FINAL TOWNSHIP TESTING NITRATE REPORT: STEARNS COUNTY 2014-2015

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Pesticide and Fertilizer Management Division

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EXECUTIVE SUMMARY

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

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

The primary goal of the Township Testing Program is to identify areas that have high nitrate concentrations in their groundwater. The program also informs residents about the health risk of their well water. Areas were selected based on historically elevated nitrate conditions, aquifer vulnerability and row crop production. The MDA plans to offer nitrate 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 2014 private wells in the Stearns County study area (14 townships) were sampled for nitrate. Samples were collected from private wells using homeowner collection and mail-in methods. These initial samples were collected from 1,883 wells representing a 29% percent response rate of homeowners. Well log information was obtained when available and correlated with nitrate results.

The MDA completed follow-up sampling and well site visits at 389 wells in 2015. A follow-up sampling was offered to all homeowners with wells that had a detectable nitrate result.

A well site visit was conducted to identify wells that were unsuitable for analysis. Wells with construction issues or nearby potential point sources of nitrogen were removed from the final well dataset. Point sources of nitrogen include: feedlots, subsurface sewage treatment systems, fertilizer spills, and bulk storage of fertilizer. A total of 95 (5%) wells were removed from the dataset. The final well dataset had a total of 1,788 wells.

The final well dataset was analyzed to determine the percentage of wells over the HRL of 10 mg/L nitrate-N. When analyzed at the township or city scale the percent of wells over the HRL ranged from 0.0 to 11.4 percent.

INTRODUCTION

The Minnesota Department of Agriculture (MDA) is the lead agency for nitrogen fertilizer use and management. The NFMP is the state's blueprint for prevention or minimization of the impacts of nitrogen fertilizer on groundwater. The MDA revised the Nitrogen Fertilizer Management Plan (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 tests to more than 70,000 private well owners in over 300 townships between 2014 and 2019.

In 2014, 14 townships in Stearns 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 lab 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 Stearns County occurred in 2015. 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 A). Wells that had questionable construction integrity or are near a point source of nitrogen were removed from the final well dataset. After the unsuitable wells were removed, the nitrate-N concentrations of well water were assessed for each area.

For further information on the NFMP and Township Testing Program, please visit the following webpages:

www.mda.state.mn.us/nfmp
www.mda.state.mn.us/townshiptesting

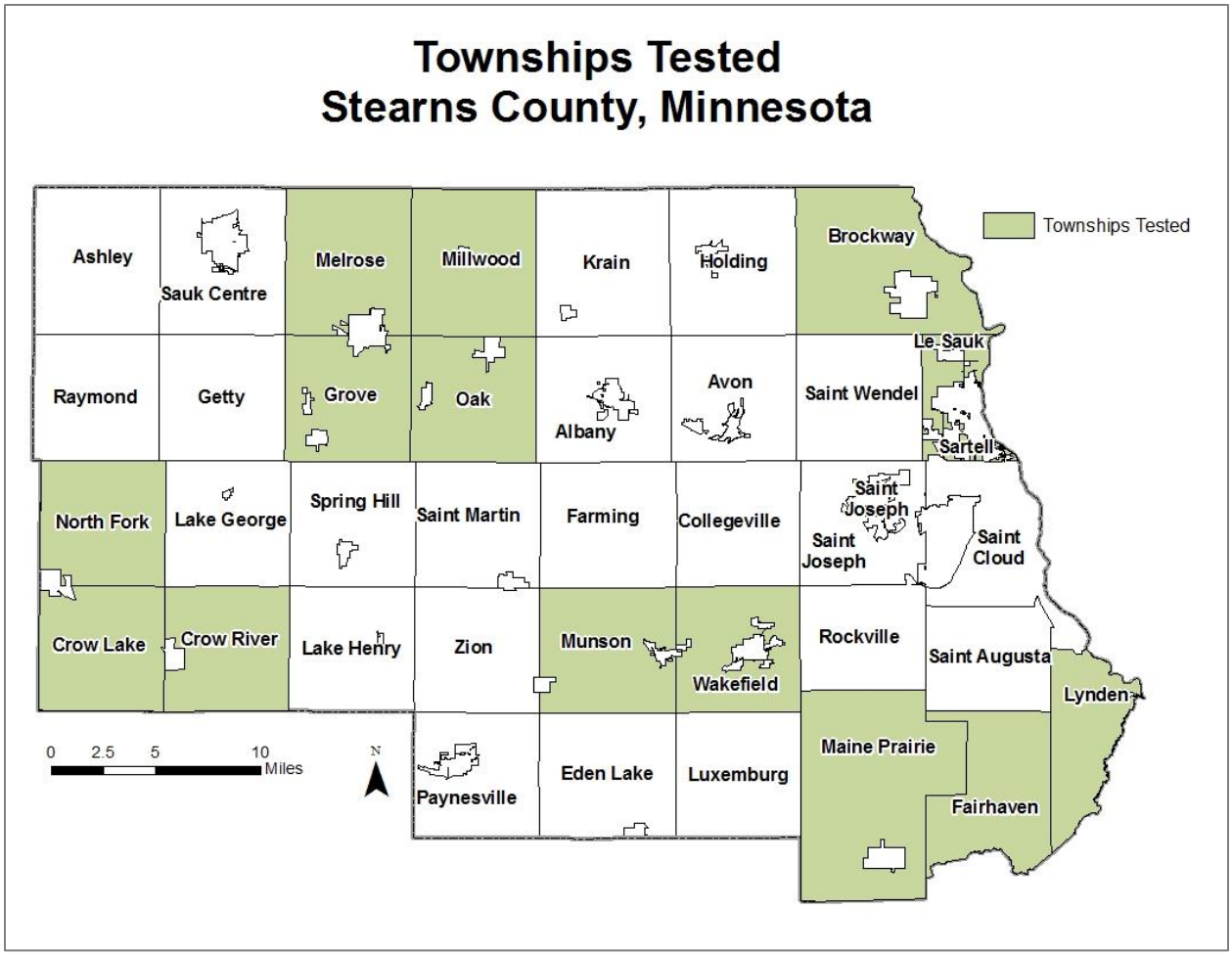

Figure 1. Townships Tested in Stearns County

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 as nitrogen (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. Shallow groundwater in coarse-textured soils (glacial outwash) generally has low concentrations of organic carbon and is well oxygenated, so denitrification is often limited in these conditions. As a result, areas like Stearns County with glacial outwash aquifers and intensive row crop agriculture, are 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).

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, bulk storage of fertilizer, and wastewater treatment plants are considered in this section. Below is a brief overview of these sources in Stearns 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).

Stearns County keeps electronic records of SSTS permits, inspections and maintenance. There are electronic records of inspections since 2009, pumping records from 2000-2013 and permits records since 2015. According to Stearns County (2015), 75 percent of their inspections during this five year period were compliant, 25 percent were non-compliant of which, three percent were an “imminent threat to public health and safety” (ITPHS) (Appendix B, Table 6).

FEEDLOT

Manure produced on a feedlot can be a potential source of nitrogen pollution if improperly stored or spread. In the Stearns County study area there are a total of 340 feedlots. The

majority of the feedlots are permitted to house less than 1000 animal units (AU) (Appendix B; Figure 3). Melrose Township has the most permitted AU per square mile (Appendix B; Table 8).

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 Stearns County study area has three bulk fertilizer storage licenses, two anhydrous ammonia facilities, 103 chemigation sites, and two abandoned sites (Appendix B; Table 9).

