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Class 3 & 4 Water Quality Standards Revision

Technical Support Document

MINNESOTA POLLUTION CONTROL AGENCY

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Acronyms and Abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
ASAM	*Agricultural Salinity Assessment and Management*. American Society of Civil Engineers. (2011).
AWWDF	Average wet weather design flow
California State Board	California State Water Pollution Control Board
CFS	Cubic feet per second
CWA	Clean Water Act
EC_e	Electrical Conductivity of soil extract waters
EC_w	Electrical conductivity of irrigation waters
EPA	United States Environmental Protection Agency
ET	Evapotranspiration
Handbook 60	United States Department of Agriculture Handbook No. 60, *Diagnosis and Improvements of Saline and Alkali Soils*. Richards, L.A. (Ed.). (1954).
HVAC	Heating, ventilation, and air conditioning
K_{sat}	K_{sat} a unit of measure used in describing the hydraulic conductivity of soils. It refers to the ease with which pores in a saturated soil transmit water; expressed in terms of micrometers per second (µm/s) or inches per hour.
MDF	Maximum design flow
mgy	Million gallons per year
Minn. R.	*Minnesota Rules*
µm/s	Micrometers per second
mm/y	Millimeters per year
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MWPCC	Minnesota Water Pollution Control Commission
NDSU	North Dakota State University
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NRCS	Natural Resource Conservation Service
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PEM	Polioencephalomalacia

PHREEQC	PHREEQC is a computer program for simulating chemical reactions and transport processes in natural or polluted water, in laboratory experiments, or in industrial processes
Q_{10}	The river flow rate that is exceeded by 90% of all recorded flows; a low flow condition
RFC	Request for Comment
RO	Reverse osmosis
RP	Reasonable potential
SAR	Sodium adsorption ratio
SONAR	Statement of Need and Reasonableness
SR	*State Register*
SSC	Site-specific criteria
SSURGO	Soil Survey Geographic Database
TDS	Total dissolved solids
TSD	Technical support document
UAA	Use attainability analysis
UMN	University of Minnesota
USDA	United States Department of Agriculture
UVD	Use and value demonstration
WET	Whole effluent toxicity
WLA	Wasteload allocation
WQBEL	Water quality–based effluent limit
WWTP	Wastewater treatment plant

Introduction

Water Quality Standards

The federal Clean Water Act (CWA) requires states and authorized tribes to designate beneficial uses for all water bodies and develop water quality standards to protect each use. State statutes authorize the Minnesota Pollution Control Agency (MPCA) to establish standards necessary to protect beneficial public uses[1] and to adopt rules for grouping designated waters of the state into classes considering the best usage in the public's interest.[2]

Water quality standards include several components:

- **Designated beneficial uses** identify how people, aquatic communities, and wildlife use waters.
- **Narrative standards** are descriptions of conditions necessary to protect beneficial uses.
- **Numeric standards** are typically the allowable concentrations of specific chemicals in a water body established to protect designated beneficial uses. They may also include measures of biological health. Numeric standards often have three parts:
    - Magnitude – the acceptable amount of a parameter's concentration or level of concern
    - Duration – the time over which the in-stream concentration of a pollutant is considered for comparison with the magnitude of the standard or criterion
    - Frequency – the number of instances a standard can be exceeded in a specified period of time without affecting a designated beneficial use
- **Antidegradation policy and implementation procedures** provide additional protection for unique waters (i.e., outstanding resource value waters), waters of high quality and existing uses. High water quality means water quality that exceeds levels necessary to support aquatic life and recreation. Existing uses are those beneficial uses actually attained in a surface water on or after November 28, 1975.

Together, the designated beneficial uses, narrative and numeric standards, and antidegradation protections provide the framework for achieving CWA goals. *Minnesota Rules* (*Minn. R.*) chapter 7050 assigns a series of beneficial use classifications to all waters of the state. Use classifications include domestic consumption, aquatic life and recreation, industrial consumption, agriculture and wildlife use, and aesthetic enjoyment and navigation.

The MPCA proposes to amend water quality standards for industrial consumption[3] (Class 3) and agriculture and wildlife uses[4] (Class 4). This rulemaking will not address the Class 4A wild rice sulfate standard, which is the subject of ongoing evaluation.

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[1] *Minnesota Statute* (*Minn. Stat.*) 115.03, subd. 1 and *Minn. Stat.* 115.44, subd. 2
[2] *Minn. Stat.* 115.44, subd. 2
[3] *Minn. R.* 7050.0223
[4] *Minn. R.* 7050.0224

Past Public Reviews and Comments Specific to Industrial and Agricultural Uses

Class 3 and Class 4 standards were first adopted into rule on a statewide basis in the late 1960s and have remained largely unchanged since that time. While a re-examination of the Class 3 and Class 4 standards has been proposed several times in the past, other high-priority rules have taken precedence.

The MPCA has had a long-term interest and identified need to revise the Class 3 (industrial consumption) and 4 (agriculture and wildlife) water quality standards. Formal opportunities for the public to comment on the scope and options for the revisions include the 2008, 2013, and 2017 Triennial Standards Reviews (33 *State Register [SR]* 224, 38 *SR* 603, and 42 *SR* 632) and a specific Request for Comment (RFC) published on February 8, 2016 (40 *SR* 965).

The groups providing substantial comments included the U.S. Environmental Protection Agency (EPA), other governmental organizations (Minnesota Department of Transportation, and city wastewater treatment operators), private industries and their representatives (Minnesota Chamber of Commerce, food growers and processors, and mining operators), environmental and public health nonprofit organizations, and concerned citizens.

Comments received made various suggestions to the MPCA, including that the MPCA should:

- Prioritize pollution prevention and protection of waters of the state to meet the CWA requirements;
- Provide assurance that any revisions or removal of Class 3 and 4 numeric standards, especially for pH, chloride, specific conductance, and other ionic parameters, will not inadvertently affect industry, farming, and wildlife or other beneficial uses of surface waters such as aquatic life (Class 2) or domestic consumption (Class 1);
- Remove the industrial and agricultural uses on waters where these uses are not attainable or feasible and retain them only where there are Minnesota Department of Natural Resources (MNDNR) appropriation permits;
- Replace statewide, generic numeric standards with narrative standards for application on a regional or site-specific basis, use Class 2 standards, or other specific numeric standards based on sound, peer-reviewed science; and
- Prioritize this rulemaking due to National Pollutant Discharge Elimination System (NPDES) permitting delays and potential implementation costs related to the use of the outdated standards for setting effluent limits.

In the 2016 RFC, MPCA shared possible options for revising the approaches for designating waters as Classes 3 and 4A (irrigation) and the narrative and numeric standards for each of the uses.

- Possible changes for the Class 3 use included replacing numeric standards for the existing subclasses (3A–3D) with a single narrative standard and only applying the standard to surface waters subject to the MNDNR water appropriations permitting program for specific industrial uses. In other words, the Class 3 use class would no longer apply to all surface waters of the state.
- Options for changes to Class 4A and Class 4B centered on updating numeric standards to reflect current science and applying Class 4A standards on a seasonal basis (during growing season months) only to waters with an active MNDNR water appropriations permit. Class 4B standards would continue to apply to all surface waters of the state.

The MPCA noted that it would also consider any other rule changes needed to implement the desired changes to the Class 3 and Class 4 standards but that these amendments would *not* address the Class 4A wild rice sulfate standard, which was the subject of a separate rulemaking proposal (since withdrawn).

The current ideas described in this technical support document (TSD) have moved away from seasonally-applied standards and the option that related to restricting how surface waters are designated. This is primarily due to concerns about the extensive CWA requirements to remove the applicability of beneficial uses and due to improved use of the available information and tools, which allowed the MPCA to refine how industrial and agricultural uses are addressed. The details of the draft Class 3 and 4 standards revisions are described fully in the TSD, and should explain the MPCA's rationale behind the changes since the 2016 RFC.

The MPCA provides, below, a high-level response to comments on issues that are not otherwise discussed in the TSD, primarily regarding lessening of protection to waters of the state, including drinking water uses and aquatic life.

Protection of waters of the state and other beneficial uses:

MPCA fully recognizes and acknowledges that for some pollutants, Classes 3 and 4 contain the only existing or most stringent numeric standards. Stakeholders expressed concern that removal or revision may lead to increases in concentrations of these pollutants in some surface waters. However, the MPCA does not expect significant increases in ionic pollutants or specific conductance relative to existing conditions, because of the plans to develop detailed implementation procedures for the considered narrative standards.

In addition, while standards are designed to protect specific beneficial uses, all of Minnesota's waters carry multiple beneficial uses. The Class 3 and Class 4 standards were not designed to protect aquatic life. Ongoing and regular implementation of other water quality standards – such as existing Class 1 and Class 2 numeric standards for pH and chloride – also serve to protect water quality. MPCA has significant existing authority and many avenues to ensure protection of water quality and aquatic life and recreation. For example, Class 2 standards include those that directly measure aquatic life health. In addition, if the MPCA discovers an aquatic life issue caused by any stressor – including those that currently have numeric Class 3 and 4 standards – the MPCA can use the existing narrative standard for aquatic life to restrict pollution as needed.

- Many wastewater facilities where the "salty" or high ion parameters currently covered by these pollutants are of concern also have concerns about meeting limits related to the Class 2 chloride standard.
    - Many of these facilities will need variances from the existing chloride standard due to a current lack of affordable end of pipe treatment options. Variances require pollutant minimization plans. Because chloride and other ionic parameters are closely linked, many minimization plans to reduce chloride will also lead to a reduction in other parameters (such as specific conductance, total dissolved solids, etc.)
- Class 1 waters are protected for drinking water and food processing, and *Minn. R.* 7050.0221, subp. 6 contains narrative standards that give the MPCA broad authority to prevent discharges that may "cause any material undesirable increase in the taste, hardness, temperature, chronic toxicity, corrosiveness, or nutrient content" of the water.
- MPCA has extensive surface water monitoring, including biological assessments, in all 81 watersheds and a robust program of stressor identification that would require a permittee begin monitoring for a parameter identified as a possible biological stressor.

- Major dischargers are required to complete whole effluent-based toxicity testing to protect aquatic life, and salty parameters are a key cause of failed WET tests.

MPCA also has longstanding plans to update Minnesota's water quality standards to revise the Class 2 aquatic life standard for chloride and add aquatic life standards for sulfate and nitrate. As noted in the MPCA's 2018 – 2020 standards work plan, technical information to support any revisions to these standards is still outstanding. MPCA continues to closely follow EPA's toxicity studies on these parameters. Many stakeholders feel that MPCA should not revise the Class 3 and 4 standards until new aquatic life standards for ionic parameters are established.

The MPCA acknowledges that there is peer-reviewed academic literature finding that the parameters currently included in Classes 3 and 4 can have impacts to aquatic life. However, the protection of aquatic life is not the purpose of the Class 3 and 4 standards. The best approach to aquatic life protection is for MPCA to continue to obtain the best field data on the relevant parameters, and to work with EPA Region 5 to complete needed toxicity tests and develop the basis for future aquatic life toxicity-based standards. Therefore, the MPCA will not address the aquatic life impacts of the Class 3 and 4 standards within this rulemaking. Protection of aquatic life from ionic parameters is better left to its own rulemaking package to be completed at a later date.

The draft revisions provide clearer processes to review the Class 3 and Class 4 uses, and will bring more robust data and tools to the MPCA's permitting programs for implementing protections more specific to the water body and uses as described fully in the TSD. As noted above, the MPCA received many comments requesting that the MPCA prioritize this rulemaking due to the burdens of using outdated standards to calculate effluent limits, and the resulting difficulties in permitting and implementation.

The MPCA is revising the standards based on a review of the scientific information and because of the ability to compile data and information that allows us to take a more localized and specific approach to protecting water quality. However, it should be noted that complying with effluent limits protective of the current "one size fits all" Class 3 and 4 salty parameter standards can require capital expenditures in the millions of dollars for both municipal and industrial facilities. The MPCA has performed preliminary treatment cost analysis for these parameters and found that the cost of compliance with the Class 3 and 4 water quality standards has the potential to cause substantial economic hardship to NPDES permittees. Municipal NPDES permittees are the most broadly affected by these costs. For example, if all NPDES permits were re-issued today, over 150 municipal facilities would receive effluent limitations based on the current Class 4A total dissolved salts water quality standard. Compliance with the Class 4A effluent limitations would likely cost each municipality millions of dollars and these costs would likely cause substantial economic hardship in the communities due to increased wastewater costs.

NPDES permittees understand and support the importance of complying with effluent limitations that demonstrate clear benefits to environmental or public health, even if the cost of compliance with those limits is high. However, when the benefits of complying with an effluent limitation are not readily apparent and the science behind the standards is outdated or not well supported, it raises questions about spending economic resources – often public resources – to comply. Without updating these Class 3 and 4 standards to reflect modern scientific understanding, many permittees could be required to spend economic resources to comply with water quality standards not based on sound science and with unclear environmental benefits.

Because of updated information and the ability, the MPCA contends it is needed and reasonable to revise the standards.

While costs are not considered in determining the magnitude of any given water quality standard, the complexities of program implementation – and the potential need to undertake significant individualized actions (such as site specific standards, use changes, or variances) – are part of the reason for moving forward with this rulemaking at this time. This TSD explains the methods the MPCA envisions using to ensure that the standards work to protect waters where needed, while not requiring unnecessary and expensive treatment where it is not needed to protect the beneficial uses.

Summary of Draft Revisions

Planned changes to the Class 3 use include replacing numeric standards for the existing subclasses (3A–3D) with a single narrative standard. Likewise for the Class 4A (irrigation) use, numeric standards would be replaced with a narrative standard. Both Class 3 and Class 4A standards would remain applicable to all waters of the state and apply year round. One rationale for replacing numeric with narrative standards is the recognition that identifying protective numeric values for each potential parameter necessary to protect various wide-ranging industrial and irrigation uses is not reasonable, primarily because the significant information needs make it difficult to develop scientifically defensible standards that work in all cases. As will be explained later in this TSD, the MPCA is considering the use of numeric translators of the draft narrative standards for developing effluent limits.

Planned changes to Class 4B (wildlife and livestock watering) include updating numeric standards to reflect current science and agricultural best practices, replacing the total salinity standard with a total dissolved solids standard, and adding sulfate and nitrate standards. The revised standards would continue to apply to all surface waters of the state, year round.

The MPCA is also planning to revise wetland provisions in Classes 3 and 4. In reviewing past rulemaking documents (e.g., the 1993 Statement of Need and Reasonableness for the rule adoption), it appears that the standards included in these use classes were not always put in place with the intention to protect the industrial or agriculture/wildlife designated uses, but rather to protect the wetlands themselves. Therefore, the MPCA is proposing changes to Classes 3D and 4C (wetland protections) to ensure that the waters are designated appropriately to protect the given designated uses. For some parameters (e.g., pH), there is redundancy between Class 2 (aquatic life and recreation) and Classes 3D and 4C. In these cases, the standards would simply be removed from Classes 3 and 4. Where there is no redundancy (e.g., chloride), the standards would be moved to Class 2D, which protects wetlands for aquatic life uses. The scope of these changes is not intended to make sweeping alterations to the Class 2D use, but to create better alignment between the standards and the uses they protect.

The intent of this document is to serve as a key resource providing technical information in support of this rulemaking. Note: except for the existing wild rice related Class 4 narrative language and the wild rice based sulfate standard, all aspects of Class 3 and 4 standards described in the TSD are open for comment, with some of the revisions given distinct options for consideration. The MPCA will also consider any other rule changes needed to implement the desired changes to the Class 3 and Class 4 standards.

Class 3 Water Quality Standards

Minnesota's Existing Class 3 Water Quality Standards

Minnesota's Class 3 water quality standards (*Minn. R.* 7050.0223) protect waters of the state so that they are suitable for "industrial consumption designated public uses and benefits." These uses may include product cleaning and transport at factory sites, materials transport, use of the water in the actual production of finished products, and equipment and process cooling purposes. There are four sub-classes in the Class 3 beneficial use: 3A, 3B, 3C and 3D. These four subclasses provide different levels of protection for industrial consumption and include both numeric standards and narrative standards. The State of Minnesota established water quality standards for Class 3 waters in 1967 and made revisions in 1973; for the most part, these standards have not been updated since that time. Only limited supporting documentation exists on the basis for these standards.

The Class 3 industrial consumption numeric water quality standards focus on the three parameters of pH, chloride and hardness. A brief explanation of each of these parameters is provided below:

- pH – A measurement of the acidity of water.
- Chloride – The concentration of chloride dissolved in water.
- Hardness – The summed concentration of calcium and magnesium ions dissolved in water.

The numeric standards for pH, chloride and hardness, as well as the narrative standards that are associated with Classes 3A, 3B and 3C are included in Table 1. Class 3D is specific to wetlands, and wetlands are addressed separately in a section at the end of this document.

The current Class 3 standards do not specify duration or frequency in the rule. This is consistent with typical water quality rulemaking practices prior to the CWA of 1972, for which the duration and frequency of the standard were often not specified and only the magnitude was included in rule. This can create difficulty in implementing standards.

Draft Changes to Class 3 Standards

The current and draft Minnesota water quality standards for Class 3 waters are outlined in Table 1. An expanded summary of the changes being considered for Class 3, with rationale are presented in Table 2.

Table 1. Current Class 3 numeric and narrative water quality standards by subclass (from *Minn. R.* 7050.0223) and the standards being put forward for consideration in this request for comments.

Current Standards[1]					Draft Standards[2]	
Subclass	Subclass Narrative	Parameter	Criteria Unit	Criteria	Class	Criteria
3A	"shall be such as to permit their use without chemical treatment, except softening for groundwater, for most industrial purposes, except food processing and	Chloride	mg/L	50	3	General Narrative Standard Protecting Industrial Consumption
		Hardness	mg/L, as $CaCO_3$	50		
		pH	Minimum	6.5		
		pH	Maximum	8.5		

	related uses, for which a high quality of water is required.”					
3B	“shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment.”	Chloride	mg/L	100		
		Hardness	mg/L, Ca+Mg as $CaCO_3$	250		
		pH	Minimum	6		
		pH	Maximum	9		
3C	“shall be such as to permit their use for industrial cooling and materials transport without a high degree of treatment being necessary to avoid severe fouling, corrosion, scaling, or other unsatisfactory conditions.”	Chloride	mg/L	250		
		Hardness	mg/L, as $CaCO_3$	500		
		pH	Minimum	6		
		pH	Maximum	9		

[1] Frequency and duration components of the current Class 3 standards are not explicitly described in rule.

[2] Draft narrative standards will not define the duration or frequency of the narrative standard.

Table 2. Details of draft revisions to Class 3 standards, with rationale for the changes, with requests for comments regarding options and additions to these standards.

Current Rule	Draft Rule	Rationale
Every water of the state is designated as requiring protection for industrial protection.	Every water of the state is designated as requiring protection for industrial protection.	• Does not remove the industrial consumption designated use from any water of the state and maintains a level of protection for industrial consumption. • Limiting the applicability of the industrial consumption use to only waters where industrial consumption occurs would require removing the designated use from every other water of the state not currently used for industrial consumption; this is over 100,000 waters. Removing a designated use requires substantial administrative (rulemaking) effort and legal justification; avoiding the effort required to remove a designated use simplifies this rulemaking process. • The industrial consumption designated use protects for current and future industrial consumption. The MPCA cannot predict from

		what waters and water qualities industrial consumers might want to appropriate in the future. Therefore it is prudent to maintain the industrial consumption designated use for every water of the state.
Four separate use subclasses (3A-3D).	Replace the four use subclasses with a single general class.	• The single general classification does not remove the industrial consumption designated use from any water of the state and maintains a general level of protection for industrial consumption. • The four separate use classes are intended to protect industrial consumers from operating unnecessary intake water treatment systems by separating industrial consumers into categories of required treatment. All industrial water consumers expect to fully treat water to their specific needs and as a result do not need to be categorized into classes of protection. • The designation of all waters of the state in previous rulemakings into one of the four subclasses was not done to protect any specific industrial consumer but rather was likely done presumptively in conjunction with the assignment of aquatic life or drinking water protection designated uses. Ultimately, the MPCA has not been able to find specific rationale for why certain waters were assigned a specific class. • Industrial consumers of water require widely varied qualities of water to operate and employ widely varied types of water treatment technologies to achieve those qualities of water. The wide varieties in quality and treatment needs across all industrial consumers makes it impossible to precisely categorize industrial uses into classes of water quality protection. • The industrial consumption designated use protects for current and future industrial consumption. The MPCA cannot predict from what waters and water qualities industrial consumers might want to appropriate in the future. Therefore it is prudent to maintain the industrial consumption designated use in a single class. • Administratively, it is easier for the MPCA to classify all waters of the state into a single industrial consumption designated use class.
The subclasses 3A, 3B and 3C have	Remove all numeric criteria for pH,	• Surveys of industrial water consumers in Minnesota showed that the hardness, chloride

numeric criteria for pH, hardness and chloride.	chloride and hardness and replace with a general narrative standard without any numeric standard.	and pH standard are not of essential importance to their industrial consumption water quality needs. • Industrial consumers rate consistent quality of water as being more important than the magnitude of any specific numeric standard for pH, chloride or hardness. • There is no record in the MPCA's or MNDNR's history of an industrial appropriator notifying either agency of a concern with the quality of their appropriation water with respect to chloride, hardness, pH or any other parameter. This is a strong indicator that the Class 3 numeric standards are not of an essential nature to the operations of industrial appropriators. • Every industrial appropriator expects to treat hardness to meet its specific water quality needs. As long as the incoming hardness quality is consistent, industrial appropriators expect to install and operate hardness treatment systems to meet their needs independent of what the level of the incoming hardness is. • The Class 3 pH and chloride standards were likely developed to manage for corrosion using technologies current in 1967. However, the logic used to select each specific standard is either non-existent or poorly reasoned by modern rulemaking standards. Corrosion management has progressed substantially since 1967 and these specific parameters are not important when considering modern corrosion management techniques for industrial consumption. • It is impossible to develop a single numeric water quality standard for a given parameter that is neither overprotective nor underprotective for the range of industrial water consumers in Minnesota.
The current rule specifies the degrees of treatment (chemical, moderate or high) each industrial use subclass is intended to protect for.	Remove all mention of degrees or categories of treatment in the general narrative standard.	• There is no clear explanation of what defines the degree of treatment in rule (chemical, moderate or high) and as such it is impossible to find a significant distinction between the three degrees of treatment in rule. • It is not possible to accurately categorize all current and future industrial consumers into the distinct degrees of treatment required to meet their individual water quality needs.

General Narrative Standard Protecting Water Quality for Industrial Consumption

Minn. R. ch. 7050 contains standards to protect ambient water quality for source water use for a variety of industrial purposes. Table 1 describes the narrative goals in current three subclasses, showing the accompanying numeric standards, with protection for wetlands in Class 3D. Addressing and maintaining some water quality parameters and characteristics to support use in industrial processes and cooling waters is common in state water quality standards, but this beneficial use has not been emphasized by EPA or states. In general, while important, standards to protect these uses are less specific and less frequently updated. In addition, generally the most relevant water quality parameters for industrial consumption are less stringent than those to protect aquatic life or drinking water use. Because they are not often the controlling standard, they have not been a priority to update. However, the MPCA has taken on a review and survey of industrial use to propose the following revisions.

First, the MPCA currently contends that the protection afforded under the existing Class 3 subclasses could be best addressed with a single industrial beneficial use supported by a narrative standard. A single narrative standard fits with the available information and addresses several concerns with the existing standards, such as ensuring protection for future industrial consumption, neither over- nor under protecting water quality for water bodies used for industrial purposes, and better reflecting a modern understanding of industrial water treatment practices.

While the MPCA does not have potential language at this time, we envision that the narrative standard would speak to the need to have water quality that prevents adverse impacts when it is used in industrial processes. The narrative water quality standard would prescribe the general qualities or properties of the waters of the state that are necessary so that the water can be used by those operating industrial processes.

The narrative standard would continue to allow for the use of waters of the state for industrial consumption with the understanding that industrial appropriators are willing and able to fund, operate, and maintain treatment systems to meet their specific water quality needs. The narrative standard would not prescribe categories or levels of water treatment technologies industrial consumers require, nor would it define the best or most affordable ways for industries to meet their specific appropriation water quality needs. The narrative standard would define a high-quality water, with respect to industrial consumption, as the water quality that the industrial appropriator is able and willing to appropriate and treat for their specific industrial needs.

Need for Revisions to Class 3 Standards

The existing Class 3 water quality standards were promulgated in the 1960s. A 1963 reference book titled *Water Quality Criteria* by McKee and Wolf states:

> *The ideal quality of water required for industrial use varies widely for the many purposes to which water is put. Needless to say, it impossible to organize the quality requirements of the waters used for each of the many different industrial processes into a single set of standards. Such quality requirements differ far too much to allow any broad generalization or simplification. Within any industrial plant, water may have several functions, the quality requirements for which vary markedly. A brewery, for example, needs soft water for bottle washing but can utilize hard water for brewing. Many industries require water of one quality for boiler feed, another for cooling towers, and a third quality for production processes…*

Industries are generally willing to accept for most processes, water that meets drinking-water standards. Where water of higher quality is needed, e.g., for television-picture-tube manufacture, certain food and beverage preparation, or for high-pressure boilers, industry recognizes that additional treatment is the responsibility of the water user.

One characteristic, however, is of primary importance for all industries, namely, the concentrations of the various constituents of the water should remain relatively constant. That the water is originally of poor quality for a particular industrial use is probably not important, once a process is started and the difficulties created by the presence of undesirable constituents in water are eliminated, as having the quality remain constant. Short time variations in concentrations of substances in the process water require continued attention and added expense.

Although many studies have been made of the quality requirements of water for use in certain industries, there remain innumerable other industries for which the requirements of water quality have not been specified in public documents except in a general and qualitative way.

Further, the 1952 California *Water Quality Criteria* publication contains the quote below with regards to developing a singular numeric value protective of all industrial water quality needs (McKee and Edward, 1952).

Needless to say, it is impossible to organize the quality requirements of the waters used for each of the many different industrial processes into a single standard.

In important ways, the water quality requirements for industrial water consumption have not changed since 1963. In 2018, the quality of water required for industrial consumption still varies widely by industry type. Industries are still generally willing to accept water that is generally suitable for treatment to be ultimately used as drinking water. However, some industrial appropriators are willing to accept water of lower quality than drinking water quality, while other industrial appropriators treat their water to better than drinking water quality. Industry recognizes that treatment is the responsibility of the water appropriator. Industries still rate consistent water quality as their primary water quality concern. There is still a lack of public documents that numerically define various industries' water quality requirements. It is still difficult to organize the quality requirements of the waters used for each of the many different industrial processes into a single standard.

Replacing the Class 3 numeric standards with a general narrative standard would be protective of the industrial consumption designated use and consistent with a modern understanding of industrial water consumption protections. The reasonableness of the current Class 3 numeric standards to protect for the industrial consumption designated use is not apparent when examining any prior justification through current day understanding of industrial water quality needs. Industrial consumers of water in Minnesota do not consider the Class 3 numeric standards to provide an essential protective aspect to their industrial water consumption needs. Industrial consumers of water also do not use any of the Class 3 numeric criteria as reference values in the design or operation of their water treatment systems. Instead, industrial consumers of water are committed to treating water quality to their specific needs.

Additionally, updating the Class 3 standards to reflect a modern understanding of industrial consumption water quality needs would reduce unneeded and unintended economic consequences of the Class 3 standards currently in rule. The MPCA has received comments from industrial and municipal wastewater dischargers about the substantial economic hardship that complying with the current Class 3 numeric standards has already caused and will cause in the future if these standards are not updated. The MPCA recognizes that water quality standards must be developed to protect for the designated use without considerations of the economic costs of complying with the standards. The MPCA also recognizes that in the Minnesota rulemaking process, the cost and benefits of new water quality standards must be described. Ultimately, the MPCA used the unneeded and unintended economic consequences of the Class 3 standards as factors that increased the priority and urgency of this rulemaking and as factors that emphasized the importance of protecting industrial consumption using a modern understanding of water quality science.

This TSD lays out the rationale for making changes to the Class 3 water quality standards based on these key factors.

Background

Current Surface Water Classifications

There are four sub-classes in the Class 3 beneficial use; 3A, 3B, 3C and 3D (Table 3). These four subclasses were set to provide different levels of protection for industrial consumption and these levels of protection are explained in greater detail in the following section. The discussion and proposals around Class 3D wetland standards are addressed in more detail later in the Wetlands section of this document.

Table 3. Industrial consumption designated use classes.

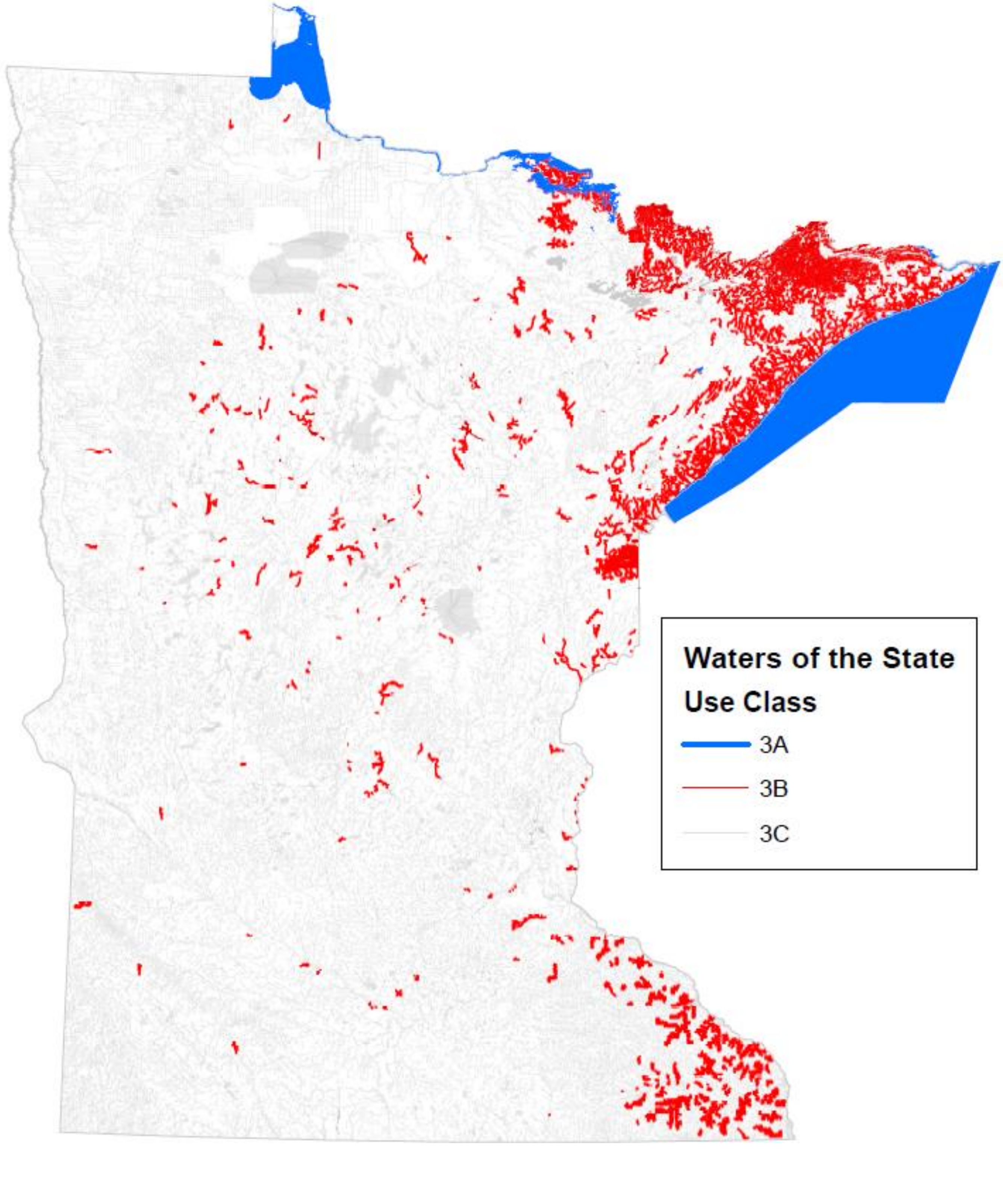
Classification	Industrial Use Type
3A	Use without chemical treatment*
3B	Use with moderate degree of treatment*
3C	Use for industrial cooling and material transport without a high degree of treatment
3D	Use (of wetlands) with only a moderate degree of treatment*

*Except for food processing.

Every surface water of the state has a Class 3A, 3B, 3C, or 3D classification. There are no surface waters without a Class 3 designation, and therefore every water of the state is protected so it may be used for industrial water consumption. The default classification for every surface water of the state is 3C, unless that water is a wetland. If a surface water is a wetland, then that water is classified as a 3D water. *Minn. R.* 7050.0470 lists every water that has a specific 3A or 3B designation. If a water is listed in *Minn. R.* 7050.0470 as a 3A or 3B water, it is also classified as a 3C water pursuant to *Minn. R.* 7050.0410. Designating a Class 3A or Class 3B water also as a Class 3C water is a hold-over from the original classification scheme that was adopted in 1967. At that time, differences between the standards in the Class 3A, 3B, and 3C use classifications were greater than they are today. Given that *Minn. R.* 7050.0450 clearly states that if the water quality standards for particular parameters for the various classes are different, the most restrictive of the standards apply, there is a certain redundancy in classifying a Class 3A or Class 3B water also as a Class 3C water. The potential changes to the Class 3 use classifications described in this TSD will remove this redundancy.

A map showing Class 3A, 3B and 3C waters is presented in Figure 1.

Figure 1. Minnesota waters colored by Class 3 use class.



Existing Locations of Industrial Water Appropriation in Minnesota

The MNDNR maintains a database of water appropriators and uses this database to track each appropriator's water usage and permit status. The MPCA used the most current version of this database (as of July 17, 2018) to visualize and count industrial water appropriators across the state (Tables 4 and 5 and Figures 2 and 3).

Every water appropriator in the MNDNR database is classified by the MNDNR into categories of water appropriation by use type. The use types range from irrigation to cooling and can be found in Table 4. The MPCA used these categories to determine whether an appropriator would be considered an industrial water appropriator as noted in the Class 3 Use column of Table 4. The MPCA also chose to only consider permits that are marked as active by the MNDNR. Active permits are those permits that have their yearly fees paid for and are in good standing with the MNDNR. The MPCA has not, to date, considered inactive permits; doing so inflates the number of users currently appropriating waters of the state by over 2000 users. We chose to focus on only active users in order to simplify the analysis in this rulemaking. Future implementation of the rule will also likely focus on active appropriation permits, but can be expanded to include areas where information is available demonstrating that industrial consumption is an existing use (due to the presence of an appropriation permit since November 28, 1975).

Table 4. How the MPCA defined an industrial consumer in reference to the MNDNR water appropriation categories.

Use Category	Use Type	Class 3 Use
Agricultural Irrigation	Agricultural Crop Irrigation	No
	Nursery Irrigation	No
	Orchard/Vineyard Irrigation	No
	Pasture Irrigation	No
	Sod Farm Irrigation	No
	Wild Rice Irrigation	No
Heating/Cooling	Commercial/Institutional Building AC	Yes
	District Heating/Cooling	Yes
	Geothermal Groundwater Exchange with Reinjection (heating, ventilation, and air conditioning [HVAC])	Yes
	Geothermal Systems (HVAC)	Yes
	Once-through Systems (HVAC)	Yes
	Other Air Conditioning	Yes
Industrial Processing	Agricultural/Food Processing	Yes
	Industrial Process Cooling - Once Through	Yes
	Metal Processing	Yes
	Mine Processing (excludes sand/gravel)	Yes
	Non-metallic Processing (rubber, plastic, glass, concrete)	Yes
	Other Industrial Processing	Yes
	Petroleum-Chemical Processing/Ethanol	Yes
	Sand and Gravel Washing	Yes

	Wood Products Processing	Yes
Non-Crop Irrigation	Cemetery Irrigation	No
	Golf Course Irrigation	No
	Landscaping/Athletic Field Irrigation	No
	Other Non-Crop Irrigation	No
Power Generation	Hydro Power	Yes
	Other Power Generation	Yes
	Thermoelectric Power Cooling - Once Through	Yes
	Thermoelectric Power Cooling - Recirculating	Yes
	Thermoelectric Power Generation - Non Cooling	Yes
Special Categories	Aquaculture	No
	Construction Non-dewatering	No
	Dust Control	No
	Livestock Watering	No
	Other Special Categories	No
	Pipeline and Tank Testing	No
	Pollution Containment	No
	Sewage Treatment	No
	Snow/Ice Making	Yes
Water Level Maintenance	Basin (Lake) Level Maintenance	No
	Construction Dewatering	No
	Groundwater Dewatering	No
	Mine Dewatering	No
	Other Water Level Maintenance	No
	Pumped Sumps	No
	Quarry Dewatering	No
	Sand/Gravel Pit Dewatering	No
Water Supply	Campground/Wayside/Highway Rest Area Water Supply	No
	Commercial/Institutional Water Supply	Yes
	Fire Protection Water Supply	Yes
	Municipal/Public Water Supply	No
	Other Water Supply	No
	Private Water Supply	No
	Rural Water District Supply	No
(blank) *(No category given)*	Nuclear power plant	Yes
	Other Temporary	No
	(blank) (*No category given*)	No

Table 5. Industrial appropriators in Minnesota by category and whether their appropriation permits are active or inactive.

		Groundwater Locations			Surface Water Locations		
Use Category	**Use Type**	**Active**	**Inactive**	**Pending Review**	**Active**	**Inactive**	**Pending Review**
Heating/Cooling	Commercial/Institutional Building AC	23	76		3		
	District Heating/Cooling	9	5			1	
	Geothermal Groundwater Exchange with Reinjection (HVAC)	2					
	Geothermal Systems (HVAC)	2	4		3	1	
	Once-through Systems (HVAC)	98	186				
	Other Air Conditioning	2	102		2		
Industrial Processing	Agricultural/Food Processing	222	211		7	17	
	Industrial Process Cooling - Once Through	53	38		4	5	
	Metal Processing	58	49		1	2	
	Mine Processing (excludes sand/gravel)	21	11	16	63	41	13
	Non-metallic Processing (rubber, plastic, glass, concrete)	89	87	1	4	24	1
	Other Industrial Processing	61	509			150	2
	Petroleum-Chemical Processing/Ethanol	87	32		6	3	
	Sand and Gravel Washing	130	74	2	144	163	5
	Wood Products Processing	19	19		9	8	
Power Generation	Hydro Power				1	4	
	Other Power Generation	11	64		4	31	
	Thermoelectric Power Cooling - Once Through	12	11		70	25	
	Thermoelectric Power Cooling - Recirculating	21	14		1	2	
	Thermoelectric Power Generation - Non Cooling	24	7		2	3	
Special Categories	Snow/Ice Making	28	24		19	20	
Water Supply	Commercial/Institutional Water Supply	193	200		5	5	
	Fire Protection Water Supply	21	13			22	
(blank) *(No category given)*	Nuclear power plant	6			2		
Grand Total		**1192**	**1736**	**19**	**350**	**527**	**21**

Figure 2. Locations of permitted industrial appropriators from surface water

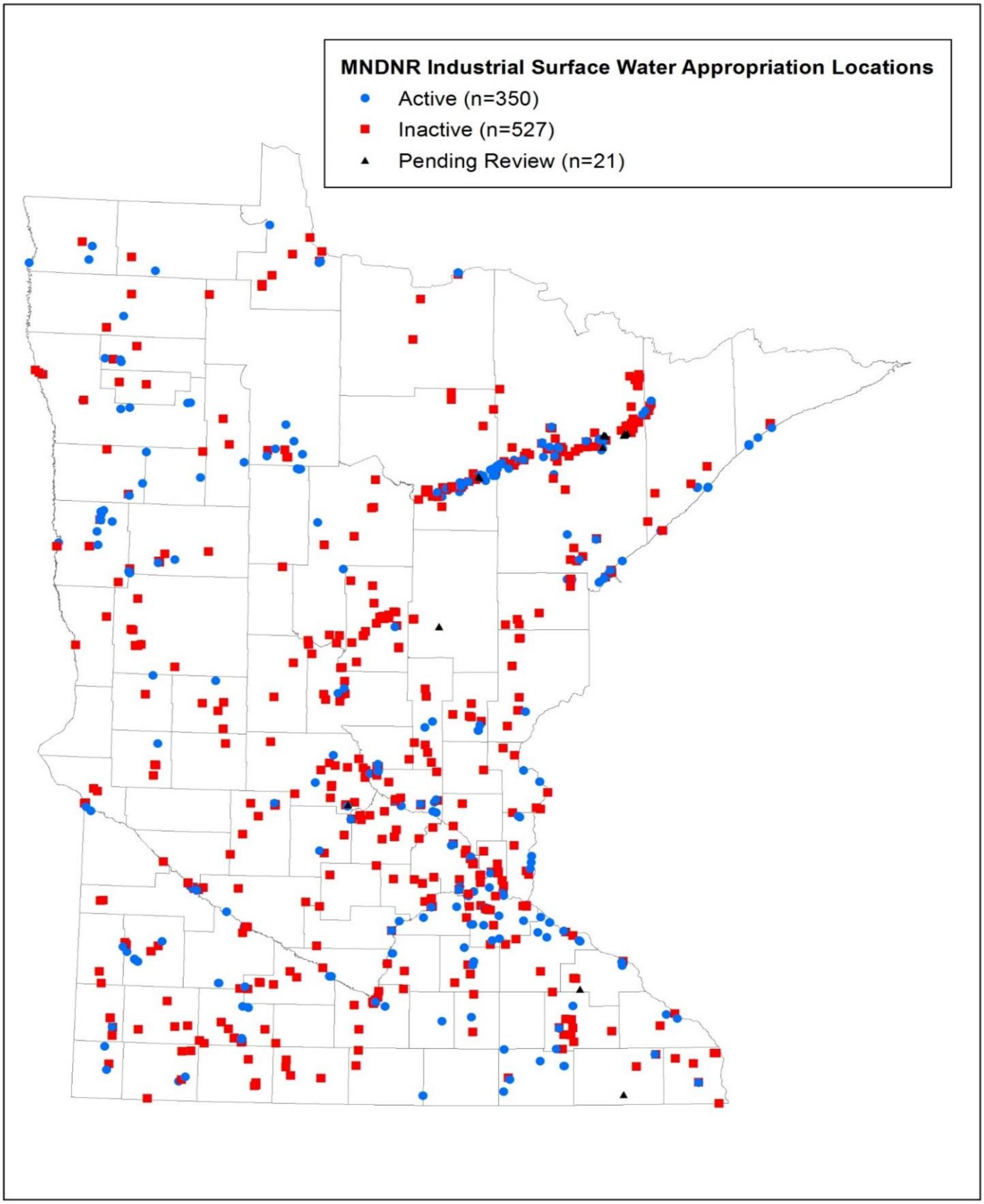
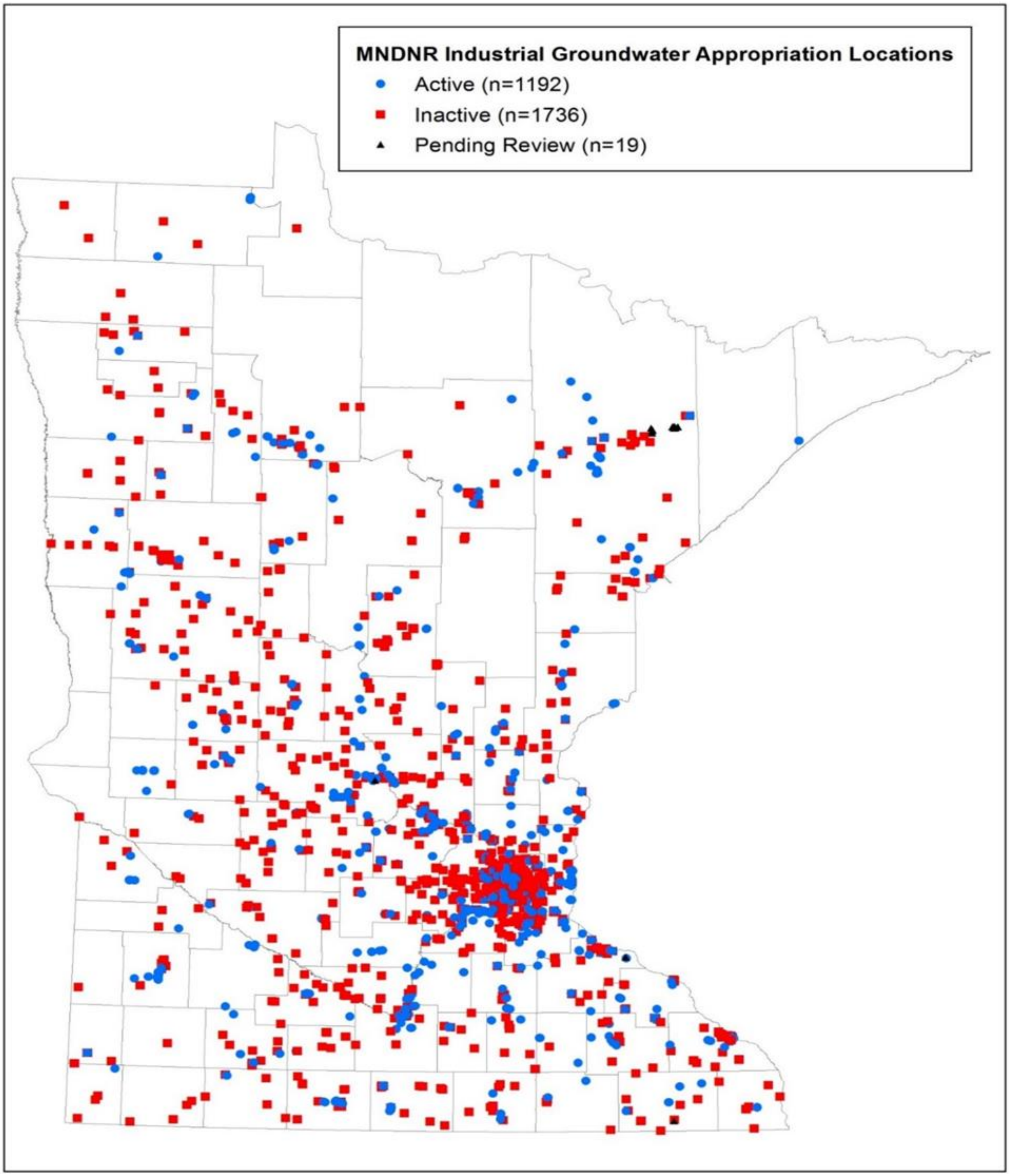


Figure 3. Locations of permitted industrial appropriators from groundwater



Rationale for Draft Changes to Class 3 Standards

Lack of Justification

When revising an existing rule, an important part of a TSD is to evaluate and build upon previous work and findings when considering the technical underpinnings of a potential revised rule. Unfortunately, the documentation supporting the 1967 Class 3 rulemaking is limited. When developing the Class 3 industrial consumption water quality standards, the authors did not document their rationale with the level of rigor that is standard today. This lack of documentation both make it difficult to implement the currently rule, and limits our ability to evaluate the technical knowledge underpinning the choices made when the rule was originally promulgated.

There is no written justification for the three numeric criteria for chloride in the 3A to 3C subclasses. It seems likely that these numbers were taken from reference texts at the time. Rulemaking hearing testimony by state engineer George Koonce in 1966 mentions that specific industries need chloride less than 100 mg/L, chloride in excess of 100 mg/L can make the water taste salty, chloride in excess of 60 mg/L affects the brewing of beer, and chloride in excess of 3 mg/L increases the corrosion rate of steel. No references to where these numbers come from are provided, and it is unclear how Koonce prioritized one of these numbers over another. It is difficult to read back through the limited rulemaking documents and make any definitive statement about the rationale behind selecting any specific Class 3 numeric chloride standard.

Existing and Natural Water Quality

It is unlikely that the rulemakers of the 1960s compared the Class 3 numeric criteria to measured surface or groundwater quality across the state. If they did, they certainly were not able to do so using the amount of data currently available to the MPCA. The 1966 testimony below is an indicator that that the original writers of the rule did not consider existing or natural water quality when assigning these standards.

Testimony from February 16, 1966 hearing in regards to the adoption of WPC-15

Paul Bolton, Consulting Engineer for Grand Rapids, Omaha, Nebraska
Stated that the standards may prohibit discharge of some groundwaters to surface water courses.

MPCA response

This is possible in a few cases because of very poor natural water quality of the groundwater, but can be avoided in adoption of specific standards either by exclusion or by variance.

Paul Bolton's statement is, with respect to the water quality parameter hardness, correct in many locations in Minnesota. The MPCA's response to his statement shows that the MPCA had limited information to understand existing or natural water quality with respect to hardness in Minnesota.

Since the 1960s, the MPCA and other organizations have collected well over 1,000,000 surface and groundwater samples across the state and stored those values in digital databases. Using these digital databases, detailed maps showing water quality that would have taken weeks in the 1960s can be created in a matter of hours. Figures 4 and 5 show the hardness concentrations in Minnesota groundwater and surface waters, respectively.

Figure 4. Groundwater hardness concentrations in Minnesota. Data is from the MPCA groundwater database and is for the uppermost groundwater aquifer. This map is suggestive of the concentration in a given location.

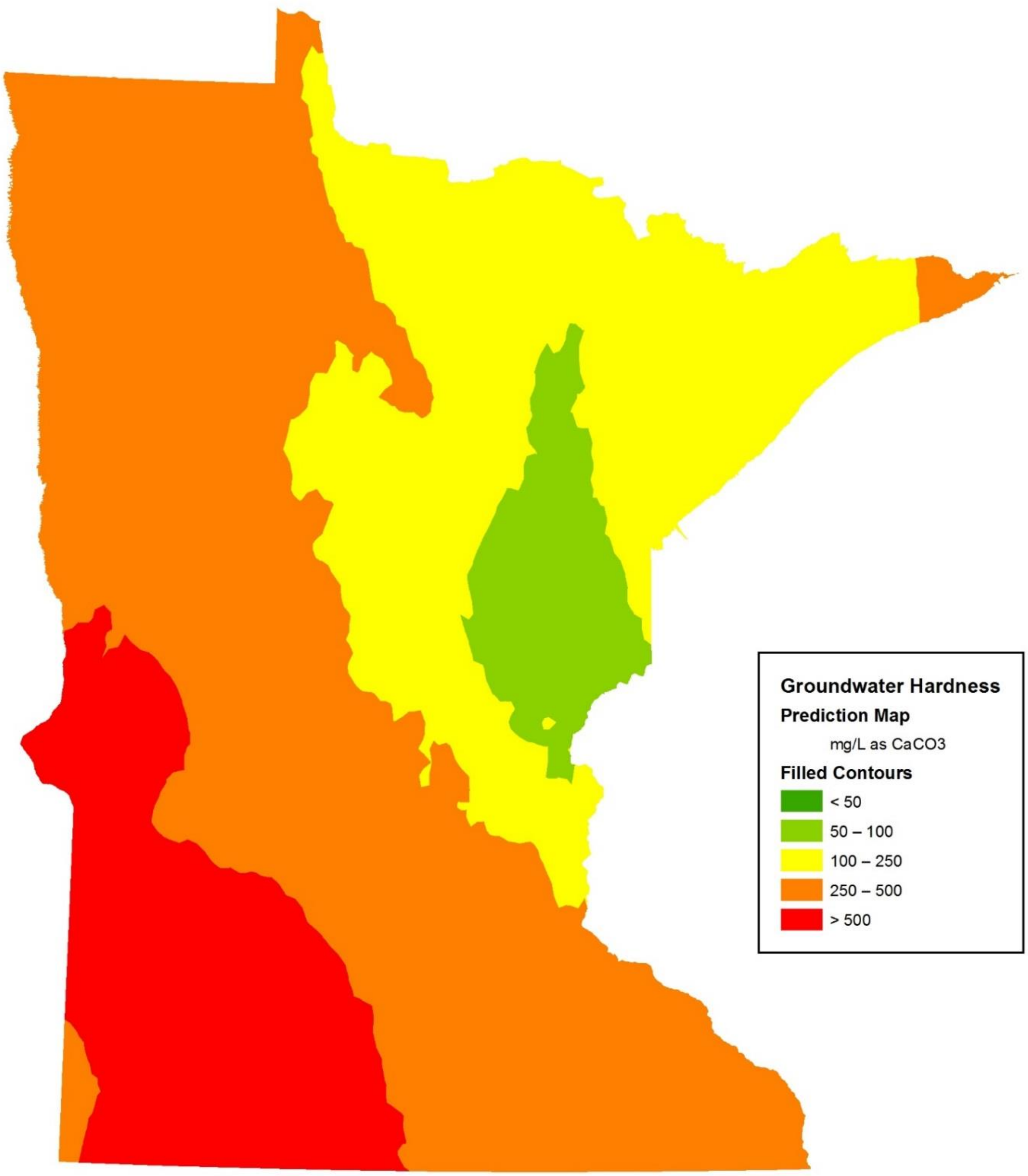
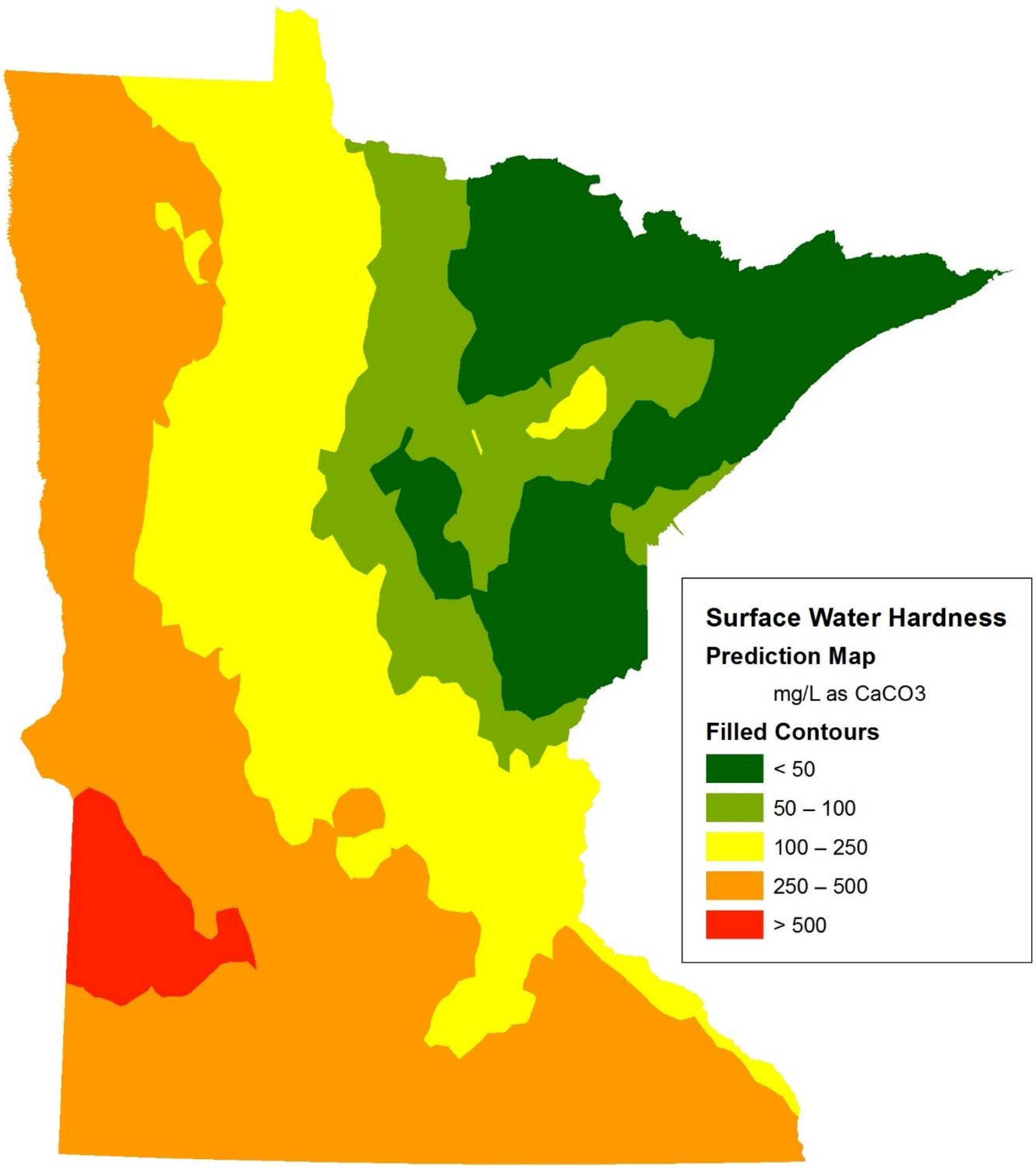


Figure 5. Surface water hardness concentrations in Minnesota. Data is from the MPCA surface water database. This map is suggestive of the concentration in a given location.



