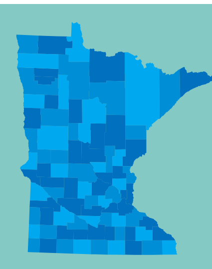
Sulfate standard procedures

January 2024

Procedures for implementing the Class 4A wild rice sulfate standards in NPDES wastewater permits in Minnesota

MINNESOTA POLLUTION CONTROL AGENCY



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Contents

Abbreviations used

ADWDF: average dry weather design flow
AUID: Assessment Unit Identification
AWWDF: average wet weather design flow
BPJ: best professional judgement
EPA: U.S. Environmental Protection Agency
HUC: Hydrologic Unit Code
IWM: intensive watershed monitoring
MDF: maximum design flow
MPCA: Minnesota Pollution Control Agency
NPDES: National Pollutant Discharge Elimination System
RP: reasonable potential
SD: surface discharge
TMDL: total maximum daily load
TSD: technical support document
USGS: U.S. Geological Survey
WLA: wasteload allocation
WQBEL: water quality-based effluent limit
WRAPS: Watershed Restoration and Protection Strategy
WWTF: wastewater treatment facility

Abstract

This document is a comprehensive review of the procedures for evaluating and developing sulfate water quality-based effluent limits (WQBELs) for National Pollution Discharge Elimination System (NPDES) wastewater treatment facility (WWTF) permits to protect waters subject to Minnesota's Class 4A wild rice sulfate standard. EPA's technical support document (TSD) provides a general template for establishing WQBELs (EPA, 1991). In these procedures, MPCA incorporates some of the TSD's limit review methods in addition to regional and pollutant-specific concepts. This document will cover common procedures and assumptions for developing sulfate WQBELs in Minnesota. Example WQBELs are provided to illustrate the process (see Appendices C and D).

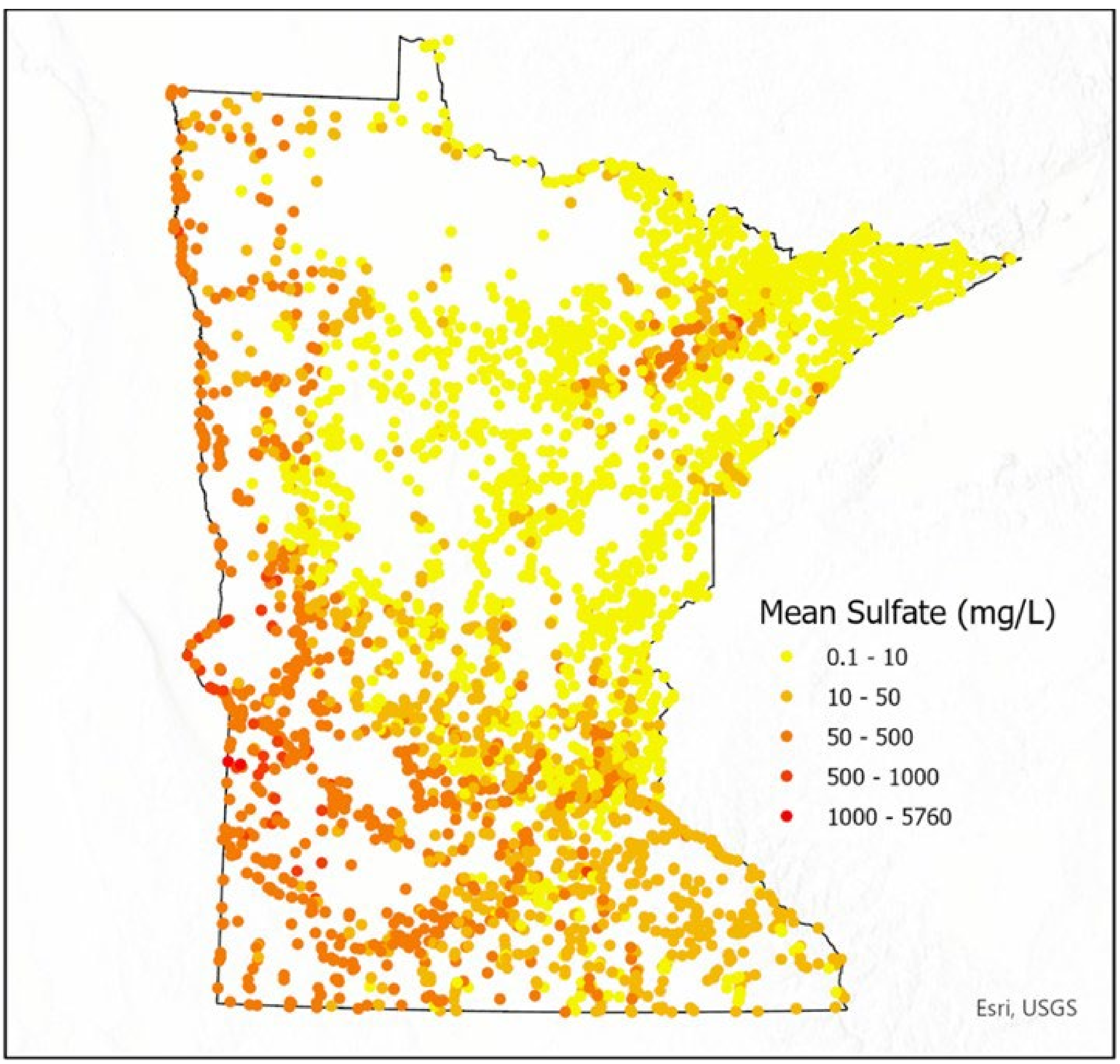
A brief discussion of Minnesota's sulfate standards and waters used for production of wild rice is included. Sulfate concentrations in lakes and rivers vary considerably across the state. Waters used for production of wild rice are most common in central and northern Minnesota. Most water quality standards are applicable to all waters of the state. Therefore, for most pollutants, WWTF limits are set on the basis of conditions in the immediate receiving water downstream of the WWTF outfall. The Class 4A sulfate standard only applies to some waters of the state, namely waters used for production of wild rice. Thus, sulfate/wild rice limits are established based on (and to protect) the water quality in the first downstream water with a water used for production of wild rice designation. When the baseline concentration of sulfate is less than 10 mg/L and multiple WWTFs contribute to a water used for production of wild rice, a contributing area watershed review can be used. In watershed reviews, effluent limits setters will explore the possibility of tier-based sulfate limits when a few WWTFs contribute the majority of the sulfate load to the water used for production of wild rice.

