Geological Survey.

Hernandez, J.A., & Schmitt, M.A. (2012). *Manure Management in Minnesota* (WW-03553). Retrieved from www.extension.umn.edu/agriculture/manure-management-and-air-quality/manure-management-basics/manure-management-in-minnesota/doc/manure-management-in-minnesota.pdf.

Katz, B.G., (2012). Nitrate contamination in karst groundwater. In W. B. White & D.C. Culver (Eds.), *Encyclopedia of Caves* (pp. 564-568). Tallahassee, FL: US Geological Survey.

Knowles, R. (1982). Denitrification. *Microbiol*. Rev. 46 (1), 43–70.

Minnesota Department of Agriculture [MDA]. (2016). *Township Testing Program Sampling and Analysis Plan*. Available Upon Request.

Minnesota Department of Agriculture [MDA]. (2017). *Agricultural Chemical Incidents* [Data file]. Retrieved from gisdata.mn.gov/dataset/env-agchem-incidents.

Minnesota Department of Health [MDH], Well Management Section. (2014*). Well Owner's Handbook – A Consumer's Guide to Water Wells in Minnesota*. St. Paul, MN: Minnesota Department of Health. Retrieved from www.health.state.mn.us/divs/eh/wells/construction/handbook.pdf

Minnesota Department of Health [MDH]. (2018) *Minnesota Well Index.* Retrieved from www.health.state.mn.us/divs/eh/cwi/.

Minnesota Department of Natural Resources [MDNR]. (1991). Criteria and guidelines for assessing geologic sensitivity of ground water resources in Minnesota, St. Paul, MN: Minnesota Department of Natural Resources. Retrieved from: https://files.dnr.state.mn.us/waters/groundwater_section/mapping/sensitivity/docs/assessing_geologic_sensitivity.pdf.

Minnesota Department of Natural Resources [MDNR]. (2016). *DNR Water Permits*. Retrieved from www.dnr.state.mn.us/permits/water/index.html.

Minnesota Department of Natural Resources [MDNR]. (2017). *Minnesota Water Use Data* [Data File]. Retrieved from dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html.

Minnesota Department of Natural Resources, Minnesota Geologic Survey, and University of Minnesota – Duluth [MDNR, MGS, UMD]. (1997). *Geomorphology of Minnesota* [map]. (ca. 1:100,000).

Minnesota Geologic Survey [MGS]. (n.d.-a). *County Atlas Website*. St. Paul, MN: Minnesota Geologic Survey. Retrieved from www.mngs.umn.edu/county_atlas/countyatlas.htm.

Minnesota Geologic Survey [MGS]. (n.d.-b). *Frequently asked questions about the MGS County Well Index*. Retrieved from: http://www.mngs.umn.edu/cwifaq.html.

Minnesota Pollution Control Agency [MPCA]. (1999). *Baseline Water Quality of Minnesota's Principal Aquifers, Region 5, Southeast Minnesota*. Retrieved from https://www.pca.state.mn.us/sites/default/files/baselinese-sum.pdf .

Minnesota Pollution Control Agency [MPCA]. (2011). *Land Application of Manure: Minimum State Requirements* (wq-f8-11). St. Paul, MN: Minnesota Pollution Control Agency. Retrieved December 16, 2015, from /www.pca.state.mn.us/sites/default/files/wq-f8-11.pdf

Minnesota Pollution Control Agency [MPCA]. (2013a). *Compliance Inspections for Subsurface Sewage Treatment Systems (SSTS)* (wq-wwists4-39). St. Paul, MN: Minnesota Pollution Control Agency. Retrieved from https://www.pca.state.mn.us/sites/default/files/wq-wwists4-39.pdf.

Minnesota Pollution Control Agency [MPCA]. (2013b). *Nitrogen in Minnesota Surface Waters: Conditions, trends, sources, and reductions* (wq-s6-26a). St. Paul, MN: Minnesota Pollution Control Agency. Retrieved from: https://www.pca.state.mn.us/sites/default/files/wq-s6-26a.pdf.

Minnesota Pollution Control Agency [MPCA]. (2015a). *Feedlot Registration Form* (wq-f4-12). St. Paul, MN: Minnesota Pollution Control Agency. Retrieved from www.pca.state.mn.us/sites/default/files/wq-f4-12.pdf.

Minnesota Pollution Control Agency [MPCA]. (2015b). *State of Minnesota General Animal Feedlots NPDES Permit* (wq-f3-53). St. Paul, MN: Minnesota Pollution Control Agency. Retrieved from www.pca.state.mn.us/sites/default/files/wq-f3-53.pdf.

Minnesota Pollution Control Agency [MPCA]. (2017a). *2016 SSTS Annual Report, Subsurface Sewage Treatment Systems in Minnesota*. St. Paul, MN: Minnesota Pollution Control Agency. Retrieved from https://www.pca.state.mn.us/sites/default/files/wq-wwists1-56.pdf.

Minnesota Pollution Control Agency [MPCA]. (2017b). *Livestock and the Environment: MPCA Feedlot Program Overview* (wq-f1-01). St. Paul, MN: Minnesota Pollution Control Agency. Retrieved from www.pca.state.mn.us/sites/default/files/wq-f1-01.pdf.

Minnesota Pollution Control Agency [MPCA]. (2018). *Feedlots in Minnesota* [Data file]. St. Paul, MN: Minnesota Pollution Control Agency. Retrieved from: gisdata.mn.gov/dataset/env-feedlots.

Minnesota Rules, part 4725.4450 (2014)

Minnesota State Demographic Center. (2017). *Latest annual estimates of Minnesota and its cities and townships' population and households, 2016* [Data file]. Retrieved from https://mn.gov/admin/assets/mn_cities_townships_estimates_sdc_2016_tcm36-303998.xlsx.

Minnesota Statutes 2015, section 115.55, subdivision 5

Nolan, B.T., & Stoner, J.D. (2000). Nutrients in Groundwaters of the Conterminous United States, 1992-95. *Environmental Science and Technology*, *34*(7), 1156-1165. https://doi.org/10.1021/es9907663.

Nolan, B.T. (2001). Relating Sources and aquifer susceptibility to nitrate in shallow ground waters of the United States. *Groundwater*, *39*(2), 290-299. https://doi.org/10.1111/j.1745-6584.2001.tb02311.x.

Panno, S.V., Hackley, K.C., Hwang, H.H., & Kelly, W.R. (2001). Determination of the sources of nitrate contamination in karst springs using isotopic and chemical indicators. *Chemical Geolo*gy, *55*, 113-128. https://doi.org/10.1016/S0009-2541(01)00318-7.

Peterson, F.W. (2008). *Homes in the Heartland: Balloon Frame Farmhouses of the Upper Midwest, 1850-1920.* Minneapolis, MN: University of Minneosota Press.

Rivett, M.O, Buss, S.R., Morgan, P., Smith, J.N., & Bemmet, C.D. (2008). Nitrate attenuation in groundwater: A review of biogeochemical controlling processes*. Water research*, *42*, 4215-4232. https://doi.org/10.1016/j.watres.2008.07.020.

Runkel, A.C., Tipping, R.G., Alexander, E.C., Jr., Green, J.A., Mossler, J.H., and Alexander, S.C., (2003). Hydrogeology of the Paleozoic bedrock in southeastern Minnesota. *Minnesota Geological Survey Report of Investigations 61*. Retrieved from: https://conservancy.umn.edu/bitstream/handle/11299/58813/R?sequence=4.

Sanders, L.L. (1998). *A Manual of Field Hydrogeology*. Upper Saddle River, NJ: Prentice Hall.

Setterholm, Dale, R. (2014). *C-34, Geologic Atlas of Winona County, Minnesota*. Retrieved from http://hdl.handle.net/11299/164935.

National Secondary Drinking Water Regulations, 40 C.F.R. §143 (2011).

United States Environmental Protection Agency. (2009). *National primary drinking water regulations list* (EPA 816-F-09-004). Retrieved from, https://www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.pdf.

United States Geological Survey [USGS]. (2016). *Water properties: Temperature*. Retrieved from: https://water.usgs.gov/edu/temperature.html.

United States Department of Agriculture National Statistics Service [USDA NASS]. (2013). *Cropland Data Layer, 2013* [Data file]. Retrieved from gisdata.mn.gov/dataset/agri-cropland-data-layer-2013.

Warner, K.L., & Arnold, T.L. (2010). *Relations that Affect the Probability and Prediction of Nitrate Concentration in Private Wells in the Glacial Aquifer System in the United States* (Scientific Investigations Report 2010-5100). Reston, VA: U.S. Geological Survey. Retrieved from: https://pubs.usgs.gov/sir/2010/5100/pdf/sir2010-5100.pdf.

Winona County, Minnesota. (2016). *Winona County, Minnesota Zoning Ordinance.* Retrieved from:http://www.co.winona.mn.us/sites/co.winona.mn.us/files/files/Ordinances/Ordinance41.pdf.

Wood, A.D., Ruff, J.F., and Richardson, E.V. (1977). *Pumps and Water Lifters for Rural Development*. Fort Collins, CO: Colorado State University. Retrieved from: https://dspace.library.colostate.edu/handle/10217/180912.