Large portions of Minnesota naturally have groundwater and surface water hardness greater than the Class 3B and 3C hardness water quality standards of 250 and 500 mg/L (Figures 4 and 5). In these parts of the state, if municipalities pump the naturally hard water out of the ground for drinking water and discharge it to surface water this could cause a violation of the 250 or 500 mg/L Class 3B or 3C water quality standards in the receiving water (assuming no assimilative capacity for dilution) because municipal wastewater treatment plants are not designed to treat hardness. Additionally, many surface waters of the state have hardness naturally higher than the Class 3B 250 mg/L hardness criteria (Figure 5), and some exceed the Class 3C 500 mg/L hardness standard. These waters could be in violation of the Class 3 standard without any wastewater input. *Minn. R.* 7050.0170 notes that " The waters of the state may, in a natural condition, have water quality characteristics or chemical concentrations approaching or exceeding the water quality standards" and states that "[w]here background levels exceed applicable standards, the background levels may be used as the standards for controlling the addition of the same pollutants from point or nonpoint source discharges in place of the standards." This clearly demonstrates that the MPCA has never intended that water quality standards would lead to the absurd result of requiring pollutants in water to be removed to levels below that which occurs naturally.

In summary, natural concentrations of hardness in many parts of Minnesota can exceed the Class 3 standards for hardness. Dischargers should not be obligated to treat water to levels below natural background, and this was not considered in the rulemaking in the 1960s. Natural background should be considered when developing the updated standards for industrial consumption and their implementation; it is taken into consideration in the numeric interpretation of the narrative standard process that is described in detail in a later section of this document.

Applicability to All Waters of the State

Currently, all waters of the state (except wetlands) are designated as either a Class 3A/3C, 3B/3C, or 3C water. Wetlands are currently designated as Class 3D, but as discussed in the wetland section below, the MPCA is proposing to remove the 3D use class, and instead designate all wetlands as waters in the general Class 3 designated use class.

MPCA currently plans that every water of the state would remain designated for industrial consumption use, but would be classified under a single industrial consumption use class. In 2010, the MPCA envisioned limiting where Class 3 designations would apply to only surface waters subject to the MNDNR water appropriations permitting program for specific industrial consumption uses. After some consideration, the MPCA now contends that the Class 3 standards should remain on all waters of the state, including wetlands. Restricting the designated use to a limited number of waters would not protect the waters for potential future industrial users, and has more procedural complications than maintaining the designation for all waters of the state. Removing the industrial use from all waters of the state without a MNDNR appropriation permit, including any past permits that are currently inactive, would require a huge amount of effort in terms of MPCA staff resources. There are also potential data limitations.

To remove a designated use from a water body, federal regulations (40 CFR § 131.10(h)) require that the state demonstrate that the use to be removed is not an existing use or an attainable use. An existing use is defined as a use attained any time since November 28, 1975. An attainable use is defined as a use that can be achieved when technology based standards are imposed on point source dischargers (through sections 301(b)(1)(A and B) and 306 of the CWA) and when cost-effective and reasonable best management practices are imposed on nonpoint source dischargers. Additionally, 40 CFR § 131.10(g) provides additional scenarios that may indicate that the use is not attainable, such as low flows or other natural conditions that prevent the water from attaining a use. Any demonstration for the removal of an irrigation use would need to take the form as a use and value demonstration (UVD) or use attainability analysis (UAA) (40 CFR 131.10(k)) and require rulemaking.

If the MPCA decided to only apply Class 3 standards to those surface waters with MNDNR appropriations for industrial use, the MPCA would have to remove the industrial use from all other surface waters of the state, via a UVD or UAA through rulemaking. The amount of work required to demonstrate that the industrial use is not existing or attainable on each of the state's more than

100,000 water bodies would be prohibitive. Each water body would need to be assessed as to whether the use had existed since November 28, 1975. One way the existing use could be determined would be to evaluate whether the water meets or has met the applicable standards, requiring an evaluation of water quality monitoring data all the way back to 1975. Other factors included in 40 CFR § 131.10(g) could also be considered for each water body, but the data for flow rates, natural background, costs to upstream dischargers, etc. would need to be evaluated on a case-by-case basis. For one water body, an evaluation of all water quality data, uses of the water, and assessment of additional factors could be reasonably completed, but to complete this for the majority of Minnesota's more than 100,000 water bodies, would take years and significant public resources. The more appropriate approach to this is to maintain the industrial use designation on all waters, and conduct a UVD or UAA for individual water bodies where it can be clearly demonstrated that the use is not existing or attainable. *Minn. R.* 7050.0405 allows outside parties to petition the MPCA to consider use change for a specific water body.

Industrial Appropriators Treat Water to Meet Their Quality Needs

Industrial water appropriators have a wide range of water quality needs based on their specific industrial process requirements. The types of water quality parameters industrial water appropriators are concerned with varies widely from dissolved salts to pathogens to invasive species to contaminants of emerging concern. The examples below are intended to convey the complexity of the variety of water quality needs across the wide range of industrial water appropriators in Minnesota. These examples illustrate that developing a singular or even a short list of numeric standards protective of all industrial consumption water quality is not possible given the wide range of water quality needs of Minnesota's industries. A singular, numeric industrial-consumption water quality standard for a given parameter would always be unnecessarily restrictive for some industrial consumers and not restrictive enough for the rest.

A given appropriator might even have different water quality needs for various water uses within an individual industrial facility. For example:

- An industrial power plant water appropriator needs to process waters of several different hardness quality levels in order for its power plant to produce electrical power. A typical steam/electric power plant can use untreated surface water for once-through cooling towers but also requires highly purified water for high-pressure boilers. For example, a once-through cooling tower can operate with hardness values at ambient surface water values (100 – 500 mg/L as $CaCO_3$), but a high-pressure boiler can only function with water treated to remove hardness to 0 mg/L. All Minnesota stream/electric power plants operate water treatment systems to treat their boiler water to their specific water quality needs and do not treat hardness in their once-through cooling tower water.
- An ethanol plant water appropriator needs waters of several different quality levels in order to produce ethanol. A typical ethanol facility uses half of its water supply for recirculating non-contact cooling water. The remainder is evenly split between boiler water and water used for processes. A typical ethanol facility would also need tap water suitable for hand washing and human consumption. These four types of water usage (recirculating cooling, boiler, process, and tap) require different degrees of water quality and thus different degrees of water treatment. The type of treatment required for some of these water qualities is well defined. For example, high-pressure boiler water always requires treatment systems capable of treating hardness to 0 mg/L. In contrast, recirculating cooling tower water is rarely treated for hardness using chemical water treatment processes. Rather than removing specific chemicals, the chemistry of recirculating cooling tower water is controlled by chemical additives and managing water evaporation.

- A taconite mining water appropriator also needs waters of several different qualities in order to operate successfully. A taconite mine needs water of one quality to maintain water levels in the tailings basin, a different quality for mineral processing facilities, and a third, very high quality of water for high-pressure boilers. Like the power plant and ethanol industries mentioned above, taconite mining facilities need varied water qualities and operate treatment systems to meet their specific water quality needs.

As can be seen from the three examples above, industrial water appropriators frequently have a wide range of water treatment needs and consequently must use a wide variety of technologies to meet their specific water quality requirements. The variety of water treatment needs across the range of industrial appropriators in Minnesota is so varied that it is impossible to specify a single numeric value that would appropriately protect for all industrial appropriation uses.

A survey conducted in 2015 gauged the importance of the Class 3 water quality standards to industrial appropriators. Using the MNDNR surface water appropriators database, the MPCA identified 45 industrial appropriators (excluding aquaculture appropriators). Aquaculture facilities were excluded because *Minn. Stat.* 17.491 states that “aquaculture is an agricultural pursuit,” and therefore aquaculture facilities should not be considered industrial appropriators. The MPCA sent the survey by e-mail to these 45 industrial appropriators, and 18 surveys were returned completed (Table 6).

Table 6. The 18 returned surveys were from 11 industrial appropriators across a wide range of MNDNR appropriator categories.

Category	Surveys Received
Commercial/Institutional Building air conditioning	1
Metal Processing	1
Ski Resort	1
Agricultural/Food Processing	1
Commercial/Institutional Building air conditioning	1
Industrial Process Cooling - Once Through	3
Metal Processing	1
Mine Processing (excludes sand/gravel)	3
Steam Power Generation - Cooling, Once Through	4
Wood Products Processing	1
Agricultural/Food Processing	1

Industrial appropriators in the survey generally commented that the consistency of the quantity and quality of the water was most important to their water appropriation needs. None of the surveyed appropriators ranked consistent quantity as less important than a 5 on a 1–10 scale where 10 is “extremely important,” and 10 of the 18 appropriators ranked water quality consistency as extremely important. Consistent quality of water was rated as being of moderate importance to most appropriators but was ranked as being less important than consistent quantity of water by 17 of the 18 industrial appropriators surveyed.

No surveyed industrial appropriator considered any Class 3 chloride or hardness criteria to be of essential importance for their industrial appropriation needs. Three appropriators considered the Class 3 pH standards to be of essential importance. Those three appropriators operate water treatment technologies (lime softening, coagulation and flocculation, and chlorine disinfection) where having water with a known and consistent pH is important for effective treatment operation.

It is unclear from the survey whether the specific pH standards were considered important or whether the need was to have a consistent pH. The only facility that considered the pH criteria to be of essential importance also has a pH 8.5 effluent restriction based on the Class 3A pH standard that has required them to purchase and install pH control technologies in their discharge. This water appropriator reported no concerns with the pH of the surface water they appropriate.

There is no record in the MPCA's or MNDNR's history of an industrial appropriator submitting a notification to either the MPCA or MNDNR expressing concern with the quality of their appropriation water with respect to chloride, hardness, pH, or any other parameter. This is a strong indicator that industrial appropriators are able to design treatment systems to meet their water quality needs, and that the Class 3 water quality standards regarding pH, chloride, and hardness are not essential to the operation of the industrial appropriators.

Current Numeric Standards Are Based on Outdated Industrial Water Treatment Technologies

Many of the water treatment technologies available when the industrial consumption standards were originally created in 1967 are still widely used today. Fundamental wastewater technologies such as coagulation, flocculation, media filtration, ion exchange, and lime softening are still used by industrial water appropriators in Minnesota. However, many of these treatment technologies have been substantially improved since 1967, and many new water treatment technologies are available.

For example, in the 1960s, water treatment engineers used distillation to produce high-purity water devoid of chloride and hardness for use in high-pressure boilers. Distillation is a very expensive, energy-intensive treatment process and by all accounts was difficult to operate and maintain. No Minnesota industrial appropriator uses distillation anymore to produce high-purity water. Instead industrial appropriators use membrane treatment such as reverse osmosis or ultrafiltration. In 1960, membrane treatment was a technology that only existed at the bench scale in advanced academic research laboratories. Since the 1960s, membrane treatment research and design has become one of the most important fields within water treatment, and the technology has become widely available at a commercial scale. Modern industrial appropriators use membrane filtration to produce high-purity water because it is more effective, less energy intensive, and substantially easier to operate than any other treatment system.

Another example of treatment technology that has been substantially improved over time is cooling tower design. In the 1960s, the material science of corrosion control was still in its relative infancy, and compared to today, relatively little thought was given to the types of materials used in cooling tower construction. Today, cooling towers are built out of alloys developed using advanced material science to minimize corrosion and increase design life. Additionally, modern cooling tower engineers have developed advanced protocols using site-specific engineering and advanced water chemistry manipulation to minimize scaling and corrosion. A modern cooling tower is not only more energy efficient, it is also more resistant to corrosion than the cooling towers of the 1960s.

In summary, then, the Class 3 pH, hardness, and chloride water quality standards are based on outdated assumptions about what water quality industrial appropriators require and are capable of treating for. Since industrial appropriators are more capable of treating their water than ever before, they do not need the specific chloride, hardness, and pH water quality standards currently in rule. Industrial appropriators design treatment for the water quality they have, and consistency is the most important factor of water quality.

Implementation of Narrative Standard in NDPES Permits Using a Narrative Translator Process

Although separate from designing numeric or narrative water quality standards, it is important to understand how water quality standards are implemented. That is perhaps particularly important when dealing with narrative standards. Federal regulations at 40 CFR § 122.44(d)(1)(i) require that NPDES wastewater permits contain effluent limitations that ensure that pollutants do not have the reasonable potential to cause or contribute to the exceedance of a state numeric or narrative water quality standard (RP). If the permitting agency finds that a wastewater discharger has reasonable potential (RP) for a given water quality standard in a receiving water, then the agency must include an effluent limitation in the wastewater discharge permit that is protective of that water quality standard. The process used to determine whether a wastewater discharger has the reasonable potential to cause or contribute to a water quality standard is referred to in shorthand as "the RP process."

The RP process for numeric water quality standards is specific to a given parameter and is performed for all parameters of concern during the issuance of wastewater permit. The RP process uses a complex numeric formula that requires knowing the measured effluent concentrations, the assimilative capacity of the receiving water to receive pollution from the discharger, the magnitude, duration and frequency of the water quality standard in question, and statistical factors to ensure a protective margin of safety. The RP process for numeric water quality standards always produces a binary answer of either "yes" or "no." An answer of "yes" indicates that the wastewater discharger in question has RP for the parameter of concern and that an effluent limit for that parameter must be included in the permit. An answer of "no" indicates that the wastewater discharger in question does not have RP for the parameter of concern and that an effluent limit for that parameter is not necessary in the permit.

Narrative water quality standards are qualitative descriptions of the conditions that are protective of the designated use, and do not contain numeric values. There is no generally established method to calculate RP or develop an effluent limit for a narrative standard. This is because the RP process requires knowing numeric values that are protective of the designated use to precisely and numerically determine the RP status for the discharger (either yes or no). Because narrative standards do not include numeric values to use to determine if a facility has RP, a "narrative translator" process is needed.

This narrative translator is a process that translates a narrative water quality standard into a numeric expression of the narrative standard applicable within the NPDES permit. The numeric expression of the narrative water quality standard is a value that is protective of the designated use, and can then be used to numerically assess RP and ensure the wastewater discharger is meeting the narrative water quality standard. If the discharger has RP, the numeric expression of the narrative standard is also used to set an effluent limit protective of the designated use. In short, to assess RP for narrative standards, a process to develop a numeric expression of the narrative standard is required. After the narrative translator process generates a numeric translation of the narrative water quality standard, RP can be assessed and an effluent limit calculated, if necessary.

Neither the CWA nor Minnesota rules have any defined process for how to translate a narrative standard into numeric values. For a given NPDES wastewater discharger, the narrative translator process takes place within a wastewater permit and is subject to public comment during the issuance of the wastewater permit.

The MPCA has an established narrative translator process for only one parameter, whole effluent toxicity (WET). WET testing measures the aggregate toxic effect to aquatic organisms from all pollutants in a wastewater effluent. WET tests measure wastewater's effects on specific test organisms' ability to survive, grow and reproduce. WET testing is one way to implement the CWA's prohibition of the wastewater discharge of toxic pollutants and to ensure protection of Minnesota's Class 2 (aquatic life and recreation) designated-use general narrative standard. The MPCA's WET narrative translator process converts the results of wastewater effluent WET testing into a numeric value, measured in toxic units. Then the RP calculation ensures that wastewater dischargers do not cause or contribute to an exceedance of one toxic unit at any time in waters of the state. Any value above one toxic unit caused by a wastewater discharger is considered an exceedance of the narrative water quality standard for general toxicity to aquatic life and requires the wastewater discharger to receive an effluent limit protective of WET.

To develop a numeric interpretation of the Class 3 narrative water quality standard, instead of testing aquatic organisms, a process to evaluate whether the industrial consumption designated use is being met needs to be conducted. The MPCA is considering multiple options for how and when to develop the process for determining the numeric expression of the Class 3 narrative standard. These options are presented below, and MPCA requests comments on the preferred option to move forward with during rulemaking.

Options for Developing the Numeric Interpretation of the Narrative Standard

Two options for ensuring protection of the draft Class 3 narrative standard through numeric interpretations of the narrative standard in NPDES permits are explained below.

1. Option 1: MPCA, through this rulemaking, develops a process to translate the narrative standard into a numeric value, and this process is incorporated into rule. This translation process could be either placed into rule directly or incorporated by reference through a document that either can or cannot be revised without further rulemaking.
2. Option 2: MPCA finalizes the changes to the standards but delays developing the process to translate the narrative standard into a numeric value. Instead, after the rulemaking, the MPCA works collaboratively with stakeholders and other to develop the process and publish a guidance document.

The two options are mutually exclusive, but MPCA believes there are good arguments and justifications for both. We ask that reviewers and commenters consider the details of both options below and provide comments as to which option you prefer. If neither option is acceptable, please provide comments on how the option could be improved or other potential paths for implementation. Regardless of which option you prefer, please also provide any comments on the details of the potential process laid out in option 1.

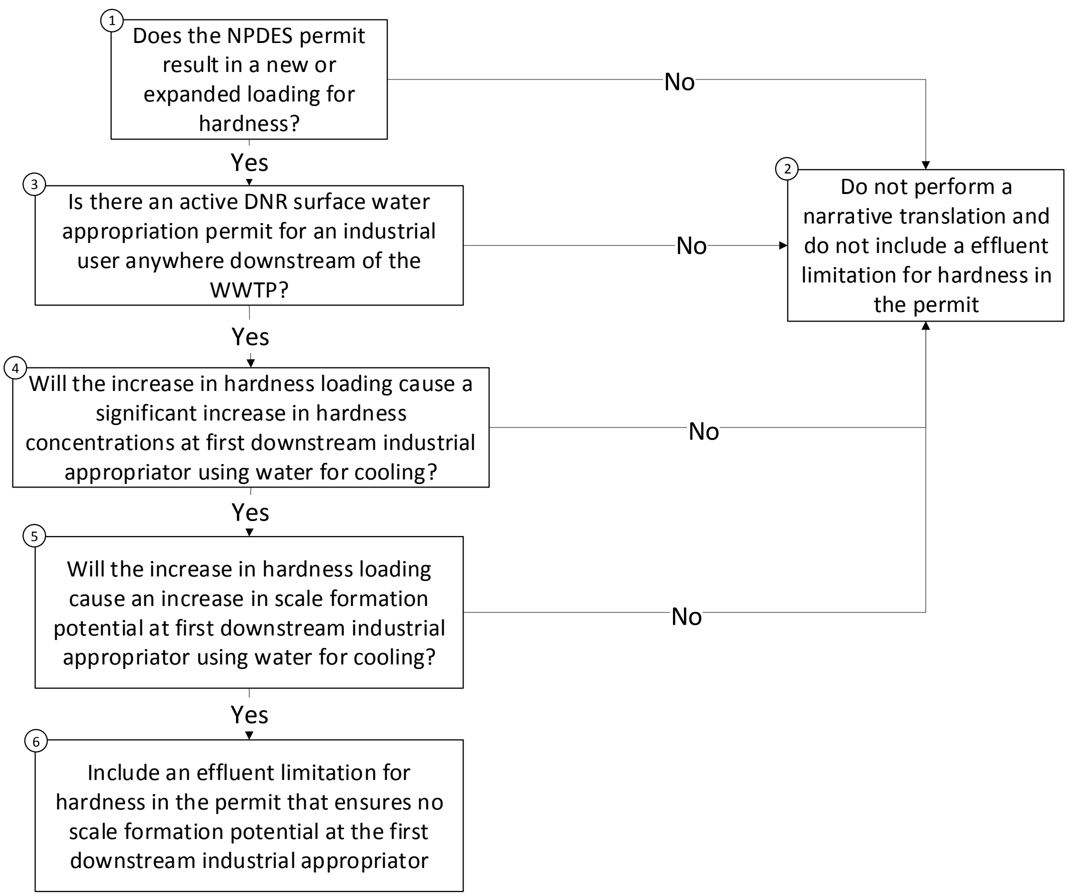
MPCA also notes here that the need to develop a process to set numeric effluent limits based on a narrative standard is relatively specific to the MPCA's plan to establish narrative standards for Class 3. MPCA is also required to issue permits that protect downstream waters, including those of other states or tribes. If a downstream state or tribe has a numeric water quality standard, that must also be evaluated.

Option 1: Develop the narrative translator process described below in this rulemaking

Figure 6 describes a narrative translation process that protects industrial consumers of water for use in cooling towers using a numeric translation of a general industrial consumption narrative standard. The flowchart describes a narrative translator process that includes an evaluation of the need for an effluent limit. The flowchart ends up in one of two options: include or do not include an effluent limitation for hardness in the NPDES permit that is protective of industrial consumption for cooling tower water.

The narrative translator process ensures that water appropriated for use in industrial cooling structures does not have excess calcium hardness that could cause unwanted scaling in industrial cooling structures. Hardness is a measurement of the sum of calcium and magnesium molecules in water; calcium hardness is the fraction of total hardness attributable to calcium alone. In wastewater dischargers, calcium and magnesium chemistry are linked together. For Minnesota wastewater dischargers, if calcium is high then magnesium is also high and if calcium is low then magnesium is also low. Therefore, if calcium hardness is controlled by the narrative translator process then magnesium hardness should be controlled as well. The rationale for protecting industrial cooling structures from calcium hardness scaling is further explained below.

Figure 6. Flowchart explaining the draft industrial consumption narrative translator process



Box 1: Does the NPDES permit result in a new or expanded loading for hardness?

If the NPDES permit is new or the NPDES wastewater treatment plant (WWTP) will be expanding loading of hardness, then the need for a narrative translator should be evaluated.

Expanded loading would be defined as an increase mass loading of hardness. Determining whether there would be an increase in loading would require effluent monitoring for hardness to appropriately establish a numeric baseline of existing hardness loading. A significant increase above the existing baseline would be considered an increase in loading. Existing hardness loading would be defined by multiplying the highest hardness data point recorded at the station by the average wet weather design flow (municipals) or the maximum design flow (industrials). Expanding loading would typically be associated with the permittee increasing permitted design flow rates for the facility and going through an antidegradation review.

Rationale for only including hardness as the only parameter to be concerned about in the narrative translator process:

1. It is unwieldy to develop a narrative translator process that addresses every possible pollutant of concern in a NPDES discharge that could conceivably affect the wide range of downstream industrial appropriators.
2. The current Class 3 standards only have numeric protections for hardness, chloride, and pH. Since these are the only three parameters with numeric standards, and therefore historically the parameters of most concern, these parameters warrant consideration during the narrative translator process. The MPCA requests comments on whether other parameters should be considered.
3. Wastewater chloride discharges are regulated through NPDES permitting and permit limits to ensure protection of the 230 mg/L chloride aquatic life and recreation water quality standard. The MPCA has developed a NPDES chloride permitting strategy to help facilities comply with chloride permit limits and minimize their chloride discharge. This chloride permitting strategy ensures that chloride cannot be discharged by NPDES permittees at unbounded levels that could cause negative effects for industrial water appropriators.
4. Every NPDES wastewater discharger is required to discharge pH between 6 and 9 under the state discharge restrictions in *Minn. R.* 7053.0215. This range is similar to the current Class 3 pH standards and will ensure that neutral pHs are present in waters of the state that would be generally suitable for industrial consumption and protect aquatic life.
5. Hardness is not regulated by a numeric standard in any other designated use. Therefore, a numeric translator of the narrative standard that protects industrial consumers from the potential for excess hardness in their water appropriation is needed for NPDES discharges.

Rationale for only being concerned about new or expanded loadings:

1. Industrial surface water appropriators have indicated through a survey that consistent water quality is their primary concern.
2. A review of the consistency of hardness effluent quality from over 100 industrial and municipal NPDES discharges demonstrates that more than 99% of dischargers have consistent hardness water quality as defined by having the coefficient of variation less than 0.6. The coefficient of variation is the standard statistical measure of discharge variability in NPDES permitting; a value less than 0.6 is considered to be of low variability. As a result of this analysis, the measured variability of hardness water quality for Minnesota NPDES dischargers is consistent.

3. Industrial appropriators have already adapted their water treatment processes to account for the consistent hardness discharged from existing NPDES dischargers upstream of their surface water intake structures.
4. Only an increase in hardness loading from a NPDES discharge upstream of an industrial appropriator would have the potential to cause a substantial change in water quality at the intake structures of industrial appropriators.

Rationale for only being concerned about cooling towers:

1. Cooling towers are the dominant water appropriator category by water volume in Minnesota.
2. Cooling towers frequently employ evaporative technologies that concentrate minerals when mineral-free water evaporates away. This causes cooling towers to have higher scale potential as salt concentration accumulates.

Box 2: Do not perform a narrative translation

This step indicates that performing a narrative translation of a narrative industrial consumption standard is not needed for the NPDES permit issuance or re-issuance. No effluent limitation would be included in the permit for hardness and monitoring for hardness would be continued in the NPDES permit.

Box 3: Is there an active DNR surface water appropriation permit for an industrial user anywhere downstream of the WWTP?

Rationale:

1. The narrative translator process, to determine if effluent limits are needed, should only be applicable to active industrial appropriators.
2. The narrative translator process should only be concerned about industrial surface water appropriators. NPDES discharges to surface water are only likely to affect industrial appropriators that pull from surface water.
3. The narrative translator process should only target industrial users because they are the only surface water appropriators that need industrial water quality protections.

Box 4: Will the increase in hardness loading cause a significant increase in hardness concentrations at the first downstream industrial appropriator appropriating water for cooling?

Rationale for only being concerned with hardness at the first downstream industrial appropriator using surface water for cooling:

1. Protecting the first downstream industrial water appropriator using water for cooling from excess hardness through the narrative translator process should protect all downstream cooling water appropriators. This is because as you go further downstream, river flow increases which further dilutes the effects of the increase in calcium loading from the upstream NPDES discharger being evaluated through the narrative translator process.
2. Excess calcium hardness could increase carbonate scaling that could impact industrial cooling structure efficiencies by reducing heat transfer efficiency among other negative outcomes.
3. Water used for cooling structures is not typically treated to remove calcium hardness, and the standards should ensure appropriators only need to implement standard types of treatment.

4. The MNDNR water appropriation database allows the MPCA to identify industrial surface water appropriators who use their water for cooling.
5. The calculation for assessing calcium scale formation potential is complex and data intensive. It is simpler to first determine whether a significant increase in hardness would occur at the first downstream industrial water appropriator. Only if a significant increase in hardness is found would the need for performing the more complex scale formation calculation be needed.

Rationale for being concerned about a significant increase in hardness:

1. An effluent hardness limitation should only be put in the permit if there is an assessment that there will be a significant increase in hardness concentrations and at the first downstream industrial appropriator appropriating water for cooling.
2. Significant increase would be measured by evaluating the projected magnitude increase of change in hardness concentrations at the industrial appropriator intake structure and comparing that magnitude to existing measured natural variability. If the magnitude of change is greater than the measured natural variability, then there would be a measureable and significant increase in hardness water quality for the purposes of the narrative translator process.
3. Using the 90% exceedance flow rates (Q_{10}) is the appropriate flow when performing the calculation of measurable hardness increase. This is because industrial appropriators cannot appropriate surface water when rivers are below the Q_{10} flow rate under the terms of their MNDNR water appropriation permits.
4. Using the average dry weather design flow for municipalities is the appropriate discharge flow for municipalities in the calculation. This is because the Q_{10} is a low-flow stream condition, and it is unlikely that wastewater facilities would be discharging at their higher wet weather design flow. The maximum design flow is the appropriate discharge for industrial dischargers in the mass balance calculation since industrial wastewater flow rates are not typically associated with weather conditions.
5. If the increase in hardness concentration is the result of the new or expanded discharger upstream of the industrial appropriator and is within the normal variability of the measure water quality, then there should not be a limit included in the new or expanded permit. This is because the industrial appropriator is not going to have to change treatment processes significantly to treat the increase in hardness loading.

Box 5: Will the increase in hardness loading cause a significant increase in scale formation potential at the first downstream industrial appropriator using surface water for cooling?

Limitations on scale forming potential will be implemented by using the calcium carbonate precipitative index as the numeric parameter that quantifies scale formation potential.

Rationale for using the calcium carbonate precipitation index as the indicator of scale formation:

1. The primary way excess hardness could impact an industrial appropriator is through increasing the potential for calcium carbonate scale formation. Excess calcium carbonate scaling could potentially impact industrial cooling structures by reducing heat transfer potential.
2. Magnesium salts are more soluble than calcium salts. Therefore addressing the least soluble calcium salt (calcium carbonate) is protective of both excess calcium and magnesium hardness.
3. The calcium carbonate precipitation index is the most accepted way to measure the calcium scale formation potential of water.

4. An effluent limitation for calcium would only be needed if the calcium carbonate precipitation indicated that scale would form as indicated by a positive calcium carbonate precipitation index.
5. Calculating the calcium carbonate precipitation index requires using the water quality modeling program such as PHREEQC or one of the accepted ways in the AWWA journal in the citations.

Rationale for only being concerned with calcium carbonate precipitation index at the first downstream industrial appropriator using surface water for cooling:

1. Protecting the first downstream industrial water appropriator using water for cooling from excess scale through the narrative translator process should protect all downstream cooling water appropriators. This is because as you go further downstream, river flow increases, which further dilutes the effects of the increase in calcium loading from the upstream wastewater discharger being evaluated through the narrative translator process.
2. Hardness is a measurement of the sum of calcium and magnesium molecules dissolved in water. In wastewater dischargers, calcium and magnesium chemistry are linked together. Rarely is calcium very high and magnesium very low or vice versa. Therefore, if calcium is controlled by the narrative translator process then magnesium should be controlled as well.
3. Excess calcium hardness would increase carbonate scaling that could impact industrial cooling structure efficiencies by reducing heat transfer potential, among other negative outcomes.
4. Water used for cooling structures is not typically treated to remove calcium hardness, and the standards should ensure appropriators only need to implement standard types of treatment.
5. Treating cooling tower water to remove calcium hardness would place a financial burden on the industrial consumer of water.
6. The MNDNR water appropriation database allows the MPCA to identify industrial surface water appropriators who use their water for cooling.

Option 1: Sub-option – To include in rule or as guidance

The narrative translator process described above could either be put into rule or included as guidance along with this rulemaking. These two separate options are described below and MPCA asks the reviewer to consider both and choose one.

1. Use translator as described above (or with modifications) and clearly specify IN RULE – either directly or incorporated by reference – how the process would work.
2. Use translator as described above (or with modifications) but include it as guidance.

Including the translator in rule has the advantage of enhanced regulatory certainty compared to the second option. If the process is included in rule, then NPDES permittees can predict with certainty whether they have RP and will receive an effluent limit. Including the process in rule also minimizes MPCA discretion when applying the Class 3 narrative standard. A disadvantage is that it would not allow for regulatory flexibility when considering other translation methods that could also be protective of industrial consumption. This could be mitigated by incorporating the process by reference and allowing the reference document to be changed without requiring rulemaking.

Using guidance to implement the process has the advantage of enhanced regulatory flexibility compared to the first option. If the process is included as guidance associated with the rule, then NPDES permittees can still predict with reasonable certainty whether NPDES permittees have the RP to receive an effluent limit, but there is greater flexibility to modify the translator process to consider other important factors yet to be determined.

Option 2: Do not develop a narrative translator process in this rulemaking

The CWA and Minnesota rules require NPDES wastewater discharge permits to protect for narrative water quality standards. 40 CFR § 122.44(d)(1)(vi)(A) says that states may use an explicit state policy or regulation interpreting its narrative water quality standard when setting limits based on a narrative standard.

In fact, 40 CFR § 131.11(a)(2) provides that when a state adopts narrative criteria for toxic pollutants to protect designated uses, the state must provide information identifying the method by which the state intends to regulate point source discharges of toxic pollutants based on such narrative criteria. A key term in the regulation is "toxic pollutants." Toxic pollutants in the CWA are those listed in 40 CFR § 401.15, and the list does not include the three parameters with numeric standards in the Class 3 standards (pH, chloride, and hardness). Because these three parameters are not listed as toxic pollutants, a narrative translator process is not required in this rulemaking for these three parameters pursuant to 40 CFR § 131.11(a)(2).

After examining federal and state statutes, MPCA has determined it is not necessary, *within this specific rulemaking,* to develop a narrative translator process to ensure that NPDES dischargers are discharging water quality at levels that would protect for industrial consumption. The MPCA must ultimately develop a narrative translator policy, but developing the policy need not occur within the confines of this specific rulemaking. The process or policy could be developed after this rulemaking is complete and could be done as a policy guideline not in rule or referenced in rule.

Developing a Class 3 NPDES narrative translator process within this rulemaking is optional as long as a translator is eventually developed and implemented. There could be advantages to waiting to develop the narrative translator process as guidance outside of this rulemaking. Developing a narrative translator policy outside of this specific rulemaking could allow for greater flexibility to adapt to the complexities and the ever-changing nature of industrial consumption water quality needs. For example, the narrative translator process above only addresses concerns with excess hardness for industrial water quality consumption for cooling uses yet there could be other parameters that are concerning for industrial consumers of water in the future.

Developing a narrative translator policy outside of this rulemaking does have drawbacks, primarily the potential for the NPDES Class 3 narrative translator to be developed, or to be perceived as having been developed, without significant public input. Many wastewater permittees have made clear to the MPCA that they strongly oppose the MPCA developing wastewater permitting policy outside of rulemaking.

Under this option, the MPCA envisions facilitating a Class 3 narrative translator working group outside of this rulemaking. The working group would include NPDES municipal and industrial permit holders upstream of industrial consumers of surface water and by industrial consumers of water themselves as well as representatives of state, local, and other governments – such as the MNDNR and tribal entities – and stakeholders and other affected parties. The working group would be given charge and authority to consider permitting options for the Class 3 narrative NPDES translator and to recommend a Class 3 narrative translator permitting policy the MPCA would abide by in the future.

This working group approach was used successfully in the past to address municipal permit holder concerns regarding high wastewater chloride dischargers and could be a successful model going into the future to ensure that permit holders' concerns are incorporated into the MPCA policy.

Class 4A Water Quality Standards

Minnesota's Existing and Draft Class 4A Water Quality Standards

The current and draft updated Minnesota water quality standards for Class 4A waters are outlined in Table 7. An expanded summary of the changes to be made to Class 4A and their rationale is presented in Table 8.

Table 7. Summary of existing and draft standards for Class 4A.

	Existing Standards[1]	**Draft Standards**
Bicarbonates (HCO_3)	5 milliequivalents per liter	Replace numeric standard with narrative standard
Boron (B)	0.5 mg/L	Replace numeric standard with narrative standard
pH minimum	6.0	Replace numeric standard with narrative standard
pH maximum	8.5	Replace numeric standard with narrative standard
Specific conductance	1,000 micromhos per centimeter at 25°C	Replace numeric standard with narrative standard
Total dissolved salts	700 mg/L	Replace numeric standard with narrative standard
Sodium (Na)	60% of total cations as milliequivalents per liter	Replace numeric standard with narrative standard
Sulfates (SO_4)	10 mg/L, applicable to water used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels.	Not subject to change in this rulemaking
Radioactive Materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.	Not planned for change at this time

[1] *Minn. R.* 7050.0224, subp. 2 states the "standards shall be used as a guide".

Background

The Class 4A introductory rule language in *Minn. R.* 7050.0224, subpart 2 is as follows:

> *Subp. 2.* ***Class 4A waters.*** *The quality of Class 4A waters of the state shall be such as to permit their use for irrigation without significant damage or adverse effects upon any crops or vegetation usually grown in the waters or area, including truck garden crops. The following standards shall be used as a guide in determining the suitability of the waters for such uses, together with the recommendations contained in Handbook 60 published by the Salinity Laboratory of the United States Department of Agriculture, and any revisions, amendments, or supplements to it:*

The Class 4A water use standards are intended to protect the quality of the waters of the state for irrigation purposes.

The Class 4A agricultural water use classification has been a long standing beneficial use in Minnesota's water quality rules dating back to the 1960s; it was first applicable to specific river reaches and their tributaries, and later applicable to all Minnesota intrastate and interstate waters. Due to its state-wide applicability, the Class 4A use class is among the "core" set of water uses (see *Minn. R.* 7050.0410, 7050.0420, and 7050.0430 – note the wetland exclusionary statements in these rules as well as 7050.0425). Aside from: 1) the removal of the bacterial standards in 1973 (total coliform) and 1981 (fecal coliform); 2) the addition of the wild rice sulfate standard and the addition of the word "waters" to the subpart 2 narrative introduction in 1973; and 3) the addition of the wild rice narrative standard in 1998, the Class 4A irrigation-based numeric standards have remained unchanged from the standards that were originally adopted in 1967.

The origin of including agricultural irrigation as a beneficial use in Minnesota water quality standards rule can be traced back to criteria documents sponsored by the California State Water Pollution Control Board (California State Board) during the 1950s and 1960s. The first document, a report adopted by the California State Board in 1952 titled *Water Quality Criteria* (McKee and Edward, 1952), was the work product of the California Institute of Technology in Pasadena, California. The California State Board had contracted with this institution to conduct an:

> "*investigation and critical evaluation of the technical and scientific literature and other documents or sources of water-quality criteria, or requirements, for various beneficial uses of fresh and/or salt water such as domestic water supplies, shellfish, culture, recreation, wildlife propagation, agricultural, and industrial. The investigation was intended to include a survey of all criteria or standards that had been embodied in and applied through ordinances, legislation, and the rules and regulations of governing bodies and water pollution control agencies, with particular emphasis on the sources of such criteria or standards and the original research upon which they are based."*

Chapter 1 introductory statements in this 1952 report go on to say:

> *" … the report has been entitled 'Water Quality Criteria' rather than 'Water Quality Standards.' The word 'standard' applies to any definite rule, principle, or measure established by authority, whereas 'criterion' designates a means by which anything is tried in forming a current judgement respecting it. This report is primarily a compendium of criteria that should be useful, per se, in case-by-case analyses, but it can be used as a guide to any agency that desires to establish standards."*

A supplemental addendum was published in 1954 as an update to the 1952 report. In 1960 the California State Board again contracted with the California Institute of Technology for a revised and updated review and evaluation of the technical and scientific literature pertaining to water quality criteria. The resulting report, titled *Water Quality Criteria, Publication 3-A,* edited by J. E. McKee and H. W. Wolf, California State Water Resources Control Board, Second Edition, 1963 (often referred to simply as "McKee and Wolf") was considered to be a premier criteria document used by many states, including Minnesota, in the development of their water quality standards and use classification rules.

The current 4A numeric water quality standards appear to come from a 1966 memorandum written by Leon Bernstein at the United States Salinity Laboratory in Riverside California. A copy of that letter text is reproduced below and has similar values to those found in McKee and Wolf. What is notable from this letter is the lack of scientific justification or cited references for any of the numbers recommended; it appears that Mr. Bernstein used his best professional judgement in conjunction with irrigation water quality values taken from McKee and Wolf. For example, the entire justification for the bicarbonate standard in Mr. Bernstein's memo is a single ten word sentence. Rulemaking documents from that era provide no further clarification for how these numbers were critically evaluated by Minnesota rule authors.

> **Subject: Water quality standards proposed for irrigation by Water Pollution Control Commission, Minnesota**
>
> To: C.A. Bower, Director, U.S. Salinity Laboratory
>
> Date: February 4, 1966
>
> The water quality standards for agriculture and wildlife, page 10 of the Water Pollution Control Commission of Minnesota report, contain some inconsistencies, some unnecessary or intentional restrictions, and some unrealistic quality standards.
>
> Permissible ranges imply unsuitability of the water on either side of the range. This is certainly not intended for chloride, specific conductance, sodium, and sulfate. Values below the indicated ranges are, in all cases, equal to or better in quality than values within the range. Therefore, permissible limits should be substituted for ranges in these cases.
>
> From the point of view of irrigation water quality, and without considering usage by wildlife or livestock, the following revisions are recommended:
>
> 1. Considering rainfall and the supplemental character of irrigation needs in Minnesota, the higher specific conductance of 1,000 µmho/cm can be set for the class A water, which would be consistent with the total salts content of about 700 mg/L.
>
> 2. Considering rainfall and the mainly supplemental character of irrigation needs in Minnesota, no specific maximum chloride need be set for waters having specific conductance of less than 1 µmho/cm (*later memo corrected this to 1,000 µmho/cm*) therefore containing no more than short 10 meq/L total salts. For irrigation waters, no maximum permissible sulfate level need be set.
>
> 3. With a maximum permissible salt content 10 meq/L, the permissible sodium percentage can be safely set at 60% or even 75%.
>
> 4. A permissible limit of bicarbonate of 5 meq/L is recommended.
>
> 5. The possible occurrence in excess of other trace elements such as heavy metals, lithium, selenium, fluoride, and others, may not be of immediate concern in Minnesota, but provision for future restrictions of such contaminants should be considered.

Permissible levels in irrigation waters for some of these elements have not as yet been firmly established.

7. Class B waters: the pH range should be as for class A; permissible salinity can be set at 1,000 mg/L as proposed.

The permissible limits for class A waters therefore become –

Boron	0.5 mg/L
Specific Conductance	1,000 µmho/cm and total salinity of 700 mg/L
Sodium	60%
Bicarbonate	5 meq/L
Radioactive materials	As stated in the report.

Leon Bernstein, Plant Physiologist

Another important document specific to the Class 4A irrigation use class that was utilized by staff of MPCA's predecessor, the Minnesota Water Pollution Control Commission (MWPCC), in the development of Minnesota's water quality standards and use classification rule was the United States Department of Agriculture's Handbook No. 60, Diagnosis and Improvements of Saline and Alkali Soils, United States Salinity Laboratory Staff, edited by L. A. Richards, Riverside, California, issued February 1954 (Handbook 60). This handbook was specifically referenced by McKee and Wolf under the section discussing Agricultural Water Supply (Irrigation). Handbook 60 was also ultimately incorporated by reference in the narrative portion of Minnesota's Class 4A use classification. No guidance was provided in the rulemaking as to how to use or interpret Handbook 60 when assessing irrigation water quality.

Current Status: Guide vs Standard and Implementation

The current Class 4A narrative rule language is unique among the water use classifications included in *Minn. R.* ch. 7050. The Class 4A standard includes a sentence stating that "*The following standards shall be used as a guide in determining the suitability of the waters for such uses, together with the recommendations contained in Handbook 60 published by the Salinity Laboratory of the United States Department of Agriculture, and any revisions, amendments, or supplements to it: …"*. Two key phrases in this sentence "used as a guide" and "recommendations contained in Handbook 60" are important to the discussions concerning the Class 4A amendments.

In Minnesota, due to limited written documentation from the 1967 rulemaking proceedings, the original intent to include the phrase "used as a guide" in the Class 4A narrative standards is obscure. The MPCA suspects that this phrase was included in this section of the rule to either: 1) imply that the numerical and narrative listings under Class 4A are to be treated as guidance numbers, with somewhat diminished regulatory standing; or 2) was included to direct the reader to use the Class 4A listed numbers and narrative language in comparison with the analytical results of a given water source in order to conclude whether the water would or would not be suitable for irrigation purposes.

Under the first alternative, it would be reasonable to assume that the intent was that they should <u>not</u> be interpreted as definitive standards, because the use of the word *guide* is unique in the context of numeric water quality standards, and is in contrast to the use of the words *shall not be exceeded* associated with Class 4B standards. In the second alternative, much less emphasis is placed on the term “guide” and a literal read of the Class 4A introductory paragraph would establish that the listed numeric and narrative standards are established water quality standards against which a comparison can be made to judge a particular water as being suitable for irrigation. From the discussions presented in both McKee and Wolf and Handbook 60 on irrigation water quality, one can argue that the listed agricultural use criteria values were presented assuming there would be flexibility in their application. These documents make several statements such as: “*Owing to the many variable factors, no rigid limits of salinity can be set for irrigation waters*”; and “*Because of all the variables involved, the classification of waters for irrigation use must be somewhat arbitrary and the limits set cannot be too rigid*.” (McKee and Wolf, second edition 1963 at page 107).

Previous MWPCC rule authors must have taken this into account by choosing to tailor the Class 4A narrative by including the phrase “used as a guide” in that specific subpart of the rule. From a practical standpoint, it does seem that if a number is listed as a guide, a different number might serve as well, or better, in a given site-specific situation.

Another consideration that supports the premise that “used as a guide” was intended to provide flexibility in Minnesota’s irrigation water quality rule is the fact that both McKee and Wolf and Handbook 60 were compiled in an attempt to provide guidance to those involved in irrigation activities in arid and semi-arid regions of the country. In the case of McKee and Wolf, while their contractors’ literature search efforts were comprehensive, looking for information irrespective of the country of origin, the final document was primarily intended to address a broad suite of the water pollution challenges faced by the nine Regional Water Quality Control Boards of California, including those associated with agricultural production in the state. The importance of irrigated agriculture cannot be understated for the State of California. In 2013, for instance, California was second only to Nebraska in the total number of acres under irrigated production. California far exceeds other states in terms of the amount of water used for irrigation purposes.

Handbook 60, published by the United States Salinity Laboratory, was primarily the work product of a collaborative effort of 17 western states (located in areas of the country where average annual precipitation typically is less than 20 inches and is insufficient to support crops without supplemental water). The purpose of Handbook 60 was to gather and summarize information for professional agricultural workers in order to diagnose and improve saline and alkali soils. The handbook was intended as a “*practical guide for those confronted with soil, plant, and water problems involving salinity and alkali.*” Handbook 60 goes on to state: “*In sub-humid regions, when irrigation is provided on a standby or supplemental basis, salinity is usually of little concern, because rainfall is sufficient to leach out any accumulated salts. But in semi-arid and arid regions salinity is usually an ever-present hazard and must be taken into account at all stages of planning and operation.*” (Handbook 60 at page 35).

In Minnesota, the mean annual gross precipitation ranges from 21 inches in the northwestern part of the state to areas in the southeast and that exceed 35 inches per year. Therefore produce, forage crop, and landscape irrigation in Minnesota is considered a supplemental use primarily practiced to boost production yields. Compared to the semi-arid portions of the country, the salinity threat to Minnesota’s agricultural production and soil conditions is low. While the salinization threat may be low on a statewide basis, irrigation still needs protective water quality levels.

As shown above and further explained in this TSD, the suitability of water for crop irrigation depends on many factors – ranging from the exact constituents of the water to the crop and soil types. The MPCA contends that in order to protect for the assigned Class 4A designated uses, specific situations will need to be evaluated. Because using numeric values in rule “as a guide” is no longer consistent with how MPCA operates its water quality standards program, changes are needed. At this time, MPCA thinks that the best approach is to continue to designate all waters of the state as Class 4A waters, and to broadly protect them through a narrative statement in rule. This narrative standard can be coupled with a robust implementation process that considers the variety of factors (e.g. climate, soil type, frequency and method of irrigation, species of plants grown, etc.) on a case-by-case basis in order to evaluate the need for regulatory controls. The Class 4A narrative interpretation process is outlined and discussed in the sections describing the Class 4A narrative translator below.

Perhaps because of the fact that the standards were stated as numbers to be "used as a guide", until the 2000s, MPCA's focus on, and enforcement of, Class 4A standards was sporadic. Some has been complaint driven. MPCA staff can only recall one past situation where there was a citizen complaint regarding salinity levels in their irrigation waters. During that particular complaint investigation, it was found that a greenhouse operation was appropriating shallow groundwater to water their nursery stock. Diminished plant size and leaf browning prompted sample collections; analyses revealed high levels of sodium and chloride in the groundwater. The suspected source of the contamination was a nearby outdoor road salt storage facility that lacked proper cover and containment.

In recent years, more attention has been given to the presence and environmental effects of a group of salty discharge parameters. Many of these are directly related to the Class 4A numeric standards currently in rule. Therefore the MPCA is re-examining this fifty-year old rule and describing a planned implementation process that may be used to evaluate irrigation source waters potentially affected by NPDES permitted discharges. The Class 4A draft rule changes enable the MPCA to have the flexibility to evaluate the various factors affecting irrigation uses and assessing whether or not there is RP that discharge effluent limits may be needed to protect the designated use.

Summary of Potential Changes to Class 4A Standards

The following tables summarizes MPCA's current thinking on the direction of likely changes to the Class 4A standards. The rationale for each change is briefly described here, with more detailed technical information later in the document.

Table 8. Details of draft changes to Class 4A standards, with rationale behind the changes.

Current Rule	Draft Changes	Rationale
Every water of the state is designated as requiring protection for irrigation.	Every water of the state is designated as requiring protection for irrigation.	• Does not remove the irrigation designated use from any water of the state and maintains a level of protection for irrigation. • Limiting the applicability of the irrigation use to only waters where irrigation currently occurs would require removing the designated use from every other water of the state not currently used for industrial consumption; this is over 100,000 waters. Removing a designated use requires substantial administrative (rulemaking) effort and legal justification; avoiding the effort required to remove a designated use simplifies this rulemaking process for these 100,000 waters. • The irrigation designated use protects for current and future irrigation. The MPCA cannot predict from what waters irrigators might want to appropriate in the future, therefore it is prudent to maintain the irrigation designated use for every water of the state.

The numeric standard for bicarbonate is set at 5 meq/L.	Remove numeric standard and change to general narrative	• The academic literature on irrigation does not support the contention that bicarbonate by itself is directly toxic to plants. The toxicity of bicarbonate to crops is also associated with the accompanying ion to bicarbonate. • Bicarbonate levels above the calcium carbonate saturation index in irrigation water can increase scaling and plugging of irrigation equipment. However, this scaling and plugging only occurs in the limited scenarios when the source of irrigation water is groundwater, pH is greater than 8.5 and spray irrigation in warm temperatures is used. There is no evidence that scaling and plugging of spray irrigation equipment is a widespread problem in Minnesota. • The narrative translator process protects for excess total salinity, which includes bicarbonate. • There is no record in the MPCA's or MNDNR's history of an irrigator notifying either agency of a concern with the quality of their appropriation water with respect to bicarbonate. This is a strong indicator that the bicarbonate numeric standard is not of an essential nature to irrigators. • The available justification for the current numeric standard is limited and would not be sufficient to justify adoption of the same rules today.
The numeric standard for boron is set at 0.5 mg/L.	Remove numeric standard and change to general narrative	• Different plants have different sensitivities to excess boron and it is difficult to pick a singular boron value that is neither under protective nor over protective. For example, a protective value for boron sensitive crops (< 0.5 mg/L for blackberries) would be at least twelve times less than a protective value for very tolerant crops (6-15 mg/L for asparagus). This wide range in boron tolerance makes setting a single appropriately protective value difficult. • Many soils in Minnesota are deficient in boron and boron is frequently added as a fertilizer for select crops. • Boron related crop toxicity is not a likely problem in Minnesota if farmland is properly managed. Due to Minnesota climate, natural rainfall serves to flush boron from the root zone which, mitigates boron toxicity. • There is no record in the MPCA's or MNDNR's history of an irrigator notifying either agency of a concern with the quality of their appropriation water with respect to boron. This is a strong indicator that the boron numeric standard is not considered a problem for irrigators.

		• The available justification for the current numeric standard is limited and would not be sufficient to justify adoption of the same rules today.
The numeric standard for pH minimum and pH maximum are 6.0 and 9.0, respectively.	Remove numeric standard and change to general narrative	• There are already numeric Class 2 aquatic life protections for pH that are very similar to the current Class 4A numeric standard. These Class 2 protections have defined durations and frequency which makes them easier to enforce. • Every wastewater discharger must discharge between pH values of 6 and 9 as part of Minnesota's technology based effluent limits. • There is no record in the MPCA's or MNDNR's history of an irrigator notifying either agency of a concern with the quality of their appropriation water with respect to pH. This is a strong indicator that the pH numeric standards are not of an essential nature to irrigators. • The available justification for the current numeric standard is limited and would not be sufficient to justify adoption of the same rules today.
The standard for specific conductance is set at 1,000 micromhos per centimeter at 25°C	Remove numeric standard and change to general narrative	• The specific conductance of irrigation water a given crop can receive depends on a range of factors including crop type, soil type, soil drainage, irrigation type, climate, desired crop aesthetic quality, and crop yield reduction tolerance. It is important to consider these critical local factors in order to neither over-protect nor under-protect the irrigation designated use when determining protective levels of specific conductance in irrigation water. Appropriately accounting for all of these conditions to consider all of the possible crops, soil conditions, and drainage conditions found in Minnesota would produce a prohibitively large and convoluted table of protective values that would make implementation and development of the values difficult for the MPCA, citizens, and regulated parties. • If a statewide specific conductance irrigation standard were set at a conservative value protective of the most sensitive crops in the most sensitive soil conditions (i.e. < 500 µS/cm for blackberries grown in already saline clay soils), then that value would be overly protective for every other Minnesota crop and soil condition. Some crops would be substantially over-protected by a single conservative number, for example, the protective root zone specific conductance value for barley is over sixteen times greater than for blackberries. The goal of this rulemaking is to be appropriately protective with a general narrative

		standard and a narrative translator process that will allow flexibility to consider site-specific factors. • The MPCA has developed a draft narrative translator process to ensure that waters used for irrigation do not have excess specific conductance attributable to NPDES dischargers. • There is no record in the MPCA's or MNDNR's history of an irrigator notifying either agency of a concern with the quality of their appropriation water with respect to specific conductance. • The available justification for the current numeric standard is limited and would not be sufficient to justify adoption of the same rules today.
The criteria for sodium is 60% of total cations as milliequivalents per liter.	Remove numeric standard and change to general narrative	• Modern soil and irrigation literature considers sodium adsorption ratio (SAR) to be the appropriate soil and water quality parameter to ensure soils and crops are not exposed to excess sodium. • The protective SAR for a given soil and crop is a function of soil type, climate, drainage management and irrigation practices. Appropriately accounting for all of these conditions to consider all of the possible crops, soil conditions, drainage conditions, found in Minnesota would produce a prohibitively large and convoluted table of protective values that would make implementation and development of standard difficult for the MPCA, citizens, and regulated parties. • If a statewide SAR standard were set at a conservative value protective of the most sensitive soil conditions (<3 SAR for soils with moderate salinization risk that are poorly managed for drainage) then that value would be overly protective for every other Minnesota soil condition. The goal of this rulemaking is to be appropriately protective and a general narrative standard allows flexibility to consider site-specific factors. • A narrative translator process has been developed to ensure that waters used for irrigation do not have excess sodium caused by NPDES dischargers by evaluating the SAR. • There is no record in the MPCA's or MNDNR's history of an irrigator notifying either agency of a concern with the quality of their appropriation water with respect to sodium. • The justification for the current numeric standard is unclear.