FERTILIZER SPILLS AND INVESTIGATIONS

A total of 14 historic fertilizer spills have occurred in the Stearns County study area. Crow Lake had the most, six, incidents and spills (Appendix B; Table 10 and 11).

TOWNSHIP TESTING METHODS

VULNERABLE TOWNSHIPS

Well water sampling is focused on areas that are considered vulnerable to groundwater contamination by 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 can be found in the initial Stearns County report (MDA, 2016a). Additional factors such as previous nitrate results and local knowledge of groundwater conditions were, and continue to be, used to prioritize townships for testing.

Aquifer sensitivity ratings from the Minnesota Department of Natural Resources were used to estimate the percentage of geology vulnerable to groundwater contamination. 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 depicting these sensitivities and a more detailed description can be found in the initial Stearns County report (MDA, 2016a). 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 Stearns County can be found in Appendix C (Figure 5, Table 12).

PRIVATE WELL SAMPLING - NITRATE

The testing is done in two steps in each township: "initial" sampling and "follow-up" sampling. The initial sampling for nitrate-N was conducted in 2014. In the initial sampling, all private well

owners in the selected townships or cities 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 brochure (Appendix D). Well water samples were collected by 1883 homeowners using the mail-in kit (Table 1). These 1883 samples are considered the "initial well dataset".

All of the homeowners with a nitrate-N 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 2015 by MDA staff and supplemented by Stearns County conservation district staff. A total of 381 follow-up samples were analyzed (Table 1).

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, 2016b). 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).

Table 1. Homeowner Participation in Initial and Follow-Up Well Water Sampling, Stearns County

Township	Estimated Households on Private Wells*	Initial Well Dataset	Well Site Visit & Follow Up Sampling Conducted
Brockway	987	263	80
Crow Lake	138	34	5
Crow River	118	46	5
Fair Haven	569	152	33
Grove	168	46	8
Le Sauk	566	164	32
Lynden	698	233	28
Maine Prairie	703	204	36
Melrose	280	67	13
Millwood	354	87	11
Munson	559	201	33
North Fork	98	20	1
Oak	197	52	9
Wakefield	1045	314	87
Total	6480	1883	381

***House hold estimate from the Minnesota State Demographic Center, 2013.

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 Well Information and Potential Nitrate Source Inventory 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.

All hand dug wells were removed from the dataset, even if the nitrate-N result was less than 5 mg/L. 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.

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.

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 or wells with cracked casing. Wells with significant problems such as these were excluded from the final well dataset.

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

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 did not visually examine these wells.

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.

Using these criteria, a total of 95 wells were removed to create the final well dataset. See Appendix E (Table 15) for a summary of the removed wells.

RESULTS

FINAL WELL DATASET

A total of 1,883 well water samples were collected by homeowners from the two communities. A total of 95 (5%) wells were removed to create the final well dataset. The final analysis was conducted on the remaining 1,788 wells (Table 2). The wells in the final well dataset represent ambient groundwater conditions.

WELL WATER NITROGEN ANALYSIS

The final analysis was based on the number of wells over the nitrate-N Health Risk Limit of 10 mg/L. [11.4] percent.

Table 2 shows the results for all townships sampled. The percent of wells at or over the Health Risk Limit ranged from 0.0 to 11.4 percent.

Table 2. Initial and Final Well Dataset Results, Stearns County

Township	All Sampled Wells	Final Well Water Dataset	Wells ≥10 mg/L nitrate-n	
			Count	Percentage
Brockway	263	253	25	9.9%
Crow Lake	34	34	2	5.9%
Crow River	46	45	1	2.2%
Fair Haven	152	146	10	6.8%
Grove	46	44	5	11.4%
Le Sauk	164	156	10	6.4%
Lynden	233	223	4	1.8%
Maine Prairie	204	194	7	3.6%
Melrose	67	61	2	3.3%
Millwood	87	84	1	1.2%
Munson	201	197	9	4.6%
North Fork	20	19	0	0.0%
Oak	52	51	0	0.0%
Wakefield	314	281	23	8.2%
Total	1,883	1,788	124	5.5%

The individual nitrate-N results from this final well dataset are displayed spatially in Figure 2. Due to the inconsistencies with geocoding the locations, the accuracy of the points may be variable.

The final well dataset summary statistics are shown in Table 3. The minimum values were all below the detection limit. The maximum values ranged from 1.9 to 69.8 mg/L nitrate-N, with

Melrose having the highest result. The 90th percentile ranged from 0.5 to 13.3 mg/L nitrate-N, with Grove having the higher result.

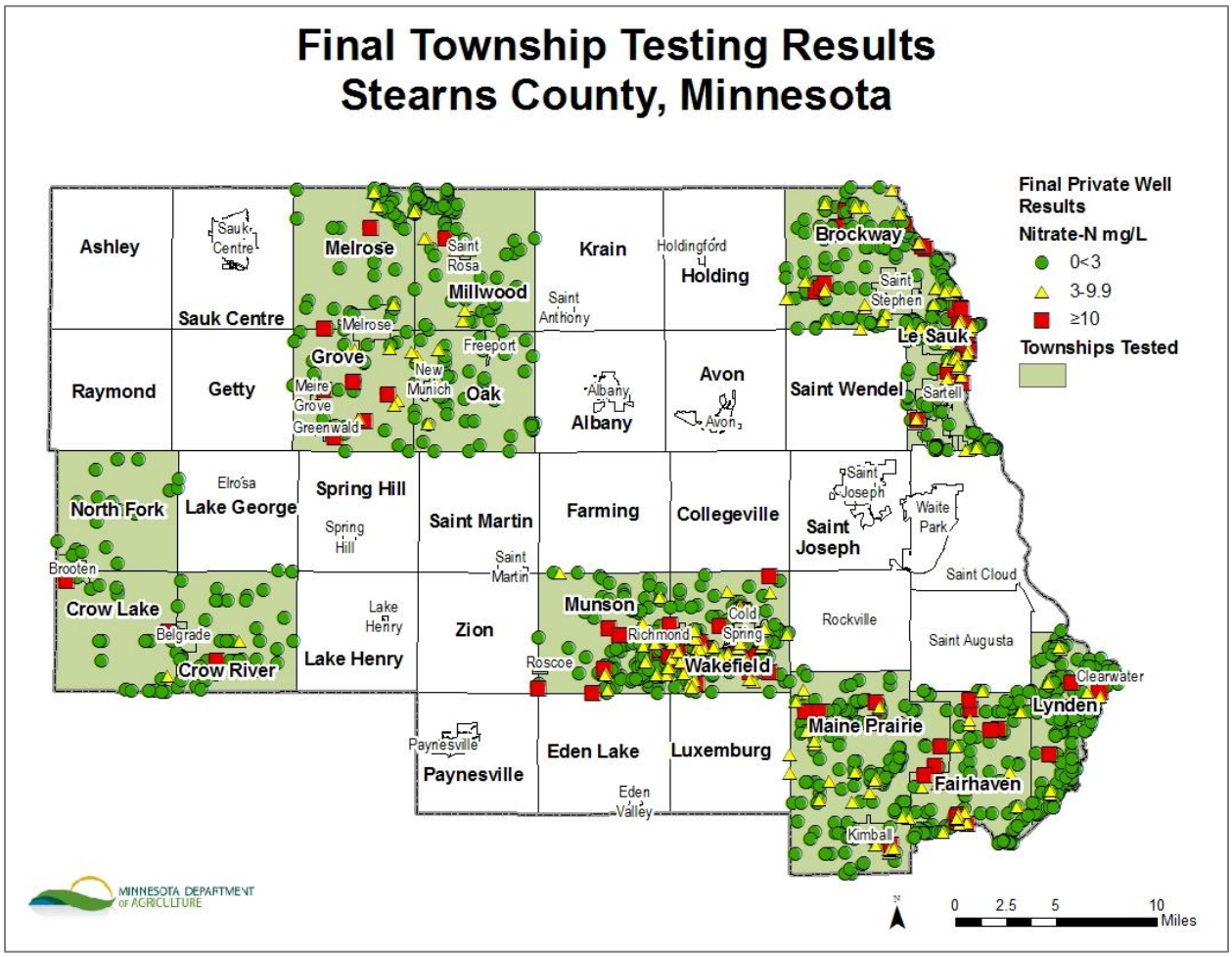

Figure 2. Well Locations and Nitrate Results from Final Well Dataset in Stearns County