APPENDIX A

Well information and Potential Nitrate Source Inventory Form

Site ID_____**Unique ID**_____ **Date** _____

MDA -Private Well Field Log & Well Survey Form

Water Treatment Information

1. Is this well used for drinking water? ☐ Yes ☐ No
2. Is there an indoor water treatment system? ☐ Yes ☐ No

   If yes, check system: ☐ Activated Carbon ☐ Distilled ☐ Iron Filter
   ☐ Reverse Osmosis ☐ Sediment Filter ☐ Softened
   ☐ Other_____
3. Is there water treatment on the outdoor spigot? ☐ Yes ☐ No

   If yes, what type?_____

Well Construction Information

	HO Survey	Homeowner or Observation (circle one or both)	Well Log
Construction Type			
Construction Date			
Well Depth			
Well Diameter			
Well/Pump Installer			

1. Have you made any changes to your well in the last year? ☐ Yes ☐ No

   If yes, what type? ☐ Upgraded Well Casing ☐ Raised Well ☐ Replaced Piping
   ☐ Replaced Pump ☐ Replaced Well ☐ Other_____

Field Survey Information

1. Are there any other wells on this property? ☐ Yes ☐ No

   If yes, list well type, use, and UID if available_____
2. Is fertilizer stored on this property? ☐ Yes ☐ No

   If yes, what is the distance and direction from the well?_____
3. Historical fertilizer storage? ☐ Yes ☐ No

   If yes, what is the distance and direction from the well?_____
4. Historic/Abandoned septic system? ☐ Yes ☐ No

   If yes, what is the distance and direction from the well?_____
5. Have pesticides been used in the last month? ☐ Yes ☐ No

   If yes, what type/brand name, when, and location_____

Updated: March, 2017

Site ID_____**Unique ID**_____ **Date** _____

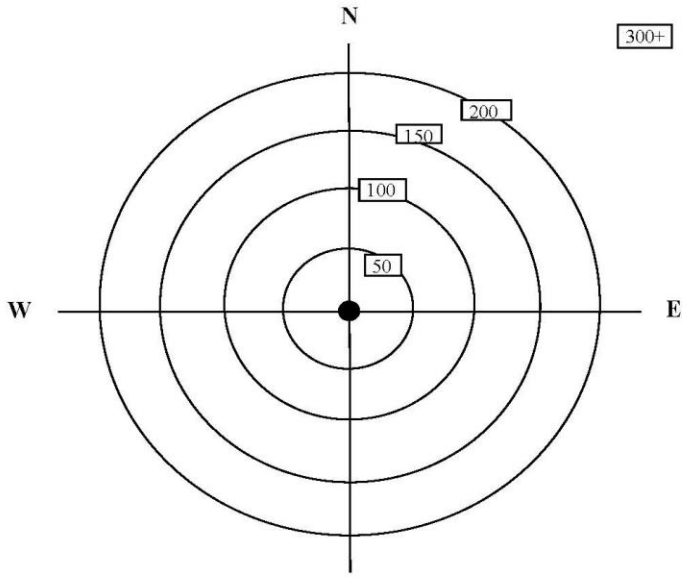
MDA -Private Well Field Log & Well Survey Form

DIRECTIONS

Describe the type, position and distance to potential nitrate sources within 300 feet of the well. Use the bullseye to draw in and label nitrate sources relative to the well (center dot). Indicate house location when applicable.

AFL: Animal Feedlot
AGG: Dry Well, Leaching Pit, Seepage Pit, Injection Well, Ag Drainage Well
APB: Animal/Poultry Building
DRA: Drain field - Above or Below Grade
FIELD: Agricultural Field
FSA: Fertilizer Storage Area
FWP: Feeding or Watering Area
GOLF: Golf Course
LAP: Land Application of Manure, Septage, Sewage
MSA: Manure Storage Area
PRV: Privy (Old Outhouse)
SAA: Small Animal Area (chicken coop, rabbit pen, etc)
SET: Septic Tank

6. Does water drain toward the well? ☐ Yes ☐ No
7. Which direction does the landscape slope? (Draw arrow across bullseye through well)
8. Is the slope: ☐ Steep ☐ Shallow ☐ Flat
9. Are there any *obvious* problems with the well? ☐ Yes ☐ No ☐ No Access ☐ Not Found
   Describe any well issues seen_____
10. Distance from ground surface to bottom of well cap (round to nearest inch)_____
11. Source codes, distances, and direction (<300ft)_____
    _____
12. Source codes, distances, and direction (>300ft)_____



ADDITIONAL SURVEY NOTES

Updated: March, 2017

APPENDIX B

SUBSURFACE SEWAGE TREATMENT SYSTEM

Most homes that have private wells also have private subsurface sewage treatment systems (SSTS). These treatment systems can be a potential point source for contaminants such as nitrate and fecal material. To protect drinking water supplies in Minnesota, SSTS septic tanks and the associated drain fields are required to be at least 50 feet away from private drinking water wells. The minimum required distance doubles for wells that have less than ten feet of a confining layer or if the well has less than 50 feet of watertight casing (MDH, 2014).

Technical and design standards for SSTS systems are described in Minnesota Rules Chapter 7080 and 7081. Some local government units (LGU) have their own statutes that may be more restrictive or differ from these standards.

Many LGUs collect information on the condition of SSTS in their jurisdiction. Often information is collected when a property is transferred, but inspections can occur at other times as well. A SSTS inspection determines if a system is compliant or non-compliant. A non-compliant treatment system can be further categorized as “failing to protect groundwater (FTPGW)” or “imminent threat to public health and safety (ITPHS)”. A system is considered FTPGW if it is a seepage pit, cesspool, the septic tanks are leaking below their operating depth, or if there is not enough vertical separation to the water table or bedrock. A system is considered ITPHS if the sewage is discharging to the surface water or groundwater, there is sewage backup, or any other condition where the SSTS would harm the health or safety of the public (Minnesota Statutes, section 115.55.05 and MPCA, 2013a).

In 2016, Winona County reported a total of 4,905 SSTS and 1.8 percent were inspected for compliance. Compliance inspections are conducted in Winona County during property transfers, when building permits are applied for, upon completion of new or replacement SSTS, before the addition of a bedroom, anytime the use of a building changes in a way that may affect the septic system, and anytime the county deems appropriate (Winona County, 2016). The owner is required to upgrade, repair, replace, produce a certificate of compliance for, or abandon a septic system if a bedroom is added to their house, if it is deemed to endanger groundwater, or if is deemed to pose an imminent threat to public health or safety (Winona County, 2016). Holding tanks are only allowed under limited circumstances (Winona County, 2016).

There was not data available on the compliance statistics of inspected wells for Winona County

FEEDLOT

The amount of nitrogen in manure depends on the species of animal. For example, there is approximately 31 pounds of nitrogen in 1,000 gallons of liquid dairy cow manure, and 53-63 pounds in 1,000 gallons of liquid poultry manure. Most of the nitrogen in manure is in organic nitrogen or in ammonium (NH_4^+) forms (Hernandez and Schmitt, 2012).

Under the right conditions organic nitrogen can be converted into ammonium and then eventually transformed into nitrate. Nitrate is a highly mobile form of nitrogen that can move into groundwater and become a contamination concern (MPCA, 2013b).

Government agencies regulate feedlots to reduce the risk of contamination to water resources. Rules pertaining to feedlots have been in place since the 1970's; they were revised in 2000, and 2014 (MPCA, 2017b). The degree of regulation of a feedlot is dependent on the amount of manure that is produced; measured in animal units (AU) (MPCA, 2011). One AU is equal to the amount of manure produced by one beef cow (**Error! Reference source not found.**) (MPCA, 2017b).

Table 9. Animal Unit Calculations (MPCA, 2017b)

Animal Type	Number of Animal Units (AU)
Mature dairy cow (over 1,000 lbs.)	1.4
Cow/calf pair	1.2
Stock cow/steer	1.0
Horse	1.0
Dairy heifer	0.7
Swine (55-300 lbs.)	0.3
Sheep	0.1
Broiler (over 5 lbs., dry manure)	0.005
Turkey (over 5 lbs.)	0.018

Animal feedlots with 1-300 AU require a 50 foot setback from private water wells. Larger feedlots (≥300 AU) must be at least 100 feet away from private water wells. The minimum required distance doubles for wells that have less than ten feet of a confining layer or if the well has less than 50 feet of watertight casing (MDH, 2014).

Farmers must register a feedlot through the Minnesota Pollution Control Agency (MPCA) if they have at least 50 AU, or 10 AU if the feedlot is located near shoreline. Larger feedlots must follow additional regulations. Feedlots with more than 300 AU must submit a manure management plan if they do not use a licensed commercial applicator. Feedlots with more than 1,000 AU are regulated through federal National Pollutant Discharge Elimination (NPDES) permits (MPCA, 2011) and must submit an annual manure management plan as part of their permit (MPCA, 2015a).

As part of new feedlot construction, an environmental assessment must be completed for feedlots with a proposed capacity of greater than 1,000 AU. If the feedlot is located in a sensitive area the requirement for an environmental assessment is 500 AU (MPCA, 2017b).

Farmers must register their feedlot if it is in active status. Feedlots are considered active until no animals have been present on the feedlot for five years. To register, farmers fill out paperwork

which includes a chart with the type and maximum number of animals on the feedlot (MPCA, 2015a). Registration is required to be completed at least once during a set four year period, the current period runs from January 2018 to December 2021. As of November 2017, approximately 24,000 feedlots were registered in Minnesota (MPCA, 2017b). A map and table of the feedlots located in the Winona County study area can be found below (Figure 7; Table 10).

On average there are 197 AU per square mile (0.31 AU/acre) over the entire study area (Table 10). Manure is often applied to cropland so it is pertinent to look at the AU per cropland acre. In the Winona County study area livestock densities average 1.00 AU per acre of row crops (MPCA, 2017b; USDA NASS, 2013).

