FINAL TOWNSHIP TESTING NITRATE REPORT: NOBLES COUNTY 2016-2017

October 2019

Minnesota Department of Agriculture

Pesticide and Fertilizer Management Division

ACKNOWLEDGEMENTS

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FUNDING

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

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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 Nobles County study area (four 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 45 wells representing an average response rate of 18 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, 77.8 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 601 residents could be consuming well water with nitrate-N at or over the HRL. However, this estimate may be high since many households are on a rural water supply.

The MDA completed follow-up sampling and well site visits at 12 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 35 (78 percent) wells were determined to be unsuitable and were

removed from the dataset. The final well dataset for the entire study area only had a total of 10 wells.

In two of the four townships, 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 33 to 67 percent. However, it is important to note that in Grand Prairie Township there were no wells left in the data set and that in the remaining three townships there were 4 or less samples in each township. The final data set is not adequate to characterize a township in terms of private drinking water wells.

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 March 2019, 306 townships in 42 counties have completed the initial sampling with the goal of providing nitrate testing in over 300 vulnerable townships by 2019.

In 2016, four townships in Nobles 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 Nobles 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, please visit the following webpages:
www.mda.state.mn.us/nfmp
www.mda.state.mn.us/townshiptesting

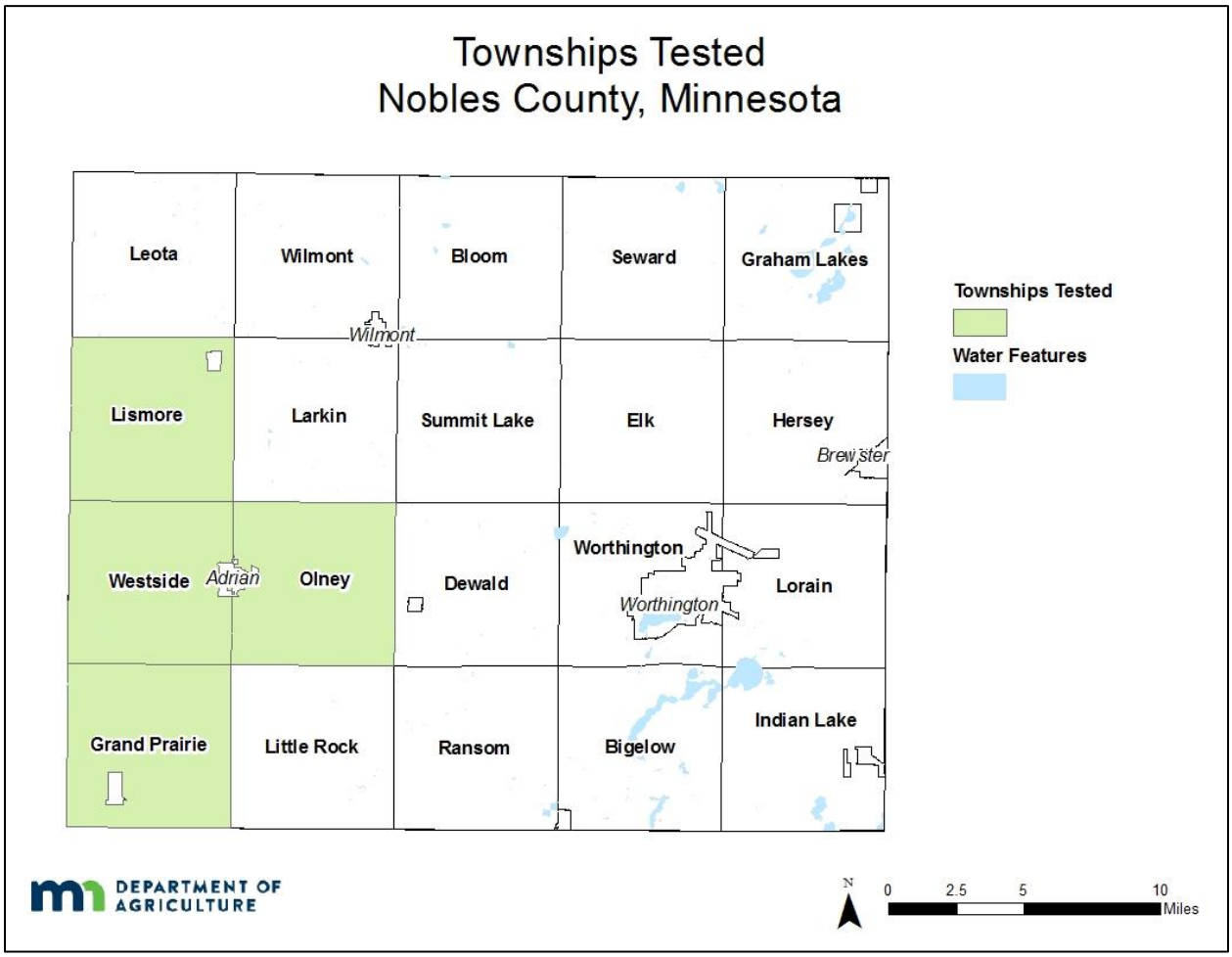

Figure 1. Townships Tested in Nobles County

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. The geomorphology of the study area in Nobles County shows that the area is a mix of glacial outwash and till plain (MPCA, 1998). The outwash and drift are both low in organic carbon, because of this denitrification is often limited. The combination of low denitrification and intensive row crop agriculture makes the area particularly vulnerable to elevated nitrate concentrations. However, geochemical conditions can be highly variable within an aquifer or region and can also change over-time (MPCA, 1998).

GEOLOGY AND HYDROGEOLOGY

The geology in Nobles County is heavily influenced by glacial deposits. The glacial deposits are comprised of fine textured till (which is unsorted, unstratified sediment) and scattered buried outwash deposits. Outwash is material consisting primarily of sand and gravel that was deposited by running water that flowed from melting ice during the last glacial period.

The glacial till can be divided into two different types of deposits (MDNR, MGS, UMD, 1997). In eastern Nobles County the till is defined as supraglacial drift complex. Supraglacial drift complex was sediment that accumulated on top of a glacier and became deposited when the ice melted beneath it, it then formed lateral and medial moraines. In western Nobles County, which the four townships in the study are located, is classified as till plain. This plain was deposited when a piece of the main body of a glacier broke off and melted in place.

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 Nobles County as presented in Figure 2.

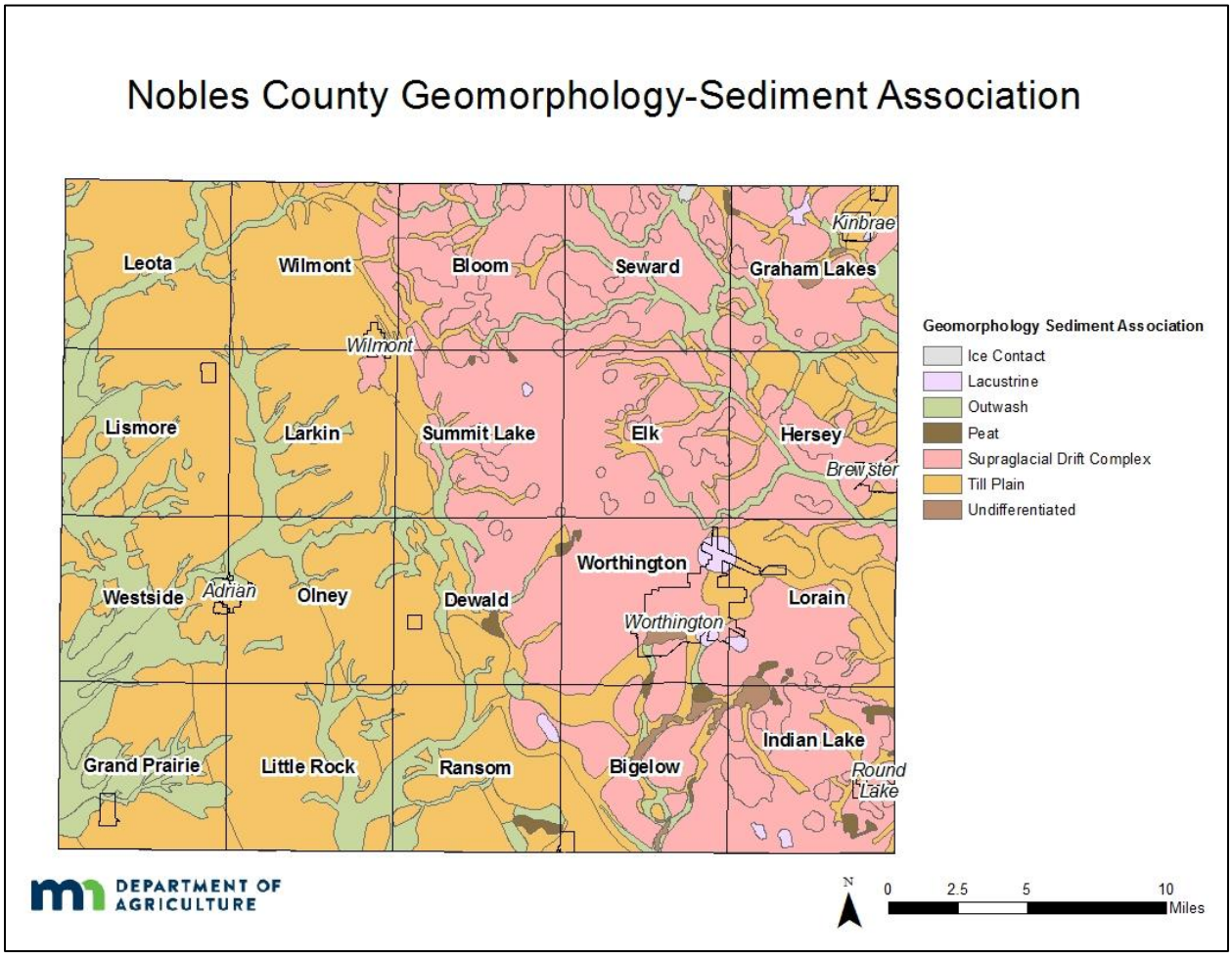

Figure 2. Statewide Geomorphology Layer, Sediment Association in Nobles County (MDNR, MGS, UMD, 1997)