Overview of wild rice sulfate standard

Wild rice is an important part of the ecosystem for numerous lakes and streams in Minnesota. It is also a cultural resource for many Minnesotans, particularly members of Minnesota's Dakota and Ojibwe tribal communities, and an economic resource to those who harvest and market it. At present, Minnesota has approximately 2,400 waters documented as waters used for production of wild rice. Wild rice can be inhibited by sulfate in surface waters. Sulfate that enters surface waters is converted to sulfide by sulfate reducing bacteria in organic rich sediments. Sulfide is the form of sulfur that inhibits the growth and production of wild rice. Controlling sulfate additions to surface waters limits sulfide production in sediments.

Sulfate concentrations in surface waters vary across Minnesota. Sulfate has not been monitored as much as other parameters, but clear patterns emerge from the existing data. Sulfate is generally quite low in the surface waters of northeast Minnesota and higher in the western portion of the state (Figure 1). More sulfate samples will be collected in the coming years to better characterize sulfate concentrations in waters used for production of wild rice. Current sulfate levels in many of Minnesota's surface waters are not a concern except for specific downstream waters used for production of wild rice.

Figure 1. Surface water sulfate concentrations (mg/L) in Minnesota.



Minnesota's Class 4 agriculture and wildlife use classification covers agricultural uses (crop irrigation and livestock uses), as well as wildlife uses (Table 1). Under the Class 4A use classification, Minnesota has a water quality standard of "10 mg/L sulfate - applicable to waters used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels" (Minn. R. 7050.0224, subp. 2). This 10 mg/L sulfate standard was adopted into the Minnesota Pollution Control Agency (MPCA) water quality standards in 1973 to protect wild rice and it applies to waters used for production of wild rice. Minnesota also has a Class 4B sulfate standard, set at 600 mg/L, to protect livestock and wildlife from adverse effects of high sulfate in their drinking water.

Table 1. Sulfate criteria by receiving water class.

Use class	Description	Sulfate (mg/L)	Duration, Frequency
Class 4A Wild rice	Only applies to waters used for production of wild rice	10	Annual average, only exceed 1 in 10 years
Class 4B	Drinking water criterion for wildlife and livestock	600	30-day average, never to exceed

Numeric water quality standards have three parts – the magnitude, or the numeric value; the duration, or the averaging time; and the frequency, or how often the standard can be exceeded. The sulfate rule indicates that the 10 mg/L sulfate standards is, "applicable to waters used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels."[1] This statement provides the basis for determining the duration and frequency of the standard, which is critical to developing permit limits to protect the wild rice beneficial use. The MPCA has determined that the 10 mg/L sulfate level should only be exceeded 1 in 10 years at the annual $365Q_{10}$ flow (Appendix A). This is a critical decision for the reasonable potential analysis.

