Final Township Testing Nitrate Report:
Lincoln County 2018-2019

October 2020

Minnesota Department of Agriculture
Pesticide and Fertilizer Management Division
## ACKNOWLEDGEMENTS

### MDA PRIMARY AUTHOR

Jaime Nielsen, Ryan Meyer, and Nikol Ross

### MDA CONTRIBUTORS AND REVIEWERS

Kimberly Kaiser, Larry Gunderson, and Jen Schaust

### FUNDING

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

Acknowledgements........................................................................................................... 2

Table of Contents.................................................................................................................. 3

List of Figures ........................................................................................................................... 4

List of Tables ............................................................................................................................ 5

Executive Summary.................................................................................................................. 7

Introduction ............................................................................................................................... 8

Background ............................................................................................................................... 10

Township Testing Methods...................................................................................................... 14

Initial Results ............................................................................................................................ 19

Final Results ............................................................................................................................. 25

Summary ................................................................................................................................ 30

References ................................................................................................................................. 31

Appendix A ................................................................................................................................ 34

Appendix B ................................................................................................................................ 36

Appendix C ................................................................................................................................ 42

Appendix D ................................................................................................................................ 47

Appendix E ................................................................................................................................ 48

Appendix F ................................................................................................................................ 49

Appendix G ................................................................................................................................ 50

Appendix H ................................................................................................................................ 51

Appendix I ................................................................................................................................ 53

Appendix J ................................................................................................................................ 54
LIST OF FIGURES

Figure 1. Townships Tested in Lincoln County .......................................................... 9

Figure 2. Statewide Geomorphology Layer, Sediment Association in Lincoln County (MDNR, MGS, and UMD, 1997) ....................................................................................... 12

Figure 3. Minnesota Vulnerable Townships Tested for Nitrate in Private Wells ......................... 14

Figure 4. Pollution Sensitivity of Near Surface Materials (Adams, 2016) in Lincoln County ........... 16

Figure 5. Well Locations and Nitrate Results from Initial Dataset in Lincoln County .................. 20

Figure 6. Results of Initial Testing by Township in Lincoln County ........................................ 21

Figure 7. Well Locations and Nitrate Results from Final Well Dataset in Lincoln County ............. 26

Figure 8. Results of Final Testing by Township in Lincoln County ........................................... 27

Figure 9. Feedlot Locations in Lincoln County (MPCA, 2019c) ................................................. 39

Figure 10. Fertilizer Spills and Investigations in Lincoln County (MDA, 2018a) ......................... 41

Figure 11. Land Cover in Lincoln County (USDA NASS Cropland Data Layer, 2013) ................. 43

Figure 12. Active Groundwater Use Permits in Lincoln County (MDNR, 2018) ......................... 46
LIST OF TABLES

Table 1. Pollution Sensitivity of Near-Surface Materials, (Adams, 2016) ................................................................. 15
Table 2. Homeowner Participation in Initial and Follow-Up Well Water Sampling, Lincoln County ............... 17
Table 3. Lincoln County Township Testing Summary Statistics for Initial Well Dataset ............................................ 22
Table 4. Estimated Population with Water Wells Over 10mg/L Nitrate-N, Lincoln County ........................ 23
Table 5. Initial and Final Well Dataset Results, Lincoln County ................................................................. 25
Table 6. Lincoln County Township Testing Summary Statistics for Final Well Dataset .................................. 28
Table 7. Township Nitrate Results Related to Vulnerable Geology and Row Crop Production, Lincoln County ........................................................................................................... 29
Table 8. Animal Unit Calculations (MPCA, 2017b) .................................................................................................. 37
Table 9. Feedlots and Permitted Animal Unit Capacity, Lincoln County ........................................................ 38
Table 10. Fertilizer Storage Facility Licenses and Abandoned Sites, Lincoln County ........................................ 40
Table 11. Spills and Investigations by Chemical Type, Lincoln County ............................................................. 40
Table 12. Land Cover Data (2013) by Township, Lincoln County (USDA NASS Cropland Data Layer, 2013) ........................................................................................................................................... 44
Table 13. Active Groundwater Use Permits by Township, Lincoln County .......................................................... 45
Table 14. Active Groundwater Use Permits by Aquifer, Lincoln County ............................................................ 45
Table 15. Reasons Wells Were Removed from the Final Well Dataset by Township, Lincoln County ....... 48
Table 16. Completed Site Visits for Wells Removed from the Final Well Dataset by Township, Lincoln County ......................................................................................................................................................... 48
Table 17. Aquifer Type Distribution of Active Drinking Water Wells in Minnesota Well Index by Township, Lincoln County .................................................................................................................. 49
Table 18. Property Setting for Well Location ............................................................................................................. 51
Table 19. Well Construction Type ......................................................................................................................... 51
Table 20. Age of Well ................................................................................................................................................. 51
Table 21. Depth of Well ............................................................................................................................................. 51
Table 22. Unique Well ID Known ............................................................................................................................. 51
Table 23. Livestock Located on Property ................................................................. 51
Table 24. Fertilizer Stored on Property ................................................................. 51
Table 25. Farming on Property .............................................................................. 52
Table 26. Distance to an Active or Inactive Feedlot .............................................. 52
Table 27. Distance to Septic System ..................................................................... 52
Table 28. Distance to an Agricultural Field ........................................................... 52
Table 29. Drinking Water Well ............................................................................... 52
Table 30. Treatment System Present (Treatment System Used for Drinking Water) ........................................................................... 52
Table 31. Last Tested for Nitrate ........................................................................... 52
Table 32. Last Nitrate Test Result .......................................................................... 52
Table 33. Well Construction Type for Final Well Dataset .................................... 53
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-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. More than 90,000 private well owners have been offered nitrate testing in 344 townships since 2013. This is one of the largest nitrate testing efforts ever conducted and completed.

