Final Township Testing Nitrate Report:

Dodge County 2016-2017

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Pesticide and Fertilizer Management Division

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EXECUTIVE SUMMARY

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

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

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

In 2016, private wells in the Dodge County study area (seven townships) were sampled for nitrate-N. Samples were collected from private wells using homeowner collection and mail-in methods. These initial samples were collected from 654 wells representing an average response rate of 33 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, 7.0 percent of private wells sampled were at or above the health standard of 10 mg/L for nitrate-N. Based on the initial results, it is estimated that over 384 residents could be consuming well water with nitrate-N at or over the HRL.

The MDA completed follow-up sampling and well site visits at 111 wells in 2017 and the spring of 2018. A follow-up sampling was offered to all homeowners with wells that had a detectable nitrate-N result.

A well site visit was conducted to identify wells that were unsuitable for final analysis. The final well dataset is intended to only include private drinking water wells potentially impacted by applied commercial agricultural fertilizer. Therefore, wells with construction issues or nearby potential point sources of nitrogen were removed from the final well dataset. Point sources of nitrogen can include: feedlots, subsurface sewage treatment systems, fertilizer spills, and bulk storage of fertilizer. A total of 66 (10 percent) wells were determined to be unsuitable and were removed from the dataset. The final well dataset had a total of 588 wells.

The final well dataset was analyzed to determine the percentage of wells at or over the HRL of 10 mg/L nitrate-N. When analyzed at the township scale the percent of wells at or over the HRL ranged from 0.0 to 4.8 percent. All of the tested townships in Dodge County have less than five percent of wells at or over the HRL.

INTRODUCTION

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

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

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

Well owners with detectable nitrate-N results were offered a no cost pesticide sample and a follow-up nitrate-N sample collected by MDA staff. The MDA began evaluating pesticide presence and concentrations in private water wells at the direction of the Minnesota Legislature. The follow-up pesticide and nitrate-N sampling in Dodge County occurred during the summer of 2017 and spring of 2018. The follow-up included a well site visit (when possible) in order to rule out well construction issues and to identify potential point sources of nitrogen (Appendix B).

Wells that had questionable construction integrity or 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, visit the following webpages:
www.mda.state.mn.us/nfmp
www.mda.state.mn.us/townshiptesting

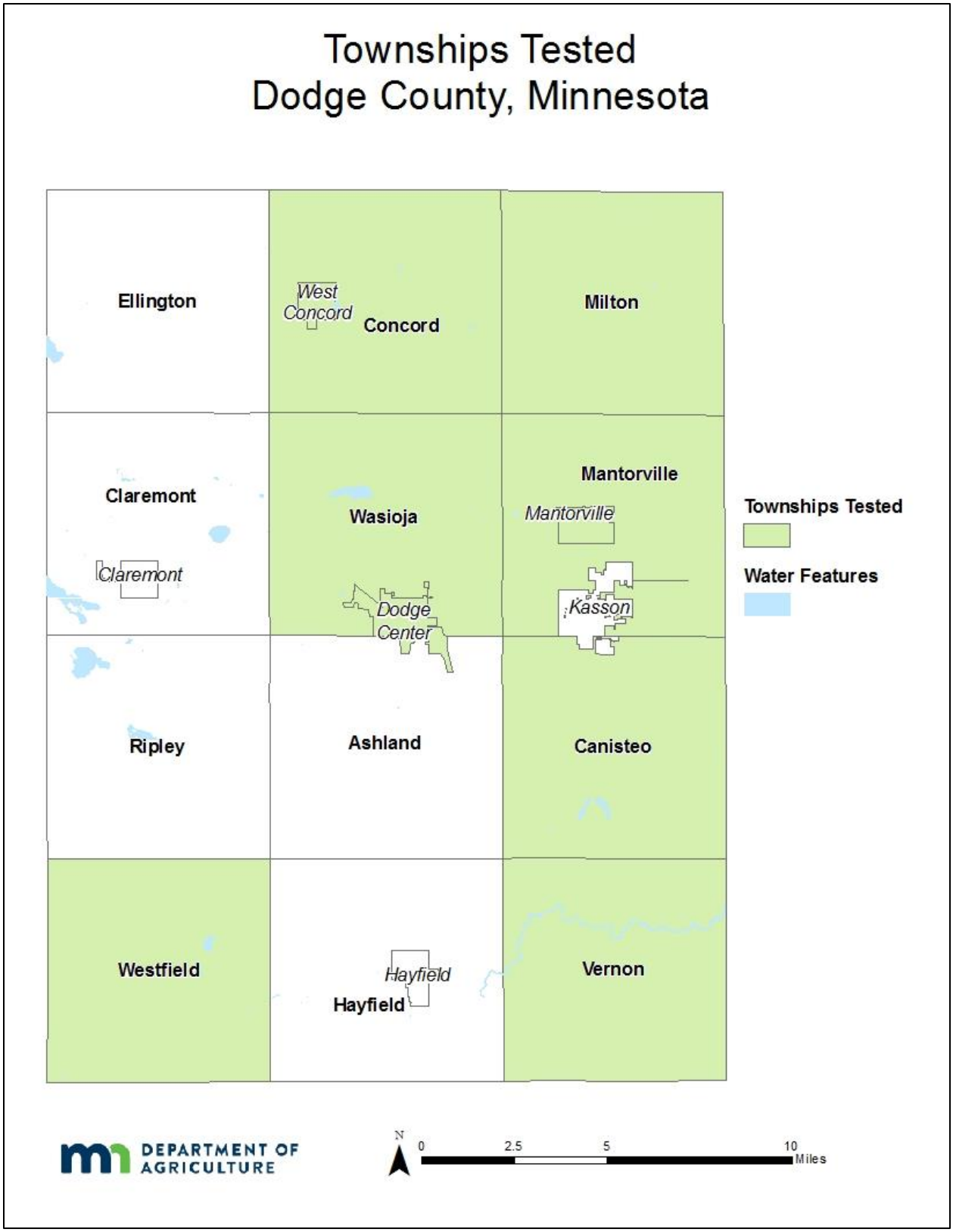

Figure 1. Townships Tested in Dodge County

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. In systems with thin layers of soil or other confining material above shallow aquifers, such as parts of Dodge County, contaminants such as nitrate can travel quickly to the aquifer, leaving little chance for denitrification or other attenuating processes (Aller et al. 1987). As a result certain areas of Dodge County, with shallow aquifers, thin soils, and intensive row crop agriculture, are particularly vulnerable to elevated nitrate concentrations (Nolan, 2001; Anderson, 2002). However, geochemical conditions can be highly variable within an aquifer or region and can also change over-time (MPCA, 1999).

GEOLOGY AND HYDROGEOLOGY

During the most recent glacial advance of the Des Moines Lobe (~14,000 years ago) only the most western portion of Dodge County was covered. Much of the glacial material deposited in Dodge County occurred during earlier glacial advances from 300,000 to 130,000 years ago. During these glaciation periods glacial till were deposited directly by the glaciers. The till is typically poorly sorted clay, silt, sand,

gravel, cobbles, and boulders and is generally thicker in the western part of the county, and thinner to the east. Glacial outwash and fluvial sediments were deposited by meltwater associated with these glaciations. The glacial outwash tends to be made of stratified silt, sand, and gravel, and is most prominent near the western border of the county. The fluvial sediments consist of stratified fine and course sand with layers of gravel, silt, and clay and are located in river valleys throughout the county. The thickness of glacial material ranges widely from just a few feet to several hundred feet (Anderson, 2002).

Karst is prominent geologic feature in eastern parts of Dodge County. However, it is not present in western Dodge County where 50 feet or more of unconsolidated sediments overlays bedrock material. Karst is defined as “terrain with distinctive landforms and hydrology created primarily from the dissolution of soluble rocks”. Distinctive features such as sink holes, springs and caves can been seen as visual evidence of karst activity on the land’s surface. Karst features are important when discussing groundwater because these features can allow rapid water flow from the surface to the groundwater, which can allow contaminants to move quickly as well (Adams, Barry, and Green, 2016)

Statewide geomorphological mapping conducted by the Minnesota Department of Natural Resources (MDNR), the Minnesota Geological Survey (MGS) and the University of Minnesota at Duluth (MDNR, MGS, and UMD, 1997) indicates the extent of glacial deposits in Dodge County as presented in Figure 2.

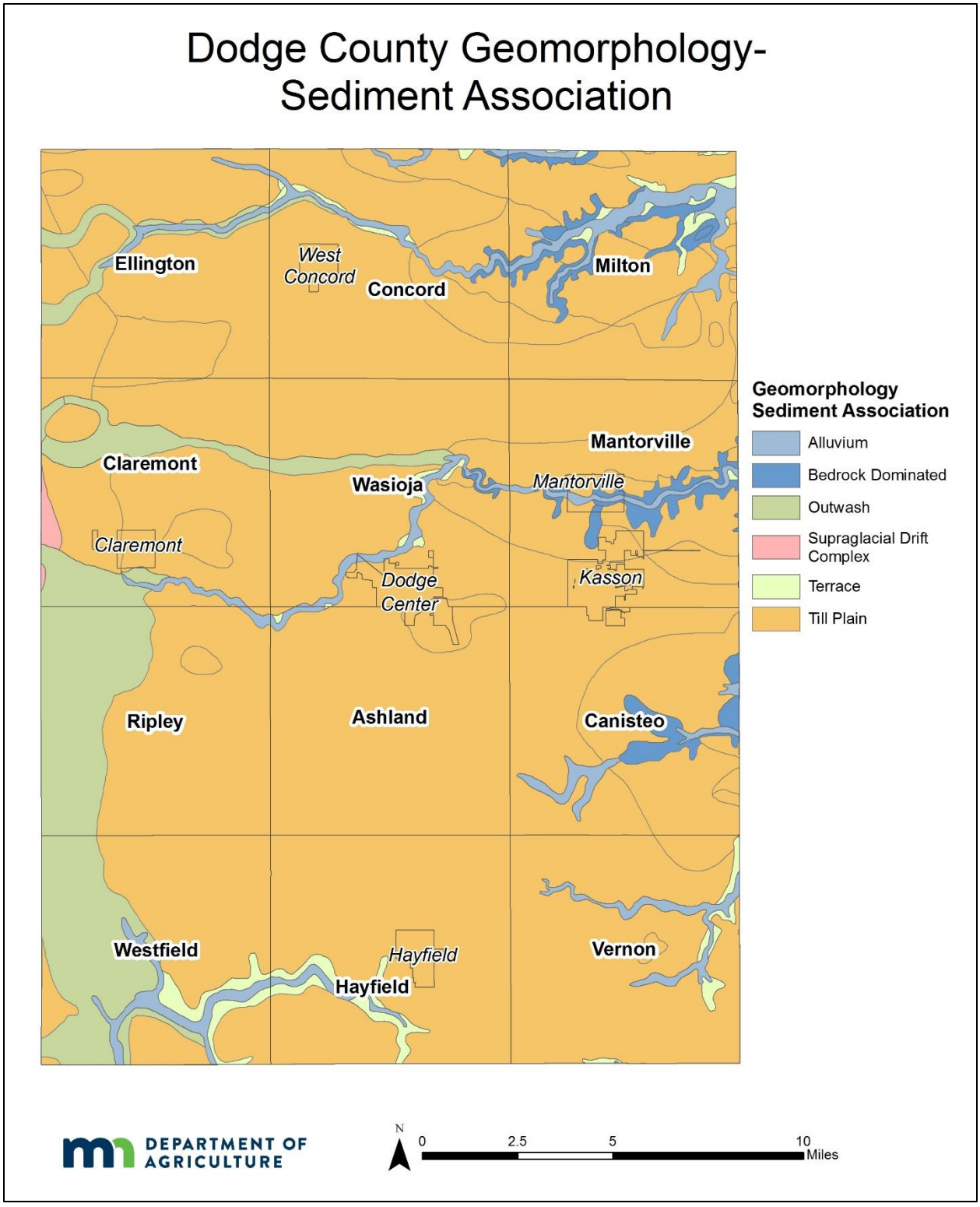

Figure 2. Statewide Geomorphology Layer, Sediment Association in Dodge County (DNR, MGS, and UMD, 1997)

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 Dodge 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 3,006 SSTS were reported in Dodge County for 2016. Over a recent 15 year period (2002-2016), 1,074 construction permits for new, replacement, or repairs for SSTS were issued. Of all the reported septic systems in Dodge County, 36 percent are newer than 2002 or have been repaired since 2002 (MPCA, 2017a). When new SSTS's are installed they are required to be in compliance with the rules at the time of installation. Newer systems meet modern SSTS regulations and must comply with the current well code; which requires a 50 foot horizontal separation from the well (MDH, 2014).