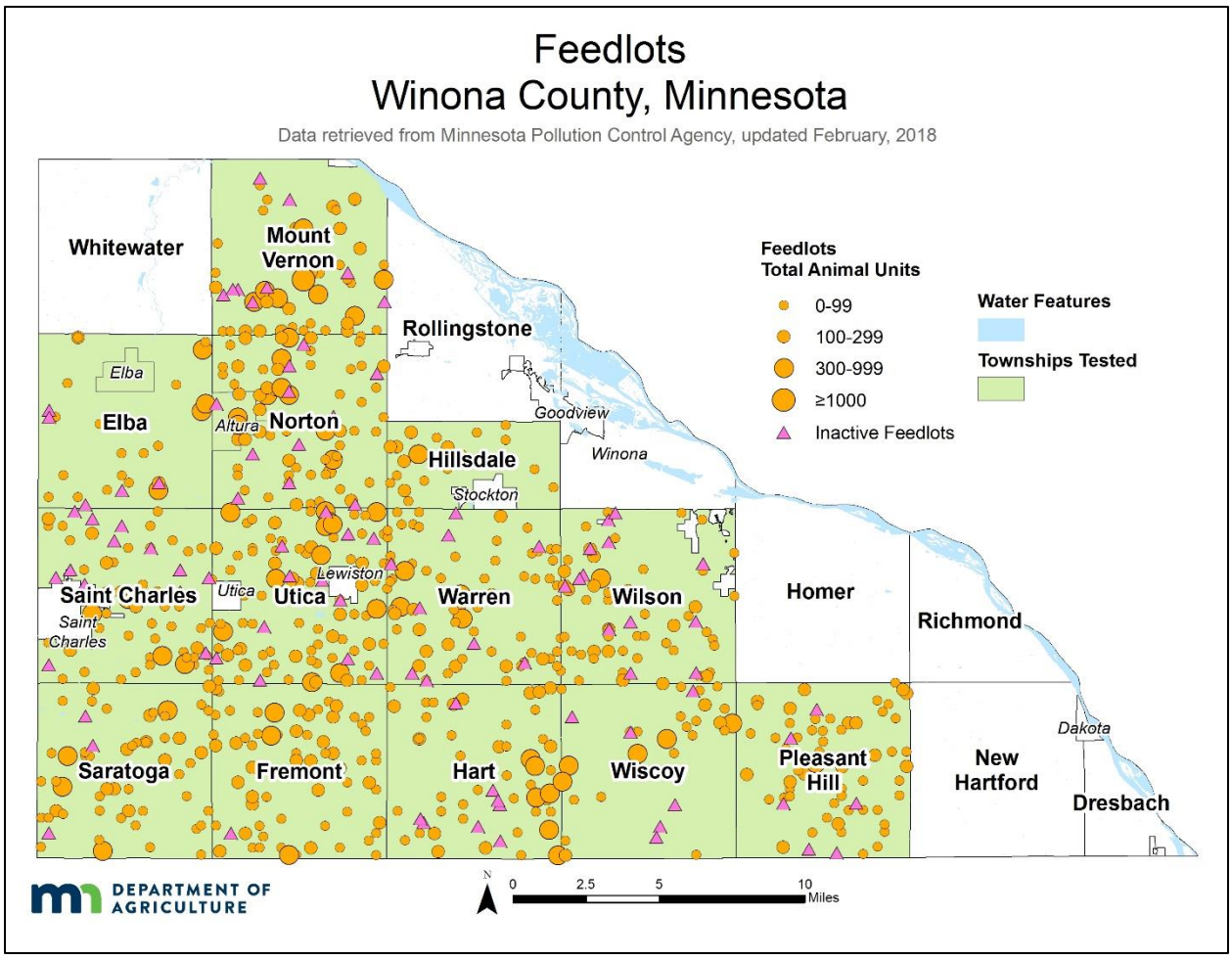


Figure 7. Feedlot Locations in Winona County (MPCA, 2018)

Table 10. Feedlots and Permitted Animal Unit Capacity, Winona County

Township	Total Feedlots	Active Feedlots	Inactive Feedlots	Average AU Permitted** Per Feedlot	Total Permitted** AU	Total Square Miles	Permitted** AU per Square Mile
Elba***	27	21	6	144	3028	35	85
Fremont	67	66	1	128	8442	36	236
Hart	54	46	8	175	8036	36	226
Hillsdale	21	21	0	103	2173	16	136
Mount Vernon	53	44	9	216	9496	35	269
Norton****	78	66	12	160	10551	36	297
Pleasant Hill	70	64	6	85	5459	36	153
Saint Charles	66	51	15	119	6064	32	190
Saratoga	56	53	3	107	5657	36	158
Utica	96	84	12	145	12173	34	360
Warren	77	68	9	99	6704	36	188
Wilson	68	54	14	87	4700	34	137
Wiscoy	36	30	6	124	3716	36	104
Total	769	668	101	*129	86199	437	*197

* Represents an average value

**Animals permitted may not be the actual animals on site. The total animals permitted is the maximum number of animals that are permitted for a registered feedlot. It is common for feedlots to be have less livestock than permitted.

*** Includes Elba City

**** Included Altura City

FERTILIZER STORAGE LOCATION

The Minnesota Department of Agriculture (MDA) tracks licenses for bulk fertilizer storage facilities, anhydrous ammonia, and chemigation sites (**Error! Reference source not found.**). Abandoned sites are facilities that once housed fertilizer chemicals. These sites are also noted and tracked by the MDA as they are potential contamination sources.

Table 11. Fertilizer Storage Facility Licenses and Abandoned Sites, Winona County

Township	*Bulk Fertilizer Storage	*Anhydrous Ammonia	*Chemigation Sites	*Abandoned Sites	Total
Elba**	0	0	0	0	0
Fremont	0	0	0	0	0
Hart	0	0	0	0	0
Hillsdale	0	0	0	0	0
Mount Vernon	0	0	0	0	0
Norton***	1	0	0	0	1
Pleasant Hill	0	0	0	0	0
Saint Charles	2	1	0	0	3
Saratoga	0	0	0	0	0
Utica	3	0	0	0	3
Warren	0	0	0	0	0
Wilson	0	0	0	0	0
Wiscoy	0	0	0	0	0
Total	6	1	0	0	7

* Data retrieved from MDA Pesticide and Fertilizer Management Division, 2018; updated March 2018

**Includes Elba City

*** Includes Altura City

SPILLS AND INVESTIGATIONS

The MDA is responsible for investigating any fertilizer spills within Minnesota. Figure 8 shows the locations of mapped historic spills within the Winona County study area from fertilizer. While other types of spills are recorded, only sites that are potential point sources of nitrogen to the groundwater are reported here (MDA, 2017).

The MDA tracks several types of incidents. Incident investigations are typically for larger spills. There are five in the study area. Contingency areas are locations that have not been remediated because they were inaccessible or the contaminant could not be removed for some other reason. They are often a part of an incident investigation. There is one contingency area in this study area. Old emergency incidents were closed prior to March 1st, 2004 (MDA, 2017), but they can still be a point source. At most of these older sites, the contaminants are unknown and their location may not be precise. Small spills and investigations are typically smaller emergency spills such as a truck spilling chemicals. It is important to note that while the locations of the incidents described are as accurate as possible, it is an incomplete dataset (MDA, 2017). Many types of spills are reported to the MDA, however only spills that potentially contain nitrogen are reported here. A breakdown of chemical type of these incidents can be found in Table 12. A breakdown of the fertilizer specific spills and investigations, by township, can be found in Table 13.

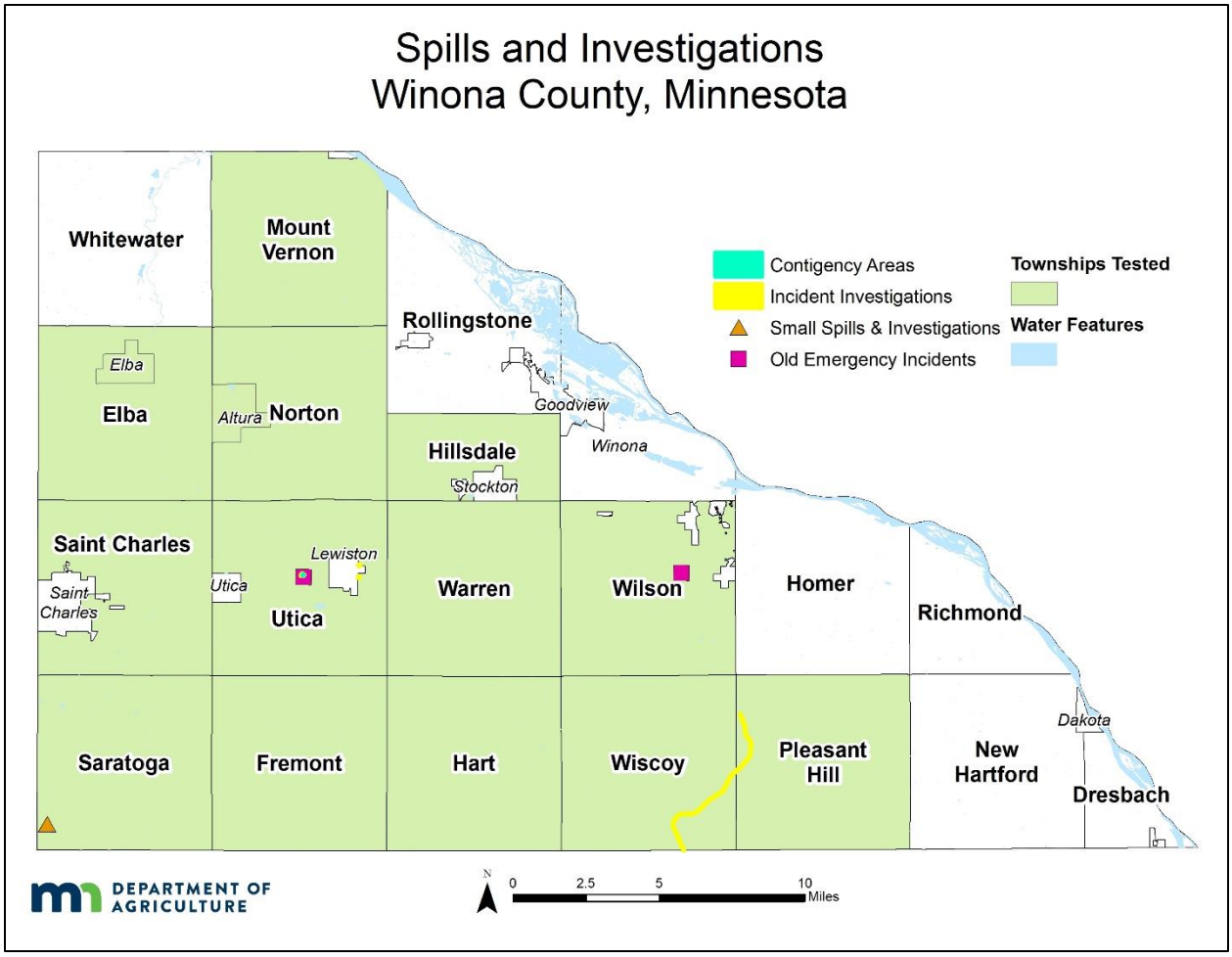


Figure 8. Fertilizer Spills and Investigations in Winona County (MDA, 2017)