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 Nobles 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 2,385 SSTS were reported in Nobles County for 2016. Over a recent 15-year period (2002-2016), 543 construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Nobles County, 23 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 Nobles County study area, there are a total of 141 active feedlots. The majority of the feedlots are permitted to house between 300 and 999 animal units (AU) (Appendix B; Figure 9). Lismore Township has the most active feedlot while Olney Township houses the largest permitted feedlots and has the most permitted AU per square mile (Appendix B; Table 11).

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 Nobles County study area does not have any fertilizer storage locations (Appendix B, Table 12).

FERTILIZER SPILLS AND INVESTIGATIONS

There was 1 historic fertilizer spill and investigation that occurred in the Nobles County study area. This was a small spill and investigation incident in Olney Township (Appendix B; Table 13).

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.

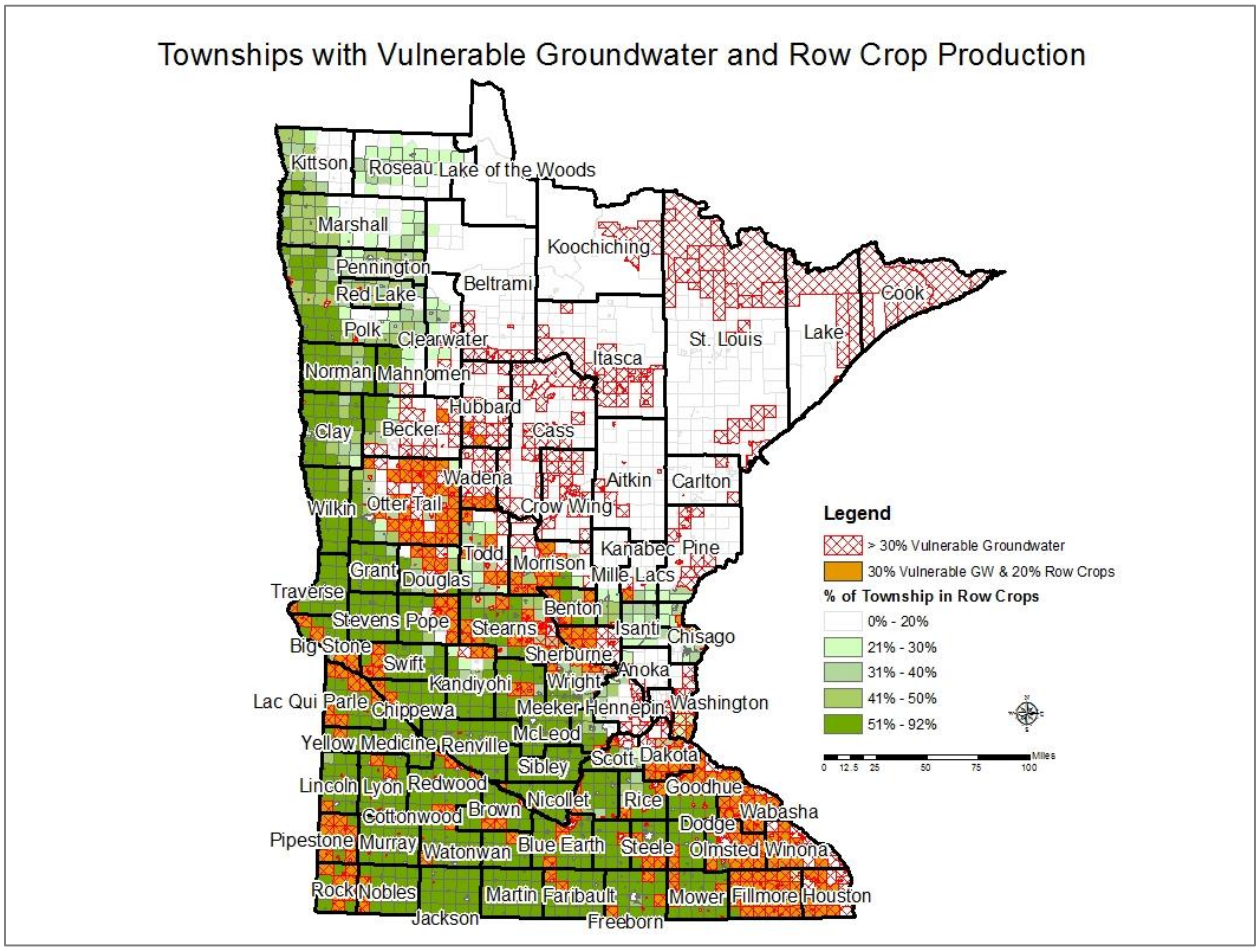

Figure 3. Minnesota Townships with Vulnerable Groundwater and Row Crop Production

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 Nobles 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
Outwash, Ice Contact	High
Supraglacial Drift Complex, Peat, Lacustrine	Medium
Till Plain	Low

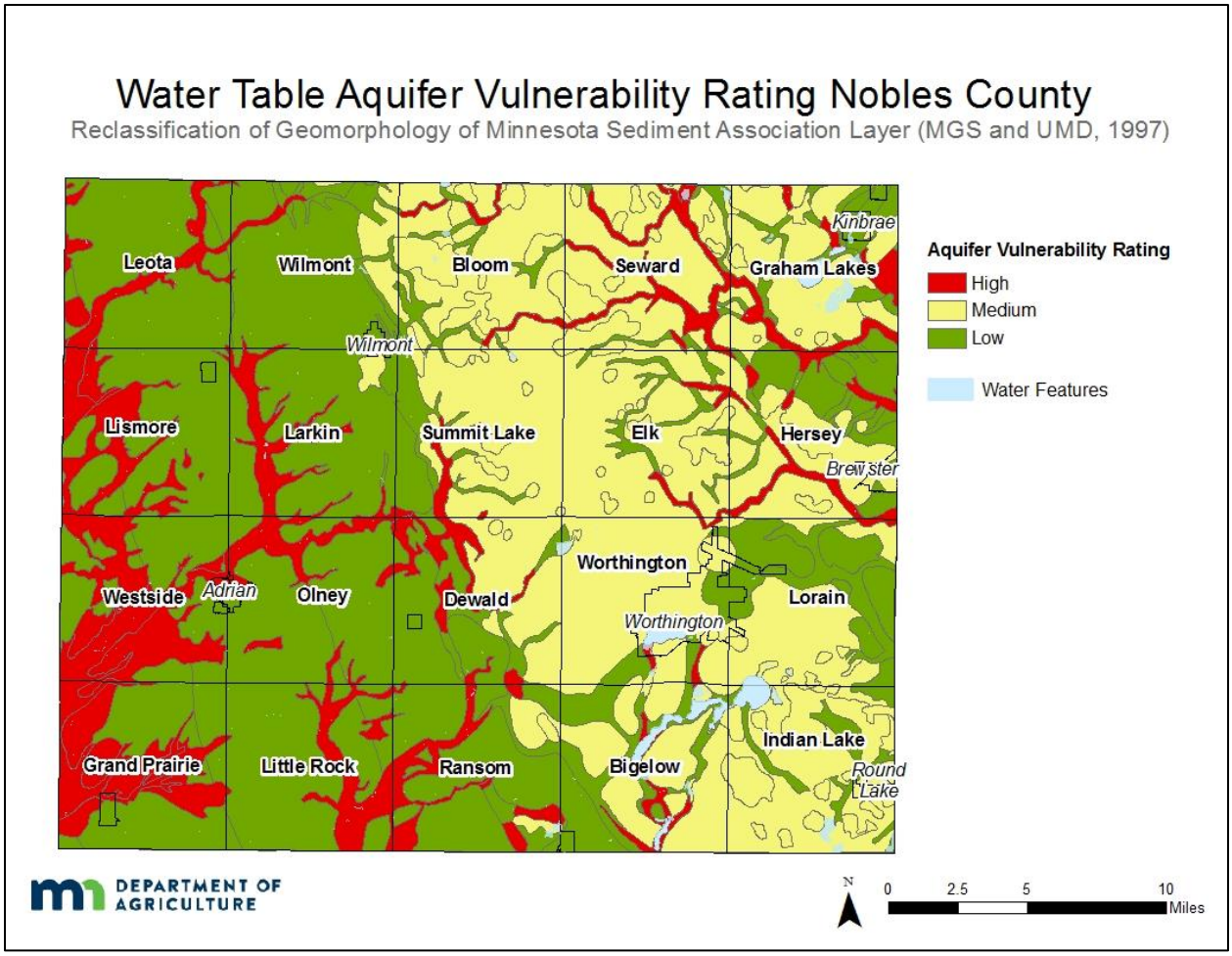

Figure 4. Water Table Aquifer Vulnerability Rating in Nobles County

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 Nobles County can be found in Appendix C (Figure 11, Table 15). On average 84 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 45 homeowners using the mail-in kit (Table 2). These 45 samples are considered the “initial well dataset”. On average, 18 percent of the homeowners in these townships responded to the free nitrate test offered by MDA.