FEEDLOT

Manure produced on a feedlot can be a potential source of nitrogen pollution if improperly stored or spread. In the Dodge County study area there are a total of 321 active feedlots. There are 35 feedlots permitted to house 300 or more animal units (AU) and four that house more than 1000 AU (Appendix B; Figure 7). The majority of the feedlots with 300 or more AU house swine, with the smaller feedlots primarily housing dairy and beef cattle.

FERTILIZER STORAGE LOCATION

Bulk fertilizer storage locations are potential point sources of nitrogen because they store large concentrations of nitrogen based chemicals. Licenses are required for individuals and companies that store large quantities of fertilizer. The Dodge County study area has a total of 17 fertilizer storage licenses with the majority in Westfield, Wasioja, and Concord Townships. (Appendix B; Table 11).

FERTILIZER SPILLS AND INVESTIGATIONS

A total of 30 historic fertilizer spills and investigations occurred in the Dodge County study area. The majority of these were incident investigations, or small spills and investigations. The majority of spills were located in Wasioja and Westfield Townships (Appendix B; Table 13).

TOWNSHIP TESTING METHODS

VULNERABLE TOWNSHIPS

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

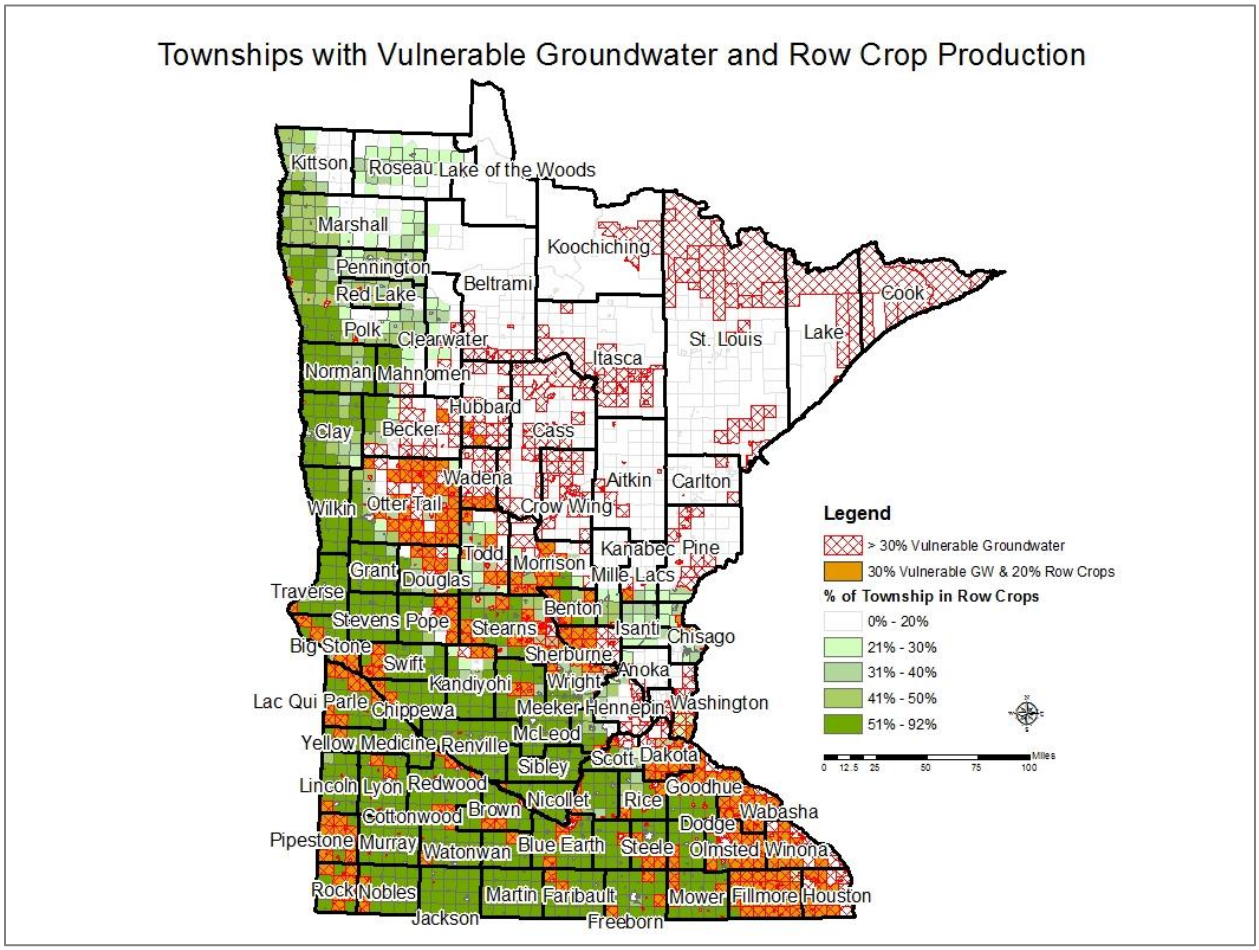

Figure 3. Minnesota Townships with Vulnerable Groundwater and Row Crop Production

Aquifer sensitivity ratings from the Minnesota Department of Natural Resources were used to estimate the percentage of geology vulnerable to groundwater contamination. The same geologic mapping project presented in Figure 2 was used to classify the state into aquifer sensitivity ratings. There are three ratings for aquifer sensitivity: low, medium, and high. Sensitivity ratings are described in Table 1.

The ratings are based upon guidance from the Geologic Sensitivity Project Workshop's report "Criteria and Guidelines for Assessing Geologic Sensitivity in Ground Water Resources in Minnesota" (MDNR, 1991). A map of Dodge County depicting the aquifer vulnerabilities is shown in Figure 4.

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

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

The National Agriculture Statistics Service data (USDA NASS, 2013) on cropland was used to determine the percentage of row crop agriculture. A map and table depicting the extent of the cropland in Dodge County can be found in Appendix C (Figure 9, Table 14). On average 69 percent of the land cover was row crop agriculture.

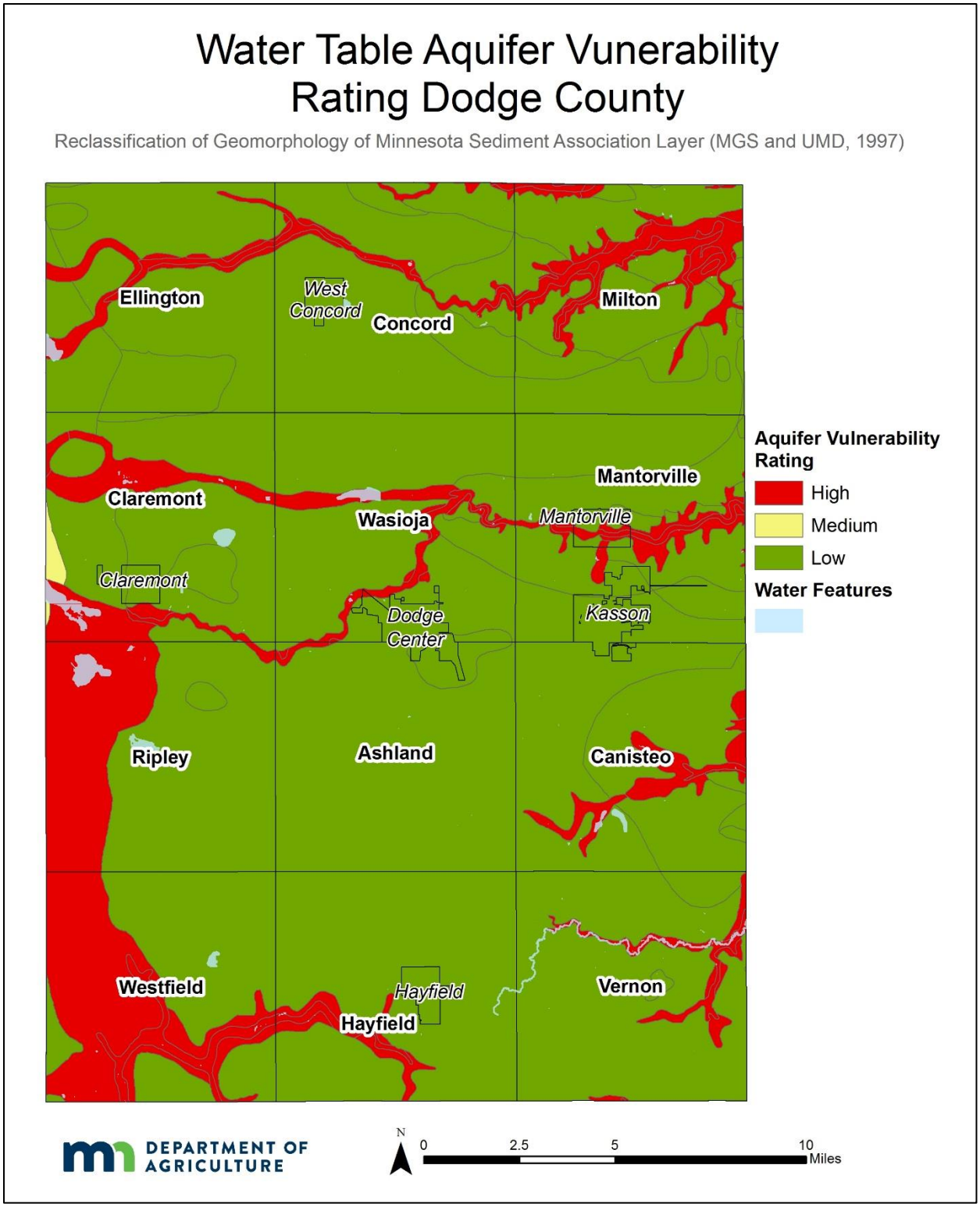

Figure 4. Water Table Aquifer Vulnerability Rating in Dodge County

PRIVATE WELL SAMPLING - NITRATE

The testing is done in two steps in each township: "initial" sampling and "follow-up" sampling. The initial nitrate sampling was conducted in 2016. In the initial sampling, all private well owners in the selected townships are sent a nitrate test kit. These kits include instructions on how to collect a water sample, a sample bottle, a voluntary survey, and a prepaid mailer. Each homeowner was mailed the nitrate result for their well along with an explanatory nitrate brochure (Appendix D). Well water samples were collected by 654 homeowners using the mail-in kit (Table 2). These 654 samples are considered the "initial well dataset". On average, 33 percent of the homeowners in these townships responded to the free nitrate test offered by MDA.

All of the homeowners with a nitrate detection from the initial sampling were asked to participate in a follow-up well site visit and sampling. The well site visit and follow-up sampling was conducted in 2017 and 2018 by MDA staff. A total of 111 follow-up samples were analyzed (Table 2).

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

Township	Kits Sent	Initial Well Dataset	Well Site Visits & Follow-Up Sampling Conducted
Canisteo	237	57	18
Concord	236	75	15
Mantorville	437	154	28
Milton	302	93	15
Vernon	241	70	12
Wasioja	322	104	8
Westfield	184	71	15
Total	1,959	654	111

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

The well site visit was used to collect information on potential nitrogen point sources, well characteristics (construction type, depth, and age), and the integrity of the well construction. Well site visit information was recorded on the Private Well Field Log & Well Survey Form (Appendix A).

WELL ASSESSMENT

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

Using the following criteria, a total of 66 wells were removed to create the final well dataset. See Appendix E (Tables 17 and 18) for a summary of the removed wells.

HAND DUG

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

POINT SOURCE

Well code in Minnesota requires wells to be at least 50 feet away from most possible nitrogen point sources such as SSTS (septic tanks and drain fields), animal feedlots, etc. Wells with a 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 potentially 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.

