FINAL TOWNSHIP TESTING NITRATE REPORT: ROCK COUNTY 2016-2017

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Pesticide and Fertilizer Management Division

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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, private wells in the Rock County study area (seven 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 171 wells representing an average response rate of 25 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, 50.9 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 909 residents could be consuming well water with nitrate-N at or over the HRL. In the initial well dataset all of the townships tested had more than 10 percent of wells at or over the HRL.

The MDA completed follow-up sampling and well site visits at 58 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 112 (65 percent) wells were determined to be unsuitable and were removed from the dataset. The final well dataset had a total of 59 wells.

Over half (4 of 7) of the townships sampled in Rock County are showing significant problems with 10 percent of wells at or over the HRL. The percent of wells at or over the HRL ranged from 0 to 50 percent. However, it is important to note that in each of the townships there were less than 20 wells left in the dataset. The final dataset is not adequate to characterize a township in terms of private drinking water wells for the purposes of the NFMP.

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 hydrogeologically 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 February 2019, 306 townships in 42 counties have completed the initial sampling.

In 2016, seven townships in Rock 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 departments, 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 pesticide and nitrate-N sampling in Rock County occurred during the summer 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 nitrate-nitrogen results over 5 mg/L were removed from the initial dataset to form the final dataset if a potential non-fertilizer source or well problem was identified, there

was insufficient information on the construction or condition of the well, or for other reasons which are outlined in Appendix E. 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, visit the following webpages: www.mda.state.mn.us/nfmp and www.mda.state.mn.us/townshiptesting.

Figure 1. Townships Tested in Rock 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 (Dubrovsky et al., 2010) 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 (Knowles, 1982). Shallow groundwater in coarse-textured soils generally has low concentrations of organic carbon and is well oxygenated, so denitrification is often limited in these conditions. As a result, areas like Rock County with areas of sand and gravel deposited by glacial streams (Patterson, 1995) and intensive row crop agriculture, are particularly vulnerable to elevated nitrate concentrations.

GEOLOGY AND HYDROGEOLOGY

During the most recent glaciation event 14,000 years ago much of Minnesota was covered by glacial ice. However, the southwest corner of Minnesota, where Rock County is located, was

free of ice. Most of the surficial sediment was deposited from earlier glacial events, but some is bedrock material.

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 glacial deposits in Rock County as presented in Figure 2. The surficial geology in Rock County is predominately outwash plains, and till plain, and isolated areas of bedrock (Lusardi, 1997).

The exposed bedrock is known as “Sioux Quartzite”. During the Early Proterozoic period of the Precambrian Era (over 1,600 million years ago) ancient streams flowed through southwest Minnesota. Sand was deposited into basins and this sand eventually formed into sandstone and then recrystallized into the quartzite seen today (Boerboom, 1994) Precambrian Sioux Quartzite bedrock underlies all of Rock County and is exposed on the surface in the northern part of the county. In the southern region of Rock County, Cretaceous bedrock overlies the Sioux Quartzite (Southwick, 2002). Some wells utilize the quartzite as a drinking water aquifer (MPCA, 1998). Yields are typically low in this bedrock but can be variable depending on how well connected the bedrock is to the surface and the features of the fractures (Bradt, 1997).

Till and outwash deposits originate from glaciation events (Lusardi, 1997). As a glacier advances it catches hold of debris and the debris transported with the glacier as it advances. When this material is eventually deposited it is classified as till (Lusardi, 1997). Till can be found in each of the tested townships (Figure 2). It is mainly composed of unsorted fine textured sediments such as clay, silt, and fine sands, but it can contain larger materials such as pebbles and boulders. These surficial tills were deposited in the Pre-Wisconsin Age, which occurred 75,000 years ago, and are much older than most of the till found in Minnesota (Patterson, 1995; Lusardi, 1997).

Outwash sediments in Rock County were deposited by glacial meltwater flowing from the melting ice during the last glacial event in the Late-Wisconsin Age. Glacial outwash is relatively coarse-textured compared to other glacial deposits such as till. Outwash primarily consists of sand and gravel (Patterson, 1995). Surficial and buried outwash sediments create many of the aquifers in Rock County.

The shallow surficial aquifers area typically located adjacent to modern day streams and rivers. Water quality within these aquifers is primarily controlled by precipitation and land practices. They are susceptible to contamination from the surface and high nitrate concentrations are common. Surficial aquifers are utilized most often because they typically have higher water yields and have lower concentrations of dissolved minerals. However, these aquifers sparse and so they are not available to many residents (Bradt, 1997).

When shallow surficial aquifers are not available, confined quaternary aquifers are often utilized. These aquifers are more difficult to locate and often have much lower water yields. The groundwater chemistry in buried aquifers is primarily influenced by the surrounding geology (Bradt, 1997). Regional studies in southwest Minnesota show that water from buried aquifers is typically very hard, with high concentrations of sulfate, iron and manganese (MPCA, 1998).

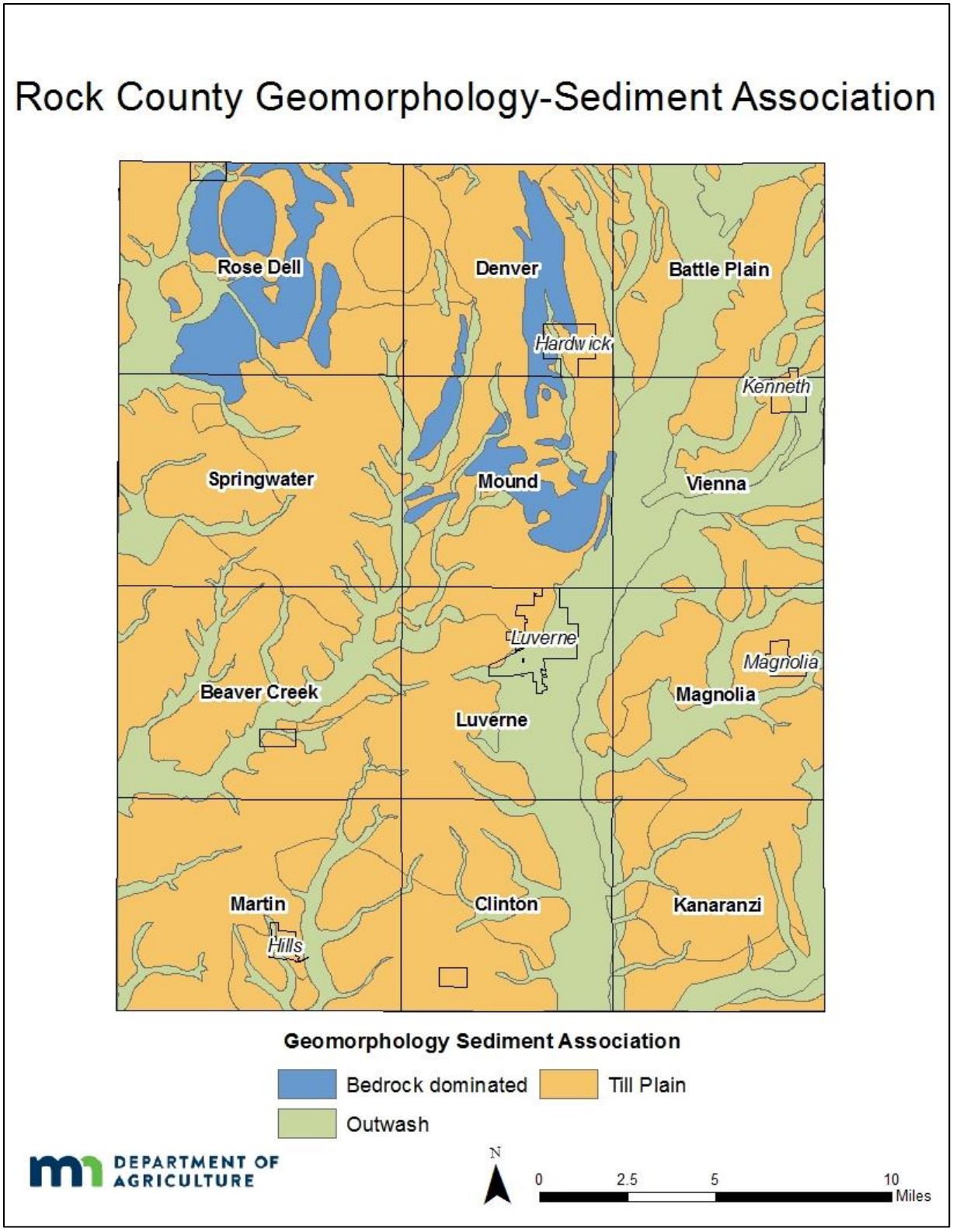

Figure 2. Statewide Geomorphology Layer, Sediment Association in Rock County (DNR, MGS, UMD, 1997)

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 Rock 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 1,330 SSTS were reported in Rock County for 2016. Over a recent 15 year period (2002-2016), 386 construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Rock 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 Rock County study area there are a total of 282 active feedlots. The majority of the feedlots are permitted to house less than 300 animal units (AU) (Appendix B; Figure 9). Mound Township has the most feedlots, and Magnolia Township has the most permitted AU per square mile (Appendix B; Table 10).

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 Rock County study area has a total of 8 fertilizer storage licenses with majority located in Battle Plain Township (Appendix B; Table 11).

FERTILIZER SPILLS AND INVESTIGATIONS

A total of 3 historic fertilizer spills and investigations occurred in the Rock County study area. The majority of these were small spills and 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.