All 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 were conducted in 2017 by MDA staff. A total of 12 follow-up samples were analyzed (Table 2).

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

Township	Kits Sent	Initial Well Dataset	Response Rate for Initial Samples	Well Site Visits & Follow-Up Sampling Conducted
Grand Prairie	67	14	21%	3
Lismore	56	7	13%	2
Olney	58	9	16%	3
Westside	67	15	22%	4
Total	248	45	18%	12

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 35 wells were removed to create the final well dataset. See Appendix E (Table 18 and 19) 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, wells with cracked casing or bored wells due to their susceptibility to pollution. Wells with significant problems such as these were excluded from the final well dataset.

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 45 well owners returned water samples for analysis across the four 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 for all townships were less than the detection limit (<DL) which is 0.03 mg/L. The maximum values ranged from 29.0 to 76.7 mg/L, with Lismore having the highest result. Median values range from 9.4 to 17.9 mg/L, with Westside Township having the highest median value. The 90th percentiles range from 28.4 to 57.4 mg/L, with Olney Township having the highest 90th percentile.

Initial results from the sampling showed that in Grand Prairie, Lismore, Olney, and Westside Townships, ten percent or more of the wells were 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 Grand Prairie, Lismore, Olney, Westside 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.

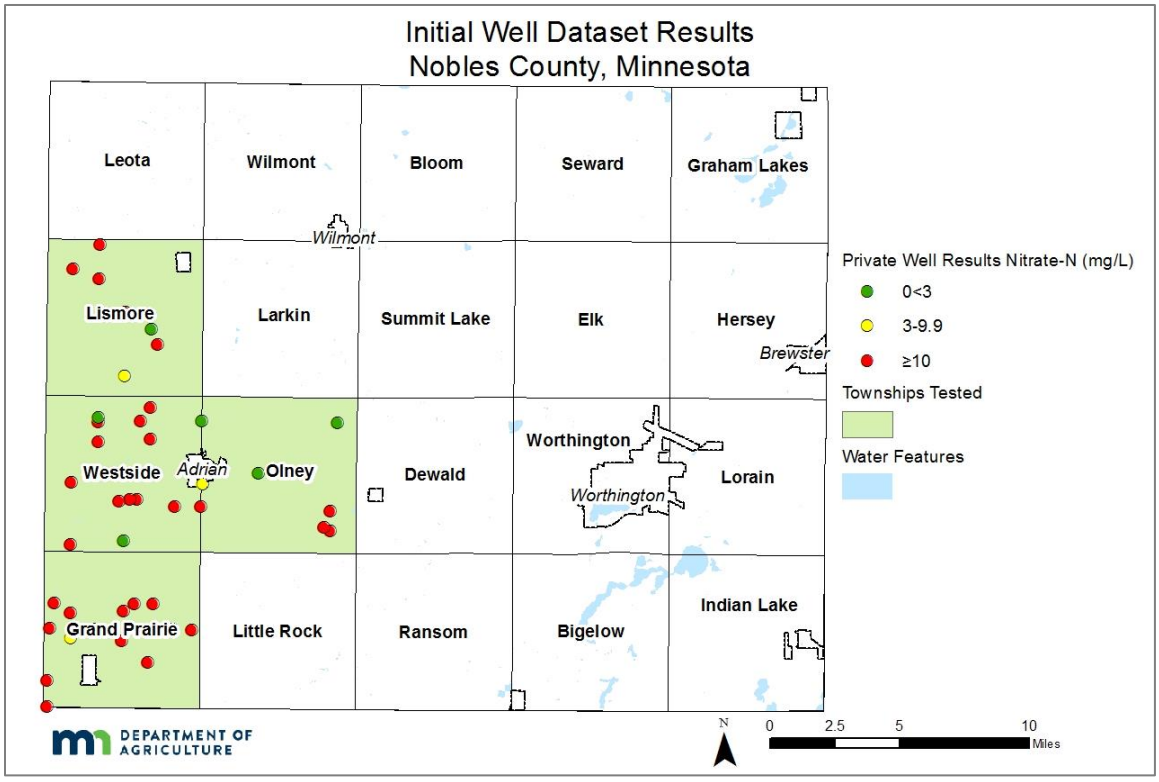

Figure 5. Well Locations and Nitrate Results from Initial Dataset in Nobles County

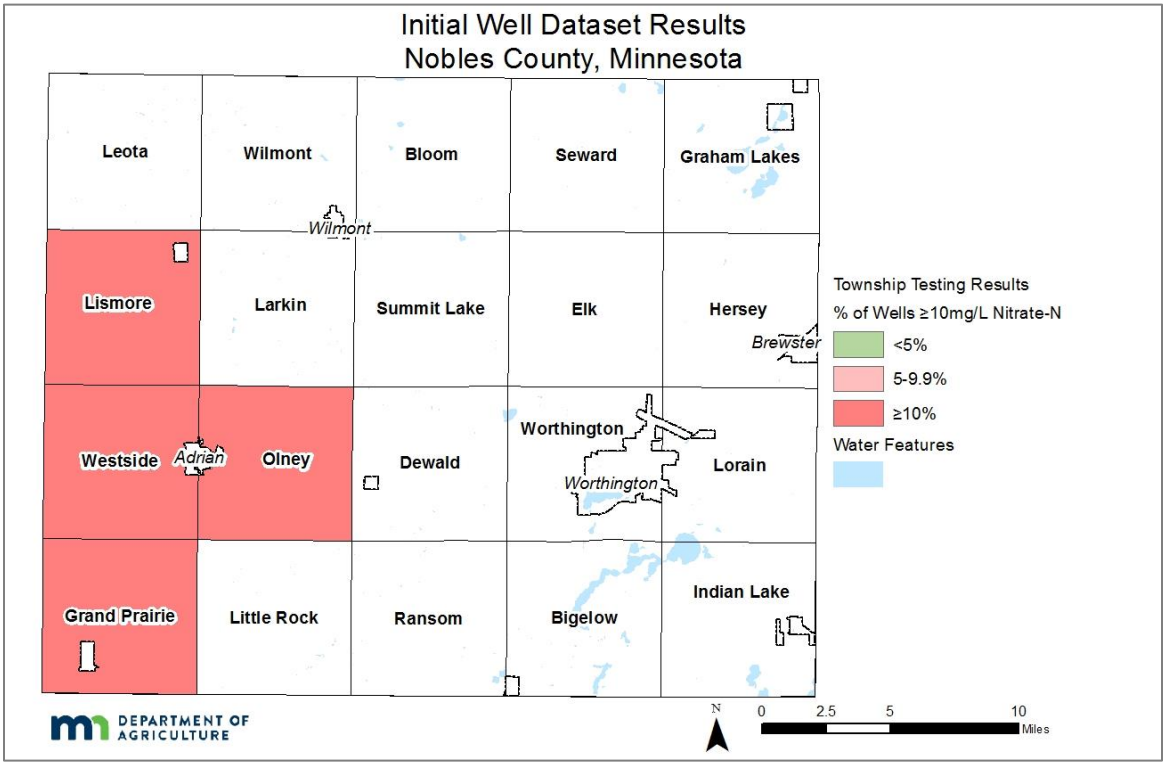

Figure 6. Results of the Initial Testing by Township

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

Township	Total Wells	Values			Percentiles					Number of Wells					Percentage 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 ppm																	
Grand Prairie	14	5.760	52.7	20.6	17.7	22.4	35.9	49.0	53	0	1	14	13	13	0.0%	7.1%	100.0%	92.9%	92.9%
Lismore	7	0.032	29.0	16.1	15.9	24.7	28.4	29.0	29	1	1	6	5	5	14.3%	14.3%	85.7%	71.4%	71.4%
Olney	9	0.038	76.7	17.5	9.4	23.8	57.4	76.7	77	3	2	6	5	4	33.3%	22.2%	66.7%	55.6%	44.4%
Westside	15	0.668	45.6	18.5	17.9	23.2	37.1	43.5	46	2	0	13	13	13	13.3%	0.0%	86.7%	86.7%	86.7%
Total	45	0.032	76.7	18.6	17.3	22.7	34.0	47.4	77	6	4	39	36	35	13.3%	8.9%	86.7%	80.0%	77.8%

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

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 601 people in Nobles County's study area have drinking water over the nitrate HRL (Table 4). Nitrate contamination is a significant problem across much of Nobles County. Additional public awareness and education programming will need to take place in many of the townships. The Lincoln-Pipestone Rural Water system is present in much of this area and therefore not all households in these townships are utilizing private water wells for their source of drinking water.