There are 35 sulfate/wild rice impairments in Minnesota, as approved by U.S. Environmental Protection Agency (EPA) through the 2022 impaired waters list. More waters used for production of wild rice are likely to be included on the impaired waters list as data are collected in the coming years. Minnesota's sulfate/wild rice standard requires a surface water designated as a water used for production of wild rice to have a minimum of 5 samples over the past 10 years to demonstrate that sulfate exceeds 10 mg/L *on average* (Table 1). The procedures for summarizing sulfate data for assessment are included in the 2022 *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List* (MPCA, 2022).

In some locations, there is interest in modifying the existing 10 mg/L wild rice sulfate standard. This might be achieved through two principle means: 1) developing a site-specific standard, or 2) consideration of baseline levels to inform modifications of the water quality standards (Minn. R. 7050.170). Guidance on these matters is outside of the scope of this document. For clarity, the term "baseline" means ambient water, either measured or calculated, without point source contributions. Baseline is used to avoid confusion with terms like natural water quality, natural background, or simply background (Minn. R. 7050.0170).

[1] Minn. R. 7050.0224, subp. 2.

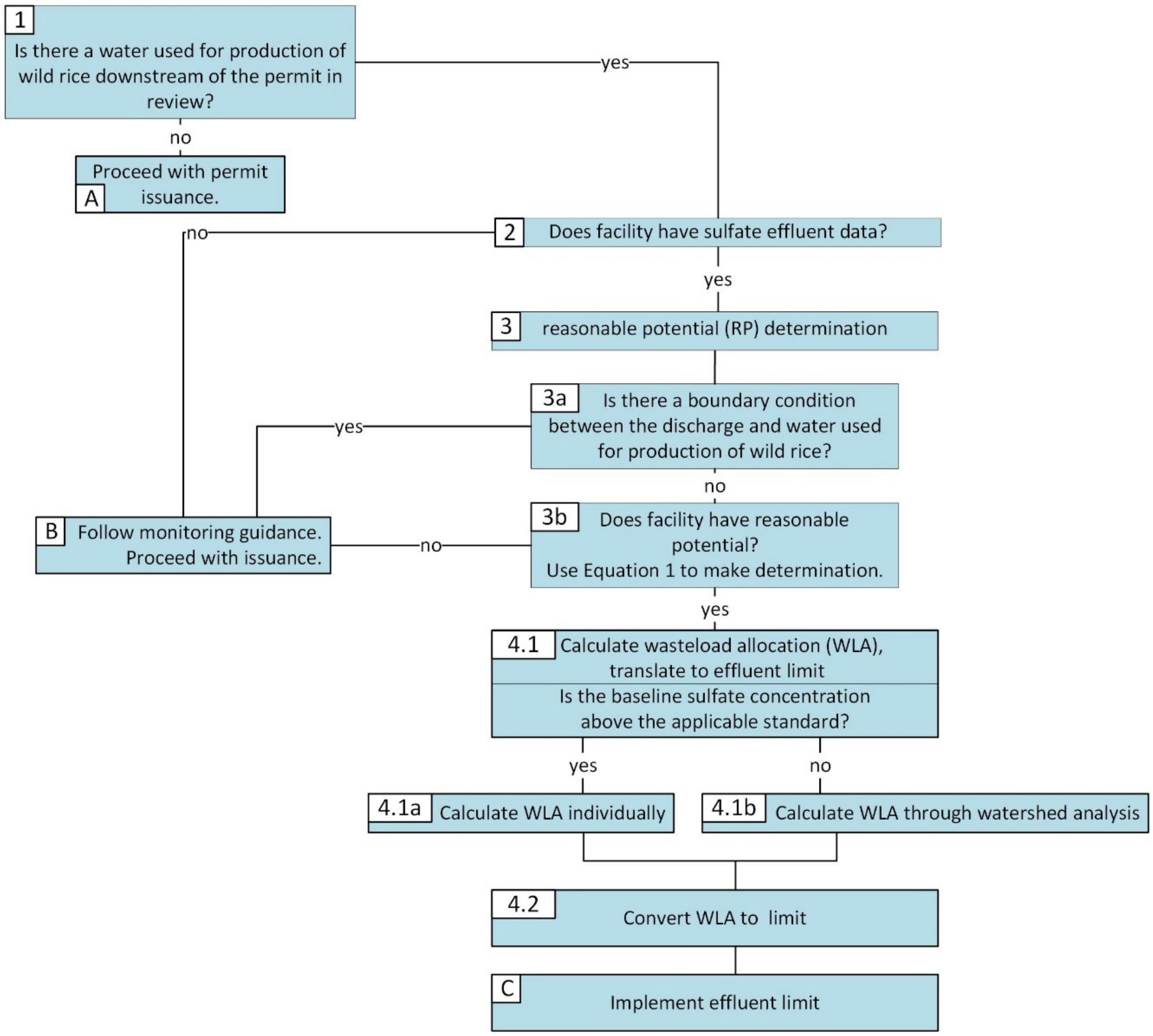
Limit implementation procedures

The overall process of reviewing the need for effluent limits has four critical components. The below simplified decision tree provides the basic limit outcomes for NPDES WWTFs (Figure 2 and Outline of decision tree). The first step requires the effluent limit staff to determine if there are any waters used for production of wild rice downstream of the outfall of the WWTF of concern. Effluent data from the WWTF of interest is examined in the second step. The third step requires the effluent limit setter to determine whether the WWTF has the reasonable potential (RP) to cause or contribute to an exceedance of the sulfate/wild rice standard in any of the waters used for production of wild rice that are located downstream of it. If RP exists, a wasteload allocation (WLA) is calculated in Step 4 and translated into an effluent limit. The procedures outlined in this document are meant to guide ELU staff rather than eliminate flexibility when establishing effluent limits for the unique combination of NPDES permittees and waters in Minnesota.

The method for evaluating the effluent limit is dependent upon whether the watershed has assimilative capacity and if the water used for production of wild rice has multiple contributing WWTFs. If the water used for production of wild rice of interest is in an area where baseline is greater than the applicable standard, no assimilative capacity exists, and effluent limits will be considered individually upon reissuance. In areas where baseline is below the applicable standard, limits may be evaluated on a watershed basis. In time, WLAs will be determined with the TMDL process. The goal of this document is to establish WLAs and WQBELs that will be compatible with future TMDLs.