In 2018, private wells in the Lincoln County study area (one township) were sampled for nitrate-N. Samples were collected from private wells using homeowner collection and mail-in methods. These initial samples were collected from seven wells representing an average response rate of 44 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, 57.1 percent of private wells sampled were at or above the health standard of 10 mg/L for nitrate-N. Based on the initial results, it is estimated that 103 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 and the estimate is based off of only seven wells.

The MDA completed follow-up sampling and well site visits at one well in 2019. A follow-up sample 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 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. Point sources of nitrogen can include: feedlots, subsurface sewage treatment systems, fertilizer spills, and bulk storage of fertilizer. A total of four (57.1 percent) wells were determined to be unsuitable and were removed from the dataset. The final well dataset had a total of three wells.

The final well dataset was analyzed to determine the percentage of wells at or over the HRL of 10 mg/L nitrate-N. When analyzed at the township scale the percent of wells at or over the HRL was 33.3 percent. The one township in Lincoln County had more than 10 percent of wells at or over the HRL revealing significant problems within the county. However, it is important to note that the final well dataset for this township only has three wells in it. The final dataset 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. More than 90,000 private well owners have been offered nitrate testing in 344 townships since 2013.

In 2018, one township in Lincoln County was 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 Lincoln County occurred during 2019. 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
www.mda.state.mn.us/townshiptesting
Figure 1. Townships Tested in Lincoln 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 (Dubrovsky et al., 2010). In systems with sand and gravel that were deposited by glacial meltwater, such as parts of Lincoln County, contaminants like nitrate can travel quickly to the aquifer (Patterson, 1995), leaving little chance for denitrification or other attenuating processes. As a result, certain areas of Lincoln County with sand and gravel geologic material and intensive row crop agriculture may be particularly vulnerable to elevated nitrate concentrations. It is important to note that geochemical conditions can be highly variable within an aquifer or region and can also change over-time (MPCA, 1998).

**GEOLOGY AND HYDROGEOLOGY**

From approximately 2.5 million years ago to 11,700 years ago, much of the northern Hemisphere, including Minnesota, was intermittently covered by sheets of slowly moving ice known as glaciers (Lusardi & Dengler, 2017). During colder times, the glaciers would grow and move farther south, sometimes covering most of Minnesota, and during warmer times the glaciers would melt and retreat farther north, away from Minnesota (Lusardi & Dengler, 2017). As these glaciers moved, they moved the earth beneath them and deposited it in other places, destroying old landscapes and creating new ones in their place (Lusardi & Dengler, 2017).

The geology of Lincoln county was heavily shaped by glaciation. Older glaciers deposited till, a mixture of larger rocks with sand and/or clay, throughout the county (Patterson, 1995). This was later eroded and covered by more recent glacial sediments in all but the southwest corner of Lincoln County (Patterson,
During the most recent glacial period that occurred from about 14,000 to 12,000 years ago, a portion of the glacier called the Des Moines Lobe periodically advanced and retreated across southwestern Minnesota, each time depositing sediments, mostly tills (Gowan and Jennings, 2016). These tills typically provide good protection for underlying aquifers, as they contain clay and silt which prevent the downward flow of contaminated water (Bradt, 1997a; Bradt, 1997b).