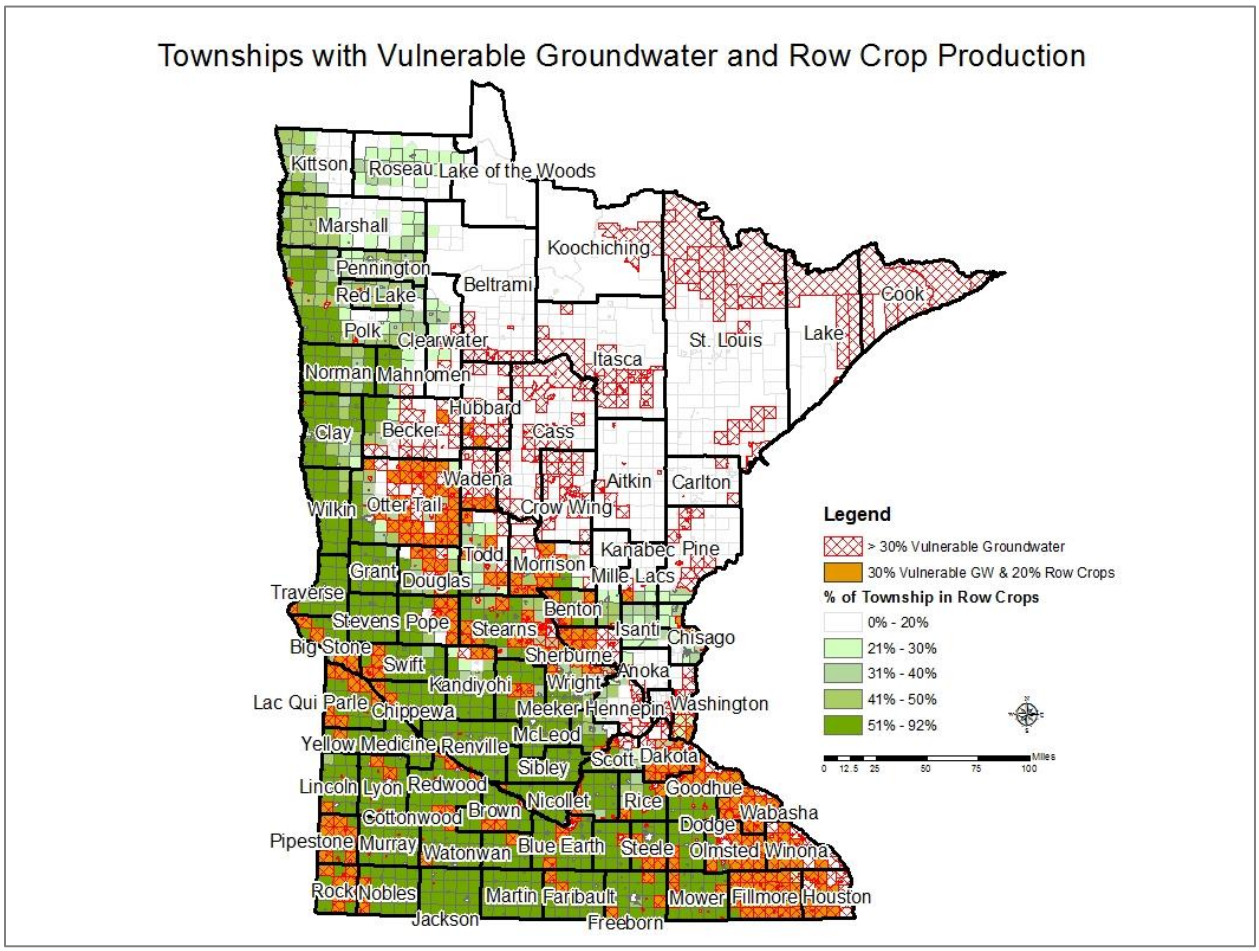

Figure 3. Minnesota Townships with Vulnerable Groundwater and Row Crop Production

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 Rock County depicting the aquifer vulnerabilities is shown below in Figure 4.

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

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 Rock County can be found in Appendix C (Figure 11, Table 14). On average 80 percent of the land cover was row crop agriculture.

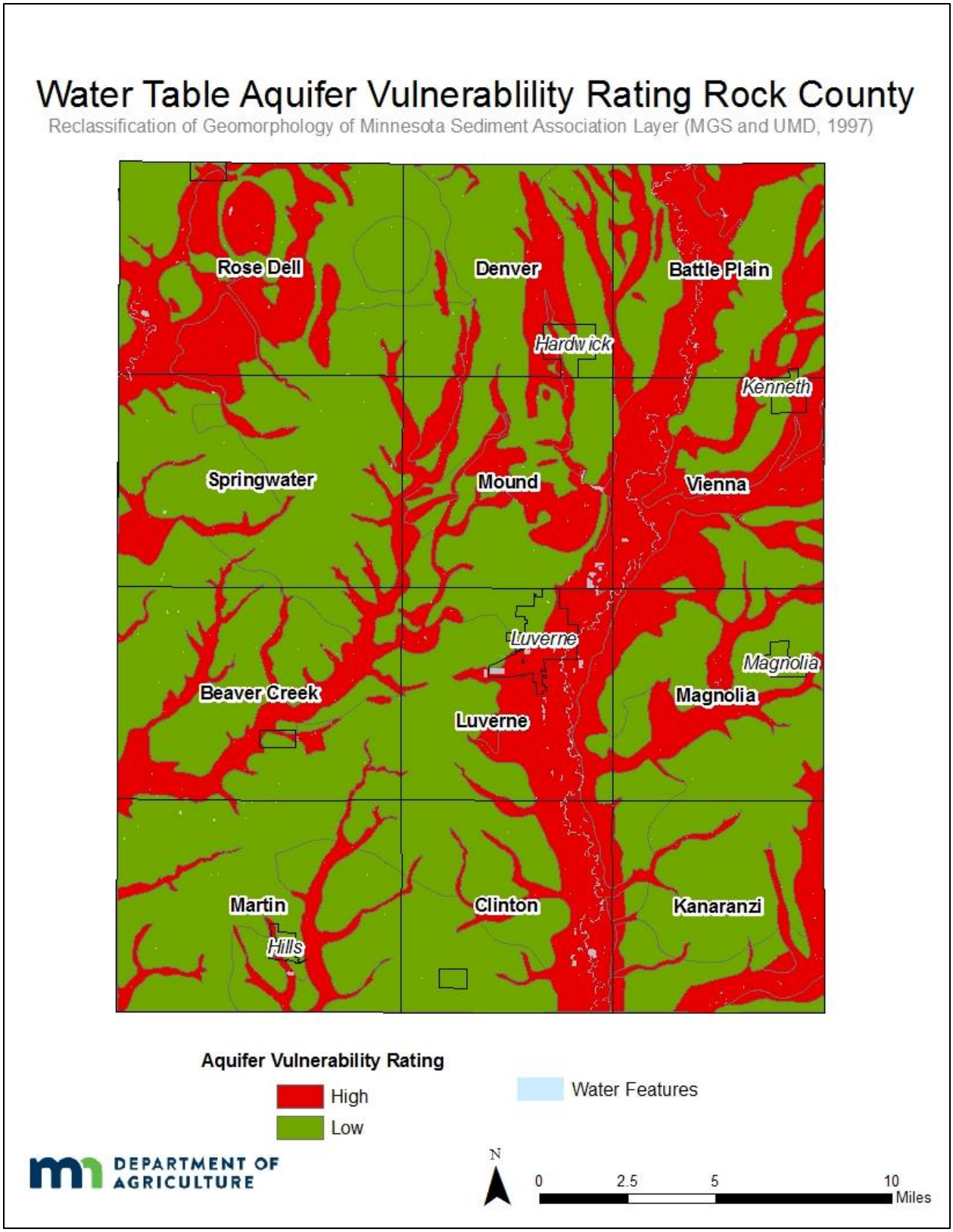

Figure 4. Water Table Aquifer Vulnerability Rating in Rock County

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 171 homeowners using the mail-in kit (Table 2). These 171 samples are considered the "initial well dataset". On average, 25 percent of the homeowners in these townships responded to the free nitrate test offered by 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 58 follow-up samples were analyzed (Table 2).

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

Township	Kits Sent	Initial Well Dataset	Well Site Visits & Follow-Up Sampling Conducted
Battle Plain	83	23	11
Clinton	101	10	1
Luverne	160	37	15
Magnolia	87	20	4
Mound	90	28	10
Rose Dell	87	30	14
Vienna	66	23	3
Total	674	171	58

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 and 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 112 wells were removed to create the final well dataset. See Appendix E (Table 17 and 18) 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. Wells with a higher concentration of nitrate 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, wells with cracked casing. Wells with significant problems such as these were excluded from the final well dataset.

BORED WELL

Bored wells are wells with a larger diameter than traditional drilled wells. Bored wells are fundamentally the same as “dug wells”. These wells may differ from hand dug wells since they were constructed using specialized drilling equipment. However, like dug wells they have large diameters, are typically shallow and are more susceptible to contamination. Many of the wells identified as bored wells in Rock County are shallow and were constructed before modern day well code. Methods used to construct these wells are no longer legal for drinking water wells

(MDH, 2011). These wells are looked at individually and may be excluded from the final data set based on the condition of the well.

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

If the water source of the sample was uncertain, or from an unwanted source, then data pertaining to the sample was removed. For example, these samples include water that may have been collected from an indoor tap with a reverse osmosis system. Water samples that were likely collected from a municipal well or the Lincoln-Pipestone Rural Water system were also removed from the dataset. This study examines raw well water not treated water or municipal water.

SITE VISIT COMPLETED - WELL NOT FOUND & CONSTRUCTED BEFORE 1975 OR AGE UNKNOWN & 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. Additionally, if the age of the well could not be determined it was assumed to an older well.

NO SITE VISIT & CONSTRUCTED BEFORE 1975 OR AGE UNKNOWN & NO WELL ID

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. If the age of the well could not be determined these were again assumed to be older wells.

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

A total of 171 well owners returned water samples for analysis across the seven townships (Figure 5). These wells represent the initial well dataset. The initial well dataset depicts what people have for drinking water, regardless of potential the nitrogen sources. The following paragraphs provide a brief discussion of the statistics presented in Table 3.

The minimum values of nitrate for all townships were less than the detection limit (<DL) which is 0.03 mg/L. The maximum values ranged from 21.0 to 119.0 mg/L, with Battle Plain Township having the highest result. Median values range from 6.8 to 17.9 mg/L, with Battle Plain Township having the highest median value. The 90th percentiles range from 19.1 to 60.5 mg/L, with Vienna Township having the highest 90th percentile.

Initial results from the sampling showed that all seven of the tested townships had ten percent or more of the wells at or over 10 mg/L nitrate (Figure 6). The township testing results contrast findings from a 2010 USGS report on nitrate concentrations in private wells in the glacial aquifer systems across the upper United States (US) in which less than five percent of sampled private wells had nitrate concentrations greater than 10 mg/L (Warner and Arnold, 2010). Data from the township testing program suggests that private well water in Battle Plain, Clinton, Luverne, Magnolia, Mound, Rose Dell and Vienna Townships are more heavily impacted by nitrate than other areas of the upper United States. Both the USGS and the township testing studies indicate that nitrate concentrations can vary considerably over short distances.