The criteria for total dissolved salts is set at 700 mg/L.	Remove numeric standard and change to general narrative	• Total dissolved salts is an antiquated measurement and is not currently in used in this field. • If the total dissolved salts were meant to protect salinity in irrigation water, these would be better represented by using the calculated SAR and specific conductance.
The criteria for sulfates is set at 10 mg/L, applicable to water used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels.	No change	----
Radioactive materials are not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.	Radioactive materials are not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.	• The Class 4A radioactivity standard is already a narrative standard that contains no numeric values. • Parallel rule language concerning radioactive materials also included under Class 2, Class 3, and Class 4B water use classifications.
"The following standards shall be used as a guide in determining the suitability of the waters for such uses…"	Remove the use of the term "guide" for the standards, consider other language to ensure that the important potentially damaging parameters are evaluated as part of the decision making process.	• Considering standards as a "guide" is inconsistent with current usage and rulemaking practice. • Potential pollutants to consider could include pH, conductance, total dissolved solids, and calculated sodium adsorption ratio • Requiring the MPCA to consider the parameters ensures that the potential characteristics are evaluated as part of the decision making process

No process to translate the narrative portion of the standard into protective numeric standards.	Develop a narrative translator process to ensure protection of the designated use.	• Develop a narrative translator process in guidance that protects the Class 4A designated uses for waters actively being used for irrigation purposes.
"…together with the recommendations contained in Handbook 60 published by the Salinity Laboratory of the United States Department of Agriculture, and any revisions, amendments, or supplements to it…"	If reference documents are used, switch to more current literature	• The reference "Handbook 60" is over fifty years old. Current literature, in all forms, should be used to make up to date decisions about irrigation water quality. • Allows more flexibility in what academic literature is being considered and represents the ever-changing nature of irrigation science. • List of current references can be updated and maintained when numeric translators are required in NPDES permits.

The MPCA envisions a narrative standard that speaks to the type of adverse effects that demonstrate that water is not suitable for irrigation, and the pollutants that may cause those kinds of effects. Potential language for such a narrative standard could read as follows:

> *The narrative water quality standard in this part prescribe the qualities or properties of the waters of the state that are necessary for the irrigation designated public uses and benefits. The quality of Class 4A waters of the state shall be such as to permit their use for irrigation without significant damage or adverse effects upon crops or vegetation grown in the areas that are being irrigated. Substances, characteristics, or pollutants including but not limited to specific conductance, and the calculated sodium adsorption ratio shall be considered when assessing the suitability of waters for irrigation based upon current literature. Assessments of a water's suitability for irrigation must consider: water quality at the location of irrigation water appropriation, sensitivities of crops being irrigated, suitability of soils to receive irrigation water, soil drainage practices, irrigation practices, rainfall tendency to leach the soil of the parameters of concern and the crop yield losses the farmer is willing to accept to irrigate crops with water of elevated salinity.*

Rationale for Draft Changes to Class 4A Standards

Applicability to Water Bodies

Currently, all waters of the state (except for wetlands) are designated as 4A waters. Wetlands are currently designated as 4C waters, which includes by reference the values listed in Class 4A. Therefore, as written, any changes to the 4A standards will also apply to 4C waters. However, as discussed in the wetland section below, the MPCA is proposing to remove the 4C use class, and instead designate all wetlands as Class 4A and 4B.

Under the draft rule, every water of the state would retain the irrigation designated use. In 2010, the MPCA envisioned limiting Class 4A designations to apply only to surface waters subject to the MNDNR water appropriations permitting program for irrigation uses. After some consideration, the MPCA is instead planning that the Class 4A standards remain on all waters of the state, including wetlands. Restricting the designated use to a limited number of waters would not protect the waters for potential future irrigation users, and has more complications than designating every water of the state as a Class 4A water. MPCA would have to remove the irrigation use from all waters of the state without a MNDNR appropriation permit, which would be major effort in terms of MPCA staff resources.

To remove a designated use from a water body, federal regulations (40 CFR § 131.10(h)) require the state demonstrate that the use to be removed is not an existing use or an attainable use. An existing use is defined as a use attained any time on or after November 28, 1975. An attainable use is defined as a use that can be achieved when effluent limits from technology based standards are imposed on point source dischargers (through sections 301(b)(1)(A and B) and 306 of the CWA) and when cost-effective and reasonable best management practices are imposed on nonpoint source dischargers. Additionally, 40 CFR § 131.10(g) provides additional scenarios that may indicate that the use is not attainable, such as low flows or other natural conditions that prevent the water from attaining a use. Any demonstration for the removal of an irrigation use would need to take the form of a use and value determination (UVD) or use attainability analysis (UAA) as laid out in 40 CFR § 131.10(k).

If MPCA decided to only apply Class 4A standards to those waters with MNDNR appropriations for irrigation use, MPCA would have to conduct a UVD or UAA covering all other waters of the state. The amount of work required to demonstrate that the irrigation use is not existing or attainable on each of the state's more than 100,000 water bodies would likely be prohibitive. Each water body would need to be assessed to evaluate whether the use had existed since November 28, 1975, and also if it were attainable to meet the use. This would require a review of all permits and water quality monitoring data dating to 1975.

Other factors included in 40 CFR § 131.10(g) could also be considered for each water body, but the data for flow rates, natural background, costs to upstream dischargers, etc. would need to be evaluated on a case-by-case basis. For one water body, an evaluation of all water quality data, uses of the water, and assessment of additional factors could be reasonable, but to complete this for the majority of Minnesota's water bodies would take several years. The more appropriate approach to this is to maintain the irrigation use designation on all waters. The MPCA can then, as needed, conduct a UVD or UAA for individual water bodies or segments where it can be clearly demonstrated that the use is not existing or attainable.

Existing Locations of Irrigation Water Appropriation in Minnesota

The MNDNR maintains a database of water appropriators in Minnesota. Every water appropriator with the potential to appropriate more than 10,000 gallons per day or more than 1,000,000 gallons per year is required to have a water appropriation permit from the MNDNR. The MNDNR maintains the water appropriation database to track each appropriator's water usage and permit status. MNDNR also classifies appropriators into permit categories. The MPCA used the most current version of this database (as of July 17, 2018) to visualize and count agriculture water appropriators across the state (Tables 9 and 10 and Figures 7 and 8).

Every water appropriator in the MNDNR database is classified by the MNDNR into categories of water appropriation by use type. The agriculture use types range from non-crop irrigation to crop irrigation and can be found in Table 9. The MPCA used these categories to determine whether an appropriator would be considered an agricultural or landscape water appropriator as noted in the Class 4A Use column of Table 9.

The dominant type of irrigator by count in Minnesota is a crop irrigator that appropriates water from groundwater; there are over seven times as many groundwater irrigators as surface water irrigators. The location of groundwater and surface appropriators is not equally distributed across the landscape. For example, Murray County in southwestern Minnesota does not have a single active groundwater appropriator whereas Otter Tail County in central Minnesota has over 1,000 active groundwater appropriation locations. The same geographic pattern holds true for surface water appropriation with some counties (Martin, Faribault) having zero active surface water irrigation appropriators and other counties (Polk, Otter Tail) have over fifty surface water appropriation locations.

The MDNR database includes reported volumes of water used by permittees on a yearly basis. Over the course of 2008 – 2017, on average, 9,104 million gallons per year (mgy) of surface waters were appropriated for irrigation. This compares to an estimated 94,932 mgy of ground water used for irrigation purposes. To put this into perspective, a rain event of just under 1.2 inches of rain falling evenly over Sherburne County, Minnesota would produce approximately 9,103 million gallons of water.

Table 9. How the MPCA defined an irrigation consumer in reference to the MNDNR water appropriation categories.

Use Category	Use Type	Class 4A Use
Agricultural Irrigation	Agricultural Crop Irrigation	Yes
	Nursery Irrigation	Yes
	Orchard/Vineyard Irrigation	Yes
	Pasture Irrigation	Yes
	Sod Farm Irrigation	Yes
	Wild Rice Irrigation	Yes
Heating/Cooling	Commercial/Institutional Building AC	No
	District Heating/Cooling	No
	Geothermal Groundwater Exchange with Reinjection (HVAC)	No
	Geothermal Systems (HVAC)	No
	Once-through Systems (HVAC)	No
	Other Air Conditioning	No
Industrial Processing	Agricultural/Food Processing	No
	Industrial Process Cooling - Once Through	No
	Metal Processing	No
	Mine Processing (excludes sand/gravel)	No
	Non-metallic Processing (rubber, plastic, glass, concrete)	No
	Other Industrial Processing	No
	Petroleum-Chemical Processing/Ethanol	No
	Sand and Gravel Washing	No
	Wood Products Processing	No
Non-Crop Irrigation	Cemetery Irrigation	Yes
	Golf Course Irrigation	Yes
	Landscaping/Athletic Field Irrigation	Yes

	Other Non-Crop Irrigation	Yes
Power Generation	Hydro Power	No
	Other Power Generation	No
	Thermoelectric Power Cooling - Once Through	No
	Thermoelectric Power Cooling - Recirculating	No
	Thermoelectric Power Generation - Non Cooling	No
Special Categories	Aquaculture	No
	Construction Non-dewatering	No
	Dust Control	No
	Livestock Watering	No
	Other Special Categories	No
	Pipeline and Tank Testing	No
	Pollution Containment	No
	Sewage Treatment	No
	Snow/Ice Making	No
Water Level Maintenance	Basin (Lake) Level Maintenance	No
	Construction Dewatering	No
	Groundwater Dewatering	No
	Mine Dewatering	No
	Other Water Level Maintenance	No
	Pumped Sumps	No
	Quarry Dewatering	No
	Sand/Gravel Pit Dewatering	No
Water Supply	Campground/Wayside/Highway Rest Area Water Supply	No
	Commercial/Institutional Water Supply	No
	Fire Protection Water Supply	No
	Municipal/Public Water Supply	No
	Other Water Supply	No
	Private Water Supply	No
	Rural Water District Supply	No
(blank) *(No category given)*	Nuclear power plant	No
	Other Temporary	No
	(blank) *(No category given)*	No

Table 10. Counts of MNDNR irrigators by category, permit status and whether the appropriator takes water from surface or groundwater.

		Groundwater			**Surface Water**		
Use Category	**Use Type**	Active	Inactive	Inactive-pending	Active	Inactive	Inactive-pending
Agricultural Irrigation	Agricultural Crop Irrigation	7206	2383	46	569	2380	9
	Nursery Irrigation	97	36		12	30	

	Orchard/Vineyard Irrigation	24	6		12	9	
	Pasture Irrigation	4			1	2	
	Sod Farm Irrigation	49	18		14	24	
	Wild Rice Irrigation	2	9		166	357	
Non-Crop Irrigation	Cemetery Irrigation	11	4		2		
	Golf Course Irrigation	556	137		260	149	
	Landscaping/Athletic Field Irrigation	297	72	1	53	89	
	Other Non-Crop Irrigation	10	2		6	2	
Total		8256	2667	47	1095	3042	9

Figure 7. MNDNR surface water irrigation permits classified by active or inactive status of the permit.

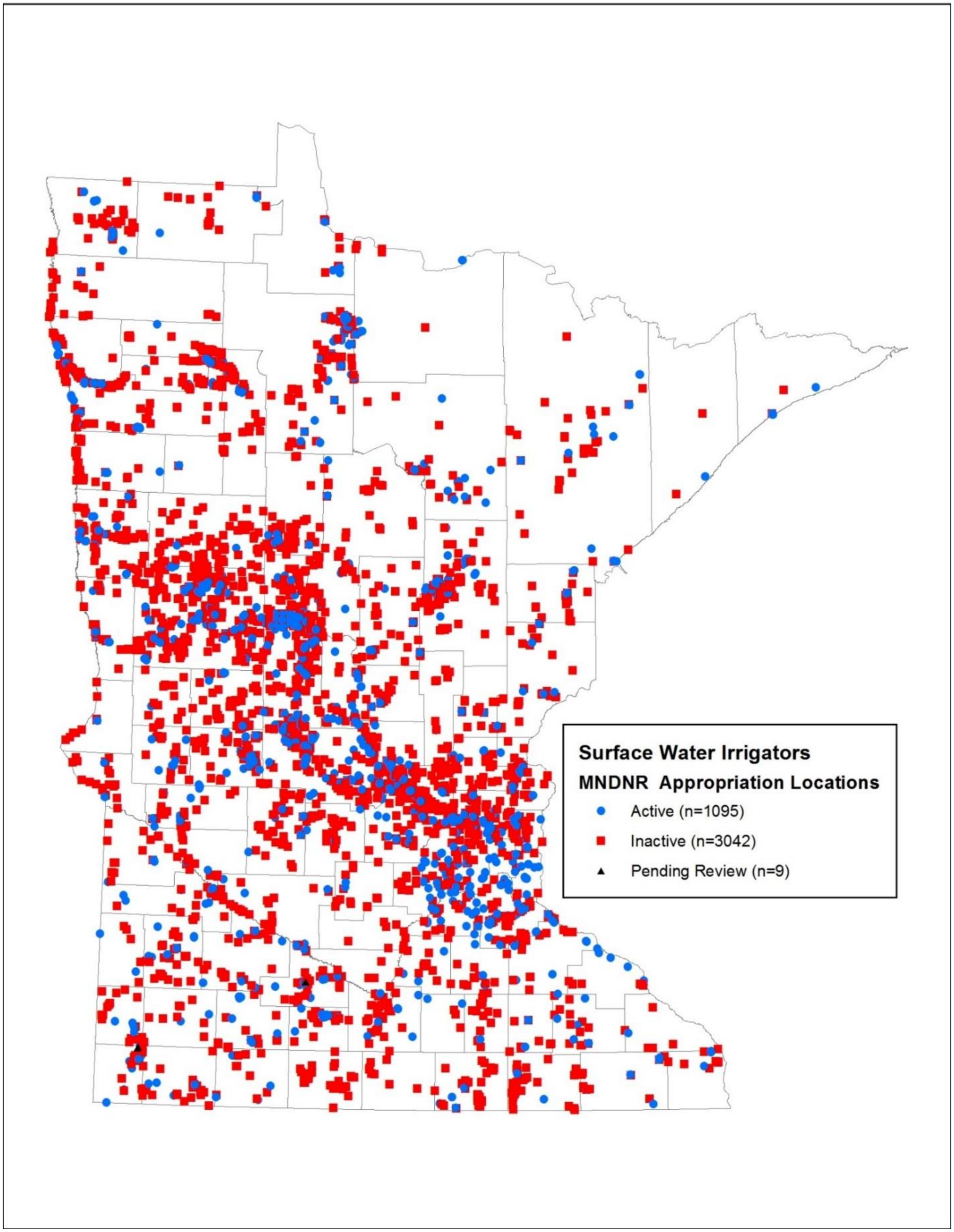
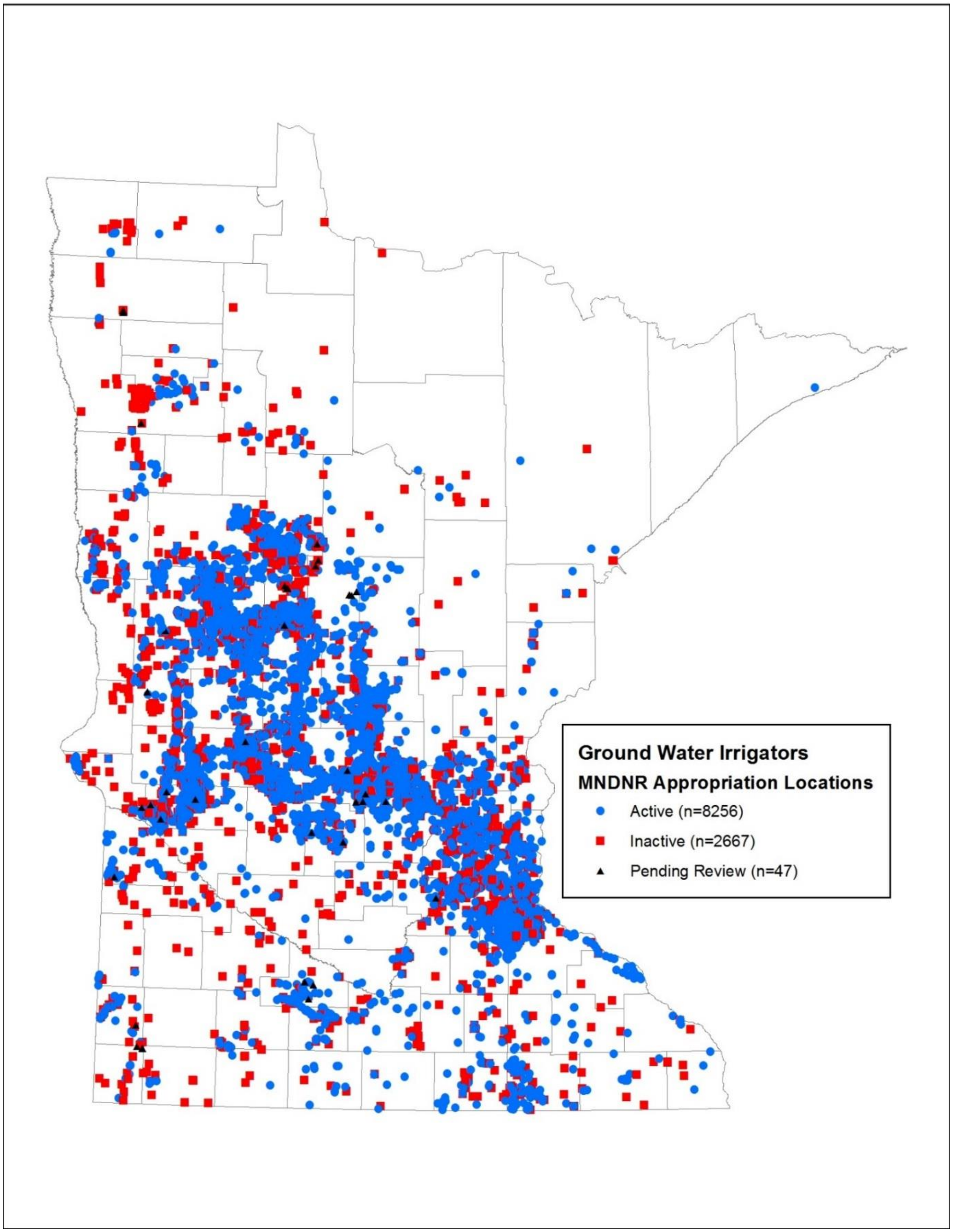


Figure 8. MNDNR groundwater irrigation permits classified by active or inactive status of the permit.



Managing Irrigation Water Quality

Managing for irrigation water quality is a complex field of study that requires an understanding of chemistry, plant biology, soils, economics, water quality, climate, and hydrology among other factors. The American Society of Civil Engineers produced a manual in 2011 titled *Agricultural Salinity Assessment and Management* (ASAM, 2011) and the chapter on irrigation water quality contains the introductory statement below.

> *A meaningful assessment of the quality of water used for irrigation should consider such local factors as the chemical reactivity of constituents dissolved in the water, the soil's chemical and physical properties, climate, and irrigation management practices. It should also consider the effects of irrigation on the quality of agricultural drainage, effects on humans and animals of chemicals concentrated in harvested plant products, and economic conditions that determine how much salinity-induced reduction in yield or quality can be tolerated.*

Irrigation water quality salinity must be considered at a local scale because the factors above can change radically even within a single Minnesota field and are difficult to apply generally statewide. Irrigation water quality is multi-faceted. Not properly considering one of these important facets could generate water quality assessments that are either under- or over-protective of actual irrigation water quality needs.

Water Quality Parameters of Concern

Irrigation water quality is a complex field of study. There is a nearly limitless number of water quality parameters that have the potential to impact water quality and its appropriateness for irrigation. Parameters broadly ranging from pesticides to fluorinated compounds to human pathogens to radiation to nutrients can all affect irrigation water quality.

Because there are many parameters that could potentially affect irrigation water quality, the MPCA has chosen in this rulemaking to limit the parameters of concern to a reasonably defined subset of parameters. Not to do so would be infeasible given agency resources. It is planned that this rulemaking will be limited to the salinity related parameters that currently have numeric Class 4A standards.

The salinity related parameters discussed in this document are listed and defined below.

- Anions – Negatively charged molecules.
- Bicarbonate – A product of dissolved carbon dioxide gas in water.
- Boron – A metalloid element in the periodic table of elements.
- Cations – Positively charged molecules.
- Calcium – A metallic element in the periodic table of elements that is generally present in water as a cation.
- Chloride – An inorganic negatively charged anion that when combined with a cation, forms a "salt".
- Magnesium – A metallic element in the periodic table of elements that is generally present in water as a cation.
- pH – A measurement of the acidity of a solution.
- Salinity – Another way to generally refer to all of the dissolved ionic compounds (salts) in water.
- Salt – An ionic compound composed of cations (positively charged molecules) and anions (negatively charged molecules).

- Sodium – A metallic element in the periodic table of elements that is generally present in water as a cation.
- Sodium adsorption ratio (SAR) – A calculated ratio of the amount of sodium dissolved in water relative the amount of calcium and magnesium dissolved in water.
- Specific Conductance – A measurement of the electrical conductivity of water. Pure water devoid of all dissolved salt does not conduct electricity and the conductivity of water increases in direct proportion to the dissolved salt content of the water. Using the proportionality between electrical conductivity and salt content, scientists can use the electrical conductivity of the water as a close surrogate for the dissolved salt content of the water. Specific conductance is cheap and easy to measure, does not require sending samples to a lab and gives an instantaneous reading; these simplifying factors make specific conductance a widely measured field parameter in water quality.
- Total Dissolved Salts – A measurement of the summed dissolved mineral salt content in water. This measurement is always performed at a laboratory. The term total dissolved salts is an outdated term; the modern terminology is total dissolved solids, which better reflects what the analytical methodology is actually capable of measuring.
- Total Dissolved Solids – A measurement of all dissolved compounds in water. Primarily composed of dissolved inorganic salt minerals with dissolved organic minerals typically comprising a smaller fraction of the dissolved solids content.

Previous Rulemaking Research

In 2008, the MPCA commissioned a report from the University of Minnesota (UMN) to provide technical information to help revise the Class 3 and 4 water quality standards (Bloom and Mulla, 2010). The report consulted the academic literature, national and international experts, reviewed other states' water quality standards and ultimately provided generalized recommendations as to how to revise the Class 4A water quality standards. This report did not generate any specific numeric water quality standard recommendations but did identify factors that should be considered when evaluating irrigation water quality needs with respect to salinity.

The UMN report found that irrigation water quality needs depend on several critical factors. These factors are consistent with the factors that other irrigation manuals also consider to be important (ASAM 2011, Ayers and Westcott, 1994).

- Crop type
- Soil type
- Soil drainage management techniques
- Annual rainfall and general climate patterns
- Irrigation practices
- Presence of dissolved salt minerals in soils
- Crop yield loss tolerances a given farmer is willing to accept to irrigate crops

The UMN report provided no information as to how to incorporate or account for these critical factors in evaluating irrigation water quality with respect to salinity related parameters. Because the factors listed above have been identified as critically important, the MPCA performed a more rigorous evaluation of the literature to determine how to better incorporate these factors into irrigation water quality assessments.

Importance of Considering Critical Local Factors

It is essential to consider the critical local factors listed above when assessing irrigation water quality. Absent such consideration, the protective numeric irrigation water quality values generated in an assessment will be either under-protective or over-protective of the irrigation designated use for the specific irrigation use in question. There is no "one size fits all" irrigation water quality parameter or numeric value that protects for the wide variety of irrigation water quality needs in Minnesota. It could be argued that the MPCA could simply choose the most sensitive crop type and set the standards at the level needed to protect that crop and soil condition. Certainly, when developing aquatic life standards, we protect for the most sensitive species. However, crops are different. Soil types do not change and the types of crops grown in any given location are relatively stable within a given crop rotation. In addition, the most sensitive species tend to be those that are less commonly grown or grown at scale (such as strawberries or blackberries). Given the availability of data, the MPCA contends that the approach we are putting forward provides an appropriate level of tailored protection for irrigated crops of all types.

The rest of this section provides an in-depth evaluation of the importance of the local factors when assessing irrigation water quality needs. Ultimately, the MPCA contends that a singular numeric standard for any salinity related parameter is not needed to protect for the irrigation designated use. Rather, the right approach is a narrative standard that allows for the consideration of critical local factors and a statewide numeric standard would not. The MPCA is able to develop an implementation process to consider local factors.

Critical Local Factor: Crop Type

Takeaway

Different crops grown in Minnesota have different water quality needs for the salinity-related parameters currently in the Class 4A irrigation water quality standards. Understanding how these parameters behave in the environment and affect crops is critical to avoid setting water quality standards that do not appropriately protect the irrigation designated use.

The MPCA could choose to reduce the complexities of irrigation water quality salinity needs by conservatively protecting for the most sensitive crop as a way to also protect every other crop. However, this would be substantially overprotective for other crops grown in Minnesota. If the MPCA were to attempt to identify and place in rule the protective values for every crop that could be grown in Minnesota, it would likely result in a complicated multi-parameter table that would be difficult to interpret and administer. This would not further the goal of regulatory simplicity or certainty.

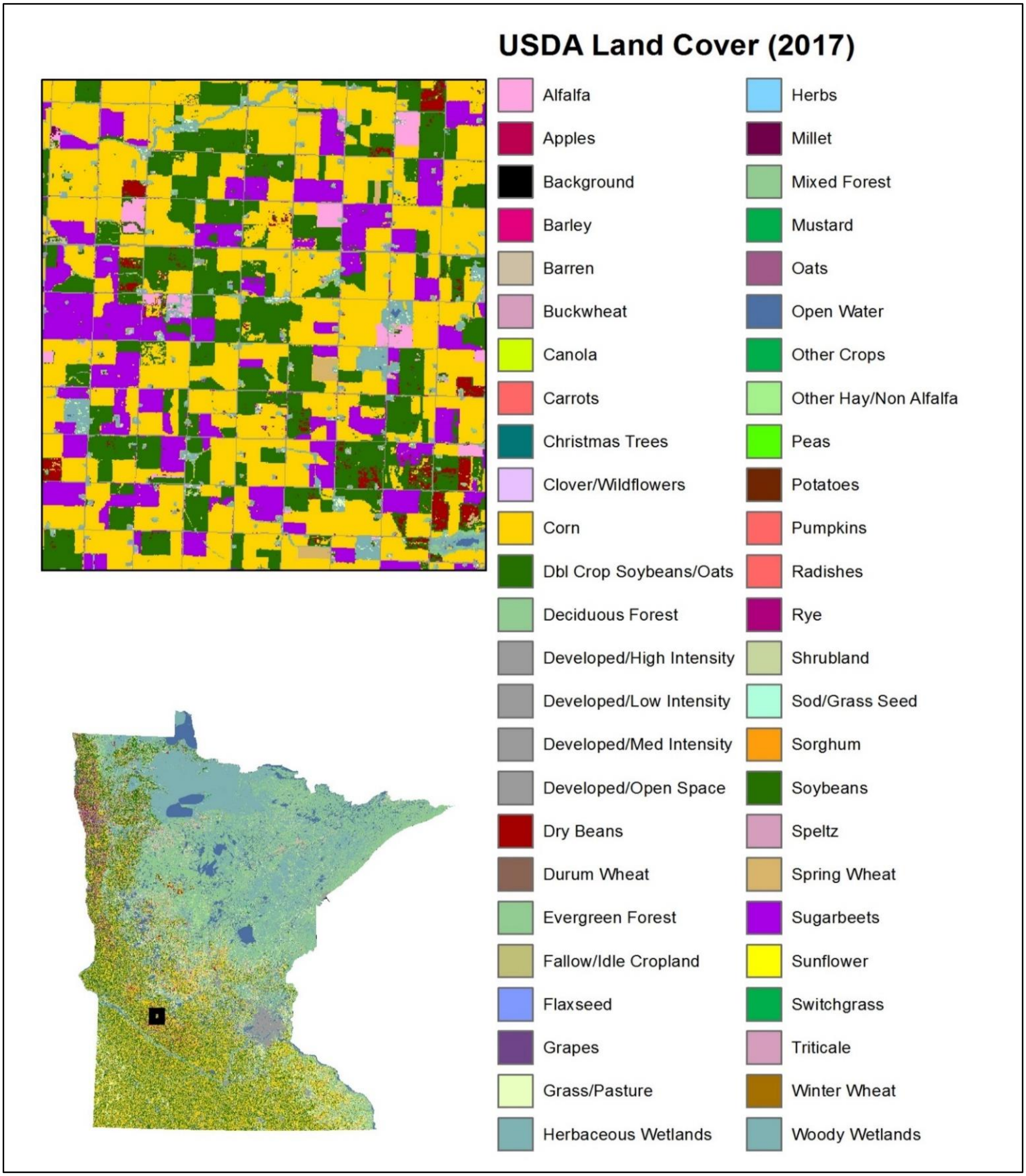
Minnesota Crop Types

The current Class 4A irrigation designated use indicates that ensuring irrigation water quality protections for all types of crops is necessary. The quotation below is from the general introductory Class 4A narrative currently in rule. The statement broadly defines the crops of concern for the Class 4A irrigation water quality designated use to include any crops or vegetation including truck garden crops. "Truck garden crops" is a loosely defined term generally meant to define the types of crops sold at farmers markets.

> *The quality of Class 4A waters of the state shall be such as to permit their use for irrigation without significant damage or adverse effects upon any crops or vegetation usually grown in the waters or area, including truck garden crops.*

Farmers in Minnesota grow and irrigate a wide variety of crops, ranging from Christmas trees to cauliflower to strawberries to corn and soybeans. The U.S. Department of Agriculture (USDA) produces annual land cover maps of the state that accurately classify the landscape into types of vegetation and common crops types (Figure 9) (USDA – NASS 2017). The resolution of these land cover maps is highly detailed as can be seen in the zoomed in portion of the figure that shows how different fields are planted with different crops in the central Minnesota landscape in 2017. This USDA dataset does have some limitations: most notably it focuses on the largest cash crops and does not include most of the smaller scale truck garden crops. For example, there are many commercial strawberry plots in Minnesota but none appear on this USDA map as areas used for strawberry production. There is no dataset at the county, state or federal level that tracks where truck garden crops are being grown in Minnesota or whether any of those crops are being irrigated.

Figure 9. Annual 2017 Land Cover of Minnesota produced by the USDA. The zoomed in area shows the variety and spatial resolution of crop types in an area of central Minnesota farmland.



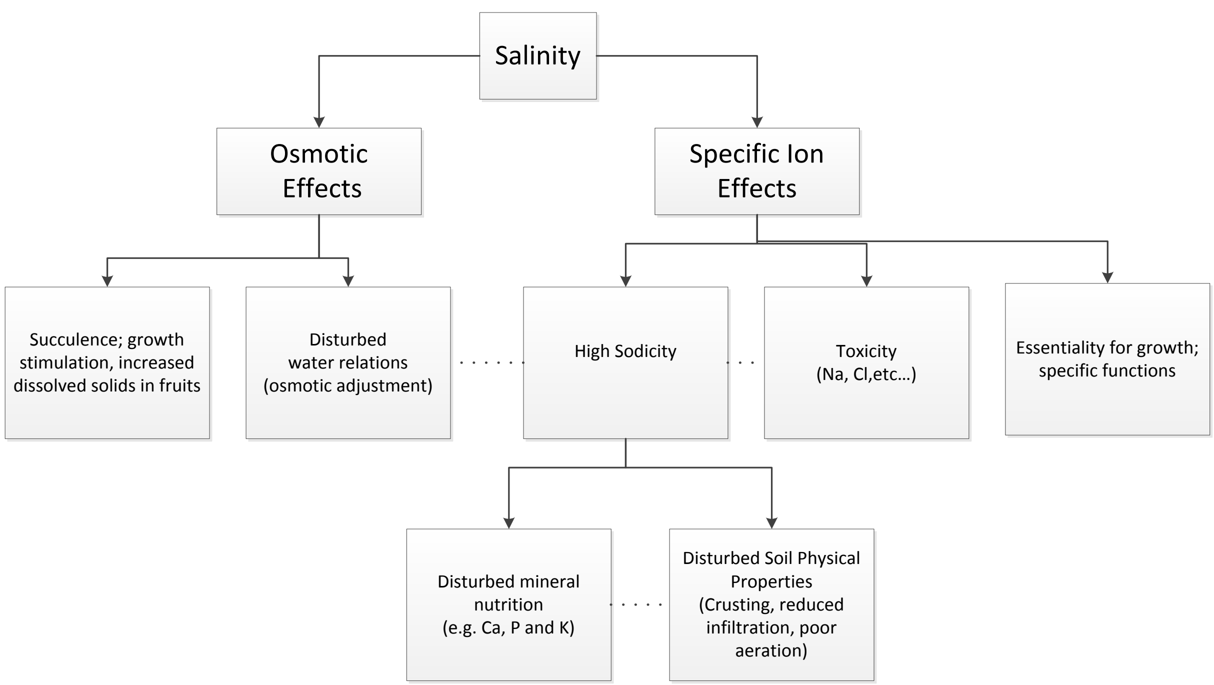
Effects on Different Crops Due to Salinity Related Parameters

There are two generalized effects on crops related to salinity (Figure 10): osmotic effects related to the impact of salts on how water is taken up and moves through the plant, and ion effects related to the specific impacts of the type of ion of concern. It is often difficult to disentangle the effects of osmotic and specific ion effects from one another. "Osmotic effects" refers to the overall salt content (i.e., all the ions combined) or salinity of the water in the root zone of the plant. Osmotic effects occur because plants need to regulate the osmotic potential or the salt content of the water in their bodies to specific levels. It costs the plants additional energy to transport low salt water into the plant body from high saline waters (high osmotic pressure effects) than from low saline waters (low osmostic pressure effects). The additional energy costs of processing high salinity water into the plant can have negative effects on plant yield. Specific ion effects are those effects on crops related to a single salty parameter such as sodium or boron with each specific ion having different effects on crops.

Figure 10 also distinguishes between general salinity related effects and the specific ion effects of sodium through sodicity. Sodicity refers to the relative proportions of sodium with respect to calcium and magnesium in irrigation water; in general, greater sodicity is worse for the plant of concern. The dashed lines show that is often difficult to fully distinguish between the effects of sodicity and salinity when evaluating effects on crops. Additionally, the dashed lines also show that is also difficult to fully distinguish between the effects of specific ion toxicity to the plants themselves and the impacts those ions have on soil health. Poor soil health caused by high salinity or sodicity can be just as detrimental to plants as poor plant health from elevated concentrations of specific ions (soils are discussed more in later sections)

The value at which a given crop starts to experience decreases in yield because of an excess of a given parameter is called the yield threshold value. Every crop has unique tolerances to a given parameter in irrigation water and some crops are more sensitive to high salinity than others. Additionally, different crop genotypes within a given crop species frequently have different sensitivities to excess salinity.

Figure 10. Adapted from ASAM Figure 6-1. Effects of salinity and sodicity on plants.

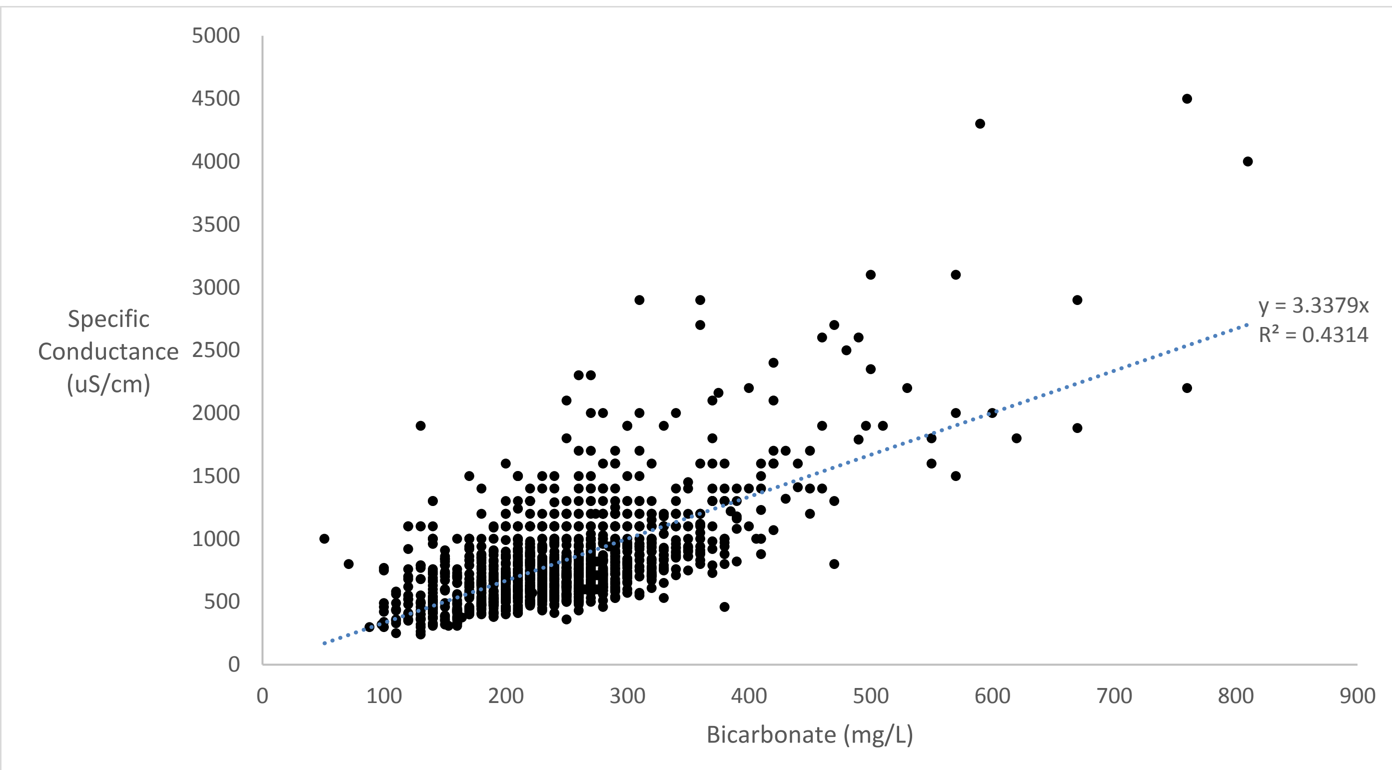


Bicarbonate

The irrigation literature does not strongly support the contention that bicarbonate by itself is directly toxic to plants. The positive ion, or cation, that is associated with the negatively charged bicarbonate ion is what primarily causes toxicity to plants. For example, solutions of sodium bicarbonate have greater toxicity than solutions of calcium carbonate to tomatoes (Navarro et al, 2000). It appears that ensuring that the cation associated with bicarbonate is not toxic is as or more important in protecting crop health than maintaining a protective value for bicarbonate.

Elevated bicarbonate can be generally correlated with toxicity associated with overall excess total salinity. This is because high bicarbonate waters are correlated with overall high salinity in Minnesota surface waters (Figure 11). When assessing irrigation water quality, it is often difficult to distinguish between the specific ion effects of elevated bicarbonate and the high overall salinity associated with elevated bicarbonate waters.

Figure 11. Relationship between bicarbonate concentrations and specific conductance of 1,383 Minnesota surface water quality samples with paired bicarbonate and specific conductance sampling in the MPCA water quality database. There is a moderate statistical relationship between bicarbonate levels and specific conductance of the water. Of the three singular major anions (sulfate, bicarbonate, chloride), bicarbonate has the best statistical correlation with specific conductance.



High bicarbonate levels in high pH, calcium carbonate-rich soils can reduce the availability of other micronutrients such as iron, zinc, manganese and copper by precipitating them as biologically unavailable oxides (Poschenrieder et al., 2018), and the reductions in bioavailability of those nutrients will ultimately reduce crop yield. It is not clear that applying irrigation water with high bicarbonate levels would change the availability of these micronutrients because the pH buffering capacity of the carbonate rich soil would still make those micronutrients biologically unavailable due to chemical precipitation.

Boron
Boron is an essential mineral for plant life yet can be toxic to plants in high levels. At elevated concentrations (>0.5 mg/L), boron can be toxic to very sensitive plants if those plants are chronically exposed to elevated boron concentrations. Different plants have different sensitivities to boron. For example, blackberries are very sensitive to excess boron and will experience decreases in crop yield if soil water boron concentrations are above 0.5 mg/L over the growing season, whereas sugar beets can tolerate boron concentrations up to 6.0 mg/L for the extent of the growing season (Ayers and Westcot, 1994) .

Boron behaves similarly to other dissolved minerals in that it is flushed from the root zone as rainwater percolates through the soil horizon. Minnesota's climate has consistent precipitation year round and, therefore, boron soil root zone concentrations will not be consistently high year-round. The resulting flushing of boron from the root zone allows for greater boron concentrations in irrigation water, because the boron concentrations in the root zone would not be the same as the irrigation water on a season-long basis.

Some Minnesota soils tend to be deficient in boron (Figure 12) and the University of Minnesota extension service has detailed boron fertilizer recommendations that are specific to individual crops planted in specific soil types (Table 11; Sutradhar et al., 2016). These boron fertilizer recommendations can be used to better understand Minnesota crops sensitivities and needs for boron. It is clear from the University of Minnesota boron crop yield recommendations that there is no single boron value for irrigation water quality that would simultaneously provide necessary boron to all crops in all soil conditions while not also causing boron toxicity.

Table 11. Boron fertilizer recommendations by the UMN soil extension survey. Boron fertilizer recommendations are a function of crop type, soil texture, soil boron concentrations and application method.

Soil Test Boron	Relative Level	Boron Fertilizer to apply*
< 1 ppm	low	2 - 4 lbs/acre
1.0 - 5.0 ppm	Adequate	0 lbs per acre
> 5.0 ppm	High	0 lbs per acre

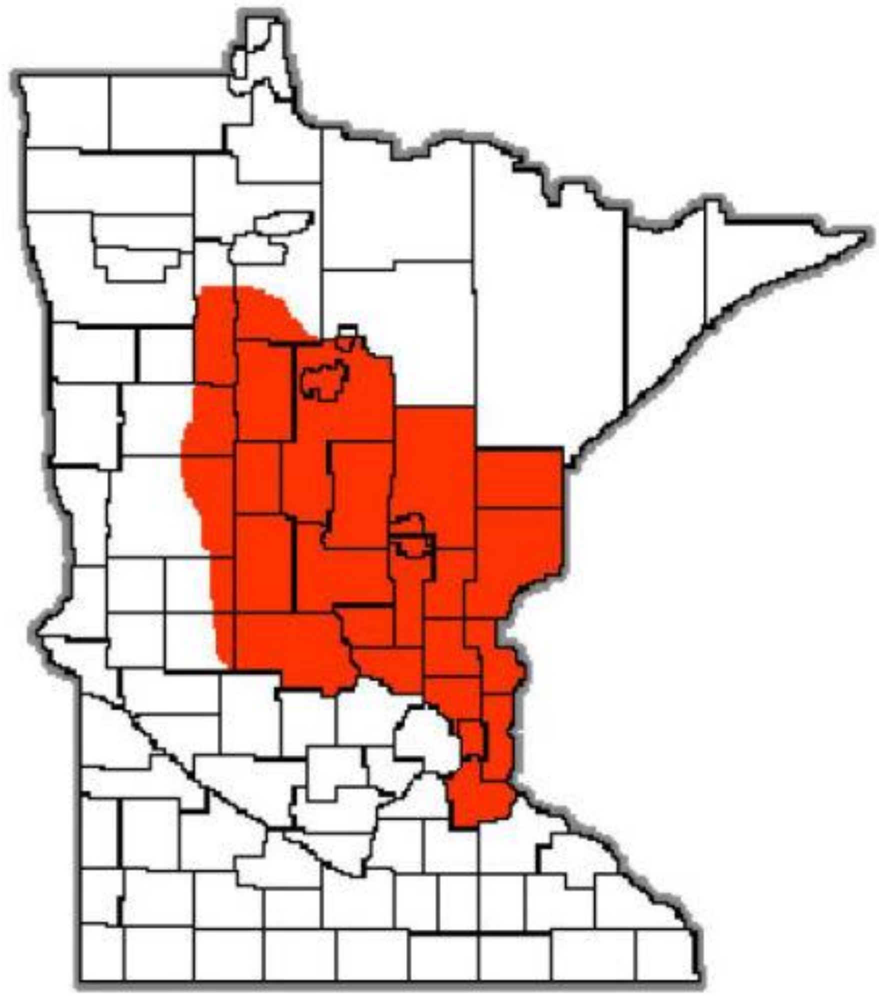
*Boron fertilizer should only be applied to crops that are in the large response category in the table below. Caution should be used when applying boron fertilizer to sandy soils and when using fertilizer application techniques that allow the fertilizer to directly contact plant tissues.

Table 12. Response to boron fertilizer.

Response to Boron Fertilizer		
Large	**Moderate**	**Small**
Alfalfa, apple, broccoli, canola, cauliflower, celery, red beet, sugar beet, sunflower, turnip	Cabbage, carrot, clover, grape, lettuce, onion, radish, spinach, strawberry, tomato	Asparagus, barley, blueberries, field corn, cucumber, oats, pasture grasses, pea, pepper, potato, raspberry, rye, soybean, sweet corn, wheat

For example, some Minnesota crops respond well to additional boron in the root zone (sugar beets, alfalfa, apples) and other crops see little benefit, or even a negative effect, when additional boron is applied (soybean, corn, potato) (Table 12). Boron-sensitive crops like corn are recommended not to receive additional boron unless location specific testing is performed that includes sampling soil and plant tissue to confirm that boron fertilizer is needed. For many crops, it appears that managing fields for increased soil organic matter will naturally provide necessary boron in a slow release, biologically available form that is likely to benefit crops more than applying boron in irrigation water. When considering the many ways boron can impact crops in Minnesota, it is difficult to develop a single numeric value that is neither under protective nor over protective considering the variety of crops and soil conditions in Minnesota.

Figure 12. Figure from the University of Minnesota soil extension service webpage. The area in red are areas of the state where a deficiency of boron in the soil is more likely.



Sodium

Excess sodium can have both direct toxic effects on crops and negative effects on the soil texture, which in turn negatively affects crops. Different crops and soils have different sensitivities to excess sodium. Some crops are classified as sodium sensitive (green beans, lentils, corn) and others are classified as tolerant (alfalfa, sugar beets, barley) (Ayers and Westcot, 1994).

Plants can uptake excess sodium from water both in their root zone and through absorption of high sodium water sprayed on their leaves. A notable mechanism of sodium exposure to crops in dry climates is poorly managed sprinkler irrigation with high sodium water. When high sodium irrigation water is applied in warm, dry conditions the water evaporates from the leaves, concentrating the sodium in the water and causing leaf burn in sensitive plants. Leaf burn can be effectively minimized through two mechanisms: applying lower sodium irrigation water or changing irrigation practices to minimize evaporation. There is no evidence that sodium toxicity is a major concern for Minnesota crops statewide. For example, the UMN extension service does not have any information on its website on managing for excess sodium in Minnesota. This is in marked contrast to states such as Texas and California that have widespread issues with excess sodium in crops and have published guidance manuals to address sodium in irrigated crops.

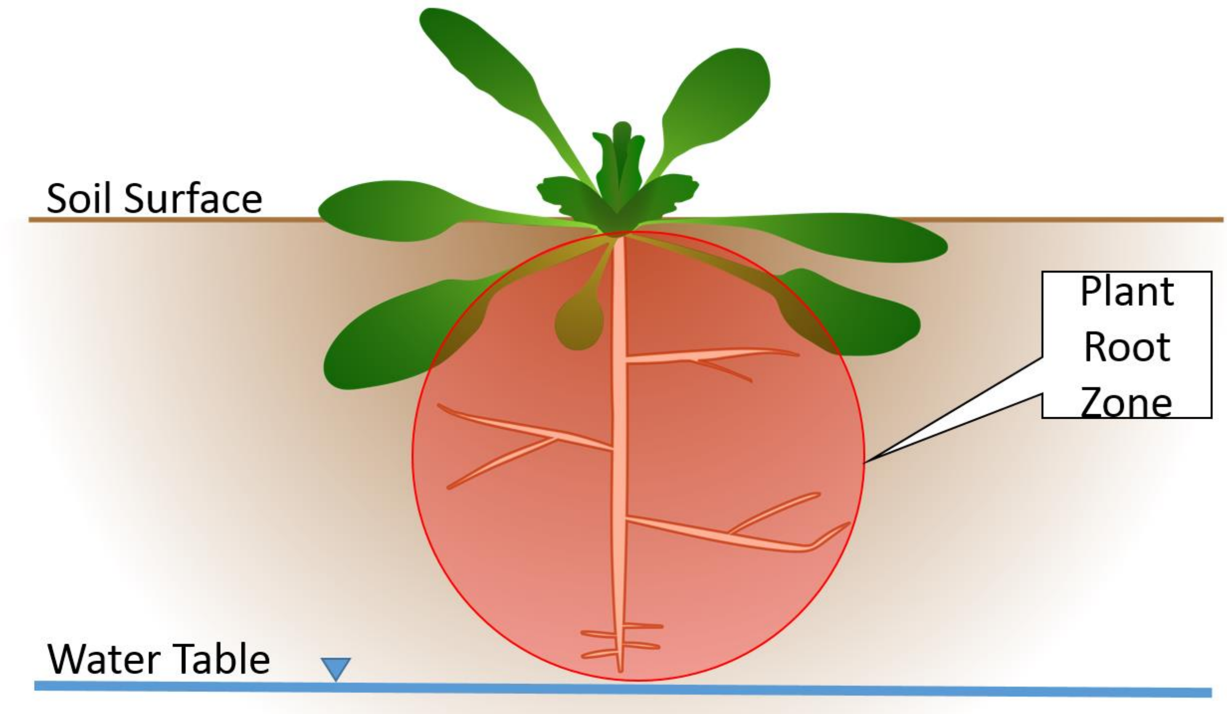
Sodium toxicity to crops is reduced when high amounts of calcium or magnesium are also present in the water (Ayers and Westcot, 1994 and ASAM, 2011). For example, gypsiferous soils, with high amounts of calcium, can better tolerate high sodium content in irrigation water than soils with low calcium content (Ayers and Westcot, 1994). The sodium content of an irrigation water is frequently assessed using the sodium adsorption ratio (SAR). This is a ratio that looks at the relative abundance of sodium in proportion to the amount of calcium and magnesium present. The sodium irrigation water quality literature suggests that protecting soil health from excess SAR will also provide protections for direct sodium toxicity to plants. SAR values that are protective of soils will also tend to have sodium concentrations that are also protective of general crop toxicity from excess sodium. Therefore a SAR value protective of a given location's soils will also provide generalized protections from excess sodium to crops.

Minnesota has a wide variety of soils and crops with different susceptibility to excess sodium in irrigation water. It is difficult to pick a single metric that is neither under protective nor over protective of excess sodium considering the wide variety of crops and soil conditions these crops are grown in. A more in-depth examination of the effects on sodium on soils can be found below in the soils section.

Specific Conductance or Total Salinity—Magnitude

Almost every irrigation water quality manual or guidance document available contains general reference tables that list the sensitivities of various crops to excess total salinity. These general reference tables for irrigation water quality values are meant to protect for the water quality a plant experiences in the rooting zone of the crop of concern. Most Plants process water into their tissues at the root zone, not through the leaves or above ground plant surfaces. Plants can absorb salts into their tissues from water on their leaf surface and this can be a major mechanism of decreased crop yield in warm, dry climates when spray irrigation is being used (ASAM, 2011). All of the irrigation water quality values in the tables discussed below are meant to ensure appropriate water quality in the rooting zone of the plant (Figure 13 below). Toxicity of salinity associated with leaf absorption was not considered in this analysis because Minnesota has a colder and wetter climate than climates where crop salinity absorption through leaves is a major concern, so protecting for root zone salinity will also protect for leaf absorption toxicity.

Figure 13. Schematic representation of a plant showing the root zone of the plant. Only high salinity water in the soil matrix of the root zone of the plant has the potential to affect the crop yield threshold.



Irrigation salinity reference tables list the sensitivity of common crops in the units of Electrical Conductivity (EC_w) of irrigation water at which no appreciable decrease in crop yield would occur. This is called the yield threshold value. Electrical conductivity or specific conductance is an indirect measurement of the total dissolved salt content of a water and does not assess the relative abundance of the types of salts that are present in the water. Table 13, below, shows the root zone yield thresholds of select crops. The values in the table are predicated on specific assumptions such as consistent soil types among the crops in question, similar water table elevations, consistent irrigation practices, and water quality ionic composition; they do not account for natural rainfall that might limit the need for supplemental irrigation. These assumptions control for important variables in order for the irrigator to understand the relative sensitivities of various crops to excess salinity in irrigation water.

The table below shows that some crops are up to seven times more tolerant of general salt content than other crops (e.g., strawberries vs. sugar beets). The table also shows that there is uncertainty as to the exact yield threshold for some crops (blackberries) due to the lack of agreement between the values in the three reference tables.

Using the reference tables below, the MPCA could decide to take a conservative approach and protect irrigation water quality salinity for the most sensitive crop to salinity. Choosing the most conservative number in the table (< 0.5 dS/m for blackberry irrigation) would be protective of all other crop irrigation needs. However, choosing the most protective value would be significantly over protective for other crops in Minnesota and give the impression that every type of crop needs water of very low salinity level to grow productively. The existing background water quality for surface water specific conductance values across the state is shown in Figure 46 and it demonstrates that there are many areas of the state (i.e. southwest MN) where surface water specific conductance values naturally exceed 0.5 dS/m (500 µS/cm).

Table 13. Yield threshold of select Minnesota crops found in three irrigation manuals. The yield threshold represents the value of electrical conductivity of the water in the rooting zone at which no decrease in crop yield would occur.

Crop	**Reference Table of Yield Thresholds EC_w (dS/m)**		
	ASAM	UMN 2010 Report	Texas A&M Irrigation Manual
Strawberry	1	0.75 - 1.0	1
Blackberry	< 0.5	1.5	---
Potato	1.7	1.0-2.0	1.7
Corn	1.7	1.7	1.7
Soybean	5.0	5.0	5.0
Sugar Beet	7	7	7
Wheat	6	6	6

The yield threshold numbers listed above are distillations and simplifications of complex and finely detailed agricultural crop yield studies. An examination of the literature supporting the yield threshold values in the above tables generates a more nuanced view of the accuracy of the yield threshold values in these tables. The quote below from ASAM, 2011 summarizes this well and reminds the reader that yield threshold values can have considerable uncertainty because of the complexities and difficulties of accurately and precisely performing this type of crop yield research.

> *There is considerable uncertainty regarding the yield-threshold soil salinity values…Despite intense control of salinity and all other important variables related to plant yield in salt tolerance trials, for many crops the standard errors can be 50% to 100% percent of the best-fit threshold value. (ASAM, 2011)*

Another confounding consideration to the values in the table above is that the majority of salinity yield threshold studies used sodium chloride (i.e., table salt) to increase the electrical conductivity of the irrigation water in the studies. Not accounting for the ionic composition of a high electrical conductivity irrigation water could give a false impression that the high electrical conductivity itself makes the water unsuitable for irrigation for the crop of concern. Instead, effects may be due to the specific ion at issue. As an example, most Minnesota irrigation comes from waters whose ionic composition is naturally dominated by sulfate and bicarbonate salts; in general, sodium chloride salts are naturally low in concentration statewide. Generally, chloride is typically more toxic to plants than sulfate or bicarbonate (ASAM, 2011). Therefore, using readily available reference values that do not consider the type of ion present in the irrigation water could give a false impression that a given crop needs a specific level of water quality with respect to electrical conductivity. For example, sensitive nursery crops in Israel and the Netherlands have been successfully irrigated using irrigation water of high electrical conductivity (> 3,000 µS/cm) as long as the sodium and chloride content was also low (ASAM, 2011).