In addition to these till deposits, the meltwater from both the Des Moines Lobe and the older glaciers deposited sandy glacial stream deposits sporadically throughout the county (Lusardi et al., 2019). The highest concentration of these deposits for Lincoln County is in our study area in the southwestern corner of the county which can be seen in Figure 2. These glacial stream deposits contain more sand and gravel than the till, allowing for contaminated water to more easily travel through (Bradt 1997b). Thus aquifers within or beneath the glacial stream deposits tend to be more vulnerable to contamination (Adams, 2016; Bradt, 1997b).

The thickness of this glacial sediment ranges from about 200 feet deep in the northeastern part of the county to more than 800 feet deep in the central-southwest (Patterson et al., 1995). Beneath the glacial deposits, in all but the southwestern corner of the county, lies undifferentiated cretaceous rock consisting of varied materials including conglomerate, sandstone, mudstone, and shale (Jirsa et al., 2011). Below the Cretaceous rock lies much older (>541 million years) Precambrian deposits. The deposits consist of varying types of volcanic and metamorphosed rocks, mostly granites and metamorphosed granites, and do not tend to be very high-yielding aquifers (Bradt, 1997a).

The primary water sources in the county are sand and gravel deposits within the glacial sediments and sandstone within the undifferentiated Cretaceous rock (Bradt, 1997a). Many of the wells drawing from glacial sediments in the area are unconfined, meaning they do not have a protective layer of fine-grained material above them (Bradt, 1997a). These wells are particularly susceptible to contamination (Bradt, 1997a).
Figure 2. Statewide Geomorphology Layer, Sediment Association in Lincoln County (MDNR, MGS, and 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 Lincoln County. Further details are in Appendix B.

SUBSURFACE SEWAGE TREATMENT SYSTEM

Subsurface sewage treatment systems (SSTS) can be a potential source for contaminants in groundwater such as nitrate and fecal material (MDH, 2014). A total of 1,870 SSTS were reported in Lincoln County for 2018. Over a recent 17-year period (2002-2018), 746 construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Lincoln County, 40 percent are newer than 2002 or have been repaired since 2002 (MPCA, 2019b). 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 Lincoln County study area, there are a total of 19 active feedlots. No feedlots are permitted to house 300 or more animal units (AU) (Appendix B; Figure 9).

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 Lincoln County study area has one fertilizer storage license, which is for a bulk fertilizer facility (Appendix B; Table 10).

FERTILIZER SPILLS AND INVESTIGATIONS

A total of six historic fertilizer spills and investigations occurred in the Lincoln County study area. (Appendix B; Table 11).
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. Additional factors such as previous nitrate results and local knowledge of groundwater conditions were used to prioritize townships for testing. A statewide map of townships that were chosen for testing is shown in Figure 3.

Figure 3. Minnesota Vulnerable Townships Tested for Nitrate in Private Wells.
An updated statewide sensitivity rating from the Minnesota Department of Natural Resources (Adams, 2016) was used to estimate the percentage of geology vulnerable to groundwater contamination when it became available. There are several ratings for aquifer sensitivity: ultra-low, very low, moderate, high and special conditions. Sensitivity ratings are described in Table 1. The ratings are based upon DNR’s “Pollution Sensitivity of Near-Surface Materials” (Adams, 2016). A map of Lincoln County depicting the aquifer vulnerabilities is shown in Figure 4. 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 Lincoln County can be found in Appendix C (Figure 11, Table 12). On average 68 percent of the land cover was row crop agriculture.

Table 1. Pollution Sensitivity of Near-Surface Materials, (Adams, 2016)

<table>
<thead>
<tr>
<th>Near-Surface Pollution Sensitivity</th>
<th>Time of Travel</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>≤ 170 hours</td>
<td>Hours to a week</td>
</tr>
<tr>
<td>Moderate</td>
<td>&gt;170–430 hours</td>
<td>A week to weeks</td>
</tr>
<tr>
<td>Low</td>
<td>&gt;430–1600 hours</td>
<td>Weeks to months</td>
</tr>
<tr>
<td>Very Low</td>
<td>&gt;1600–8000 hours</td>
<td>Months to a year</td>
</tr>
<tr>
<td>Ultra-Low</td>
<td>&gt;8000 hours</td>
<td>More than a year</td>
</tr>
</tbody>
</table>
Pollution Sensitivity of Near Surface Materials
Lincoln County, Minnesota

Figure 4. Pollution Sensitivity of Near Surface Materials (Adams, 2016) in Lincoln County
The testing is done in two steps: “initial” sampling and “follow-up” sampling. The initial nitrate sampling was conducted in 2018. In the initial sampling, all private well owners in the selected township 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 seven homeowners using the mail-in kit (Table 2). These seven samples are considered the “initial well dataset”. On average, 44 percent of the homeowners 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 was conducted in 2019 by MDA staff. A total of one follow-up sample was analyzed (Table 2).