Table 3. Stearns County Township Testing Summary Statistics for Final Well Dataset

Township	Total Wells	Values			Percentiles					Number of Wells					Percent of Wells				
		Min	Max	Mean	(50th) Median	75th	90th	95th	99th	<3	3<10	≥5	≥7	≥10	<3	3<10	≥5	≥7	≥10
		Nitrate-N mg/L or parts per million (ppm)																	
Brockway	253	<0.03	31.2	2.9	0.51	2.9	9.4	15.6	24.3	193	35	43	34	25	76.3%	13.8%	17.0%	13.4%	9.9%
Crow Lake	34	<0.03	32.7	1.9	<0.03	0.3	2.5	15.4	32.7	31	1	3	2	2	91.2%	2.9%	8.8%	5.9%	5.9%
Crow River	45	<0.03	31.4	1.2	<0.03	0.2	1.9	5.0	31.4	42	2	2	2	1	93.3%	4.4%	4.4%	4.4%	2.2%
Fair Haven	146	<0.03	31.1	2.2	<0.03	1.2	8.5	11.7	28.2	118	18	23	18	10	80.8%	12.3%	15.8%	12.3%	6.8%
Grove	44	<0.03	27.2	3.2	<0.03	3.2	13.3	21.2	27.2	32	7	7	6	5	72.7%	15.9%	15.9%	13.6%	11.4%
LeSauk	156	<0.03	36.8	2.2	0.04	2.5	5.8	11.4	24.3	120	26	23	13	10	76.9%	16.7%	14.7%	8.3%	6.4%
Lynden	223	<0.03	23.0	0.5	<0.03	0.0	0.5	2.9	12.5	212	7	6	5	4	95.1%	3.1%	2.7%	2.2%	1.8%
Maine Prairie	194	<0.03	30.3	1.6	<0.03	0.5	6.5	8.2	22.5	162	25	24	17	7	83.5%	12.9%	12.4%	8.8%	3.6%
Melrose	61	<0.03	69.8	2.2	<0.03	0.8	5.2	8.7	63.5	54	5	6	4	2	88.5%	8.2%	9.8%	6.6%	3.3%
Millwood	84	<0.03	15.0	0.8	<0.03	0.1	2.8	6.0	13.2	77	6	5	3	1	91.7%	7.1%	6.0%	3.6%	1.2%
Munson	197	<0.03	41.2	1.6	<0.03	0.5	5.1	9.3	23.4	170	18	21	14	9	86.3%	9.1%	10.7%	7.1%	4.6%
North Fork	19	<0.03	1.9	0.3	<0.03	0.4	1.4	1.8	1.9	19	0	0	0	0	100.0%	0.0%	0.0%	0.0%	0.0%
Oak	51	<0.03	8.0	0.5	<0.03	0.0	1.1	3.8	8.0	48	3	2	1	0	94.1%	5.9%	3.9%	2.0%	0.0%
Wakefield	281	<0.03	25.2	2.6	0.11	3.7	8.4	13.1	20.0	207	51	58	39	23	73.7%	18.1%	20.6%	13.9%	8.2%
Total	1,788	<0.03	69.8	1.9	<0.03	1.1	6.2	10.6	24.2	1485	204	223	158	99	83.1%	11.4%	12.5%	8.8%	5.5%

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 4 compares the final results to the percent of vulnerable geology (MDNR, 1997) and row crop production (USDA NASS Cropland Data Layer, 2013) in both communities. The percent land area considered vulnerable geology and in row crop production was estimated using a geographic information system known as ArcGIS.

Table 4. Township Nitrate Results Related to Vulnerable Geology and Row Crop Production, Stearns County

Township	Total Wells	Percent Vulnerable Geology	Percent Row Crop Production	Percent ≥7 mg/L	Percent ≥10 mg/L
				Nitrate-N mg/L or parts per million (ppm)	
Brockway	253	20%	41%	13.4%	9.9%
Crow Lake	34	99%	51%	5.9%	5.9%
Crow River	45	86%	57%	4.4%	2.2%
Fairhaven	146	60%	37%	12.3%	6.8%
Grove	44	30%	54%	13.6%	11.4%
Le Sauk	156	79%	38%	8.3%	6.4%
Lynden	223	84%	30%	2.2%	1.8%
Maine Prairie	194	58%	53%	8.8%	3.6%
Melrose	61	11%	45%	6.6%	3.3%
Millwood	84	36%	48%	3.6%	1.2%
Munson	197	44%	47%	7.1%	4.6%
North Fork	19	63%	54%	0.0%	0.0%
Oak	51	28%	60%	2.0%	0.0%
Wakefield	281	37%	40%	13.9%	8.2%
Total	1788	52%	47%	8.8%	5.5%

ESTIMATES OF POPULATION AT RISK

The human population at risk of consuming well water over the HRL of 10 mg/L nitrate-N was estimated based on the sampled wells. An estimated 1,303 people in Stearns County's study area may have drinking water over the nitrate-N Health Risk Limit (Table 5). Nitrate contamination is a significant problem across much of Stearns County. Additional public awareness and education programming will need to take place in many of the townships.

Table 5. Estimated Population with Water Wells Over 10 mg/L Nitrate-N, Stearns County

Township	2013 Households[1]	2013 Population[1]	Estimated Population ≥10 mg/L Nitrate-N
Brockway	987	2,690	276
Crow Lake	138	330	19
Crow River	118	352	8
Fair Haven	569	1,558	133
Grove	168	472	62
Le Sauk	566	1,582	125
Lynden	698	1,968	59
Maine Prairie	703	1,908	112
Melrose	280	817	49
Millwood	354	1,020	23
Munson	559	1,363	81
North Fork	98	266	0
Oak	197	605	12
Wakefield	1,045	2,973	350
Total	6,480	17,904	1,303

[1] Estimates based off of the estimated households on private wells and the 2013 persons per household data gathered from Minnesota State Demographic Center (http://mn.gov/admin/demography/)

WELL AND WATER CHARACTERISTICS

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells within the Stearns County final well dataset. The well logs provided information on the well age, depth, and construction type. These well characteristics were also provided by some homeowners. The well characteristics are described below and a more comprehensive view is provided in Appendix F (Table 16-18).

- The majority of the 1,788 wells were drilled (83%), only 126 (7%) were sand point wells, and 10% were unknown.
- The median depth of wells was 72 feet, and the shallowest was 19 feet
- The median year the wells were constructed in was 1998

WELL WATER PARAMETERS

MDA staff conducted the follow-up sampling. Field measurements of the well water parameters were recorded on a field log (Appendix G). 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 H (Table 19-22).