IRRIGATION WELL

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

UNSURE OF WATER SOURCE

If the water source of the sample was uncertain, or from an unwanted source, then data pertaining to the sample was removed. For example, these samples include water that may have been collected from an indoor tap with a reverse osmosis system. Water samples that were likely collected from a municipal

well 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 dataset. These wells did not have an associated well log, were not visited by MDA staff, and the homeowner did not fill out the initial well survey or the address could not be found.

DUPLICATE / EXTRA KIT

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

INITIAL RESULTS

INITIAL WELL DATASET

Approximately 654 well owners returned water samples for analysis across the seven townships (Figure 5). These wells represent the initial well dataset.

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

The minimum values of nitrate for all townships were less than the detection limit (<DL) which is 0.03 mg/L. The maximum values ranged from 11.9 to 26.1 mg/L, with Canisteo Township having the highest result. Median values were all less than the detection limit (<DL). The 90th percentiles ranged from 0.5 to 12.4 mg/L, with Milton Township having the highest 90th percentile.

Initial results from the sampling showed that in Canisteo, Concord, and Milton Townships ten percent or more of the wells were at or over 10 mg/L nitrate-N. The township testing results contrasted findings from a 2010 USGS report on nitrate concentrations in private wells in the glacial aquifer systems across the upper United States (US) in which less than five percent of sampled private wells had nitrate concentrations greater than 10 mg/L (Warner and Arnold, 2010). Data from the Township Testing Program suggests that private well water, in Canisteo, Concord, and Milton Townships, is more heavily impacted by nitrate than other areas of the upper United States. Both the USGS and the township testing studies indicate that nitrate concentrations can vary considerably over short distances.

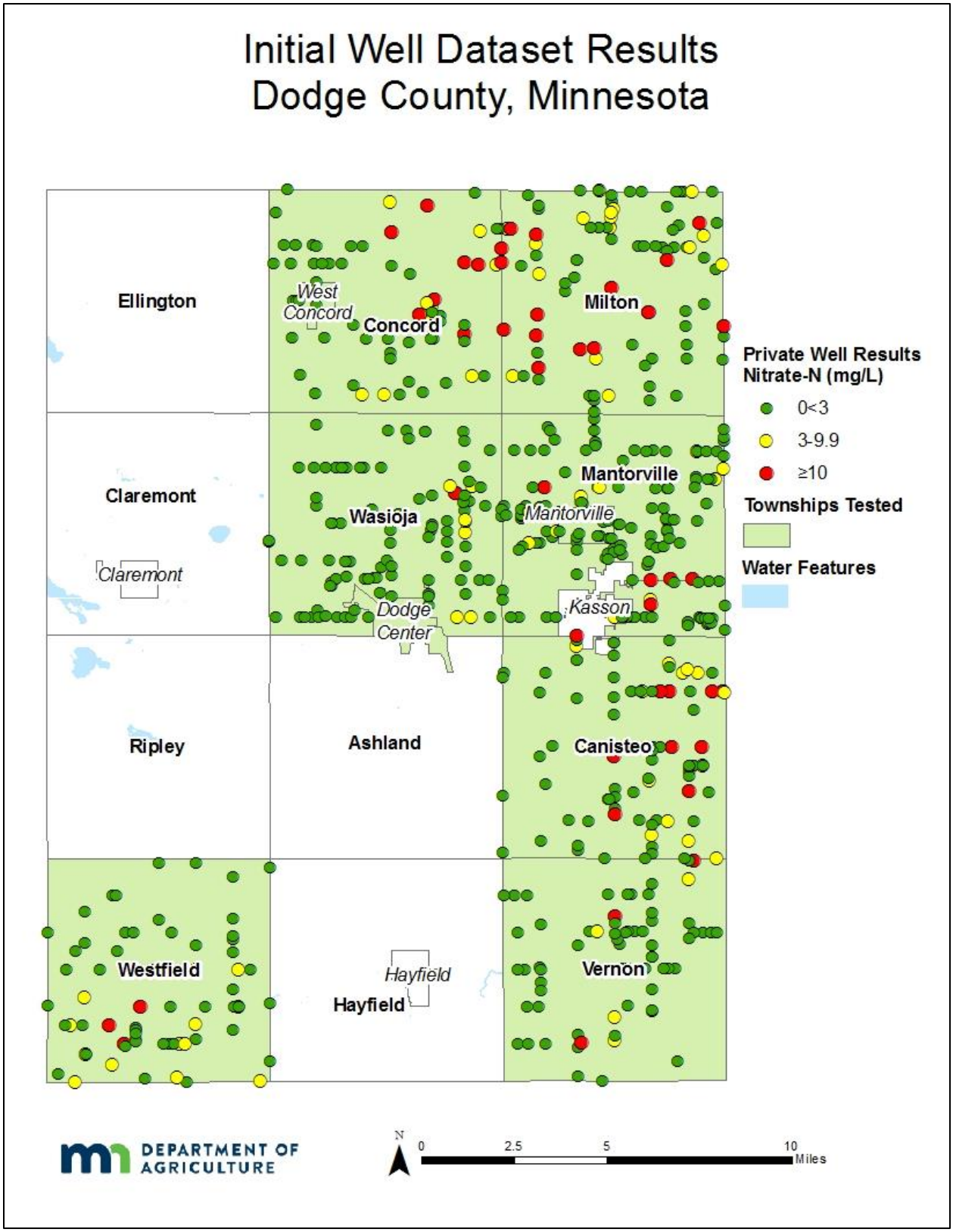

Figure 5. Well Locations and Nitrate Results from Initial Dataset in Dodge County

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

Township	Total Wells	Values				Percentiles				Number of Wells					Percent of Wells				
		Min	Max	Mean	Median	75th	90th	95th	99th	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L	<3 mg/L	3<10 mg/L	≥5 mg/L	≥7 mg/L	≥10 mg/L
		Nitrate-N mg/L or PPM																	
Canisteo	87	<DL	26.1	2.8	<0.03	4.1	10.1	12.8	23.4	64	14	21	16	9	74%	16%	24%	18%	10%
Concord[1]	75	<DL	18.3	2.6	<0.03	4.8	10.1	13.8	17.8	54	12	18	13	9	72%	16%	24%	17%	12%
Mantorville[2]	154	<DL	18.1	1.0	<0.03	0.1	3.2	9.4	15.1	138	10	12	10	6	90%	6%	8%	6%	4%
Milton	93	<DL	18.5	3.4	<0.03	6.7	12.4	15.6	18.5	63	16	26	21	14	68%	17%	28%	23%	15%
Vernon	70	<DL	13.4	1.0	<0.03	0.04	4.7	9.1	13.3	63	4	7	5	3	90%	6%	10%	7%	4%
Wasioja[3]	104	<DL	11.9	0.4	<0.03	0.02	0.5	3.3	8.2	97	6	1	1	1	93%	6%	1%	1%	1%
Westfield	71	<DL	12.9	1.8	<0.03	2.8	5.2	10.7	12.6	54	13	8	4	4	76%	18%	11%	6%	6%
Total	654	<DL	26.1	1.8	<0.03	0.3	7.7	11.7	17.4	533	75	93	70	46	81%	11%	14%	11%	7%

[1] Includes 3 wells from West Concord City

[2] Includes 11 wells from Mantorville City

[3] Includes 2 wells from Dodge Center City

<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 384 people in Dodge County's study area have drinking water over the nitrate HRL (Table 4). Nitrate contamination is a significant problem for many wells in Dodge County.

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

Township	Estimated Households on Private Wells[1]	Estimated Population on Private Wells[1]	Estimated Population ≥10 mg/L Nitrate-N[2]
Canisteo	237	643	66
Concord[3]	222	574	69
Mantorville[4]	655	1,955	76
Milton	266	729	110
Vernon	239	666	29
Wasioja[5]	340	908	9
Westfield	165	453	25
Total	2,124	5,928	384

[1]Data collected from the Minnesota State Demographic Center, 2017
[2]Estimates based off of the 2016 estimated households per township gathered from Minnesota State Demographic Center and percentage of wells at or over the HRL from the initial well dataset
[3]Does not include West Concord City in population estimate since there is a municipal water system within the city
[4]Does not include Mantorville City in population estimate since there is a municipal water system within the city
[5]Does not include Dodge Center City in population estimate since there is a municipal water system within the city

WELL SETTING AND CONSTRUCTION

MINNESOTA WELL INDEX AND WELL LOGS

The Minnesota Well Index (MWI) (formerly known as the "County Well Index") is a database system developed by the Minnesota Geological Survey 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 (MGS, 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).

In some cases, well owners were able to provide unique well identification numbers for their wells. When the correct unique IDs are provided, a well log can be used to identify the aquifer that the well withdraws water from. The well logs were obtained from the MWI for 469 documented wells (Table 5). Therefore, approximately 57 percent of the sampled wells had corresponding well logs and only 312 (48 percent) of these wells had an aquifer identified. Thus, the data gathered on aquifers represents approximately half of the total sampled wells.

The aquifers in Table 5 are arranged from the geologically youngest units on the top to the older units. According to the well log data, the most commonly utilized aquifer in the sampled wells was from Galena Group, with the Prairie Du Chien Group and St. Peter Formation in a close second and third. All of these rock formations were deposited during the Ordovician time period (458 to 447 million years ago) (Anderson, 2002). This predominance of these three aquifers reflects the overall findings for all documented wells in the focus area (Appendix F, Table 19). The average well depth was 247 which is relatively deep when compared to private wells in other areas of the state, such as the central sands region.

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

QUATERNARY

The Quaternary aquifers represent the youngest geological aquifer formation identified in Dodge County. These sediments were deposited during the last glacial period less than 2.5 million years ago (Anderson, 2002).

UPPER CARBONATE PLATEAU

In southeast Minnesota a group of Paleozoic aquifers make up the “Upper Carbonate Plateau”. These aquifers include the Galena Group, the Maquoketa Formation, and the Wapsipinicon and Cedar Valley Groups. These aquifers are all comprised of carbonate rocks and are grouped together as they often act as one aquifer system (Green, Barry, and Alexander, 2014).

SPILLVILLE FORMATION

The Spillville formation is one of the uppermost aquifers in the Upper Carbonate Plateau. It is part of the Wapsipinicon Group. This formation was deposited in the Devonian time period and is composed of carbonate rocks, specifically dolostone (Green, Barry, and Alexander, 2014).

MAQUOKETA FORMATION

The Maquoketa formation is typically considered an aquitard since it contains a layer of shale. An aquitard is considered a rock unit that slows the flow of water vertically. However, all of the Paleozoic bedrocks in this region can yield large quantities of water it is not surprising that some wells utilize this formation for a water source (Green, Barry, and Alexander, 2014).

GALENA GROUP

The Galena Group is comprised of several formations. This group is mainly limestone which was formed in deeper parts of the historic continental sea that once covered this area (Anderson, 2002). The lower Galena formation is an aquitard sometimes referred to as the Cummingsville-Glenwood aquitard. This aquitard separates the newer water from deeper older water.

ST. PETER FORMATION

Below the Upper Carbonate Plate is the St. Peter Formation. It is composed of a homogeneous, well sorted sandstone. This bedrock was formed at the beaches and sandbars of a large ancient continental sea that covered this region during the Ordovician period (Anderson, 2002).

PRAIRIE DU CHIEN GROUP

Prairie Du Chien Group is the deepest aquifer represented in this report. It is composed of two formations; the Oneota Dolomite, and the Shakopee Formation. This group is mainly comprised of dolomite and some areas of sandstone (Green, Barry, and Alexander, 2014).