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

<table>
<thead>
<tr>
<th>Township</th>
<th>Kits Sent</th>
<th>Initial Well Dataset</th>
<th>Well Site Visits &amp; Follow-Up Sampling Conducted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>16</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

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, 2018b). 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). Starting in 2018 a digital version of this form was utilized.

WELL ASSESSMENT

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

Using the following criteria, a total of four wells were removed to create the final well dataset. See Appendix E (Tables 15 and 16) 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 high nitrate (>5 mg/L) concentration 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, wells with a cap missing or a crack in the cap makes the groundwater in that well susceptible to pollution. Other examples include wells buried underground or wells with cracked casing. Wells with significant problems such as these were excluded from the final well dataset.

Unsure of Water Source or Known Non Drinking 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 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 be an older well.

No Site Visit & Constructed Before 1975 or Age Unknown & No Well ID

If no site visit was 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 final well 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.
INITIAL RESULTS

INITIAL WELL DATASET

A total of seven well owners returned water samples for analysis in the study area (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 value of nitrate was 0.08 mg/L. The maximum value was 38.0 mg/L. The mean value was 14.5 mg/L. The 90th percentile was 35.1 mg/L.

Initial results from the sampling showed that 57 percent of wells in the study area were at or over 10 mg/L nitrate-N (Figure 6). The township testing results differ from 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). 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 Lincoln County
Figure 6. Results of Initial Testing by Township in Lincoln County
Table 3. Lincoln County Township Testing Summary Statistics for Initial Well Dataset

<table>
<thead>
<tr>
<th>Township</th>
<th>Total Wells</th>
<th>Values</th>
<th>Percentiles</th>
<th>Number of Wells</th>
<th>Percent of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>Verdi</td>
<td>7</td>
<td>0.08</td>
<td>38.0</td>
<td>14.5</td>
<td>11.1</td>
</tr>
</tbody>
</table>

<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-N was estimated based on the sampled wells. An estimated 103 people in Lincoln County’s study area have drinking water over the nitrate HRL (Table 4). Nitrate contamination is a significant problem for many homeowners in Lincoln County. 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, Lincoln County

<table>
<thead>
<tr>
<th>Township</th>
<th>Estimated 2018 Households on Private Wells*</th>
<th>Estimated 2018 Population on Private Wells*</th>
<th>Estimated Population ≥10 mg/L Nitrate-N**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>71</td>
<td>181</td>
<td>103</td>
</tr>
</tbody>
</table>

*Data collected from the Minnesota State Demographic Center (Minnesota SDC, 2020)
**Estimates based off the 2018 estimated households per township gathered from 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 constructed 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 (Setterholm, 2012). 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).

For Lincoln County, none of the 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.

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 from the initial sampling in 2018 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 in Appendix H at the end of this document, (Tables 18-32).

All seven of the wells in Verdi Township are located in the country.

Approximately 42.9 percent of sampled wells are of drilled construction, 14.3 percent are classified as other.

Most of the sampled wells are between 50-99 feet deep, and no wells are between 0-15 feet deep or over 300 feet deep. Approximately 43 percent of homeowners did not know or did not response to this question.

None of the wells had been tested for nitrate within the last ten years or homeowners were unsure if they had been tested. No homeowners responded that their well had been tested for nitrate in the last year. Therefore, the results in this study will provide new information for the homeowners.

**POTENTIAL NITRATE SOURCE DISTANCES**

The following summary relates to isolation distances of potential point sources and non-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 in Appendix H at the end of this document (Tables 18-32).

- On average, farming takes place on 42.9 percent of the properties.
- Agricultural fields are further than 300 feet from wells at about 28.6 percent of the properties.
- Less than 15 percent of wells are less than 100 feet from an active or inactive feedlot.
- No well owners in the township store more than 500 pounds of fertilizer on their property.
- No wells are less than 50 feet away from septic systems.
A total of seven well water samples were collected by homeowners in one township. Four wells (57.1 percent) were found to be unsuitable and were removed to create the final well dataset. One factor in the high removal rate is the small set of initial data, since many people in these areas are on rural water rather than using private wells. The final analysis was conducted on the remaining three wells (Table 5). 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 5 shows the results for the one township sampled. The percentage of wells at or over the HRL for the final well dataset was 33.3 percent.

**Table 5. Initial and Final Well Dataset Results, Lincoln County**

<table>
<thead>
<tr>
<th>Township</th>
<th>Initial Well Dataset</th>
<th>Final well Dataset</th>
<th>Final Wells ≥10 mg/L Nitrate-N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>Percentage</td>
<td>Count</td>
</tr>
<tr>
<td>Verdi</td>
<td>7</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

The individual nitrate results from this final well dataset are displayed spatially in Figure 7.