- The temperatures ranged 7.08 °C to 16.56 °C
- The median specific conductivity was 652 µS/cm, and was as high as 2,580 µS/cm
- The water from the wells had a median pH of 7.57
- The dissolved oxygen readings ranged from 0 mg/L to 10.95 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, 2015).

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, 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 is to assess nitrate-N concentrations in groundwater impacted by row crop production. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Approximately 33 percent of the land cover is row crop agriculture and there are over 36,059 acres of groundwater irrigation in the study area.

Fourteen townships were sampled covering over 325,454 acres. The initial (homeowner collected) nitrate sampling resulted in 1,883 samples, which was 39 percent of the population on private wells. Well owners with measureable nitrate results were offered a follow-up nitrate sample and a pesticide sample. The MDA resampled and visited 381 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 95 (5%) wells were found to be unsuitable and were removed from the final well dataset of 1,788 wells. The remaining wells were wells believed to be impacted by nitrogen fertilizer and were included in the final well dataset.

A majority of wells (83%) were drilled while only seven percent were sand points. The median depth of the wells was 72 feet and depths ranged from 19 to 453 feet.

In Grove Township more than 10 percent of the wells were over the Health Risk Limit of 10 mg/L. The percent of wells over the Health Risk Limit in each township ranged from 0.0 percent to 11.4 percent.

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APPENDIX A

Well information and Potential Nitrate Source Inventory Form

UNIQUE NUMBER:_____ or SITE ID:_____

Well Information and Potential Nitrate Source Inventory Form

General Information

Date of Visit: _____County: _____ Township_____

Well Unique Number (6 digits): _____ Parcel Number: _____

Site ID (from township sampling if no Unique ID):_____

GPS location of well: Latitude:_____ Longitude:_____

Owner Name: _____

Owner Phone: _____

Owner Address: _____

e-mail:_____

Inspector Name:_____Inspector Phone: _____

Well Construction Information

1. Is this well used for drinking water? (Circle One) a) YES or b) NO
2. Is the outdoor water raw or filtered? (softened, distilled, reverse osmosis, activated carbon, etc.)

   _____
3. Well Information collected from (Circle One):
   - a) Well Log (**Attach**) or b) Verbal (Indicate Person): _____
4. Well Construction Type: _____ (Drilled, Sand point, Hand-dug, other)
5. Well Construction Date: _____
6. Well Depth (Feet): _____
7. Well Diameter (Inches): _____
8. Pump Installer (Sticker):_____
9. Who services the well (if available)? _____
10. Is there more than one well on this property?_____
    - If yes, list well type and Unique No. if available:_____

1

UNIQUE NUMBER:_____ or SITE ID:_____

11. Is Fertilizer stored on this property(Circle One) a) YES or b) NO
    - If yes, what is the distance to the well?_____
12. Historical fertilizer storage? a) YES or b) NO
    - If yes, what is the distance to the well? _____
13. Historic/Abandoned septic system? a) YES or b) NO
    - If yes, what is the distance to the well?_____
14. List sample types collected at this site:_____
15. Have you made any changes to your well in the last year? _____

    (added filtration system, raised well, replaced pump, upgraded well casing, replaced well, etc.)

16. Are there potential nitrate sources nearby that are >300 ft. away from the well, if so list type and approximate distance_____

Go to last page for Source Codes and well drawing.

ADDITIONAL NOTES:

_____
_____
_____
_____

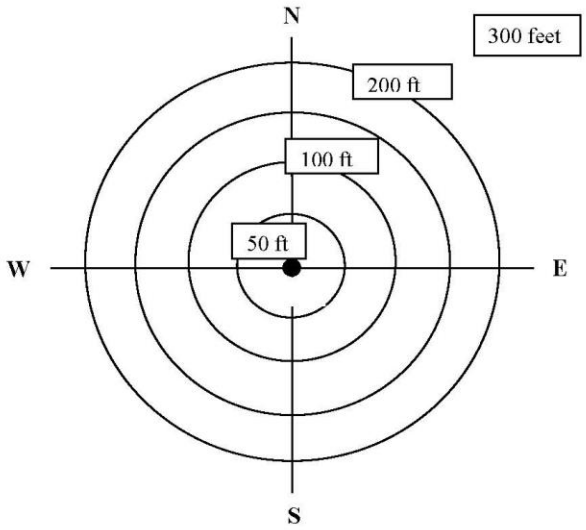
UNIQUE NUMBER:_____ or SITE ID:_____

DIRECTIONS: Stand at the well, find north and describe the type, position and distance to potential nitrate sources with 300 feet of the well. Put a dot where nitrate source is relative to the well. Label the dot with the appropriate code and label the distance. Codes are given below:

CODES

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

17. Does water drain toward the well? a) YES or b) NO
18. Which direction does the landscape slope? (Draw arrow across bull's eye, through well, and label)
19. Is the slope: a) Steep or b) Shallow
20. Are there any *obvious* problems with the well? a) YES or b) NO
21. If yes, describe the problem:_____
20. Source Codes and Distances:_____



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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 holding 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 335.01 and MPCA, 2013a).

There were 3,479 SSTS inspections performed in Stearns County from 2010 thru 2014. Each SSTS was given a compliance rating of either *compliant* or *non-complaint*. The non-compliant ranking consists of 4 categories: non-compliant, non-compliant (FTPGW), non-compliant (ITPH), and non-compliant (Ordinance #422 Deficiencies). Ordinance #422 is specific to Stearns County and more restrictive than Minnesota's current rule; therefore, cases which were determined to be non-compliant by Stearns County due to Ordinance #422 are being considered as compliant for this study (Stearns County, 2010).

Table 6. SSTS compliance 2010-2014.

SSTS Compliance		
Number of Inspections		3,479
Compliant		75%
Non-compliant	Not Failing or ITPH	21%
	Failing only	1%
	ITPH only	3%
	Failing and ITPH	4%
Non-compliant (total)		25%

FEEDLOT

The amount of nitrogen in manure depends on the species of animal. For example, there is approximately 31-32 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, 2014). 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 7) (MPCA, 2014).

Table 7 Animal Unit Calculations (MPCA, 2014)

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 (MPCA, 2014). Feedlots with more than 1,000 AU are regulated through federal National Pollution Discharge Elimination (NPDES) permits (MPCA, 2011) and must submit an annual manure management plan as part of their permit (MPCA, 2015d).

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, 2014).

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. Registration is required to be completed at least once during a set four year period, the most recent period ran from January 2014 to December 2017 (MPCA, 2015b). From 2010 to 2014, approximately 18,000 feedlots were registered in Minnesota (MPCA, 2014). A map and table of the feedlots located in the Stearns County study area can be found below (Figure 3; Table 8).