Table 5. Nitrate Concentrations within Sampled Groundwater Aquifers

Aquifer Group/Formation	Total Wells	Ave Depth (Feet)	Number of wells			Percent of wells		
			<3	3<10	≥10	<3	3<10	≥10
			Nitrate-N mg/L					
Quaternary	2	96	2	0	0	100.0%	0.0%	0.0%
Spillville formation	7	172	6	1	0	85.7%	14.3%	0.0%
Maquoketa formation	19	196	17	2	0	89.5%	10.5%	0.0%
Galena Group	98	153	84	9	5	85.7%	9.2%	5.1%
St. Peter Formation	85	333	81	3	1	95.3%	3.5%	1.2%
Prairie Du Chien Group	96	362	93	1	2	96.9%	1.0%	2.1%
Multiple	5	316	4	1	0	80.0%	20.0%	0.0%
Not Available	157	112	111	28	18	70.7%	17.8%	11.5%
Total	469	247	398	45	26	84.9%	9.6%	5.5%

WELL OWNER SURVEY

The private well owner survey, sent out with the sampling kit, provided additional information about private wells that were sampled. The survey included questions about the well construction, depth and age, and questions about nearby land use. A blank survey can be found in Appendix G. It is important to note that well information was provided by the well owners and may be approximate or potentially erroneous. The following section is a summary of information gathered from the well owner survey (complete well survey results are located in Appendix H at the end of this document, Tables 20-34).

The vast majority of wells (81 percent) in the townships were located on "rural" property.

Approximately 72.6 percent of sampled wells were of drilled construction and less than two percent were sand point wells. Sand point (also known as drive-point) wells are typically completed at shallower depths than drilled wells. Sand point wells are also usually installed in areas where sand is the dominant geologic material and where there are no thick confining units such as clay. This makes sand point wells more vulnerable to contamination from the surface. As mentioned previously hand dug wells are also shallow and more sensitive to local surface runoff contamination than deeper drilled wells. According to the homeowner survey here were only two hand dug wells sampled in the townships, although one additional hand dug well was discovered during follow up sampling.

Most of the sampled wells were over 100 feet deep. Concord had the lowest percentage of wells over 100 feet deep (36 percent) and Milton had the highest percent of wells more than 100 feet deep (59 percent). Approximately, 28 percent of homeowners did not know or did not response to this question.

Most of the wells had not been tested for nitrate within the last ten years or homeowners were unsure if they had been tested. Less than ten percent of homeowners responded that their well had been tested for nitrate in the last year. Therefore, the results most homeowners received from this study were new information.

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 located in Appendix H at the end of this document (Tables 20-34).

- On average, farming takes place on 37.8 percent of the properties.
- Agricultural fields are less than 300 feet from wells at about 50 percent of the properties.
- Approximately nine percent of well owners across all the townships responded that they have livestock (greater than ten head of cattle or other equivalent) on their property.
- The majority of wells (over 63 percent) are over 300 feet from an active or inactive feedlot.
- Very few well owners (2.1 percent) across all townships store more than 500 pounds of fertilizer on their property.
- A small minority of wells (less than four percent) are less than 50 feet away from septic systems.

FINAL RESULTS

FINAL WELL DATASET

A total of 654 well water samples were collected by homeowners across seven townships. A total of 66 (10 percent) wells were found to be unsuitable and were removed to create the final well dataset. The final analysis was conducted on the remaining 588 wells (Table 6). The wells in the final well dataset represent drinking water wells potentially impacted by applied commercial agricultural fertilizer.

WELL WATER NITROGEN ANALYSIS

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

Table 6 shows the results for all townships sampled. The percent of wells at or over the HRL ranged from 0.0 to 4.8 percent.

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

Township	Initial Well Dataset	Final well Dataset	Final Wells ≥10 mg/L Nitrate-N	
			Count	Percentage
Canisteo	87	71	1	1.4%
Concord[1]	75	63	3	4.8%
Mantorville[2]	154	147	4	2.7%
Milton	93	76	3	3.9%
Vernon	70	64	0	0.0%
Wasioja[3]	104	100	0	0.0%
Westfield	71	67	2	3.0%
Total	654	588	13	2.2%

[1] Includes 3 wells from West Concord City
[2] Includes 11 wells from Mantorville City
[3] Includes 2 wells from Dodge Center City

The individual nitrate results from this final well dataset are displayed spatially in Figure 6. Due to the inconsistencies with geocoding the locations, the accuracy of the points is variable. Three wells are not displayed in this figure, but are accounted for in the statistical analysis.

The final well dataset summary statistics are shown in Table 7. The minimum values were all below the detection limit. The maximum values ranged from 5.0 to 16.6 mg/L nitrate-N, with Milton Township having the highest result. The 90th percentile ranged from 0.2 to 6.9 mg/L nitrate-N, with Milton Township having the lowest result and Concord Township having the highest result.

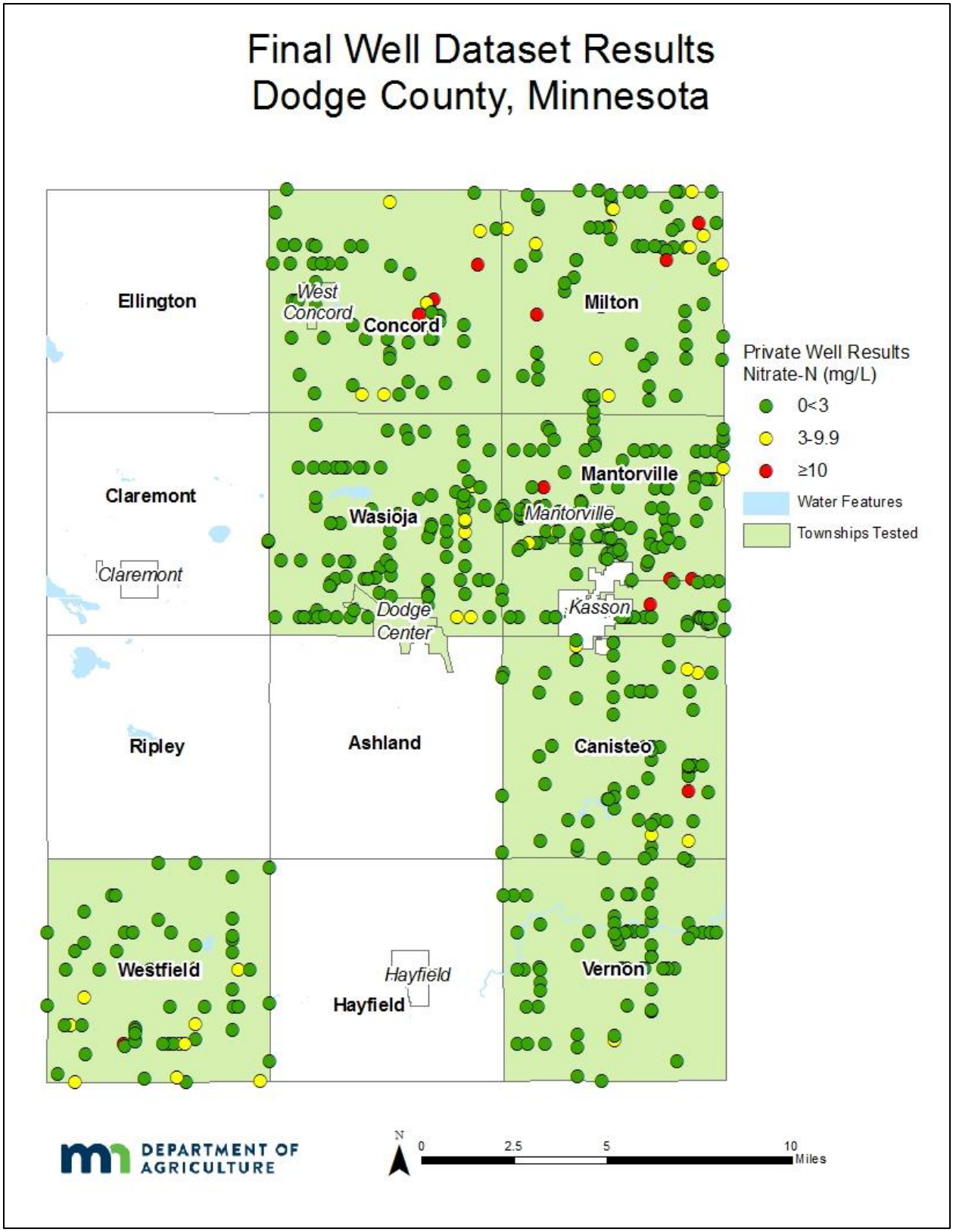

Figure 6. Well Locations and Nitrate Results from Final Well Dataset in Dodge County

Table 7. Dodge 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)																	
Canisteo	71	<DL	12.4	0.8	<DL	0.1	2.8	6.0	11.7	64	6	5	3	1	90.1%	8.5%	7.0%	4.2%	1.4%
Concord[1]	63	<DL	14.5	1.3	<DL	0.2	5.2	9.8	14.1	53	7	7	4	3	84.1%	11.1%	11.1%	6.3%	4.8%
Mantorville[2]	147	<DL	15.1	0.6	<DL	0.1	1.3	3.3	14.1	138	5	5	5	4	93.9%	3.4%	3.4%	3.4%	2.7%
Milton	76	<DL	16.6	1.6	<DL	0.8	6.9	9.3	15.7	62	11	10	7	3	81.6%	14.5%	13.2%	9.2%	3.9%
Vernon	64	<DL	6.7	0.2	<DL	<DL	0.2	0.4	6.2	63	1	1	0	0	98.4%	1.6%	1.6%	0.0%	0.0%
Wasioja[3]	100	<DL	5.0	0.3	<DL	<DL	0.4	2.9	4.9	95	5	0	0	0	95.0%	5.0%	0.0%	0.0%	0.0%
Westfield	67	<DL	11.7	1.4	<DL	2.4	4.5	5.7	11.7	54	11	4	2	2	80.6%	16.4%	6.0%	3.0%	3.0%
Total	588	<DL	16.6	0.8	<DL	0.1	3.0	5.6	12.8	529	46	32	21	13	90.0%	7.8%	5.4%	3.6%	2.2%

[1] Includes 3 wells from West Concord City

[2] Includes 11 wells from Mantorville City

[3] Includes 2 wells from Dodge Center City

<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 8 compares the final results to the percent of vulnerable geology (MDNR, 1991) and row crop production (USDA NASS, 2013) in each township. The percent land area considered vulnerable geology and in row crop production was estimated using a geographic information system known as ArcGIS.

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

Township	Final Well Dataset	Percent of Land in Row Crop Production 2013[1]	Percent of Land in Vulnerable Geology	Percent ≥7 Nitrate-N mg/L or parts per million (ppm)	Percent ≥10 Nitrate-N mg/L or parts per million (ppm)
Canisteo	71	76%	11%	4.2%	1.4%
Concord[2]	63	76%	7%	6.3%	4.8%
Mantorville[3]	147	66%	10%	3.4%	2.7%
Milton	76	54%	23%	9.2%	3.9%
Vernon	64	72%	8%	0.0%	0.0%
Wasioja[4]	100	68%	11%	0.0%	0.0%
Westfield	67	79%	47%	3.0%	3.0%
Total	588	70%	17%	3.6%	2.2%

[1] Data retrieved from USDA NASS Cropland Data Layer, 2013
[2] Includes West Concord City
[3] Includes Mantorville City
[4] Includes Dodge Center City

WELL AND WATER CHARACTERISTICS

WELL CONSTRUCTION

Unique identification numbers from well logs were compiled for the wells in the Dodge County final well dataset. Additionally, Dodge County provided many unique IDs for older wells that typically are not found on well tags. 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 (Tables 35-37).

- The majority of wells were drilled (80 percent), and only 7 wells (6 percent) were identified as sand point wells.
- The median depth of wells was 243 feet, and the deepest was 565 feet.
- The median year the wells were constructed in was 1989.

WELL WATER PARAMETERS

MDA staff conducted the follow-up sampling and well site surveys at 111 wells. Only 91 follow-up wells are included in the final well dataset, and four of these did not have field measurement collected. Field measurements of the well water parameters were recorded on the first page of the Private Well Field Log & Well Survey Form (Appendix J). The measurements included temperature, pH, specific conductivity, and dissolved oxygen. The well was purged for 15 minutes, so that the measurements stabilized, ensuring a fresh sample of water was collected. The stabilized readings for the final well dataset are described below and a more comprehensive view is available in Appendix K (Tables 38-41).