Additionally, excess salinity is not always bad for crops. Excess salinity can improve the taste and nutrition of crops (Bernstein and Ayers, 1953; Mizrahi and Pasternak 1985), such as by making them contain more antioxidants (Grieve, 1994). All of this can translate into economic advantages. A quote from ASAM (2011) captures this well:

With proper management practices, it is likely that economic losses associated with yield reductions due to salinity may be offset by production of high-quality food crops that can be marketed at a premium to meet the changing demands of the market and health conscious consumers.

Strawberries present a good case example, illustrating the difficulties and complexities of interpreting salinity irrigation literature to find an appropriately protective yield threshold salinity value for a crop in Minnesota.

Strawberries are generally one of the more salt sensitive crop species (Haifa Group, 2016). Salinity damage can be due to high concentrations of salts in the root zone of the berry, the accumulation of specific ions to toxic levels in plant tissue, or imbalances in salt ion ratios. The protective yield-threshold value for strawberry seems to vary. A team of Brazilian researchers published a study indicating mild salt stress improves strawberry fruit quality (Galli et al., 2016). A separate team of researchers showed that some genotypes of strawberries were not particularly sensitive to salt stress while other genotypes were quite sensitive to salt (Garria et al., 2015). Surprisingly, strawberries can tolerate fairly high salinity levels in irrigation water as long as those high salinity levels do not come from sodium chloride salts (Ferreira et al., 2018). Additionally, the AWWA research foundation (Thompson et al., 2006) recommends a specific conductance yield threshold value for strawberries of 500 µS/cm, while the (ASAM, 2011) recommends a value of 1000 µS/cm. A protective specific conductance yield threshold value of approximately 1000 µS/cm could be set for strawberry root zone water quality provided that chloride concentrations are also below approximately 100 mg/L and that the soils being irrigated are amenable to irrigation. But the data available in the literature also justifies setting a protective specific conductance irrigation value at 900 or 1100 µS/cm. While MPCA always deals with uncertainty in setting water quality standards, an additional factor here is that certain farmers might prefer to irrigate with water of higher salinity or specific salt ion content to increase the aesthetic value of their crops. Matters of fruit aesthetics would be difficult for the MPCA to account for when selecting a protective number for strawberries.

The conflicting literature values for strawberry irrigation make it difficult to calculate an appropriate yield threshold value for the parameters that are likely to truly impact strawberry irrigation water quality across the strawberry genotypes of concern in Minnesota. However, it would be nearly impossible to perform this level of research for every possible crop and crop genotype that could be grown in Minnesota. It would be even more challenging to make the correct discretionary best professional judgement call for the appropriate irrigation water quality values for each crop and crop genotype.

Specific Conductance or Total Salinity—Duration

The above section dealt with the magnitude of salinity-related effects on crop irrigation. Another consideration is the duration of that magnitude. The duration is the interval of time that a crop can tolerate being exposed to a specific concentration of salinity in irrigation water without adverse effects.

Understanding the duration of time a given crop might be able to tolerate high salinity is complicated by the fact that most plants tend to vary in their sensitivity to salinity over their life cycle. A given crop will generally be more sensitive to high-salinity irrigation water during the emergence and early vegetative development stages than during more mature phases of the plant's life.

Annual crops tend to be more sensitive to short periods of high salinity because annual crops must pass through all life stages every year. Perennial crops tend to be less sensitive to periods of high salinity because they spend longer periods in the mature phases of their lives, during which they are generally less sensitive to high salinity. The research on the subject of crop yield threshold duration tends to produce complicated and unintuitive results that vary by plant species and even plant genotype within a species. For example, peppers tend to respond to seasonal mean soil salinity whereas tomatoes are more sensitive to short periods of high salinity. As another example, protective root zone salinity for plum trees should be integrated over a two season period rather than a single season (Catlin, et al., 1993).

The ASAM states that “mean soil seasonal salinity is probably a reasonable estimate” unless better information is available for a given plant. Seasonal, in this case, would mean May to September – the typical growing season in Minnesota.

Specific Conductance or Total Salinity—Frequency
The frequency of a crop yield threshold value is how often the magnitude and duration can be exceeded. For example, a crop might experience no decrease in yield as long the root zone electrical conductivity (magnitude) is not exceeded over a seasonal average (duration) not more than once every three seasons (frequency).

The irrigation literature on the subject of crop yield threshold frequency is less robust than the literature on crop yield threshold magnitude. This seems to be because determining crop yield threshold frequency requires irrigation studies to be performed over multiple growing seasons and multi-season studies are more expensive and difficult to perform than studies performed over a single growing season.

It would stand to reason that the crop yield threshold frequency for annual plants is, at a maximum, once per annual growing season. That is, that a certain level of a problem parameter could be exceeded once per growing season without impact. The literature is unclear how frequently specific annual crops can withstand high salinity irrigation water within a growing season but it is clear that different species of annual crops will have different responses to being frequently exposed to high salinity irrigation water.

Perennial crops can recover from periods of high salinity water in their root zone but it can take several years to do so (ASAM, 2011). For example, plums trees exposed to several years of high salinity irrigation water in the central valley of California were able to recover after a two year period of low salinity irrigation (Catlin et al., 1993).

Critical Local Factor: Soil Type

Takeaway
Understanding the soil type is a critically important factor when evaluating a given location’s suitability to receive irrigation water of a specific quality. Different soil types have very different abilities to receive irrigation water of poor quality, and Minnesota has a substantial heterogeneity in soil types at both large and small scales. Given the heterogeneity of Minnesota soils, it is impossible to develop a single numeric value that is appropriately protective of all Minnesota soil types. The MPCA could take the approach of protecting for the most sensitive soils using a single numeric value, but this would be unnecessarily protective of less sensitive soils.

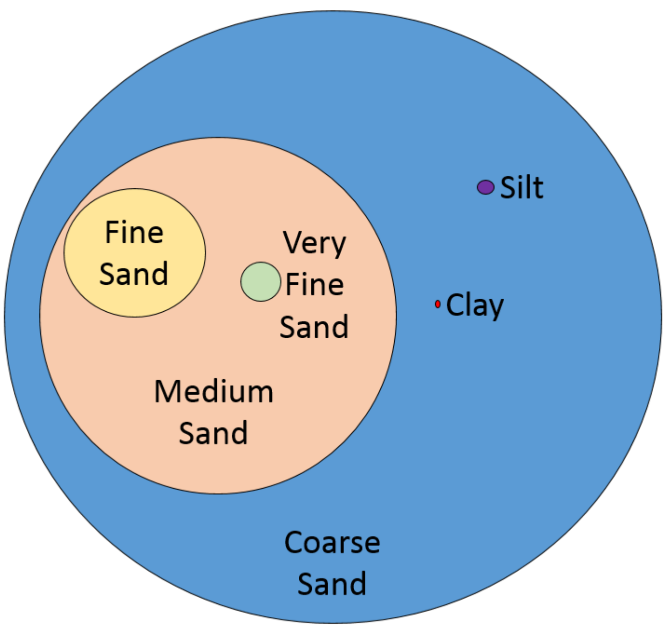
Soil Health
Healthy soil is essential for plant growth. Soil is a complicated mixture of organic matter, mineral compounds, gases, water and organisms that combine to allow plants to effectively grow. There are innumerable ways to characterize soil health, so this section will consider the soil health parameters most likely to be affected by salinity related parameters. The two most important parameters to consider when evaluating soil health with respect to irrigation water are clay content and soil texture.

Soil Texture and Salinity

Soil texture is important in understanding what type of water and how much salinity is present in the root zone of the plant. Knowing the soil texture helps predict whether a crop will experience negative effects from irrigation water with elevated salinity. In general, finer soils with a high percentage of clays or silts are more susceptible to negative effects from irrigation water with elevated salinity than coarser, sandier soils.

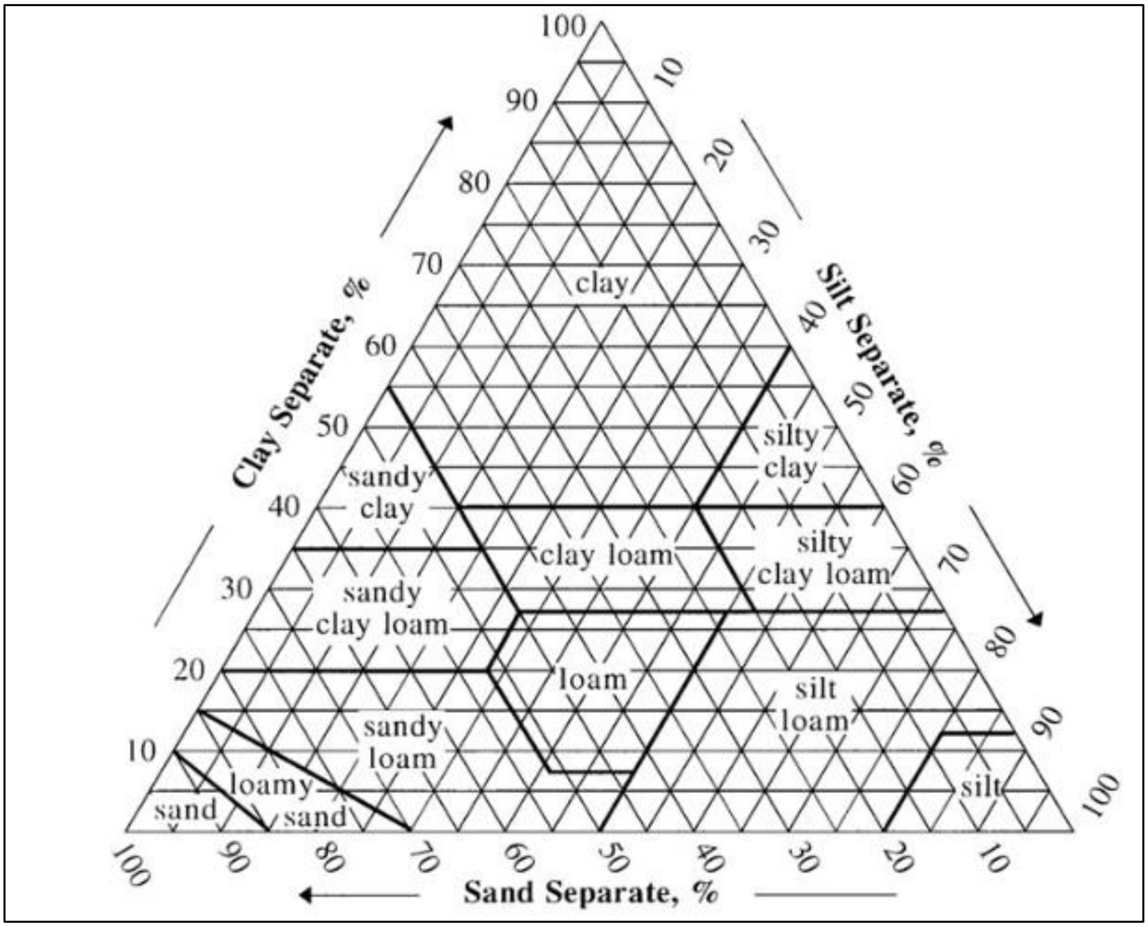
Soil texture analysis is a method to classify soil based on the physical properties of the particles of the soil. The USDA classifies soils based on the percentages of sand, silt and clay present in the soil. These soil texture classes are based on the diameter of the particles in the soil; the diameter of the particle determines whether it is a sand, silt or clay (Figure 14). Once the relative abundance of the sand, silt and clay fractions have been determined in a soil sample, the USDA uses the concepts in the soil triangle (Figure 15) to classify the soil into a major soil texture class based on relative abundance of sand, silt and clay. Once the general soil texture class is known, the USDA has more advanced methods to further categorize the soil into more detailed soil texture subcategories. These soil texture subcategories are described and visualized in the section below titled "Minnesota soil types and the Soil Survey Geographic Database (SSURGO)".

Figure 14. Soil texture classes and their respective diameters. The image is not to scale; clay particles are so small they would be invisible to the human eye at this scale.



Soil Texture	USDA Diameter (mm)
Clay	less than 0.002
Silt	0.002 - 0.05
Very fine sand	0.05 - 0.10
Fine sand	0.10 - 0.25
Medium sand	0.25 - 0.50
Coarse sand	0.50 - 1.00

Figure 15. USDA soil triangle used to classify a soil into a major soil texture class. This system uses the percentage of clay, silt and sand in the soil to classify the soil into classes of soil texture.



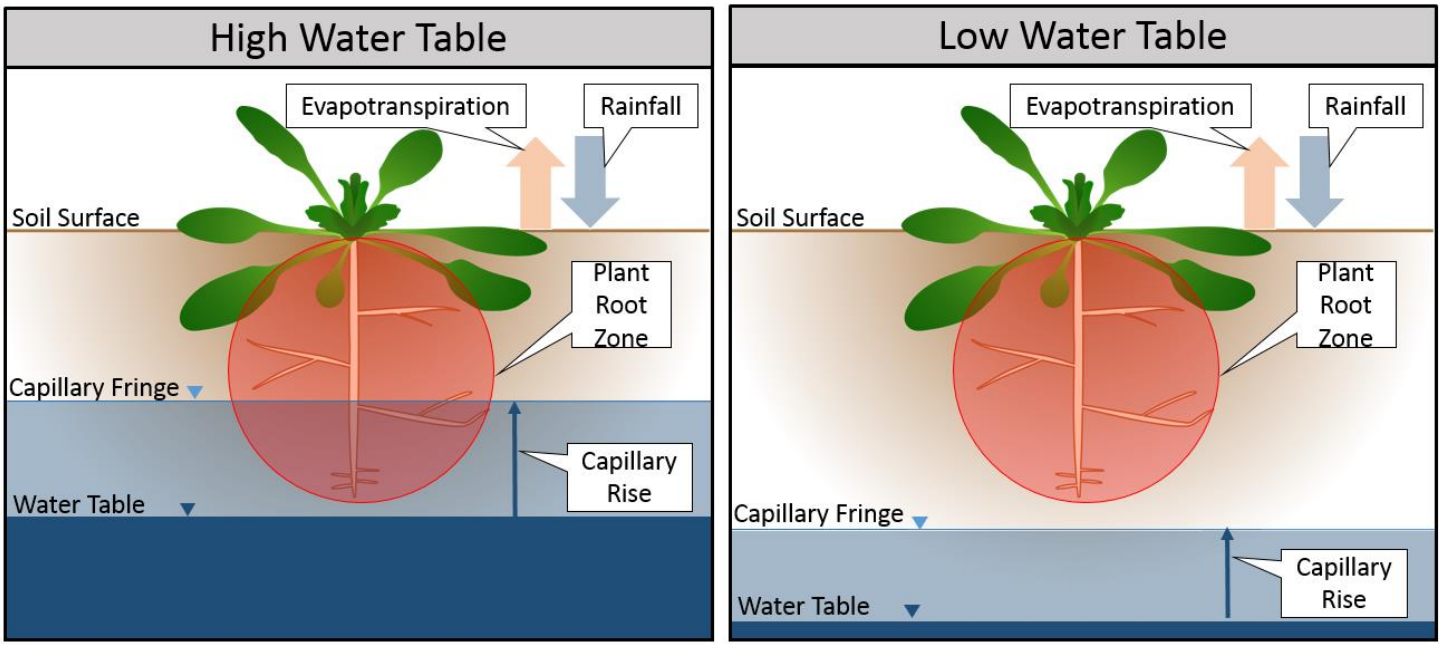
The soil texture is a critical determinant of the moisture content and water quality in the root zone of a plant. Because all plants need some degree of moisture in their root zone, it is important to understand the ways moisture can enter or leave the root zone of a plant and the ways soil texture affects soil moisture.

There are three main ways water moisture can enter or leave the root zone of a non-irrigated plant: rainfall, evapotranspiration, and water table interactions including capillary rise (Figure 16). The amount and salinity of moisture in the plant root zone is a function of the same methods. These three methods all have different effects on the salinity in the root zone of the plant, as defined and explained below.

- Rainfall – The amount of moisture entering the soil surface. Rainfall is functionally devoid of mineral salts and percolates downward through the root zone leaching minerals from the soil. Rainfall tends to decrease salinity in the root zone.
- Evapotranspiration – The summed amount of water leaving the plant and soil from either physical evaporation at the soil surface or plant transpiration of water. Evapotranspiration causes capillary rise by creating a moisture gradient from the water table to root zone of the plant. Evapotranspiration can increase root zone salinity if the water table has high salinity water and that high salinity water is wicked into the root zone.
- Water Table – The soil zone were the open pores of the soil are fully saturated with water.

- Capillary Rise – The ability of water to wick upward through soil pore structure against gravity.
- Capillary Fringe – The upper height above the water table that can wick upward through the soil from the water table. The height is a function of soil texture; finer textured soils will have a taller capillary fringe.

Figure 16. Schematic diagram of ways moisture and salinity can enter the plant root zone of a non-irrigated plant. The amount of moisture in the plant root zone is a function of rainfall, evapotranspiration, water table elevation and the height of capillary rise. The left figure shows how the water table overlaps the root zone when the water table is high. The right figure shows how the water table does not overlap the root zone when the water table is low.



Different soil textures have very different abilities to wick water into the water table. Finely textured soils with high percentages of silts create a capillary rise two to three times greater than coarser soils with more sand (Figure 17). In general, soils with high clay percentages do not allow for rapid movement of water into the root zone and plants do not grow well in them. If the water table has elevated salinity levels and the water table interacts with the plant's root zone, then those water table interactions would cause salinity stress on the plant.

Figure 17. Figure 1 from the North Dakota State University Extension Service publication (NDSU Extension 2018). The figure shows how capillary rise is greater in finely textured soils with less pore volume than in coarsely textured soils with larger pore volumes.

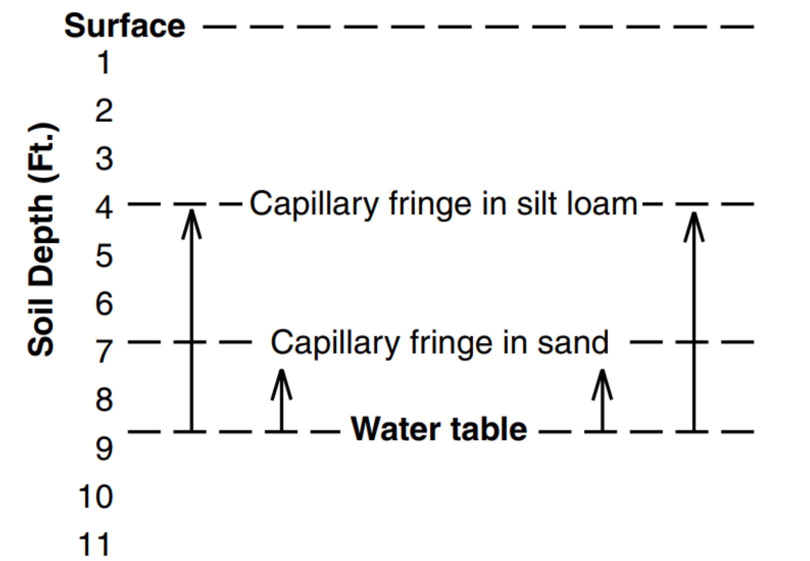


Figure 1. Capillary rise from a water table depends on soil texture. Capillary rise will extend higher in a silt loam, silty clay loam and a very fine sandy loam than in a clay, clay loam or sand.

Clay Content, Sodium and Soil Texture

Soils with a high content of clay or silt particles are particularly sensitive to irrigation water with high sodium content; this phenomenon has been extensively documented in irrigation literature (ASAM, 2011). A high sodium content in the soil matrix interacts with the soil clay particles and causes the clay particles to swell and absorb excess water. This swelling reduces the pore volume of the soil matrix and “closes” the soil structure, preventing the flow of water and making it difficult for plant roots to penetrate the soil and grow. Soil pore waters with high total mineral content and low sodium content do not cause clay swelling and the associated negative effects on crops (ASAM, 2011). Knowing the clay content of soil is necessary to understand whether the soil is amenable to irrigation with water of high sodicity.

Modern soil and irrigation literature considers the sodium adsorption ratio (SAR) to be the appropriate soil and water quality parameter to ensure soils and crops are not exposed to excess sodium from irrigation water. Some irrigation guidelines recommend the use of the adjusted SAR, which is a more complicated and precise version of the SAR that uses pH, partial pressures of carbon dioxide gas in soils and ionic strength to consider in the potential of calcium to precipitate in high carbonate soils. The standard SAR is suitable for typical irrigation waters (Lesch and Suarez, 2009) and is a much simpler calculation than the adjusted SAR. The adjusted SAR will not be further evaluated due to its additional computational complexity and the general protective nature of the conventional SAR.

The protective SAR for a given soil is a not just a function of soil type but is also a function of crop selection, climate, drainage management and irrigation practices. For example, a video produced by the North Dakota State University (NDSU) extension service shows how managing for high sodium and salinity content is not as simple as solely considering soil texture, but requires considering other factors; using appropriate cover crops and managing for appropriate drainage can protect from excess salinity and sodium content in the root zone of soils.[5]

As a general rule, irrigation waters with low SAR values are more protective of crops than high SAR values, but the exact protective SAR value for a given location is site-specific. For example, when very low SAR waters (SAR < 3) are exposed to clay soils that are already salinized with excess sodium, the low SAR water can cause immediate soil sealing so that there is no functional water infiltration, which negatively affects the soil structure for growing crops (ASAM, 2011 and Ayers and Westcot, 1994). For soils that have low salinization risk (i.e., the majority of Minnesota soils; Figure 27 in soil chemistry section below), a SAR value of less than ten in irrigation water would generally be protective (NDSU Extension, 2018; Texas A&M Extension Service, 2003). However, for soils with a moderate or high salinization risk, a SAR of less than six in irrigation water is likely to be protective of soils under appropriate soil management conditions (NDSU Extension, 2018). If soils with moderate salinization risk were not well managed through poor irrigation, drainage and cropping, a SAR of less than three might be needed to ensure protection (ASAM, 2011). The rationale for the numbers in this paragraph are further explained in section 10 of the narrative translator document below.

Appropriately accounting for all of the possible crops, soil conditions, and drainage conditions found in Minnesota would produce a prohibitively large and convoluted spatial table of protective SAR values that would identify the protective values for each individual soil map unit in the state. Developing this table would be a large and complex effort, and it would be difficult to implement on a landscape scale. The MPCA could take the approach of protecting for the most sensitive soil conditions and select a singular statewide numeric SAR value (i.e., < 3 SAR for areas with soils of moderate salinity risk that are poorly managed), but this approach would be overly protective for every other soil condition statewide. Using this conservative approach has some drawbacks; for example, the MPCA does not believe that it is appropriate to develop water quality standards that require irrigators to use specific farm practices. A general narrative standard allows flexibility to consider site-specific factors and ensure appropriate protection of the irrigation designated use more so than a numeric standard.

Minnesota Soil Types and the Soil Survey Geographic Database (SSURGO)

Takeaway

Minnesota soils are very heterogeneous and can vary substantially in type and texture within a small area – even any given farmer's fields. Because different soil types require different irrigation water quality, it is challenging to pick one numeric value that is appropriately protective of all Minnesota soils. To be appropriately protective of Minnesota soils for irrigation, it is necessary to consider soil at a very localized scale. The flexibility inherent in a narrative water quality is the most appropriate way to make these localized considerations.

Minnesota's diverse range of soil types can support different types of agricultural production and irrigation practices. The soil types present in a given location are a general reflection of natural geology. Soil types can be categorize using characteristics of interest ranging from parameters measured directly, such as slope or surface texture, to calculated parameters, such as ponding frequency or salinization risk.

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[5] Available at https://www.youtube.com/watch?v=ZVKJqk9O8dA

The scale of the landscape being evaluated is important to consider. Soil types follow general geographic patterns in Minnesota that allow for broad classifications of soils at the statewide scale. The Minnesota Department of Agriculture has developed maps that categorize the Minnesota landscape into 39 agroecoregions (Figure 18). Each agroecoregion is associated with a specific combination of soil types, landscape and climatic features, and land use. Agroecoregions are units that have relatively homogeneous climate, soil and landscapes, and land cover. Agroecoregions can be associated with a specific set of soil and water resource concerns, and a specific set of management practices to minimize the impact of land-use activities on soil and water resource quality.

The 39 Minnesota agroecoregions are not perfectly descriptive of where MNDNR irrigation water appropriation permits occur on the landscape. For example, the "alluvium and outwash" agroecoregion class in central Minnesota is strongly associated with high groundwater irrigation permit density but the same agroecoregion class in the arrowhead of northeastern Minnesota contains zero groundwater irrigation permits (Figure 19). The location of irrigation water appropriation permits can be used as a loose surrogate for the suitability and need of a given region soils for irrigation (Figure 19). This reflects the assumption that farmers have a deep understanding of their farmland and its suitability for irrigation, so they will only invest in irrigation infrastructure if it will provide more benefits than costs. Ultimately, more localized scales of assessment than agroecoregions are needed to understand a specific location's suitability for irrigation.

At the local scales, Minnesota soils have substantial heterogeneity (Figures 20–22). The national cooperative soil survey over the past century has undertaken an extensive soil survey of the nation and made that data publicly available online in the SSURGO database. The data was gathered by walking over the land and observing the soil, the use of aerial mapping, and extensive collections of soil data analyzed in laboratories. The fundamental geographic spatial unit of SSURGO is the soil map unit. The map units describe soils with continuous and unique properties, interpretations, and productivities. An example of the detailed mapping of soil units is provided in Figures 20–22. Figure 20 shows the large number of individual polygons representing individual soil map units in a farming area of several square miles in central Minnesota. Figure 21 shows how the predominant soil texture of each map unit within this central Minnesota area and demonstrate the substantial heterogeneity of soil textures within a single farm field. Figure 22 shows how the SSURGO database uses the properties of each individual map unit to develop rankings that rate each map unit into its suitability for farming under specific farming practices.

Figure 18. Minnesota Agroecoregions determined by the Minnesota Department of Agriculture

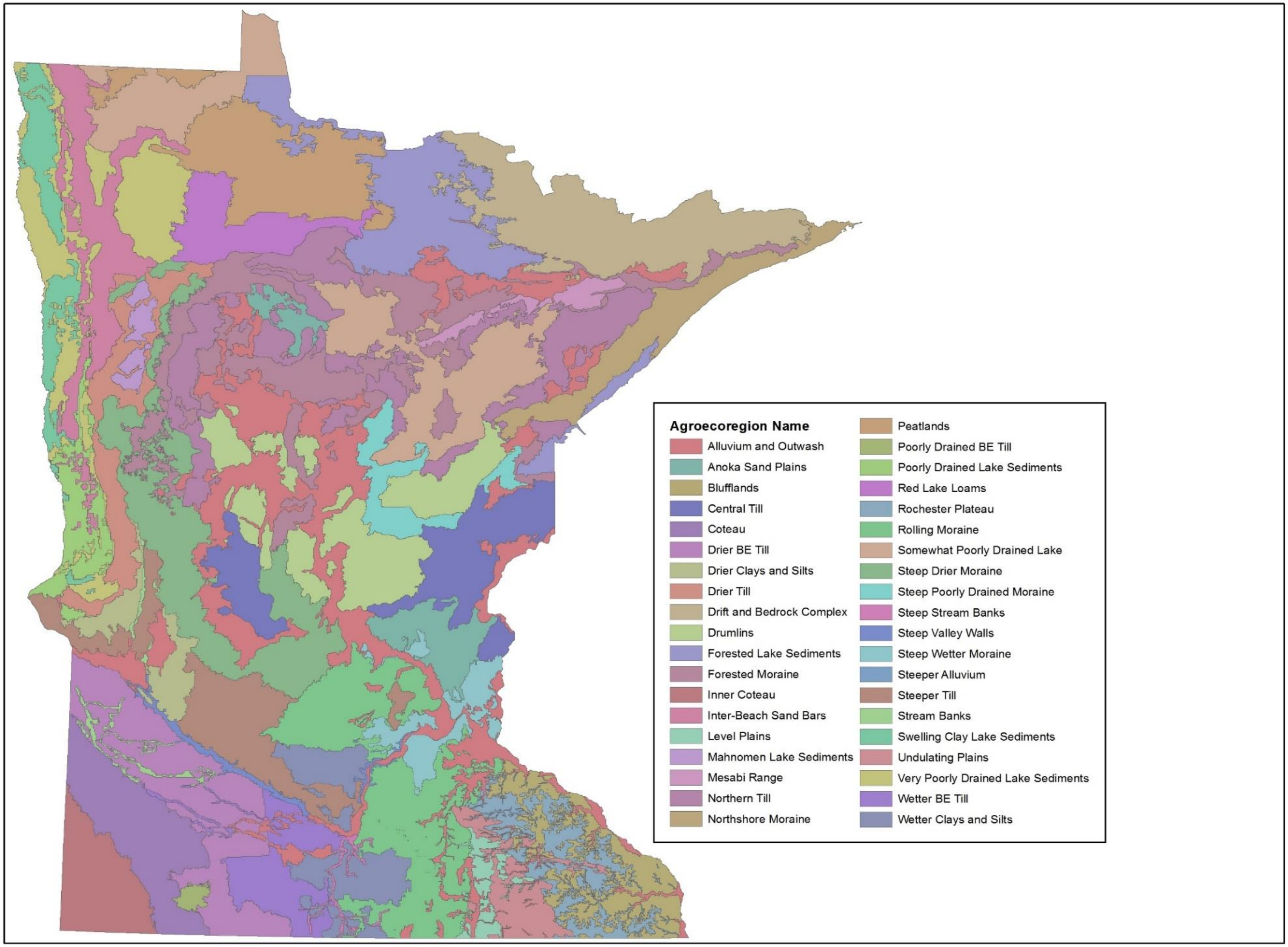

Figure 19. Minnesota Agroecoregions determined by the Minnesota Department of Agriculture. Active MNDNR irrigation water appropriation permits are shown. Black dots are active groundwater irrigation permits and red triangles are active surface water irrigation permits.

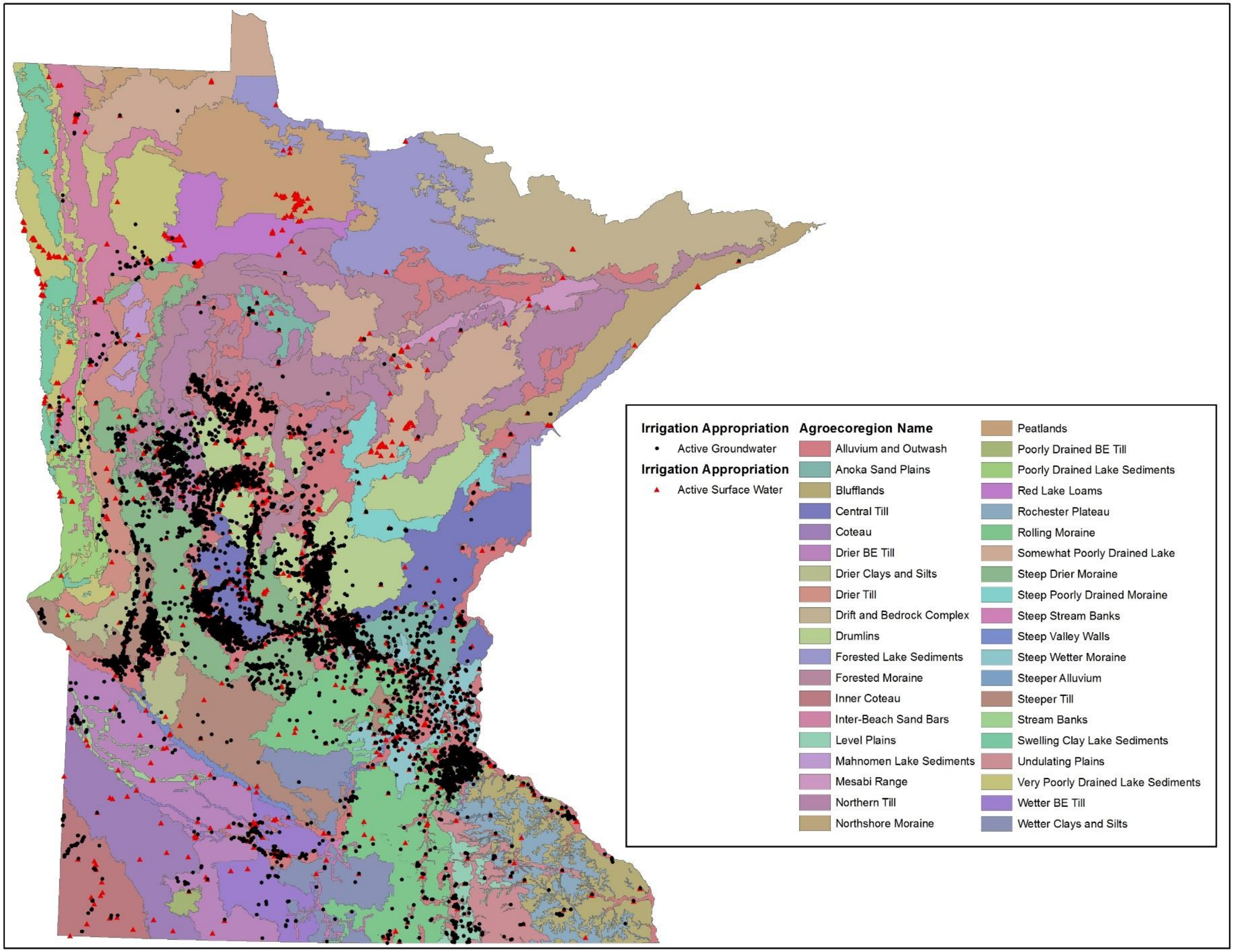

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Figure 20. Soil map units in the SSURGO data set in central Minnesota farmland. Each line represents a soil map unit polygon and has been extensively studied and categorized. This example shows the extremely fine resolution and categorization of Minnesota soils.

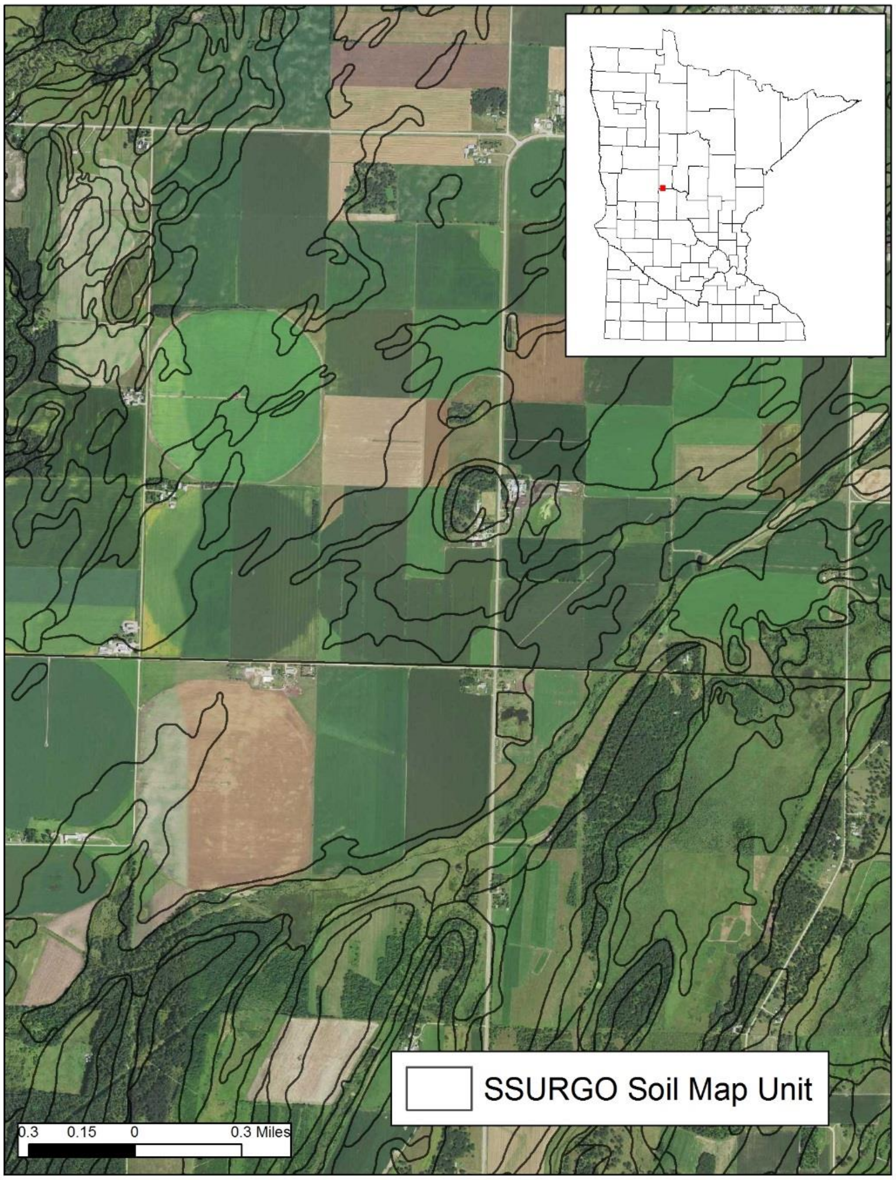


Figure 21. Predominant soil texture of each individual soil map unit in central Minnesota farmland. Soil texture varies substantially over the landscape at a localized scale. This landscape is dominated by sandy loam soil textures.

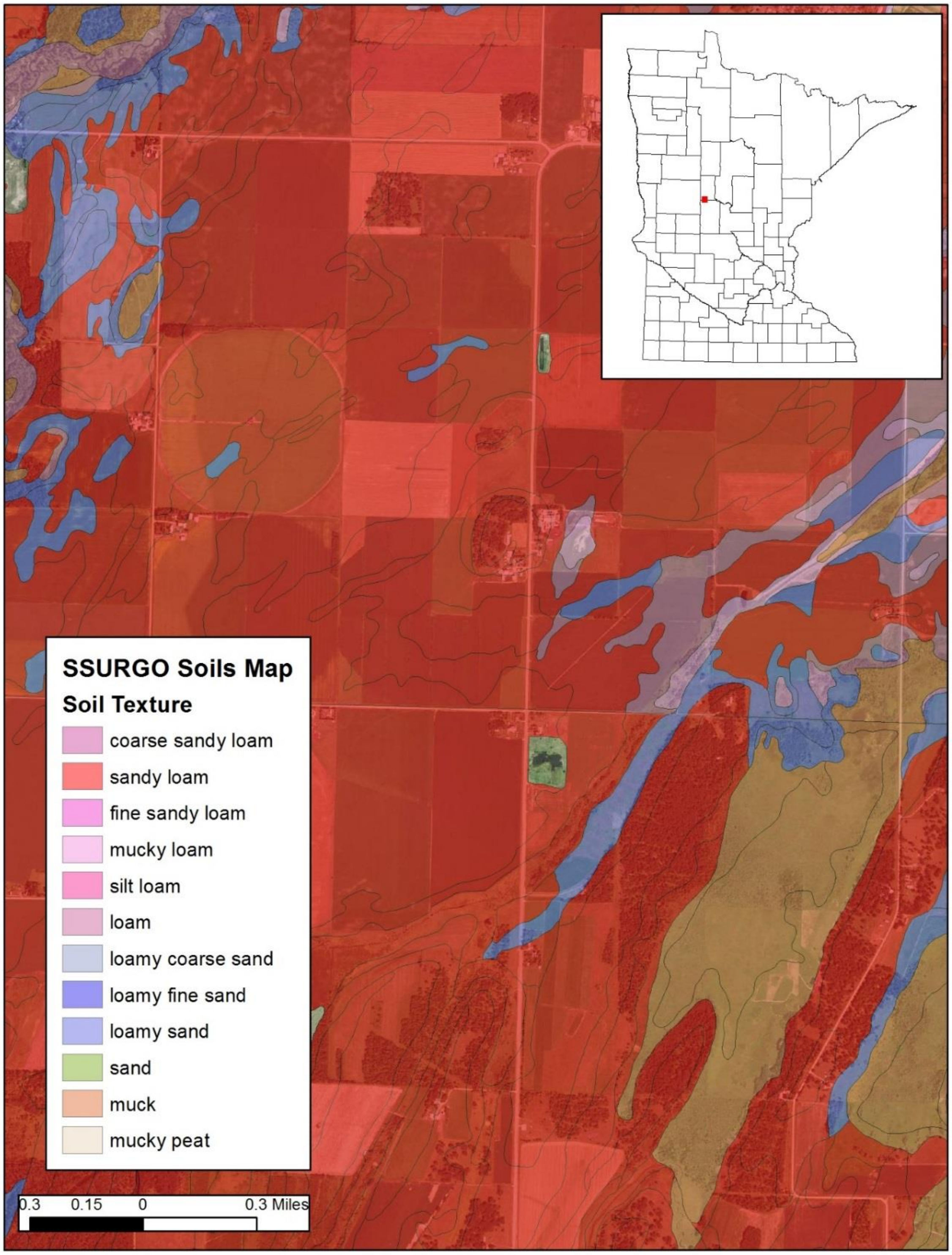
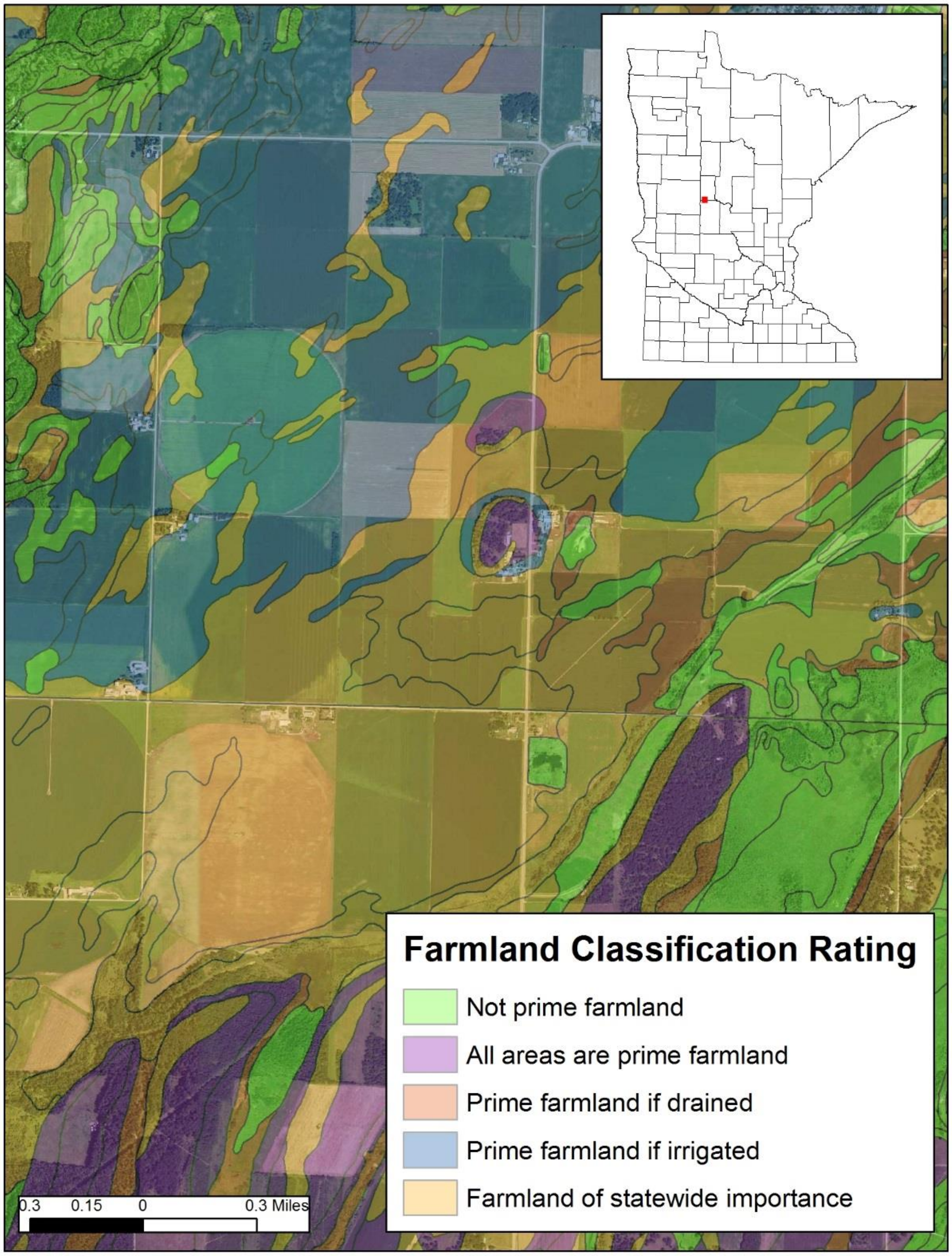


Figure 22. Farmland classification rating of soil map units in central Minnesota farmland. This is an example of how varied Minnesota soils are within a localized landscape. For example, areas of “prime farmland” are immediately adjacent to areas of “not prime farmland” within a single farm field.



Critical Local Factor: Presence of Salinity in Soils

Takeaway

Compared to many other locations nationwide, Minnesota soils have low salinity as expressed by the electrical conductivity of the soils and the SAR. The majority of Minnesota's soils have low salinity and sodium content, with some localized areas of higher salinity. The overall low salinity of Minnesota soils means that statewide, Minnesota soils do not have a soil salinization risk. The soil salinization risk is an assessment that categorizes a soils likelihood of salinizing; a soil with a low salinization risk is unlikely to be salinized under typical Minnesota irrigation practices. There are localized pockets of areas with higher soil electrical conductivity, sodium and salinization risk in the Red River Valley.

Soil Salinity in Minnesota

On a nationwide scale, Minnesota has low salinity soils as expressed by the electrical conductivity of the soils (Figure 23). For example, Minnesota soils are substantially less saline than the soils of the central valley of California, where much of the research in irrigation water quality and salinity has taken place. Salinity varies over the extent of the Minnesota landscape (Figures 24 and 25), with the majority of the state having low salinity except for localized areas in the Red River Valley.

The soil parameter described in Figures 23 and 24 is electrical conductivity of soils. Soil electrical conductivity is an indirect measure of the mineral leaching potential of the soil. Electrical conductivity is measured by taking a sample of soil and then mixing that soil with deionized water that is free of minerals. The ions in the soil matrix that are labile and capable of dissolving, will dissolve into the water and increase the electrical conductivity of the water in proportion to the amount of ions dissolved (ASAM, 2011).

The electrical conductivity of a soil can be thought of as a maximum bound on the electrical conductivity that could be present in the soil (assuming moisture percolating through the soil matrix is ion free rainwater). A plant grown in a soil with an electrical conductivity of 1.0 dS/m, could never experience a soil conductivity of greater than 1.0 dS/m assuming that the only source of water in the soil was mineral free rainfall. Since most of Minnesota has low soil salinity (< 2.0 dS/m), there is less concern about soil mineral leaching impact crop growth than if Minnesota had saline soils like the central valley of California.

Soil Sodicity in Minnesota

Minnesota has low SAR values in most locations statewide (Figure 26) which means that the majority of Minnesota soils do not contribute high concentrations of sodium to water in crop root zones. This means that the majority of Minnesota soils are naturally low in labile sodium that could impact crop production. There are localized areas of higher SAR values in the Red River Valley.

Salinization Risk in Minnesota

The salinization risk is a calculated parameter in the SSURGO dataset and has been assessed at almost every point on the Minnesota landscape (Figure 27). The salinization risk assessment procedures were developed by the USDA-Natural Resource Conservation Service (NRCS). The salinization risk considers soil drainage, flooding and ponding frequency, soil salinity, the potential for water gathering on the soil surface, climate, depth to water table and the persistence of salts in the water table. The assessment categorizes all Minnesota soils into high, medium or low risk for salinization. Definitions of the high, medium and low risks are provided below.

- **High surface salinization risk or already saline** - indicates that the soil has features that are very favorable for the accumulation of salts at the surface or are already saline. These soils are already limited by excess surface salts.
- **Medium surface salinization risk** - indicates that the soil has features that are somewhat favorable for surface salinization. Careful management will be needed to avoid damage from salinity and have the potential for salinization to occur. These soils are not well drained and require appropriate irrigation and drainage management to not become salinized. With proper management, these soils can be productively irrigated especially if salinity tolerant crops are selected to be grown.
- **Low surface salinization risk** - indicates that the soil has one or more features that are unfavorable for salinization. These soils exist in climates where salinization does not occur or on landscape positions where salts are unlikely to accumulate. Soils with a low salinization risk are well drained and have minimal interaction with the salinity in the water table of the soil horizon and are expected to have the potential for consistent flushing of salinity from the root zone due to natural rainfall and infiltration. As a result soils in this low salinization risk category have little potential for soil salinization to occur.

Figure 23. Estimated surface soil salinity from the NRCS of the contiguous USA expressed as electrical conductivity in units of dS/m. Not all locations have been sampled for conductivity and some locations have been

estimated based on soil types and other data inputs. The NOTCOM grey polygons are areas where soil surveys have not occurred yet.

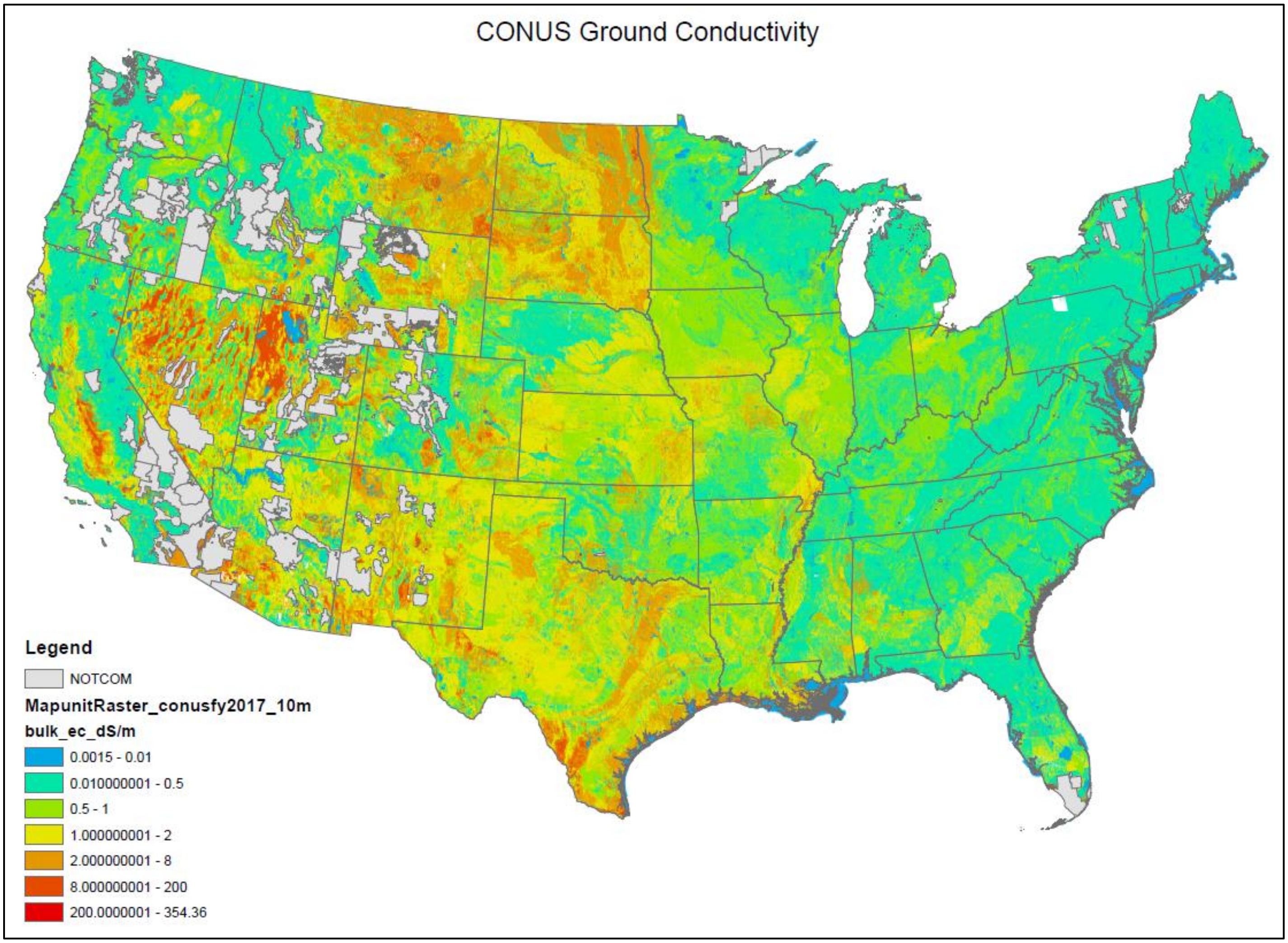


Figure 24. Estimated soil electrical conductivity by the NRCS. Not every soil in Minnesota has been sampled for electrical conductivity and the NRCS used soil characteristics to estimate soil conductivity in unsampled locations. The salinity estimates in the figure below contain soil horizons below the top soil layers. This figure should be used to compare one location to another statewide and not to assess the exact conducitivity of a given location.

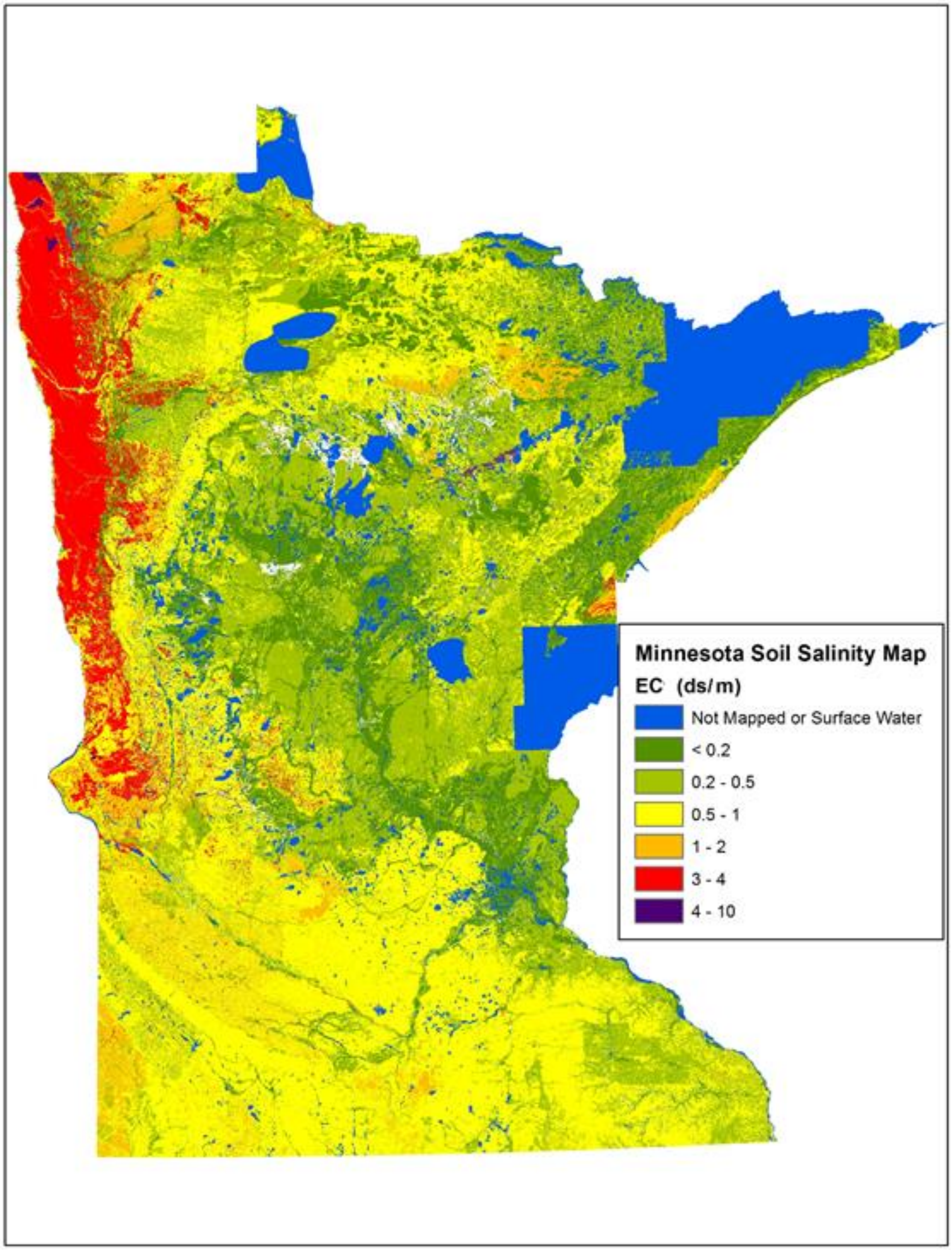


Figure 25. Measured soil conductivty in the SSURGO database in the uppermost soil layer. The NRCS only samples salinity in specific soil map units that have soil types that are associated with increased salinity. The values colorized are the maximum possible value in that soil area.