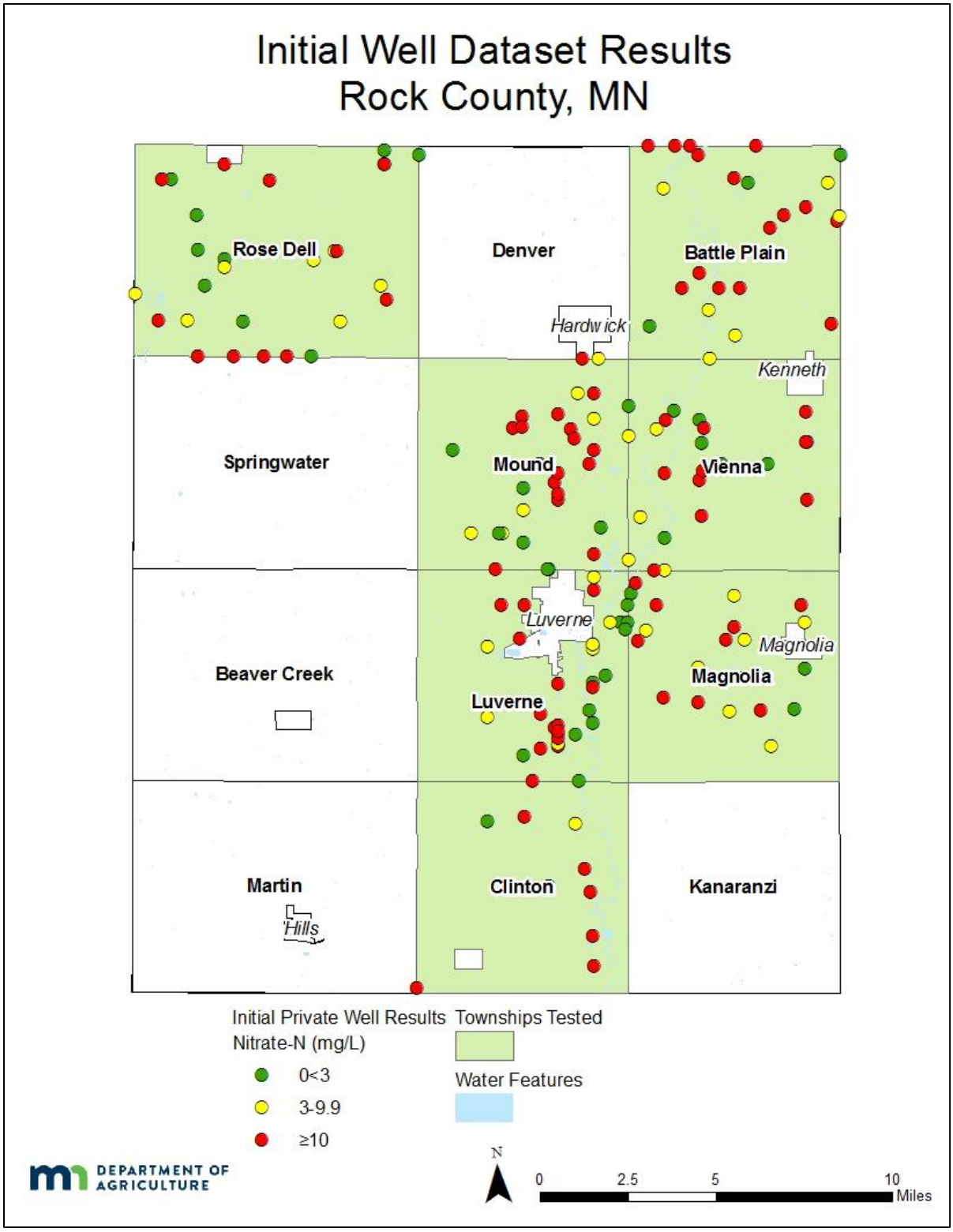

Figure 5. Well Locations and Nitrate Results from Initial Dataset in Rock County

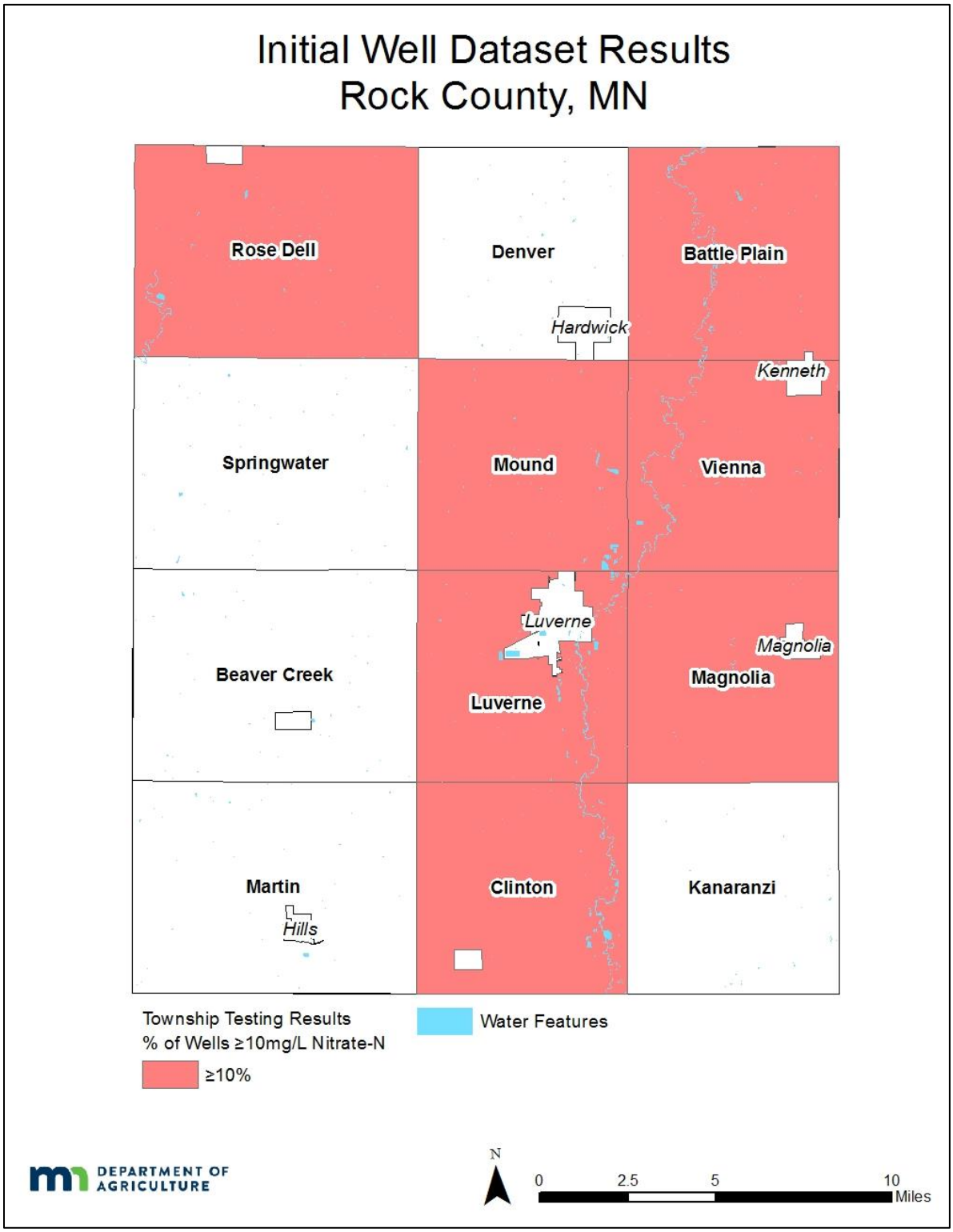

Figure 6. Results of the Initial Testing by Township

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

Township	Total Wells	Values				Percentiles				Number of Wells					Percent of Wells				
		Min	Max	Mean	Median	75th	90th	95th	99th	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L
		Nitrate-N mg/L or parts per million (ppm)																	
Battle Plain	23	<0.03	119.0	21.1	17.9	24.6	35.3	72.3	119.0	3	5	19	17	15	13.0%	21.7%	82.6%	73.9%	65.2%
Clinton	10	<0.03	24.0	13.4	15.5	16.3	20.4	24.0	24.0	1	1	9	8	8	10.0%	10.0%	90.0%	80.0%	80.0%
Luverne	37	<0.03	21.0	8.0	6.8	13.8	19.1	20.3	21.0	13	9	22	18	15	35.1%	24.3%	59.5%	48.6%	40.5%
Magnolia	20	<0.03	57.3	16.2	9.4	21.4	41.3	50.5	57.3	3	8	16	16	9	15.0%	40.0%	80.0%	80.0%	45.0%
Mound	28	<0.03	29.2	11.2	11.9	14.9	25.9	27.0	29.2	6	6	22	18	16	21.4%	21.4%	78.6%	64.3%	57.1%
Rose Dell	30	<0.03	61.0	12.0	8.1	18.3	27.0	48.0	61.0	10	7	18	16	13	33.3%	23.3%	60.0%	53.3%	43.3%
Vienna	23	<0.03	85.2	20.2	9.9	32.1	60.5	76.6	85.2	6	6	15	14	11	26.1%	26.1%	65.2%	60.9%	47.8%
Total	171	<0.03	119.0	13.9	11.1	18.1	28.8	44.3	82.4	42	42	121	107	87	24.6%	24.6%	70.8%	62.6%	50.9%

< DL stands for less than a detectable limit. This means results are less than 0.03 mg/L. The 50th percentile (75th, 90th, 95th, and 99th) is the value below which 50 percent (75%, 90%, 95%, and 99%) of the observed values fall.

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 1,846 people in Rock County's study area have drinking water over the nitrate HRL (Table 4). Nitrate contamination is a significant problem across much of Rock County. Additional public awareness and education programming will need to take place in all of the townships.

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

Township	2016 Estimated Households on Private Wells*	2016 Estimated Population on Private Wells*	Estimated Population ≥10 mg/L Nitrate-N**
Battle Plain	71	187	122
Clinton	98	271	217
Luverne	168	471	191
Magnolia	83	207	93
Mound	82	229	131
Rose Dell	74	203	88
Vienna	60	140	67
Total	636	1,708	909

* Data collected from the Minnesota State Demographic Center, 2016 (Minnesota SCD, 2017)

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

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 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, 2016).

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 23 documented wells (Table 5). Approximately 13 percent of the sampled wells had corresponding well logs. However, seven of the wells with a well log do not have a defined aquifer, so only 16 wells have a known aquifer. Thus, the data gathered on aquifers represents a small portion of the total sampled wells.

According to the well log data, the most commonly utilized aquifer in the sampled wells was from the Quaternary buried aquifers. This majority reflects the overall findings for all documented wells in the focus area (Appendix F, Table 19). The wells in these aquifers average 138 feet deep.

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

The Quaternary aquifers represent the youngest geological aquifer formation identified in Rock County. These aquifers are comprised of sand and gravel deposits that are scattered along modern streams and rivers. Quaternary aquifers are the main aquifers used in domestic drinking water wells (MPCA, 1998)

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.

The Quaternary Buried aquifers are similar to the QWTA except that the confining materials (typically clay) are more than 10 feet thick (MPCA, 1998).

Precambrian aquifers are the geologically oldest depicted in this report. Sioux Quartzite bedrock is a Precambrian era aquifer utilized in Rock County. Sioux Quartzite outcrops appear near the surface in some areas and these have been utilized as surficial aquifers. These aquifers are typically only used when there are no other options. When compared to other aquifers in the southwest Minnesota these aquifers have higher concentrations of antimony, nickel, nitrate, titanium, and Eh according to a baseline study (MPCA, 1998). Residuum is formed when parent material breaks down into unconsolidated sediments. Only one well from this study draws from an aquifer created by this weathered material (Cummins and Grigal, 1981).