Table 12. Spills and Investigations by Chemical Type, Winona County

Contaminant	Incident Investigations	Contingency Areas	Small Spills and Investigations	Old Emergency Incidents	Total
Fertilizer	1	1	1	1	4
Pesticides & Fertilizer	4	0	0	0	4
Anhydrous Ammonia	0	0	0	1	1
Total	5	1	1	2	9

Table 13. Fertilizer Related Spills and Investigations by Township, Winona County

Township	Incidents and Spills
Elba	0
Fremont	0
Hart	0
Hillsdale	0
Mount Vernon	0
Norton	0
Pleasant Hill	1
Saint Charles	0
Saratoga	1
Utica	6
Warren	0
Wilson	1
Wiscoy	0
Total	9

APPENDIX C

LAND AND WATER USE

LAND COVER

Typically locations were selected for the Township Testing Program if at least 20 percent of the land cover was in row crop production. Winona County is a mostly rural county and land cover is dominated by row crop agriculture, forest, and hay/pasture (Figure 9; Table 14). Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, wheat, dry beans and double crops involving corn and soybeans.

Winona County is situated in the southeast corner of Minnesota, and abuts the Mississippi River on the northern border. Row crop agriculture dominates wherever the landscape is flat enough, so the flattest townships (Saint Charles, Utica, and Saratoga) all consist of greater than 50 percent row crop agriculture, while the hilliest townships (including Wiscoy, Mount Vernon, Pleasant Hill, Wilson, and Hillsdale) have a lower percentage of row crop agriculture (<18%) and more forest and pasture/hay. (Figure 9; Table 14).

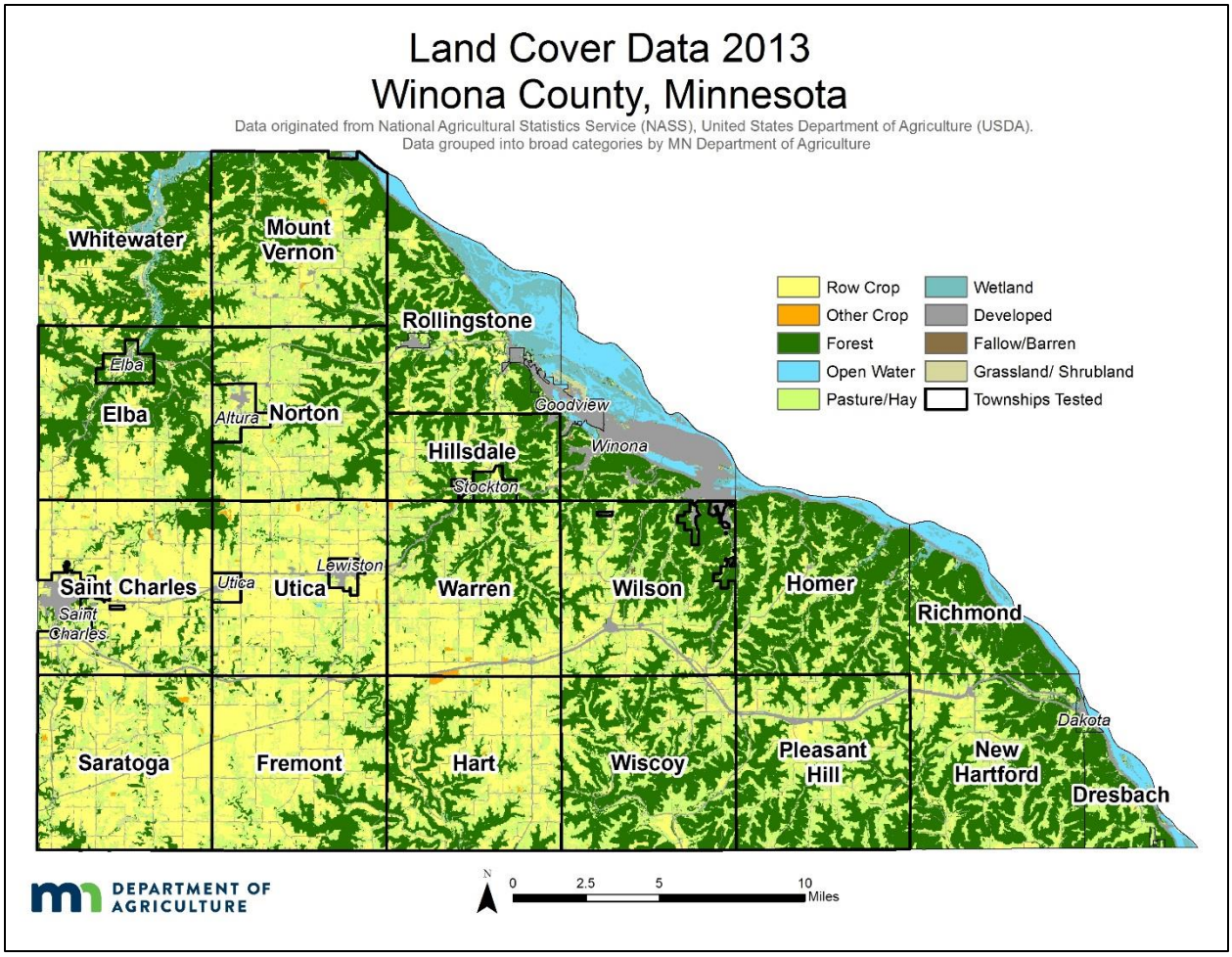


Figure 9. Land Cover in Winona County (USDA NASS Cropland Data Layer, 2013)

Table 14. Land Cover Data (2013) by Township, Winona County (USDA NASS Cropland Layer, 2013)

Township	Total Acres	Row Crop	Other Crops	Forest	Open Water	Pasture/ Hay	Wetland	Developed	Fallow/ Barren	Grassland/ Shrubland
Elba*	22,675	24%	0%	46%	0%	19%	1%	4%	0%	6%
Fremont	22,918	48%	0%	18%	0%	25%	0%	4%	0%	5%
Hart	22,758	37%	1%	28%	0%	26%	0%	3%	0%	5%
Hillsdale	10,226	17%	0%	45%	0%	27%	0%	5%	0%	5%
Mount Vernon	22,623	16%	0%	45%	1%	28%	0%	3%	0%	6%
Norton**	22,736	23%	0%	29%	0%	36%	0%	5%	0%	7%
Pleasant Hill	22,822	12%	0%	44%	0%	35%	0%	5%	0%	4%
Saint Charles	20,435	54%	0%	13%	0%	19%	0%	6%	0%	7%
Saratoga	22,848	53%	1%	10%	0%	24%	0%	4%	0%	8%
Utica	21,626	56%	1%	6%	0%	25%	0%	5%	0%	6%
Warren	22,761	31%	1%	27%	0%	30%	0%	5%	0%	6%
Wilson	22,027	15%	0%	44%	0%	29%	0%	7%	0%	5%
Wiscoy	22,843	10%	0%	50%	0%	31%	0%	4%	0%	5%
Average	21,485	31%	0%	31%	0%	27%	0%	5%	0%	6%

*Includes Elba City

**Includes Altura City

WATER USE

Water use permits are required for wells withdrawing more than 10,000 gallons of water per day or 1,000,000 gallons of water per year (MDNR, 2016). There are a total of 36 active groundwater well permits in the study area and none are used for irrigating major crops (Figure 10). There is no cropland permitted for groundwater irrigation in this area. Most permitted wells are withdrawing groundwater from Paleozoic and unclassified aquifers (Table 15; MDNR, 2017).