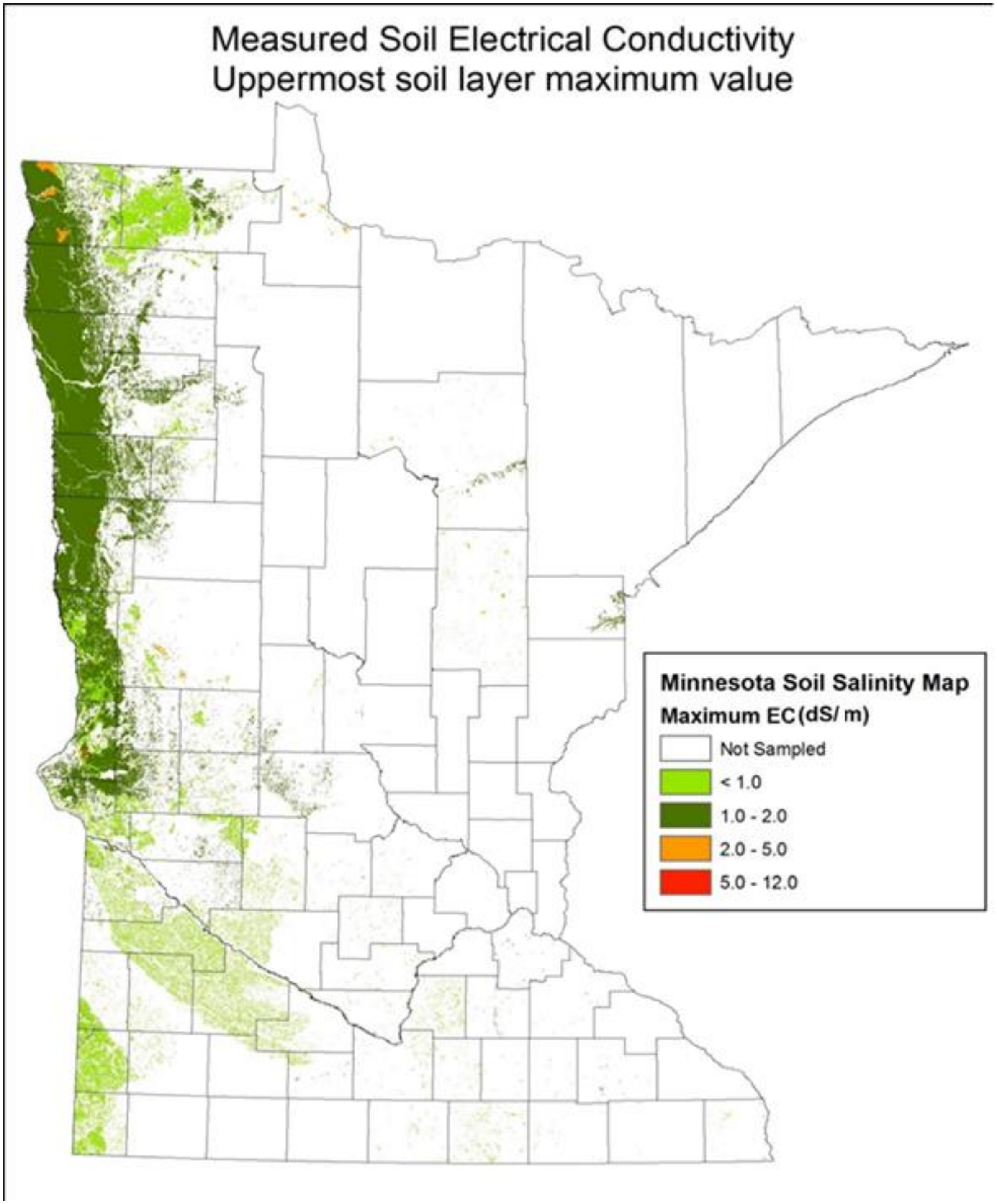


Figure 26. Measured Sodium Adsorption Ratio (SAR) in the SSURGO database in the uppermost layer of soils. The NRCS only samples SAR in specific soil map units that have soil types that are associated with increased SAR. The values colorized are the maximum possible value in that soil area. The areas not colorized are likely to have SAR values less than 1.

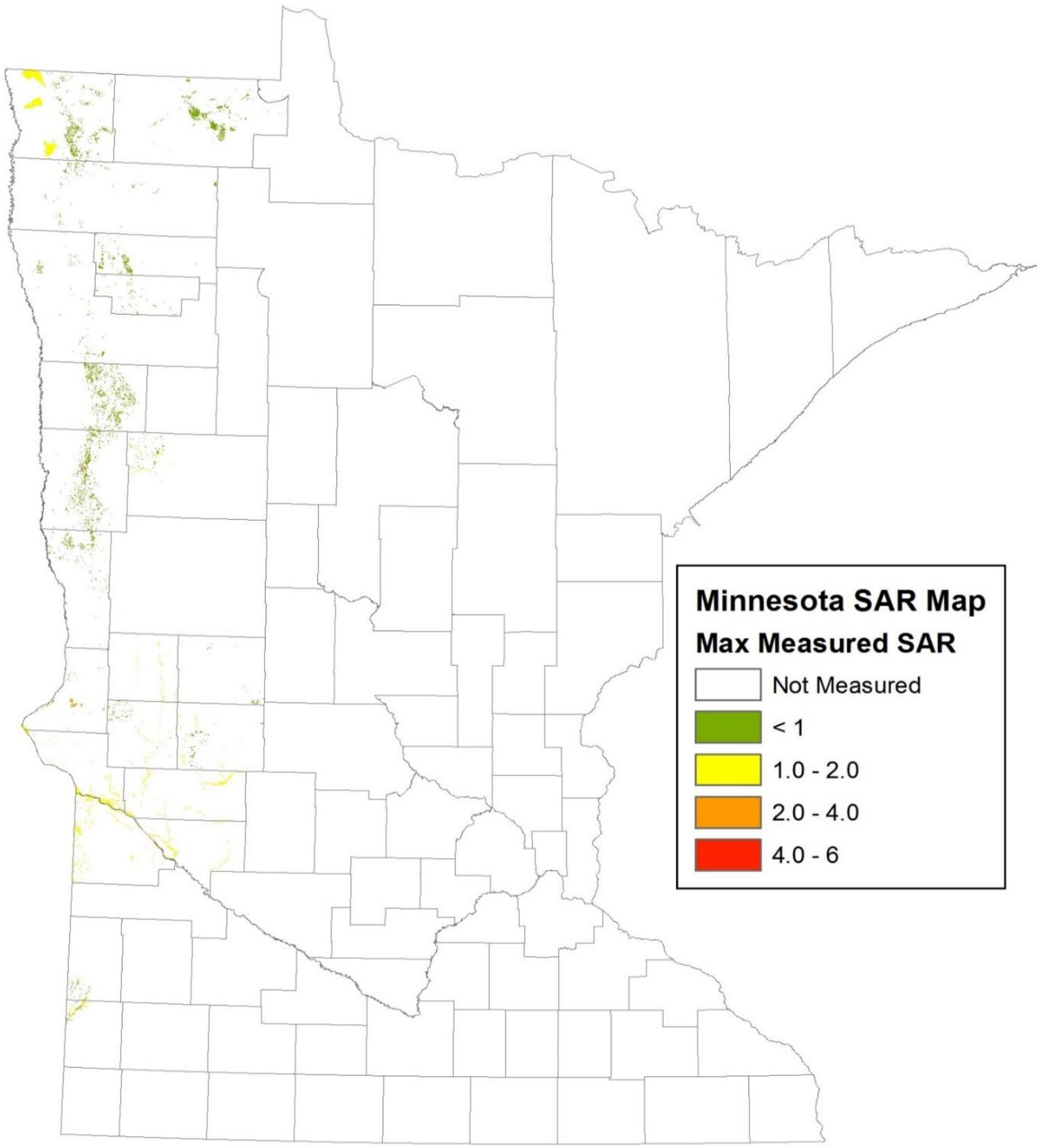
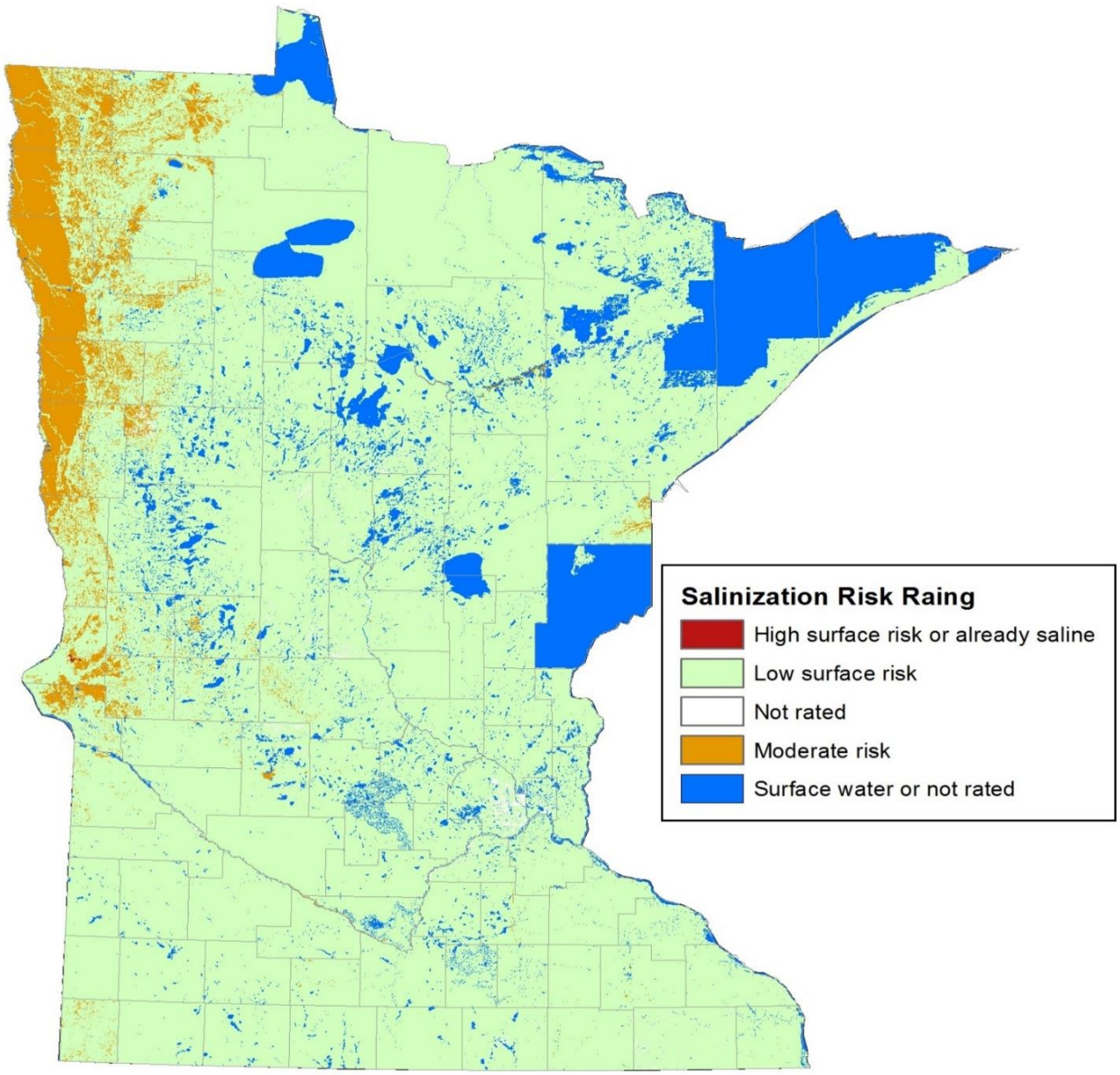


Figure 27. Salinization risk of soils in Minnesota. The salinization risk assessment was developed by the NRCS and assesses the ability of a soil to salinize based on soil type, salinity and other factors. The only area of high risk is Traverse County.



Critical Local Factor: Soil Drainage Management

Takeaway

Soil drainage is the ability of a soil, through either natural or engineered methods, to remove excess moisture from farm fields to allow for crop production. Appropriately managing soil drainage ensures that crops receive the correct quantity and quality of water in their root zone. When selecting protective irrigation water quality values, it is necessary to consider localized soil drainage properties because different types of soils have different capacities to control both water quantity and quality in the root zone of crops. Since Minnesota has such a variety of soil drainage properties and drainage management practices across the landscape, there is no singular protective irrigation water quality value that is appropriately protective of all soils and crops. A narrative water quality standard allows for the flexibility to consider local soil drainage practices when protecting for irrigation water quality needs.

Soil Drainage and Irrigation Water Quality

There are many ways soil drainage can affect the irrigation water quality that can be applied to a field. Soils in natural condition have different capacities to drain excess water from the root zone of crops based on the soil texture and properties. Farmers often used engineered drainage practices to remove excess water from soils; without these engineered drainage practices, many soils would be water logged. The sections below explain the differences between natural and engineered soil drainage and how soil drainage interacts with irrigation water quality.

Natural Soil Drainage

The soil texture is a critical determinant of the water drainage of soils and soil texture ultimately determines the moisture content and water quality in the root zone of a plant. Since all plants need some degree of moisture in their root zone, it is important to understand the ways moisture can enter or leave the root zone of a plant and the ways soil texture affects soil moisture.

There are three main ways water moisture can enter or leave the root zone of a non-irrigated plant: rainfall, evapotranspiration, and water table interactions including capillary rise (Figure 16). The amount of moisture and the salinity of that moisture in the plant root zone is a function of rainfall, evapotranspiration, water table elevation, and the height of capillary rise. These three methods all have different effects on the salinity in the root zone of the plant, as defined and explained below.

- Rainfall – The amount of moisture entering the soil surface. Rainfall is devoid of mineral salts and percolates downward through the root zone leaching minerals from the soil. Rainfall tends to decrease salinity in the root zone.
- Evapotranspiration – The summed amount of water leaving the plant soil from either physical evaporation at the soil surface or plant transpiration of water. Evapotranspiration causes capillary rise by creating a moisture gradient from the water table to root zone of the plant. Evapotranspiration can increase root zone salinity if the water table has high salinity water and that high salinity water is wicked into the root zone.
- Water Table – The soil zone were the open pores of the soil are fully saturated with water.
- Capillary Rise – The ability of water to wick upward through soil pore structure against gravity.
- Capillary Fringe – The upper height above the water table that can wick upward through the soil from the water table. A function of soil texture; finer textured soils will have a taller capillary fringe.

Different soil textures have very different abilities to wick water from the water table. Finely textured soils with high percentages of silts create a two to three time's greater capillary rise than coarser soils with more sand (Figure 17). In general, soils with high clay percentages do not allow for rapid movement of water into the root zone and plants do not grow well in them. If the water table has elevated salinity levels and the water table interacts with the plants root zone, then those water table interactions would cause salinity stress on the plant.

Heterogeneity of Natural Soil Drainage in Minnesota

Minnesota soils have substantial variety in terms of natural soil drainage at both the statewide and localized scale. It is essential to understand the extent of this variety of drainage across the Minnesota landscape in order to understand what types of fields can receive what types of irrigation water quality. As a general rule, well drained soils can receive irrigation water of lower quality than fields with poorly drained soils (ASAM, 2011).

SSURGO has eight different soil drainage classes and these designations are based on the soil texture (i.e., proportion of sand, silt and clay particle) and saturated hydraulic conductivity (i.e., a measure of how fast water moves through the pore of saturated soil column) (USDA NRCS, 2018). The soil drainage class map for the U.S. and the state of Minnesota is presented in Figures 28 and 29, and the NRCS drainage classification criteria is presented in Table 14.

Figures 28 and 29 show Minnesota has a wide variety of soil types across the state at a statewide and localized scale. Figure 28 shows that most of the poorly drained soils are found in the northwest and the southwest/south central part of the state. There is substantial localized diversity in soil and the soil drainage class across the state as presented in the zoomed version of soil drainage class map (Figure 29). Figure 29 shows that at localized scales, the drainage classification of a soil can vary substantially. For example, in Figure 29, soil units of poorly drained soils are often directly adjacent to areas of well drained soils. Therefore, it is necessary to consider soil drainage at a very localized scale when determining the suitability of a soil to receive a given quality of irrigation water.

Table 14 presents the capacity of the different soil types to drain water and shows the wide variety drainage rates of water through soil based on drainage class. Excessively drained soil can drain water six orders of magnitude faster compared to poorly drained soil. As such, excessively drained soils can receive irrigation water with higher salinity than poorly drained soils because excessively drained soils will leach salts at a much higher rate from the root zone of crops. Therefore, a narrative water quality standard capable of flexibly considering the variety of localized soil drainage is needed to protect irrigation water quality.

Table 14. Soil drainage class classification scheme from the NRCS.

Drainage class	Soil Saturated Hydraulic conductivity K_{sat} (µm/s)
Excessively drained	>100
Somewhat excessively drained	10 to 100
Well drained	1 to 10
Moderately well drained	0.1 to 1
Somewhat poorly drained	<0.001
Poorly drained	No functional water movement
Very poorly drained	No functional water movement
Subaqueous	Positive water potential at least 21 hours a day

Figure 28. Soil drainage class map for the continental United States.

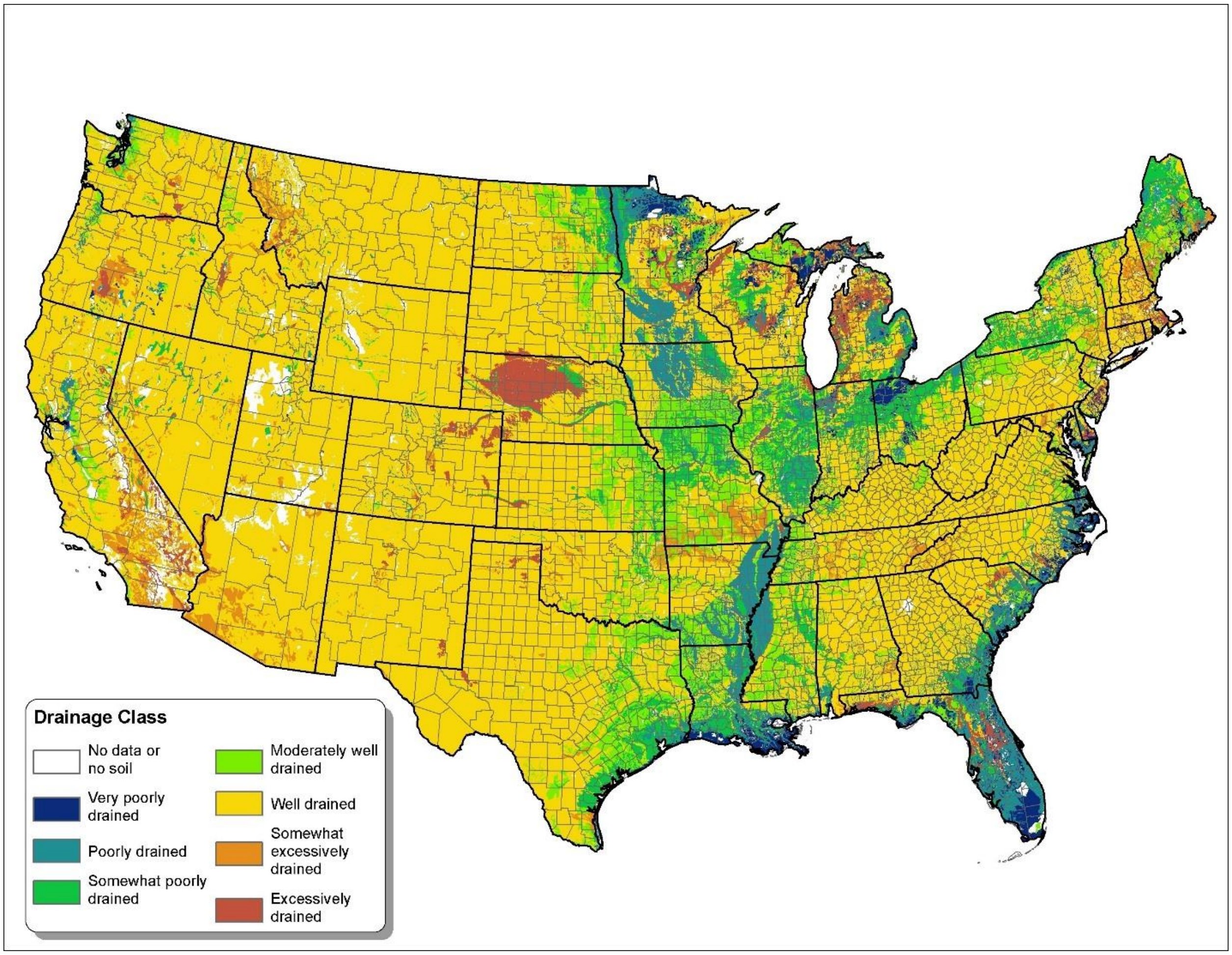
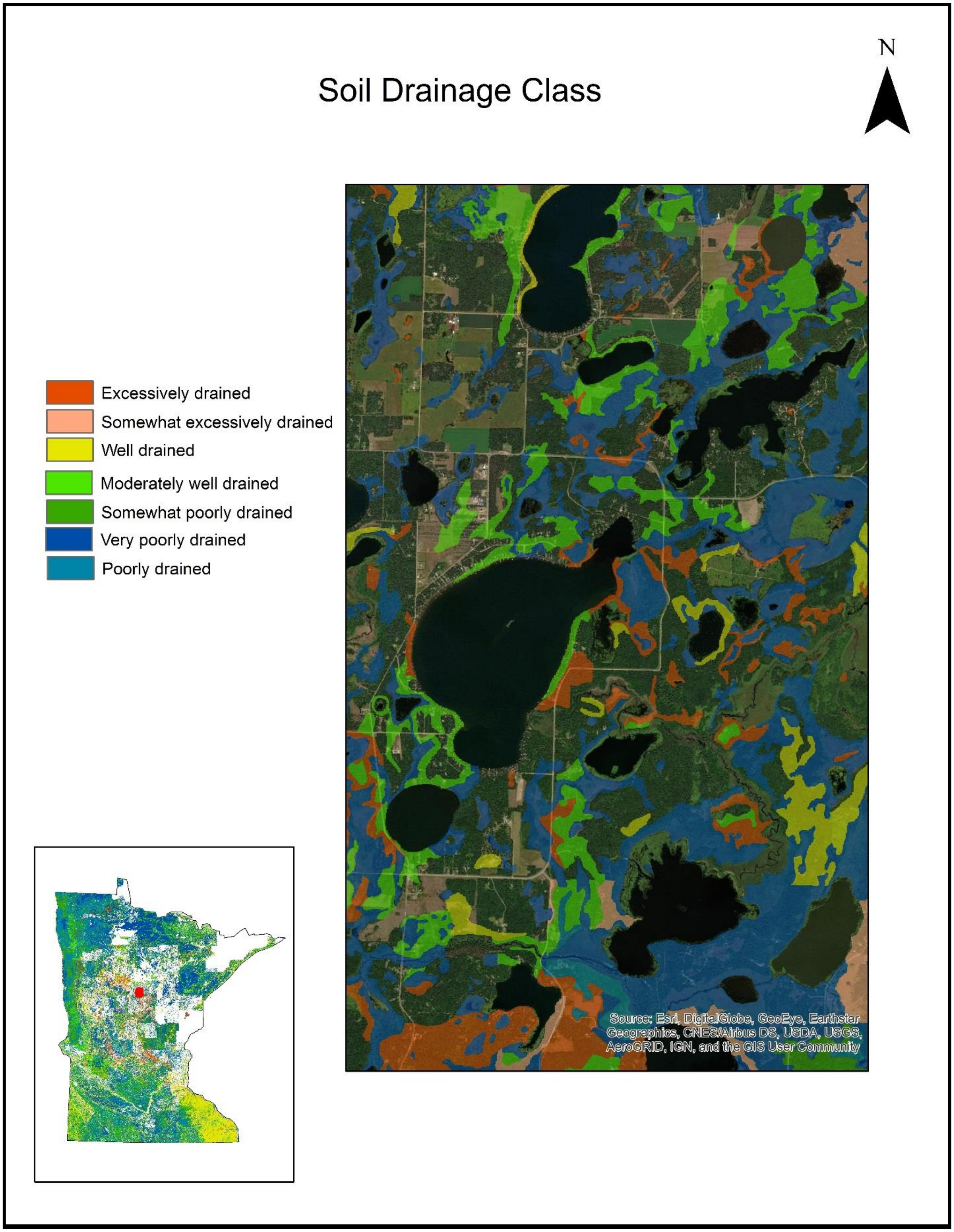


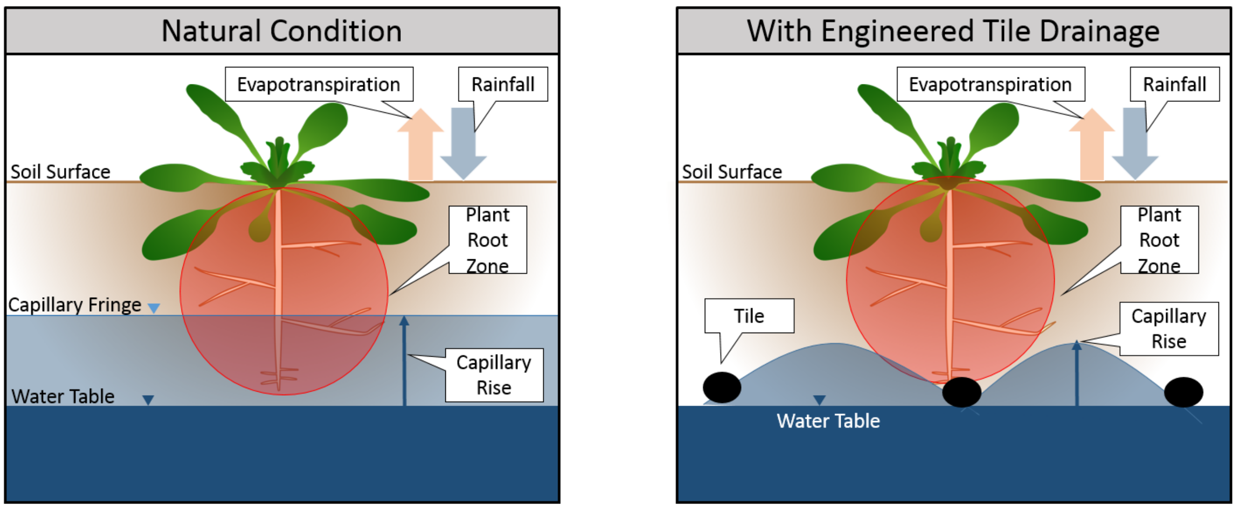
Figure 29. Soil drainage class map for the state of Minnesota.



Engineered Soil Drainage

Minnesota Farmers frequently use engineered practices to remove excess water from their poorly drained fields. These engineered practices can range from ditches to installation of tile drainage. Tile drainage is the installation of sub-surface perforated pipes that move excess water off the field, which lowers the capillary fringe of the water table and reduces the water saturation in the root zone of crops. A graphical representation of how installation of tile drainage reduces the moisture content in the root zone of crops is found below (Figure 30).

Figure 30. Soil water table interactions with and without engineered tile drainage. Tile drainage functions to lower the capillary rise of the water table, exposing the crop root zone to less moisture on average.



Lowering the water table capillary fringe through engineered mechanisms reduces the likelihood that salts will accumulate in the root zone of the crop through two mechanisms: increased leaching of salinity in the root zone and less likelihood of capillary interactions with any salts present in the water table. Therefore, farm fields that have installed engineered systems to control soil drainage are able to receive an irrigation water quality of higher salinity than fields that have not installed engineered drainage systems (ASAM, 2011).

The estimated area under engineered soil drainage for the state of Minnesota is presented in Figure 31, and shows that fields tend to use engineered soil drainage when the soil is classified as being poorly drained. There is no statewide database that keeps track of the exact location of engineered drainage in a given location; only low resolution estimates of engineered drainage locations are available. As such, when evaluating the ability of a given field to receive a specific irrigation water quality, it is necessary to accurately determine the drainage capacity of a soil and consider both natural and engineered drainage through site-specific evaluations. These evaluations ultimately allows for a more localized, robust decision on the proper irrigation water use and management.

Figure 31. Estimated area with subsurface tile drainage in Minnesota (USGS 2016).

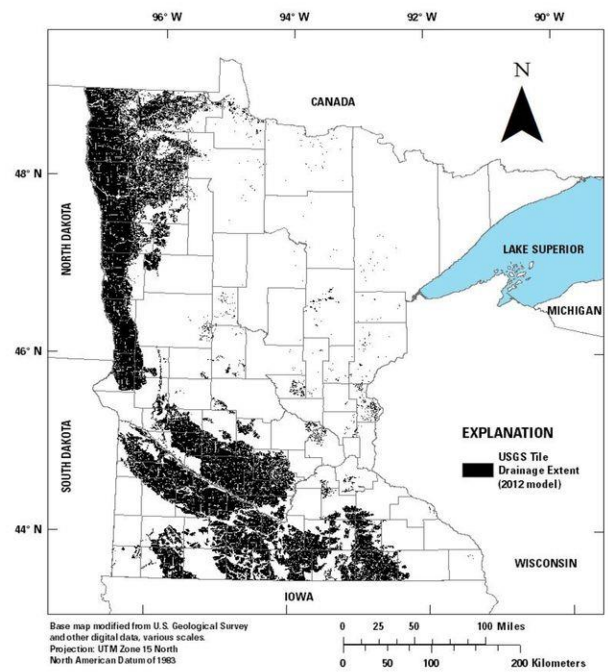


Figure 8 from paper. U.S. Geological Survey (USGS) tile drainage extent in Minnesota shown by a 30-meter raster, based on the Nakagaki and Wieczorek (2016) model of 12 Midwestern states.

Critical Local Factor: Irrigation Management

Takeaway

Irrigation is the artificial application of water to a crop and Minnesota farmers use different irrigation methods to artificially apply water to their crops. There are three main ways Minnesota irrigators apply water to their crops: spray, drip, and flood irrigation. The irrigation method used affects the water quality requirement for the crop being irrigated. For example, irrigation water applied through drip irrigation will have less negative effects on crops than irrigation water applied through spray irrigation. Since irrigation water quality needs varies based on irrigation management practices, there is no one size fits all irrigation water quality value that is appropriate for all irrigation practices.

Irrigation Management Practices in the State of Minnesota

The overwhelming majority of the state (>99%) uses natural rain to water crops according to the National Agricultural Statistics Service (NASS). The NASS dataset states that less than 1% of the Minnesota landscape is irrigated. The historical statistics of the area under irrigation is presented in Table 15, which indicates a modest increase in irrigated acreage in the state over the time. The relative proportion of irrigation management techniques is plotted in the pie chart below (Figure 32) and shows that sprinkler irrigation is the dominant form of irrigation practiced in Minnesota. Table 16 summarizes the irrigation water quality concerns associated with each irrigation management technique and shows that some irrigation management techniques (drip, flood) have less effects related to irrigation water quality than others (spray).

Table 15. Irrigated acreage in the state of Minnesota. Data from 2012 USDA census of agriculture.

	2012	2007	2002	1997
Area (Acres)	524,016	506,357	454,850	403,289
Percent coverage of the state of Minnesota	0.94	0.91	0.82	0.72

Figure 32. Estimated irrigation practices for the State of Minnesota. Data from 2012 USDA census of agriculture.

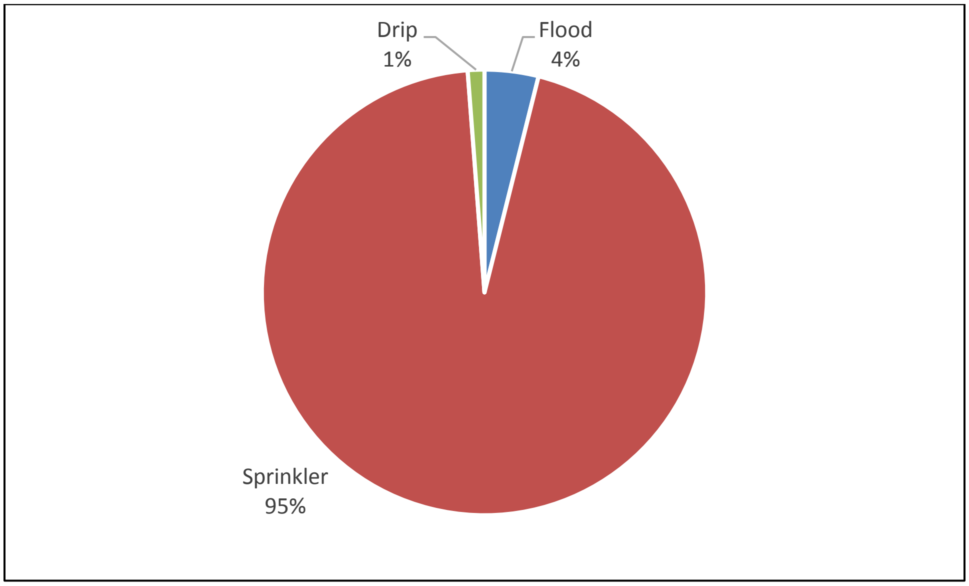


Table 16. Summary of irrigation type and associated irrigation water quality concerns.

Irrigation Type	Description	Irrigation Water Quality Concern
Spray	The application of irrigation water using overhead sprinkler systems.	Leaf burn can occur if high salinity water is sprayed on crops in highly evaporative conditions.
Drip	Precision application of water directly into the root zone of crops.	Leaf burn cannot occur if high salinity water is dripped directly into root zone.
Flood	High rate irrigation water application that causes ponding on soil surface.	Functions to flush soil salinity from root zone.

It is necessary to consider site-specific irrigation water quality given the diversity of Minnesota irrigation practices and their disparate effects on crops with regards to irrigation water quality. A narrative water quality standard is best able to consider these localized site-specific factors when determining whether the irrigation water quality needs of a given location are being met.

Critical Local Factor: Precipitation and Climate

Takeaway

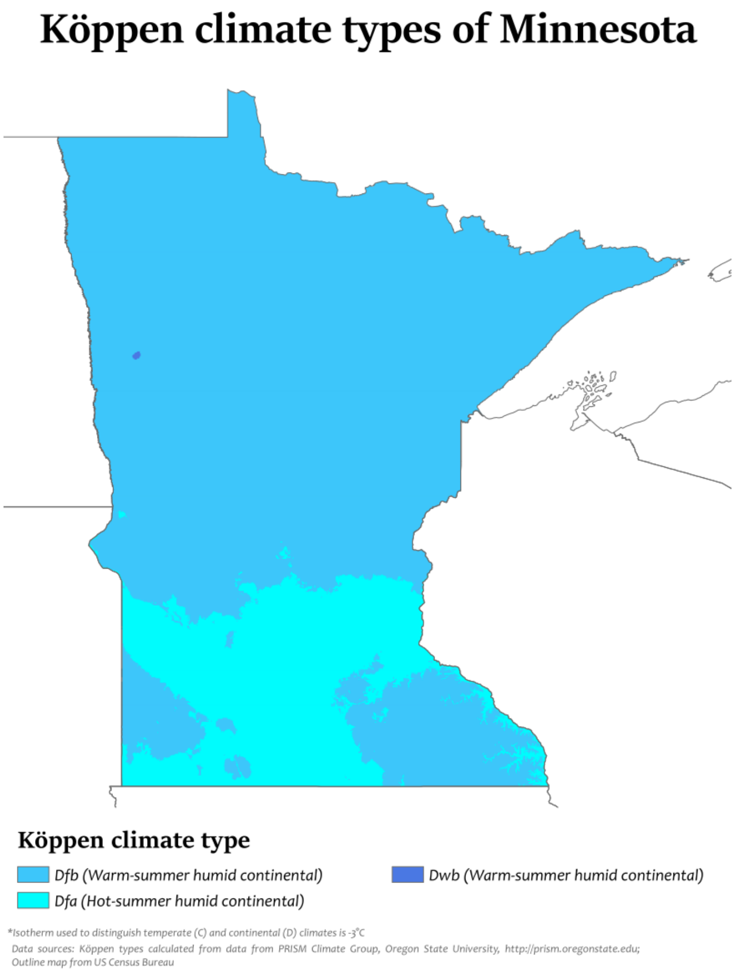
The climate and typical precipitation of a given location are important to consider when evaluating irrigation water quality. The amount of rainfall a given field and crop receives is related to the salinity leaching potential of a given soil. The salinity leaching of a soil due to excess rainfall can allow for higher salinity values in irrigation water quality than would be necessary in a dry, arid climate with less salinity leaching potential. Since Minnesota does not have a dry or arid climate, it is essential to consider Minnesota's precipitation and climate when evaluating protective irrigation water quality standards in Minnesota. Additionally, the salinity leaching of the Minnesota soils varies from SE Minnesota to NW Minnesota, with SE Minnesota having a greater salinity leaching potential than NW Minnesota. Not appropriately accounting for climate and precipitation in a given location would generate unnecessarily protective water quality values that are overly protective of irrigation.

Since there is such variety in precipitation and climate trends in Minnesota on a statewide basis and considering climate in irrigation water quality assessment is so important, a narrative standard is appropriate because it allows for flexibility to consider the site-specific nature of climate trends (including climate change) in Minnesota.

Climate and Precipitation in Minnesota

The amount of precipitation that falls across the state of Minnesota varies on a spatial and temporal scale, which can affect the amount of irrigation that is needed to support different types of agricultural production. The precipitation amount in a given location is a product of the climate. While the amount of precipitation is important to crops, so is the climate, which can impact the amount of water that evaporates or transpires into the atmosphere (transpiration is the movement of water from the roots of plants up through the leaves of the plants, where it is released into the atmosphere). Hot and/or arid conditions result in a greater amount of evaporation and transpiration (collectively referred to as evapotranspiration), while cooler, humid climates see less evapotranspiration. Minnesota is considered a humid climate, but the state is also considered to have either a hot or warm summer climate (Figure 33).

Figure 33. Köppen climate map for Minnesota (Peterson, 2016)



The MNDNR maintains average precipitation maps for Minnesota, including a map that takes into consideration the evapotranspiration in relation to precipitation. In areas where precipitation is greater than evapotranspiration, more water is available for crops and soil salinity leaching than in areas where more of the precipitation is lost to evapotranspiration. Figures 34–36 demonstrate the normal annual precipitation, the normal precipitation over most of the growing season, and the ratio between precipitation and evapotranspiration, respectively. There are clear trends that the southeast portion of the state receives the most precipitation, especially when considering only the growing season. However, because this area of the state is also one of the warmest parts of the state, the ratio of precipitation to evapotranspiration is lower there than in the northeast part of the state, which gets less rainfall, but is colder, so less water is lost to evapotranspiration.

When water, either from precipitation or irrigation, moves downward through the soil horizon, it carries dissolved salts and nutrients with it, away from the plant. This can be both beneficial and detrimental. The removal of nutrients can have negative effects; however, leaching, especially from rainfall, can be beneficial in removing salts from the root zone of plants thereby decreasing the plant’s exposure. When evapotranspiration exceeds precipitation over a defined time scale, less leaching occurs. Rainfall has functionally no salt in it, so in areas with greater amounts of rainfall, and less evapotranspiration, salt is leached from the root zone and replaced with less saline water. The opposite is also true: when evapotranspiration rates are high, and precipitation is low, salts can remain in the root zone because water is being lost to the atmosphere, rather than moving down through the soil. Figure 37 shows the likelihood of leaching of salts in Minnesota. The risk of soils having salinity related issues from irrigation water (in other words, where there is less likelihood of leaching) generally increases east to west across the state, with little leaching occurring in the western part of the state. Therefore, the western part of the state would need a better quality of irrigation water than the eastern part of the state. Climate and precipitation factors vary across the state and influence the appropriate water quality needed for irrigation water.

Due to Minnesota's climate, the beneficial use of surface water for irrigation is unavoidably seasonal because crops do not grow in frozen soils. Most crop irrigation occurs between May and October (personal communication, Joshua Stamper, March 23, 2016). Though off-season greenhouse production does occur in Minnesota, it is not widespread and there is no available information to indicate the annual value of production. According to a publication by the UMN Extension (Bloom and Mulla 2010), most of the cold-season greenhouse producers use groundwater for irrigation. The 4A standards apply to both surface water and groundwater, so the protections for the designated use should be maintained throughout the year, to protect cold-season crops that are irrigated via groundwater.

Figure 34. Normal annual precipitation for Minnesota.

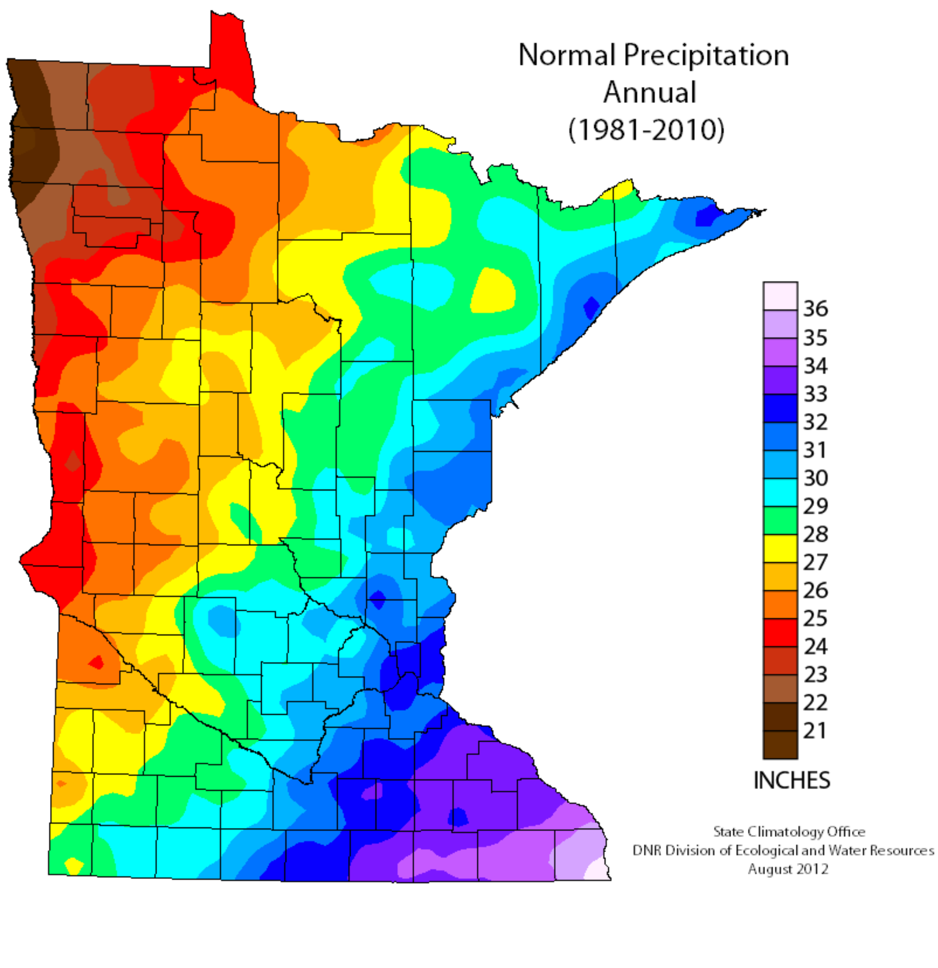


Figure 35. Normal precipitation for Minnesota during May through September, covering most of the growing season.

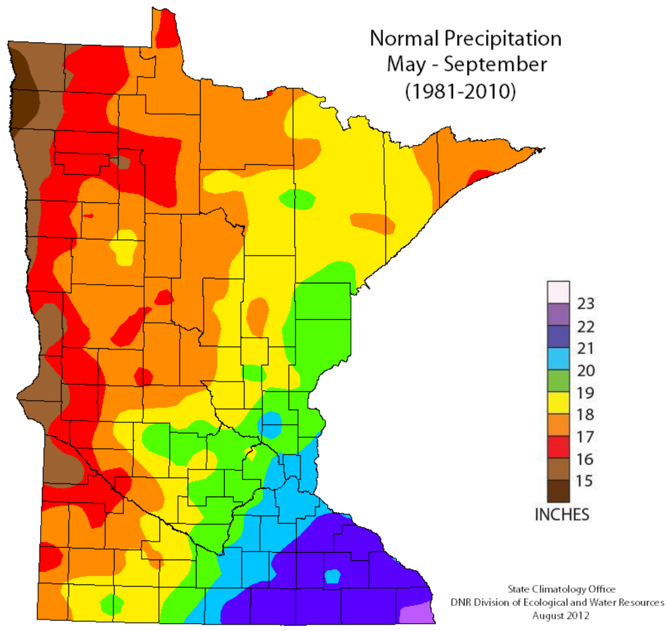


Figure 36. Ratio of precipitation to evapotranspiration across Minnesota (map from MNDNR).

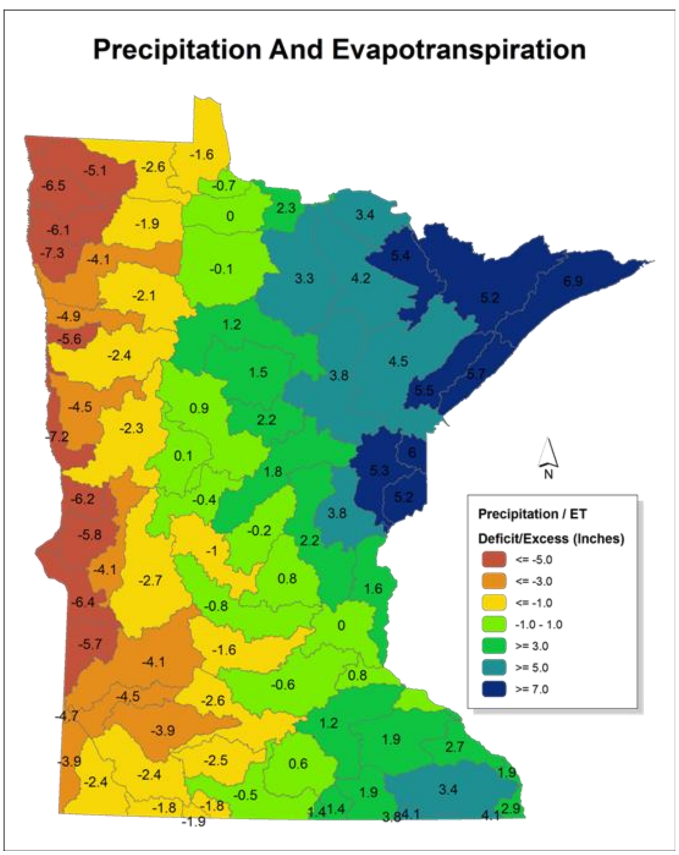
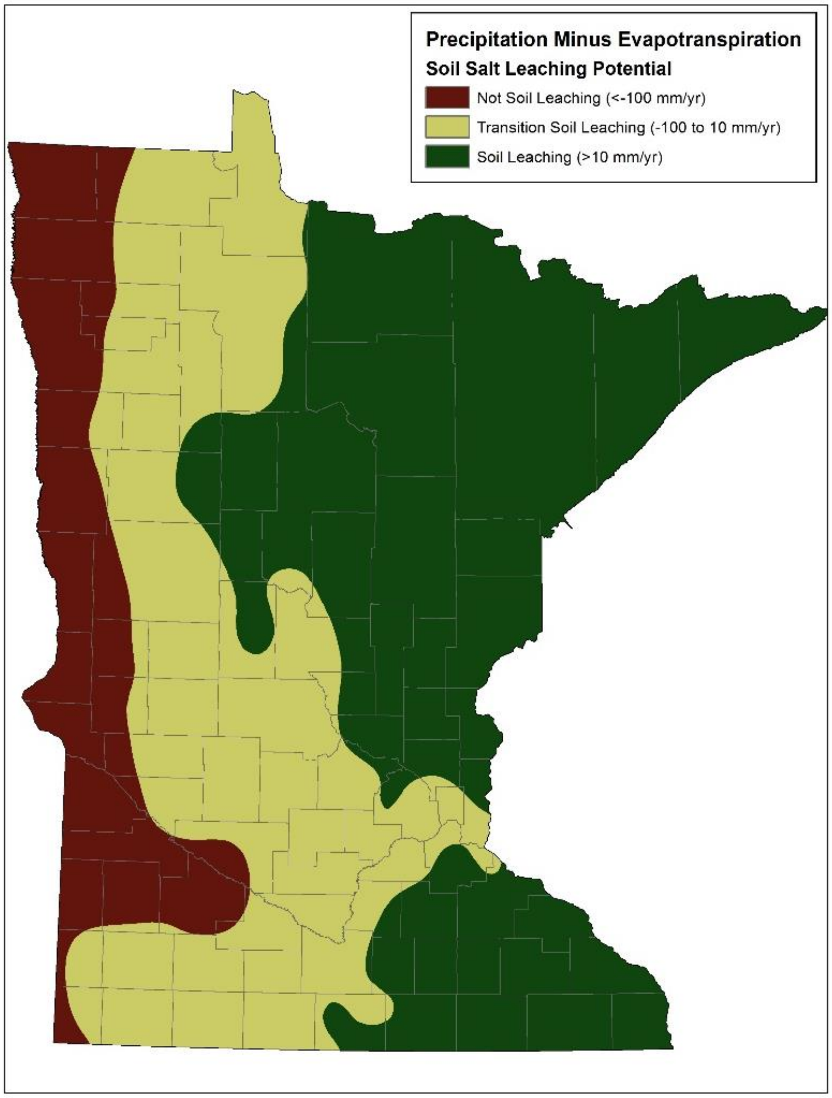


Figure 37. Leaching potential of soils in Minnesota, based on precipitation and evapotranspiration rates.



Critical Local Factor: Acceptable Crop Yield Loss Tolerances

Takeaway

A key factor in irrigation water quality assessment is the crop yield tolerance a farmer is willing to accept. The crop yield tolerance a farmer is willing to accept is a function of agronomics; as a general rule farmers would prefer to have no crop yield losses due to poor irrigation water quality. There could be situations where farmers might choose to irrigate with water of a poorer quality because the additional moisture will increase crop yield more than the poor quality would hurt crop yield. Making location specific agronomic crop yield assessments is outside of the regulatory authority of the MPCA and would increase economic complexities beyond what this rulemaking can appropriately accomplish. A narrative standard better allows for these site-specific agronomic evaluations than a numeric standard would.

Crop Yield Loss Tolerance and Farmers

Because poor quality irrigation water can impact the yield of crops, one of the considerations in determining protective irrigation water quality standards is determining what reduction in yield may be acceptable. Stakeholders most affected by poor irrigation water quality would be farmers who are using the water on their crops. Profit margins for crops are often small and dependent upon a number of factors, including those, such as weather, that are not controllable. Therefore, a reduction in yield, and thus profit, due to poor irrigation water is likely going to be unacceptable to a farmer.

In 2017, the value of Minnesota's corn production was over $4.51 billion (USDA 2017). If the yield were reduced 10% for any reason, including poor irrigation water quality, the value of the crop would be reduced by 10%. This would result in an annual loss of $451 million for farmers in Minnesota for corn crops alone. Utilizing the same calculations for soybeans, an annual loss of over $347 million could be possible for soybean farmers across the state (USDA 2017). This is a potential loss of nearly $800 million for two crops resulting from a 10% reduction in yield, if all waters in the state used for irrigation were at a level that reduced yield by this degree. While widespread reductions in yield is an unlikely scenario, it is reasonable to assume that reductions in yield would be unacceptable to the individual farmers using the irrigation water.

Managing Crop Yield Loss Tolerance

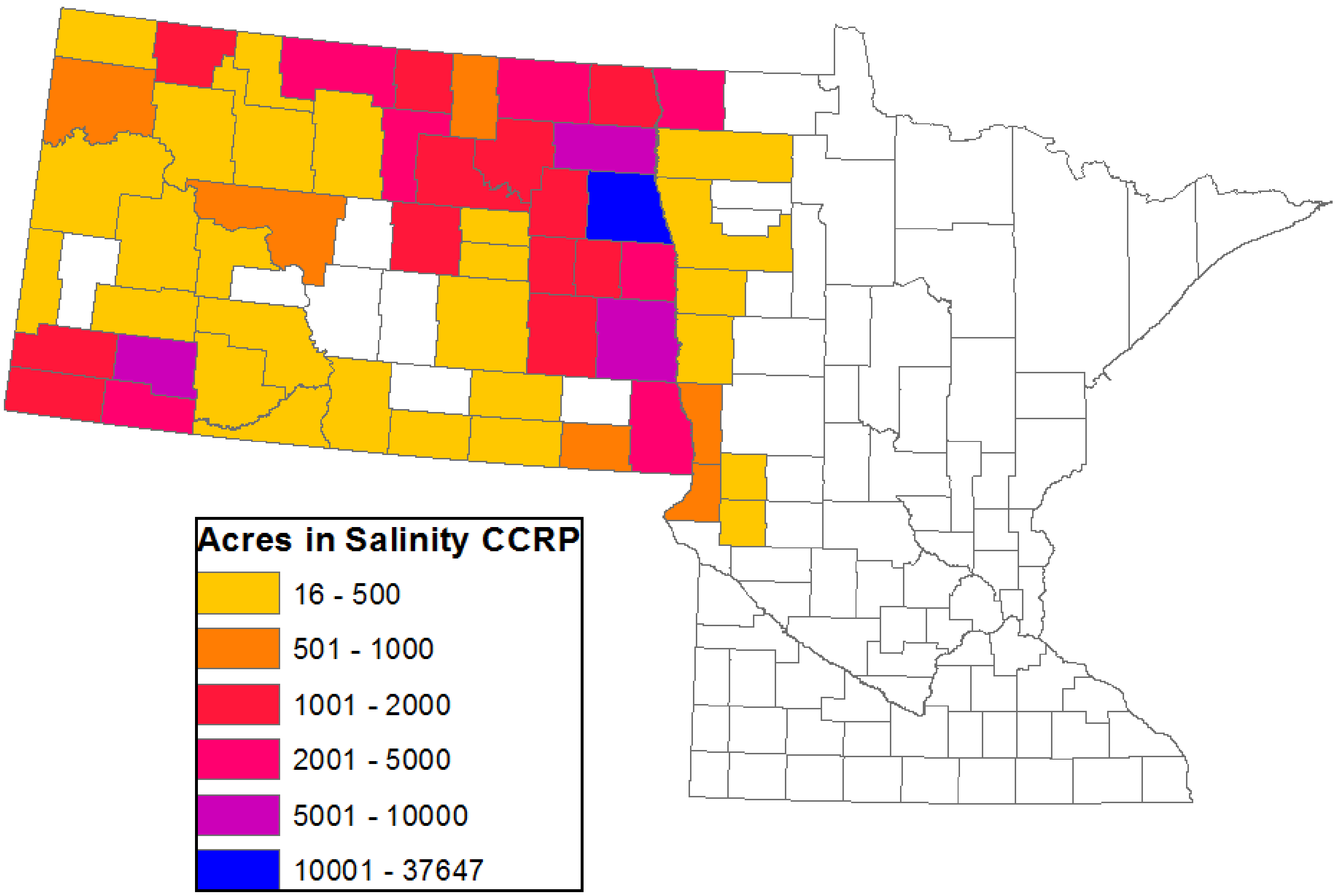
Farmers that have problems with excess salinity in their fields often find that is more economical to plant salinity tolerant crops that are capable of producing good yields in their salinized fields. Planting lower value crops with high yields can be more profitable than planting higher value crops with low yields in salinized fields. These assessments are highly individualized, complex decisions and often require splitting fields into sub-plots based on the very fine scale attributes of the field in consideration.[6] The MPCA does not have the desire, resources or capabilities to make these kind of cropping recommendations to farmers to help them make decisions. Farmers know their fields best and the MPCA does not want to tell farmers how to manage their fields for crop yield.