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

Township	Estimated Households on Private Wells*	Estimated Population on Private Wells*	Wells ≥10mg/L Nitrate-N (Percentage)	Estimated Population ≥10 mg/L Nitrate-N**
Grand Prairie	77	202	92.9%	188
Lismore	62	169	71.4%	121
Olney	62	194	44.4%	86
Westside	72	207	86.7%	179
Total	273	772	77.8%	601

* Data collected from the Minnesota State Demographic Center, 2016

** Estimates based off 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 (MGS, n.d.). 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 (MDH, 2018).

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 3 documented wells (Table 5). Approximately 57 percent of the sampled wells had corresponding well logs. Thus, the data gathered on aquifers represents a 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 20). The wells in these aquifers are relatively shallow, averaging 216 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 Nobles 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. The Quaternary Buried aquifer wells have more than ten feet of confining material (typically clay) between the land surface and the well screen (MPCA, 1998).

The sedimentary rocks from the Cretaceous aquifers have been eroded by glacial events and therefore can be distributed unevenly. Cretaceous aquifers are more prevalent in south and southwestern Minnesota and only scattered in western Sherburne (Lusardi, 2013).

The Paleozoic (Pre-Cretaceous) aquifer is dominated by sandstone and shale. Upper parts of this formation were eroded during the later Quaternary glaciation (Lusardi, 2013).

Precambrian aquifers are the deepest and geologically oldest depicted in this report. Concentrations of chemicals in these aquifers are defined by the rock parent material. Thus, chemicals such as boron and beryllium are more common in this aquifer than in others (MPCA, 1998).

Table 5. Nitrate Concentrations within Sampled Groundwater Aquifers

Aquifer Group	Average Depth (feet)	Total Wells	Number of Wells			Percent of Wells		
			<3	3<10	≥10	<3	3<10	≥10
			Nitrate-N mg/L or parts per million (ppm)					
Quaternary Water Table	51	1	0	0	1	0%	0%	100%
Quaternary Buried	102	2	1	0	1	50%	0%	50%
Unknown	NA	42	5	4	33	11.9%	9.5%	78.6%

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 21-35).

The majority of wells in each township are located on “country” or “rural” property. The remaining properties gave no answer.

Approximately 31 percent of sampled wells are of drilled construction and 49 percent of homeowners did not answer the question. Eighteen percent said that their well is in the “other” category. Only two homeowners said that they have hand dug wells. As mentioned previously hand dug wells are shallow and more sensitive to local surface runoff contamination than deeper drilled wells.

Approximately half of the wells in the townships are less than 100 feet deep. Lismore has the lowest percentage of wells less than 100 feet deep (42 percent) and Grand Prairie has the highest percent of wells less than 100 feet deep (64 percent).

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 21-35).

- Farming takes place on at least 60 percent of the properties.
- Agricultural fields are less than 300 feet from wells at 49 percent of the properties.
- Thirty-one 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.
- Forty-seven percent of wells are less than 300 feet from an active or inactive feedlot.
- Few well owners (7 percent) across all townships store more than 500 pounds of fertilizer on their property.
- A small minority of wells (less than 3 percent) are less than 50 feet away from septic systems.

FINAL RESULTS

FINAL WELL DATASET

A total of 45 well water samples were collected by homeowners across four townships. A total of 35 (78 percent) wells were found to be unsuitable and were removed to create the final well dataset. This is the highest percentage of wells that has been taken out of a county's data set since the inception of the program. One factor in the high removal rate is the small set of initial data, since many people in these areas are on rural water. The final analysis was conducted on the remaining 10 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. There were no wells left in Grand Prairie Township. The percent of wells at or over the HRL ranged from 0.0 to 66.7 percent.

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

Township	Initial Well Dataset	Final Well Dataset	Final Number of Wells ≥10 mg/L Nitrate	Final Percentage of Wells ≥10 mg/L Nitrate
Grand Prairie	14	0	NA	NA
Lismore	7	3	2	66.7%
Olney	9	4	0	0.0%
Westside	15	3	1	33.3%
Total	45	10	3	30.0%

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 5.6 to 29.0 mg/L nitrate, with Lismore having the highest result. The 90th percentile ranged from 5.6 to 29.0 mg/L nitrate-N, with Olney Township having the lowest result and Lismore Township having the highest result. However, it is important to note that in Grand Prairie Township there were no wells left in the dataset and that in the remaining three townships there were 4 or less samples 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 (Figure 8).

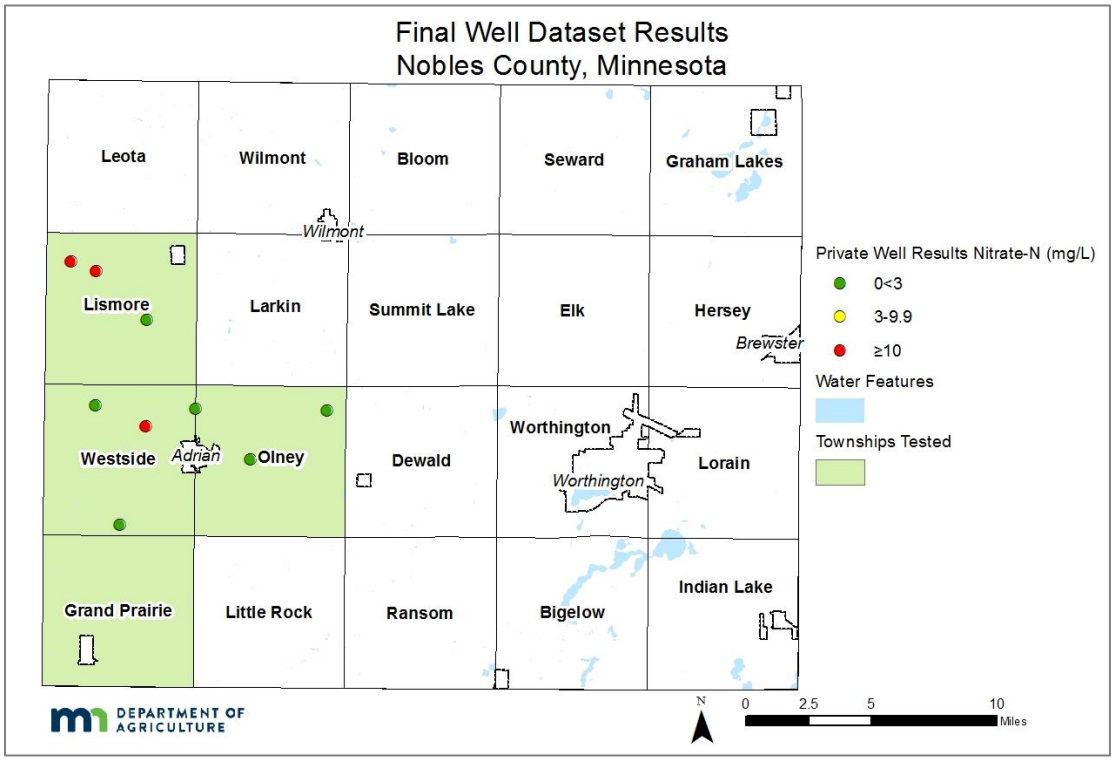

Figure 7. Well Locations and Nitrate Results from Final Well Dataset in Nobles County