Wild Rice Sulfate Limit Decision Process

Figure 2. Decision tree for wild rice sulfate effluent limits in Minnesota.



Outline of decision tree

1. **Is there a water used for production of wild rice downstream?**

   No -> No water used for production of wild rice downstream.

   Outcome A: Consider Class 4B wildlife sulfate standard and move on with permit reissuance.

   Yes -> water used for production of wild rice is downstream. Proceed to Step 2.

2. **Does the facility have sulfate effluent data?**

   No -> Insufficient effluent samples.

   Outcome B: Follow wild rice sulfate monitoring guidance and move on with permit reissuance.

   Yes -> Sufficient effluent samples have been collected, 10 samples for continuous discharges or 5 samples for controlled discharges. Other discharge frequencies will be evaluated on a case-by-case basis. Proceed to Step 3.

3. **Does the facility have RP?**

3a. Is there a boundary condition between the outfall and the water used for production of wild rice? Are there waters between the discharge outfall point and the water used for production of wild rice that have long-term average concentrations below the water quality standard? If so, the facility does not cause or contribute to an exceedance of the standards in the downstream water used for production of wild rice. If not, continue to question 3b. (See Boundary conditions for more information.)

Yes -> This facility does not have RP.

Outcome B: Follow wild rice sulfate monitoring guidance and move on with permit reissuance.

No -> Continue to Step 3b**.**

3b. Does the facility have RP to cause or contribute to a wild rice sulfate exceedance? Is the projected sulfate concentration at the $365Q_{10}$ flow above the applicable standard in the water used for production of wild rice of concern, when the facility is at design flow (70% of AWWDF for municipals). See the Reasonable potential analysis (Equation 1).

No -> This facility does not have RP.

Outcome B: Follow wild rice sulfate monitoring guidance.

Yes -> Proceed to Step 4.

4. **Calculate sulfate limit.**

If a facility is found to have RP, a WLA will be derived and translated into an effluent limit. This limit evaluation will be conducted in one of two ways, individually, or as a watershed with multiple dischargers. The baseline sulfate in the contributing areas to the water used for production of wild rice will determine if a watershed review is necessary.

4.1 Determine whether the baseline sulfate concentration in the water of interest has a concentration higher or lower than the applicable standard. Is the baseline sulfate concentration higher than the standard? If yes, continue to 4.1a, if not go to 4.1b.