Table 5. Nitrate Concentrations within Sampled Groundwater Aquifers, Rock County

Aquifer	Total Wells	Ave Depth (Feet)	Number of wells			Percent of wells		
			<3	3<10	≥10	<3	3<10	≥10
			Nitrate-N mg/L					
Quaternary Water Table	3	37	0	2	1	0%	67%	33%
Quaternary Buried	7	138	4	0	3	57%	0%	43%
Quaternary Undifferentiated	1	30	1	0	0	100%	0%	0%
Weathering Residuum	1	207	0	1	0	0%	100%	0%
Sioux Quartzite	3	255	0	2	1	0%	67%	33%
Multiple	1	327	1	0	0	100%	0%	0%
Total	16	150	6	5	5	38%	31%	31%

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 20-34).

The overwhelming majority of wells in each township are located on “rural” property. There were no lake homes and very few homes located on a river or in a subdivision.

Approximately 49 percent of sampled wells are of drilled construction and less than three 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. About four percent of wells were hand dug wells. As mentioned previously hand dug wells are shallow and more sensitive to local surface runoff contamination than deeper drilled wells.

Approximately 45 percent of the wells in the townships are less than 100 feet deep.

Very few (less than 12 percent) homeowners that responded on the survey that their well was constructed recently (1985 to present). Most homeowners that answered the survey indicated their well was constructed before 1975.

Most of the wells had not been tested for nitrate within the last ten years or homeowners were unsure if they had been tested. Therefore, the results most homeowners receive from this study will provide new information.

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 20-34).

- On average, farming takes place on nearly half of the properties.
- Agricultural fields are greater than 300 feet from wells at 46 percent of the properties.
- Over a quarter 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. Compared to other counties in the township testing program this is a high percentage.
- Nearly 34 percent of wells are less than 300 feet from an active or inactive feedlot.
- Less than three percent of sites across all townships store more than 500 pounds of fertilizer on their property.
- A few wells (less than five percent) are less than 50 feet away from septic systems.

FINAL RESULTS

FINAL WELL DATASET

A total of 171 well water samples were collected by homeowners across seven townships. A total of 112 (65 percent) wells were found to be unsuitable and were removed to create the final well dataset. The final analysis was conducted on the remaining 59 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 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 50.0 percent.

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

Township	Initial Well Dataset	Final well Dataset	Final Wells ≥10 mg/L Nitrate-N	
			Count	Percentage
Battle Plain	23	4	1	25.0%
Clinton	10	2	1	50.0%
Luverne	37	17	1	5.9%
Magnolia	20	5	0	0.0%
Mound	28	8	1	12.5%
Rose Dell	30	14	3	21.4%
Vienna	23	9	0	0.0%
Total	171	59	7	11.9%

The individual nitrate results from this final well dataset are displayed spatially in Figure 7. 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 7.2 to 22.0 mg/L nitrate, with Rose Dell Township having the highest result. The 90th percentile ranged from 5.6 to 18.7 mg/L nitrate-N, with Rose Dell Township having the highest result and Luverne Township having the lowest result. It is important to not that all of the townships have less than 20 wells in the dataset. The final dataset is not adequate to characterize a township in terms of private drinking water wells for the purposes of the NFMP (Figure 8).

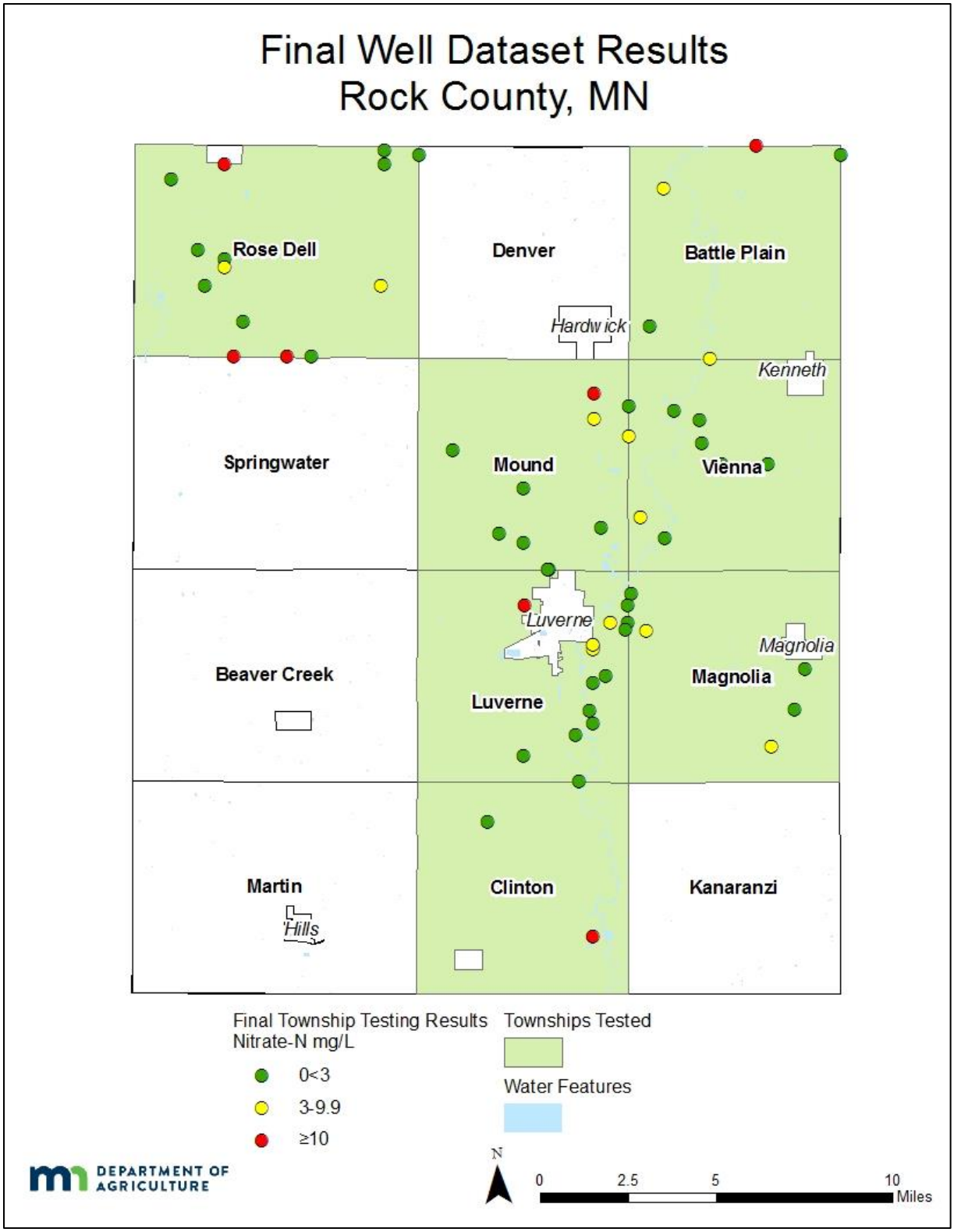

Figure 7. Well Locations and Nitrate Results from Final Well Dataset in Rock County

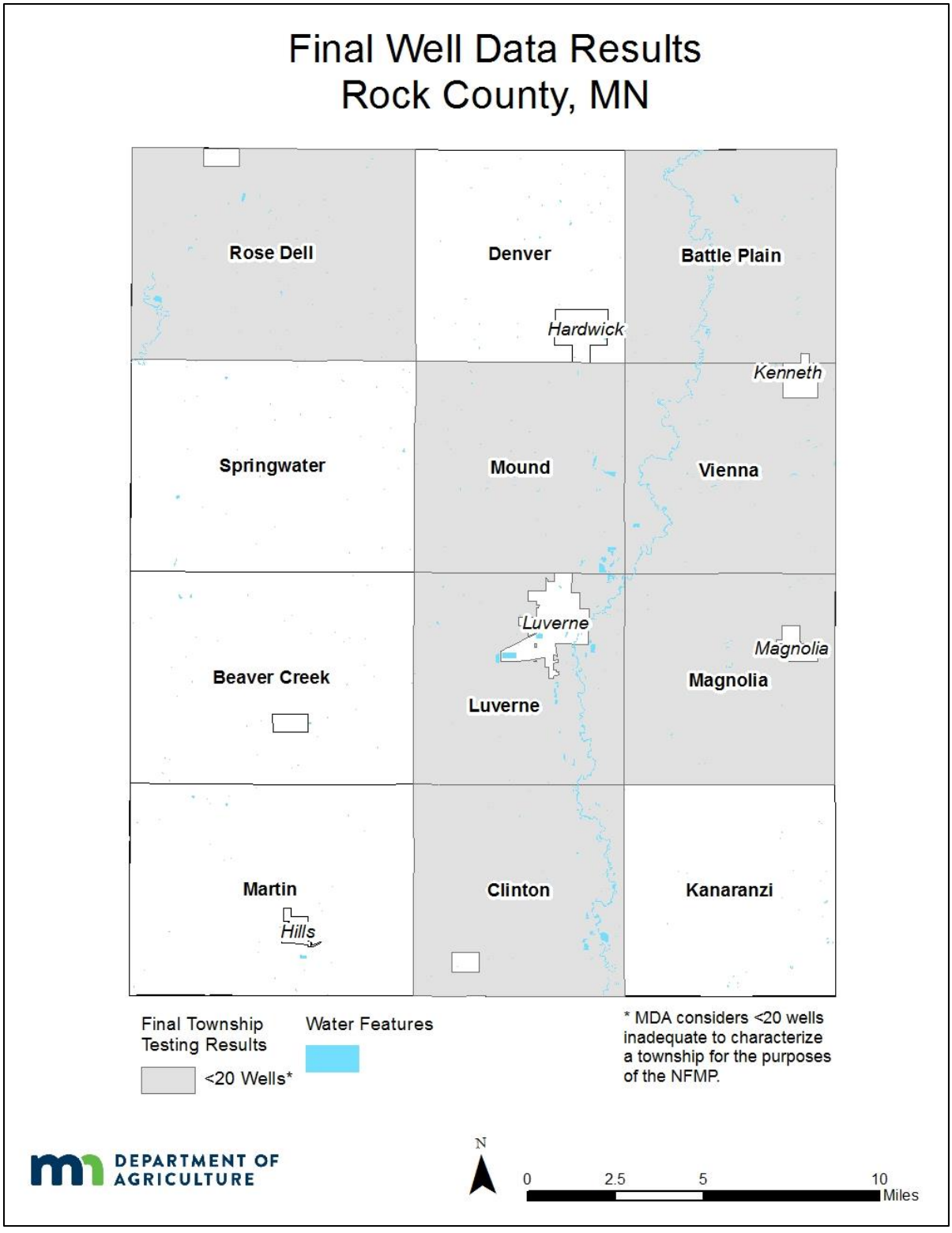

Figure 8. Results of the Final Testing by Township

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

Township	Final Total Wells	Values			Percentiles					Number of Wells					Percent				
		Min	Max	Mean	(50th) Median	75th	90th	95th	99th	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L
Battle Plain	4	<DL	17.2	5.1	1.7	10.3	17.2	17.2	17.2	2	1	1	1	1	50.0%	25.0%	25.0%	25.0%	25.0%
Clinton	2	<DL	16.1	8.1	8.1	16.1	16.1	16.1	16.1	1	0	1	1	1	50.0%	0.0%	50.0%	50.0%	50.0%
Luverne	17	<DL	21.0	2.5	0.2	3.6	5.6	15.6	21.0	12	4	4	1	1	70.6%	23.5%	23.5%	5.9%	5.9%
Magnolia	5	<DL	7.2	2.6	1.6	4.9	7.2	7.2	7.2	3	2	1	1	0	60.0%	40.0%	20.0%	20.0%	0.0%
Mound	8	<DL	13.4	2.8	0.3	4.2	11.4	13.4	13.4	6	1	2	1	1	75.0%	12.5%	25.0%	12.5%	12.5%
Rose Dell	14	<DL	22.0	5.1	2.0	4.1	18.7	21.3	22.0	9	2	3	3	3	64.3%	14.3%	21.4%	21.4%	21.4%
Vienna	9	<DL	9.9	2.1	0.8	3.2	7.4	9.9	9.9	6	3	1	1	0	66.7%	33.3%	11.1%	11.1%	0.0%
Total	59	<DL	22.0	3.5	0.8	4.1	13.9	17.8	21.9	39	13	13	9	7	66.1%	22.0%	22.0%	15.3%	11.9%