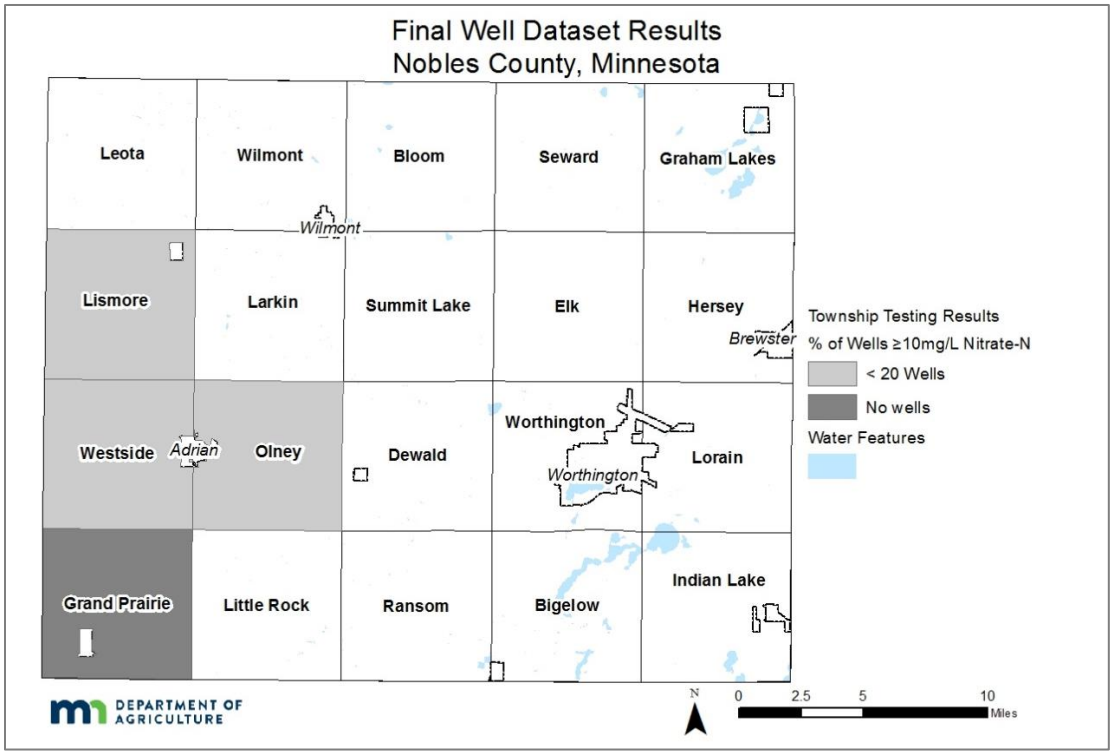

Figure 8. Final Township Results for Nobles County

Table 7. Nobles 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	3<10	≥5	≥7	≥10	<3	3<10	≥5	≥7	≥10
		Nitrate-N mg/L or ppm																	
Grand Prairie	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lismore	3	0.03	29.0	15.0	15.9	25.7	29.0	29.0	29.0	1	0	2	2	2	33.3%	0.0%	66.7%	66.7%	66.7%
Olney	4	0.04	5.6	1.8	0.7	3.4	5.6	13.9	13.9	3	1	1	0	0	75.0%	25.0%	25.0%	0.0%	0.0%
Westside	3	0.67	16.6	6.0	0.8	12.6	16.6	16.6	16.6	2	0	1	1	1	66.7%	0.0%	33.3%	33.3%	33.3%
Total	10	0.03	29.0	7.0	1.0	15.9	22.8	29.0	29.0	6	1	4	3	3	60.0%	10.0%	40.0%	30.0%	30.0%

*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, Nobles County

Township	Final Well Dataset	Percent Vulnerable Geologic Setting	Percent Row Crop	Final Percent of Wells ≥7 mg/L Nitrate-N	Final % of Wells ≥10 mg/L Nitrate-N
Grand Prairie	0	48%	85%	NA	NA
Lismore	3	33%	85%	66.7%	66.7%
Olney	4	18%	83%	0.0%	0.0%
Westside	4	53%	78%	33.3%	33.3%
Total	10	38%*	83%*	30.0%	30.0%

* Represents an average value

** Data retrieved from USDA NASS, 2013

WELL AND WATER CHARACTERISTICS

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells in the Nobles 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 are described below, and a more comprehensive view is provided in Appendix I (Tables 36-38).

- Half of the wells were drilled (75 percent), the other were unknown
- The median depth of wells was 116 feet, and the shallowest was 51 feet
- The median year the wells were constructed in was 1997

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 & 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 39-42).

- The temperatures ranged 13.35 °C to 16.1 °C
- The water from the wells had a median pH of 7.09
- The dissolved oxygen readings ranged from 0.82 mg/L to 5.76 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 Nobles County. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Approximately 84 percent of the land cover is row crop agriculture and there are over 240 acres of groundwater irrigation in the study area.

Four townships were sampled covering over 91,000 acres. The initial (homeowner collected) nitrate sampling resulted in 45 samples. The 45 households that participated represent approximately 18 percent of the population on private wells. The initial well dataset represents private well drinking water regardless of the potential source of nitrate. Well owners with measureable nitrate results were offered a follow-up nitrate sample and a pesticide sample. The MDA resampled and visited 12 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 35 (78 percent) wells were found to be unsuitable and were removed from the initial well dataset of 45 wells, leaving only 10 in the final data set. The remaining 10 wells are believed to be impacted by nitrogen fertilizer and are included in the final well dataset.

For the wells in the final well dataset, half of the wells were drilled. The median depth of the wells was 116 and depths ranged from 51 to 180 feet.

In two of the four townships, 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 33 to 67 percent. However, it is important to note that in Grand Prairie Township there were no wells left in the dataset and that in the remaining three townships there were 4 or less samples 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

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** _____

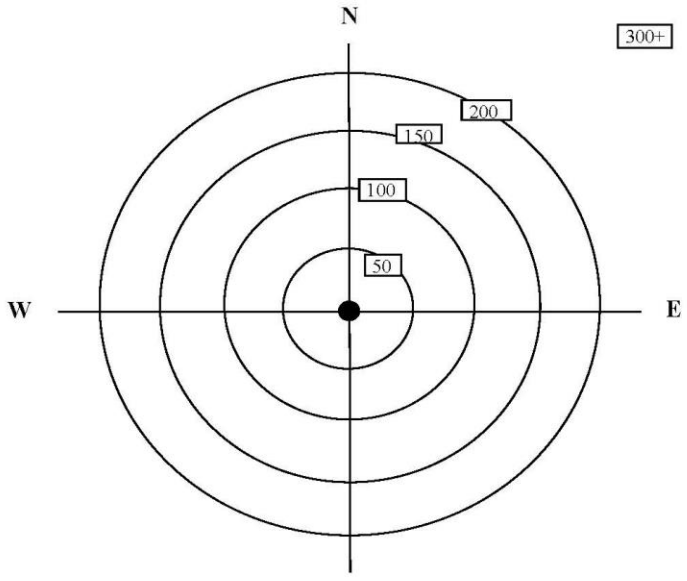
MDA -Private Well Field Log & Well Survey Form

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).

Nobles County has the authority to inspect SSTS for all townships in Nobles County. In 2016 Nobles County reported a total of 2,385 SSTS and 0.5 percent were inspected for compliance. Compliance inspections are conducted in Nobles County during property transfers, when building permits are applied for, upon completion of new or replacement SSTS, and anytime the county deems appropriate (MPCA, 2017a). Nobles County reported that an estimated 54 percent of SSTS are non-compliant (Nobles County, 2015; Table 9)

Table 9. Subsurface Sewage Treatment System Compliance Rates in Nobles County

Description	Number or Rate
Inspections of Existing SSTS's	2352
Estimated Complaint	44%
Estimated Non-Compliant FTPGW	36%
Estimated Non-Compliant ITPHS	18%
Total Estimated Non-Compliant	54%

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, 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 10) (MPCA, 2017c).

Table 10. 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, 2015c).

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, 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. From 2014-2017, approximately 24,000 feedlots were registered in Minnesota (MPCA, 2017c). A map and table of the feedlots located in the Nobles County study area can be found below (Figure 9; Table 11).

On average there are 483 AU per square mile (0.75 AU/acre) over the entire study area (Table 11). Manure is often applied to cropland so it is pertinent to look at the AU per cropland acre. In the Nobles County study area livestock densities average 0.90 AU per acre of row crops (MPCA, 2017b; USDA NASS, 2013).

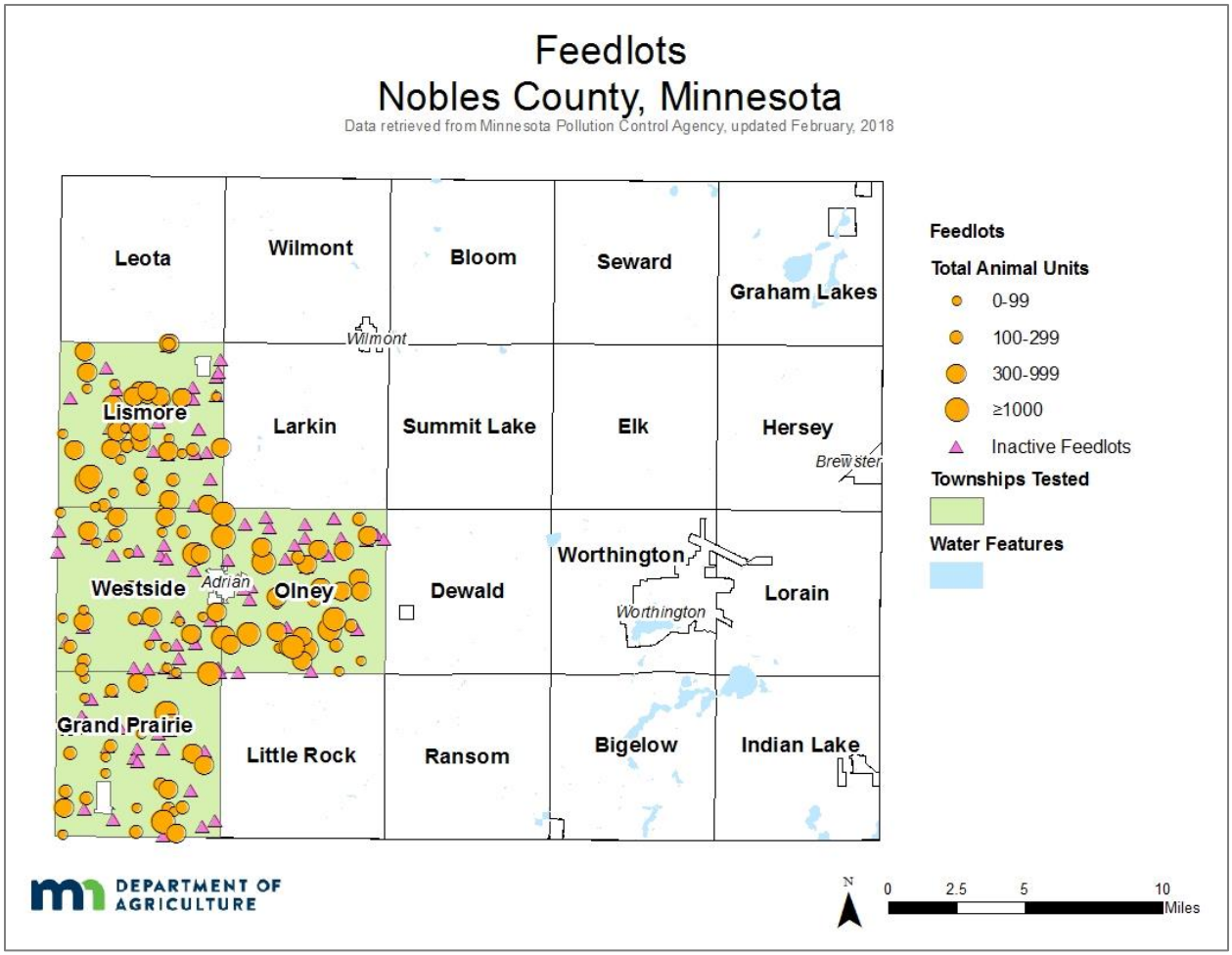


Figure 9. Feedlot Locations in Nobles County (MPCA, 2017b)