The final well dataset summary statistics are shown in Table 6. The minimum value was 0.08 mg/L nitrate. The maximum value was 18.1 mg/L nitrate. The 90th percentile was 18.1 mg/L nitrate-N. However, it is important to note that in the township there were only three samples. 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 Lincoln County
Figure 8. Results of Final Testing by Township in Lincoln County
Table 6. Lincoln County Township Testing Summary Statistics for Final Well Dataset

<table>
<thead>
<tr>
<th>Township</th>
<th>Total Wells</th>
<th>Values</th>
<th>Percentiles</th>
<th>Number of Wells</th>
<th>Percent of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>50th (Median)</td>
<td>75th</td>
</tr>
<tr>
<td>Verdi</td>
<td>3</td>
<td>0.08</td>
<td>18.1</td>
<td>1.28</td>
<td>13.9</td>
</tr>
</tbody>
</table>

Nitrate-N mg/L or parts per million (ppm)

<DL stands for less than detectable limit. The detectable limit is <0.03 to 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 7 compares the final results to the percent of vulnerable geology (Adams, 2016) and row crop production (USDA NASS, 2013) in Verdi Township. The percent land area considered vulnerable geology and in row crop production was estimated using a geographic information system known as ArcGIS.

Table 7. Township Nitrate Results Related to Vulnerable Geology and Row Crop Production, Lincoln County

<table>
<thead>
<tr>
<th>Township</th>
<th>Final Well Dataset</th>
<th>Percent of Land in Row Crop Production 2013*</th>
<th>Percent of Land in Vulnerable Geology**</th>
<th>Percent ≥7 mg/L N or parts per million (ppm)</th>
<th>Percent ≥10 mg/L N or parts per million (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>3</td>
<td>68%</td>
<td>24%</td>
<td>33.3%</td>
<td>33.3%</td>
</tr>
</tbody>
</table>

*Data retrieved from USDA NASS Cropland Data Layer, 2013.
**The DNR Pollution Sensitivity of Near Surface Materials was used determine vulnerability (ratings of High, Karst, Moderate and Bedrock at or close to surface are included in this "vulnerable" rating)

WELL AND WATER CHARACTERISTICS

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells in the Lincoln 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 for the final well dataset were also provided by some homeowners. The well characteristics are described below, and a more comprehensive view is provided in Appendix I (Table 33).

- Two thirds (2/3) of the wells were drilled, no wells were sand points, and one well was identified as “other” for well construction type.
- The final well dataset only contains three sites. Well logs from the MWI could not be found for these three sites, therefore there are no recorded well depths or dates of construction.

WELL WATER PARAMETERS

MDA staff conducted the follow-up sampling and a well site survey at one well. The one follow-up well is included in the final well dataset, but none of the field measurements were collected at this site. Field measurements of the well water parameters were recorded on the Private Well Field Log & Well Survey Form (Appendix J). Starting in 2018 a digital version of this form was utilized. The measurements include temperature, pH, specific conductivity, and dissolved oxygen. The well was purged for 15 minutes ensuring a fresh sample of water was collected. There are no stabilized readings for the final well dataset in Lincoln County.
SUMMARY

The focus of this study was to assess nitrate concentrations in groundwater impacted by commercial agricultural fertilizer in selected townships in Lincoln County. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Row crop agriculture covers 68 percent of the land in the study area with 715 acres (2.9 percent of land cover) permitted for groundwater irrigation.

One township, Verdi Township, was sampled covering over 24,705 acres. The initial (homeowner collected) nitrate sampling resulted in seven samples. The seven households that participated represent an approximately 44 percent return rate of homeowner-offered sampling kits. The initial well dataset represents private well drinking water regardless of the potential source of nitrate. Well owners with measurable nitrate results were offered a follow-up nitrate sample and a pesticide sample. The MDA visited and collected a follow-up sample at one well.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of four (57.1 percent) wells were found to be unsuitable and were removed from the initial dataset to form the final dataset of three wells. The remaining wells were believed to be impacted by nitrogen fertilizer and were included in the final well dataset.

In the final well dataset, most of the wells (66.7 percent) are drilled; there were no sand point wells. One well was designated as other.

For the final well dataset, Verdi Township had more than 10 percent of wells 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 Verdi Township was 33.3 percent. However, it is important to note there were only three samples for the final well dataset. The final dataset is not adequate to characterize Verdi Township in terms of private drinking water wells for purposes of the NFMP.
REFERENCES


32


Minnesota Statutes 2015, section 115.55, subdivision 5.