Economic Losses Because of Excess Salinity

Although most of Minnesota's crop lands do not have problems due to salinity, it appears that there are salinity related concerns in the Red River Valley. This is based on mapping the counties where farmers have received funding to put salinized land in conservation reserve (Figure 38). The NRCS allows land to be placed in conservation reserve in Minnesota if the soils have high salinity that requires the farmland to be taken out of production. According to NRCS criteria, if a soil has greater than 4.0 dS/m conductance within the first eight feet of the surface, the soil can go into conservation reserve. The total allowable area allowed to be put in conservation reserve per site is 50 acres and the practice is not available to irrigation-induced saline conditions.

[6] See example from NDSU Soil Extension Service at https://www.youtube.com/watch?v=u3mdQhz6-pk

Figure 38. Acres in salinity conservation reserve in Minnesota and North Dakota. Only counties in the Red River Valley of Minnesota have land in conservation reserve because of excess salinity. Almost every county in North Dakota has land in salinity conservation reserve, with the majority of North Dakota salinity related acres occurring in the Red River Valley.



Implementation of Narrative Standard in NDPES Permits Using a Narrative Translator Process

Federal regulations at 40 CFR § 122.44(d)(1)(i) require NPDES wastewater permits to contain effluent limitations that ensure pollutants do not have the reasonable potential to cause or contribute to the exceedance of a state numeric or narrative water quality standard (RP). If the permitting agency finds that a wastewater discharger has RP for any given numeric or narrative water quality standard in a receiving water, then the agency must include an effluent limitation in the wastewater discharge permit that is protective of that water quality standard. The process used to determine whether a wastewater discharger has RP is referred to in shorthand as "the RP process."

The RP process for numeric water quality standards is specific to a given parameter and is performed for all parameters of concern during the issuance of wastewater permit. The RP process uses a complex numeric formula that requires knowing the measured effluent concentrations, the assimilative capacity of the receiving water to receive pollution from the discharger, the magnitude, duration and frequency of the water quality standard in question, and statistical factors to ensure a protective margin of safety. The RP process for numeric water quality standards always produces a binary answer of either “yes” or “no.” An answer of “yes” indicates that the wastewater discharger in question has RP for the parameter of concern and that an effluent limit for that parameter must be included in the permit. An answer of “no” indicates that the wastewater discharger does not have RP for the parameter of concern and that an effluent limit for that parameter is not necessary in the permit.

Narrative water quality standards are narrative descriptions of the conditions that are protective of the designated use, and do not contain numeric values. There is no generally established method to calculate RP or develop an effluent limit for a narrative standard. This is because the RP process always requires knowing numeric values that are protective of the designated use to precisely and numerically determine the RP status for the discharger (either yes or no). Because narrative standards do not include numeric values to determine if a facility has RP, a “narrative translator” process is needed.

This narrative translator is a process that translates a narrative water quality standard into a numeric expression of the narrative standard applicable within the NPDES permit. The numeric expression of the narrative water quality standard is a value that is protective of the designated use, and can then be used to numerically assess RP and ensure the wastewater discharger is meeting the narrative water quality standard. If the discharger has RP, the numeric expression of the narrative standard is also used to set an effluent limit protective of the designated use. In short, to assess RP for narrative standards, a process to develop a numeric expression of the narrative standard is required. After the narrative translator process generates a numeric translation of the narrative water quality standard, RP can be assessed and an effluent limit calculated, if necessary.

Neither the CWA nor Minnesota rules have any defined process for how to translate a narrative standard into numeric values. For a given NPDES wastewater discharger, the narrative translator process takes place within a wastewater permit and is subject to public comment during the issuance of the wastewater permit.

The MPCA has an established narrative translator process for only one parameter, whole effluent toxicity (WET). WET testing measures the aggregate toxic effect to aquatic organisms from all pollutants in a wastewater effluent. WET tests measure wastewater’s effects on specific test organisms’ ability to survive, grow, and reproduce. WET testing is one way to implement the CWA’s prohibition of the wastewater discharge of toxic pollutants and to ensure protection of Minnesota’s Class 2 (aquatic life and recreation) designated-use general narrative standard. The MPCA’s WET narrative translator process converts the results of wastewater effluent WET testing into a numeric value, measured in toxic units. Then the RP calculation ensures that wastewater dischargers do not cause or contribute to an exceedance of one toxic unit at any time in waters of the state. Any value above one toxic unit caused by a wastewater discharger is considered an exceedance of the narrative water quality standard for general toxicity to aquatic life and requires the wastewater discharger to receive an effluent limit protective of WET.

To develop a numeric interpretation of the Class 4A narrative water quality standard, instead of testing aquatic organisms, a process to evaluate whether the irrigation designated use is being met needs to be conducted. The MPCA is proposing multiple options for how and when to develop the process for determining the numeric expression of the Class 4A narrative standard. These options are presented below, and MPCA requests comments on the preferred option to move forward with during rulemaking.

Options for Developing the Numeric Interpretation of the Narrative Standard

Two options for ensuring protection of the proposed Class 4A narrative standard through numeric interpretations of the narrative standard in NPDES permits are explained below.

Option 1: MPCA, through this rulemaking, develops a process to translate the narrative standard into a numeric value, and this process is incorporated into rule. This translation process could be either placed into rule directly or incorporated by reference through a document that either can or cannot be revised without further rulemaking.

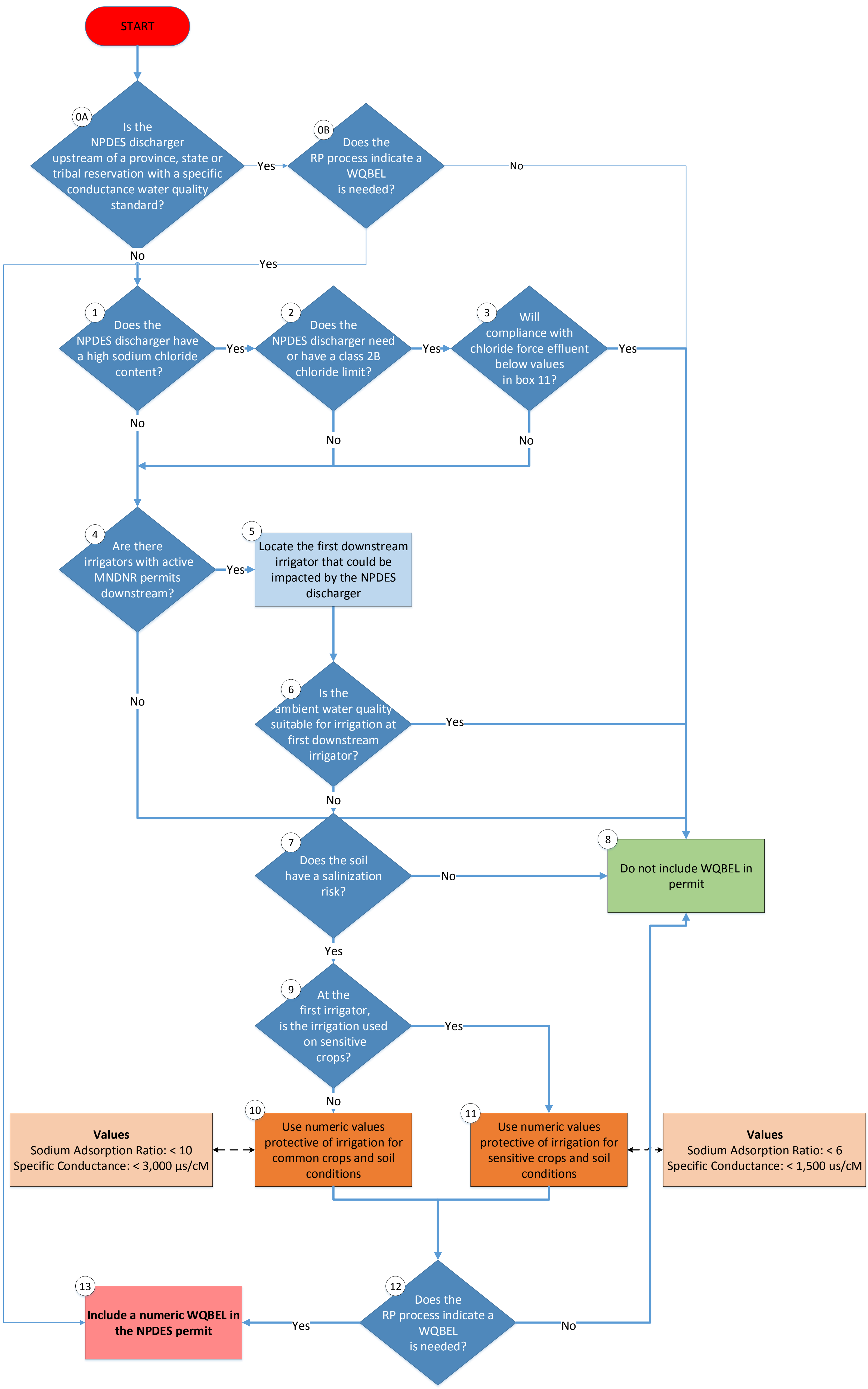
Option 2: MPCA finalizes the changes to the standards but delays developing the process to translate the narrative standard into a numeric value. Instead, after the rulemaking, the MPCA works collaboratively with stakeholders and other to develop the process and publish a guidance document.

The two options are mutually exclusive, but MPCA believes there are good arguments and justifications for both. We ask that reviewers and commenters consider the details of both options below and provide comments as to which option you prefer. If neither option is acceptable, please provide comments on how the option could be improved or other potential paths for implementation. Regardless of which option you prefer, please also provide any comments on the details of the potential process laid out in option 1.

Option 1: Develop the narrative translator process described below in this rulemaking

Narrative standards can be effectively implemented through a “translation” process that allows setting a numeric effluent limit where needed. The implementation shown in Figure 39 will help to assess when a numeric translator and associated effluent limited is needed to protect the waters for irrigation use.

Figure 39. Flowchart explaining the proposed irrigation narrative translator process.



0A) Is the NPDES discharger upstream of a province, state or tribal reservation with a specific conductance water quality standard?

When assessing the need for an effluent limitation for a NPDES discharger, the MPCA must ensure that the NPDES discharger does not cause or contribute to the violation of any downstream water quality standard. If the NPDES permittee discharges to waters of the state of Minnesota that ultimately flow into tribal waters, then the MPCA must ensure that the NPDES discharger does not cause or contribute to a violation of a tribal water quality standard. Tribes have authority to promulgate their own water quality standards under the CWA and some Minnesota tribal governments have adopted or plan to adopt water quality standards for parameters that are not in Minnesota rule.

The Fond du Lac Band of Lake Superior Chippewa has proposed a specific conductance water quality standard to protect aquatic life in waters wholly within the tribal reservation, which borders the St. Louis River. They are the only nearby downstream entity that has or has proposed such a standard. As currently drafted, this section (boxes 0A and 0B) specifically references specific conductance because, under the plans described in this TSD, that parameter would have no numeric Minnesota standard, is potentially of concern for the suitability of water for irrigation use, and due to the proposal by the Fond du Lac Band to implement a numeric standard.

While the MPCA always looks to protect downstream waters, it seemed useful to provide some specific information on how that would be considered. The process as laid out could be used for any similar irrigation-related parameter where there is a tribal or state numeric standard. However, the example of the specific conductance standard at Fond du Lac will be used in this case. The proposed tribal standard – a specific conductance value of 300 µS/cm as a maximum, never to exceed, standard – has not yet received tribal or EPA approval.

Water quality is generally affected by upstream dischargers; therefore, in order to ensure that any water quality standard is met in a waterbody, it is important to determine which NPDES dischargers are upstream. In the example here, once the Fond du Lac specific conductance water quality standard is finalized, it is possible that an upstream NPDES discharge could be causing or contributing to the exceedance of the tribal specific conductance water quality standard. NPDES facilities upstream of the Fond du Lac reservation can be found in Table 17.

Table 17. NPDES permittees upstream of the Fond du Lac reservation.

NPDES Permittee	Permit ID
ArcelorMittal Minorca Mine Inc - Laurentian	MN0059633
Aurora WWTP	MN0020494
Babbitt WWTP	MN0020656
Biwabik WWTP	MN0053279
Cliffs Erie - HL Tailings Basin Area	MN0054089
Cliffs Erie LLC - Hoyt Lakes	MN0042536
Conrad Fafard Inc	MN0057428
Dyno Nobel Inc	MN0060704
Enbridge Energy Ltd - Clearbrook	MN0056324
Eveleth WTP	MNG640031
Eveleth WWTP	MN0023337
Floodwood WWTP	MNG580048
Gilbert WWTP	MN0020125

Hibbing Taconite Co	MN0001465
Hibbing WWTP South Plant	MN0030643
Hoyt Lakes WWTP	MN0020206
Iron Junction WWTP	MNG580049
Kubena Sand & Gravel	MNG490202
Laurentian Aggregate LLC	MNG490302
McKinley WWTP	MN0024031
Meadowlands WWTP	MNG580034
Mesabi Bituminous Inc - Schley Mine A	MNG490021
Mesabi Mining Area	MN0069078
Mesabi Nugget Delaware LLC	MN0067687
Minnesota Power - Laskin Energy Center	MN0000990
MNDNR - St Paul	MNG490239
Mountain Iron WWTP	MN0040835
Northshore Mining Co - Babbitt	MN0046981
SB Son Inc	MNG490033
St Louis County Highway Dept	MNG490140
St Louis County Land Department	MNG490177
Ulland Brothers Inc	MNG490069
United Taconite LLC - Fairlane Plant	MN0052116
United Taconite LLC - Thunderbird Mine	MN0044946
US Steel - Minntac Mining Area	MN0052493
Virginia Department of Public Utilities	MN0003379
Virginia WWTP	MN0030163
Waupaca NorthWoods LLC	MN0061549

0B) Does the RP process indicate a WQBEL is needed?

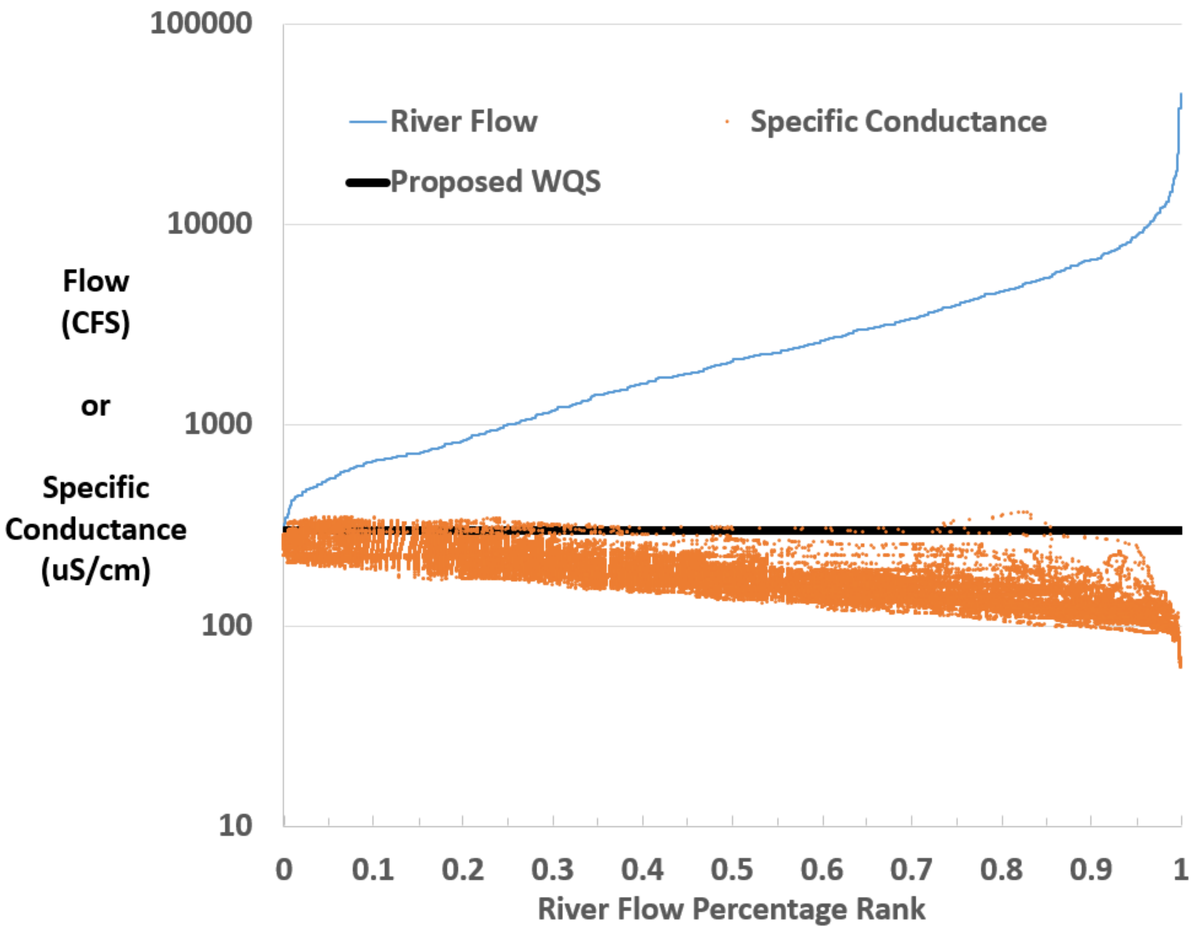
This process determines whether a NPDES discharger upstream of state or tribe with a numeric water quality standard would need a water quality based effluent limit (WQBEL) protective of that numeric standard – again, using specific conductance as the example.

We cannot determine whether any given NPDES discharger would have the reasonable potential to cause or contribute to the exceedance of a downstream specific conductance water quality standard without specific inputs to the reasonable potential calculation. Parameters such as the defined magnitude, duration, and frequency of the water quality standard, the protective receiving water flow rate, and discharger specific information are necessary to perform the RP calculation.

Once these water quality standard parameters have been defined it would be possible to determine whether a discharger has RP for the relevant standard. The RP process would use specific conductance load duration curves such as the one below in Figure 40. The RP process would also use a mass balance approach to apportion salinity loading to upstream dischargers to protect the downstream water quality standard. Effluent limitations protective of the water quality standard would be included in NPDES permits as needed. The duration, magnitude and frequency of the effluent limitations would be protective of the duration, magnitude and frequency of the water quality standard.

As an example of how this process would work, using the proposed tribal specific conductance standard, Figure 40 shows hourly specific conductance and flow rate of the USGS flow gauge on the St. Louis River at Scanlon. Over 74,000 hourly specific conductance samples have been collected since 2011 and over 97.4% of those samples are below the 300 µS/cm Fond du Lac proposed water quality standard. Flows at the gauge during this time have ranged from extreme flood (flows of >45,000 cubic feet per second [CFS]) to drought conditions (< 300 CFS). The specific conductance of the St. Louis River tends to decrease as river flow increases.

Figure 40. Load duration curve of specific conductance on the St. Louis River at Scanlon. Data is hourly starting in 2011. The blue line represents ranked flow in the river in cubic feet per second (CFS). The orange points represents measured specific conductance in the river at the indicated river flows. At low river flows specific conductance is higher than at high river flows. The $7Q_{10}$ drought flow rate for this river is 300 CFS. The black line represents the proposed Fond du Lac 300 µS/cm water quality standard.



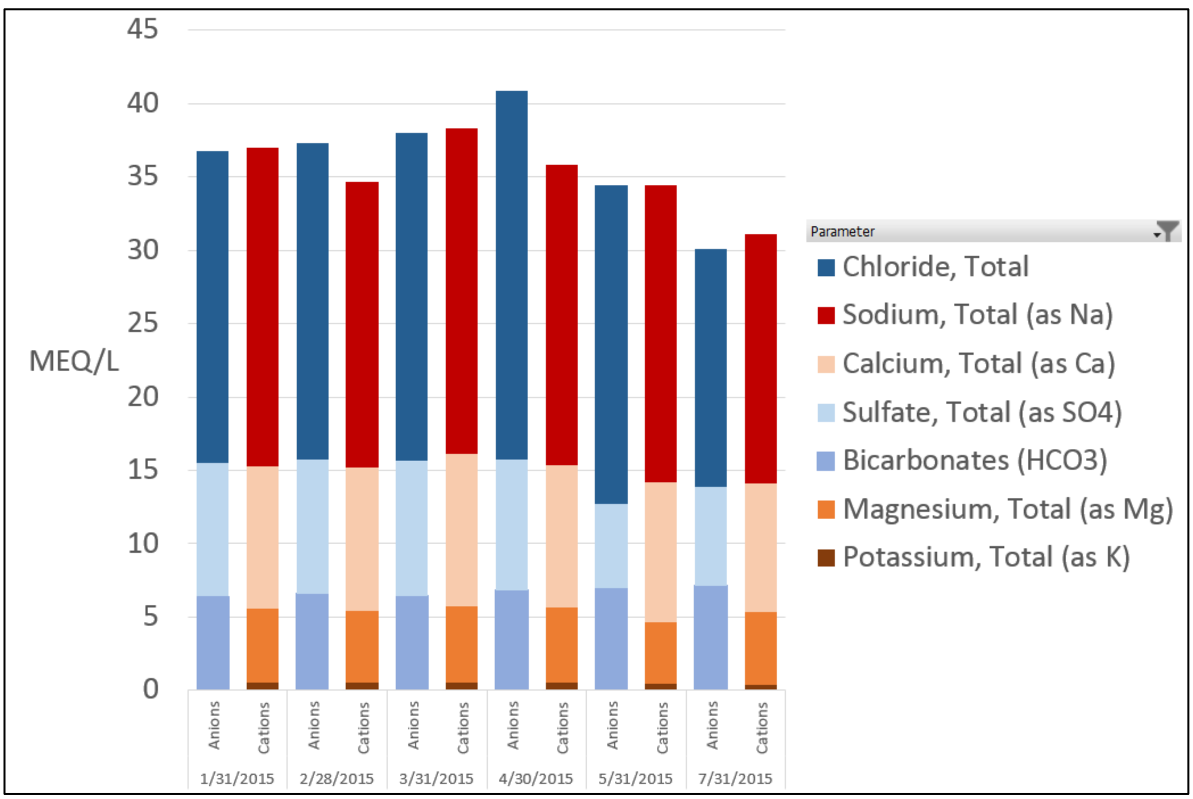
1) Does the NPDES discharger have a high sodium chloride content?

The ionic makeup of discharge water can be analyzed to determine what types and proportions of major mineral salts are present. This requires monitoring for the concentrations of the major ions present. Once the concentrations of the major ions are known, then the relative proportions of each ion present in the water can be calculated. If the water has elevated sodium and chloride concentrations in approximately 1:1 molar proportion to each other, this indicates that the water has a high sodium chloride content. Elevated concentrations of sodium and chloride would be defined as having either sodium or chloride higher than 100 mg/L.

The vast majority (80 to 90%) of Minnesota municipal wastewater treatment plant (WWTP) effluents likely have high sodium chloride content using the criteria defined above. Relatively few industrial WWTP effluents have high sodium chloride content. When industrial facilities have high sodium chloride concentrations, this are typically means they are using ion exchange water softening or processing food using salt brines – such as pickling or cheese making.

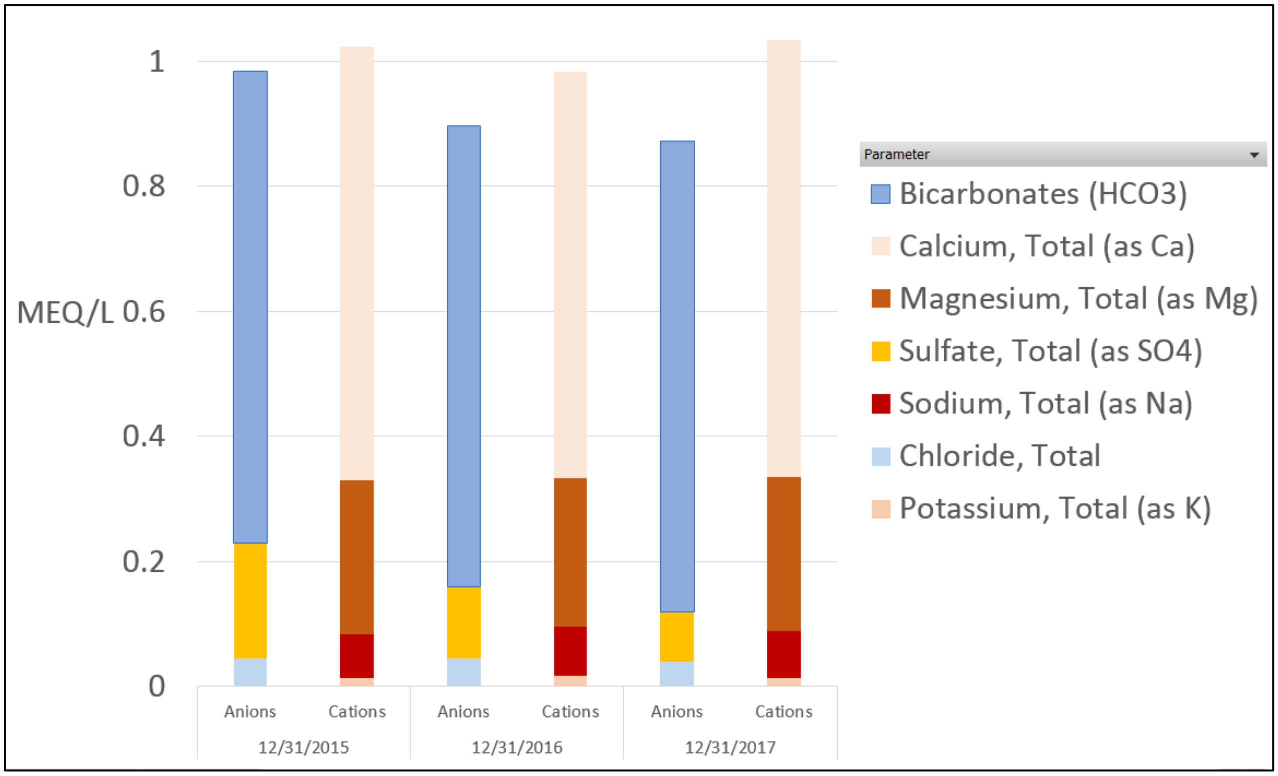
The Lakefield WWTP major ion concentration is provided below as an example of a sodium chloride dominated effluent (Figure 41). Figure 41 shows the results of monthly major cation and anion monitoring for the Lakefield WWTP with each set of bars representing one month of monitoring. The upper stacked cation bars represent the four major positively charged ions (calcium, magnesium, sodium and potassium); the anionic stacked bars represent the three negatively charged ions (sulfate, chloride and bicarbonate) with each color representative of the ion of interest. The height of each bar is representative of the milliequivalents per liter for that ion, which is a measurement of the amount of the ion present in the solution. The Lakefield WWTP clearly has sodium chloride dominated effluent because the amount of sodium and chloride are high and in approximately equal proportion.

Figure 41. Major Ion balance visualization for the Lakefield WWTP effluent. Data is from monthly effluent samples collected in 2015. The height of each stacked bar is in units of miliequivalents per liter. This is a sodium chloride-dominated water because of the high proportions and concentrations of sodium and chloride in the water. Chloride concentrations for this facility are high and range from 300 to 800 mg/L and sodium concentrations range from 300 to 700 mg/L. The chloride and sodium concentrations in the Lakefield drinking water source are less than 30 mg/L, meaning that over ninety percent of the sodium chloride loading to the Lakefield WWTP is anthropogenic.



An example of an effluent not dominated by sodium chloride is provided below in Figure 42. Figure 42 shows the results of annual major ion monitoring for the MNDNR French River Fish Hatchery with each bar representing one day of monitoring. The upper stacked bars represent the four major positively charged ions (calcium, magnesium, sodium and potassium); the anionic stacked bars represent the three negatively charged ions (sulfate, chloride and bicarbonate) with each color representative of the ion of interest. The height of each bar is representative of the milliequivalents per liter for that ion, which is a measurement of the amount of ions present in the solution. The French River Hatchery is not dominated by sodium chloride ions but is rather dominated by calcium, magnesium and bicarbonate ions.

Figure 42. Major Ion balance visualization for the MNDNR French River Fish Hatchery. Visible data is from annual effluent samples from 2015 to 2017. The height of each stacked bar is in units of miliequivalents per liter. This is a calcium, magnesium and bicarbonate dominated water because of the low proportions of sodium and chloride in the water. Chloride concentrations for this facility are low and range from 1.4 to 1.8 mg/L and sodium concentrations range from 1.6 to 1.8 mg/L.



2) Does the NPDES discharger need or have a Class 2 aquatic life based chloride limit?
If the facility has sodium chloride-dominated water and it also has need for a chloride limit, then the facility must reduce chloride loading to ensure compliance with the 230 mg/L Class 2 chronic water quality standard for chloride.

If the facility does not have a chloride limit, then the facility does not need to reduce chloride loading because it is discharging chloride a concentrations that are protective of the 230 mg/L Class 2 water quality standard for chloride.

3) Will compliance with chloride limits force effluent concentrations below values in box 11?
Any reduction in sodium chloride loading in a wastewater effluent, associated with compliance with a chloride limit, will also decrease the SAR and specific conductance of the effluent. Lowering these two

parameters will improve suitability for irrigation of sensitive crops and soils. The water chemistry underlying this calculation relies on the water chemistry principles detailed in the chloride linkage permitting process employed by the MPCA. This chloride linkage process was approved by EPA to permit NPDES dischargers for salty parameters such as chloride and specific conductance. A document explaining the concepts in the chloride linkage can be found in a recent report by MPCA (MPCA 2018). The chloride linkage calculation relies on the assumption that reducing the hardness of the water supplied from a centralized municipal drinking water plant will allow water users to disconnect ion exchange water softeners and therefore reduce chloride loading to levels in compliance with chloride permit limits. Any resultant reductions in chloride loading would represent a reduction in the total salt content of the effluent. The chloride linkage is most applicable to municipal wastewater plants and will not apply to most industrial wastewater plants. This is because most industrial wastewater plants do not have high sodium chloride content from ion exchange water softeners; most industries do not use ion exchange water softeners extensively.

Figure 43 visualizes the effluent of the Lakefield municipal WWTP to show how compliance with chloride effluent limits will lower the SAR and specific conductance of the effluent to levels protective of irrigation for sensitive crops and soil conditions. The Lakefield WWTP has a 230 mg/L monthly average chloride effluent limit in its current NPDES permit that is based on the Class 2B aquatic life and recreation 230 mg/L chloride water quality standard. The Lakefield WWTP has a sodium chloride-dominated effluent (Figure 41 in section above) and when chloride concentrations are decreased sodium will also decrease, which in turn reduces the SAR. The predicted SAR is a function of the chloride management alternative chosen with lime softening producing a higher SAR (5.3) compared to reverse osmosis softening (range 3-4).

The reductions in sodium chloride associated with complying with the chloride limit also reduce the specific conductance of the water to levels below 1,500 µS/cm (Figure 44). Table 18 shows the relationship between sodium chloride mineral content and specific conductance; the table can be used to predict specific conductance decreases when sodium chloride is removed or added to the water. Figure 44 visualizes the recorded specific conductance effluent discharge concentrations of the Lakefield municipal WWTP to show how compliance with chloride effluent limits will lower specific conductance of the effluent. The predicted specific conductance is a function of the chloride management alternative chosen with lime softening producing a lower specific conductance (900-1,300 µS/cm) compared to reverse osmosis softening (1,500-2,000 µS/cm).

Figure 43. Sodium adsorption ratio (SAR) of the Lakefield WWTP historical effluent concentrations under three different scenarios. The blue line represents the Lakefield WWTPs measured effluent monthly average SAR value from 2010 to 2016 without chloride compliance (SAR range 4.44 to 16.7). The red line represents the SAR of the Lakefield WWTP if the hardness is reduced to 120 mg/L as $CaCO_3$ using lime softening at the drinking water plant and chloride concentrations are reduced to the monthly average chloride limit of 230 mg/L. The green line represents the SAR of the Lakefield WWTP if the hardness is reduced to 120 mg/L as $CaCO_3$ using reverse osmosis (RO) softening at the drinking water plant and chloride concentrations are reduced to the monthly average chloride limit of 230 mg/L. Both the red and green lines are below a SAR of 6, indicating that when the Lakefield WWTP complies with a SAR protective of irrigation in sensitive soil conditions.

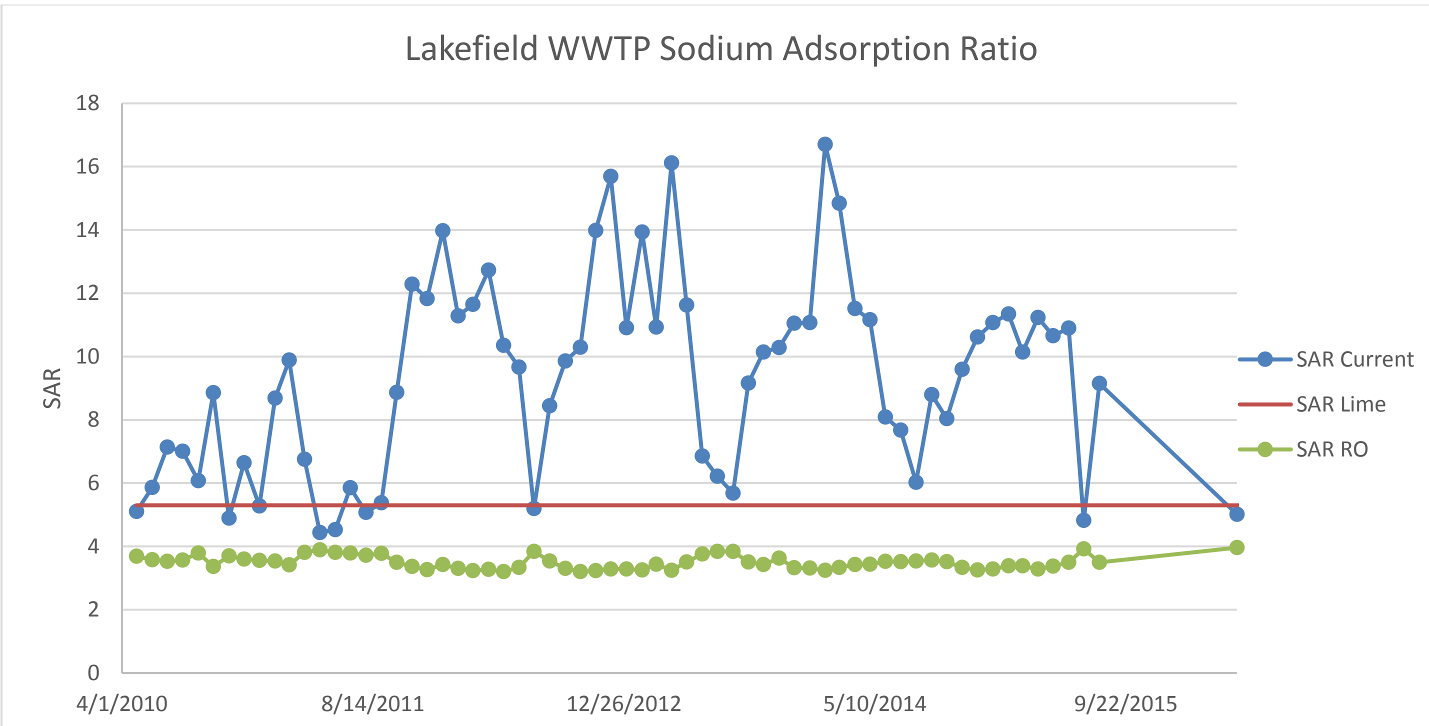
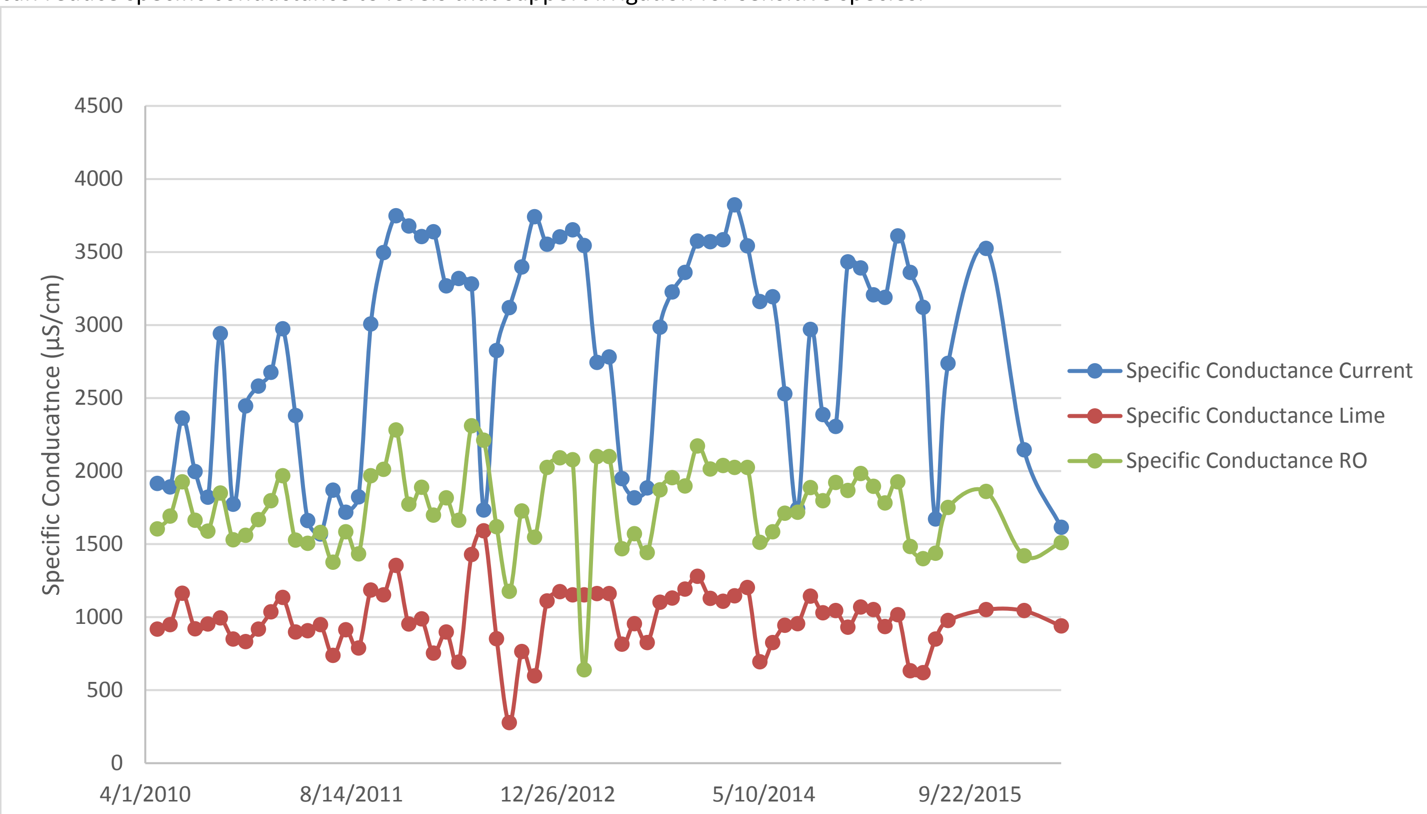


Table 18. Relationship between chloride, sodium, sodium chloride and specific conductance in a water solution. For every 1 mg/L of chloride reductions, there will also be a 0.64 mg/L reduction of sodium. Every 1 mg/L of sodium chloride reductions will reduce specific conductance by approximately 1.2-1.4 µS/cm dependent on the overall salinity of the solution. The calculations were performed using pure sodium chloride solution by the MPCA in the PHREEQC water quality modeling program developed by the United States Geological Survey.

Cl (mg/L)	Na (mg/L)	NaCl (mg/L)	Specific Conductance (µS/cm)
0	0	0	0
100	65	165	252
200	130	330	473
300	195	495	680
400	259	659	876
500	324	824	1064
600	389	989	1246
700	454	1154	1423
800	519	1319	1595
900	584	1484	1764
1000	649	1649	1930

Figure 44. Specific conductance of the Lakefield WWTP historical effluent concentrations under three different scenarios. The blue line represents the Lakefield WWTPs measured effluent monthly specific conductance value from 2010 to 2016 without chloride compliance (1500-3600 µS/cm). The red line represents the specific conductance of the Lakefield WWTP if the hardness is reduced to 120 mg/L as CaCO3 using lime softening at the drinking water plant and chloride concentrations are reduced to the monthly average chloride limit of 230 mg/L. The green line represents the specific conductance of the Lakefield WWTP if the hardness is reduced to 120 mg/L as CaCO3 using reverse osmosis (RO) softening at the drinking water plant and chloride concentrations are reduced to the monthly average chloride limit of 230 mg/L. Only the red line is consistently below 1,500 µS/cm, indicating that compliance with a chloride limit can reduce specific conductance to levels that support irrigation for sensitive species.



4) Are there irrigators with active MNDNR permits downstream?

This steps asks whether there are active MNDNR surface water irrigators downstream of the NPDES discharger.

To determine whether a NPDES discharger has active surface irrigators downstream, first the water flow path downstream of the WWTP is determined, and then a half-mile buffer is put around that flow path. Only active MNDNR surface water irrigators within that half-mile buffer will be considered as being downstream of the WWTP. The half-mile buffer distance was selected to more easily automate the process that determines the locations of downstream users. An example of this process is provided for the Lakefield WWTP in Figure 45.

Figure 45. Flow path downstream of the Lakefield WWTP. Lakefield has three downstream active surface water irrigators with MNDNR permits within the half-mile buffer and they are labeled with their MNDNR water appropriation ID. Table 19 summarizes the irrigators within the buffer zone.

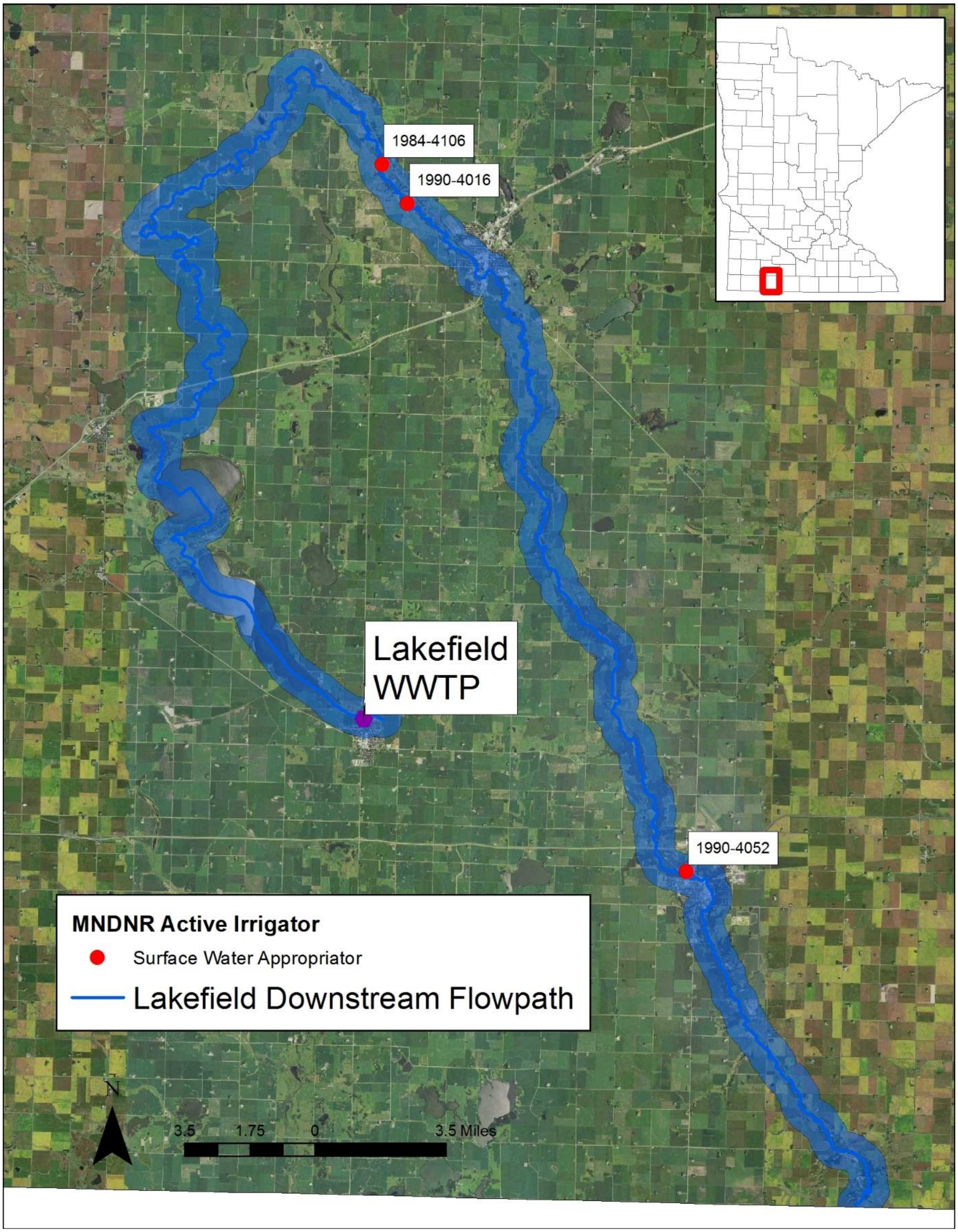


Table 19. Example summary of the active MNDNR irrigators downstream of the Lakefield WWTP.

Permit Number	Resource Category	Resource Type	Use Type
1984-4106	Surface Water	Dug Pit/Holding Pond	Agricultural Crop Irrigation
1990-4016	Surface Water	Quarry/Mine	Golf Course Irrigation
1990-4052	Surface Water	Stream/River	Golf Course Irrigation

5) Locate the first downstream irrigator that could be impacted by the NPDES discharger

Only surface water appropriators that pull water directly from the flow path downstream of the NPDES discharger will be considered. Surface water irrigators pulling water directly from waters downstream of a NPDES discharger are most likely to be impacted by water quality from the upstream NPDES discharger.

Using the MNDNR irrigator appropriation database, it is possible to locate the location of each applicable downstream appropriator and appraise whether that appropriator is appreciably drawing from surface water. If an irrigator is affected by more than one upstream wastewater discharger the MPCA would evaluate that scenario on a site-specific and case-by-case basis.

In the example using the Lakefield WWTP, the first downstream surface water appropriator that pulls water directly from the flow path downstream of the NPDES discharger is appropriator/permit ID 1990-4052 and is approximately 50 river miles downstream of the Lakefield WWTP (Figure 45 and Table 19).

6) Is the ambient water quality suitable for irrigation at the first downstream irrigator?

The MPCA has a substantial database of surface water quality data to assess whether a water is suitable for irrigation by looking at the specific conductance and SAR of a water. The MPCA has collected over 200,000 surface water quality samples for specific conductance statewide (Figure 46). The MPCA has collected less data for the SAR of a given water body; however, there are still over 1,700 locations that have been sampled for the cations (Na, Ca, Mg) used in calculating the SAR (Figure 47).

These water quality data points can be used to determine whether a water is suitable for irrigation for sensitive crops by comparing to the values in the values in Table 20. The values in Table 20 are suitable for irrigation for sensitive crops in Minnesota climates; the justification for the magnitude of these values can be found in the discussion of box 9. In order for a water to be considered as being suitable in this section, it must be below the magnitude for both the SAR and specific conductance.

Table 20. Protective values for irrigation for sensitive crops in sensitive soil conditions to be used when determining whether ambient water quality is suitable for irrigation. These values assume that spray irrigation is used.

Parameter	Magnitude	Sample Locations Required	Number of Data points needed
Sodium adsorption ratio	< 6	One location upstream of irrigator and downstream of discharger	At least once within last ten years
Specific conductance	< 1,500 µS/cm	One location upstream of irrigator and downstream of discharger	At least once within last ten years

An example of this process is provided below using the flow path downstream of the Lakefield WWTP on the Des Moines River and Heron Lake (Figure 48). Heron Lake and the Des Moines River have been sampled in eight locations for specific conductance and none of those samples are greater than 852 µS/cm. Comparing these values to the protective specific conductance value in Table 20 demonstrates that the water quality that the irrigators might use on this reach is suitable for irrigation for sensitive crops with regards to specific conductance and SAR. The SAR at all the samples location in Figure 48 is less than 6, even though the SAR has never been formally sampled at any location. The maximum possible SAR is known because it is possible to calculate a potential maximum upper bound on the SAR if the specific conductance and hardness of the sample are both known. This calculation is complex and will not be detailed in this document, but will be explained in greater detail in the final TSD if requested.

Figure 46. Surface water quality specific conductance concentrations collected by the MPCA. Each dot represents a location where specific conductance has been measured. The color of the dot is based on the average specific conductance of a sample location. Some locations have been sampled over one hundred times and some locations have only been sampled once.

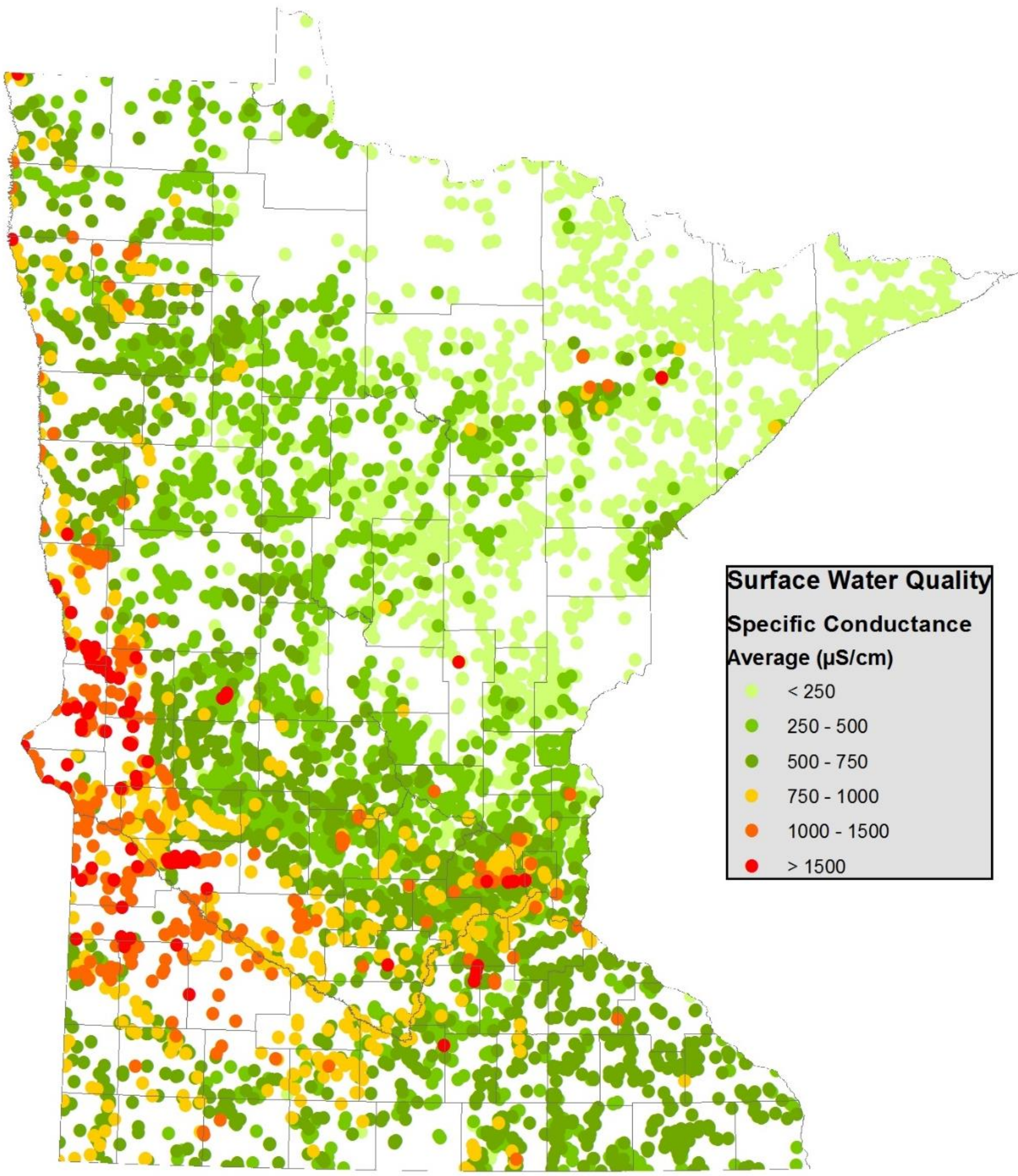


Figure 47. Surface water quality sodium adsorption ratio (SAR) concentrations collected by the MPCA. Each dot represents a location where SAR has been measured. The color of the dot is based on the average SAR of a sample location. Some locations have been sampled over twenty times and some locations have only been sampled once.