- The temperatures ranged from 8.90 °C to 16.47 °C
- The median specific conductivity was 618 µS/cm, and was as high as 1,157 µS/cm
- The water from the wells had a median pH of 7.30
- The dissolved oxygen readings ranged from 0.10 mg/L to 9.44 mg/L

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

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

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

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

SUMMARY

The focus of this study was to assess nitrate concentrations in groundwater impacted by commercial agricultural fertilizer in selected townships in Dodge County. In order to prioritize testing, the MDA looked at townships with significant row crop production and vulnerable geology. Approximately 69 percent of the land cover in row crop agriculture with 726 acres of cropland are permitted for groundwater irrigation in the study area.

Seven townships were sampled covering over 162,000 acres. The initial (homeowner collected) nitrate sampling resulted in 654 samples. The 654 households that participated represent approximately 33 percent return rate of homeowners offered sampling kits. Well owners with measureable nitrate results were offered a follow-up nitrate sample and a pesticide sample. The MDA visited and collected follow-up samples at 111 wells.

The MDA conducted a nitrogen source assessment and identified wells near potential point sources and wells with poor construction. A total of 66 (10 percent) wells were found to be unsuitable and were removed from the final well dataset of 588 wells. The remaining 588 wells were wells believed to be impacted by nitrogen fertilizer and were included in the final well dataset.

A majority of wells (80 percent) are drilled; less than two percent are sand points. The median depth of the wells is 243 and depths range from 10 to 565 feet.

Less than five percent of the wells were at or over the nitrate-N Health Risk Limit of 10 mg/L for all the townships tested Dodge County. The percent of wells at or over the nitrate Health Risk Limit in each township ranged from 0.0 to 4.8 percent.

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APPENDIX A

Well information and Potential Nitrate Source Inventory Form

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

MDA -Private Well Field Log & Well Survey Form

Water Treatment Information

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

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

   If yes, what type?_____

Well Construction Information

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

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

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

Field Survey Information

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

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

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

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

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

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

Updated: March, 2017

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

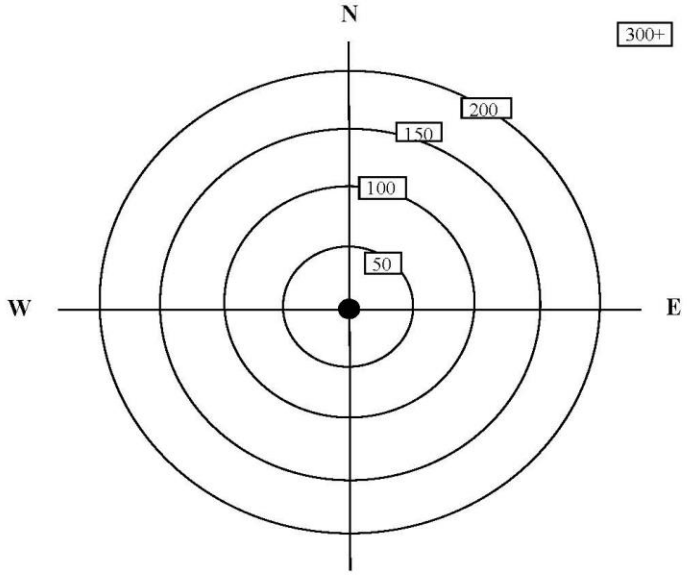
MDA -Private Well Field Log & Well Survey Form

DIRECTIONS

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

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

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



ADDITIONAL SURVEY NOTES

Updated: March, 2017

APPENDIX B

SUBSURFACE SEWAGE TREATMENT SYSTEM

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

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

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

In 2016 Dodge County reported a total of 3,006 SSTS and 1.5 percent were inspected for compliance (MPCA, 2017a). Compliance inspections are conducted in Dodge County during property transfers, when building permits are applied for, upon completion of new or replacement SSTS, when any bedroom or a living space greater than 120 square feet is added to a dwelling, when a complaint is received, and when discharge to a road is observed during road construction (Dodge County, 2016). Any SSTS determined to be “failing to protect groundwater (FTPGW)” or an “Imminent Threat to Public Health or Safety” must be upgraded, repaired, replaced, or abandoned by the homeowner within 2 years or 10 months of notice, respectively. All dwellings are required to have a SSTS with a drainfield; holding tanks are not allowed except where no other viable option for a SSTS exists (Dodge County, 2016).

FEEDLOT

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

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

Government agencies regulate feedlots to reduce the risk of contamination to water resources. Rules pertaining to feedlots have been in place since the 1970's; they were revised in 2000 and 2014 (MPCA, 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 9) (MPCA, 2014).

Table 9. 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. Feedlots with more than 1,000 AU are regulated through federal National Pollutant Discharge Elimination (NPDES) permits (MPCA, 2011) and must submit an annual manure management plan as part of their permit (MPCA, 2015).

As part of new feedlot construction, an environmental assessment must be completed for feedlots with a proposed capacity of greater than 1,000 AU. If the feedlot is located in a sensitive area the requirement for an environmental assessment is 500 AU (MPCA, 2017c). Farmers must register their feedlot if it is in active status. Feedlots are considered active until no animals have been present on the feedlot for five years. To register, farmers fill out paperwork which includes a chart with the type and maximum number of animals on the feedlot (MPCA, 2017b). Registration is required to be completed at least once during a set four year period, the current period runs from January 2018 to December 2021. As of November 2017, approximately 24,000 feedlots were registered in Minnesota (MPCA, 2017c). A map and table of the feedlots located in the Dodge County study area can be found below (Figure 7; Table 10).

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

Township	Total Feedlots	Active Feedlots	Inactive Feedlots	Average AU Permitted[2] Per Feedlot	Total Permitted[2] AU	Total Square Miles	Permitted[2] AU per Square Mile
Canisteo	70	51	19	94	4,807	36	135
Concord[3]	74	41	40	95	3,915	38	103
Mantorville[4]	52	41	11	130	5,343	33	161
Milton	137	58	79	131	7,593	36	211
Vernon	58	47	11	100	4,720	36	131
Wasioja[5]	72	55	18	159	8,732	38	229
Westfield	49	28	21	228	6,389	36	177
Total	512	321	199	129[1]	41,499	253	164[1]

[1] Represents an average value
[2]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.
[3]Includes West Concord City
[4]Includes Mantorville City
[5]Includes Dodge Center City

On average there are 164 AU per square mile (0.26 AU/acre) over the entire study area (Table 10). Manure is often applied to cropland so it is pertinent to look at the AU per cropland acre. In the Dodge County study area livestock densities average 0.37 AU per acre of row crops (MPCA, 2018; USDA NASS, 2013).

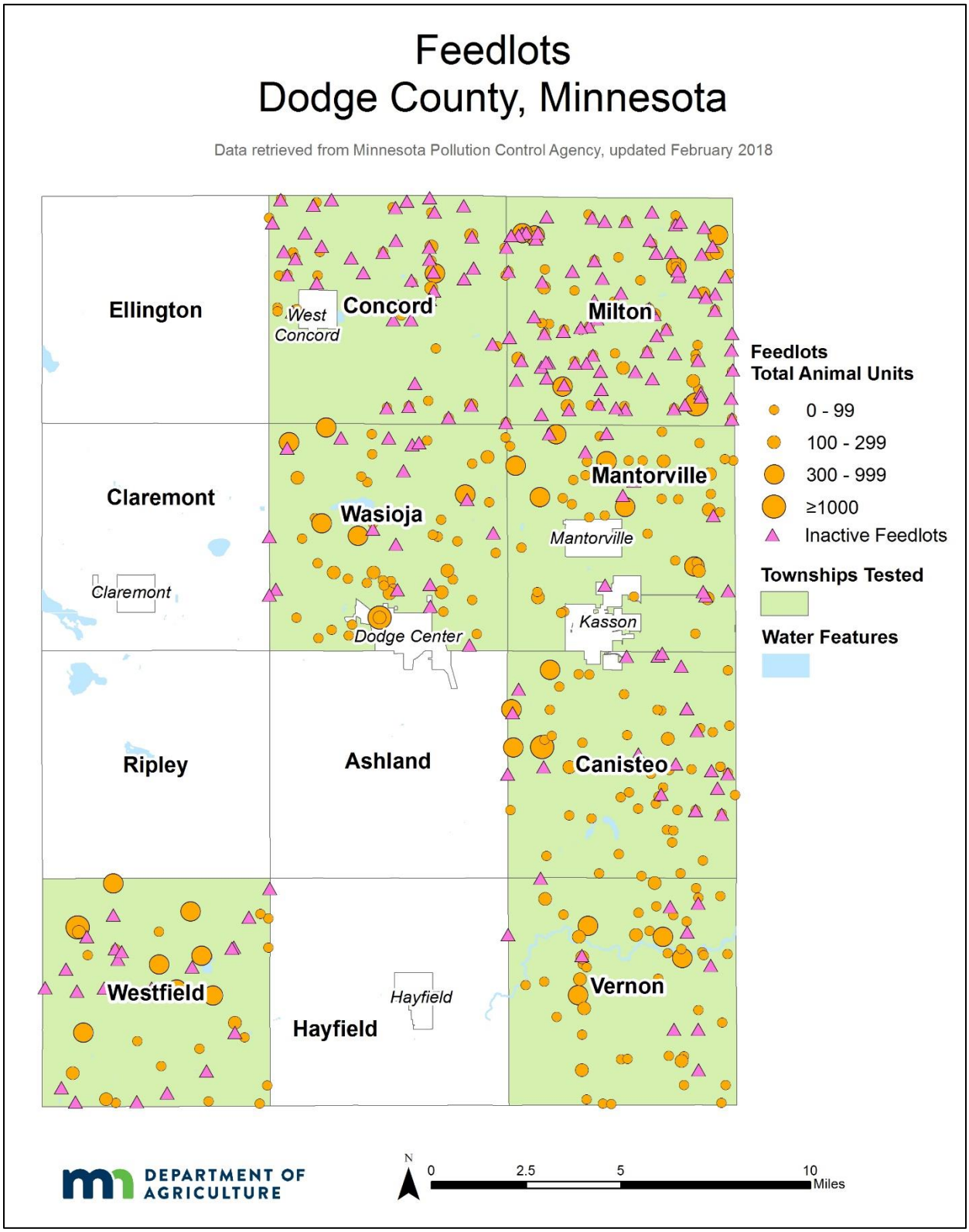


Figure 7. Feedlot Locations in Dodge County (MPCA, 2018)

FERTILIZER STORAGE LOCATION

MDA tracks licenses for bulk fertilizer storage facilities, anhydrous ammonia, and chemigation sites (Table 11). Abandoned sites are facilities that once housed fertilizer chemicals. These sites are also noted and tracked by the MDA as they are potential contamination sources.

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

Township	Bulk Fertilizer Storage	Anhydrous Ammonia	Chemigation Sites	Abandoned Sites	Total
Canisteo	0	0	0	0	0
Concord1	3	1	0	0	4
Mantorville[2]	0	0	0	0	0
Milton	1	0	0	0	1
Vernon	0	0	0	0	0
Wasioja[2]	0	0	4	2	6
Westfield	1	1	0	4	6
Total	5	2	4	6	17

Data retrieved from MDA Pesticide and Fertilizer Management Division, 2018; updated March 2018
[1] Includes West Concord City
[2] Includes Mantorville City
[3] Includes Dodge Center City

SPILLS AND INVESTIGATIONS

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

The MDA tracks several types of incidents. Incident investigations are typically for larger spills. There are 11 in the study area. Contingency areas are locations that have not been remediated because they were inaccessible or the contaminant could not be removed for some other reason. They are often a part of an incident investigation. There are no contingency areas in this study area. Old emergency incidents were closed prior to March 1st, 2004 (MDA, 2017), but they can still be a point source. At most of these older sites, the contaminants are unknown and their location may not be precise. There are six in the study area. Small spills and investigations are typically smaller emergency spills such as a truck spilling chemicals. There are 13 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, 2017). Many types of spills are reported to the MDA, however only spills that potentially contain nitrogen are reported here. A breakdown of chemical type of these incidents can be found in Table 12. A breakdown of the fertilizer specific spills and investigations, by township, can be found in Table 13.