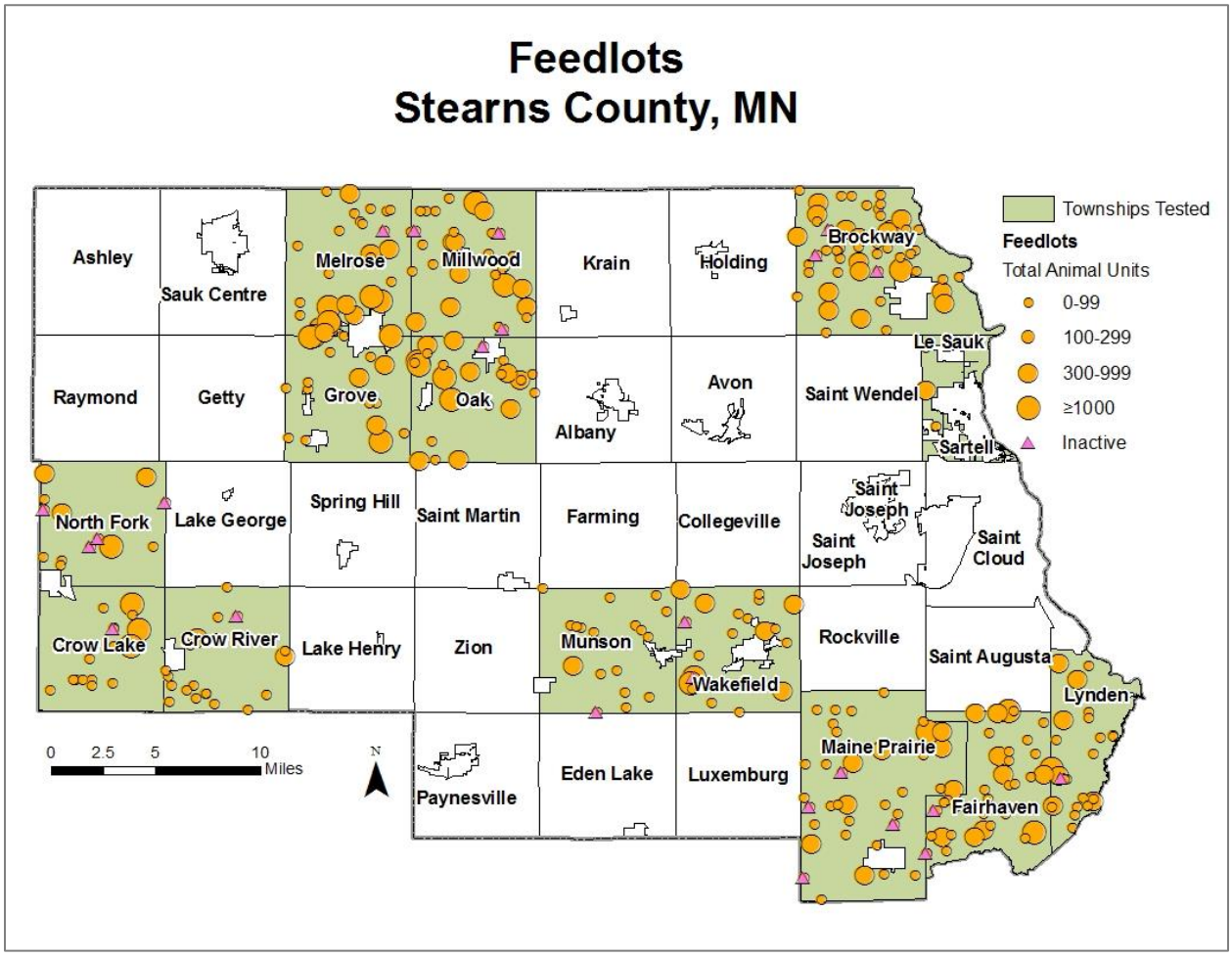

Figure 3. Feedlot Locations in Stearns County (MPCA, 2015c)

Table 8. Feedlots and Permitted Animal Unit Capacity, Stearns County

Township	Total Feedlots	Inactive feedlots	Average Animals	Total Animals	Average AU	Total AU	Total Square Miles	AU per Square Mile
Brockway	53	3	6,470	323,497	95	4,773	48	99
Crow Lake	17	1	1,018	16,290	241	3,863	35	110
Crow River	19	1	76	1,368	51	911	34	27
Fairhaven	37	1	4,289	154,400	99	3,573	36	100
Grove	18	0	12,817	230,711	282	5,082	34	150
Le Sauk	3	0	58	173	51	152	10	15
Lynden	24	1	2,103	48,362	56	1,296	25	51
Maine Prairie	38	5	108	3,565	77	2,540	65	39
Melrose	28	1	8,511	229787	311	8,407	40	210
Millwood	29	3	7,324	190423	120	3,133	41	76
Munson	18	1	61	1036	33	555	38	15
North Fork	13	4	16,018	144161	138	1,244	35	36
Oak	24	1	11,180	257129	259	5,957	34	174
Wakefield	19	2	5,593	95082	110	1,866	33	57
Total	340	24	*5,367	1,695,984	*137	43,351	508	85

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

On average there are 85 AU per square mile (0.13 AU/acre) over the entire study area (Table 8). Manure from AU is often applied to cropland so it is pertinent to look at the AU per cropland acre. In the Stearns County study area livestock densities average 0.40 AU per acre of row crops (MPCA, 2015c; USDA NASS, 2013).

FERTILIZER STORAGE LOCATION

MDA tracks licenses for bulk fertilizer storage facilities, anhydrous ammonia, and chemigation sites (Table 9). Abandoned sites are facilities that once housed fertilizer chemicals. These sites are also noted and tracked by MDA as they are potential contamination sources.

Table 9. Fertilizer Storage Facility Licenses and Abandoned Sites, Stearns County

Township	*Bulk Fertilizer Storage	*Anhydrous Ammonia	*Chemigation Sites	*Abandoned Sites	Total
Brockway	0	0	4	0	4
Crow Lake	1	2	43	0	46
Crow River	1	0	17	0	18
Fairhaven	0	0	9	0	9
Grove	0	0	0	0	0
Le Sauk	0	0	0	1	1
Lynden	0	0	0	0	0
Maine Prairie	0	0	8	0	8
Melrose	1	0	1	1	3
Millwood	0	0	0	0	0
Munson	0	0	3	0	3
North Fork	0	0	10	0	10
Oak	0	0	0	0	0
Wakefield	0	0	8	0	8
Total	3	2	103	2	110

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

SPILLS AND INVESTIGATIONS

MDA is responsible for investigating any fertilizer spills within Minnesota. Figure 4 shows the locations of mapped historic spills within the Stearns County study area. These sites are potential point sources of nitrogen to the groundwater (MDA, 2015b).

MDA tracks several types of incidents. Incident investigations are typically for larger spills. There are eight 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, 2015a), 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, 2015a). Many types of spills are reported to the MDA, however only spills that potentially contain nitrogen are reported here. A breakdown of chemical type of these incidents can be found in Table 10. A breakdown of the fertilizer specific spills and investigations, by township, can be found in Table 11.