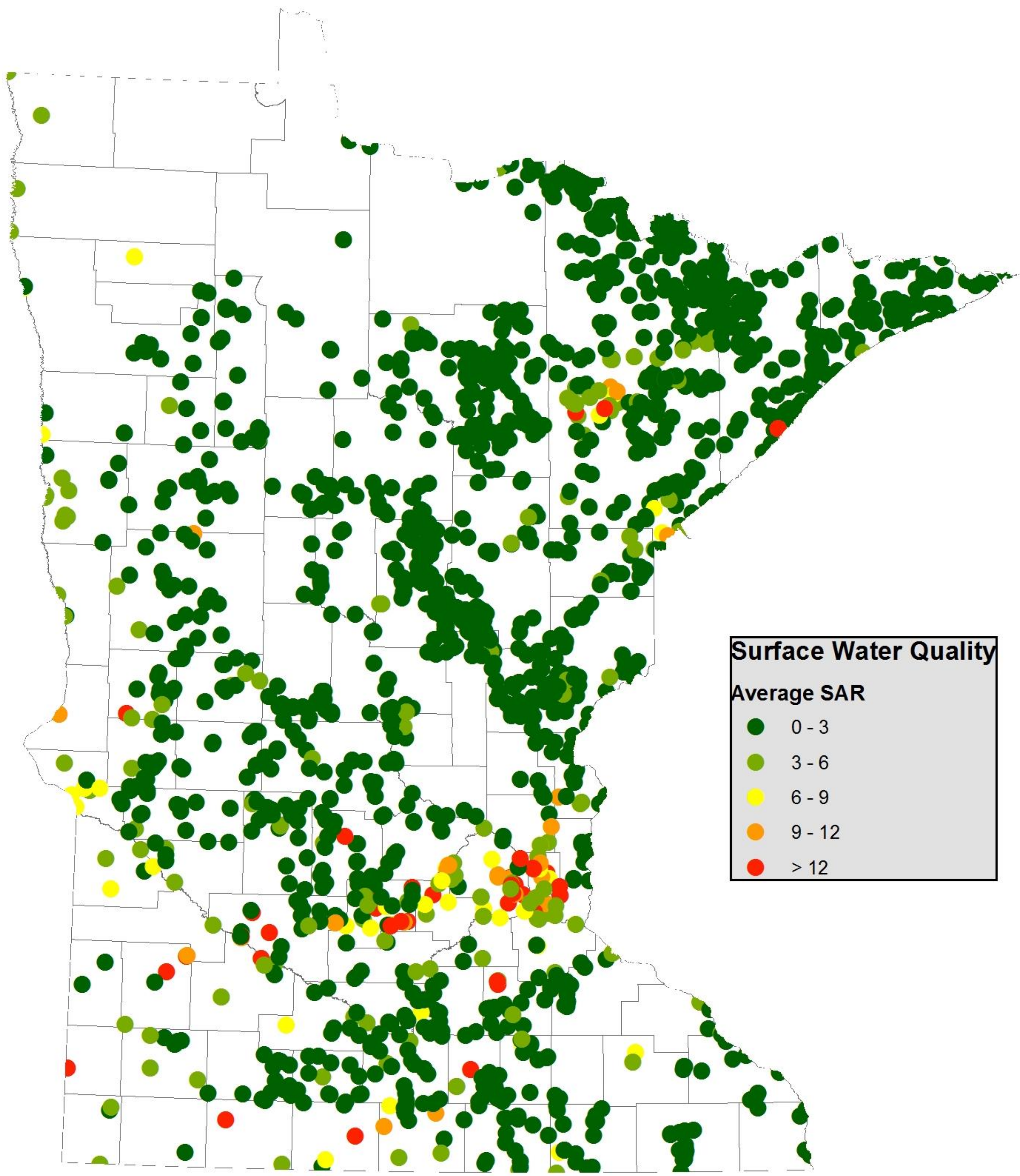
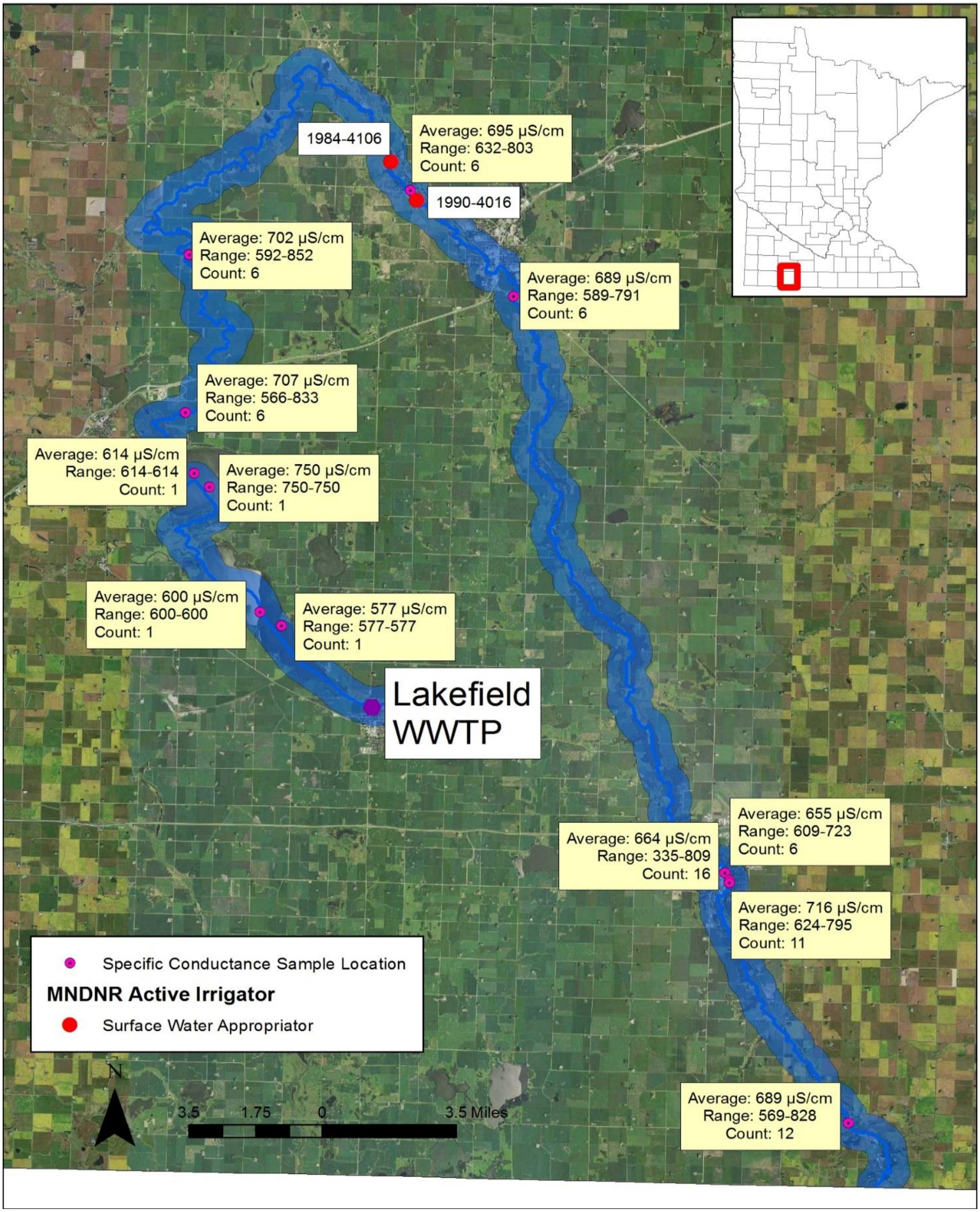


Figure 48. Specific conductance surface water quality samples downstream of the Lakefield WWTP. All specific conductance samples downstream of the Lakefield WWTP but upstream of the first downstream irrigator are less than 1,000 µS/cm.

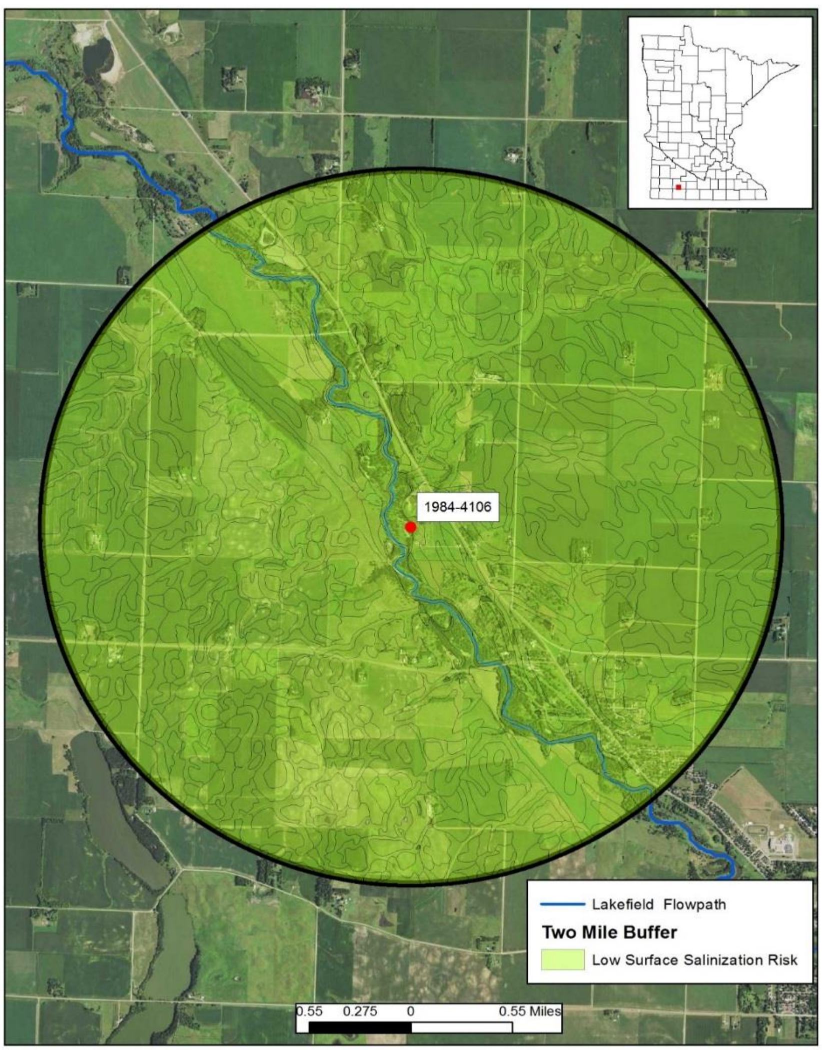


7) Does the soil have a salinization risk?

This step evaluates available soil data to determine whether the soil has a risk to become salinized. The primary datasets in this analysis will come from SSURGO, maintained by the USDA-NRCS. A two mile circular buffer surrounding the first downstream irrigator will be created and salinization risk within that buffer will be assessed by each individual soil map unit. The two-mile buffer distance was selected because it is very unlikely that the irrigator would construct irrigation equipment capable of irrigating from a distance greater than two miles.

Only if the two-mile buffer contains one or more soil map units with a medium or high salinization risk will the soil surrounding the irrigator be considered as being unsuitable for irrigation. If the entire two-mile buffer surrounding the first downstream irrigator is comprised of solely low surface salinization risk soil map units, the soil would be considered suitable for irrigation with little risk to excess salinity. An example of this assessment for MNDNR irrigator 1984-4106 downstream of the Lakefield WWTP is provided below in Figure 49.

Figure 49. Salinization risk assessment within a two-mile buffer of irrigation permit 1984-106. The polygons within the circular two mile radius circle are all the individual soil map units in the SSURGO soil map database. All of the soil map units within this buffer have a low salinization risk rating as visualized by the green color.



8) Do not include WQBEL in permit

If this box is reached then no water quality based effluent limit for specific conductance or SAR should be included in the permit. This is because there is minimal likelihood that the irrigation water quality in question would affect crops. Effluent monitoring for these parameters should be continued but at a reduced frequency.

9) At the first irrigator, is the irrigation used on sensitive crops?

This section will look at available land-use data to determine whether the landscape contains sensitive crops that might be being irrigated. The primary datasets in this analysis will come from the USDA-NRCS land-use dataset.

Crops sensitive to excess salinity will be defined by the criteria in ASAM (2011). The list of sensitive crops that will be used in this assessment can be found in Table 21. A two-mile circular buffer surrounding the first downstream irrigator will be created and land use within that buffer will be assessed by looking at the percentage of each land-use cover in the buffer. The two-mile buffer distance was selected because it is very unlikely that the irrigator would construct irrigation equipment capable of irrigating from a distance greater than two miles.

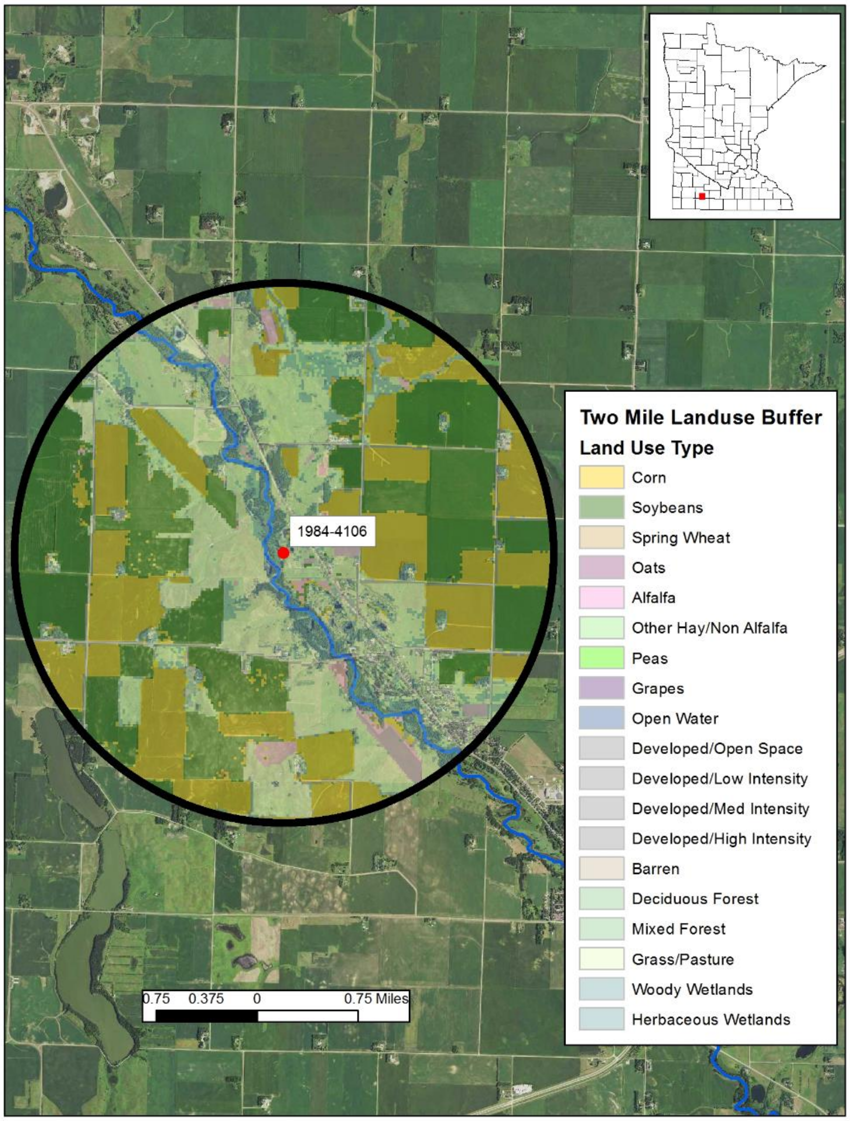
If the two-mile buffer area contains a sensitive crop in Table 21 at greater than 0.5% of the total buffer area (40 acres), then the irrigator will be considered as having the potential to irrigate sensitive crops. If a sensitive crop is present at less than 0.5% of the buffer, then the locations of that sensitive crop will be analyzed to determine whether that sensitive crop is in a contiguous plot of land and actually present on the landscape. The MPCA will also look at all available aerial imagery to determine whether the irrigator is actually using irrigation water on a sensitive crop.

An example of this process is demonstrated in Figure 50. Figure 50 shows that the two-mile buffer surrounding irrigator 1984-4106 does not have any sensitive crops within it at a greater than 0.5% of the landscape.

Table 21. Sensitive crops to excess salinity as defined by the ASAM 2011. Tropical crops such as mangoes, limes and oranges were removed from the list because these crops cannot be grown in Minnesota's climate.

Sensitive Crops (From: ASAM, 2011)	
Herbaceous Crops	**Woody Crops**
Bean, Common	Apple
Bean, Mung	Apricot
Carrot	Blackberry
Fennel	Boysenberry
Onion	Cherry
Parsnip	Peach
Pea	Pear
Pidgeon Pea	Raspberry
Strawberry	Walnut

Figure 50. Example of land use within a two-mile buffer of a surface water irrigator. The land-use types with 0.5% or lower percent in the buffer are not actually present on the landscape. For example, none of those land uses are within a contiguous area that resembles a field or plot. The inclusion of these land-use classes is false positive that is a result of the land-use classification methodology employed by the USDA.



Land Use Type	Percent In Buffer
Soybeans	30.05%
Corn	25.61%
Grass/Pasture	25.08%
Herbaceous Wetlands	10.26%
Developed/Open Space	3.54%
Alfalfa	2.18%
Mixed Forest	0.77%
Open Water	0.74%
Developed/Low Intensity	0.61%
Deciduous Forest	0.30%
Other Hay/Non Alfalfa	0.24%
Barren	0.21%
Woody Wetlands	0.14%
Oats	0.13%
Developed/Med Intensity	0.11%
Spring Wheat	0.01%
Peas	0.01%
Grapes	0.01%
Developed/High Intensity	0.01%

10) Use numeric values protective of irrigation for common crops and soil conditions

Protecting for common crops and soil conditions using numeric water quality values is the primary goal of this section. The values in Table 22 will be used in the narrative translator process to protect for irrigation for common Minnesota crops and soils conditions. The justification for these values is explained in more detail later in this section.

Table 22. Protective values for irrigation for common Minnesota crops in typical soil conditions to be later when calculating the need for NPDES effluent limitations. These values assume spray irrigation is being used.

Parameter	Magnitude	Duration	Frequency
Sodium adsorption ratio	10	Summer average (May to October)	Once per year
Specific conductance	3,000 µS/cm (3.0 dS/m)	Summer average (May to October)	Once per year

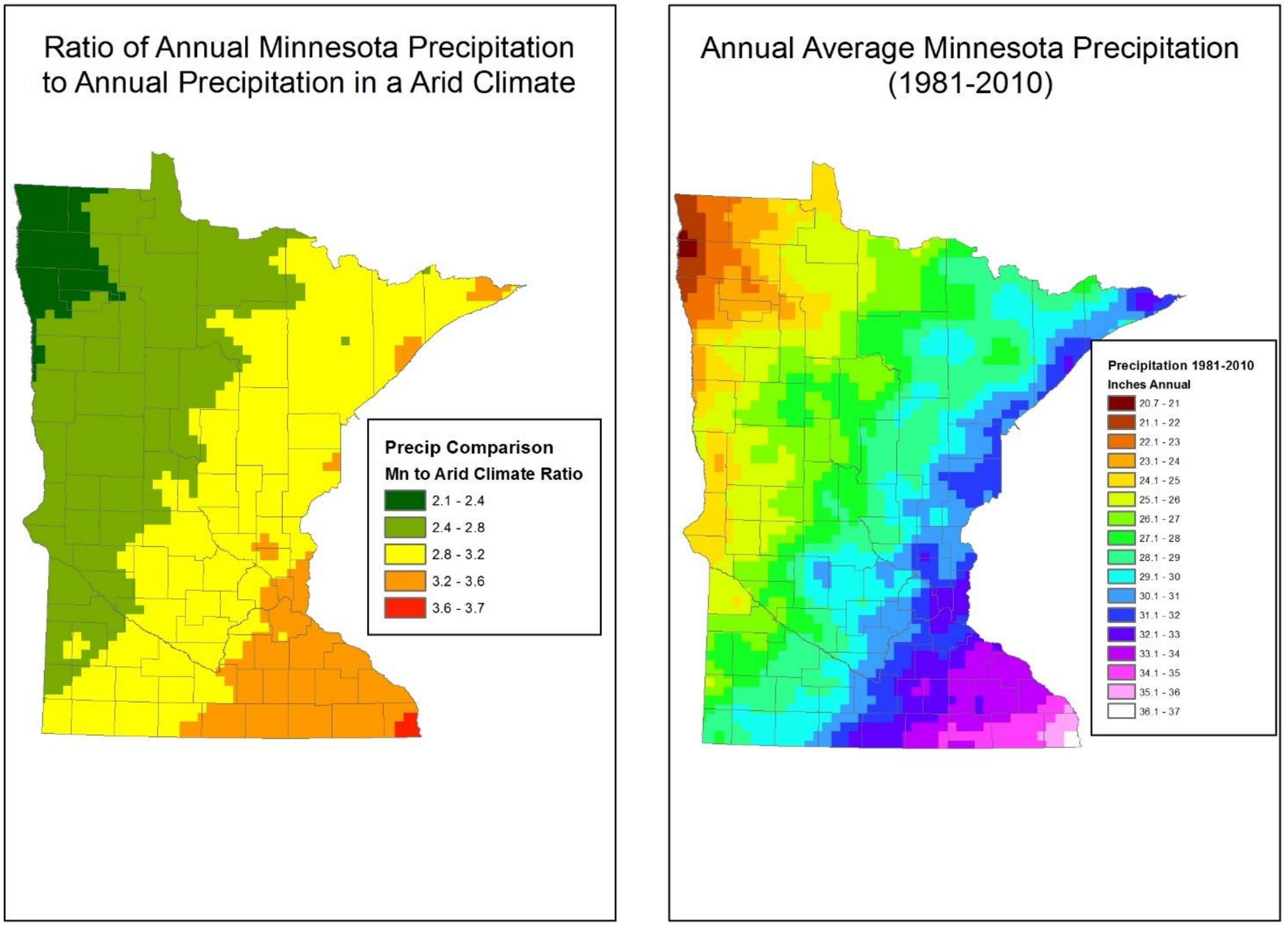
Protecting for excess salinity by selecting a protective specific conductance value

Minnesota agriculture is dominated by a select few crops and protecting for these dominant crops will protect the greatest amount of irrigated farmland in Minnesota. The dominant crops in Minnesota can be found in Table 23 by acreage of farmed land. Table 23 also contains the conservative protective salinity values typically found in irrigation manuals. For example, 99% of the 2017 harvested crop acreage is comprised of just seven crops; just three crops (soybeans, corn and hay) comprise 87.3% of that 99%. Of the major crops grown in Minnesota, only two crops (dry beans and peas) are classified as having a sensitive salinity tolerance ranking (ASAM, 2011) and all other major crops are classified as being moderately sensitive or tolerant.

The protective salinity values in Table 23 were developed for continuous irrigation in arid and semi-arid climates with less than or equal to 9.85 inches of annual average precipitation (ASAM, 2011; Thomas, 2011). Everywhere in Minnesota receives at least 2.1 times more rainfall on average than the 9.85 inches or less of annual precipitation value that defines arid climates (Figure 51). That consistent annual precipitation functions to flush salinity from the root zone of soils more than considered in developing the protective values in Table 23. This additional salinity flushing due to precipitation functions to increase the protective salinity irrigation water quality value. Using the upper bound of the moderately sensitive range (1.5-3 dS/m) is therefore appropriate because the ratio between the upper bound and lower bound of that range is exactly 2, and this ratio is less than the 2.1 times minimum difference between Minnesota's climate and an arid climate.

Choosing to protect for the moderately sensitive salinity tolerance ranking in Table 23 would be protective of the majority (>99%) of Minnesota crops by acreage. Using the upper bound of the moderately sensitive range (1.5-3 dS/m; footnote 1 in Table 23) in (ASAM, 2011) would be appropriately protective of most commonly grown Minnesota crops, soil conditions and climate.

Figure 51. Minnesota annual precipitation compared to precipitation in an arid climate. Minnesota receives at least 2.1 times more annual precipitation than an arid climate with some portions of the state receiving substantially more precipitation than others.



The summer average duration and the once per year frequency is based on the sections in the crops and soils section of this document. In summary: most crop yields respond to crop salinity over the entire growing season duration; because Minnesota receives precipitation year round, there is constant flushing of the soil root zone salinity in the growing season so soil salinity will rarely be the same value. This means there is no need to protect for specific periods of the year and a summer duration is protective. The once per year frequency is justified because all of the crops in Table 23 are annual crops and should therefore be protected on an annual time step at a minimum.

Table 23. Major crops in Minnesota by harvested acres in 2017. Harvest acreage data from the USDA National Agriculture Statistics Service Minnesota Field Office. The protective salinity values are taken from irrigation reference manuals and the values are based on the conservative assumptions in footnote 4 below.

Crop	Harvested Acres in 2017	Percentage of Total Harvested Acres in 2017	Cumulative Percentage of Total Harvested Acres in 2017	Protective Salinity Value in Root Zone of Crop[4] (dS/m)	Salinity Tolerance Rating[1] (ranking conductivity range in dS/m)
Soybeans	8,150,000	31.5%	31.5%	5.0[1]	Moderately Tolerant
Corn	8,050,000	31.2%	62.7%	1.7[1]	Moderately Sensitive
Hay & Haylage	6,360,000	24.6%	87.3%	2.0[5]	Moderately Sensitive
Wheat	2,270,000	8.8%	96.1%	6.0[1]	Moderately Tolerant
Sugarbeets	420,000	1.6%	97.7%	7.0[1]	Tolerant
Oats	170,000	0.66%	98.4%	3.3[2]	Tolerant
Dry Beans	168,100	0.65%	99.0%	1.0[3]	Sensitive
Barley	80,000	0.31%	99.3%	8.0[1]	Tolerant
Peas	49,300	0.19%	99.5%	1.0[3]	Sensitive
Potatoes	46,000	0.18%	99.7%	1.7[1]	Moderately Sensitive
Sunflower	38,700	0.15%	99.9%	1.7[1]	Moderately Tolerant
Canola	36,000	0.14%	99.99%	9.7[1]	Tolerant
Pumpkins	930	0.004%	100%	< 3[3]	Moderately Sensitive

1. Source: ASAM (2011) references defines the salinity tolerance ratings for no crop yield loss as below:

Salinity Tolerance Rating	Range (dS/m)
Sensitive	< 1.5
Moderately Sensitive	1.5 - 3
Moderately Tolerant	3 -6
Tolerant	6 -10

2. From New South Wales Irrigation Manual 2016

3. Estimated by MPCA using species salinity sensitivity rankings in (ASAM, 2011) for herbaceous crops.

4. These values assume semi-arid or arid climates, that sodium chloride is the predominant mineral present, that the crops are grown in moderately saline soils and no loss in crop yield (i,e., crop yield threshold = 100%).

5. Protective value for alfalfa from (ASAM, 2011) used as a surrogate for hay and haylage.

Protecting for soil infiltration

The SAR is an irrigation water quality parameter that helps determine the suitability of an irrigation water in terms of its likelihood to cause (or not cause) soil swelling and resulting water infiltration problems. High SAR water applied to soils with a high clay content can cause swelling of soil clay particles which reduces the pore volume of the soil (ASAM 2011; Ayers and Westcott, 1994). This reduction in pore volume makes it hard for water to infiltrate into the root zone of the soil and for crop roots to penetrate the soil. Excessively poor water infiltration and root penetration will ultimately reduce crop yields (ASAM 2011; Ayers and Westcott, 1994).

The formula for calculating the SAR is below. In the SAR calculation, Na, Ca and Mg represent sodium, calcium and magnesium concentrations in units of milliequivalents per liter.

$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Modern understanding of irrigation water quality recommends that the SAR to be interpreted in conjunction with the specific conductance of the water (ASAM 2011; Ayers and Westcott, 1994).The Food and Agriculture Organization of the United Nations maintains and publishes an irrigation manual titled “Water quality for irrigation” written by Ayers and Westcott. It is considered by many to be the “go-to” source of information on irrigation water quality and it contains numeric recommendations for irrigation water quality. The values in that manual for evaluating SAR are re-printed below in Table 24.

Protective SAR values cannot be interpreted in the same way as protective values for a conventional toxic pollutant parameter, in the sense that lower SAR values are not always more protective than high SAR values (Ayers and Wescott, 1994). The values in Table 24, taken from Ayers and Westcott, do not recommend a singular upper bound on SAR, but instead recommend that within a given SAR range, specific conductance also needs to be within certain bounds to have no, moderate, or severe restrictions on irrigation use to protect for water infiltration into the soil. For example, if SAR is low (0-3) then there are no restrictions on irrigation use as long as specific conductance is greater than 0.7 dS/m or 700 uS/cm. Meanwhile, if SAR is low (0-3) then there are severe restrictions on irrigation use when specific conductance is less than 0.2 dS/m or 200 uS/cm. Rainfall in Minnesota has SAR values less than 3 and rainfall specific conductance is typically < 60 uS/cm (ASAM 2011), meaning that according to Table 24, rainfall is unsuitable for watering crops; however, this is only a concern in soils that have already salinized due to high sodicity.

The interpretation of and assumptions behind the values in Ayers and Wescott should be carefully considered in the context of Minnesota’s irrigation water quality needs. Ayers and Wescott caution that “wide deviations from the assumptions might result in wrong judgements on the usability of a particular water supply”.

The important and relevant assumptions for this rulemaking for the numbers in Table 24 and most other irrigation references (ASAM, 2011; Texas A&M, 2003; New South Wales, 2016) are:

- Climate is semi-arid to arid
- Rainfall does not play a significant role in meeting crop water demand or soil leaching requirement
- Soil textures range from sandy-loam to clay-loam.

All of the above assumptions are not applicable to Minnesota. Minnesota's climate is not semi-arid or arid but rather it is continental with moderate precipitation year round. In Minnesota, rainfall plays a significant role in meeting crop water demand as evidenced by the fact that there are substantial numbers of farmers that successfully farm only watering their crops with rainfall. Finally, in Minnesota it is common for soils to have textures that are not sandy-loams or clay-loams.

Table 24. Guidelines for interpretations of water quality for irrigation for SAR and specific conductance to manage for infiltration rate of water into the soil. Re-printed from Ayers and Westcott, 1994. Assumptions behind these values are referenced above.

Sodium Adsorption Ratio (SAR)	Specific Conductance (dS/m)		
	Restriction On Use		
	None	Slight to Moderate	Severe
0 – 3	> 0.7	0.7 – 0.2	< 0.2
3 – 6	> 1.2	1.2 – 0.3	< 0.3
6 – 12	> 1.9	1.9 – 0.5	< 0.5
12 – 20	> 2.9	2.9 – 1.3	< 1.3
20 – 40	> 5.0	5.0 – 2.9	< 2.9

Generally for irrigation water quality, it would be preferable to have a lower SAR as long as specific conductance is not also very low (Table 24). There are no nationwide reference values published for selecting a protective SAR value for irrigation. However, a water with a SAR less than 10 appears to be the common threshold defining low impact irrigation in states with generally drier climates than Minnesota such as Texas, North Dakota and South Dakota (Table 25). The less than 6 SAR value in Table 25 developed by the NDSU extension service is protective of continuous irrigation where natural rainfall is not a significant source of crop water needs; this SAR value would be higher if natural rainfall were a significant source of water.

Table 25. Protective SAR values in the literature.

Source	SAR with Low Impact on Irrigation
South Dakota Irrigation Water Quality Standard (Chapter 74:51:01:53)	< 10
Texas A&M Extension Service 2003	< 10
NDSU Extension 2018	< 6 for continuous irrigation
Ayers and Westcott, 1994	Protective SAR function of specific conductance

	(See Table 24)

11) Use numeric values protective of irrigation for sensitive crops and soil conditions
Protecting for all crops, including sensitive crops and soil conditions, is the primary goal of this part of the narrative translator process. The values in Table 26 will be used in the narrative translator process to protect for irrigation for sensitive crops and soil conditions. The justification for these values is explained in more detail later in this section.

Table 26. Protective values for irrigation for sensitive crops in sensitive soil conditions to be used when calculating the need for NPDES effluent limitations.

Parameter	Magnitude	Duration	Frequency
Sodium adsorption ratio	< 6	Summer average (May to October)	Once per year
Specific conductance	< 1,500 µS/cm	Annual average (May to October)	Once per year

Protecting for excess salinity by selecting an protective specific conductance value for sensitive crops

Choosing to protect for the sensitive salinity tolerance ranking in Table 23 would be protective of the sensitive crops grown in Minnesota. Using the upper bound of the sensitive range (1.5 dS/m; footnote 1 in Table 23) in ASAM (2011) would be appropriately protective of sensitive crops. There are sensitive crops within this class with lower protective values than 1,500 µS/cm (peas for example; Table 23); however, these values assume no significant rainfall. When accounting for Minnesota's consistent annual precipitation, a higher protective irrigation value could be used to safely irrigate.

Protecting for soil infiltration

Using a SAR value of < 6 is consistent with the protective irrigation values developed by the North Dakota State Extension service (Table 25). The < 6 SAR value was developed for protecting for continuous irrigation for farmland that receives insufficient precipitation to support crop water need (NDSU Extension, 2018). Since the < 6 value is recommended statewide in North Dakota and western North Dakota has a significantly drier climate than anywhere in Minnesota, a < 6 SAR value should be sufficient protective of Minnesota irrigation.

12) Perform RP analysis using numeric values protective of irrigation for typical crops and soil conditions
Reasonable potential is a term used to describe the analysis for determining whether a WQBEL is necessary for a permitted wastewater discharger. The term is taken from federal regulations, which require that effluent limits must control all pollutants or pollutant parameters which are or may be discharged at a level that will cause, have the reasonable potential to cause, or contribute to an excursion above any state water quality standard. Federal regulations require that all discharges with RP to cause or contribute to the exceedance of a state water quality standard receive a WQBEL (40 CFR 122.44).

If the facility does not have RP, future routine effluent monitoring may be recommended to ensure continued protection of downstream waters. If a facility has reasonable potential, a wasteload allocation

(WLA) is derived from the amount of pollutant load the facility can discharge without causing or contributing to an exceedance of the standard in a downstream water.

A WLA is the amount of a pollutant that an existing or future facility may discharge. WQBELs for point source discharges are developed from WLAs. Neither EPA nor MPCA guidance requires a WLA to be calculated a specific way when setting effluent limits. However, a WLA should be based on: 1) the pollutant load that would meet the standard, and 2) the pollutant load that is currently present in the receiving water. When calculating a WLA, the MPCA has developed pollutant-specific practices that account for the unique chemistry of each pollutant.

The calculation of the WLA considers the assimilative capacity of the receiving water. The assimilative capacity of the receiving water is the difference between current loading and the highest load that still allows the water quality standard to be met. As long as the current loading is less than the load required to meet the water quality standard, there is available assimilative capacity. If the current loading is greater than the load that will meet the water quality standard, there is no available assimilative capacity and reductions are needed for the water body to meet its beneficial use. The following mass balance equation (Equation 1) calculates a WLA in units of concentration for a single facility. The WLA is dependent on the variables in the mass balance equation. The value for the translator must be known before a WQBEL can be determined for a water to protect for irrigation.

Equation 1. General mass balance equation for WLA

$$WLA = \frac{Translator * \ Q_s + Translator * Q_e - Q_{s*} C_s}{Q_e}$$

- WLA = Wasteload allocation
- Translator = Values in either box 12 or 13 depending on whether sensitive crops are being protected.
- Qs = Protective receiving water flow rate ($122Q_{10\,;}$ June to September)
- Qe = Individual point source effluent flow rate. (70% of AWWDF for municipal WWTPs, MDF for industrial dischargers)
- Cs = Background concentration of pollutant in receiving water (see background concentration section)

Lakefield WWTP RP Calculation Example: Specific Conductance

A summary of the WLA and RP calculation for the Lakefield WWTP for specific conductance can be seen in Table 27. This is an example calculation and assumes that the first downstream irrigator is the same one as in Figure 50 above.

The calculations in Table 27 protects for irrigation for common crops at the first downstream surface irrigator from the Lakefield WWTP. There is a substantial amount of dilution (44.4:1) in this scenario, and as a result, the Lakefield WWTP does not need a specific conductance or sodium limit in this scenario.

Table 27. Input and select outputs from the Lakefield WWTP RP calculation. This calculation determines the need for an effluent limit to protect the first downstream irrigator from Lakefield.

Abbreviation	Lakefield Reasonable Potential Calculation	Unit	Value
Qe	70% of Lakefield Wet Weather Design Flow	MGD	0.41
Qs	$122Q_{10}$ flow rate at first downstream irrigator	CFS	28
	Stream to Effluent Dilution Ratio	---	44.4
Cs	Des Moines River Background Concentration Specific Conductance	µS/cm	852
Translator	Protective Water Value for Common Crops	µS/cm	3000
WLA	Wasteload Allocation	µS/cm	1,510,000
RP Calculation	Duration of Protective Value	Days	122
	Lakefield WWTP Effluent Max Specific Conductance	µS/cm	3800
	Lakefield WWTP Effluent Specific Conductance Coefficient of Variation	---	0.3
	Lakefield Monthly Average Effluent Limit Protective of 3000 µS/cm	µS/cm	1,940,000
	RP to exceed Monthly Average Limit	RP	**NO**

Protective Flow Rate (Qs)

Water quality standards are defined by a duration and frequency, as described previously. The MPCA is proposing a May to October average duration for the 4A narrative translator. In order to ensure that the effluent limit developed protects the water quality standard at the specified duration and frequency, an appropriately protective stream flow rate must be determined. The flow rate is used for streams and loading to lakes fed by streams. The flow rate defines the critical flow condition, which is then used in the effluent limits calculation.

A seasonal $122Q_{10}$ flow rate is protective of the irrigation designated use when calculating the need for a NPDES permit to receive effluent limits. The $122Q_{10}$ flow rate is defined in *Minn. R.* 7050.0150 and means the "122-day ten-year low flow" or "$122Q_{10}$" means the lowest average 122-day flow with a once in ten-year recurrence interval. The 122 day length is roughly equivalent to the length of Minnesota summer (June through September).

The $122Q_{10}$ flow rate is protective of irrigation for the following reasons:

1. Minnesota receives rainfall consistently throughout the crop growing season. There may be dry periods, but in Minnesota dry periods are always followed by rain and this rain will act to flush salts out of the soils. This means that soil salinity will significantly decrease after rainfall events and soil salinity is unlikely to be consistently high over an extended period.
2. Irrigation is most likely to occur during the height of the growing season which can be operationally defined as June to September.
3. The one in ten year recurrence interval is more protective than the once per year frequency interval proposed in sections 10 and 11 above.

Point Source Effluent Flow Rate

The facility effluent flow rate used in effluent limit reviews should be protective of the water quality standard's critical condition. Municipal WWTPs must treat all the water flowing into the facility (inflow). Once treated, the discharge (effluent) flows into the receiving water. The maximum capacity of a municipal facility to treat wastewater is known as the average wet weather design flow (AWWDF). The AWWDF is comprised of the everyday base wastewater flow plus the additional flow reaching the plant because of inflow and infiltration in the wastewater collection system during storm events. During dry periods when precipitation and thus infiltration is much lower, the flow a wastewater plant is designed to treat is referred to as the average dry weather design flow. Average dry weather design flow for municipal WWTP and maximum design flow (MDF) for industrial WWTPs have traditionally been used to calculate effluent limits for toxic parameters. For toxic pollutants, the critical condition is an extreme low flow; municipal facilities typically discharge at the average dry weather design flow at this time because of lack of inflow and infiltration. However, the irrigation narrative translator values have an annual duration, and seventy percent of AWWDF represents the approximate maximum level at which a municipal treatment can operate at over a longer duration of time. Likewise, it is reasonable to assume that industries will discharge at the MDF, although given the complex nature of some industrial facilities, the MPCA may in some cases use a facility-specific flow rate.

The 70th percentile of the average wet weather design flow (AWWDF) for municipal WWTPs and maximum design flow (MDF) for industrial WWTPs should be used in effluent limit calculations to be protective of the irrigation designated use. Municipal facilities operating at over 70% AWWDF on a long term average basis are likely at or exceeding full AWWDF during storm events and will need to expand the size of their treatment plants. For many facilities, 70% AWWDF is near average design flow capacity. Using the 70th percentile AWWDF for municipal facilities allows staff to analyze the potential impact from a WWTP under flow conditions considered at maximum capacity without needing to expand the facility. For industrial facilities the MPCA will use the full MDF unless an alternative flow condition is considered more appropriate given the unique nature of their process. The MPCA will likely continue the practice of using the 70th percentile of the AWWDF for municipal WWTPs and MDF for industrial WWTPs as it does for the river eutrophication standard -based effluent limit setting.

Estimating Background Concentrations

The MPCA has a long-standing practice of using background concentrations to account for receiving water dilution as part of the effluent limit review process. “Background,” in the context of effluent limits, is the level of water quality in the receiving water of interest without facility impacts.

Methods for determining background concentrations are ranked below in terms of preference when site-specific data are not available. The MPCA prefers using site-specific data but may rely on other methods to determine background concentrations.

1. Subtraction - This is the process where the current actual point source loading is subtracted from ambient river loading. This approach allows the MPCA to account for the different contributions from point and non-point sources.
2. Substitution - This is the process of using watersheds or water bodies with similar characteristics to predict background receiving water concentrations in the receiving water of interest. The MPCA tends to use the average or median of site-specific data as the background concentrations when setting effluent limits.
3. Water Quality Model - This is the process of using mathematical techniques to simulate and predict water quality. A typical water quality model consists of a collection of formulations representing physical mechanisms that determine position and behavior of pollutants in a water body.

Expression of Effluent Limits

Any effluent limitation generated from this process will be expressed as monthly average concentration limits only applicable during May to October not to be exceeded more than once a yearexcept in the case of greenhouse operations appropriating surface waters to water their plants. For those exceptional instances, monthly average concentration limits can be tailored to coincide with the greenhouse plant production period.

Option 2: Delay developing the process to translate the narrative standard into a numeric value.

The CWA and Minnesota rules require NPDES wastewater discharge permits to protect uses for which there are narrative water quality standards. 40 CFR § 122.44(d)(1)(VI)(A) says that states may use an explicit state policy or regulation interpreting its narrative water quality standard when setting limits based on a narrative standard.

In fact, 40 CFR § 131.11(a)(2) provides that when a state adopts narrative criteria for toxic pollutants to protect designated uses, the state must provide information identifying the method by which the state intends to regulate point source discharges of toxic pollutants based on such narrative criteria. A key term in the regulation is “toxic pollutants.” Toxic pollutants in the CWA are those listed in 40 CFR § 401.15, and the list does not include the parameters that currently have numeric Class 4A standards. Because these parameters are not listed as toxic pollutants, a narrative translator process is not required in this rulemaking for these parameters pursuant to 40 CFR § 131.11(a)(2).

After examining federal and state statutes, MPCA has determined it is not necessary, *within this specific rulemaking,* to develop a narrative translator process to ensure that NPDES dischargers are discharging water quality at levels that would protect for industrial consumption. The MPCA must ultimately develop a narrative translator policy, but developing the policy need not occur within the confines of this specific rulemaking. The process or policy could be developed after this rulemaking is complete and could be done as a policy guideline that is not in rule or referenced in rule.

Developing a Class 4A NPDES narrative translator process within this rulemaking is optional as long as as translator is eventually developed and implemented. There could be advantages to waiting to develop the narrative translator process policy as a guideline outside of this rulemaking. Developing a narrative translator process outside of this specific rulemaking could allow for greater flexibility to adapt to the complexities and the ever changing nature of irrigation water quality needs. For example, the narrative translator process above only addresses concerns with specific conductance and sodium yet there could be other parameters that are concerning for irrigators in the future.

Developing a narrative translator policy outside of this rulemaking does have drawbacks, primarily the potential for the NPDES Class 4A narrative translator to be developed, or perceived as having been developed, without significant public input. Many wastewater permittees have made clear to the MPCA that they strongly oppose the MPCA developing wastewater permitting policy outside of rulemaking.

Under this option, the MPCA envisions facilitating a Class 4A narrative translator working group outside of this rulemaking. The working group would include NPDES municipal and industrial permit holders upstream of agricultural consumers of surface water and by agricultural consumers of water themselves as well as representatives of state, local, and other governments – such as the MNDNR and tribal entities – and stakeholders and other affected parties. The working group would be given charge and authority to consider permitting options for the Class 4A narrative NPDES translator and to recommend a Class 4A narrative translator permitting policy the MPCA would abide by in the future.

This working group approach was used successfully in the past to address municipal permit holder concerns regarding high wastewater chloride dischargers and could be a successful model going into the future to ensure that permit holders’ concerns are incorporated into the MPCA policy.

Class 4B Water Quality Standards

Minnesota's Existing Class 4B Water Quality Standards

Minnesota's Class 4 water quality standards (*Minn. R.* 7050.0224) protect the waters of the state so that they are suitable for "the agriculture and wildlife designated uses." Class 4B (*Minn. R.* 7050.0224, subp 3) relates specifically to livestock and wildlife designated uses; the narrative standard for 4B waters states that they should "permit their use by livestock and wildlife without inhibition or injurious effects." The State of Minnesota established water quality standards for Class 4B waters in 1967 and made revisions in 1973 and 1981; these standards have not been updated since that time. Only limited supporting documentation exists to explain the basis for these standards. The existing numeric, pollutant-specific standards are presented in Table 28.

The Class 4B standards are outdated based on newer scientific studies and lack information that fully explains how they are intended to be applied to protect the livestock and wildlife drinking water use. The numeric standards do not have any specified duration in the rule. This is consistent with historical water quality rulemaking practices prior to the CWA of 1972 when the duration and frequency of the standards were often not specified and only the magnitude was included in rule. The Class 4B standards do, however, have an implied frequency component in rule, as shown in the statement that "The standards for substances, characteristics, or pollutants given below shall not be exceeded in the waters of the state." Therefore, the current standards for 4B have a "never to exceed" component for the frequency, but lack a duration component - though "never to exceed" is often interpreted as an instantaneous measurement. All these factors have contributed to the lack of certainty in these standards. Therefore, previous reviews (University of Minnesota, 2010), additional scientific literature, and solicitation of public comments are used to set the foundation for the proposed revisions.

Proposed Changes to Class 4B Standards

The current and proposed updated Minnesota water quality standards for Class 4B waters are outlined in Table 28. An expanded summary of the changes being considered for Class 4B, with rationale are presented in Table 29.

Table 28. Summary of existing (from *Minn. R. 7050.0224*) and draft proposed standards for Class 4B.

	Existing Standards[1]	**Draft Proposed Standards**[2]
pH minimum	6.0	6.0
pH maximum	9.0	9.0
Total Salinity	1,000 mg/L	Remove and replace with total dissolved solids
Total Dissolved Solids	n/a	3,000 mg/L
Sulfate (as SO_4^{2-})	n/a[3]	600 mg/L
Nitrate (as NO_3-N)	n/a	100 mg/L

Radioactive Materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.
Toxic Substances	None at levels harmful either directly or indirectly	None at levels harmful either directly or indirectly

[1] The frequency and duration components of the current Class 4B standards are not explicitly described in rule. The rule does indicate that the standards "shall not be exceeded," which implies a frequency of "never to exceed."

[2] The proposed standards will have a 30-day averaging period as the duration component, and will maintain the "never to exceed" frequency.

[3] While there currently is not a sulfate standard specific to wildlife and livestock watering in *Minn. R.* 7050.0224, subp. 3, historically, and on a site-specific basis, MPCA staff have used a Canadian water quality sulfate guideline of 1,000 mg/L (CCME, 2008).

Table 29. Details of proposed revisions to Class 4B standards, with rationale for the changes, with requests for input regarding options and additions to these standards.

Current Rule	Proposed Rule	Rationale
Every water of the state is designated for livestock and wildlife use.	Every water of the state remains designated for livestock and wildlife use.	• Limiting the applicability of the livestock and wildlife use to certain waters is not feasible, because wildlife has the potential to use all waters of the state. • Limiting the livestock designated use to where feedlot operations occur would require removing the designated use from every other water of the state not currently used for feedlot consumption; this would be thousands of waters. Removing a designated use requires substantial administrative effort (rulemaking) and legal justification; avoiding the effort required to remove a designated use simplifies this rulemaking process for these waters. • The livestock and wildlife designated use protects for current and future use by terrestrial animals. The MPCA cannot predict from what waters feedlot operators might want to appropriate water in the future. Therefore, it is prudent to maintain the livestock designated use for every water of the state.
Duration and frequency of the standards are not	Add an appropriate duration and frequency: a 30-day	• The duration of the livestock and wildlife standards should be a 30-day averaging period. The effects of the parameters in Class 4B are generally exhibited after longer-term exposures

clearly defined for the Class 4B use.	averaging period, not to be exceeded.	to the parameters. A short-term exposure to these contaminants will not result in extensive adverse effects. • Most studies evaluating the effects of these contaminants demonstrated effects between 30 and 120 days. Therefore, an averaging period of 30 days is appropriate. • Not to be exceeded as a 30-day average
The numeric standards for pH minimum and pH maximum are 6.0 and 9.0, respectively.	Numeric standards for pH remain the same.	• There are no conclusive studies in the literature that indicate a change in this pH range is needed to protect livestock and wildlife. • More acidic waters (lower pH) would likely be acceptable to and tolerated by livestock and wildlife. However, because lower pH can cause leaching of toxic substances, such as metals, from water distribution pipes, a pH of 6 is being maintained as the minimum pH for this use class.
The standard for total salinity is 1,000 mg/L.	Change total salinity to total dissolved solids (TDS), and change the protective standard value to 3,000 mg/L.	• Total salinity is an outdated measure of salts in the water. No current monitoring is done measuring total salinity. TDS is more frequently used to measure the dissolved salts in water. • The 1,000 mg/L total salinity value does not have supporting information in the historical rule record for why it was used as the basis to limit excess salt. • Current literature and agricultural guidelines support the use of 3,000 mg/L as a protective value for livestock. There is limited wildlife information, but using livestock as a surrogate and using the most sensitive livestock species should protect wildlife.
There is no sulfate standard in the current 4B standards, but a value of 1,000 mg/L sulfate has been applied on a site-specific basis in the past.	Add a numeric sulfate protective standard.	• Sulfate can cause neurological disorders and reduction in performance, thereby impacting the designated use. • There is limited wildlife information, but using livestock as a surrogate and using the most sensitive livestock species should protect wildlife. • The most sensitive species are ruminants, with most studies completed using cattle.[7] The diet of

[7] Ruminants are animals that have a complex, multi-chambered stomach called a rumen. Examples of ruminant animals are cows, goats, sheep, moose and deer. Most animals are not ruminants, and when they are being referred to in comparison to ruminants they are sometimes referred to as monogastric (one stomach) animals or non-ruminants.

		the animals can influence the toxicity. To protect the most sensitive species/diet, a value of 600 mg/L is proposed. • There is an option to apply a less restrictive value in cases where livestock consuming a low forage diet are not present. The protective value for animals consuming a diet greater than 40% forage would be 1,000 mg/L. • MPCA seeks comments from stakeholders regarding how to address the difference in toxicity from sulfate.
There is no nitrate standard in the current 4B standards.	Add a nitrate protective standard of 100 mg/L nitrate as nitrogen (NO_3-N/L).	• High intake of nitrate can cause methemoglobinemia, potentially leading to death, thus, impacting the designated use. • The most sensitive species are ruminants, with most studies completed with cattle. To protect the most sensitive species, a value of 100 mg/L is proposed. • Current literature and agricultural guidelines support the use of 100 mg NO_3-N/L as a protective value for livestock. There is limited wildlife information, but using livestock as a surrogate, and using the most sensitive livestock species, should protect wildlife.
The rule contains narrative standards for radioactive materials and toxic substances.	Narrative standards remain the same.	• The narrative standards currently provide additional protection for substances that are not explicitly called out in rule.
No additional parameters are specifically included.	MPCA requests comments on if the 4B rule should include any additional parameters.	• Contaminants other than pH, TDS, sulfate, and nitrate could potentially have negative impacts to the livestock and wildlife designated use. • MPCA requests comments from stakeholders regarding information that could inform the need for standards for additional parameters to protect the livestock and wildlife designated use.
"Additional selective limits may be imposed for any specific waters of the state as needed."	MPCA requests comments on whether this language should remain in rule or be removed.	• Having this language allows for additional parameters to be considered, if they are discovered to be impacting the designated use. • Could this text be revised to limit its applicability, or to better clarify methods or decisions that would need to be made to decide when an additional parameter would be considered?

Need for Revisions to Class 4B Standards

The rationale for why the specific Class 4B total salinity and pH numeric values were chosen was not well documented during the original 1967 Class 4B water quality standards rulemaking. It seems likely that the originators of the rule used a combination of best professional judgement and texts such as the 1952 or 1963 *Water Quality Criteria* by the State of California (McKee and Edward, 1952; McKee and Wolf, 1963). The pH ranges were amended in the 1973 rulemaking, on the advice of the National Technical Advisory Committee and an expert at the National Water Quality Laboratory in Duluth (MPCA, 1973). Because the adopted standards were not well documented, a current review of the appropriate parameters and concentrations to be included in Class 4B was necessary. The MPCA considered available information, including science generated since the original rulemaking, to inform decisions on the appropriate standards to include in this rulemaking.

Rationale for Changes to Class 4B Standards

Limitations of Current Data

The Class 4B standards are set to protect livestock and wildlife uses of water. The MNDNR appropriations database indicates that livestock (generally defined as animals kept for use or profit, such as cows, horses, pigs, chickens, etc.) may frequently utilize groundwater instead of surface water. The majority of wildlife obtains water from surface waters. Therefore, in many surface waters, the standards may only be protecting wildlife. Most data related to effects of water quality to terrestrial animals are centered on livestock or laboratory species, rather than wildlife species. Due to the general lack of wildlife data, the information available for livestock species is currently being used as surrogate data for terrestrial wildlife species. Where wildlife data was available, this information was considered as well.

Many studies found in the literature are decades old. Because of this, many of the recommended guidelines for livestock are based on studies with animals that were not subject to the genetic selection for ultra-performance characteristics that are found in today's livestock. Some authors note that tolerances for contaminants may decline as livestock are selected for higher performance characteristics, but insufficient studies have been completed using these animals to reach a definite conclusion. This is an area where additional studies may be needed to better characterize the effects to the current status of livestock performance (Olkowski, 2009). These revisions evaluated more recent literature, but even literature that is "new" compared to data available in the 1960s may be 10 to 20 years old. These revisions considered all available literature to update these standards, but as with any standard, science is always evolving. This data limitation regarding high performance livestock is mentioned to acknowledge a source of uncertainty where additional information would be beneficial for future updates.

pH

Limited research has been conducted on pH requirements for wildlife or livestock. The available research shows the existing standards of a pH range from 6.0 to 9.0 appear to be acceptable to maintain wildlife and livestock health. Studies related to the effects of acidified water provided to poultry species have been completed, indicating that acidified waters do not affect poultry health (Acikgoz et al., 2011; Cornelison et al., 2005; Watkins et al., 2004). Acidified water is even used to prevent bacterial growth in the water supplies or the gut/intestine of laboratory and food production animals, without detriment to animal health (Acikgoz et al., 2011; van der Wolf et al., 2001; Tober-Meyer et al., 1981). While a pH level lower than the current standard minimum (pH of 6.0) may be tolerated by livestock and wildlife, the lower end of the pH range in the current standard will provide additional protection to livestock. A pH of 6.0 is protective of leaching of toxic substances, such as metals, from pipes or sediment into the water sources of livestock or wildlife. Metals can be toxic, but can also reduce the palatability of the water, resulting in decreased water consumption, which can affect performance (Raisbeck et al., 2008). Therefore, the minimum level of the standard is not being changed.

Data is far more limited regarding the appropriate maximum standard for pH, because there do not appear to be advantages for livestock production to raising the pH of livestock drinking water, as is seen with acidifying drinking water. Therefore, studies have not been completed to determine the range of pH values that animals can tolerate on the basic end of the spectrum. Because of this, sufficient data are not available indicating the need to change the upper limit of the pH range in the standard (Raisbeck et al., 2008). After reviewing several sources, there were some references to a preferred upper limit to protect dairy cattle or poultry (8.0 to 8.5), but empirical data to demonstrate adverse effects at pH 9.0 were not found. Additionally, the National Research Council (NRC) (2001) had no specific recommendations for the appropriate range of pH in drinking water for dairy cattle.

The current minimum and maximum standards for pH remain in place because there is not sufficient evidence to change the upper limit of the pH range, and the lower limit, while potentially overprotective for direct ingestion by livestock, is protective of the leaching of toxic substances. Also, there are other beneficial use classes that also have pH standards that would further limit the range in surface water or be influenced if natural background conditions had supporting data warranting site-specific standards.

Total Salinity/Total Dissolved Solids (TDS)

The existing standard of 1,000 mg/L total salinity is being revised to 3,000 mg TDS/L. TDS is a more appropriate and typical analytical term used to describe dissolved substances in the water than total salinity. TDS is the measure of the sum of the inorganic and organic solids in water that are smaller than 2 microns, often used in freshwater as a measure of salinity and water quality. Commonly, the ionic make up of TDS includes the cations calcium, sodium, magnesium, and potassium, as well as the anions chloride, sulfate, nitrate, and carbonates; but all dissolved ions present in the water contribute to the TDS (US EPA, 1986; Weber-Scannel and Duffy, 2007). TDS is a quantitative measure of all dissolved constituents, and does not differentiate between any individual ions that make up the total solids. The ions present in water vary in different proportions that may affect the toxicity of the water, depending upon the dominant ions present (some ions induce effects at concentrations lower than others). While an assessment of individual ion toxicity would be ideal, there is a general lack of data for individual ions, with most research being conducted only based on TDS (Raisbeck et al., 2008). Therefore, a standard based on TDS is being proposed to provide protection for livestock and wildlife uses.