Table 11. Feedlots and Permitted Animal Unit Capacity, Nobles County

Township	Total Feedlots	Active Feedlots	**Inactive Feedlots**	Average AU Permitted** Per Feedlot	Total Permitted** AU	Total Square Miles	Permitted** AU per Square Mile
Grand Prairie	62	31	31	357	11065	36	311
Lismore	72	43	29	450	19351	36	539
Olney	65	34	31	864	29375	35	831
Westside	61	33	28	272	8965	35	253
Total	260	141	119	488	68757	142	483

* 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.

FERTILIZER STORAGE LOCATION

MDA tracks licenses for bulk fertilizer storage facilities, anhydrous ammonia, and chemigation sites. 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. There are no fertilizer storage locations in the Nobles County study area (Table 12).

Table 12. Fertilizer Storage Facility Licenses and Abandoned Sites, Nobles County

Township	Bulk Fertilizer Storage	Anhydrous Ammonia	Chemigation Sites	Abandoned Sites	Total
Grand Prairie	0	0	0	0	0
Lismore	0	0	0	0	0
Olney	0	0	0	0	0
Westside	0	0	0	0	0
Total	0	0	0	0	0

Data retrieved from MDA Pesticide and Fertilizer Management Division, 2015; updated December 2015

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 Nobles 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 were no incidents 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 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. There was only one small fertilizer spill in Olney Township (Figure 10; Tables 13-14).

Table 13. Spills and Investigations by Chemical Type, Nobles County

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

Table 14. Fertilizer Related Spills and Investigations by Township, Nobles County

Township	Incidents and Spills
Grand Prairie	0
Lismore	0
Olney	1
Westside	0
Total	1

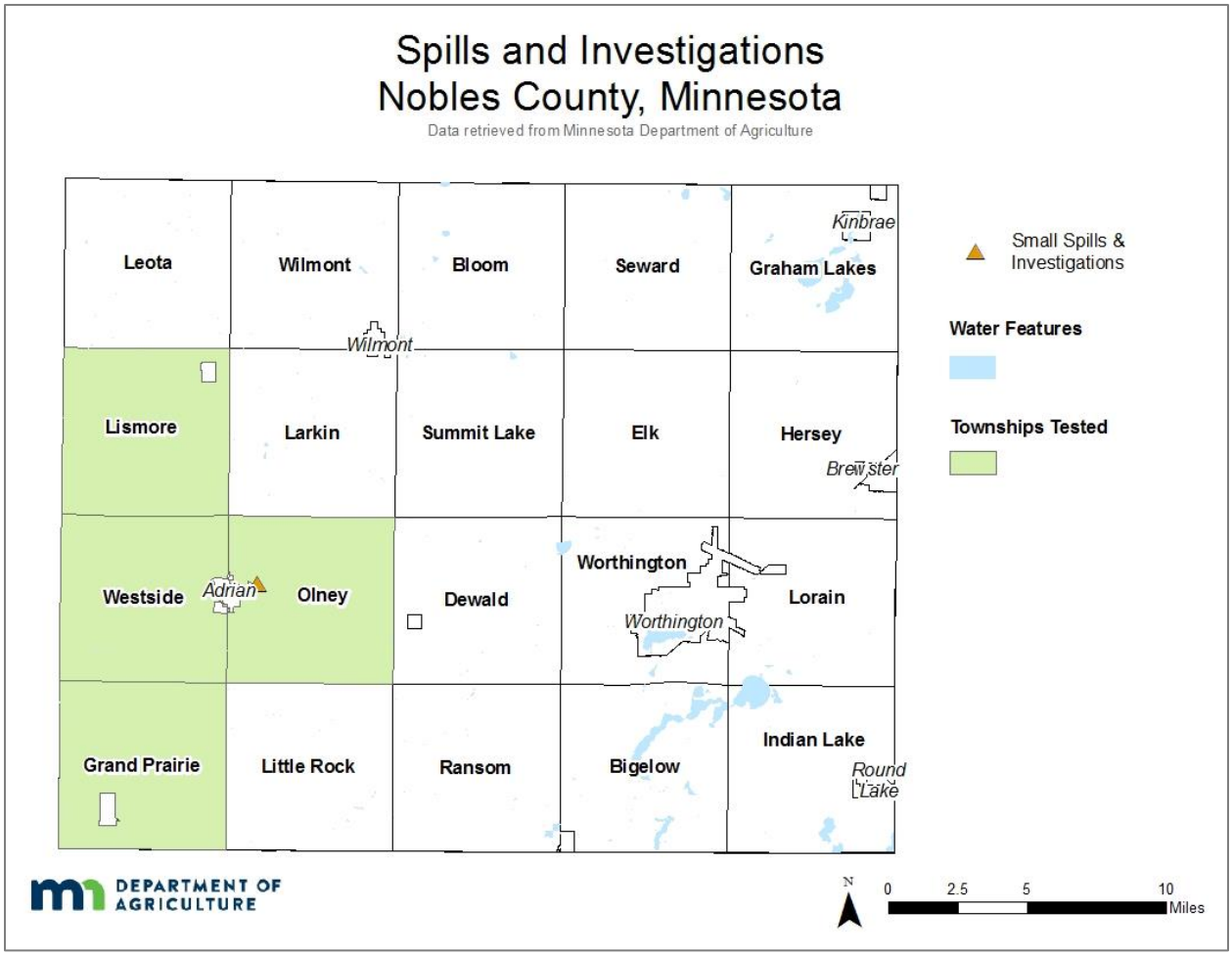


Figure 10. Fertilizer Spills and Investigations in Nobles County (MDA, 2017)

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. Nobles County is dominated by agricultural activities (Figure 11; Table 15). Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, durum wheat, dry beans and double crops involving corn and soybeans.

Nobles County is located in the southwest region of the State and shares its southern border with Iowa. The largest city is Worthington located in the eastern part of the county. Over 80% of land cover in the townships tested is designated as row crops. At 86%, Lismore Township has the most land designated as row crops (Figure 11; Table 15).