<DL stands for less than detectable limit. The detectable limit is <0.03 nitrate-N. 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 Related to Vulnerable Geology and Row Crop Production, Rock County

Township	Final Well Dataset	Percent of Land in Row Crop Production 2013**	Percent of Land in Vulnerable Geology	Percent ≥7 mg/L	Percent ≥10 mg/L
				Nitrate-N mg/L or parts per million (ppm)	
Battle Plain	4	81%	56%	25.0%	25.0%
Clinton	2	83%	35%	50.0%	50.0%
Luverne	17	78%	48%	5.9%	5.9%
Magnolia	5	84%	32%	20.0%	0.0%
Mound	8	69%	43%	12.5%	12.5%
Rose Dell	14	75%	48%	21.4%	21.4%
Vienna	9	79%	69%	11.1%	0.0%
Total	59	78%*	47%*	15.3%	11.9%

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

WELL AND WATER CHARACTERISTICS

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells in the Rock 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/). These well characteristics were also provided by some homeowners. The well characteristics for the final well dataset are described below and a more comprehensive view is provided in Appendix I (Tables 35-37).

- The majority of wells were drilled (66 percent), and only 2 were sand point wells
- The median depth of wells was 153 feet, and the shallowest was 30 feet
- The median year the wells were constructed in was 2004

WELL WATER PARAMETERS

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 and Well Survey Form (Appendix J). The measurements included temperature, specific conductivity, pH, 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 (Tables 38-41).

- The temperatures ranged from 9.79 °C to 15.31 °C
- The median specific conductivity was 727 µS/cm, and was as high as 1,487 µS/cm
- The water from the wells had a median pH of 7.23
- The dissolved oxygen readings ranged from 0.10 mg/L to 10.06 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 Rock County. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Approximately 80 percent of the land cover is row crop agriculture and there are over 470 acres of groundwater irrigation in the study area.

Seven townships were sampled covering over 165,000 acres. The initial (homeowner collected) nitrate sampling resulted in 171 samples. The 171 households that participated represent approximately 25 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 58 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 112 (65 percent) wells were found to be unsuitable and were removed from the final well dataset of 59 wells. The remaining 59 wells were wells believed to be impacted by commercial nitrogen fertilizer and were included in the final well dataset.

A majority of wells (66 percent) were drilled. The median depth of the wells was 153 and depths ranged from 30 to 395 feet.

In four of the seven townships tested, 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 50.0 percent. However, it is important to note that there were less than 20 wells left in each township. The final dataset is not adequate to characterize a township in terms of private drinking water wells for purposes of the NFMP.

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APPENDIX A

Private Well Field Log and Well Survey 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** _____

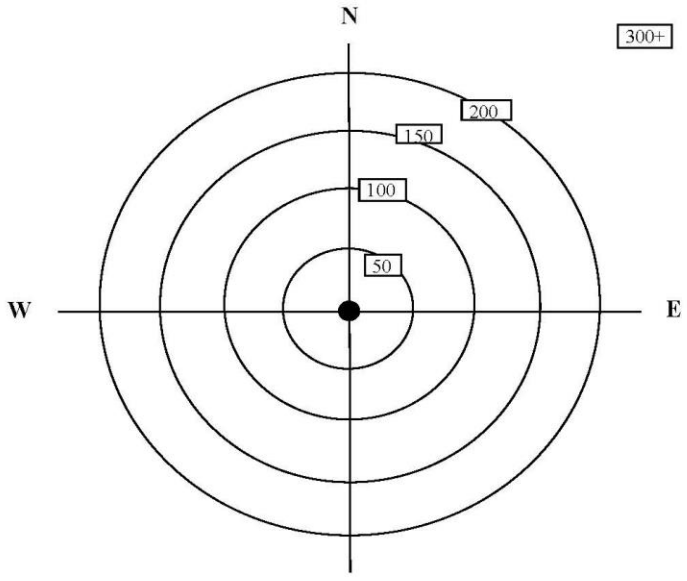
MDA -Private Well Field Log & Well Survey Form

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).

Rock County has the authority to inspect SSTS for all townships in Rock County. In 2016 Rock County reported a total of 1,330 SSTS and none were inspected for compliance. Rock County does not conduct compliance inspections during property transfers, which many counties elect to do (MPCA, 2017a). Rock County will perform compliance inspection when a construction permit is required for a SSTS upgrade or repair, when a building is expanded or there is a change or use in the building and that could impact the SSTS, and anytime the county deems appropriate such as after a complaint or malfunction (Rock County Ordinance NO 2014-01, 2014).

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 (NH4+) 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, 2017c). 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 (Table 9) (MPCA, 2017c).

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

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, 2015).

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, 2017c).

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, 2017b*). 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. From 2014-2017, approximately 24,000 feedlots were registered in Minnesota (MPCA, 2017c). A map and table of the feedlots located in the Rock County study area can be found below (Figure 9; Table 10).

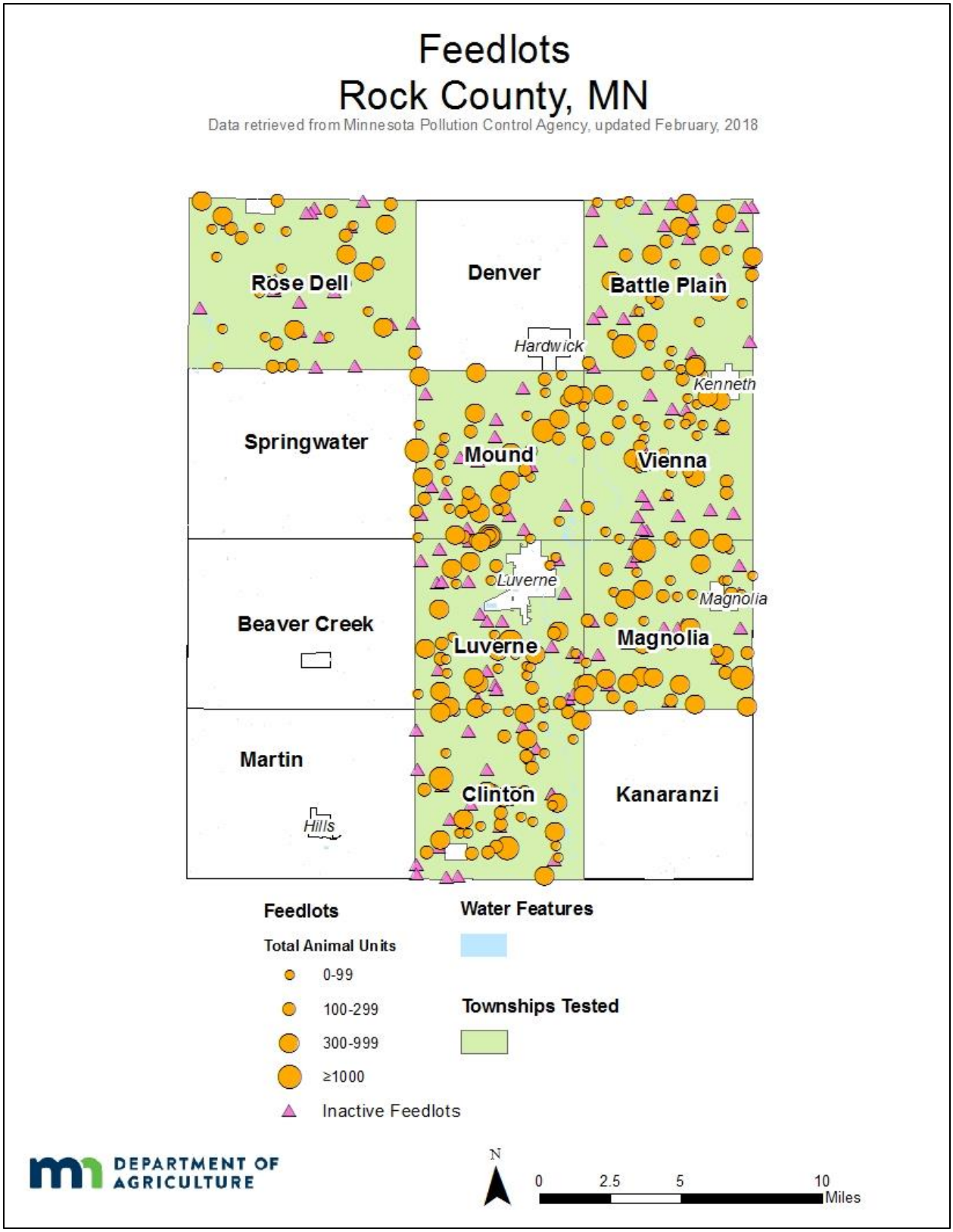


Figure 9. Feedlot Locations in Rock County (MPCA, 2018)

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

Township	Total Feedlots	Active Feedlots	Inactive Feedlots	Average AU Permitted** Per Feedlot	Total Permitted** AU	Total Square Miles	Permitted** AU per Square Mile
Battle Plain	54	34	20	346	11,756	36	324
Clinton	62	43	19	319	13,731	36	385
Luverne	63	41	22	312	12,806	33	394
Magnolia	58	42	16	481	20,206	35	573
Mound	68	50	18	394	19,677	36	549
Rose Dell	52	34	18	244	8,306	48	173
Vienna	54	38	16	183	6,948	35	199
Total	411	282	129	331*	93,430	259	361*

* 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.

On average there are 361 AU per square mile (0.565 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 Rock County study area livestock densities average 0.710 AU per acre of row crops (MPCA, 2017c; USDA NASS, 2013).