## 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**

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>HO Survey</th>
<th>Homeowner or Observation (circle one or both)</th>
<th>Well Log</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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*
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; MPCA, 2019a).

In 2018 Lincoln County reported a total of 1,870 SSTS and three percent were inspected for compliance. Compliance inspections are conducted in Lincoln County during property transfers, which is common in Minnesota, but it is not a state-level requirement (MPCA, 2019b). Inspections are also required in the following situations: 1) when a construction permit is needed to repair, modify, or upgrade an existing system; 2) when there is an expansion of a building that may affect the performance of the system; 3) if there is a change in property use that has an SSTS and if the change in system may impact the system; 4) anytime that deems appropriate upon receipt of a complaint or other notice of a system malfunction (Lincoln County Comprehensive Development Ordinance No. 40, 2009).

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, 2013).

Government agencies regulate feedlots to reduce the risk of contamination to water resources. Rules pertaining to feedlots have been in place since the 1970’s; they were revised in 2000 and 2014 (MPCA, 2017b). The degree of regulation of a feedlot is dependent on the amount of manure that is...
produced; measured in animal units (AU) (MPCA, 2011). One AU is equal to the amount of manure produced by one beef cow (Table 8) (MPCA, 2017b).

Table 8. Animal Unit Calculations (MPCA, 2017b)

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

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, 2017b). Farmers must register their feedlot if it is in active status. Feedlots are considered active until no animals have been present on the feedlot for five years. To register, farmers fill out paperwork which includes a chart with the type and maximum number of animals on the feedlot (MPCA, 2017a). Registration is required to be completed at least once during a set four-year period; the current period runs from January 2018 to December 2021. As of November 2017, approximately 24,000 feedlots were registered in Minnesota (MPCA, 2017b). A map and table of the feedlots located in the Lincoln County study area can be found below (Figure 9; Table 9).
Table 9. Feedlots and Permitted Animal Unit Capacity, Lincoln County

<table>
<thead>
<tr>
<th>Township</th>
<th>Total Feedlots</th>
<th>Active Feedlots</th>
<th>Inactive Feedlots</th>
<th>Average AU Permitted** Per Feedlot</th>
<th>Total Permitted** AU</th>
<th>Total Square Miles</th>
<th>Permitted** AU per Square Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>38</td>
<td>19</td>
<td>19</td>
<td>*97</td>
<td>1,850</td>
<td>39</td>
<td>*48</td>
</tr>
</tbody>
</table>

*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 have less livestock than permitted.

On average there are 48 AU per square mile (0.075 AU/acre) over the study area (Table 9). Manure is often applied to cropland, so it is pertinent to look at the AU per cropland acre. In the Lincoln County study area livestock densities average 0.11 AU per acre of row crops (MPCA, 2019c; USDA NASS, 2013).
Figure 9. Feedlot Locations in Lincoln County (MPCA, 2019c)
FERTILIZER STORAGE LOCATION

MDA tracks licenses for bulk fertilizer storage facilities, anhydrous ammonia, and chemigation sites (Table 10). 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 10. Fertilizer Storage Facility Licenses and Abandoned Sites, Lincoln County

<table>
<thead>
<tr>
<th>Township</th>
<th>Bulk Fertilizer Storage</th>
<th>Anhydrous Ammonia</th>
<th>Chemigation Sites</th>
<th>Abandoned Sites</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

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 fertilizer spills within the Lincoln County study area. While other types of spills are recorded, only sites that are potential point sources of nitrogen to the groundwater are reported here (MDA, 2018).

The MDA tracks several types of incidents. Incident investigations are typically for larger spills. There are two 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 1, 2004 (MDA, 2018a), 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. There is one in the study area. Small spills and investigations are typically smaller emergency spills such as a truck spilling chemical. There are three in the study area. It is important to note that while the locations of the incidents described are as accurate as possible, it is an incomplete dataset (MDA, 2018a). A breakdown of chemical type of these incidents can be found in Table 11.

Table 11. Spills and Investigations by Chemical Type, Lincoln County

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Incident Investigations</th>
<th>Contingency Areas</th>
<th>Small Spills and Investigations</th>
<th>Old Emergency Incidents</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Pesticides &amp; Fertilizer</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anhydrous Ammonia</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>
Figure 10. Fertilizer Spills and Investigations in Lincoln County (MDA, 2018a)
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. Lincoln County has a significant amount of land devoted to row crop agriculture (Figure 11; Table 12). Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, durum wheat, dry beans and double crops involving corn and soybeans.