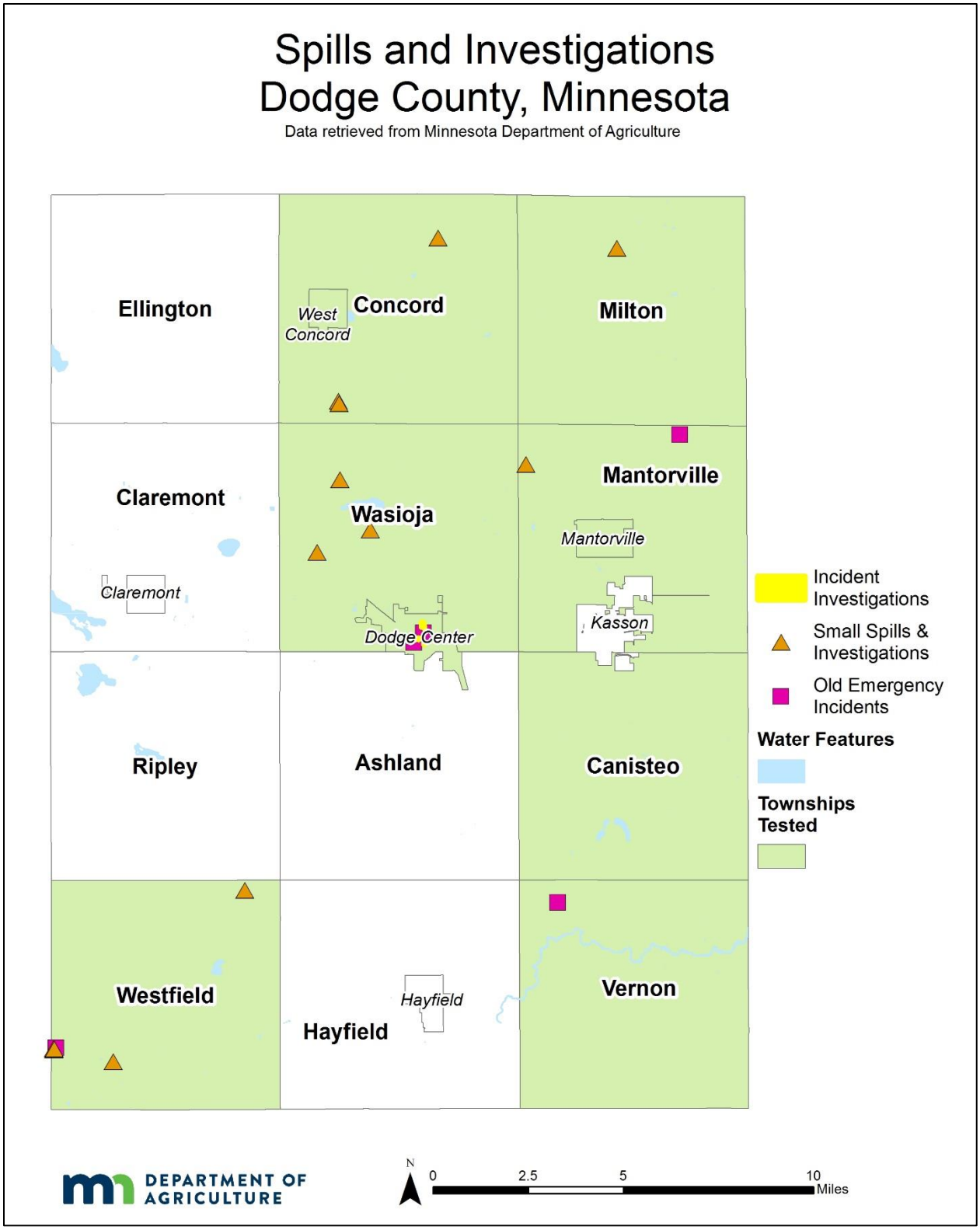


Figure 8. Fertilizer Spills and Investigations in Dodge County (MDA, 2017)

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

Contaminant	Incident Investigations	Contingency Areas	Small Spills and Investigations	Old Emergency Incidents	Total
Fertilizer	2	0	4	4	10
Pesticides & Fertilizer	9	0	0	0	9
Anhydrous Ammonia	0	0	9	2	11
Total	11	0	13	6	30

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

Township	Incidents and Spills
Canisteo	0
Concord	3
Mantorville	2
Milton	1
Vernon	1
Wasioja	14
Westfield	9
Total	30

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. Dodge County is mostly rural and is dominated by row crop agriculture (Figure 9; Table 14). Row crops can include: corn, sweet corn, soybeans, alfalfa, sugar beets, potatoes, durum wheat, dry beans and double crops involving corn and soybeans.

Dodge County is situated between the cities of Owatonna on the west and Rochester on the east. However, the Dodge County study area is not heavily influenced by urband development. Only 7% of the land cover is considered developed. Mantorville and Milton townships have the highest percentage of forest at 10% and 14%, respectively and the highest percentage of pasture/hay at 10% and 15%, respectively. Every township has greater than 50% row crop land cover, with Westfield having the highest (82%) and Milton having the lowest (51%) (Figure 9; Table 14).

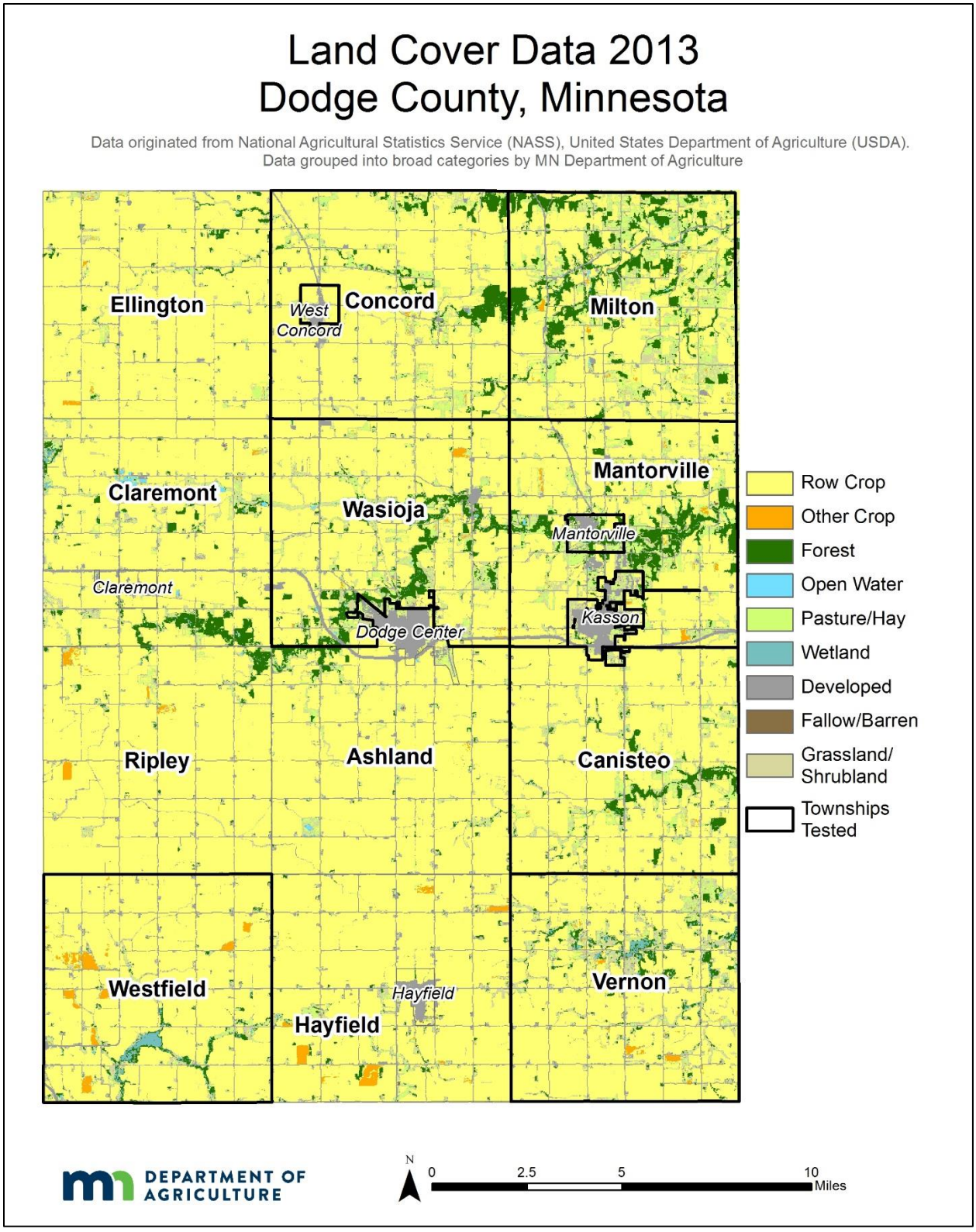


Figure 9. Land Cover in Dodge County (USDA NASS Cropland Data Layer, 2013)

Table 14. Land Cover Data (2013) by Township, Dodge 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
Canisteo	22,841	77%	0%	4%	0%	6%	0%	5%	0%	8%
Concord[1]	24,230	76%	0%	5%	0%	6%	0%	6%	0%	7%
Mantorville[2]	21,309	61%	1%	10%	0%	10%	0%	8%	0%	10%
Milton	23,019	51%	1%	14%	0%	15%	0%	6%	0%	13%
Vernon	23,093	73%	1%	4%	0%	4%	1%	7%	0%	10%
Wasioja[3]	24,428	65%	0%	7%	0%	7%	0%	11%	0%	10%
Westfield	23,106	82%	2%	2%	0%	1%	1%	6%	0%	4%
Average	162,025	69%	1%	6%	0%	7%	1%	7%	0%	9%

[1] Includes West Concord City

[2] Includes Mantorville City

[3] Includes Dodge Center City

WATER USE

Water use permits are required for wells withdrawing more than 10,000 gallons of water per day or 1,000,000 gallons of water per year (MDNR, 2016). There are a total of 43 active groundwater well permits in the study area, 6 of which are used for agricultural irrigation (Figure 10). About 726 acres of cropland are permitted for groundwater irrigation in this area (Table 15). Most permitted wells are withdrawing groundwater from Paleozoic aquifers (Table 16; MDNR, 2017).

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

Township	Major Crop Irrigation Well Permits	Average Depth (feet)	Acres Permitted
Canisteo	0	NA	0
Concord[1]	0	NA	0
Mantorville[2]	0	NA	0
Milton	0	NA	0
Vernon	1	205	200
Wasioja[3]	3	124	267
Westfield	2	127	259
Total	6	139	726

[1] Includes West Concord City
[2] Includes Mantorville City
[3] Includes Dodge Center City

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

Water Use Well Permits	Total	Average Depth (feet)	Aquifer			
			Water Table	Quaternary	Paleozoic	Not Classified
Major Crop Irrigation	6	139	0	1	4	1
Non-Crop Irrigation	1	264	0	0	1	0
Waterworks	6	728	0	0	6	0
Industrial Processing	1	300	0	0	1	0
Water Level Maintenance	1	0	0	0	0	1
Special Categories[1]	29	295	0	0	23	6
Total	43	325	0	1	35	8

[1] All Special Categories displayed in the map and table are for Livestock Watering.