FERTILIZER STORAGE LOCATION

MDA tracks licenses for bulk fertilizer storage facilities, anhydrous ammonia, and chemigation sites (Table 11). 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, Rock County

Township	*Bulk Fertilizer Storage	*Anhydrous Ammonia	*Chemigation Sites	*Abandoned Sites	Total
Battle Plain	0	0	5	0	5
Clinton	0	0	1	0	1
Luverne	0	0	0	0	0
Magnolia	1	1	0	0	2
Mound	0	0	0	0	0
Rose Dell	0	0	0	0	0
Vienna	0	0	0	0	0
Total	1	1	6	0	8

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

SPILLS AND INVESTIGATIONS

The MDA is responsible for investigating any fertilizer spills within Minnesota. Figure 10 shows the locations of mapped historic spills within the Rock 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 no incident investigations in the tested 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 are no contingency areas 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.

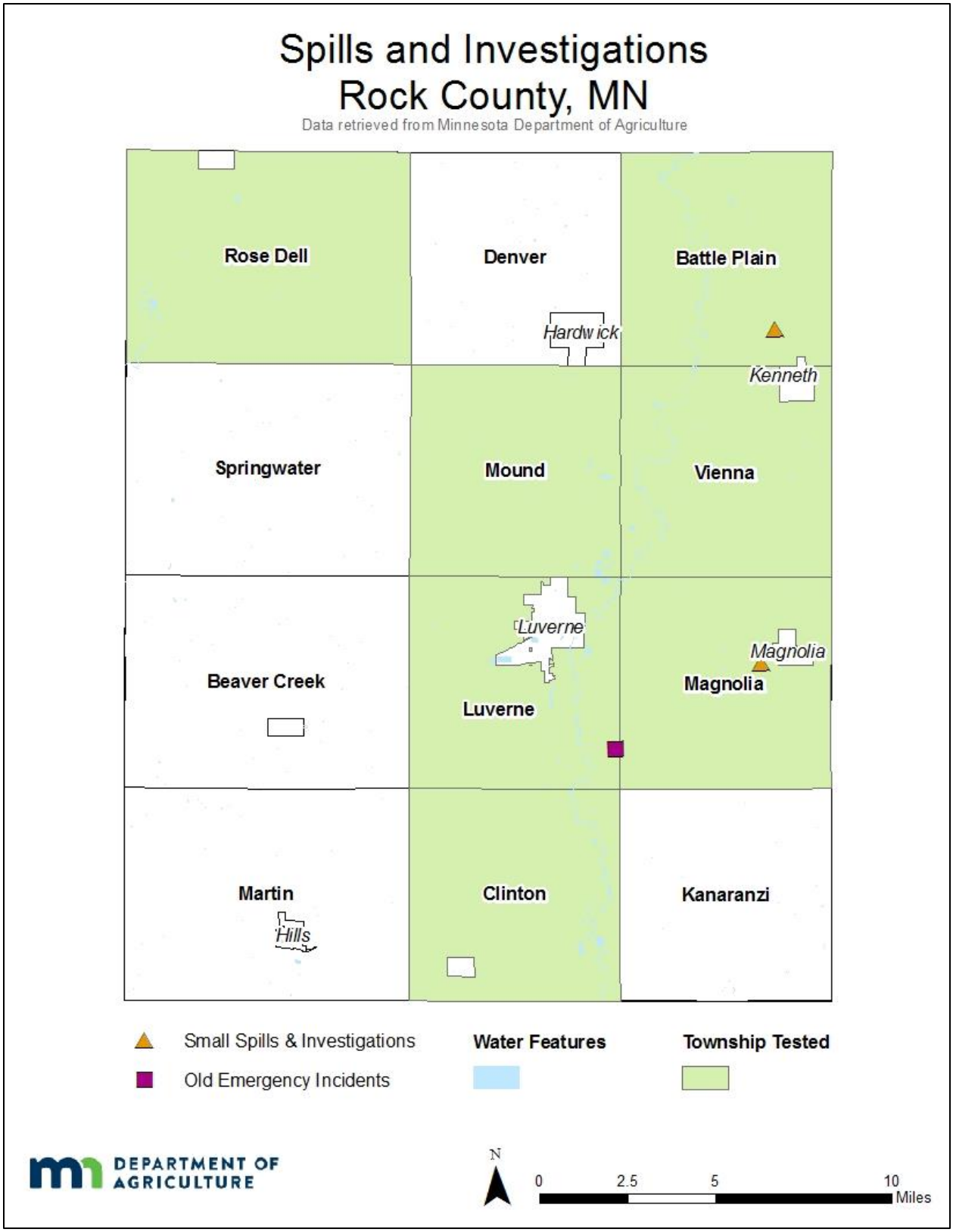


Figure 10. Fertilizer Spills and Investigations in Rock County (MDA, 2017)

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

Contaminant	Incident Investigations	Contingency Areas	Small Spills and Investigations	Old Emergency Incidents	Total
Fertilizer	0	0	1	1	1
Pesticides & Fertilizer	0	0	0	0	0
Anhydrous Ammonia	0	0	1	1	2
Total	0	0	2	1	3

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

Township	Incidents and Spills
Battle Plain	1
Clinton	0
Luverne	1
Magnolia	1
Mound	0
Rose Dell	0
Vienna	0
Total	3

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. Rock County is dominated by agriculture (Figure 11; Table 14). Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, durum wheat, dry beans and double crops involving corn and soybeans.

Rock County is located in the southwest corner of the state. It shares its southern border with Iowa and its western border with South Dakota. There is essentially no open water and wetlands are scarce in this landscape. The majority of the land in the study area of Rock County is classified as row crops. At about 85%, Clinton and Magnolia Townships have the highest percentage of land classified as row crops (Figure 11; Table 14).

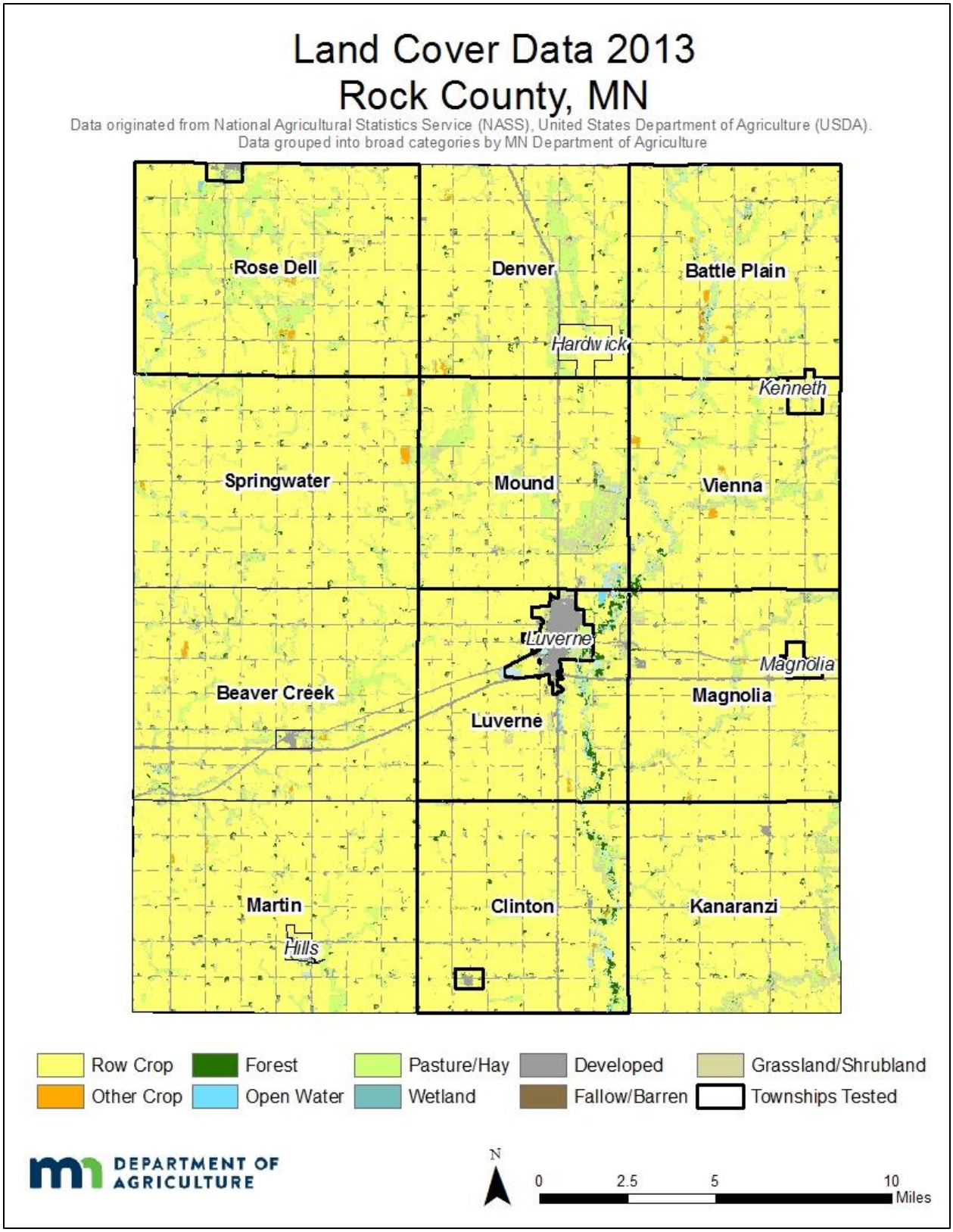


Figure 11. Land Cover in Rock County (USDA NASS, 2013)

Table 14. Land Cover Data (2013) by Township, Rock County (USDA NASS, 2013)

Township	Total Acres	Row Crop	Other Crops	Forest	Open Water	Pasture/ Hay	Wetland	Developed	Fallow/ Barren	Grassland/ Shrubland
Battle Plain	23,242	81%	1%	1%	0%	7%	4%	4%	0%	6%
Clinton	22,797	85%	0%	2%	0%	4%	1%	6%	0%	2%
Luverne	20,812	79%	0%	3%	0%	4%	1%	8%	0%	4%
Magnolia	22,565	85%	0%	1%	0%	4%	0%	6%	0%	4%
Mound	22,937	72%	0%	1%	0%	12%	0%	5%	0%	9%
Rose Dell	30,771	76%	0%	1%	0%	13%	0%	4%	0%	5%
Vienna	22,380	80%	1%	1%	0%	8%	0%	4%	0%	6%
Average	165,503*	80%	0%	1%	0%	8%	0%	5%	0%	5%

*Represents a total

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 48 active groundwater well permits in the study area and 9 are used for irrigating major crops (Figure 12). Over 470 acres of cropland is permitted for groundwater irrigation in this area (Table 15). Most permitted wells are withdrawing groundwater from water table aquifer (Table 16; MDNR, 2017).