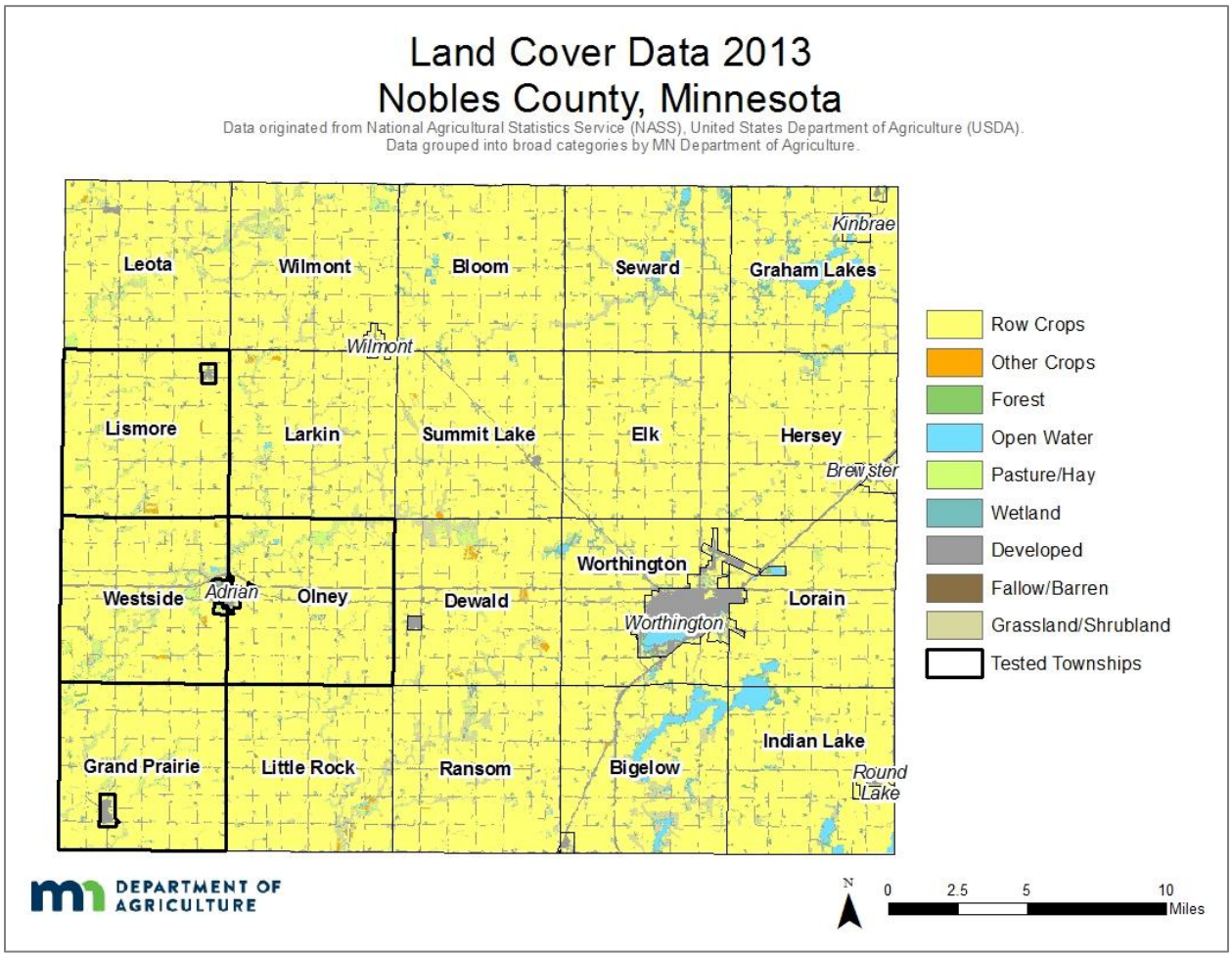


Figure 11. Land Cover in Nobles County (USDA NASS, 2013)

Table 15. Land Cover Data (2013) by Township, Nobles County (USDA NASS, 2013)

Township	Total Acres	Row Crop	Other Crops	Forest	Open Water	Pasture/ Hay	Wetland	Developed	Fallow/ Barren	Grassland/ Shrubland
Grand Prairie	22,737	85%	0%	1%	0%	3%	1%	5%	0%	4%
Lismore	22,979	86%	0%	0%	0%	2%	0%	5%	0%	4%
Olney	22,671	84%	0%	0%	0%	3%	1%	6%	0%	5%
Westside	22,696	80%	1%	1%	0%	5%	1%	7%	0%	6%
Average	22,771	84%	0%	1%	0%	4%	1%	6%	0%	5%

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 17 active groundwater well permits in the study area and 2 are used for irrigating major crops (Figure 12). Over 240 acres of cropland is permitted for groundwater irrigation in this area (Table 16). Most permitted wells are withdrawing groundwater from aquifers that are not classified (Table 17; MDNR, 2017).

Table 16. Active Groundwater Use Permits by Township, Nobles County

Township	Major Crop Irrigation Well Permits	Average Depth (feet)	Acres Permitted
Grand Prairie	0	0	0
Lismore	0	0	0
Olney	0	0	0
Westside	2	39	240
Total	2	39*	240

* Represents an average value

Table 17. Active Groundwater Use Permits by Aquifer, Nobles County

Water Use Well Permits	Total Wells	Aquifer System			
		Average Depth (feet)	Quaternary (Water Table)	Quaternary (Buried)	Not Classified
Major Crop Irrigation	2	39	1	0	1
Waterworks	3	25	3	0	0
Water Level Maintenance	1	0	0	0	1
Special Categories**	11	135	0	6	5
Total	17	96*	4	1	7

* Represents an average value

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

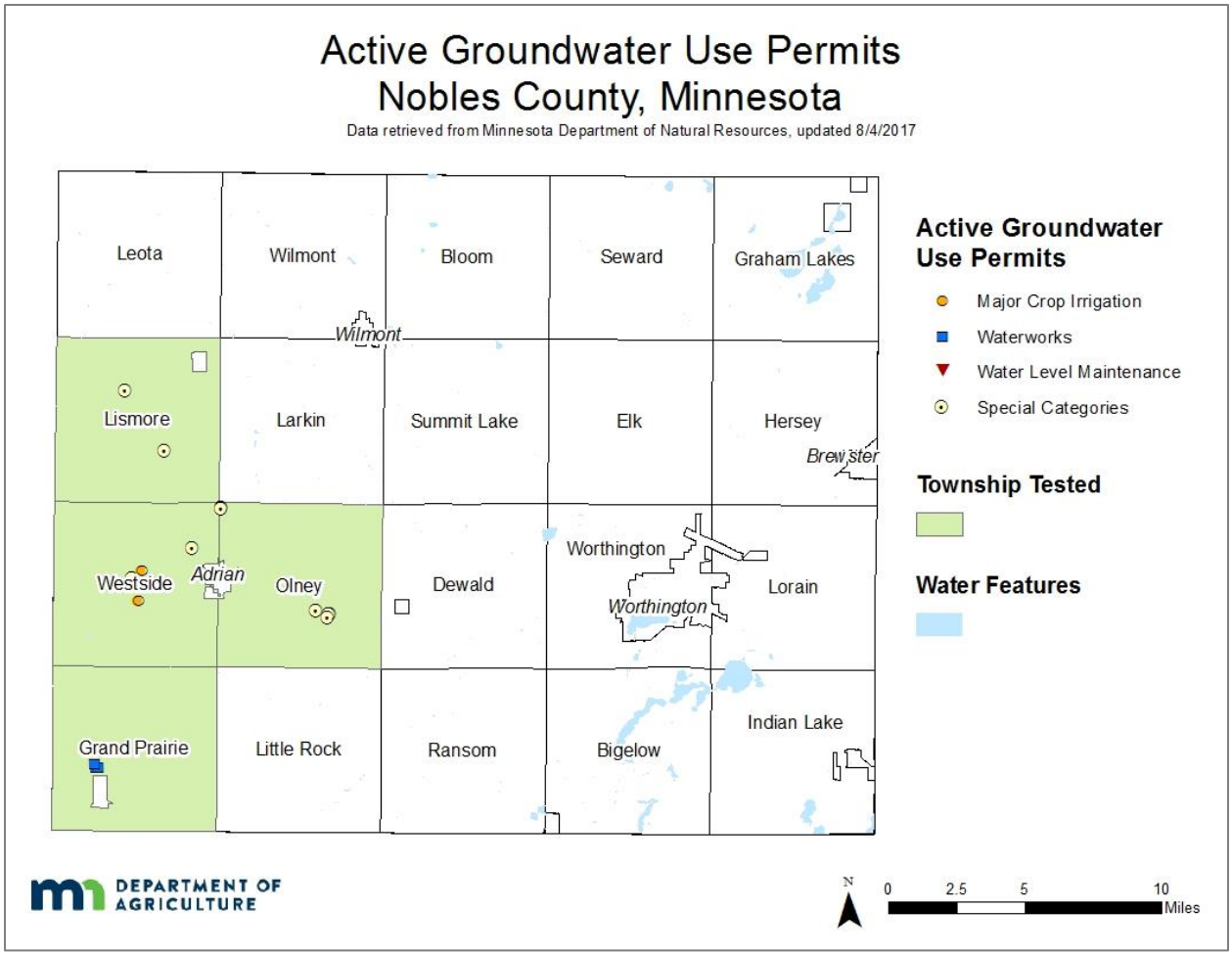


Figure 12. Active Groundwater Use Permits in Nobles County (MDNR, 2017)

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 18. Reasons Wells Were Removed from the Final Well Dataset by Township, Nobles County

Township	Point Source	Well Construction Problem (includes bored wells)	Hand Dug Well	Irrigation Well	Unsure of water source	Rural Water	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	Total Wells Removed
Grand Prairie	3	0	1	0	0	1	0	7	2	14
Lismore	1	2	0	0	0	0	0	1	0	4
Olney	0	1	0	0	0	0	0	3	1	5
Westside	2	2	0	0	0	0	1	4	2	12
Total	6	5	1	0	0	1	1	15	5	35

Table 19. Completed Site Visits for Wells Removed from the Final Well Dataset by Township, Nobles County

Township	Site Visit	No Site Visit	Total Wells Removed
Grand Prairie	3	11	14
Lismore	2	2	4
Olney	1	4	5
Westside	3	9	12
Total	9	26	35

APPENDIX F

MINNESOTA WELL INDEX

The MWI was used to gather information about the four townships in Nobles County included in the study. This section includes all drinking water wells in the study area, not just wells MDA sampled. Table 20 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 86 documented (have a verified location in the MWI) wells:

- Fourteen percent are completed in the shallow Quaternary Water Table Aquifer (QWTA) and are 35 feet deep on average.
- At 53 percent, the vast majority, are completed in a Quaternary buried aquifer and are 205 feet deep on average.
- On average Pre-Cambrian aquifers are utilized in only one percent of the wells, with a majority of these wells found in Westside. The average depth is 488 feet deep.
- Twelve percent of wells are completed in the Cretaceous aquifers. The average depth is 497 feet deep

Table 20. Aquifer Type Distribution of Wells in Minnesota Well Index

	Township	Grand Prairie	Lismore	Olney	Westside	Total	Average Depth (feet)
	Number of Wells	19	26	24	17	86	216
Aquifer Type	Quaternary Water Table	32%	15%	4%	6%	14%	35
	Quaternary Buried	58%	50%	54%	53%	53%	205
	Quaternary Undifferentiated	0%	19%	25%	24%	17%	152
	Cretaceous	11%	8%	17%	12%	12%	497
	Precambrian	0%	0%	0%	6%	1%	488
	Other	0%	8%	0%	0%	2%	518