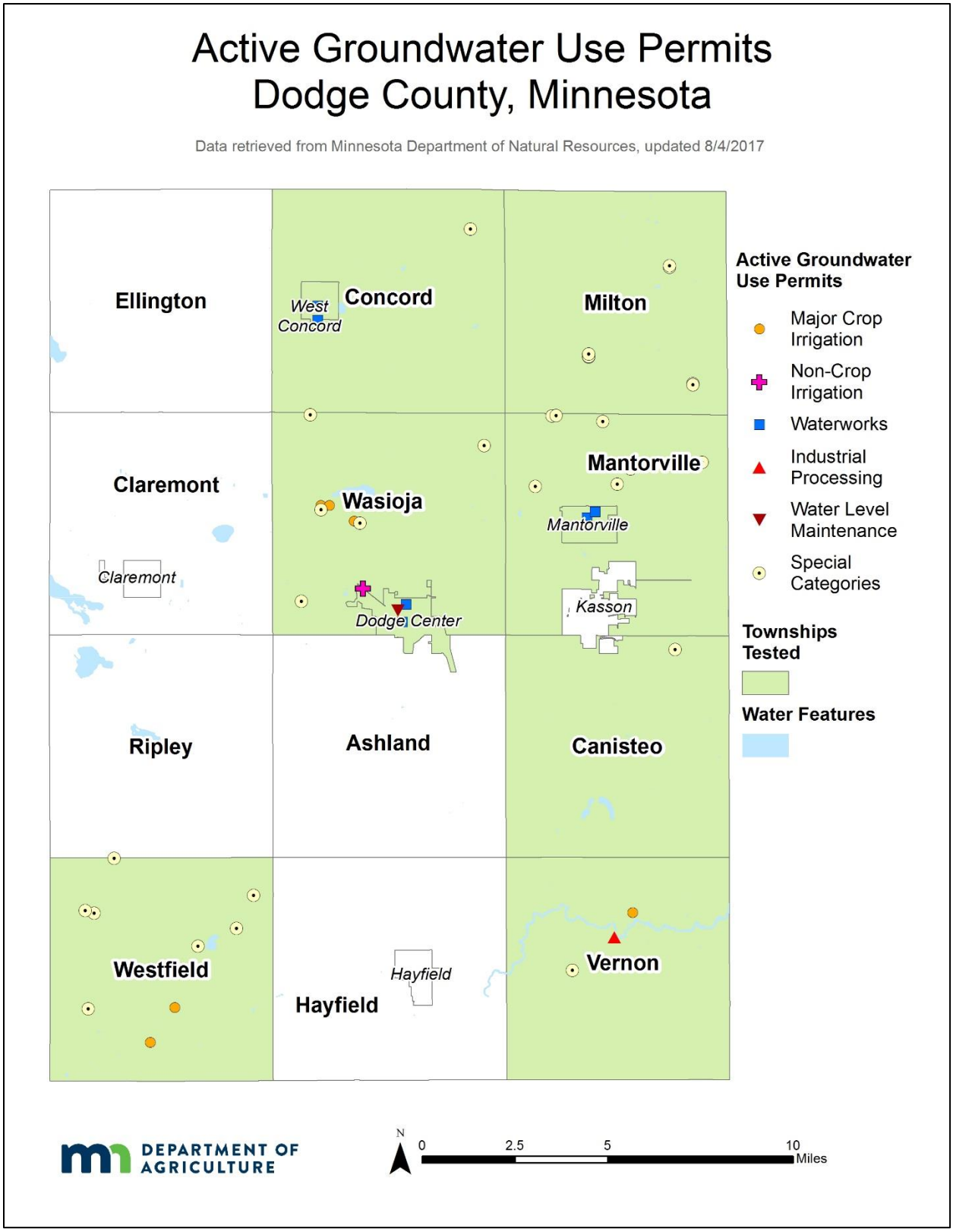


Figure 10. Active Groundwater Use Permits in Dodge County (MDNR, 2017)

APPENDIX D

Nitrate Brochure

The Minnesota Department of Agriculture and the Dodge County Environmental Services 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

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

APPENDIX E

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

Township	Point Source	Well Construction Problem	Hand Dug Well	Unsure of water source	Site Visit Completed - Well Not Found & Constructed before 1975 or Age Unknown & No Well ID	No Site Visit & Constructed before 1975 or Age Unknown & No Well ID	No Site Visit & Insufficient Data & No Well ID	Duplicate or Shared Well	Total
Canisteo	2	4	0	1	1	4	4	0	16
Concord	1	1	2	0	1	5	1	1	12
Mantorville	1	0	0	1	0	4	1	0	7
Milton	2	2	1	0	0	11	0	1	17
Vernon	0	1	0	0	1	1	3	0	6
Wasioja	1	1	0	0	0	0	0	2	4
Westfield	0	1	0	0	0	2	1	0	4
Total	7	10	3	2	3	27	10	4	66

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

Township	Site Visit	No Site Visit	Total
Canisteo	7	9	16
Concord	4	8	12
Mantorville	1	6	7
Milton	3	14	17
Vernon	2	4	6
Wasioja	2	2	4
Westfield	1	3	4
Total	20	46	66

APPENDIX F

MINNESOTA WELL INDEX

The MWI was used to gather information about the seven townships in Dodge County included in the study. This section includes all drinking water wells in the study area, not just wells MDA sampled. Table 19 summarizes the general aquifer types, while the following is a brief summary of the major aquifer types with the average well depth. According to the information from the MWI (MDH, 2018):

In these townships, there are 1,090 documented (have a verified location in the MWI) wells:

- Only 8 wells (<1%) are completed in Quaternary aquifers.
- Approximately 80% of wells documented wells in the county are completed in Paleozoic Aquifers. These include the Spillville, Maquoketa formation, Galena Group, St. Peter formation, and Prairie Du Chien Group.
    - A total of 21 (<2 percent) documented well are drilled into the Spillville aquifer at an average depth of 171.2 feet deep.
    - Maquoketa formation has 50 document wells withdrawing water from it, and the average depth of these wells is 188.5 feet.
    - Approximately 26 percent of documented wells withdraw water from the Galena Group aquifers, and are on average 162.3 feet deep.
    - Approximately 20 percent of documented wells withdraw water from the St. Peter formation, and are on average 339.9 feet deep.
    - The Praire Du Chien Group has the largest percentage (27%) of documented wells in this study area. The well are 371.2 feet deep on average
- Only 5 wells are drilled into the Jordon formation. This is the deepest local aquifer utilized, average 831 feet deep.
- 1.5% of wells were completed in multiple aquifers. The average depth of these wells is 258.5 feet.
- 17.2% of wells were undesignated with regards to which aquifer they were completed in.
- No documented wells were completed in the Quaternary water table, Cretaceous, or Precambrian aquifers.

Table 19. Aquifer Type Distribution of Wells in Minnesota Well Index

Township	Quaternary	Spillville formation	Maquoketa formation	Galena Group	St. Peter Formation	Prairie Du Chien Group	Jordon Formation	Multiple	Not Available	Total
	Number of wells drawing water from an aquifer									
Canisteo	0	0	2	49	29	20	0	0	47	147
Concord	1	0	0	35	20	15	2	2	23	98
Mantorville	1	0	0	31	82	148	1	5	25	293
Milton	1	0	0	8	29	102	0	3	22	165
Vernon	3	1	13	38	18	5	0	1	33	112
Wasioja	0	0	2	119	40	7	2	4	29	203
Westfield	2	20	33	8	0	0	0	1	8	72
Total	8	21	50	288	218	297	5	16	187	1,090
Average Well Depth (feet)	93.2	171.2	188.5	162.3	339.9	371.2	831.0	258.5	125.8	263.7

APPENDIX G

Example – "Participation Letter and Well Survey"

Private Well Survey for Township Testing Program

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

First name _____ **Last name**_____

Parcel Number_____ **Township**_____

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

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

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

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

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

2. Are there livestock on this property?
(more than 10 head of cattle, 30 head of hogs or an equivalent number of other livestock)
☐ Yes ☐ No

3. Do you mix or store fertilizer (500 lb. or more) on the farm site? ☐ Yes ☐ No

4. Does farming take place on this property? ☐ Yes ☐ No

WELL INFORMATION

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

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

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

7. Type of **well construction**?	☐ Drilled	☐ Sand point	☐ Hand Dug Well	☐Don't Know	☐ Other
8. Approximate **age** of your well?	☐ 0 - 10 years	☐ 11 - 20 years	☐ 21 - 40 years	☐ over 40 years	
9. Approximate **depth** of your well?	☐ 0 - 49 Feet	☐ 50 -99 feet	☐ 100 - 299 feet	☐ >=300 feet	
10. Distance to an active or inactive feedlot?	☐ 0 - 49 Feet	☐ 50 -99 feet	☐ 100 - 299 feet	☐ >=300 feet	
11. Distance to a septic system?	☐ 0 - 49 Feet	☐ 50 -99 feet	☐ 100 - 299 feet	☐ >=300 feet	
12. Distance to an agricultural field?	☐ 0 - 49 Feet	☐ 50 -99 feet	☐ 100 - 299 feet	☐ >=300 feet	

13. Is this well currently used for human consumption (Drinking or Cooking)? ☐ Yes ☐ No

14. Please check any water treatment you have **other than a water softener**.
☐ None ☐ Reverse Osmosis ☐ Distillation ☐ Filtering system ☐ Other

15. When did you last have your well tested for nitrates?
☐ Never tested ☐ Within the last year ☐ Within the last 3 years
☐ Within the last 10 years ☐ Greater than 10 years ☐ Not sure

16. What was the result of your **last** nitrate test?
☐ <3 mg/L (ppm) ☐ 3<10 mg/L(ppm) ☐ >=10 mg/L (ppm) ☐ Don't Know

9

APPENDIX H

Table 20. Property Setting for Well Location

Township	Total	Country	River home	Lake Home	Sub-division	Other	Not available
Canisteo	87	78.2%	0.0%	0.0%	0.0%	0.0%	21.8%
Concord[1]	75	86.7%	0.0%	0.0%	0.0%	0.0%	13.3%
Mantorville[2]	154	68.2%	2.6%	0.0%	13.0%	3.2%	13.0%
Milton	93	89.2%	0.0%	0.0%	0.0%	0.0%	10.8%
Vernon	70	80.0%	0.0%	0.0%	1.4%	0.0%	18.6%
Wasioja[3]	104	89.4%	0.0%	0.0%	1.0%	0.0%	9.6%
Westfield	71	85.9%	1.4%	0.0%	4.2%	1.4%	7.0%
Total	654	81.2%	0.8%	0.0%	3.8%	0.9%	13.3%

Table 21. Well Construction Type

Township	Total	Drilled	Sand point	Hand dug	Other	Not available
Canisteo	87	67.8%	0.0%	0.0%	2.3%	29.9%
Concord[1]	75	64.0%	0.0%	1.3%	0.0%	34.7%
Mantorville[2]	154	76.0%	0.0%	0.0%	0.6%	23.4%
Milton	93	78.5%	2.2%	1.1%	0.0%	18.3%
Vernon	70	70.0%	4.3%	0.0%	1.4%	24.3%
Wasioja[3]	104	74.0%	1.0%	0.0%	1.9%	23.1%
Westfield	71	73.2%	8.5%	0.0%	0.0%	18.3%
Total	654	72.6%	1.8%	0.3%	0.9%	24.3%

Table 22. Age of Well

Township	Total	1994 to Present	1985 to 1993	1975 to 1984	Before 1975	Not available
Canisteo	87	10.3%	10.3%	9.2%	26.4%	43.7%
Concord[1]	75	18.7%	0.0%	4.0%	42.7%	34.7%
Mantorville[2]	154	19.5%	14.9%	14.3%	21.4%	29.9%
Milton	93	29.0%	5.4%	7.5%	32.3%	25.8%
Vernon	70	11.4%	4.3%	8.6%	37.1%	38.6%
Wasioja[3]	104	18.3%	2.9%	10.6%	40.4%	27.9%
Westfield	71	14.1%	7.0%	21.1%	33.8%	23.9%
Total	654	17.9%	7.3%	11.0%	32.1%	31.7%

Table 23. Depth of Well

Township	Total	0-15 Feet	16-49 Feet	50-99 Feet	100-299 Feet	≥300 Feet	Not Available
Canisteo	87	0.0%	5.7%	12.6%	26.4%	24.1%	31.0%
Concord[1]	75	0.0%	8.0%	30.7%	22.7%	13.3%	25.3%
Mantorville[2]	154	0.0%	5.8%	9.7%	29.9%	26.0%	28.6%
Milton	93	0.0%	3.2%	16.1%	31.2%	28.0%	21.5%
Vernon	70	1.4%	4.3%	14.3%	35.7%	4.3%	40.0%
Wasioja[3]	104	0.0%	2.9%	17.3%	34.6%	18.3%	26.9%
Westfield	71	2.8%	7.0%	11.3%	53.5%	2.8%	22.5%
Total	654	0.5%	5.2%	15.3%	32.7%	18.5%	27.8%