Table 15. Active Groundwater Use Permits by Aquifer, Winona County

Water Use Well Permits	Total Wells	Average Depth (feet)	Aquifer System				
			Quaternary (Water Table)	Quaternary (Buried)	Paleozoic	Precambrian	Not Classified
Major Crop Irrigation	0	NA	0	0	0	0	0
Non-Crop Irrigation	0	NA	0	0	0	0	0
Waterworks	6	453	0	0	5	0	1
Industrial Processing	2	589	0	0	2	0	0
Air Conditioning	28	358	0	0	11	0	17
Total	36	387	0	0	18	0	18

* Represents an average value
**Includes Elba City
***Includes Altura City

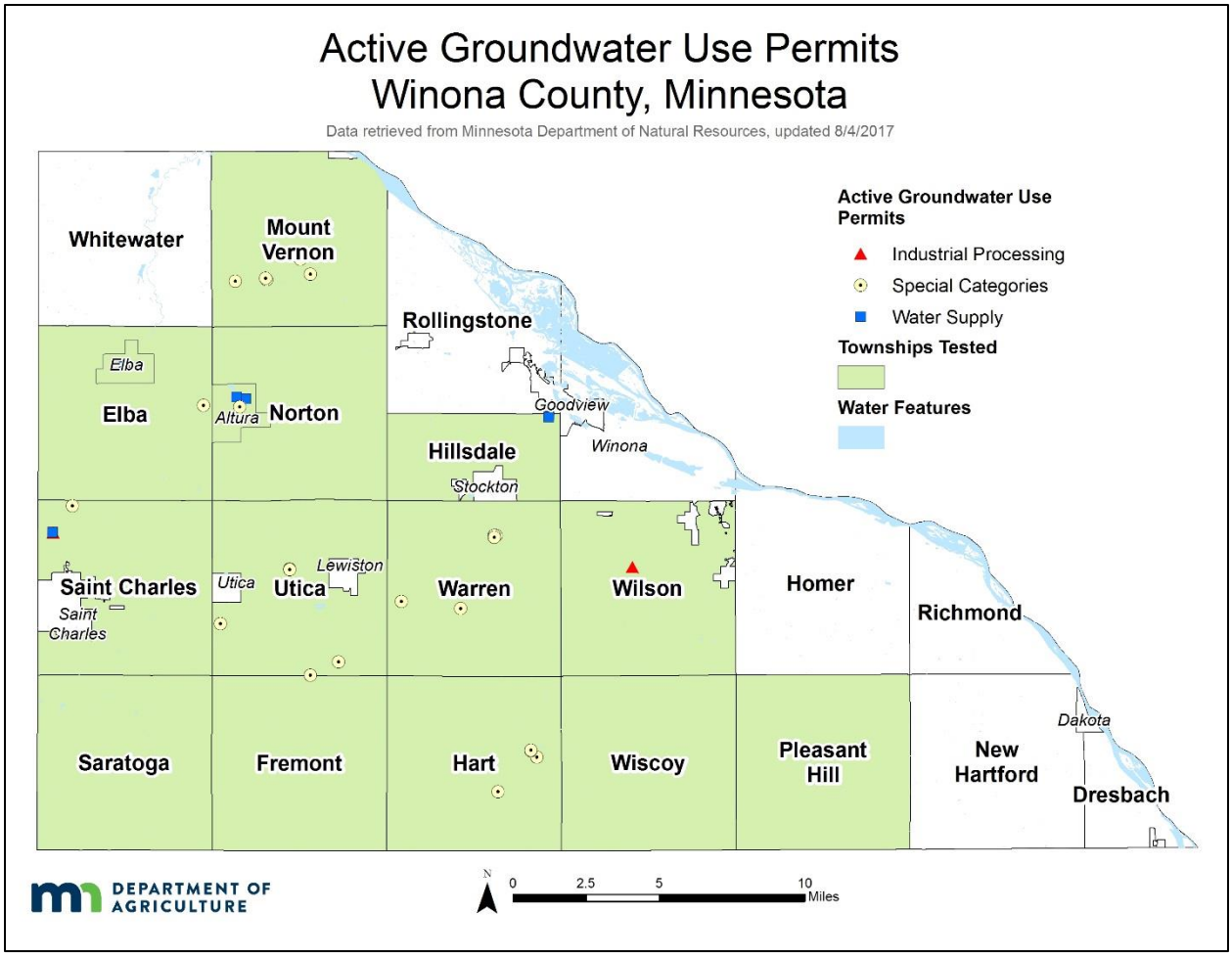


Figure 10. Active Groundwater Use Permits in Winona County (MNDNR, 2017)

APPENDIX D

NITRATE BROCHURE

The Minnesota Department of Agriculture and the _ County SWCD would like to **thank you** for participating in the private well volunteer nitrate monitoring. The results of your water sample are enclosed. Results from this sampling event will be reviewed and summarized and a summary report will be issued to the counties. In addition, the data will be used to determine the need and the design of a long-term monitoring network. Below is general information regarding nitrate result ranges.

If the Nitrate result is between 0 to 4.9 mg/L:

- Continue to test your water for nitrate every year or every other year.
- Properly manage nitrogen sources when used near your well.
- Continue to monitor your septic tank. Sewage from improperly maintained septic tanks may contaminate your water.
- Private wells should be tested for bacteria at least once a year. A Minnesota Department of Health (MDH) certified water testing lab can provide nitrate and bacteria testing services. Search for the lab nearest you at www.health.state.mn.us/labsearch.

If the Nitrate result is between 5 to 9.9 mg/L:

- Presently the nitrate nitrogen level in your water is below the nitrate health standard for drinking water. However, you have a source of contamination which may include: contributions from fertilized lawns or fields, septic tanks, animal wastes, and decaying plants.
- Test annually for both nitrate and bacteria. As nitrate levels increase, especially in wells near cropped fields, the probability of detecting pesticides also increases. MDA monitoring data indicates that pesticide levels are usually below state and federal drinking water guidelines. For more information on testing and health risks from pesticides and other contaminants in groundwater go to: http://www.mda.state.mn.us/protecting/waterprotection/pesticides.aspx
- In addition to pesticides, high nitrate levels may suggest an increased risk for other contaminants. For more information go to: http://www.health.state.mn.us/divs/eh/wells/waterquality/test.html

If the Nitrate result is above 10 mg/L:

- **Do not allow this water to be consumed by infants**, Over 10 mg/L is not safe for infants younger than 6 months of age
- **Pregnant women** also may be at risk along with **other people with specific metabolic conditions.** Find a safe alternative water supply.
- Consider various options including upgrading the well if it was constructed before the mid 1970's.
- Be sure to retest your water prior to making any significant financial investment in your existing well system. See link to MDH certified labs listed above.
    - ***Boiling your water increases the nitrate concentration in the remaining water.***

Infants consuming high amounts of nitrates may develop Blue Baby Syndrome (Methemoglobinemia). This disease is potentially fatal and first appears as blue coloration of the fingers, lips, ears, etc. Seek medical assistance immediately if detected

---

If you have additional questions about wells or well water quality in Minnesota, contact your local Minnesota Department of Health office and ask to talk with a well specialist or contact the Well Management Section Central Office at health.wells@state.mn.us or at 651-201-4600 or 800-383-9808. If you have questions regarding the private well monitoring contact Nikol Ross at 651-201-6443 or Nikol.Ross@state.mn.us.

APPENDIX E

Table 16. Reasons Wells Were Removed from the Final Well Dataset by Township, Winona County

Township	Point Source	Well Construction Problem	Well Construction Problem - Cistern	Hand Dug well	Unsure of water source	Site Visit Completed - Well Not Found & Constructed before 1975 & No Well ID	No Site Visit & Constructed before 1975 & No Well ID	No Site Visit & Insufficient Data & No Well ID	Shared Well	Total
Elba	1	2	0	0	0	0	6	1	0	10
Fremont	3	0	1	0	0	0	9	1	0	14
Hart	2	3	1	0	0	2	8	1	0	17
Hillsdale	2	0	2	1	0	0	3	0	0	8
Mt. Vernon	1	0	0	0	1	1	6	0	0	9
Norton	0	2	0	1	0	0	14	1	0	18
Pleasant Hill	2	1	1	0	0	0	4	0	0	8
St. Charles	5	5	0	0	0	0	11	2	0	23
Saratoga	2	2	0	0	1	0	11	0	0	16
Utica	5	3	0	0	2	1	21	3	0	35
Warren	8	0	1	0	0	2	19	0	0	30
Wilson	5	1	2	0	0	1	7	0	1	17
Wiscoy	0	0	0	0	0	2	2	0	0	4
Total	36	19	8	2	4	9	121	9	1	209

Table 17. Completed Site Visits for Wells Removed from the Final Well Dataset by Township, Winona County

Township	Site Visit	No Site Visit	Total Wells Removed
Elba	3	7	10
Fremont	3	11	14
Hart	8	9	17
Hillsdale	3	5	8
Mt. Vernon	3	6	9
Norton	2	16	18
Pleasant Hill	2	6	8
St. Charles	9	14	23
Saratoga	3	13	16
Utica	10	25	35
Warren	7	23	30
Wilson	7	10	17
Wiscoy	2	2	4
Total	62	147	209

APPENDIX F

MINNESOTA WELL INDEX

The Minnesota Well Index (MWI) was used to gather information about the 13 townships in Winona County included in the study. This section includes all drinking water wells in the study area, not just wells MDA sampled. Table 18 summarizes the general aquifer types, while the following is a brief summary of the major aquifer types with the average well depth. According to the information from the MWI (MDH, 2018):

In these townships, there are 883 documented (have a verified location in the MWI) wells:

- About 1% are completed in the Quaternary aquifers the Quaternary Water Table Aquifer (QWTA) and the Quaternary buried aquifer which are 65 feet deep on average. Most of these are located in Elba Township and comprise 15 percent of its documented wells.
- The most utilized aquifers in the study area are the Tunnel City, Wonewoc, Jordan and Prairie du Chien.
- The Prairie du Chien is most heavy used in St. Charles, Saratoga, Utica and Fremont Townships.
- In three percent of wells the aquifer was undocumented.