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 21. Property Setting for Well Location

Township	Total	Country	Not Available
Grand Prairie	14	85.7%	14.3%
Lismore	7	85.7%	14.3%
Olney	9	77.8%	22.2%
Westside	15	73.3%	26.7%
Total	45	80.0%	20.0%

Table 22. Well Construction Type

Township	Total	Drilled	Hand dug	Other	Not Available
Grand Prairie	14	35.7%	7.1%	21.4%	35.7%
Lismore	7	28.6%	0.0%	14.3%	57.1%
Olney	9	22.2%	0.0%	22.2%	55.6%
Westside	15	33.3%	0.0%	13.3%	53.3%
Total	45	31.1%	2.2%	17.8%	48.9%

Table 23. Age of Well

Township	Total	Before 1975	1975 to 1984	1985 to 1993	1994 to Present	Home Owner Did Not know	Not Available
Grand Prairie	14	78.6%	0.0%	0.0%	0.0%	7.1%	14.3%
Lismore	7	28.6%	14.3%	0.0%	14.3%	28.6%	14.3%
Olney	9	33.3%	0.0%	11.1%	0.0%	33.3%	22.2%
Westside	15	60.0%	6.7%	0.0%	0.0%	6.7%	26.7%
Total	45	55.6%	4.4%	2.2%	2.2%	15.6%	20.0%

Table 24. Depth of Well

Township	Total	0-15 feet	16-49 feet	50-99 feet	100-299 feet	>=300 feet	Not Available
Grand Prairie	14	7.1%	50.0%	21.4%	7.1%	0.0%	14.3%
Lismore	7	0.0%	42.9%	28.6%	0.0%	0.0%	28.6%
Olney	9	0.0%	44.4%	0.0%	11.1%	11.1%	33.3%
Westside	15	0.0%	40.0%	20.0%	6.7%	6.7%	26.7%
Total	45	2.2%	44.4%	17.8%	6.7%	4.4%	24.4%

Table 25. Unique Well ID Known

Township	Total	No	Yes	Unsure	Not Available
Grand Prairie	14	42.9%	0.0%	35.7%	21.4%
Lismore	7	42.9%	0.0%	28.6%	28.6%
Olney	9	33.3%	0.0%	44.4%	22.2%
Westside	15	33.3%	0.0%	33.3%	33.3%
Total	45	37.8%	0.0%	35.6%	26.7%

Table 26. Livestock Located on Property

Township	Total	No Livestock	Yes Livestock	Not Available
Grand Prairie	14	57.1%	28.6%	14.3%
Lismore	7	57.1%	28.6%	14.3%
Olney	9	55.6%	22.2%	22.2%
Westside	15	33.3%	40.0%	26.7%
Total	45	48.9%	31.1%	20.0%

Table 27. Fertilizer Stored on Property

Township	Total	No Fertilizer Stored	Yes Fertilizer Stored	Not Available
Grand Prairie	14	78.6%	7.1%	14.3%
Lismore	7	71.4%	14.3%	14.3%
Olney	9	66.7%	11.1%	22.2%
Westside	15	73.3%	0.0%	26.7%
Total	45	73.3%	6.7%	20.0%

Table 28. Farming on Property

Township	Total	No Farming	Yes Farming	Not Available
Grand Prairie	14	28.6%	57.1%	14.3%
Lismore	7	14.3%	71.4%	14.3%
Olney	9	22.2%	55.6%	22.2%
Westside	15	6.7%	60.0%	33.3%
Total	45	17.8%	60.0%	22.2%

Table 29. 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
Grand Prairie	14	14.3%	14.3%	28.6%	28.6%	14.3%
Lismore	7	28.6%	0.0%	28.6%	28.6%	14.3%
Olney	9	0.0%	0.0%	0.0%	55.6%	44.4%
Westside	15	13.3%	13.3%	20.0%	26.7%	26.7%
Total	45	13.3%	8.9%	20.0%	33.3%	24.4%

Table 30. Distance to Septic System

Township	Total	Septic 0-49 feet	Septic 50-99 feet	Septic 100-299 feet	Septic >=300 feet	Not Available
Grand Prairie	14	0.0%	35.7%	35.7%	14.3%	14.3%
Lismore	7	0.0%	0.0%	28.6%	57.1%	14.3%
Olney	9	0.0%	0.0%	33.3%	44.4%	22.2%
Westside	15	6.7%	20.0%	13.3%	26.7%	33.3%
Total	45	2.2%	17.8%	26.7%	31.1%	22.2%

Table 31. Distance to an Agricultural Field

Township	Total	Field 0-49 feet	Field 50-99 feet	Field 100-299 feet	Field >=300 feet	Not Available
Grand Prairie	14	14.3%	14.3%	21.4%	35.7%	14.3%
Lismore	7	14.3%	0.0%	28.6%	42.9%	14.3%
Olney	9	33.3%	0.0%	22.2%	11.1%	33.3%
Westside	15	6.7%	20.0%	20.0%	26.7%	26.7%
Total	45	15.6%	11.1%	22.2%	28.9%	22.2%

Table 32. Drinking Water Well

Township	Total	Not Drinking Water	Yes Drinking Water	Not Available
Grand Prairie	14	21.4%	64.3%	14.3%
Lismore	7	14.3%	71.4%	14.3%
Olney	9	33.3%	44.4%	22.2%
Westside	15	6.7%	66.7%	26.7%
Total	45	17.8%	62.2%	20.0%

Table 33. Treatment System Present (Treatment System Used for Drinking Water)

Township	Total	Filtering system	None	Other	Reverse Osmosis	Not Available
Grand Prairie	14	7.1%	71.4%	0.0%	7.1%	14.3%
Lismore	7	0.0%	57.1%	0.0%	28.6%	14.3%
Olney	9	22.2%	22.2%	0.0%	33.3%	22.2%
Westside	15	0.0%	53.3%	6.7%	13.3%	26.7%
Total	45	6.7%	53.3%	2.2%	17.8%	20.0%

Table 34. Last Tested for Nitrate

Township	Total	Within the last year	Within the last 3 years	Within the last 10 years	Greater than 10 years	Not sure	Never tested	Not Available
Grand Prairie	14	7.1%	14.3%	0.0%	14.3%	28.6%	21.4%	14.3%
Lismore	7	0.0%	0.0%	14.3%	28.6%	28.6%	14.3%	14.3%
Olney	9	0.0%	0.0%	11.1%	22.2%	33.3%	11.1%	22.2%
Westside	15	0.0%	6.7%	20.0%	40.0%	6.7%	0.0%	26.7%
Total	45	2.2%	6.7%	11.1%	26.7%	22.2%	11.1%	20.0%

Table 35. Last Nitrate Test Result

Township	Total	<3 mg/L	3<10 mg/L	≥ 10 mg/L	Don't Know	Not Available
Grand Prairie	14	7.1%	7.1%	7.1%	50.0%	28.6%
Lismore	7	0.0%	0.0%	0.0%	85.7%	14.3%
Olney	9	0.0%	0.0%	11.1%	55.6%	33.3%
Westside	15	0.0%	0.0%	13.3%	60.0%	26.7%
Total	45	2.2%	2.2%	8.9%	60.0%	26.7%

APPENDIX I

Table 36. Well Construction Type for Final Well Dataset

Township	Samples	Drilled	Not Available
Grand Prairie	0	0	0
Lismore	3	1	2
Olney	4	3	1
Westside	3	1	2
Total	10	5	5

Data compiled from well logs and homeowner responses.

Table 37. Well Depth for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Grand Prairie	0	.	.	.	.
Lismore	1	51	51	51	51
Olney	1	180	180	180	180
Westside	0	.	.	.	.
Total	2	24	180	51	85

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

Table 38. Year of Well Construction for Final Well Dataset.

Township	Samples	Min	Max	Median	Mean
Grand Prairie	0	.	.	.	.
Lismore	1	2009	2009	2009	2009
Olney	1	1984	1984	1984	1984
Westside	0	.	.	.	.
Total	3	1984	2009	1997	1997

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

Township	Samples	Min	Max	Median	Mean
Grand Prairie	0	.	.	.	.
Lismore	0	.	.	.	.
Olney	1	16.1	16.1	16.1	16.1
Westside	1	13.35	13.35	13.35	13.35
Total	2	13.35	16.1	13.6	14.35

Table 40. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Grand Prairie	0	.	.	.	.
Lismore	0	.	.	.	.
Olney	1	7.04	7.04	7.04	7.04
Westside	1	7.13	7.13	7.13	7.13
Total	2	7.04	7.13	7.09	7.09

Table 41. Specific Conductivity (µS/cm) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Grand Prairie	0	.	.	.	.
Lismore	0	.	.	.	.
Olney	0	.	.	.	.
Westside	0	.	.	.	.
Total	0	.	.	.	.

Table 42. Dissolved Oxygen (mg/L) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Grand Prairie	0	.	.	.	.
Lismore	0	.	.	.	.
Olney	1	0.82	0.82	0.82	0.82
Westside	1	5.76	5.76	5.76	5.76
Total	2	0.82	5.76	3.29	3.29