Table 15. Active Groundwater Use Permits by Township, Rock County

Township	Major Crop Irrigation Well Permits	Average Depth (feet)	Acres Permitted
Battle Plain	0	NA	NA
Clinton	0	NA	NA
Luverne	0	NA	NA
Magnolia	5	43	222
Mound	0	NA	NA
Rose Dell	0	NA	NA
Vienna	4	106	250
Total	9	71*	472

* Represents an average value

Table 16. Active Groundwater Use Permits by Aquifer, Rock County

Water Use Well Permits	Total Wells	Average Depth (feet)	Aquifer System			
			Quaternary (Water Table)	Quaternary (Buried)	Precambrian	Not Classified
Major Crop Irrigation	9	71	6	3	0	0
Non-Crop Irrigation	1	33	1	0	0	0
Waterworks	29	32	23	0	0	6
Industrial Processing	1	15	1	0	0	0
Special Categories **	8	264	0	4	2	2
Total	48	77*	31	7	2	8

* Represents an average value

** All Special Categories displayed on the map and table are for Livestock Watering.

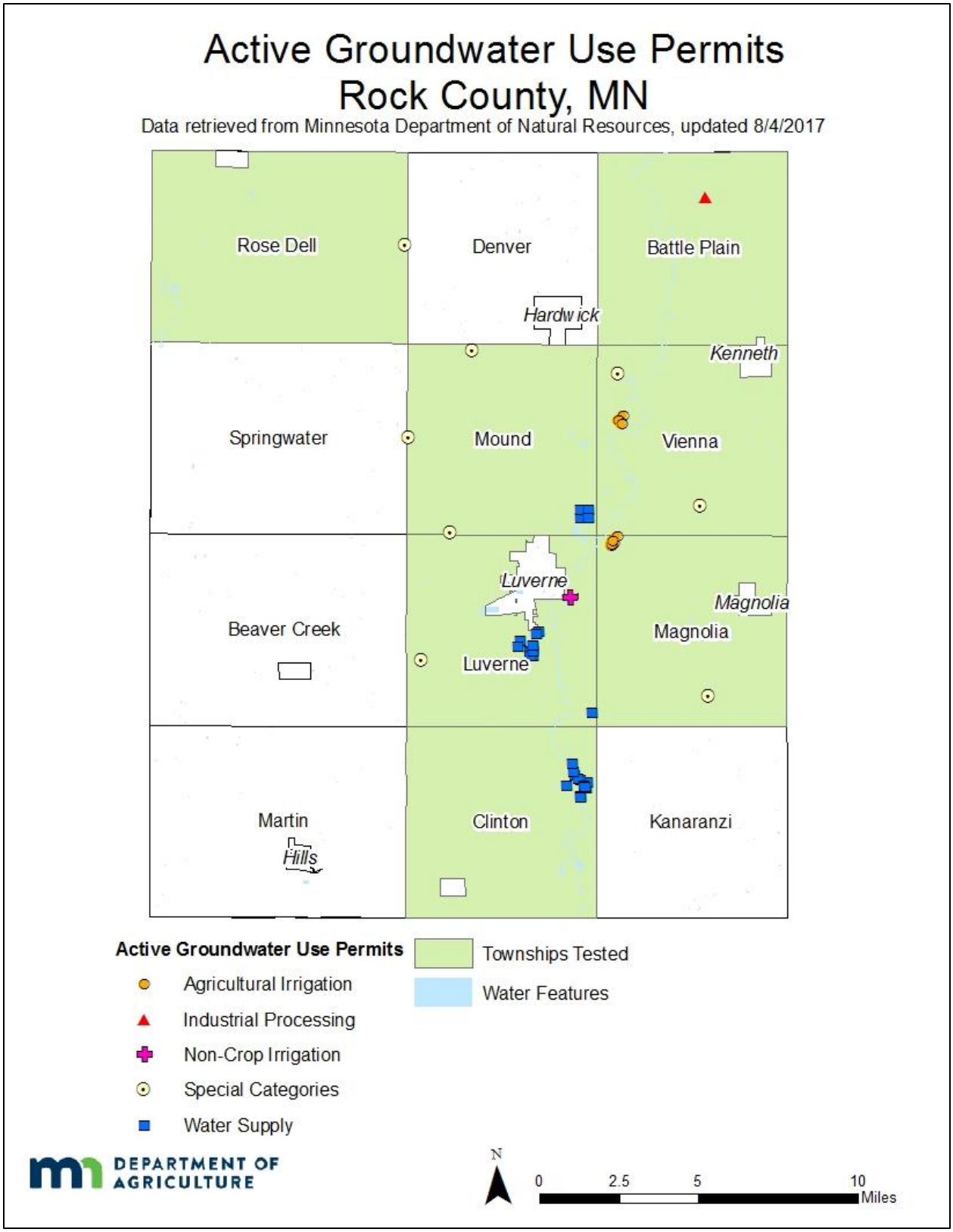


Figure 12. Active Groundwater Use Permits in Rock County (MDNR, 2017)

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 17. Reasons Wells Were Removed from the Final Well Dataset by Township, Rock County

Township	Point Source	Well Construction Problem	Bored Well	Hand Dug Well	Irrigation	Unsure of water source	Site Visit Completed - Well Not Found & Constructed before 1975 or Age Unknown & No Well ID	No Site Visit & Constructed before 1975 or Age Unknown & No Well ID	No Site Visit & Insufficient Data & No Well ID	Total
Battle Plain	2	1	8	2	0	0	0	5	1	19
Clinton	0	1	0	1	0	0	0	6	0	8
Luverne	1	2	8	2	0	1	0	6	0	20
Magnolia	0	0	2	1	0	2	0	8	2	15
Mound	8	5	0	1	0	1	0	5	0	20
Rose Dell	3	4	1	0	0	1	0	4	3	16
Vienna	4	0	1	0	0	0	0	7	2	14
Total	18	13	20	7	0	5	0	41	8	112

Table 18. Completed Site Visits for Wells Removed from the Final Well Dataset by Township, Rock County

Township	Site Visit	No Site Visit	Total
Battle Plain	10	9	19
Clinton	1	7	8
Luverne	11	9	20
Magnolia	4	11	15
Mound	9	11	20
Rose Dell	9	7	16
Vienna	2	12	14
Total	46	66	112

APPENDIX F

MINNESOTA WELL INDEX

The MWI was used to gather information about the seven townships in Rock County included in the study. This section includes all drinking water wells in the study area, not just wells MDA sampled. Table 19 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 140 documented (have a verified location in the MWI) wells:

- The majority of wells (65 percent) are completed in Quaternary aquifers.
    - Twenty-four percent of wells were completed in the Quaternary Water Table Aquifer (QWTA) and are 34.5 feet deep on average.
    - Thirty-eight percent of wells were completed in the Quaternary buried aquifer and are 143 feet deep on average.
    - The majority of the wells withdrawing from Quaternary aquifer were found in Clinton and Luverne townships.
- On average cretaceous aquifers are utilized in only six percent of the wells. The average depth is 307.5 feet deep.
- No wells were completed in the Paleozoic (Pre-Cretaceous) aquifers.
- Nearly a quarter (23% percent) of wells were completed in the Precambrian aquifers. In Rock County these aquifers are exclusively composed of Sioux Quartzite. These are primarily located in the northern Rock County, in Mound and Rosedell townships.
- Only two wells were completed in Weathering Residuum and averaged 242.5 feet deep.

Table 19. Aquifer Type Distribution of Wells in Minnesota Well Index by Township, Rock County

Township	Quaternary Water Table	Quaternary Buried	Quaternary Undifferentiated	Cretaceous	Paleozoic	Precambrian Sioux Quartzite	Weathering Residuum	Intermediate or Multiple	Undesignated	Total
	Number of wells drawing water from an aquifer									
Battle Plain	5	7	0	0	NA	0	1	0	0	13
Clinton	14	10	1	3	NA	0	0	0	0	28
Luverne	10	13	0	1	NA	0	0	1	0	25
Magnolia	1	10	1	3	NA	1	0	0	0	16
Mound	0	3	0	0	NA	17	0	2	1	23
Rosedell	0	3	0	0	NA	13	0	0	1	17
Vienna	4	7	2	1	NA	1	1	2	0	18
Total	34	53	4	8	NA	32	2	5	2	140
Average Well Depth (feet)	34.5	143.0	24.0	307.5	NA	308.5	242.5	274.8	300.0	168.8

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 20. Property Setting for Well Location

Township	Total	Country	River home	Lake Home	Sub-division	Other	Not available
Battle Plain	23	69.6%	0.0%	0.0%	0.0%	0.0%	30.4%
Clinton	10	80.0%	0.0%	0.0%	0.0%	0.0%	20.0%
Luverne	37	78.4%	8.1%	0.0%	2.7%	0.0%	10.8%
Magnolia	20	85.0%	0.0%	0.0%	0.0%	0.0%	15.0%
Mound	28	89.3%	0.0%	0.0%	0.0%	0.0%	10.7%
Rose Dell	30	83.3%	3.3%	0.0%	0.0%	0.0%	13.3%
Vienna	23	73.9%	0.0%	0.0%	0.0%	0.0%	26.1%
Total	171	80.1%	2.3%	0.0%	0.6%	0.0%	17.0%

Table 21. Well Construction Type

Township	Total	Drilled	Sand point	Hand dug	Other	Not available
Battle Plain	23	30.4%	0.0%	8.7%	8.7%	52.2%
Clinton	10	30.0%	10.0%	10.0%	0.0%	50.0%
Luverne	37	48.6%	2.7%	5.4%	10.8%	32.4%
Magnolia	20	20.0%	5.0%	5.0%	10.0%	60.0%
Mound	28	64.3%	3.6%	3.6%	0.0%	28.6%
Rose Dell	30	70.0%	0.0%	0.0%	0.0%	30.0%
Vienna	23	56.5%	4.3%	0.0%	8.7%	30.4%
Total	171	49.1%	2.9%	4.1%	5.8%	38.0%

Table 22. Age of Well

Township	Total	1994 to Present	1985 to 1993	1975 to 1984	Before 1975	Don't Know	Not available
Battle Plain	23	0.0%	0.0%	8.7%	43.5%	17.4%	30.4%
Clinton	10	0.0%	0.0%	10.0%	40.0%	30.0%	20.0%
Luverne	37	5.4%	10.8%	21.6%	27.0%	24.3%	10.8%
Magnolia	20	0.0%	0.0%	10.0%	40.0%	30.0%	20.0%
Mound	28	14.3%	7.1%	7.1%	32.1%	17.9%	21.4%
Rose Dell	30	13.3%	0.0%	3.3%	50.0%	20.0%	13.3%
Vienna	23	8.7%	8.7%	17.4%	34.8%	13.0%	17.4%
Total	171	7.0%	4.7%	11.7%	37.4%	21.1%	18.1%

Table 23. Depth of Well

Township	Total	0-15 feet	16-49 feet	50-99 feet	100-299 feet	≥300 feet	Not Available
Battle Plain	23	8.7%	21.7%	17.4%	17.4%	0.0%	34.8%
Clinton	10	20.0%	40.0%	0.0%	0.0%	10.0%	30.0%
Luverne	37	13.5%	35.1%	8.1%	18.9%	2.7%	21.6%
Magnolia	20	5.0%	50.0%	10.0%	5.0%	5.0%	25.0%
Mound	28	10.7%	10.7%	7.1%	14.3%	39.3%	17.9%
Rose Dell	30	0.0%	10.0%	20.0%	33.3%	16.7%	20.0%
Vienna	23	0.0%	26.1%	17.4%	26.1%	8.7%	21.7%
Total	171	7.6%	25.7%	12.3%	18.7%	12.3%	23.4%