Table 18. Aquifer Type Distribution of Wells in Minnesota Well Index

Aquifer Group	Mean Depth (feet)	Total Wells	Percentage of Wells the Minnesota Well Index in each Aquifer by Township													
			Elba	Fremont	Hart	Hillsdale	Mt Vernon	Norton	Pleasant Hill	St Charles	Saratoga	Utica	Warren	Wilson	Wiscoy	Combined Townships
Total Wells	277	883	80	38	33	52	43	71	64	104	71	76	57	147	47	883
Quaternary	63	15	15%	0%	0%	0%	5%	1%	0%	0%	0%	0%	0%	0%	0%	2%
St. Peter	90	1	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%
Prairie du Chien	271	68	0%	11%	6%	4%	0%	0%	8%	22%	21%	13%	7%	2%	0%	8%
Jordan	393	217	23%	34%	9%	10%	5%	31%	8%	57%	75%	30%	9%	6%	0%	25%
St. Lawrence	358	26	6%	0%	0%	6%	5%	7%	2%	0%	1%	4%	4%	2%	2%	3%
Tunnel City	387	283	46%	50%	70%	42%	42%	45%	20%	18%	1%	46%	56%	18%	11%	32%
Wonewoc	363	226	0%	3%	12%	29%	33%	11%	55%	0%	0%	5%	21%	65%	79%	26%
Eau Claire	192	2	0%	0%	0%	2%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%
Mt. Simon	309	8	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	4%	0%	1%
Multiple	458	8	0%	0%	0%	2%	2%	3%	0%	0%	0%	0%	0%	0%	9%	1%
Indeterminate	331	6	3%	0%	0%	0%	5%	0%	0%	1%	0%	0%	2%	0%	0%	1%
Unknown	105	23	8%	3%	3%	2%	5%	1%	6%	1%	1%	1%	2%	2%	0%	3%

*Represents total
**Includes Elba City
***Includes Altura City

APPENDIX G

Example – "Participation Letter and Well Survey"

Private Well Survey for Township Testing Program

The Minnesota Department of Agriculture appreciates you taking the time to answer a few questions about your well. These questions are voluntary, but will help in the analysis of your nitrate results and provide information as to nitrate concentrations across Minnesota. Your name, addresses, telephone numbers, and e-mail addresses are considered private under Minnesota Statutes Chapter 13. Only data from sample results, general location data and unique well number are considered public. Only people with a need to access your data in support of the private well nitrate sampling program will have authority to access your data unless you provide MDA with an informed consent to release the data, upon court order or provided to the state or legislative auditor to review the data. If you don't know an answer to a question, skip it and go on to the next question. Please make corrections to contact information if needed.

First name _____ **Last name**_____

Parcel Number_____ **Township**_____

Physical address_____ **City**_____ **State**_____ **Zip**_____

Mailing address _____ **City**_____ **State**_____ **Zip**_____

Phone number _____ **(in case we have questions about your survey) Email**_____

1. What setting did the water sample home from? Please choose only one.
   ☐ Sub-division ☐ Lake Home ☐River Home ☐ Country ☐Municipal/City* ☐ Other

*** If municipal/City well, stop here, your well will not be included in the private well sampling.**

2. Are there livestock on this property?
   (more than 10 head of cattle, 30 head of hogs or an equivalent number of other livestock)
   ☐ Yes ☐ No
3. Do you mix or store fertilizer (500 lb. or more) on the farm site? ☐ Yes ☐ No
4. Does farming take place on this property? ☐ Yes ☐ No

WELL INFORMATION

It is extremely helpful if you can go to your well and look for the Unique Well Number - this is a *6 digit number* found on a metal tag attached to your well casing.

5. Does your well have a Unique Well ID number? ☐ Yes ☐ No ☐Don't Know

6. If **yes**, what is the Unique Well ID? _____ (*6 digit number* found on a metal tag attached to your well casing)

7. Type of **well construction**? ☐ Drilled ☐ Sand point ☐ Hand Dug Well ☐Don't Know ☐ Other
8. Approximate **age** of your well? ☐ 0 - 10 years ☐ 11 - 20 years ☐ 21 - 40 years ☐ over 40 years
9. Approximate **depth** of your well? ☐ 0 - 49 Feet ☐ 50 -99 feet ☐ 100 - 299 feet ☐ >=300 feet
10. Distance to an active or inactive feedlot? ☐ 0 - 49 Feet ☐ 50 -99 feet ☐ 100 - 299 feet ☐ >=300 feet
11. Distance to a septic system? ☐ 0 - 49 Feet ☐ 50 -99 feet ☐ 100 - 299 feet ☐ >=300 feet
12. Distance to an agricultural field? ☐ 0 - 49 Feet ☐ 50 -99 feet ☐ 100 - 299 feet ☐ >=300 feet
13. Is this well currently used for human consumption (Drinking or Cooking)? ☐ Yes ☐ No
14. Please check any water treatment you have **other than a water softener**.
    ☐ None ☐ Reverse Osmosis ☐ Distillation ☐ Filtering system ☐ Other
15. When did you last have your well tested for nitrates?
    ☐ Never tested ☐ Within the last year ☐ Within the last 3 years
    ☐ Within the last 10 years ☐ Greater than 10 years ☐ Not sure
16. What was the result of your **last** nitrate test?
    ☐ <3 mg/L (ppm) ☐ 3<10 mg/L(ppm) ☐ >=10 mg/L (ppm) ☐ Don't Know

9

APPENDIX H

Table 19. Property Setting for Well Location

Township	Total	Country	River home	Sub-division	Other	Not Available
Elba	62	88.7%	1.6%	0.0%	1.6%	8.1%
Fremont	42	92.9%	0.0%	0.0%	0.0%	7.1%
Hart	48	89.6%	0.0%	0.0%	2.1%	8.3%
Hillsdale	52	98.1%	0.0%	0.0%	0.0%	1.9%
Mt. Vernon	33	93.9%	6.1%	0.0%	0.0%	0.0%
Norton	80	93.8%	0.0%	0.0%	0.0%	6.3%
Pleasant Hill	58	89.7%	0.0%	1.7%	3.4%	5.2%
St. Charles	85	96.5%	1.2%	1.2%	1.2%	0.0%
Saratoga	56	91.1%	0.0%	0.0%	1.8%	7.1%
Utica	86	88.4%	0.0%	0.0%	3.5%	8.1%
Warren	92	100.0%	0.0%	0.0%	0.0%	0.0%
Wilson	196	82.7%	0.0%	8.2%	4.1%	5.1%
Wiscoy	50	96.0%	0.0%	0.0%	0.0%	4.0%
Total	940	91.2%	0.4%	1.9%	1.8%	4.7%

Table 19. Well Construction Type

Township	Total	Drilled	Sand point	Hand dug	Not Available
Elba	62	85.5%	3.2%	0.0%	11.3%
Fremont	42	85.7%	2.4%	0.0%	11.9%
Hart	48	81.3%	0.0%	0.0%	18.8%
Hillsdale	52	78.8%	1.9%	1.9%	17.3%
Mt. Vernon	33	97.0%	0.0%	0.0%	3.0%
Norton	80	86.3%	2.5%	1.3%	10.0%
Pleasant Hill	58	89.7%	0.0%	0.0%	10.3%
St. Charles	85	96.5%	0.0%	0.0%	3.5%
Saratoga	56	87.5%	0.0%	0.0%	12.5%
Utica	86	76.7%	0.0%	0.0%	23.3%
Warren	92	88.0%	2.2%	0.0%	9.8%
Wilson	196	82.7%	1.0%	0.0%	16.3%
Wiscoy	50	82.0%	4.0%	0.0%	14.0%
Total	940	85.4%	1.3%	0.2%	13.1%

Table 20. Age of Well (estimated year well was installed)

Township	Total	1994 - Present	1975 - 1984	1985 - 1993	Before 1975	Not Available
Elba	62	24.2%	8.1%	6.5%	30.6%	30.6%
Fremont	42	14.3%	4.8%	14.3%	42.9%	23.8%
Hart	48	20.8%	4.2%	4.2%	41.7%	29.2%
Hillsdale	52	17.3%	17.3%	9.6%	30.8%	25.0%
Mt. Vernon	33	15.2%	3.0%	9.1%	54.5%	18.2%
Norton	80	20.0%	12.5%	10.0%	31.3%	26.3%
Pleasant Hill	58	31.0%	6.9%	0.0%	36.2%	25.9%
St. Charles	85	34.1%	9.4%	8.2%	29.4%	18.8%
Saratoga	56	23.2%	14.3%	5.4%	32.1%	25.0%
Utica	86	19.8%	2.3%	4.7%	40.7%	32.6%
Warren	92	8.7%	6.5%	7.6%	47.8%	29.3%
Wilson	196	25.0%	9.7%	8.2%	36.2%	20.9%
Wiscoy	50	40.0%	10.0%	4.0%	22.0%	24.0%
Total	940	22.9%	8.6%	7.1%	36.3%	25.1%

Table 21. Depth of Well

Township	Total	Depth 0-15 feet	Depth 16-49 feet	Depth 50-99 feet	Depth 100-299 feet	Depth >=300 feet	Not Available
Elba	62	0.0%	3.2%	3.2%	24.2%	27.4%	41.9%
Fremont	42	0.0%	0.0%	0.0%	42.9%	35.7%	21.4%
Hart	48	0.0%	0.0%	4.2%	20.8%	33.3%	41.7%
Hillsdale	52	0.0%	1.9%	3.8%	23.1%	28.8%	42.3%
Mt. Vernon	33	0.0%	0.0%	3.0%	21.2%	54.5%	21.2%
Norton	80	0.0%	5.0%	12.5%	31.3%	25.0%	26.3%
Pleasant Hill	58	0.0%	0.0%	0.0%	24.1%	37.9%	37.9%
St. Charles	85	0.0%	0.0%	3.5%	25.9%	27.1%	43.5%
Saratoga	56	0.0%	0.0%	5.4%	28.6%	41.1%	25.0%
Utica	86	0.0%	1.2%	2.3%	32.6%	26.7%	37.2%
Warren	92	1.1%	3.3%	3.3%	39.1%	27.2%	26.1%
Wilson	196	0.0%	1.5%	4.6%	24.0%	22.4%	47.4%
Wiscoy	50	6.0%	0.0%	4.0%	20.0%	20.0%	50.0%
Total	940	0.4%	1.5%	4.1%	27.7%	28.8%	37.4%