Lincoln County is in southwest Minnesota bordering South Dakota. The land use of the tested township is primarily agricultural, with 68 percent being used for row crops and 11 percent of land being used for pasture or hay. Land not in agricultural production in the study area is mostly grass or shrubland (13 percent). Relatively little land (five percent) in the study area is considered developed.
Figure 11. Land Cover in Lincoln County (USDA NASS Cropland Data Layer, 2013)
Table 12. Land Cover Data (2013) by Township, Lincoln County (USDA NASS Cropland Data Layer, 2013)

<table>
<thead>
<tr>
<th>Township</th>
<th>Total Acres</th>
<th>Row Crop</th>
<th>Other Crops</th>
<th>Forest</th>
<th>Open Water</th>
<th>Pasture/Hay</th>
<th>Wetland</th>
<th>Developed</th>
<th>Fallow/Barren</th>
<th>Grassland/Shrubland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>24,705</td>
<td>68%</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
<td>11%</td>
<td>0%</td>
<td>5%</td>
<td>0%</td>
<td>13%</td>
</tr>
</tbody>
</table>
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, 2019). There are a total of 13 active groundwater well permits in the study area, six of which are used for agricultural irrigation (Figure 12). About 715 acres of cropland are permitted for groundwater irrigation in this area (Table 13). All permitted wells are withdrawing groundwater from Quaternary aquifers (Table 14; MDNR, 2018).

Table 13. Active Groundwater Use Permits by Township, Lincoln County

<table>
<thead>
<tr>
<th>Township</th>
<th>Major Crop Irrigation Well Permits</th>
<th>Average Depth (feet)</th>
<th>Acres Permitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>6</td>
<td>159</td>
<td>715</td>
</tr>
</tbody>
</table>

Table 14. Active Groundwater Use Permits by Aquifer, Lincoln County

<table>
<thead>
<tr>
<th>Water Use Well Permits</th>
<th>Total</th>
<th>Average Depth (feet)</th>
<th>Aquifer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Quaternary</td>
</tr>
<tr>
<td>Major Crop Irrigation</td>
<td>6</td>
<td>159</td>
<td>6</td>
</tr>
<tr>
<td>Waterworks</td>
<td>5</td>
<td>63</td>
<td>5</td>
</tr>
<tr>
<td>Special Categories</td>
<td>2</td>
<td>196</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>128</td>
<td>13</td>
</tr>
</tbody>
</table>
Figure 12. Active Groundwater Use Permits in Lincoln County (MDNR, 2018)
APPENDIX D

Nitrate Brochure

The Minnesota Department of Agriculture and the Lincoln 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](http://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](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](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 15. Reasons Wells Were Removed from the Final Well Dataset by Township, Lincoln County

<table>
<thead>
<tr>
<th>Township</th>
<th>Point Source</th>
<th>Well Construction Problem</th>
<th>Hand Dug Well</th>
<th>Unsure of water source or Known Non Drinking Water Source</th>
<th>Site Visit Completed - Well Not Found &amp; Constructed before 1975 or Age Unknown &amp; No Well ID</th>
<th>No Site Visit &amp; Constructed before 1975 or Age Unknown &amp; No Well ID</th>
<th>No Site Visit &amp; Insufficient Data &amp; No Well ID</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

### Table 16. Completed Site Visits for Wells Removed from the Final Well Dataset by Township, Lincoln County

<table>
<thead>
<tr>
<th>Township</th>
<th>Site Visit</th>
<th>No Site Visit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
The MWI was used to gather information about Verdi Township in Lincoln County. This section includes all documented drinking water wells in the study area, not just wells MDA sampled. Table 17 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, 2019):

In Verdi Township, there are six documented (have a verified location in the MWI) drinking water wells:

- All six wells were completed in Quaternary Buried Artesian Aquifers. Their average depth is 63 feet.

**Table 17. Aquifer Type Distribution of Active Drinking Water Wells in Minnesota Well Index by Township, Lincoln County**

<table>
<thead>
<tr>
<th>Township</th>
<th>Quaternary Buried Artesian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of wells drawing water from an aquifer</td>
</tr>
<tr>
<td>Verdi</td>
<td>6</td>
</tr>
<tr>
<td>Average Well Depth (ft)</td>
<td>63</td>
</tr>
</tbody>
</table>
**APPENDIX G**

**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.

<table>
<thead>
<tr>
<th>First name</th>
<th>Last name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parcel Number</th>
<th>Township</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical address</th>
<th>City</th>
<th>State</th>
<th>Zip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mailing address</th>
<th>City</th>
<th>State</th>
<th>Zip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phone number</th>
<th>(in case we have questions about your survey) Email</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
Table 18. Property Setting for Well Location