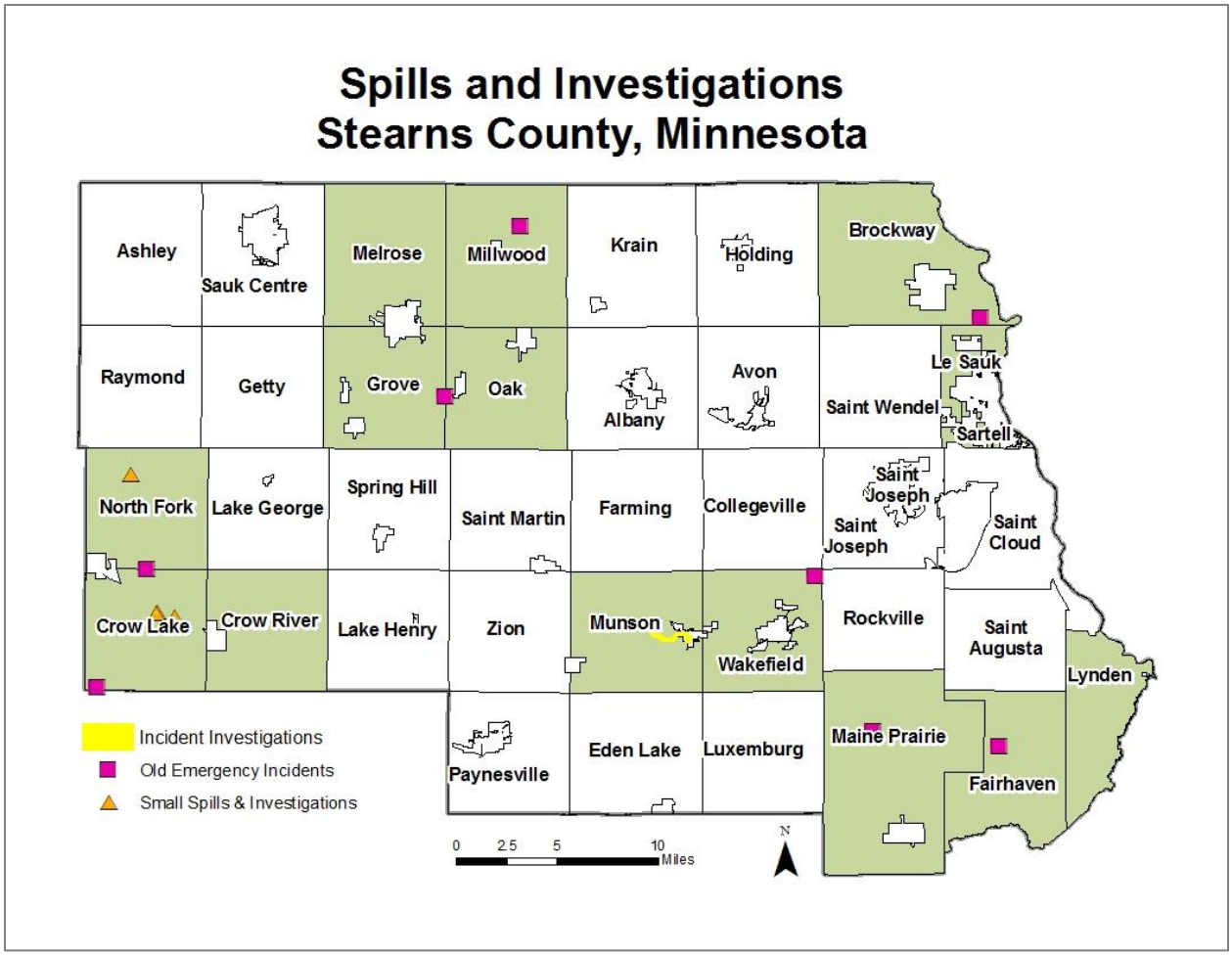

Figure 4. Fertilizer Spills and Investigations in Stearns County (MDA, 2015a)

Table 10. Spills and Investigations by Contaminant Type

Contaminant	Incident Investigations	Contingency Areas	Small Spills and Investigations	Old Emergency Incidents
Fertilizer	1	0	2	5
Pesticides & Fertilizer	1	0	0	0
Anhydrous Ammonia	0	0	2	3
Total	2	0	4	8

Table 11. Incidents and Spills by Township, Stearns County

Township	Incidents and Spills
Brockway	1
Crow lake	6
Crow River	0
Fairhaven	1
Grove	1
Le Sauk	0
Lynden	0
Maine Prairie	1
Melrose	0
Millwood	1
Munson	1
North Fork	1
Oak	0
Wakefield	1
Total	14

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. There are 325,454 acres in the study area and 108,942 acres of that is in row crop production (33%) (Figure 5; Table 12). Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, wheat, dry beans and double crops involving corn and soybeans. Pasture and hay make up 35 percent of the area. While 16 percent of the land is forested and approximately eight percent of the area is water or wetland.

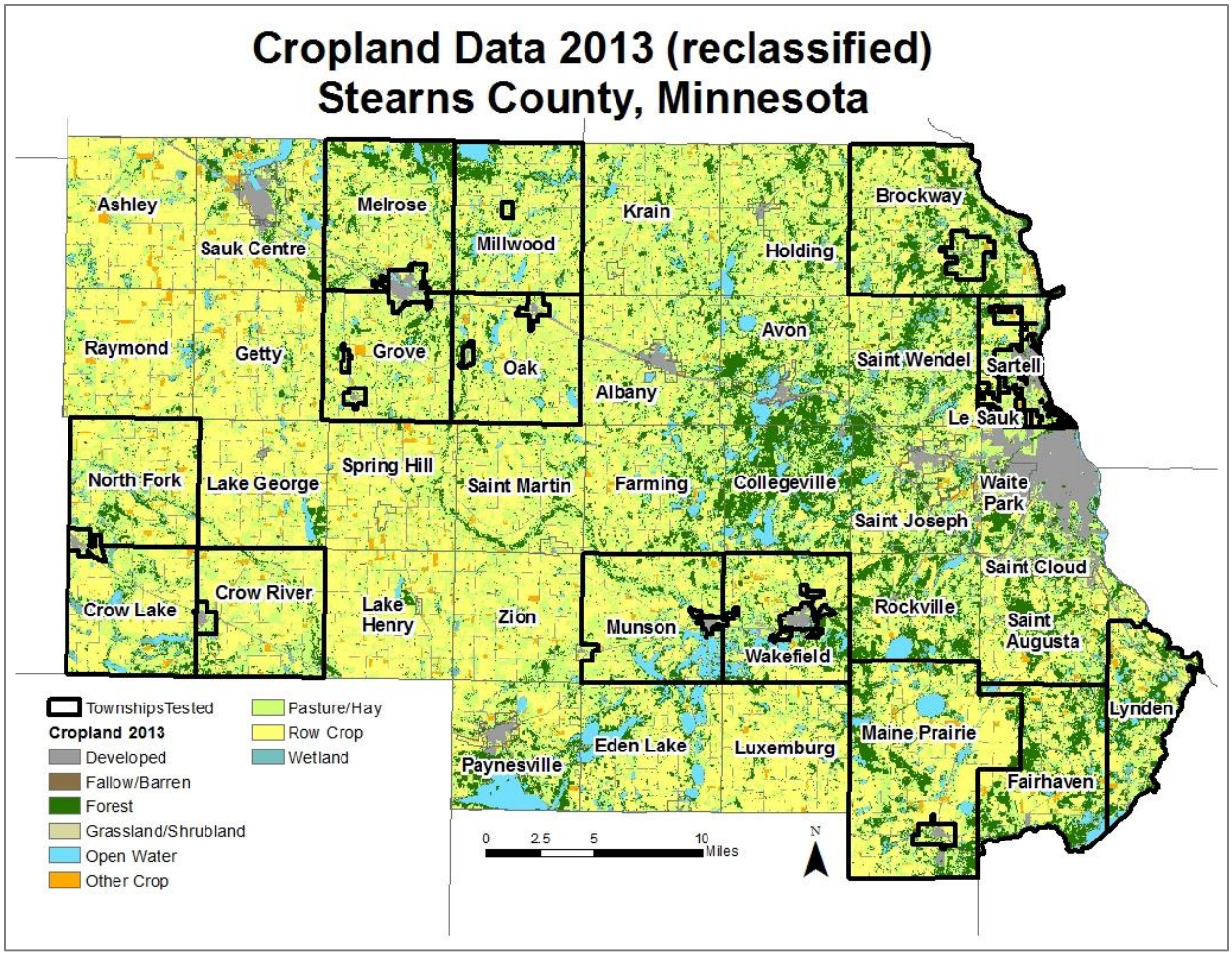

Figure 5. Land Cover in Stearns County (USDA NASS Cropland Data Layer, 2013)