Table 22. Unique Well ID Known

Township	Total	No, Unique Well ID Not known	Yes, Unique Well ID Known	Not Available
Elba	62	61.3%	30.6%	8.1%
Fremont	42	76.2%	9.5%	14.3%
Hart	48	75.0%	18.8%	6.3%
Hillsdale	52	71.2%	17.3%	11.5%
Mt. Vernon	33	63.6%	24.2%	12.1%
Norton	80	66.3%	21.3%	12.5%
Pleasant Hill	58	70.7%	17.2%	12.1%
St. Charles	85	64.7%	27.1%	8.2%
Saratoga	56	69.6%	16.1%	14.3%
Utica	86	74.4%	10.5%	15.1%
Warren	92	79.3%	13.0%	7.6%
Wilson	196	69.9%	18.4%	11.7%
Wiscoy	50	58.0%	32.0%	10.0%
Total	940	69.7%	19.3%	11.1%

Table 23. Livestock located on Property

Township	Total	No Livestock	Yes Livestock	Not Available
Elba	62	79.0%	19.4%	1.6%
Fremont	42	42.9%	52.4%	4.8%
Hart	48	62.5%	35.4%	2.1%
Hillsdale	52	84.6%	13.5%	1.9%
Mt. Vernon	33	57.6%	42.4%	0.0%
Norton	80	67.5%	31.3%	1.3%
Pleasant Hill	58	56.9%	34.5%	8.6%
St. Charles	85	76.5%	22.4%	1.2%
Saratoga	56	71.4%	26.8%	1.8%
Utica	86	55.8%	37.2%	7.0%
Warren	92	68.5%	30.4%	1.1%
Wilson	196	84.7%	12.8%	2.6%
Wiscoy	50	84.0%	16.0%	0.0%
Total	940	71.4%	26.0%	2.7%

Table 24. Fertilizer Stored on Property

Township	Total	No Fertilizer Stored	Yes Fertilizer Stored	Not Available
Elba	62	90.3%	3.2%	6.5%
Fremont	42	92.9%	2.4%	4.8%
Hart	48	89.6%	4.2%	6.3%
Hillsdale	52	94.2%	1.9%	3.8%
Mt. Vernon	33	87.9%	9.1%	3.0%
Norton	80	97.5%	1.3%	1.3%
Pleasant Hill	58	87.9%	0.0%	12.1%
St. Charles	85	94.1%	2.4%	3.5%
Saratoga	56	89.3%	3.6%	7.1%
Utica	86	88.4%	3.5%	8.1%
Warren	92	91.3%	3.3%	5.4%
Wilson	196	96.4%	0.5%	3.1%
Wiscoy	50	100.0%	0.0%	0.0%
Total	940	93.0%	2.2%	4.8%

Table 25. Farming on Property

Township	Total	No Farming	Yes Farming	Not Available
Elba	62	45.2%	48.4%	6.5%
Fremont	42	23.8%	76.2%	0.0%
Hart	48	22.9%	70.8%	6.3%
Hillsdale	52	65.4%	32.7%	1.9%
Mt. Vernon	33	42.4%	57.6%	0.0%
Norton	80	48.8%	46.3%	5.0%
Pleasant Hill	58	34.5%	56.9%	8.6%
St. Charles	85	42.4%	54.1%	3.5%
Saratoga	56	35.7%	62.5%	1.8%
Utica	86	33.7%	62.8%	3.5%
Warren	92	45.7%	52.2%	2.2%
Wilson	196	72.4%	24.5%	3.1%
Wiscoy	50	58.0%	42.0%	0.0%
Total	940	48.3%	48.3%	3.4%

Table 26. Distance to an Active or inactive Feedlot

Township	Total	Feedlot 0-49 feet	Feedlot 50-99 feet	Feedlot 100-299 feet	Feedlot ≥300 feet	Not Available
Elba	62	3.2%	3.2%	14.5%	62.9%	16.1%
Fremont	42	4.8%	7.1%	23.8%	47.6%	16.7%
Hart	48	4.2%	8.3%	22.9%	47.9%	16.7%
Hillsdale	52	7.7%	1.9%	7.7%	61.5%	21.2%
Mt. Vernon	33	3.0%	9.1%	24.2%	51.5%	12.1%
Norton	80	2.5%	11.3%	15.0%	58.8%	12.5%
Pleasant Hill	58	6.9%	5.2%	17.2%	53.4%	17.2%
St. Charles	85	2.4%	9.4%	7.1%	67.1%	14.1%
Saratoga	56	5.4%	7.1%	17.9%	57.1%	12.5%
Utica	86	4.7%	10.5%	20.9%	50.0%	14.0%
Warren	92	7.6%	8.7%	21.7%	52.2%	9.8%
Wilson	196	6.6%	2.6%	10.2%	64.3%	16.3%
Wiscoy	50	4.0%	0.0%	6.0%	70.0%	20.0%
Total	940	5.1%	6.3%	15.0%	58.5%	15.1%

Table 27. Distance to Septic System

Township	Total	Septic 0-49 feet	Septic 50-99 feet	Septic 100-299 feet	Septic ≥300 feet	Not Available
Elba	62	3.2%	3.2%	14.5%	62.9%	16.1%
Fremont	42	4.8%	7.1%	23.8%	47.6%	16.7%
Hart	48	4.2%	8.3%	22.9%	47.9%	16.7%
Hillsdale	52	7.7%	1.9%	7.7%	61.5%	21.2%
Mt. Vernon	33	3.0%	9.1%	24.2%	51.5%	12.1%
Norton	80	2.5%	11.3%	15.0%	58.8%	12.5%
Pleasant Hill	58	6.9%	5.2%	17.2%	53.4%	17.2%
St. Charles	85	2.4%	9.4%	7.1%	67.1%	14.1%
Saratoga	56	5.4%	7.1%	17.9%	57.1%	12.5%
Utica	86	4.7%	10.5%	20.9%	50.0%	14.0%
Warren	92	7.6%	8.7%	21.7%	52.2%	9.8%
Wilson	196	6.6%	2.6%	10.2%	64.3%	16.3%
Wiscoy	50	4.0%	0.0%	6.0%	70.0%	20.0%
Total	940	5.1%	6.3%	15.0%	58.5%	15.1%

Table 28. Distance to an Agricultural Field

Township	Total	Field 0-49 feet	Field 50-99 feet	Field 100-299 feet	Field ≥300 feet	Not Available
Elba	62	8.1%	8.1%	24.2%	45.2%	14.5%
Fremont	42	11.9%	7.1%	38.1%	31.0%	11.9%
Hart	48	10.4%	12.5%	43.8%	20.8%	12.5%
Hillsdale	52	7.7%	7.7%	28.8%	48.1%	7.7%
Mt. Vernon	33	12.1%	18.2%	27.3%	24.2%	18.2%
Norton	80	12.5%	23.8%	28.8%	25.0%	10.0%
Pleasant Hill	58	6.9%	22.4%	24.1%	31.0%	15.5%
St. Charles	85	7.1%	18.8%	40.0%	24.7%	9.4%
Saratoga	56	8.9%	8.9%	39.3%	35.7%	7.1%
Utica	86	12.8%	15.1%	30.2%	25.6%	16.3%
Warren	92	7.6%	14.1%	41.3%	31.5%	5.4%
Wilson	196	9.2%	8.7%	14.8%	54.1%	13.3%
Wiscoy	50	2.0%	10.0%	26.0%	54.0%	8.0%
Total	940	9.0%	13.3%	29.3%	36.9%	11.5%

Table 29. Drinking Water Well

Township	Total	Not Drinking Water	Yes Drinking Water	Not Available
Elba	62	0.0%	98.4%	1.6%
Fremont	42	0.0%	100.0%	0.0%
Hart	48	2.1%	93.8%	4.2%
Hillsdale	52	3.8%	96.2%	0.0%
Mt. Vernon	33	3.0%	97.0%	0.0%
Norton	80	0.0%	96.3%	3.8%
Pleasant Hill	58	1.7%	93.1%	5.2%
St. Charles	85	2.4%	94.1%	3.5%
Saratoga	56	1.8%	96.4%	1.8%
Utica	86	1.2%	93.0%	5.8%
Warren	92	1.1%	98.9%	0.0%
Wilson	196	0.5%	95.9%	3.6%
Wiscoy	50	0.0%	96.0%	4.0%
Total	940	1.2%	96.0%	2.9%

Table 30. Treatment System Present (Treatment System Used for Drinking Water)

Township	Total	None	Distillation	Filtering System	Reverse Osmosis	Other	Not Available
Elba	62	69.4%	0.0%	12.9%	3.2%	3.2%	11.3%
Fremont	42	61.9%	0.0%	16.7%	14.3%	0.0%	7.1%
Hart	48	83.3%	0.0%	6.3%	4.2%	0.0%	6.3%
Hillsdale	52	63.5%	0.0%	25.0%	9.6%	0.0%	1.9%
Mt. Vernon	33	78.8%	0.0%	15.2%	0.0%	6.1%	0.0%
Norton	80	70.0%	0.0%	16.3%	6.3%	0.0%	7.5%
Pleasant Hill	58	74.1%	0.0%	15.5%	0.0%	0.0%	10.3%
St. Charles	85	47.1%	0.0%	29.4%	15.3%	3.5%	4.7%
Saratoga	56	57.1%	0.0%	23.2%	5.4%	3.6%	10.7%
Utica	86	58.1%	2.3%	12.8%	18.6%	1.2%	7.0%
Warren	92	75.0%	0.0%	13.0%	10.9%	0.0%	1.1%
Wilson	196	71.9%	0.0%	16.8%	3.6%	0.5%	7.1%
Wiscoy	50	62.0%	0.0%	26.0%	4.0%	0.0%	8.0%
Total	940	67.0%	0.2%	17.6%	7.6%	1.2%	6.5%