Table 24. Unique Well ID Known

Township	Total	No, Unique Well ID Not known	Yes, Unique Well ID known	Not Available
Canisteo	87	26.4%	13.8%	59.8%
Concord[1]	75	25.3%	14.7%	60.0%
Mantorville[2]	154	20.8%	18.2%	61.0%
Milton	93	32.3%	19.4%	48.4%
Vernon	70	30.0%	8.6%	61.4%
Wasioja[3]	104	23.1%	14.4%	62.5%
Westfield	71	40.8%	9.9%	49.3%
Total	654	27.2%	14.8%	58.0%

Table 25. Livestock Located on Property

Township	Total	No Livestock	Yes Livestock	Not available
Canisteo	87	73.6%	4.6%	21.8%
Concord[1]	75	78.7%	9.3%	12.0%
Mantorville[2]	154	81.8%	7.1%	11.0%
Milton	93	67.7%	20.4%	11.8%
Vernon	70	72.9%	8.6%	18.6%
Wasioja[3]	104	79.8%	7.7%	12.5%
Westfield	71	85.9%	5.6%	8.5%
Total	654	77.5%	9.0%	13.5%

Table 26. Fertilizer Stored on Property

Township	Total	No Fertilizer Stored	Yes Fertilizer Stored	Not Available
Canisteo	87	77.0%	1.1%	21.8%
Concord[1]	75	86.7%	1.3%	12.0%
Mantorville[2]	154	87.7%	0.6%	11.7%
Milton	93	88.2%	1.1%	10.8%
Vernon	70	81.4%	0.0%	18.6%
Wasioja[3]	104	86.5%	1.9%	11.5%
Westfield	71	81.7%	11.3%	7.0%
Total	654	84.7%	2.1%	13.1%

Table 27. Farming on Property

Township	Total	No Farming	Yes Farming	Not available
Canisteo	87	41.4%	36.8%	21.8%
Concord[1]	75	46.7%	41.3%	12.0%
Mantorville[2]	154	64.3%	24.7%	11.0%
Milton	93	44.1%	44.1%	11.8%
Vernon	70	41.4%	40.0%	18.6%
Wasioja[3]	104	47.1%	40.4%	12.5%
Westfield	71	43.7%	49.3%	7.0%
Total	654	48.9%	37.8%	13.3%

Table 28. Distance to an Active or Inactive Feedlot

Township	Total	0-49 Feet to Feedlot	50-99 Feet to Feedlot	100-299 Feet to Feedlot	≥300 Feet to Feedlot	Not Available
Canisteo	87	3.4%	4.6%	4.6%	58.6%	28.7%
Concord[1]	75	8.0%	1.3%	12.0%	57.3%	21.3%
Mantorville[2]	154	1.9%	0.6%	6.5%	72.7%	18.2%
Milton	93	5.4%	5.4%	15.1%	59.1%	15.1%
Vernon	70	4.3%	2.9%	8.6%	57.1%	27.1%
Wasioja[3]	104	1.9%	3.8%	10.6%	67.3%	16.3%
Westfield	71	0.0%	4.2%	16.9%	66.2%	12.7%
Total	654	3.4%	3.1%	10.1%	63.9%	19.6%

Table 29. Distance to Septic System

Township	Total	0-49 Feet to Septic	50-99 Feet to Septic	100-299 Feet to Septic	≥300 Feet to Septic	Not Available
Canisteo	87	3.4%	19.5%	40.2%	10.3%	26.4%
Concord[1]	75	5.3%	22.7%	42.7%	17.3%	12.0%
Mantorville[2]	154	3.2%	20.8%	41.6%	16.2%	18.2%
Milton	93	5.4%	10.8%	58.1%	15.1%	10.8%
Vernon	70	4.3%	21.4%	38.6%	14.3%	21.4%
Wasioja[3]	104	1.0%	19.2%	45.2%	23.1%	11.5%
Westfield	71	5.6%	19.7%	56.3%	11.3%	7.0%
Total	654	3.8%	19.1%	45.7%	15.7%	15.6%

Table 30. Distance to an Agricultural Field

Township	Total	0-49 Feet to Field	50-99 Feet to Field	100-299 Feet to Field	≥300 Feet to Field	Not Available
Canisteo	87	4.6%	11.5%	32.2%	26.4%	25.3%
Concord[1]	75	2.7%	20.0%	36.0%	28.0%	13.3%
Mantorville[2]	154	3.2%	7.8%	30.5%	43.5%	14.9%
Milton	93	4.3%	8.6%	44.1%	31.2%	11.8%
Vernon	70	4.3%	7.1%	37.1%	31.4%	20.0%
Wasioja[3]	104	3.8%	4.8%	36.5%	43.3%	11.5%
Westfield	71	5.6%	7.0%	43.7%	33.8%	9.9%
Total	654	4.0%	9.2%	36.4%	35.3%	15.1%

Table 31. Drinking Water Well

Township	Total	Not Drinking Water	Yes, Drinking Water	Not Available
Canisteo	87	2.3%	74.7%	23.0%
Concord[1]	75	0.0%	88.0%	12.0%
Mantorville[2]	154	3.9%	83.8%	12.3%
Milton	93	0.0%	90.3%	9.7%
Vernon	70	4.3%	77.1%	18.6%
Wasioja[3]	104	2.9%	87.5%	9.6%
Westfield	71	0.0%	93.0%	7.0%
Total	654	2.1%	84.9%	13.0%

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

Township	Total	None	Distillation	Filtering System	Reverse Osmosis	Other	Not Available
Canisteo	87	40.2%	1.1%	27.6%	1.1%	1.1%	28.7%
Concord[1]	75	45.3%	2.7%	17.3%	14.7%	1.3%	18.7%
Mantorville[2]	154	42.2%	0.0%	33.8%	6.5%	3.2%	14.3%
Milton	93	50.5%	0.0%	25.8%	7.5%	3.2%	12.9%
Vernon	70	32.9%	0.0%	22.9%	10.0%	8.6%	25.7%
Wasioja[3]	104	50.0%	0.0%	26.0%	2.9%	3.8%	17.3%
Westfield	71	70.4%	0.0%	14.1%	4.2%	2.8%	8.5%
Total	654	46.8%	0.5%	25.4%	6.4%	3.4%	17.6%

Table 33. Last Tested for Nitrate

Township	Total	Within the past year	Within the last 3 years	Within the last 10 years	Greater than 10 years	Never Tested	Homeowner Unsure	Not Available
Canisteo	87	9.2%	4.6%	4.6%	14.9%	10.3%	32.2%	24.1%
Concord[1]	75	9.3%	5.3%	13.3%	25.3%	9.3%	25.3%	12.0%
Mantorville[2]	154	4.5%	10.4%	13.6%	13.0%	18.2%	29.2%	11.0%
Milton	93	23.7%	12.9%	17.2%	10.8%	9.7%	16.1%	9.7%
Vernon	70	1.4%	5.7%	14.3%	18.6%	27.1%	14.3%	18.6%
Wasioja[3]	104	3.8%	1.9%	15.4%	23.1%	15.4%	30.8%	9.6%
Westfield	71	12.7%	5.6%	11.3%	21.1%	19.7%	22.5%	7.0%
Total	654	8.9%	7.0%	13.0%	17.4%	15.6%	25.2%	12.8%

Table 34. Last Nitrate Test Result

Township	Total	<3 mg/L Nitrate-N	3<10 mg/L Nitrate-N	≥10 mg/L Nitrate-N	Not Available
Canisteo	87	9.2%	4.6%	1.1%	85.1%
Concord[1]	75	8.0%	5.3%	2.7%	84.0%
Mantorville[2]	154	7.1%	1.9%	1.3%	89.6%
Milton	93	24.7%	10.8%	1.1%	63.4%
Vernon	70	2.9%	0.0%	0.0%	97.1%
Wasioja[3]	104	9.6%	1.9%	0.0%	88.5%
Westfield	71	9.9%	5.6%	0.0%	84.5%
Total	654	10.2%	4.1%	0.9%	84.7%

[1] Includes 3 homeowner survey responses from West Concord City

[2] Includes 11 homeowner survey responses from Mantorville City

[3] Includes 2 homeowner survey responses from Dodge Center City

APPENDIX I

Table 35. Well Construction Type for Final Well Dataset

Township	Total Wells	Drilled	Sand Point	Other	Not Available
Canisteo	71	55	0	1	15
Concord[1]	63	46	0	0	17
Mantorville[2]	147	118	0	1	28
Milton	76	69	0	0	7
Vernon	64	51	2	0	11
Wasioja[3]	100	76	1	2	21
Westfield	67	54	4	0	9
Total	588	469	7	4	108

Data compiled from well logs and homeowner responses.

Table 36. Well Depth for Final Well Dataset

Township	Total Wells	Min	Max	Median	Mean
Canisteo	52	36	497	242	263
Concord[1]	31	40	425	220	228
Mantorville[2]	92	38	475	326	301
Milton	58	65	473	296	281
Vernon	38	10	565	183	211
Wasioja[3]	60	45	489	182	218
Westfield	24	50	290	186	175
Total	355	10	565	243	254

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

Table 37. Year of Well Construction for Final Well Dataset

Township	Total Wells	Min	Max	Median	Mean
Canisteo	43	1965	2008	1989	1988
Concord[1]	27	1940	2013	1995	1985
Mantorville[2]	85	1948	2013	1990	1987
Milton	52	1912	2016	1996	1990
Vernon	22	1951	2008	1991	1987
Wasioja[3]	51	1960	2015	1978	1984
Westfield	21	1946	2015	1988	1987
Total	301	1912	2016	1989	1987

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.

[1]Includes well(s) from West Concord City
[2] Includes well(s) from Mantorville City
[3] Includes well(s) from Dodge City Center

APPENDIX J

Private Well Field Log

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

MDA -Private Well Field Log & Well Survey Form

Sample#_____

Duplicate#_____**Field Blank#**_____

Additional Samples_____

Well Owner Contact Information

Name_____

Address_____

Phone #_____Township_____County_____

Sampling Information

Sampler_____Time Arrived_____

Pump Start Time_____Discharge Rate_____Time Collected_____

Sample Point Location_____

Well Location_____

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

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

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

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

Field Comments - sample specific notes

Updated: March, 2017

APPENDIX K

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

Township	Samples	Min	Max	Median	Mean
Canisteo	11	9.62	11.34	10.02	10.33
Concord[1]	11	10.13	12.79	11.32	11.23
Mantorville[2]	25	8.90	16.47	10.66	11.00
Milton	12	10.36	13.20	11.38	11.64
Vernon	10	9.63	11.92	10.81	10.72
Wasioja	6	9.64	10.70	10.49	10.33
Westfield	12	10.09	13.85	11.11	11.37
Total	87	8.90	16.47	10.84	11.01

Table 39. pH of Well Water for Final Well Dataset

Township	Samples	Min	Max	Median	Mean
Canisteo	11	7.20	7.84	7.37	7.43
Concord[1]	11	7.12	7.45	7.29	7.28
Mantorville[2]	25	7.10	7.65	7.28	7.31
Milton	12	7.07	7.47	7.25	7.24
Vernon	10	7.18	7.46	7.36	7.33
Wasioja	6	6.77	7.36	7.29	7.22
Westfield	12	7.06	7.57	7.38	7.37
Total	87	6.77	7.84	7.30	7.32

[1]Includes well(s) from West Concord City

[2] Includes well(s) from Mantorville City

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

Township	Samples	Min	Max	Median	Mean
Canisteo	11	432	654	584	561
Concord[1]	11	490	1,016	822	767
Mantorville[2]	25	490	1,127	628	656
Milton	12	490	1,157	677	724
Vernon	10	457	688	533	555
Wasioja	6	593	882	677	718
Westfield	12	443	1,062	546	629
Total	87	432	1,157	618	656

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

Township	Samples	Min	Max	Median	Mean
Canisteo	11	0.13	6.40	2.91	3.04
Concord[1]	11	0.33	6.67	3.81	3.26
Mantorville[2]	25	0.11	7.91	1.37	2.57
Milton	12	0.12	8.07	4.45	3.87
Vernon	10	0.10	6.34	0.41	1.55
Wasioja	6	0.35	6.56	2.06	2.57
Westfield	12	0.16	9.44	1.62	3.20
Total	87	0.10	9.44	1.91	2.86