While many inorganic salts are necessary in small amounts to maintain animal health, waters high in dissolved solids may affect animal performance by altering the osmolar regulation within the body. High amounts of energy are expended to regulate osmolarity in body compartments. Increasing the salinity of the animal’s drinking water increases the body’s energy consumption needed for osmolar regulation and thus consumes energy that would have been used for growth, milk production or fighting disease (Raisbeck et al., 2008).

Several information sources provide recommendations on the acceptable levels of TDS that would protect livestock, including peer-reviewed journal articles, extension bulletins and recommended guidelines documents. To determine the concentration that would protect livestock and wildlife from effects of TDS, several sources of information were evaluated. The recommended guidelines for the livestock industry were evaluated to determine the recommended levels of TDS for livestock and/or wildlife. These guidelines typically came from science advisory councils (e.g., National Research Council, National Academy of Sciences), universities (e.g., University of Wyoming), industry groups (e.g., Poultry Industry Council), or government agencies (e.g., Australian and New Zealand Environment and Conservation Council). The guidelines were generally based on peer-reviewed literature available at the time, or on other guidance documents. On their own, these guidance documents may not provide enough information to support the values that are being considered in these revisions, but along with the peer-reviewed research that is presented below, the guidance documents served as a starting point and additional evidence for the concentrations chosen in the proposed revisions to the Class 4B standards.

The recommended guidelines for the amount of TDS in drinking water for livestock varies with the species of interest (Table 30). The range of TDS concentrations that may negatively affect livestock varies from approximately 3,000 to 10,000 mg/L, but the most sensitive group of species should be protected because the Class 4B standards will be applied to all waters of the state, fitting standard ecological risk assessment methods to protect the most sensitive species in a biological community-level scenario. Additionally, the standard for TDS needs to be protective of wildlife, which may use the water in areas that livestock do not. Because the data available for wildlife species is limited, the studies involving livestock are considered surrogates for wildlife species, and the standard was chosen based on the literature and recommendations that were available.

Table 30. Recommended guidelines for total dissolved solids in drinking water for different livestock[a]

Livestock	Total Dissolved Solids (mg/L)		
	Recommended upper limit for no adverse effects	Initial reluctance to drink or scouring may occur, but adaptation is likely	Loss of production expected[b]
Beef cattle	4,000	4,000 – 5,000	5,000 – 10,000
Dairy cattle	2,500	2,500 – 4,000	4,000 – 7,000
Sheep	5,000	5,000 – 10,000	10,000 – 13,000
Horses	4,000	4,000 – 6,000	6,000 – 7,000
Pigs	4,000	4,000 – 6,000	6,000 – 8,000
Poultry	2,000	2,000 – 3,000	3,000 – 4,000

[a] Adapted from Australian and New Zealand Environment and Conservation Council (ANZECC) 2000. Guidelines from other sources were similar.
[b] Levels may be tolerated for short periods of time

The recommended guidelines above indicate that poultry and dairy cattle are the more sensitive species to high levels of TDS, and the guidelines are generally supported by experimental studies conducted with the species of interest. For example, sheep have been observed to be tolerant to saline waters – sheep exposed to salinity up to approximately 13,000 mg TDS/L in drinking water were not adversely affected by several salts (Tomas et al., 1973; Potter, 1963; Peirce, 1957; Peirce, 1960; Peirce, 1959; Peirce, 1962; Peirce, 1963). However, pregnant ewes were more sensitive, and were negatively affected by salts in water at concentrations ranging from 10,000-13,000 mg TDS/L. The lambs of these ewes also showed decreased growth (Potter and McIntosh, 1974; Peirce, 1968). Similar to sheep, farmed deer species were observed to be relatively tolerant of saline water, with effects on body weight or observed stress occurring at concentrations ranging from approximately 8,500-15,000 mg TDS/L (Kii and Dryden, 2005; Ru et al., 2004). Male pigs have also been tested, with no adverse effects occurring in treatments up to 11,700 mg TDS/L (Anderson et al., 1994).

The toxicity of saline water to birds differs among species. Birds that are associated with aquatic environments appear to be less sensitive to saline waters than typical poultry species. For example, 100% of young ducks died when exposed to saline drinking water with NaCl concentrations ranging from 10,000-15,000 mg/L (TDS was not measured), while none died when exposed to 5,000 mg NaCl/L (Barnes and Nudds, 1991). Moorman et al. (1991) observed similar effects on mortality with the suggestion of 9,000 mg TDS/L as an upper limit for mottled ducks to avoid adverse effects. Body weights of Canada geese goslings were reduced at TDS concentrations of approximately 7,700 mg/L (Stolley et al., 1999), but no lower concentration was tested to determine a level of no effect. These studies were conducted with avian species that are generally associated with aquatic environments, including more saline environments, and are adapted to utilizing more saline waters. These species may encounter brackish or saline environments throughout their life cycle and they utilize a salt gland, which helps the birds excrete excess salt. The typical habitat and diet of the birds may influence their ability to excrete salt and their tolerance (Bennett and Hughes, 2003). Therefore, it would be generally expected that these species would be less sensitive to high levels of saline water than domesticated poultry species such as chickens and turkeys on which livestock drinking water recommendations are based.

Recommended guidelines for domesticated poultry species indicate that 3,000 mg TDS/L is appropriate as an upper limit for drinking water. This is supported by a study conducted by Krista et al. (1961), in which NaCl treatments as low as 4,000 mg/L increased mortality and decreased growth in turkey pullets and decreased growth in Rouen ducklings. In the same study, white leghorn chicks were shown to be less sensitive, as the lowest level to cause increased mortality and decreased growth was the 7,000 mg NaCl/L level. Additionally, in a study conducted by Ilian et al. (1981), one concentration, approximately 2,760 mg TDS/L, was tested, and performance was not affected at this level in broiler chicks or leghorn pullets. More recently, broiler chicks were observed to have reduced growth when exposed to 3,448 mg TDS/L, but not when exposed to 3,154 mg TDS/L (Ahmed, 2013), which is quite close to the proposed standard. The studies conducted with domesticated poultry support the proposed standard of 3,000 mg TDS/L.

Highly producing cattle have also been observed to be sensitive to saline water. Studies have demonstrated a decrease in milk production in dairy cattle given water with TDS concentrations ranging from approximately 2,500-5,000 mg/L (Jaster et al., 1978; Challis et al., 1987, Solomon et al., 1995). Challis et al. (1987) decreased the TDS in well water using reverse osmosis treatment, and exposed dairy cows to treated (approximately 400 mg TDS/L) and untreated water (approximately 4,300 mg TDS/L) for approximately 3 months. Significantly greater milk production was observed with the treated water. Solomon et al. (1995) observed similar results by desalinating well water. Jaster et al. (1978) increased the salinity of tap water (containing 196 mg TDS/L) by adding 2,500 mg NaCl/L. Dairy cows were given tap water or salinated water for 9 weeks, and milk production was reduced by a small amount in the cows given salinated water, which was just outside of statistical significance ($0.05<p<0.08$). Concentrations of TDS ranging from approximately 3,000-11,000 mg/L have been observed to decrease weight gain in cattle (Patterson et al., 2003; Patterson et al., 2004; Saul and Flinn, 1985). Patterson et al. (2004) observed a decrease in average daily gain in steers exposed to concentrations as low as 2,933 mg TDS/L after exposure to saline well water for approximately three months. Increasing effects were observed with increasing TDS concentration. The decreases in weight gain in cattle were observed at concentrations greater than or approximately equal to the proposed TDS standard of 3,000 mg/L; therefore, the planned standard should prevent effects on cattle performance.

The majority of studies conducted with ions in livestock drinking water used NaCl as the salt to increase TDS. The lowest concentration to cause effects in the reviewed studies using NaCl was 2,500 mg NaCl/L (and this is being conservative, since the *p*-value for the treatment compared to the control was between 0.05 and 0.08; Jaster et al., 1978). These studies observed effects well above the equivalent NaCl concentration for the aquatic life standard (230 mg chloride/L corresponds to 379 mg NaCl/L), which applies to all waters except Class 7. Therefore, the aquatic life standard for chloride would protect the Class 4B use from excess chloride. "Waters dominated by sulfates" were also tested, and measured as TDS. The proposed sulfate standard for Class 4B will address the specific toxic effects of sulfate to livestock and wildlife (see the following section of this document). Studies testing salts other than NaCl or sulfates are rare and it would be challenging to determine an appropriate level of protection for other individual salts or ions.

If the current aquatic life standard for chloride and the proposed sulfate standard for Class 4B are applied, livestock and wildlife drinking will be protected for these two ions. The aquatic life standard for chloride is protective of wildlife and livestock drinking water because effects from NaCl are observed in livestock species at concentrations much higher than the concentration necessary to protect aquatic life. Besides chloride and sulfate, sodium appears to be the other major ion that may be of concern (bicarbonate, magnesium and calcium do not generally appear to be problematic to livestock). In treating water or reducing sources for chloride, however, sodium would also be reduced, as NaCl is the primary source of anthropogenic chloride. The TDS standard would function as a backstop for other ions that do not have sufficient toxicity information for livestock/wildlife drinking water, but that may contribute to the effects of saline water. It also would serve as protection to wildlife and livestock from ionic pollution for Class 7 waters where the chloride standard for aquatic life does not apply. Further, any wastewater treatment of water that is necessary to meet the chloride and sulfate standards would result in reductions of other ions.

To summarize, the evidence for altering the standard to 3,000 mg TDS/L is based on:

1. the recommended guidelines for livestock drinking water, which indicate that loss of production in poultry could be expected starting at 3,000 mg TDS/L,
2. the controlled animal studies, especially those demonstrating that cattle performance could be affected at approximately 3,000 mg TDS/L, and
3. an understanding that standards for chloride and the proposed 4B sulfate standard should be protective in the majority of cases, and the TDS standard of 3,000 can serve as a backstop for additional ions (such as rare cases where excessive sodium discharges may be found without chloride or sulfate).

Sulfate

There is no existing Class 4B standard for sulfate, but the MPCA is considering a standard of 600 mg/L. Historically, where sulfate has been discharged in effluent in high concentrations, the MPCA has used the Canadian guideline value of 1,000 mg sulfate/L on a site-specific basis.

The sulfate ion (SO_4^{2-}) is the most common form of sulfur in water, while sulfides may also exist in some waters. Sulfate naturally occurs from the weathering of rocks, from which it runs off into waterways (Raisbeck et al., 2008). Sulfur is the toxic component of sulfate to livestock and wildlife. However, because sulfate is the most prevalent form of sulfur in water, a water quality standard based on sulfate, rather than sulfur, is being proposed here to provide protection for livestock and wildlife. In addition to drinking water sources, sulfur is also introduced to livestock and wildlife through the dry diet. Because of this, total dietary sulfur must be considered, not just the component coming from drinking water (Drewnoski et al., 2014).

As with TDS, sulfur is necessary to maintain animal health, but in excess, sulfur becomes toxic. Toxicity in studied livestock species indicate that ruminants are more sensitive to the toxic effects of sulfur than monogastric species due to the processing of inorganic sulfur (such as sulfate) in the rumen creating the toxic chemical hydrogen sulfide (H_2S). Ruminants are capable of synthesizing sulfur-based amino acids from inorganic sulfur sources, but the process involves first reducing inorganic sulfur to H_2S. When sulfur intake is excessive, large quantities of H_2S are produced, and the toxic gas produced can escape the rumen, resulting in poisoning. Monogastric animals cannot produce sulfur-based amino acids from inorganic sulfur, and are therefore less sensitive to the toxic effects of the reduction of inorganic sulfur to H_2S (Raisbeck et al., 2008).

The effects of exposure to excess sulfur vary depending upon species, concentration and degree of acclimation to high sulfur diets. For non-ruminant species, the most common effect is watery feces that may not affect animal performance. Very high concentrations can decrease performance, however (NRC 2005). In ruminant species, watery feces, decreased feed and water consumption and reduction in performance have been observed, and sulfur can be lethal to ruminants at concentrations that might only cause diarrhea in non-ruminants. Exposure to excessive levels of sulfur can lead to polioencephalomalacia (PEM), a neurological disorder than can lead to lesions on the brain, neurological symptoms and death. The exposure to the build-up of H_2S in the rumen has been determined to be the cause of sulfur-induced PEM (Drenowski, 2014; NRC, 2005). Another effect due to excess sulfur exposure can be a copper deficiency. Sulfur can bind with copper and prevent its absorption, or sulfur can create thiomolybdates in the rumen, which bind copper and make it unavailable. However, the concentration of sulfur that causes the development of PEM or decreased animal performance is what drives the maximum tolerable limit of sulfur, rather than the effects of sulfur on absorption of trace minerals (Drewnoski 2014).

More research has been conducted in ruminants than in other species, and research is typically focused on the total amount of sulfur in the diet, as a percentage of the dry feed, rather than on concentrations of sulfate in water that elicit adverse effects. Total dietary sulfur includes sulfur in both feed and water intake sources. The sulfur content of the feed impacts the tolerable amount of sulfur in the water (usually as sulfate), making the estimation of a safe water concentration more challenging, because the sulfur content in feed is variable and both feed and water intake vary. The amount of daily water consumed depends on species, temperature/humidity, palatability of the water, moisture content of the feed, and animal's condition (age, size, level of production, etc.) (NRC 2005). Higher temperatures during summer months result in increased drinking, which in turn adds additional sulfate to the total dietary intake, increasing the risk of sulfur toxicity during warmer months.

Dietary ranges of sulfur of 0.30-0.50% of the dry matter intake have been recommended as a maximum tolerance limit for ruminants to prevent the negative effects of excess sulfur, such as PEM (NRC, 1980; NRC, 2005), with the upper part of the range being acceptable for animals consuming more than 40% forage. Ruminant animals fed concentrate, rather than forage, such as those confined in feedlots, have less tolerance for high sulfate concentrations due to the increased exposure to H_2S. The abundance of fermentable carbohydrates, which are often included in the diet as an inexpensive ration in feedlots, and reduced levels of fiber in the diet can increase H_2S in the rumen gas cap of ruminant animals fed a concentrated diet. As the carbohydrates are digested, they lower the rumen pH, which in turn increases the partitioning of sulfide into the gas cap of the rumen. Because the likely route of exposure to sulfide is through inhaling eructed sulfur gases from the gas cap, increases of sulfur in the gas cap due to reduced pH from carbohydrate digestion result in an increased likelihood of developing PEM (Drewnoski, 2014).

Richter et al. (2012) demonstrated this effect on sulfur toxicity from different diets by observing decreases in average daily gain in cattle consuming 0.5-0.6% sulfur compared to cattle consuming 0.2-0.3% sulfur when fed finishing diets (high in carbohydrates). These differences were not observed while the cattle were on pasture (forage). Loneragan et al. 2001 observed that concentrations greater than 583 mg sulfate/L (0.22% dietary S) in the drinking water decreased weights in feedlot steers (high carbohydrate diets), but Digesti and Weeth (1976), saw no adverse effects in heifers given access to water with 2,500 mg sulfate/L, but fed hay (forage). Another study using steers observed that diets containing 0.46% sulfur reduced the final body weight and decreased the quality of the carcasses, while performance was not affected at 0.31% sulfur. It was also noted that effects were more pronounced in steers fed high-concentrate diets, compared to those receiving corn-silage diets (Spears 2011).

Other studies have been conducted demonstrating the appropriateness of the suggested range of dietary sulfur content (0.30 – 0.50% S). Patterson et al. (2004) demonstrated that steers consuming 1,725 mg sulfate/L, with an overall diet of 0.48% sulfur, had decreases in average daily gain and feed intake, compared to the control steers that consumed 441 mg sulfate/L, with an overall diet of 0.27% sulfur. Low et al. (1996) observed PEM in 35% of Swaledale lambs and 20% of Scottish blackface lambs who were consuming 0.43% sulfur. Kul (2006) also observed an outbreak PEM symptoms and death in dairy and beef cattle who were fed a diet estimated to be 0.45% sulfur. In the study, the symptoms of PEM were more apparent in calves and lactating dairy cattle. Gould et al. (1991) observed PEM in five of nine calves consuming 0.36% sulfur.

Because the sulfur content of both the water and the feed must be considered, determining a protective water concentration from the total dietary percentage of 0.30 – 0.50% sulfur can be challenging. One can calculate the percentage of the dry diet comprised of sulfur, and break it down as sulfur supplied from water and dry diet. Using the volume of water consumed and the concentration of sulfate in water, the total sulfur from the water alone can be calculated. This has been done for three ruminant animal types, and the values are presented in Table 31.

For example, a finishing steer drinks an average of 65L of water a day and consumes an average of 9.1 kg of feed (Colorado State University 2016). Using this example, we can assess the total amount of sulfur intake in water using 1,000 mg/L for sulfate in water (Canada's guideline for sulfate (CCME 2008), which Minnesota has used on a site-specific basis). This situation can result in a sulfur concentration for finishing steer of 0.24% when water intake is high, even without considering the intake from feed. This leaves 0.06% of sulfur to come from the food (using 0.30% as a safe level of sulfate for animals fed concentrate diets), which is an unlikely value to be met in feed. Corn, for example, ranges from 0.11% to 0.17% sulfur, while other concentrate diets consist of 0.4% to over 1% sulfur (Crawford 2007). With 1,000 mg/L sulfate in the water, in some cases, the recommended 0.30% of sulfur could easily be exceeded for animals on a concentrate diet (0.24% from water + 0.11% to 1% from diet = 0.35% to 1.24%). This would increase the likelihood of induction of PEM or decreases in performance. Given the high concentration in water, it would be challenging to feed a sufficiently low sulfur diet to manage for the concentration in the water. Decreasing the sulfate concentration in the water to 600 mg sulfate/L (as recommended in NRC 2005 for animals consuming concentrated diets) would reduce the input of sulfur from water to 0.14% in finishing steer (Table 31), which would allow for a ration containing 0.16% sulfur from the food. This would allow for management of sulfur intake by using lower sulfur diets. At least one author has recommended that the 1,000 mg/L standard currently being used in Canada should be revised based on more recent studies that indicate that 1,000 mg/L sulfate in drinking water may be too high (Olkowski 2009). While there could be sulfur issues in warmer weather for those animals being fed a concentrate diet high in sulfur, the NRC (2005) recommendation of 600 mg/L should be protective in most situations.

Table 31. Estimated sulfur percentage in diet supplied by drinking water at different water sulfate concentrations.

Water Concentration ($mg\ SO_4/L$)	% S from water		
	Sheep[1]	Dairy Cow[2]	Finishing Steer[3]
600	0.16	0.13	0.14
1,000	0.27	0.21	0.24
1,500	0.41	0.32	0.36
2,000	0.54	0.43	0.48

[1] Used 7.6 liters/individual/day (Meehan et al., 2015) for estimated water consumption, and average hot weather feed consumption estimation of 0.934 kg/day (NRC, 1981). The hot weather estimate was used because hot weather is when the most water would be consumed.
[2] Used 115 liters/individual/day (OMAFRA, 2007) for estimated water consumption, and estimated feed consumption of 18 kg/day (UMN Extension, 2017).
[3] Used Colorado State University Veterinary Diagnostic Laboratory's sulfur calculator (2016), using an 800 lb steer, which would consume 65 liters/individual/day for estimated hot weather water consumption. The calculator uses 2.5% of body weight as an estimated daily feed consumption, which would be 9.1 kg/day.

The protective value of 600 mg/L was based on livestock that consume a high carbohydrate diet low in fiber, which would typically be observed in animal feeding operations, where the animals have limited or no access to forage. The protective percentage of sulfur in the diet for those animals is 0.30% sulfur. For those animals that consume greater than 40% forage, sulfur is not converted as rapidly to sulfide, so those ruminants can tolerate up to 0.50% sulfur in their diet (NRC 2005). Therefore, a less protective value may be reasonable to protect ruminants that graze, including both livestock and wildlife. Using the calculations as described above (Table 31), it is possible to determine an appropriate water concentration to protect for a 0.50% sulfur concentration in the diet. Using the finishing steer example again, one can assess the total amount of sulfur intake in water using different concentrations of sulfate in water. A sulfate concentration of 2,000 mg/L nearly exceeds the 0.50% threshold, even without considering the intake from feed. Reducing the value to 1,500 mg/L leaves 0.14% of sulfur to come from the food. Gould et al. (2002) found that the average sulfur content of beef-cattle forages in the north-central region of the US was 0.18%. This exceeds the 0.14% that would be allowable if cattle were drinking water with a sulfate concentration of 1,500 mg/L. Decreasing the sulfate concentration in the water to 1,000 mg sulfate/L would reduce the input of sulfur from water to 0.24% in finishing steer (Table 31), which would allow for a forage containing 0.26% sulfur from the food. This would provide a margin of safety for when local forages may be higher than the average forage concentration. Therefore, for animals that are consuming greater than 40% forage, a water concentration of 1,000 mg/L should be protective in most situations.

Studies with non-ruminant species have demonstrated that these species are less sensitive to the effects of sulfur than ruminant species. Effects to mallards were observed at concentrations ranging from approximately 2,200 to 6,300 mg sulfate/L (Mitcham and Wobeser 1988, 1988b), and egg production was reduced in white leghorn pullets at approximately 8,000 mg sulfate/L (Krista et al. 1961). Adams et al. (1975) saw decreased production in hens exposed to 4,000 mg sulfate/L, but not in the hens exposed to 1,000 mg sulfate/L. Studies that exposed pigs to increased water sulfate concentrations have demonstrated that adult pigs can tolerate concentrations up to at least 3,320 mg sulfate/L (Paterson et al. 1979), while nursery pigs may be more sensitive, with reduced growth observed at concentrations as low as 1,700 mg sulfate/L (Fhlor et al. 2014). Because non-ruminants are not as sensitive to sulfur, the water quality standard for sulfate of 600 or 1,000 mg/L is protective of non-ruminants.

Using the 600 mg/L value across all 4B waters would be the most conservative and simple method of protecting the livestock and wildlife use. However, this could be overprotective in situations where there are no ruminants consuming a high carbohydrate diet utilizing a surface water downstream of a permitted facility. Some options MPCA has considered to address this are described below.

1. Implementing the 600 mg/L value across 4B waters is the most conservative option, with protection for all species consuming all diets. Where this value is overprotective, a site-specific standard could be developed via *Minn. R*. 7050.0220, subp. 7.
2. The 4B use could be split into two subclasses, one for livestock and one for wildlife. The livestock subclass would have the lower sulfate value, to protect livestock consuming little forage, and the wildlife subclass would have a higher sulfate value, because wildlife consumes greater than 40% forage. This option could potentially still be overprotective in cases where livestock graze and consume more forage, rather than eating diet low in forage.
3. Maintain the single 4B use class, but bifurcate the standard – have two values for sulfate in the standard. The values would be appropriate for waters with (600 mg/L) or without (1,000 mg/L) concentrated animal feeding operations. The appropriate standard to use would be determined in the permitting or assessment process.

The MPCA seeks input on how to address the differences in the protective values for sulfate, and this input is not restricted to the options listed above.

Nitrate

There is no existing Class 4B standard for nitrate, but the MPCA is suggesting a standard of 100 mg nitrate-nitrogen per liter (NO_3-N/L) in these revisions. The literature contains different recommendations for a “safe” nitrate value, varying over an order of magnitude (10-113 mg NO_3-N/L).

Nitrate (NO_3^-) is the most common form of nitrogen in water, with ammonia (NH_4^+) and nitrite (NO_2^-) also being found in surface waters (Moore and Bringolf, 2018). Nitrate can occur naturally, but more commonly, fertilizer use on farm fields to provide nutrients to crops is a source of nitrate in waterways (Galloway et al., 2003). Statewide, approximately 70% of nitrogen loading to surface water comes from cropland sources (MPCA, 2013). Elemental nitrogen is not biologically available, so the water quality standard is based on nitrate to provide protection for livestock and wildlife. In addition to drinking water sources, nitrate is also introduced to livestock and wildlife through the dry diet. Because of this, total dietary nitrate must be considered, not just the component coming from drinking water (Rasby, 2014; Hibberd, 1993).

Nitrogen is necessary to maintain animal health, but in excess, nitrate and nitrite can become toxic. Nitrate itself is not highly toxic, but it becomes toxic after it is converted to nitrite. Nitrite is not typically found in high concentrations in surface waters. However, nitrate can be reduced to nitrite within the body of some animals, and the resulting nitrite causes the toxicity. Toxicity in studied livestock species indicate that ruminants are more sensitive to the toxic effects of nitrate than monogastric species due to the conversion of nitrate into nitrite in the rumen. Rumen bacteria rapidly reduce nitrate to nitrite in ruminants, while little nitrate reduction occurs in non-ruminant animals, with the exception of the horse. Reduction in the horse cecum and colon occurs at a level between ruminants and other non-ruminants (Raisbeck et al., 2008).

Nitrite is toxic because of its ability to form methemoglobin through the oxidation of hemoglobin. Hemoglobin transports oxygen in the blood, but methemoglobin is unable to transport oxygen. Oxygen transport is decreased when hemoglobin is transformed to methemoglobin, and clinical signs due to reduced oxygen transportation can occur at 30-40% methemoglobin. Death can be induced at 80% methemoglobin (NRC, 2005). In ruminants, the rumen bacteria rapidly convert nitrate to nitrite. Nitrite is then converted to ammonia for bacterial protein development, rendering it no longer toxic. The conversion to ammonia is less rapid than the conversion of nitrate to nitrite, so when nitrate consumption is high, nitrite can build up in the rumen (Raisbeck et al., 2008). High carbohydrate diets have been demonstrated to speed up the conversion of nitrite to ammonia, so these diets may aid in protecting from nitrite toxicity (Crowley et al., 1974). Toxicosis from nitrate occurs when there is a disruption in the conversion of nitrite to ammonia, or when animals consume large amounts of nitrate. Because non-ruminants do not have this microbial breakdown, they typically have to ingest a much higher amount of nitrate, or nitrite directly, to develop methemoglobin (Raisbeck et al., 2008).

In ruminants, nitrates can be absorbed from the rumen, and this absorption can be rapid (NRC, 2005). Some studies showed that a dose of nitrate, when spread apart, was less toxic than when given the same dose all at once. The dose necessary to cause mortality in 50% of tested cows was 328 mg/kg body weight, when given as one dose. But, when the dose was given spread out over 24 hours, more nitrate was needed to cause the same amount of mortality (707-991 mg/kg body weight; NRC, 2005). Therefore, nitrate in water can be a greater threat than nitrate in the forage/feed because water is rapidly ingested, compared to feed.

Nitrate at 0.5% (which converts to 0.11% NO_3-N), on a dry matter basis, has been suggested as a protective level of nitrate in ruminant diets (NRC, 2005; Alberta Agriculture, Food and Rural Development, 1991). This amount would include concentrations of nitrate in both the diet and water combined. Because the nitrate content of both the water and the feed have to be considered, determining a protective water concentration from the total dietary percentage of 0.11% NO_3-N can be challenging. As was done in Table 31 for sulfur, the volume of water consumed and the concentration of nitrate in water can be used to calculate the total nitrate from the water alone (see Table 32 for a more detailed explanation of the calculations). Several sources recommend 100 mg/L NO_3-N in water alone, and based on three ruminant types, this value appears to be protective, with nitrate from the water contributing 0.08% NO_3-N or less (Table 32).

Table 32. Estimated nitrate percentage in diet supplied by drinking water at different water nitrate concentrations.

Water Concentration (mg NO_3-N/L)	% NO_3-N from water		
	Sheep[1]	Dairy Cow[2]	Finishing Steer[3]
10	0.008	0.006	0.007
100	0.08	0.06	0.07
300	0.24	0.19	0.21

[1] Used 7.6 liters/individual/day (Meehan et al., 2015) for estimated water consumption, and average hot weather feed consumption estimation of 0.934 kg/day (NRC, 1981). Hot weather estimate used because hot weather is when the most water would be consumed.

[2] Used 115 liters/individual/day (OMAFRA, 2007; falls into range given by Meehan et al., 2015) for estimated water consumption, and estimated feed consumption of 18 kg/day (UMN Extension, 2017).
[3] Used Colorado State University Veterinary Diagnostic Laboratory's sulfur calculator, using an 800 lb steer, which would consume 65 liters/individual/day for estimated hot weather water consumption. The calculator uses 2.5% of body weight as an estimated daily feed consumption, which would be 9.1 kg/day.

The recommended guidelines for the amount of nitrate in drinking water for livestock varies with the species of interest. Because the Class 4B standard will be applied to all waters of the state, the standard for nitrate needs to be protective of all species. Therefore, the standard should protect the most sensitive groups, which based on the livestock data is ruminants, which are likely representative of wild ruminant species, such as deer or moose. To protect ruminant species, the recommended standard is 100 mg NO_3-N/L.

Additional Parameters to Consider

Other constituents are mentioned throughout guidance and reference documents about protecting livestock health. The MPCA has chosen the parameters to include here based on potential impacts to livestock, the amount of data available to derive a protective value, and the pervasiveness of the parameter. Some parameters are not widespread problems, and could potentially be dealt with on a site-specific basis. However, developing site-specific criteria (SSC) for additional contaminants not in rule could be challenging because there are no methods in rule to develop SSC for livestock/wildlife drinking water. The methods provided in *Minn. R.* 7050.0218 are for SSC values based on wildlife consumption of aquatic organisms, not drinking water. When the MPCA has developed values in the past for Class 4B (e.g., sulfate), it has used the "additional selective limits may be imposed…as needed" clause in the 4B rule language. There has been question as to whether this language should remain in rule, or if standards for additional parameters should be promulgated during this rulemaking instead.

The MPCA seeks comments on additional parameters that stakeholders may have information on that would require development of additional standards to protect the livestock/wildlife designated use—specifically, supporting information demonstrating the need to protect for other parameters, and any information regarding the locations of Minnesota waters where the protective value could fall below observed concentrations. Additionally, the MPCA requests stakeholder information that would support or refute the removal of the wording that currently exists in 4B: "additional selective limits may be imposed for any specific waters of the state as needed."

Duration (Averaging Time) for Class 4B Standards

The studies conducted with livestock typically lasted three weeks to several months. The effects of the parameters evaluated for numeric standards (pH, TDS, sulfate) are not acute effects at the concentrations proposed. The parameters (TDS, sulfate, nitrate, and pH) have the potential for acute effects if in excess of the standards considered by the MPCA; however, at the planned standard concentrations, effects would only be expected after a longer-term exposure. Short-term spikes above the standard could be tolerated by the animal with minimal effects, such as watery stool. Therefore, a short-term duration is not appropriate for these standards. Based on the timing of effects observed in the evaluated studies, a 30-day averaging time (duration) appears appropriate.

Frequency for Class 4B Standards

Studies in the literature indicate that effects on animal production could occur in as little time as 30 days of being exposed to water containing high levels of contaminants. For example, milk production and weight gain were reduced, and the occurrence of PEM was increased. These effects, when seen in livestock, could reduce the producer's profits by reducing the amount of product available to sell. The reduction of body mass (through reduced weight gain or death from PEM) and milk yield is an immediate impact on the producer, and thus, an impact on the designated use. Those losses will not be recovered, so any exceedances of the standards are unacceptable. For wildlife and livestock, the same principles apply, but the losses will be seen as effects to growth and survival of the organism. Therefore, the 4B standards are proposed to be implemented on a "never to exceed" frequency. This will be based on the 30-day average, however, so the value to never be exceeded is the 30-day average.

Applicability of Class 4B Standards

Currently, all waters of the state (except for wetlands) are designated as 4B waters. Wetlands are currently designated as 4C, which includes by reference the values listed in Class 4B. Therefore, as written, any changes to the 4B standards will also apply to 4C waters. However, as discussed in the section below, the MPCA is proposing to remove the 4C use class, and instead designate all wetlands as Class 4A and 4B.

Under the proposed rule, every water of the state would retain the livestock/wildlife designated use. The applicability of the 4B standards will remain on all waters of the state because wildlife may use any of these waters. Each standard set forth in these revisions is based on the most sensitive species, so as to be representative of wildlife species that may be more sensitive than the wildlife species tested. Wildlife are widely distributed throughout the state and can be reasonably assumed to utilize all waters of the state.

As called out previously in the discussion of effects of sulfate on wildlife and livestock, there are some differences in sensitivity to sulfate effects when considering livestock being fed concentrated diets versus wildlife and livestock consuming greater than 40% forage. If the MPCA were to adopt two different values for sulfate, the MPCA proposes that all designated uses related to wildlife and livestock would still apply to all waters. Restricting the livestock use to a limited number of waters would not protect the waters for potential future water users, and has more complications than designating every water of the state as a livestock and wildlife water. The MPCA would have to remove the livestock use from all waters of the state without a ruminant concentrated animal feeding operation, which would be an insurmountable amount of effort in terms of MPCA staff resources.

To remove a designated use from a water body, federal regulations (40 CFR § 131.10(h)) require the state to demonstrate that the use to be removed is not an existing use or an attainable use. An existing use is defined as a use attained any time since November 28, 1975. An attainable use is defined as a use that can be achieved when effluent limits from technology based standards are imposed on point source dischargers (through sections 301(b)(1)(A and B) and 306 of the CWA), and when cost-effective and reasonable best management practices are imposed on nonpoint source dischargers. Additionally, 40 CFR § 131.10(g) provides additional scenarios that may indicate that the use is not attainable, such as low flows or other natural conditions that prevent the water from attaining a use. Any demonstration for the removal of a livestock use would need to take the form as a UVD or a UAA (40 CFR § 131.10(k)).

If MPCA were to decide to divide Class 4B into two subclasses and only apply a livestock subclass to those waters with ruminant concentrated animal feeding operations, MPCA would have to remove, through rulemaking, the livestock use from all other waters of the state, via a UVD or UAA. The amount of work required to demonstrate that the livestock use is not existing or attainable on each of the state's more than 100,000 water bodies would be prohibitive. Each water body would need to be assessed as to whether the use had existed since November 28, 1975, and also if it were attainable to meet the use. One way to determine if the use were existing would be to evaluate if the water meets or has met the applicable standards, requiring an evaluation of water quality monitoring data all the way back to 1975. Other factors included in 40 CFR § 131.10(g) could also be considered for each water body, but the data for flow rates, natural background, costs to upstream dischargers, etc. would need to be evaluated on a case-by-case basis. For one water body, an evaluation of all water quality data, uses of the water, and assessment of additional factors could be reasonably completed, but to complete this for the majority of Minnesota's water bodies, would take years. The more reasonable approach to this is to maintain the livestock use designation on all waters, and conduct a UVD or UAA for individual water bodies where it can be clearly demonstrated that the use is not existing or attainable. This would maintain the designated use for future livestock producers, to ensure future users are given access to waters that have been maintained for livestock consumption.

Wetland Standards in Classes 3D and 4C

Minnesota's Existing Class 3D and 4C Water Quality Standards

The Class 3 and 4 standards include subclasses that specifically address these uses for wetlands. The subclasses for wetlands were added into rule in 1993 to recognize unique features of wetlands that differ from other water body types. *Minn. R.* 7050.0223, subp. 5 states:

> The quality of Class 3D wetlands shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment.

The Class 3D standards contain the same narrative language as Class 3B standards and have "maintain background" standards for chloride, hardness and pH (Table 33).

Minn. R. 7050.0224, subp. 4 states:

> The quality of Class 4C wetlands shall be such as to permit their use for irrigation and by wildlife and livestock without inhibition or injurious effects and be suitable for erosion control, groundwater recharge, low flow augmentation, storm water retention, and stream sedimentation. The standards for Classes 4A and 4B waters shall apply to these waters except as listed below.

Class 4C standards are also listed in Table 33.

Table 33. Current Class 3D and 4C water quality standards.

Parameter	Criteria
Class 3D Water Quality Standards[1]	
Chloride	Maintain background
Hardness	Maintain background
pH	Maintain background
Class 4C Water Quality Standards[1]	
pH	Maintain background
Settleable solids	Shall not be allowed in concentrations sufficient to create the potential for significant adverse impacts on one or more designated uses

[1]The frequency and duration of the current Class 3D and 4C standards are not defined

Proposed Changes to Class 3D and 4C Standards

The proposed changes to Minnesota water quality standards for Class 3D and 4C waters are outlined in Table 34.

Table 34. Proposed changes to Class 3D and 4C standards, and the rationale behind the changes.

Current Rule	Future Rule	Rationale
Class 3D Changes		
"Maintain background" for pH	Remove standard	• The pH standard was intended to protect wetlands with naturally occurring pH levels outside of the typical range, not the 3D designated use • "Maintain background" for pH is already included in Class 2D, and all Class 3D wetlands are also Class 2D, so no protections will be lost.
"Maintain background" for chloride	Move chloride standard to Class 2D and change wording to "If background is higher than the Class 2B chloride standard, maintain background"	• The chloride standard was intended to protect wetlands with naturally occurring levels that were above the chloride standards in Class 3. The chloride "maintain background" standard was not intended to protect the 3D designated use, instead it was intended to protect wetlands with chloride occurring naturally at levels above the numeric standards in Classes 3A, 3B, and 3C. Therefore, the standard—in this case, a new narrative—needs to be moved to Class 2D because that is more appropriate for the use it was intended to protect and relates to the remaining numeric standards for chloride. • The "maintain background" standard was never intended to hold all wetlands to a background level of chloride. The 1993 SONAR indicates that the "maintain background" was intended to protect wetlands with naturally high levels of chloride from being held to the lower chloride concentrations required by the Class 3 standards.
"Maintain background" for hardness	Remove hardness standard	• The hardness standard was intended to protect wetlands with naturally occurring levels that were above the hardness numeric standards in Classes 3A, 3B, and 3C. The "maintain background" was not intended to protect the 3D designated use, but to ensure that wetlands with naturally high levels of hardness were not required to be reduced to levels outside of background. • Because there will no longer be a numeric hardness standard in Class 3, or in any other use

		class, this standard is not necessary to ensure that wetlands with naturally high levels of hardness are not regulated to an unnaturally low level of hardness.
Narrative standard for 3D: "The quality of Class 3D wetlands shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment"	Remove this language	• The current standard is the same narrative standard as for Class 3B. However, because Class 3B, along with 3A and 3C are being condensed into one narrative standard, there is no need to have a separate narrative standard for Class 3D. Having one narrative standard for Class 3, which will now include wetlands, is simpler and will still protect the designated use.
Wetlands are designated as Class 3D	Wetlands designated as Class 3	• To protect this designated use (industrial consumption), the rule revision is going to utilize only one narrative standard for the different subclasses, removing the subclasses and having a single Class 3 designation. Having a different narrative standard for wetlands is not logical, because the narrative for all of Class 3 should be protective of the designated use.
Class 4C Changes		
"Maintain background" for pH	Remove standard	• The pH standard was intended to protect wetlands with naturally occurring pH levels outside of the typical range, not the 4B designated use • "Maintain background" for pH is already included in Class 2D, and all Class 4C wetlands are Class 2D, so no protections will be lost.
Settleable solids "shall not be allowed in concentrations sufficient to create the potential for significant adverse impacts on one or more designated uses"	Move settleable solids standard to Class 2D	• Settleable solids was added as a protection for "natural organic wetland sediments, which can potentially result in an impact to other designated uses." • This standard indicates that many designated uses could be affected; therefore, it does not matter which use class it is in. Moving it to Class 2D condenses the wetland standards into one location.
The subclass 4C combines irrigation, livestock and wildlife into one subclass to protect wetlands: "The standards for classes 4A and 4B	Change wetland designation in *Minn. R.* 7050.0410 and 7050.0425 from 4C to 4A and 4B. Remove Class 4C.	• If a wetland cannot support an irrigation and/or livestock use, but could support wildlife, this use would not be able to be removed as the rule is currently written. Designating wetlands as 4A and 4B separately would allow for this change, while still providing protection for the 4A and 4B uses.

waters shall apply to these waters except as listed below:”		
Narrative standard for 4C: “The quality of Class 4C wetlands shall be such as to permit their use for irrigation and by wildlife and livestock without inhibition or injurious effects	Remove this language	• Wetlands will no longer be designated as 4C, they will be Class 4A and 4B. The narrative standards in those two use classes cover this narrative standard, so it is no longer needed.
Second half of narrative standard for 4C: “and be suitable for erosion control, groundwater recharge, low flow augmentation, storm water retention, and stream sedimentation.”	Move this narrative to *Minn. R.* 7050.0186	• This narrative standard describes services that wetlands provide that could be applied to several use classes. Because of the applicability to multiple classes, these could be included as a general narrative standard for wetlands.

Need for Revisions to Class 3D and 4C Standards

The standards laid out in Classes 3D and 4C were added into rule in 1993. The Statement of Need and Reasonableness (SONAR) written for that rulemaking (MPCA, 1993) gives background on why the standards were chosen, and it is cited throughout this section to explain the full intention of the 3D and 4C standards. In reviewing the 1993 SONAR, it became apparent that the standards included in these use subclasses were not always put in place with the intention to protect these designated uses, but to protect the known or perceived quality of the water itself. Therefore, in revising the Class 3 and 4 standards, MPCA is proposing changes to Classes 3D and 4C to ensure that the waters are designated appropriately to protect all the applicable designated uses.

Aspects of Class 3D and 4D standards are planned to move under Class 2D and the general wetland standards in *Minn. R.* 7050.0186. The proposed revisions to move standards to Class 2D, which protects wetlands for aquatic life uses, and *wetland standards and mitigation* parts of the rule do not imply that the scope of these changes is intended to make sweeping alterations to the Class 2D use or *Minn. R.* 7050.0186. Any revisions are still centered on maintaining the basis for protections related to updating Class 3 and 4 standards and better placement of some of the standards so that they are better lined up with the actual beneficial uses they were designed to protect.

Rationale for Changes to Class 3D and 4C Standards

Class 3D

In this rulemaking, the MPCA is proposing to remove the 3D designation for wetlands and include wetlands in an overarching, single general Class 3 designation. Currently, only the 3D narrative standard is clear on the protection given to industrial use. This consolidation of the standards will improve review and implementation as described in the earlier chapter on Class 3 revisions. Based on rule documents from 1993, the standards in Class 3D for pH, chloride and hardness do not seem to be directly related to protecting the industrial use. The “maintain background” standards were added to make exemptions to the numeric standards in Classes 3A, 3B and 3C, for wetlands that have natural conditions that would exceed the Class 3 numeric standards. The rationale for doing this is further explained below.

There are two sections of the current rule that would need alterations to remove the Class 3D use:

1. The listed standards for pH, chloride and hardness – “Maintain background”
2. The narrative – “The quality of Class 3D wetlands shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment.”

The changes necessary for each of these aspects of *Minn. R.* 7050.0223, subp. 5 are different and are discussed separately below.

1. <u>Listed standards for pH, chloride and hardness</u>
   The Class 3D narrative standard of “maintain background” for pH was to protect wetlands’ natural variability. The 1993 SONAR (p. 81) discusses this: “Some wetlands are characterized by low pH (bogs) or high pH (calcareous fens). Requiring circumneutral pH could significantly impact the designated uses of those wetlands.” This language makes it clear that the narrative “maintain background” for pH was implemented to protect the unique wetlands, not the industrial use. Maintaining background pH could actually cause additional treatment by the appropriator to be able to use the water for industrial uses, if natural pH levels are very acidic or basic. Therefore, having them in Class 3D is inappropriate because it is not protective of the industrial use. Additionally, “maintain background” for pH is already included in the Class 2D standards for wetlands, so these protections already exist. Similarly, *Minn. R.* 7050.0170 addresses background levels exceeding applicable standards: it allows using the background level rather than the standard in rule. The MPCA recommends removing the pH standard from the 3D use class.

   The Class 3D standard for chloride of “maintain background” was included to account for the fact that some wetlands have chloride values higher than the typical numeric values placed on the other Class 3 groups. Like pH, limiting wetlands to a specific value for chloride could result in harming the wetland community by reducing chloride to a level that would change its function. The 1993 SONAR addresses this (p. 83): “It also protects wetlands with naturally high concentrations of chloride or hardness” and “Some wetlands naturally have concentrations of chlorides and hardness that exceed these standards and ‘maintain background’ standards are proposed under Class 3D to protect these wetlands.” The SONAR makes clear that this standard was developed to protect the wetlands, not the industrial use. Therefore, the MPCA plans to move the chloride 3D standard to Class 2D. All unlisted wetlands are designated Class 2D, and effects to aquatic life should include wetland communities. Moving the “maintain background” standard to Class 2D allows the protection afforded in Class 3D to remain, so no protections would be lost by removing this standard from Class 3D. Because there are existing chloride numeric standards in Classes 2A, 2Bd and 2B, the protection for high chloride wetlands is still needed. The MPCA is also planning to clarify the intent of the standard, by changing the standard to read: "If background is higher than the Class 2B chloride standard, maintain background." The intent of the standard was not to maintain all wetlands at background concentrations, but to prevent wetlands that naturally exceeded the industrial use standards from being held to those specific numeric standards. This clarification will aid in implementing this standard to protect both the designated use and the unique wetland characteristics where needed.

The "maintain background" narrative for hardness was also included to account for the fact that some wetlands have hardness values that are naturally higher than Class 3 numeric standards, as demonstrated in the 1993 SONAR language cited above for chloride. But, unlike chloride, there are no other hardness standards in rule that could inappropriately result in a high hardness wetland being held to a lower hardness value. So, as considered for this rulemaking, if the Class 3A, 3B, and 3C hardness numeric values are removed, there will no longer be standards that would cause an inappropriate hardness standard for a high hardness wetland. Therefore, the "maintain background" standard for hardness can be removed.

2. The narrative
   The narrative describes that wetland quality should be "such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment." Currently, all wetlands are designated as Class 3D, but the narrative standard in 3D is the same narrative as used in Class 3B. The planned revisions to Classes 3A through 3C would include removing the numeric standards and including only one narrative standard, thus consolidating the subclasses into one class. Because MPCA plans to remove the Class 3D standards for pH, chloride, and hardness (as presented above), there would not be the need for the Class 3D use, since a narrative standard would be all that remained. A narrative standard will already exist in the revised general Class 3 industrial use as described in the earlier section. Therefore, the MPCA plans to remove the Class 3D designation, and instead designate all listed and unlisted wetlands as the updated, general Class 3. This would involve a change to *Minn. R.* 7050.0425, which designates the use classes for unlisted wetlands, and to *Minn. R.* 7050.0410, which adds classifications to listed wetlands. The 3D use would be removed and replaced with Class 3.

Class 4C

In this rulemaking, the MPCA is planning to remove the 4C designation for wetlands and designate wetlands as both Classes 4A and 4B waters, suitable for irrigation and livestock and wildlife uses, respectively. This is because, currently, only the direct reference to the Class 4A and 4B standards in the Class 4C narrative is clear on the protection given to irrigation, livestock and wildlife. The remaining parts of the 4C standards (the narrative and the pH and settleable solids standards) do not seem to be directly or exclusively related to irrigation or livestock and wildlife use because of the additional language referencing other physical aspects of wetland function. Additionally, the "maintain background" standard for pH was added to make exemptions to the numeric standards in Classes 4A and 4B, for wetlands that have natural conditions outside of circumneutral pH. Therefore, it is proposed to remove the 4C designation for wetlands. The rationale for doing this is further explained below.

There are three main sections of the current rule that would need alterations in some form to remove the Class 4C use:

1. The listed standards for pH and settleable solids – maintain background for pH and settleable solids "shall not be allowed in concentrations sufficient to create the potential for significant adverse impacts on one or more designated uses."
2. The tie of 4C to the standards in 4A and 4B – "The standards for Classes 4A and 4B waters shall apply to these waters except as listed below" and part of the narrative "The quality of Class 4C wetlands shall be such as to permit their use for irrigation and by wildlife and livestock without inhibition or injurious effects."
3. The additional narrative – "The quality of Class 4C wetlands shall…be suitable for erosion control, groundwater recharge, low flow augmentation, storm water retention, and stream sedimentation."

The changes necessary for each of these aspects of the Class 4C standards are different and are discussed separately below.

1. <u>Listed standards for pH and settleable solids</u>
   The Class 4C narrative standard of "maintain background" for pH was to protect wetlands' natural variability. The 1993 SONAR (p. 81) discusses this: "Some wetlands are characterized by low pH (bogs) or high pH (calcareous fens). Requiring circumneutral pH could significantly impact the designated uses of those wetlands." This language makes it clear that the narrative "maintain background" for pH was implemented to protect the unique wetlands, not the agriculture or wildlife use. Maintaining background pH could actually harm irrigation and livestock/wildlife uses, if natural pH levels are very acidic or basic. Therefore, having them in Class 4C is inappropriate because it is not protective of the agriculture or wildlife use. Additionally, "maintain background" for pH is already included in the Class 2D standards for wetlands, so these protections already exist. Removing this standard from the 4C use class is currently planned.

   The other listed standard in Class 4C is for settleable solids. This narrative standard indicates concentrations should not "create the potential for significant adverse impacts on one or more designated uses." This seems to imply that settleable solids could impact multiple designated uses, but it is unclear as to why it was placed in Class 4. The 1993 SONAR does not directly address this, but the wording of the narrative standard shows it could be included in other use classes. All unlisted wetlands are designated Class 2D, so it is reasonable to put the narrative in that class, since effects to aquatic life could clearly result from increased solids. In addition to aquatic life effects from increased solids, the 1993 SONAR (p. 84) indicates that "excessive sedimentation can smother the natural organic wetland sediments, which can potentially result in an impact to other designated uses." This SONAR statement indicates that multiple designated uses could be impacted, but does not supply information for why this standard was included in Class 4C. Therefore, MPCA is considering moving this standard to Class 2D.

2. <u>The tie of 4C to the standards in 4A and 4B</u>
   Currently, all wetlands are designated as Class 4C. The language in 4C incorporates all of the standards in Classes 4A and 4B, except for where they differ in the specifically listed standards (pH and settleable solids). Because MPCA is proposing to move those standards for pH and settleable solids (as presented above) and the additional narrative language (see discussion below), there would be no need for the Class 4C use, since it would simply reference the Class 4A and 4B standards. Therefore, it makes more sense to remove the Class 4C designation, and instead designate all listed and unlisted wetlands as both 4A and 4B. This would involve a

change to *Minn. R.* 7050.0425, which designates the use classes for "Unlisted Wetlands," and to *Minn. R.* 7050.0410, which adds classifications to "Listed Wetlands." The 4C use would be removed and replaced with 4A and 4B.

Addressing these wetland beneficial uses this way also alleviates another issue caused by how the standards are structured. The MPCA has the ability to individually assess waterbodies for their use and value. In cases where individual waterbodies have not met and cannot meet designated uses, those designated uses can be removed. But, under the existing wetlands designations, there is no way to remove either the 4A or the 4B use independently.

- Current Class 4C rule language indicates that the Classes 4A and 4B standards apply to Class 4C waters, except for where the standards listed in 4C would take precedence (in practice, only pH differs), and this is problematic for a few reasons:
  - Because wetlands are not designated under Classes 4A and 4B, only the 4C use could be removed, and removing the 4C use would effectively remove both the irrigation (4A) and livestock and wildlife (4B) protections.
  - However, Class 4B includes wildlife, and presumably all waters of the state should retain the 4B use, as it would be hard to demonstrate that no wildlife use, nor have ever (since November 28, 1975) used the water body.
  - Therefore, with the Class 4C use tied directly to the wildlife designated use, the 4C use could never be removed.
  - The 4C language could be problematic if it were determined that a wetland had never, and could not be, used for the irrigation designated use (4A). The irrigation use could not be removed without removing the 4C use. But, the 4C use could not be removed because of the existing 4B use.
- Designating all wetlands as Class 4A and 4B instead of 4C would allow for additional flexibility when determining attainable uses, such as irrigation. The 4A use could be removed if it were not an existing or attainable use, while leaving the 4B protection in place.

3. The narrative

The narrative indicates that wetlands should be "suitable for erosion control, groundwater recharge, low flow augmentation, storm water retention, and stream sedimentation." These functions of wetlands do not seem to be exclusively tied to Class 4 (irrigation and livestock/wildlife) uses. In fact, irrigation and livestock/wildlife protection is called out separately in the narrative. Additionally, these uses of wetlands are generally applicable to multiple uses classes, and are the beneficial functions of wetlands. Therefore, those uses should be protected widely. The 1993 SONAR states: "Class 4C is proposed to protect wetland designated uses that enhance agriculture and wildlife. The specific designated uses proposed are erosion control, groundwater recharge, low flow augmentation, storm water retention, and stream sedimentation. These uses are potentially important in the wetland and in downstream water resources." The 1993 SONAR then describes each use, indicating the benefit provided, each of which could be tied to multiple beneficial uses. These beneficial and narrative uses cross use classes, and the MPCA is proposing to move this narrative to be included with the general wetland narrative standard in *Minn. R.* 7050.0186, subp. 1. This language clearly relates to wetland function and all the beneficial uses that a healthy wetland supports. A discussion of each portion of the narrative is provided below.

- Erosion control. Wetlands provide erosion control by slowing down water as it moves through a watershed. Greater water velocity can cause banks to be scoured, which increases sedimentation into the water body. Sedimentation can cause waterbodies to fill in, and can also cause harm to aquatic life – shading out aquatic plants and smothering fish eggs and organisms that live on the substrate. Fish can also impacted, with gill abrasion or other effects (MPCA, 2011). The 1993 SONAR only comments about erosion control that "The decrease in erosion results in improved water quality downstream through reductions in bank erosion." Decreases in erosion that result in improved water quality is a benefit to all use classes.

- Groundwater recharge. The 1993 SONAR comments that "Water that is detained in wetlands is naturally cleansed of sediments and toxics and…given time to percolate into the aquifer." Water being cleansed of sediments and toxics is beneficial to all use classes. Time to percolate into the aquifer benefits groundwater widely, which is not tied to Class 4 uses exclusively.
- Low flow augmentation. Wetlands serve as reservoirs to hold water in place on the land. During rain events, rivers and streams wash out quickly, while water in wetlands is held in place. Wetlands slowly release water, which can be of benefit to downstream waters during low flow conditions, when the wetlands continue to discharge water. This is the only use that the SONAR calls out for specific benefit to Class 4 uses: "could lengthen the amount of time water is available for livestock and wildlife watering needs and for irrigation purposes." Maintaining flows in streams obviously can benefit the Class 4 use, as called out, but also mentioned is aquatic life: "The augmented flows from wetlands help sustain aquatic organisms downstream." Additionally, industrial and drinking water appropriators could benefit from maintaining stream flows—having a more consistent source of water.
- Storm water retention. Similar to low flow augmentation, when wetlands hold water on the land, it prevents it from immediately flushing out downstream so it is able to "moderate the peak flows after a storm event" (MPCA, 1993). Storm water retention would also benefit aquatic life by removing contaminants in storm water runoff, or reducing sediment in streams by slowing the water flow, and also moderating large fluctuations in stream flow, which are detrimental to aquatic life and their habitat (US EPA, 2016).
- Stream sedimentation. As discussed previously regarding erosion control, stream sedimentation has negative effects to aquatic life. The 1993 SONAR states, "The filtering that wetlands perform by allowing these particles to settle can greatly improve water quality downstream." Improved water quality is a benefit to all use classes.

Because these narrative descriptions of wetland beneficial functions cross use classes, moving them to the general narrative standard for wetlands in *Minn. R.* 7050.0186, subp. 1 is a more appropriate location, to improve clarity in application of wetland standards and indicate that these functions of wetlands benefit all use classes.

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