Table 31. Well Last Tested for Nitrate

Township	Total	Within the past year	Within the last 3 years	Within the last 10 years	Greater than 10 years	Never Tested	Unsure	Not Available
Elba	62	6.5%	6.5%	32.3%	24.2%	11.3%	17.7%	1.6%
Fremont	42	11.9%	14.3%	28.6%	14.3%	9.5%	21.4%	0.0%
Hart	48	10.4%	10.4%	20.8%	20.8%	10.4%	20.8%	6.3%
Hillsdale	52	5.8%	5.8%	17.3%	13.5%	25.0%	30.8%	1.9%
Mt. Vernon	33	18.2%	15.2%	3.0%	18.2%	12.1%	33.3%	0.0%
Norton	80	6.3%	15.0%	15.0%	18.8%	7.5%	32.5%	5.0%
Pleasant Hill	58	6.9%	5.2%	17.2%	31.0%	15.5%	19.0%	5.2%
St. Charles	85	7.1%	14.1%	21.2%	21.2%	12.9%	22.4%	1.2%
Saratoga	56	12.5%	12.5%	14.3%	19.6%	17.9%	23.2%	0.0%
Utica	86	8.1%	17.4%	18.6%	22.1%	9.3%	20.9%	3.5%
Warren	92	7.6%	12.0%	25.0%	23.9%	4.3%	26.1%	1.1%
Wilson	196	4.1%	9.7%	17.9%	17.9%	23.0%	25.5%	2.0%
Wiscoy	50	10.0%	16.0%	24.0%	18.0%	12.0%	18.0%	2.0%
Total	940	7.7%	11.7%	19.8%	20.3%	14.0%	24.1%	2.3%

Table 32. Last Nitrate Test Result

Township	Total	<3 mg/L Nitrate-N	3<10 mg/L Nitrate-N	≥10 mg/L Nitrate-N	Not Available
Elba	62	11.3%	11.3%	3.2%	74.2%
Fremont	42	21.4%	11.9%	11.9%	54.8%
Hart	48	6.3%	16.7%	6.3%	70.8%
Hillsdale	52	5.8%	11.5%	1.9%	80.8%
Mt. Vernon	33	12.1%	6.1%	3.0%	78.8%
Norton	80	7.5%	8.8%	2.5%	81.3%
Pleasant Hill	58	8.6%	5.2%	1.7%	84.5%
St. Charles	85	5.9%	14.1%	8.2%	71.8%
Saratoga	56	10.7%	12.5%	5.4%	71.4%
Utica	86	10.5%	12.8%	8.1%	68.6%
Warren	92	6.5%	14.1%	8.7%	70.7%
Wilson	196	11.2%	2.6%	2.0%	84.2%
Wiscoy	50	26.0%	6.0%	0.0%	68.0%
Total	940	10.4%	9.5%	4.7%	75.4%

APPENDIX I

Table 33. Well Construction Type for Final Well Dataset

Township	Total	Drilled	Sand Point	NA
Elba	52	47	3	2
Fremont	28	27	0	1
Hart	31	26	0	5
Hillsdale	44	35	1	8
Mt. Vernon	24	24	0	0
Norton	62	53	2	7
Pleasant Hill	50	44	1	5
St. Charles	62	62	0	0
Saratoga	40	37	0	3
Utica	51	45	0	6
Warren	62	56	2	4
Wilson	179	152	4	23
Wiscoy	46	37	3	6
Total	731	645	16	70

Data compiled from well logs and homeowner responses.

Table 34. Well Depth for Final Well Dataset

Township	Number of Wells	Min	Max	Median	Mean
Elba	21	60	520	355	296
Fremont	8	198	580	375	383
Hart	10	142	595	537	452
Hillsdale	12	140	505	287	300
Mt. Vernon	10	90	515	305	310
Norton	16	91	598	320	318
Pleasant Hill	11	130	620	592	491
St. Charles	23	230	594	420	438
Saratoga	12	350	572	430	440
Utica	13	300	539	400	412
Warren	13	95	612	240	339
Wilson	35	105	650	223	297
Wiscoy	17	90	585	220	291
Total	201	60	650	359	355

Data compiled from well logs only; homeowner responses are not included.

Table 35. Year of Well Construction for Final Well Dataset

Township	Number of Wells	Minimum	Maximum	Median	Mean
Elba	21	1977	2010	2002	1999
Fremont	8	1930	2011	2002	1990
Hart	11	1950	2012	2004	1999
Hillsdale	10	1975	2005	1999	1995
Mt. Vernon	8	1956	2011	2000	1993
Norton	14	1975	2010	2001	1998
Pleasant Hill	12	1920	2013	2003	1993
St. Charles	23	1979	2012	1999	2000
Saratoga	13	1911	2006	2000	1992
Utica	13	1971	2011	2004	2001
Warren	12	1972	2005	1999	1993
Wilson	35	1934	2015	1999	1996
Wiscoy	17	1991	2012	2002	2001
Total	197	1911	2015	2000	1996

Data compiled from well logs only; homeowner responses are not included. Most wells do not have a well log if they were constructed before 1974.

APPENDIX J

Private Well Field Log

Site ID_____**Unique ID**_____ **Date** _____

MDA -Private Well Field Log & Well Survey Form

Sample#_____

Duplicate#_____**Field Blank#**_____

Additional Samples_____

Well Owner Contact Information

Name_____

Address_____

Phone #_____Township_____County_____

Sampling Information

Sampler_____Time Arrived_____

Pump Start Time_____Discharge Rate_____Time Collected_____

Sample Point Location_____

Well Location_____

GPS Location_____UTM Easting (X)_____UTM Northing (Y)_____

Weather_____Wind Speed/Direction (mph)_____Air Temp (°F)_____

Nearest possible pesticide source (type, dist., dir.)_____☐ None noticeable

Time	Temp °C (1.0)	Specific Cond µs/cm (10%)	DO mg/L (10%)	pH (0.1)	Appearance/Odor/Notes

Field Comments - sample specific notes

Updated: March, 2017

APPENDIX K

Table 36. Temperature (°C) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Elba	20	10.1	15.0	10.9	11.1
Fremont	8	10.3	11.6	10.8	10.9
Hart	7	10.5	11.5	11.0	11.0
Hillsdale	5	10.9	11.7	11.6	11.4
Mt. Vernon	8	10.6	11.9	11.2	11.2
Norton	22	10.1	13.3	10.9	11.0
Pleasant Hill	16	10.1	15.2	11.3	11.9
St. Charles	21	10.1	12.5	10.3	10.6
Saratoga	10	10.5	13.3	11.0	11.2
Utica	12	10.2	12.2	10.7	11.0
Warren	33	10.1	14.1	11.0	11.2
Wilson	43	9.9	13.3	11.1	11.2
Wiscoy	10	10.5	14.2	11.1	11.4
Total	215	9.9	15.2	10.9	11.1

Table 37. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Elba	20	7.1	7.6	7.5	7.5
Fremont	8	7.2	7.8	7.6	7.5
Hart	7	7.4	7.9	7.7	7.7
Hillsdale	5	7.4	7.6	7.5	7.5
Mt. Vernon	8	7.3	7.7	7.5	7.5
Norton	22	7.2	7.6	7.5	7.4
Pleasant Hill	16	6.8	7.9	7.6	7.6
St. Charles	21	7.3	7.8	7.5	7.5
Saratoga	10	7.5	7.8	7.7	7.6
Utica	12	7.0	7.6	7.5	7.4
Warren	33	7.2	8.0	7.7	7.7
Wilson	43	7.4	8.0	7.6	7.6
Wiscoy	10	7.4	7.8	7.6	7.6
Total	215	6.8	8.0	7.6	7.6

Table 38. Specific Conductivity (µS/cm) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Elba	20	507	955	623	640
Fremont	8	526	1,232	685	753
Hart	7	447	1,103	556	661
Hillsdale	5	492	638	587	578
Mt. Vernon	8	505	729	599	610
Norton	22	442	899	632	657
Pleasant Hill	16	342	1,022	447	516
St. Charles	21	403	736	559	578
Saratoga	10	465	1,045	604	620
Utica	12	395	1,458	608	715
Warren	33	428	961	551	617
Wilson	43	311	1,041	570	573
Wiscoy	10	494	732	574	583
Total	215	311	1,458	575	612

Table 39. Dissolved Oxygen (mg/L) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Elba	20	3.3	13.5	8.9	8.3
Fremont	8	6.9	13.9	10.2	10.0
Hart	7	4.7	14.1	9.9	9.0
Hillsdale	5	6.3	12.2	8.8	9.1
Mt. Vernon	8	4.5	13.1	10.9	9.6
Norton	22	4.9	13.1	10.4	9.9
Pleasant Hill	15	1.7	7.7	4.1	4.5
St. Charles	21	2.3	11.4	8.3	7.3
Saratoga	10	3.4	12.3	10.1	9.5
Utica	12	1.0	14.6	9.2	9.1
Warren	33	3.4	14.8	6.4	6.9
Wilson	42	2.6	16.4	7.7	8.6
Wiscoy	10	3.8	8.7	4.6	5.2
Total	213	1.0	16.4	8.0	8.0