Table 24. Unique Well ID Known

Township	Total	No, Unique Well ID not known	Yes, Unique Well ID known	Not Available
Battle Plain	23	30.4%	4.3%	65.2%
Clinton	10	30.0%	0.0%	70.0%
Luverne	37	32.4%	0.0%	67.6%
Magnolia	20	45.0%	0.0%	55.0%
Mound	28	35.7%	3.6%	60.7%
Rose Dell	30	26.7%	6.7%	66.7%
Vienna	23	34.8%	4.3%	60.9%
Total	171	33.3%	2.9%	63.7%

Table 25. Livestock Located on Property

Township	Total	No Livestock	Yes Livestock	Not available
Battle Plain	23	39.1%	30.4%	30.4%
Clinton	10	80.0%	10.0%	10.0%
Luverne	37	81.1%	8.1%	10.8%
Magnolia	20	75.0%	10.0%	15.0%
Mound	28	42.9%	42.9%	14.3%
Rose Dell	30	46.7%	40.0%	13.3%
Vienna	23	43.5%	34.8%	21.7%
Total	171	57.3%	26.3%	16.4%

Table 26. Fertilizer Stored on Property

Township	Total	No Fertilizer Stored	Yes Fertilizer Stored	Not Available
Battle Plain	23	69.6%	0.0%	30.4%
Clinton	10	90.0%	0.0%	10.0%
Luverne	37	89.2%	0.0%	10.8%
Magnolia	20	85.0%	0.0%	15.0%
Mound	28	78.6%	7.1%	14.3%
Rose Dell	30	83.3%	3.3%	13.3%
Vienna	23	69.6%	8.7%	21.7%
Total	171	80.7%	2.9%	16.4%

Table 27. Farming on Property

Township	Total	No Farming	Yes Farming	Not available
Battle Plain	23	8.7%	60.9%	30.4%
Clinton	10	30.0%	60.0%	10.0%
Luverne	37	62.2%	27.0%	10.8%
Magnolia	20	45.0%	40.0%	15.0%
Mound	28	17.9%	67.9%	14.3%
Rose Dell	30	33.3%	53.3%	13.3%
Vienna	23	26.1%	52.2%	21.7%
Total	171	33.9%	49.7%	16.4%

Table 28. Distance to an Active or Inactive Feedlot

Township	Total	0-49 feet to Feedlot	50-99 feet to Feedlot	100-299 feet to Feedlot	≥300 feet to Feedlot	Not Available
Battle Plain	23	4.3%	13.0%	0.0%	47.8%	34.8%
Clinton	10	10.0%	0.0%	50.0%	20.0%	20.0%
Luverne	37	2.7%	2.7%	21.6%	56.8%	16.2%
Magnolia	20	0.0%	5.0%	5.0%	65.0%	25.0%
Mound	28	21.4%	7.1%	25.0%	28.6%	17.9%
Rose Dell	30	10.0%	16.7%	16.7%	43.3%	13.3%
Vienna	23	0.0%	21.7%	13.0%	47.8%	17.4%
Total	171	7.0%	9.9%	17.0%	46.2%	19.9%

Table 29. Distance to Septic System

Township	Total	0-49 Feet to Septic	50-99 Feet to Septic	100-299 Feet to Septic	≥300 Feet to Septic	Not Available
Battle Plain	23	0.0%	4.3%	26.1%	30.4%	39.1%
Clinton	10	10.0%	10.0%	30.0%	30.0%	20.0%
Luverne	37	13.5%	13.5%	45.9%	16.2%	10.8%
Magnolia	20	0.0%	5.0%	50.0%	25.0%	20.0%
Mound	28	3.6%	14.3%	25.0%	42.9%	14.3%
Rose Dell	30	0.0%	10.0%	43.3%	33.3%	13.3%
Vienna	23	4.3%	26.1%	26.1%	26.1%	17.4%
Total	171	4.7%	12.3%	36.3%	28.7%	18.1%

Table 30. Distance to an Agricultural Field

Township	Total	0-49 feet to Field	50-99 feet to Field	100-299 feet to Field	≥300 feet to Field	Not Available
Battle Plain	23	17.4%	0.0%	17.4%	26.1%	39.1%
Clinton	10	20.0%	10.0%	50.0%	10.0%	10.0%
Luverne	37	10.8%	5.4%	32.4%	37.8%	13.5%
Magnolia	20	35.0%	10.0%	25.0%	10.0%	20.0%
Mound	28	0.0%	14.3%	21.4%	46.4%	17.9%
Rose Dell	30	3.3%	10.0%	36.7%	36.7%	13.3%
Vienna	23	4.3%	17.4%	21.7%	34.8%	21.7%
Total	171	11.1%	9.4%	28.1%	32.2%	19.3%

Table 31. Drinking Water Well

Township	Total	Not Drinking Water	Yes, Drinking Water	Not Available
Battle Plain	23	17.4%	52.2%	30.4%
Clinton	10	30.0%	60.0%	10.0%
Luverne	37	24.3%	64.9%	10.8%
Magnolia	20	45.0%	40.0%	15.0%
Mound	28	3.6%	85.7%	10.7%
Rose Dell	30	3.3%	83.3%	13.3%
Vienna	23	26.1%	47.8%	26.1%
Total	171	19.3%	64.3%	16.4%

Table 32. Treatment System Present (Treatment System Used for Drinking Water)

Township	Total	None	Distillation	Filtering System	Reverse Osmosis	Other	Not Available
Battle Plain	23	47.8%	0.0%	4.3%	17.4%	0.0%	30.4%
Clinton	10	80.0%	0.0%	0.0%	10.0%	0.0%	10.0%
Luverne	37	67.6%	0.0%	5.4%	16.2%	0.0%	10.8%
Magnolia	20	50.0%	0.0%	5.0%	20.0%	0.0%	25.0%
Mound	28	53.6%	0.0%	10.7%	21.4%	0.0%	14.3%
Rose Dell	30	53.3%	0.0%	16.7%	13.3%	0.0%	16.7%
Vienna	23	47.8%	0.0%	8.7%	17.4%	0.0%	26.1%
Total	171	56.1%	0.0%	8.2%	17.0%	0.0%	18.7%

Table 33. 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	Homeowner Unsure	Not Available
Battle Plain	23	4.3%	8.7%	13.0%	8.7%	13.0%	21.7%	30.4%
Clinton	10	10.0%	0.0%	0.0%	40.0%	30.0%	10.0%	10.0%
Luverne	37	8.1%	13.5%	16.2%	8.1%	16.2%	27.0%	10.8%
Magnolia	20	0.0%	0.0%	10.0%	30.0%	35.0%	10.0%	15.0%
Mound	28	3.6%	0.0%	25.0%	25.0%	3.6%	28.6%	14.3%
Rose Dell	30	0.0%	3.3%	10.0%	20.0%	20.0%	33.3%	13.3%
Vienna	23	0.0%	4.3%	4.3%	21.7%	17.4%	30.4%	21.7%
Total	171	3.5%	5.3%	12.9%	19.3%	17.5%	25.1%	16.4%

Table 34. Last Nitrate Test Result

Township	Total	<3 mg/L Nitrate-N	3<10 mg/L Nitrate-N	≥10 mg/L Nitrate-N	Not Available
Battle Plain	23	0.0%	4.3%	4.3%	91.3%
Clinton	10	10.0%	0.0%	10.0%	80.0%
Luverne	37	10.8%	2.7%	5.4%	81.1%
Magnolia	20	5.0%	0.0%	0.0%	95.0%
Mound	28	3.6%	0.0%	14.3%	82.1%
Rose Dell	30	3.3%	0.0%	0.0%	96.7%
Vienna	23	8.7%	0.0%	0.0%	91.3%
Total	171	5.8%	1.2%	4.7%	88.3%

APPENDIX I

Table 35. Well Construction Type for Final Well Dataset

Township	Samples	Drilled	Sand Point	Bored Well	Not Available
Battle Plain	4	2	0	0	2
Clinton	2	1	0	0	1
Luverne	17	13	2	0	2
Magnolia	5	1	0	0	4
Mound	8	5	0	0	3
Rose Dell	14	13	0	0	1
Vienna	9	4	0	1	4
Total	59	39	2	1	17

Data compiled from well logs and homeowner responses.

Table 36. Well Depth for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Battle Plain	1	32	32	32	32
Clinton	1	36	36	36	36
Luverne	5	32	327	120	170
Magnolia	1	30	30	30	30
Mound	4	58	380	296	258
Rose Dell	3	186	395	326	302
Vienna	3	60	207	104	124
Total	18	30	395	153	181

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

Table 37. Year of Well Construction for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Battle Plain	1	2005	2005	2005	2005
Clinton	1	2015	2015	2015	2015
Luverne	5	1976	2011	1998	1992
Magnolia	0	NA	NA	NA	NA
Mound	4	2004	2013	2006	2007
Rose Dell	3	1999	2012	2003	2004
Vienna	3	1958	2014	1988	1986
Total	17	1958	2015	2004	1999

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

Township	Samples	Min	Max	Median	Mean
Battle Plain	1	15.20	15.20	15.20	15.20
Clinton	0	NA	NA	NA	NA
Luverne	4	10.52	15.31	11.93	12.42
Magnolia	0	NA	NA	NA	NA
Mound	1	10.42	10.42	10.42	10.42
Rose Dell	5	9.79	14.01	10.61	11.58
Vienna	1	12.13	12.13	12.13	12.13
Total	12	9.79	15.31	11.93	12.11

Table 39. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Battle Plain	1	7.21	7.21	7.21	7.21
Clinton	0	NA	NA	NA	NA
Luverne	4	7.15	7.34	7.20	7.22
Magnolia	0	NA	NA	NA	NA
Mound	1	7.13	7.13	7.13	7.13
Rose Dell	5	6.94	7.51	7.37	7.29
Vienna	1	7.39	7.39	7.39	7.39
Total	12	6.94	7.51	7.23	7.25

Table 40. Specific Conductivity (µS/cm) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Battle Plain	1	1,078	1,078	1,078	1,078
Clinton	0	NA	NA	NA	NA
Luverne	4	811	1,487	1,000	1,075
Magnolia	0	NA	NA	NA	NA
Mound	1	472	472	472	472
Rose Dell	5	481	642	530	543
Vienna	1	1,351	1,351	1,351	1,351
Total	12	472	1,487	727	826

Table 41. Dissolved Oxygen (mg/L) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Battle Plain	1	2.67	2.67	2.67	2.67
Clinton	0	NA	NA	NA	NA
Luverne	4	0.10	1.06	0.15	0.37
Magnolia	0	NA	NA	NA	NA
Mound	1	3.15	3.15	3.15	3.15
Rose Dell	5	4.21	10.06	5.81	6.28
Vienna	1	0.17	0.17	0.17	0.17
Total	12	0.10	10.06	2.91	3.24