Table 12. Land Cover Data (2013) by Township, Stearns County (USDA NASS Cropland Data Layer, 2013)

Township	Total Acres	Row Crop	Other Crops	Forest	Open Water	Pasture/ Hay	Wetland	Developed	Fallow/ Barren	Grassland/ Shrubland
Brockway	30,971	25%	2%	24%	1%	37%	5%	5%	0%	1%
Crow Lake	22,424	42%	2%	9%	3%	30%	8%	4%	0%	2%
Crow River	21,938	41%	3%	7%	0%	41%	3%	4%	0%	1%
Fairhaven	22,892	26%	3%	30%	4%	25%	5%	4%	0%	1%
Grove	21,677	32%	2%	9%	1%	48%	2%	5%	0%	1%
Le Sauk	6,672	31%	5%	16%	3%	29%	6%	9%	0%	1%
Lynden	16,249	22%	3%	26%	6%	28%	7%	7%	0%	1%
Maine Prairie	41,332	44%	2%	18%	5%	22%	4%	5%	0%	1%
Melrose	25,598	29%	2%	19%	2%	42%	2%	5%	0%	1%
Millwood	26,501	28%	1%	15%	7%	42%	3%	4%	0%	1%
Munson	24,137	33%	2%	11%	8%	37%	3%	5%	0%	1%
North Fork	22,276	41%	3%	8%	0%	37%	6%	3%	0%	1%
Oak	21,917	39%	1%	7%	4%	42%	1%	5%	0%	0%
Wakefield	20,871	27%	2%	19%	7%	34%	3%	6%	0%	1%
Total	325,454	33%	2%	16%	4%	35%	4%	5%	0%	1%

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 451 groundwater permits in the study region and 397 are used for irrigating crops (Appendix C, Table 13; Figure 6). Most permitted wells are withdrawing groundwater from Paleozoic aquifers (Appendix C, Table 14). More specifically the Jordon formation and the Prairie du Chien group are the most heavily utilized aquifers.

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

Township	Major Crop Irrigation Permits	Permitted Irrigated Acres	Average Depth (feet)
Brockway	20	1,919	90
Crow lake	100	8,285	63
Crow River	56	5,807	143
Fairhaven	24	1,923	83
Grove	11	766	63
Le Sauk	4	475	77
Lynden	8	554	54
Maine Prairie	76	7,583	72
Melrose	5	524	145
Millwood	0	0	0
Munson	25	1,825	39
North Fork	35	3,485	97
Oak	8	440	51
Wakefield	25	2,473	68
Total	397	36,059	80

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

Water Use Permits	Total	Average Depth (feet)	Aquifer System			
			Quaternary (Water Table)	Quaternary (Buried)	Paleozoic	Not Classified
Major Crop Irrigation	397	82	194	137	0	66
Non-Crop Irrigation	7	36	5	2	0	0
Waterworks	30	74	22	8	0	0
Industrial Processing	13	48	10	2	0	1
Water Level Maintenance	1	47	0	1	0	0
Special Categories	3	77	0	1	0	2
Total	451	79	231	151	0	69

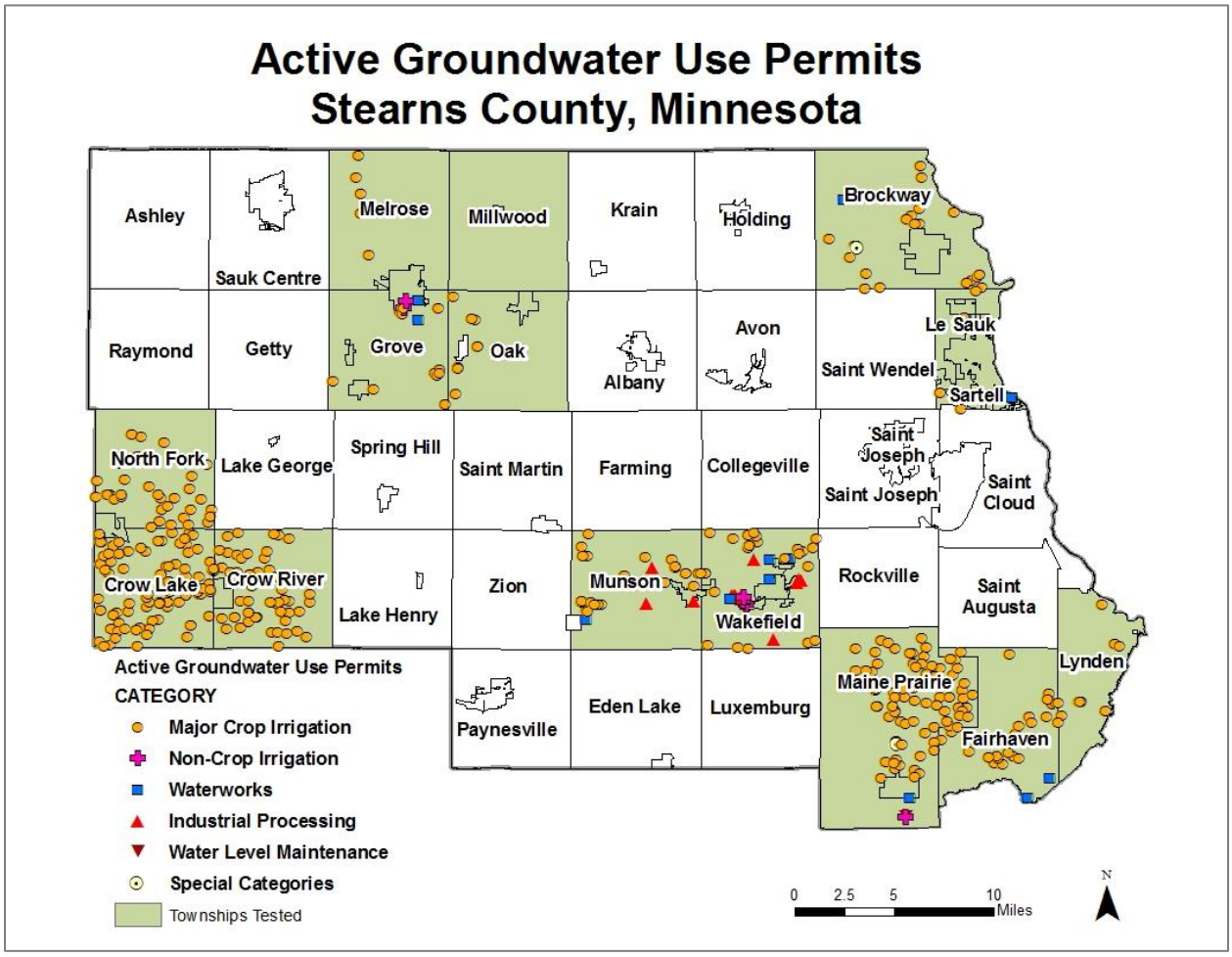

Figure 6. Active Groundwater Use Permits in Stearns County (MDNR, 2013)

APPENDIX D

Nitrate Brochure

The Minnesota Department of Agriculture and the Stearns 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.