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>County</th>
<th>Municipal</th>
<th>River Home</th>
<th>Lake Home</th>
<th>Subdivision</th>
<th>Other</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>100.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Table 19. Well Construction Type

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>Drilled</th>
<th>Sand Point</th>
<th>Hand Dug</th>
<th>Other</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>42.9%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>14.3%</td>
<td>42.9%</td>
</tr>
</tbody>
</table>

Table 20. Age of Well

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>1994 to Present</th>
<th>1985 to 1993</th>
<th>1975 to 1984</th>
<th>Before 1975</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>0.0%</td>
<td>0.0%</td>
<td>28.6%</td>
<td>14.3%</td>
<td>57.1%</td>
</tr>
</tbody>
</table>

Table 21. Depth of Well

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>0-15 Feet</th>
<th>16-49 Feet</th>
<th>50-99 Feet</th>
<th>100-299 Feet</th>
<th>≥300 Feet</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>0.0%</td>
<td>14.3%</td>
<td>28.6%</td>
<td>14.3%</td>
<td>0.0%</td>
<td>42.9%</td>
</tr>
</tbody>
</table>

Table 22. Unique Well ID Known

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>No, Unique Well ID not Known</th>
<th>Yes, Unique Well ID Known</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>42.9%</td>
<td>0.0%</td>
<td>57.1%</td>
</tr>
</tbody>
</table>

Table 23. Livestock Located on Property

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>No Livestock</th>
<th>Yes Livestock</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>42.9%</td>
<td>57.1%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Table 24. Fertilizer Stored on Property

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>No Fertilizer Stored</th>
<th>Yes Fertilizer Stored</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>100.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
### Table 25. Farming on Property

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>No Farming</th>
<th>Yes Farming</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>42.9%</td>
<td>42.9%</td>
<td>14.3%</td>
</tr>
</tbody>
</table>

### Table 26. Distance to an Active or Inactive Feedlot

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>0-49 Feet to Feedlot</th>
<th>50-99 Feet to Feedlot</th>
<th>100-299 Feet to Feedlot</th>
<th>≥300 Feet to Feedlot</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>14.3%</td>
<td>0.0%</td>
<td>14.3%</td>
<td>57.1%</td>
<td>14.3%</td>
</tr>
</tbody>
</table>

### Table 27. Distance to Septic System

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>0-49 Feet to Septic</th>
<th>50-99 Feet to Septic</th>
<th>100-299 Feet to Septic</th>
<th>≥300 Feet to Septic</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>0.0%</td>
<td>28.6%</td>
<td>28.6%</td>
<td>42.9%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

### Table 28. Distance to an Agricultural Field

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>0-49 Feet to Field</th>
<th>50-99 Feet to Field</th>
<th>100-299 Feet to Field</th>
<th>≥300 Feet to Field</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>0.0%</td>
<td>28.6%</td>
<td>42.9%</td>
<td>28.6%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

### Table 29. Drinking Water Well

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>Not Drinking Water</th>
<th>Yes, Drinking Water</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>42.9%</td>
<td>57.1%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>None</th>
<th>Distillation</th>
<th>Filtering System</th>
<th>Reverse Osmosis</th>
<th>Other</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>57.1%</td>
<td>0.0%</td>
<td>28.6%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>14.3%</td>
</tr>
</tbody>
</table>

### Table 31. Last Tested for Nitrate

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>Within the Past Year</th>
<th>Within the Last 3 Years</th>
<th>Within the Last 10 Years</th>
<th>Greater than 10 Years</th>
<th>Never Tested</th>
<th>Homeowner Unsure</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>42.9%</td>
<td>14.3%</td>
<td>42.9%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

### Table 32. Last Nitrate Test Result

<table>
<thead>
<tr>
<th>Township</th>
<th>Total</th>
<th>&lt;3 mg/L Nitrate-N</th>
<th>3&lt;10 mg/L Nitrate-N</th>
<th>≥10 mg/L Nitrate-N</th>
<th>Don’t Know</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>7</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>71.4%</td>
<td>28.6%</td>
</tr>
</tbody>
</table>
### Table 33. Well Construction Type for Final Well Dataset

<table>
<thead>
<tr>
<th>Township</th>
<th>Total Wells</th>
<th>Drilled</th>
<th>Sand Point</th>
<th>Other</th>
<th>Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdi</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Data compiled from well logs and homeowner responses.
APPENDIX J

Private Well Field Log

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Unique ID</th>
<th>Date</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>Time</th>
<th>Temp °C (1.0)</th>
<th>Specific Cond µs/cm (10%)</th>
<th>DO mg/L (10%)</th>
<th>pH (0.1)</th>
<th>Appearance/Odor/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Field Comments - sample specific notes

Updated: March, 2017