MINNESOTA DEPARTMENT OF AGRICULTURE

CLEAN WATER LAND & LEGACY AMENDMENT

APPENDIX E

Table 15. Reasons Wells Were Removed from the Final Well Dataset by Township, Stearns County

Township	Point Source	Well Construction Problem	Hand Dug Wells	Irrigation Well	Unsure of Water Source	No ID & Well Not Seen & Constructed Before 1975	No ID & No Site Visit & Insufficient Information	Total
Brockway	2	0	0	0	0	7	1	10
Crow Lake	0	0	0	0	0	0	0	0
Crow River	0	0	0	0	0	1	0	1
Fair Haven	3	0	0	0	1	2	0	6
Grove	1	0	0	0	0	1	0	2
Le Sauk	1	0	0	0	2	5	0	8
Lynden	3	0	0	0	2	5	0	10
Maine Prairie	3	0	0	0	1	6	0	10
Melrose	0	0	0	0	1	5	0	6
Millwood	1	0	0	0	0	2	0	3
Munson	1	0	0	0	0	2	1	4
North Fork	0	0	0	0	0	1	0	1
Oak	1	0	0	0	0	0	0	1
Wakefield	6	0	0	0	4	21	2	33
Total	22	0	0	0	11	58	4	95

APPENDIX F

Table 16. Well Construction Type for Final Well Dataset

Township	Samples	Drilled	Sand Point	Not Available
Brockway	253	228	4	21
Crow Lake	34	24	10	0
Crow River	45	32	11	2
Fair Haven	146	118	13	15
Grove	44	38	3	3
Le Sauk	156	128	8	20
Lynden	223	185	12	26
Maine Prairie	194	160	19	15
Melrose	61	50	4	7
Millwood	84	73	2	9
Munson	197	152	23	22
North Fork	19	15	2	2
Oak	51	42	5	4
Wakefield	281	236	10	35
Total	1,788	1,481	126	181

Data compiled from well logs and homeowner responses.

Table 17. Well Depth for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Brockway	118	24	393	63	76
Crow Lake	19	28	237	139	132
Crow River	20	60	221	140	140
Fair Haven	71	21	201	67	79
Grove	15	35	295	63	87
Le Sauk	35	22	157	69	71
Lynden	93	41	164	69	74
Maine Prairie	94	19	296	68	79
Melrose	23	28	177	58	76
Millwood	35	31	325	90	109
Munson	78	20	400	98	100
North Fork	6	65	191	97	106
Oak	18	30	453	55	88
Wakefield	102	22	430	82	113
Total	727	19	453	72	90

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

Table 18. Year of Well Construction for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Brockway	118	1975	2013	1996	1996
Crow Lake	19	1991	2013	2003	2002
Crow River	20	1987	2013	2000	2000
Fair Haven	71	1975	2014	2000	1998
Grove	15	1989	2005	1999	1997
Le Sauk	35	1977	2014	1995	1996
Lynden	93	1975	2010	1994	1994
Maine Prairie	94	1975	2013	1997	1997
Melrose	23	1988	2012	2002	2001
Millwood	35	1982	2013	1999	1999
Munson	78	1976	2013	1998	1996
North Fork	6	1984	2013	2001	2000
Oak	18	1977	2012	2001	1998
Wakefield	102	1981	2013	1997	1997
Total	727	1975	2014	1998	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 G

Private Well Field Log

Minnesota Department of Agriculture -Private Well Field Log

Well Unique#	Site ID	Sample #'s	Date	Time	Well Depth (units)
		Nitrate:			
Sampler:		Pesticide:			Well Type:
Well Owner Name:					
Well Owner Address:					
GPS: Latitude:			Longitude:		

Duplicates collected? Yes or No

Duplicate #'s: nitrate: _____ pesticide:_____

Sample point location (for example: outside tap on south side of home)_____

Pump start time: _____ Discharge rate: _____ Time sample collected:_____

Stabilization Measurements

Time	Temp (units) (1.0°)	pH (0.1)	Specific Cond. (units) (10%)	DO (units) (10%)	Appearance/Notes

Wind (units)	Air temp (units)	Weather	Nearest possible pesticide source (type and distance)

COMMENTS/Notes:

Updated 5/18/2015

APPENDIX H

Table 19. Temperature (°C) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Brockway	76	8.77	12.82	10.17	10.32
Crow Lake	5	9.31	12.34	11.03	10.86
Crow River	4	9.27	13.86	11.11	11.34
Fair Haven	30	8.93	11.62	10.60	10.63
Grove	6	9.48	11.24	9.84	10.17
Le Sauk	29	9.38	15.56	10.40	10.69
Lynden	24	9.73	12.1	10.63	10.70
Maine Prairie	33	9.8	16.3	10.79	10.94
Melrose	11	7.08	16.56	9.91	10.28
Millwood	9	9.54	16.51	10.07	11.28
Munson	28	9.44	13.21	11.36	11.34
North Fork	1	9.39	9.39	9.39	9.39
Oak	8	9.16	14.65	10.70	11.03
Wakefield	57	9.76	13.71	11.24	11.36
Total	321	7.08	16.56	10.63	10.81

Table 20. Specific Conductivity (µS/cm) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Brockway	76	388	1095	533	568
Crow Lake	5	483	842	770	681
Crow River	4	670	1118	797	846
Fair Haven	30	425	1004	572	629
Grove	6	685	1051	929	909
Le Sauk	29	479	957	634	663
Lynden	24	426	1058	647	673
Maine Prairie	33	434	1078	690	702
Melrose	11	503	1073	602	671
Millwood	9	333	918	749	719
Munson	28	511	1485	771	816
North Fork	1	720	720	720	720
Oak	8	515	1041	826	802
Wakefield	57	160	2580	748	845
Total	321	160	2580	652	700

Table 21. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Brockway	76	7.21	8.1	7.645	7.641
Crow Lake	5	7.36	7.8	7.5	7.538
Crow River	4	7.42	7.77	7.465	7.53
Fair Haven	30	7.24	8.03	7.64	7.629
Grove	6	7.07	7.65	7.305	7.322
Le Sauk	29	7.08	7.97	7.55	7.543
Lynden	24	7.28	8.58	7.695	7.725
Maine Prairie	33	7.12	8.06	7.45	7.475
Melrose	11	7.21	7.98	7.51	7.513
Millwood	9	7.03	7.88	7.51	7.53
Munson	28	7.32	8.25	7.635	7.64
North Fork	1	7.86	7.86	7.86	7.86
Oak	8	7.22	8.07	7.61	7.629
Wakefield	57	7.2	7.74	7.44	7.473
Total	321	7.03	8.58	7.57	7.574

Table 22. Dissolved Oxygen* (mg/L) of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Brockway	76	0.02	9.29	1.76	1.98
Crow Lake	5	0.03	1.47	0.13	0.59
Crow River	4	0.01	0.1	0.03	0.04
Fair Haven	30	0.15	9.73	2.83	3.97
Grove	6	0.48	5.28	3.67	3.20
Le Sauk	29	0	10.95	0.54	2.47
Lynden	24	0.08	5.01	1.39	1.86
Maine Prairie	33	0.08	7.27	2.50	2.40
Melrose	11	0.79	6.32	2.50	2.93
Millwood	9	0.02	2.4	1.47	1.18
Munson	28	0.1	4.42	1.43	1.63
North Fork	1	0.03	0.03	0.03	0.03
Oak	8	0.01	4.66	0.90	1.78
Wakefield	57	0.14	10.38	3.10	3.04
Total	321	0	10.95	1.85	2.38