4.1a. Assimilative capacity is not available. If the baseline sulfate concentration in the surrounding area is above the applicable downstream wild rice standard (i.e., 10 mg/L in most cases), there is no dilution or assimilative capacity available. The limit should be calculated individually. The WLA will closely reflect the concentration of the applicable standard because there is no available dilution or assimilative capacity. See Appendix D for an example of this case.

4.1b. Assimilative capacity is available. If the baseline sulfate concentration is less than the applicable wild rice standard (i.e., 10 mg/L in most cases), there is assimilative capacity. A watershed sulfate effluent limit analysis may be completed to determine the applicable concentration limit(s) for each contributing WWTF (see example in Appendix C).

- Note: Compliance schedules, variances, and/or site-specific standards may be considered if needed for these facilities.

Limit review process

The following section provides detailed steps for completing the effluent limit review process for WWTFs upstream of waters used for production of wild rice. The procedures are both for individual WWTF effluent limit reviews and watershed reviews for multiple WWTFs. In some situations, a watershed-based review can be used to evaluate the impact of multiple WWTFs on a specific water used for production of wild rice. The individual limits and requirements for WWTFs may be contained in a watershed memorandum. Watershed based reviews will generally be more useful when baseline sulfate concentrations are below 10 mg/L. A preliminary analysis has identified 18 waters used for production of wild rice with 10 or more upstream WWTFs (Table 2, Appendix E). The watershed review process can establish "tier-based limits" to divide up the available assimilative capacity when a few WWTFs dominate sulfate loading in the watershed. Within the watershed memoranda, multiple tributaries, including non-waters used for production of wild rice tributaries, are considered since sulfate is generally conservative in surface waters. This creates the possibility of river reaches above 10 mg/L as long as the standard is achieved in the water used for production of wild rice. An example is provided below to describe the limit and permit requirements for WWTFs upstream of a river reach with a sulfate/wild rice impairment (Appendix D).

Table 2: Waters used for production of wild rice with more than 10 upstream wastewater treatment facilities (WWTFs) located in Minnesota.

Note, some reaches, like the Mississippi river, have upstream WWTFs in other states, such as Wisconsin.

Water name	Lake or stream WID	Approximate count of WWTFs	Significant contributing drainage area with high baseline sulfate
Mississippi River	07060001-509	526	Mix
Mississippi River	07040003-627	498	Mix
Mississippi River	07010104-656	31	No
Larson	25-0016-00	30	Yes
Upper Estuary	69-1291-04	29	No
St Louis River	04010201-B66	28	No
Cannon River	07040002-501	24	Yes
Rainy River	09030008-561	23	No
Crow Wing River	07010106-721	20	Mix
Sylvan (Main Basin)	49-0036-01	20	Mix
Placid	49-0080-00	20	Mix
Lac Qui Parle (SE Bay)	37-0046-01	19	Yes
Lac Qui Parle (NW Bay)	37-0046-02	19	Yes
Rum River	07010207-556	17	Mix
Marsh	06-0001-00	11	Yes
Orwell	56-0945-00	10	Yes
Great Northern	73-0083-00	10	Yes
Zumwalde	73-0089-00	10	Yes

The procedures are applicable to existing, new, and expanding WWTFs, but the procedures do not specifically address additional permitting considerations, such as antidegradation or pollutant trading for new and expanding facilities. Sulfate effluent limit reviews for new and expanding facilities will be evaluated on a case-by-case basis. The individual limit reviews for new facilities will need to take downstream waters used for production of wild rice into consideration.

The mass balance approach covered in this document represents a simple "black box" model where inputs are mixed completely resulting in a predicted downstream concentration. This will likely be the primary modeling approach for most sulfate effluent limit reviews. In some situations, the MPCA has used more complex models for setting effluent limits for other parameters. The MPCA has extensive experience with watershed, lake, and river models; however, much of the modeling has centered on hydrology, total suspended solids, and nutrients. Sulfate has not been the focus of MPCA's Hydrological Stimulation Program – FORTRAN (HSPF) watershed models. Sulfate models could be a useful tool for setting effluent limits in the coming years for certain situations. Some models are simple while others require significant data inputs and calibration. Models are tools which can be used to establish WLAs in TMDLs and effluent limits. The MPCA will select the most appropriate model for each situation based on available calibration data, baseline concentrations of the waters of interest, available staffing resources, and other factors. The complexity of the selected model will depend on each situation. Effluent limit setters can use model outputs as the inputs for the mass balance equations. The MPCA has HSPF watershed models covering the majority of Minnesota's rivers and streams. These models can also be useful to estimate flows and concentrations of streams without monitoring.

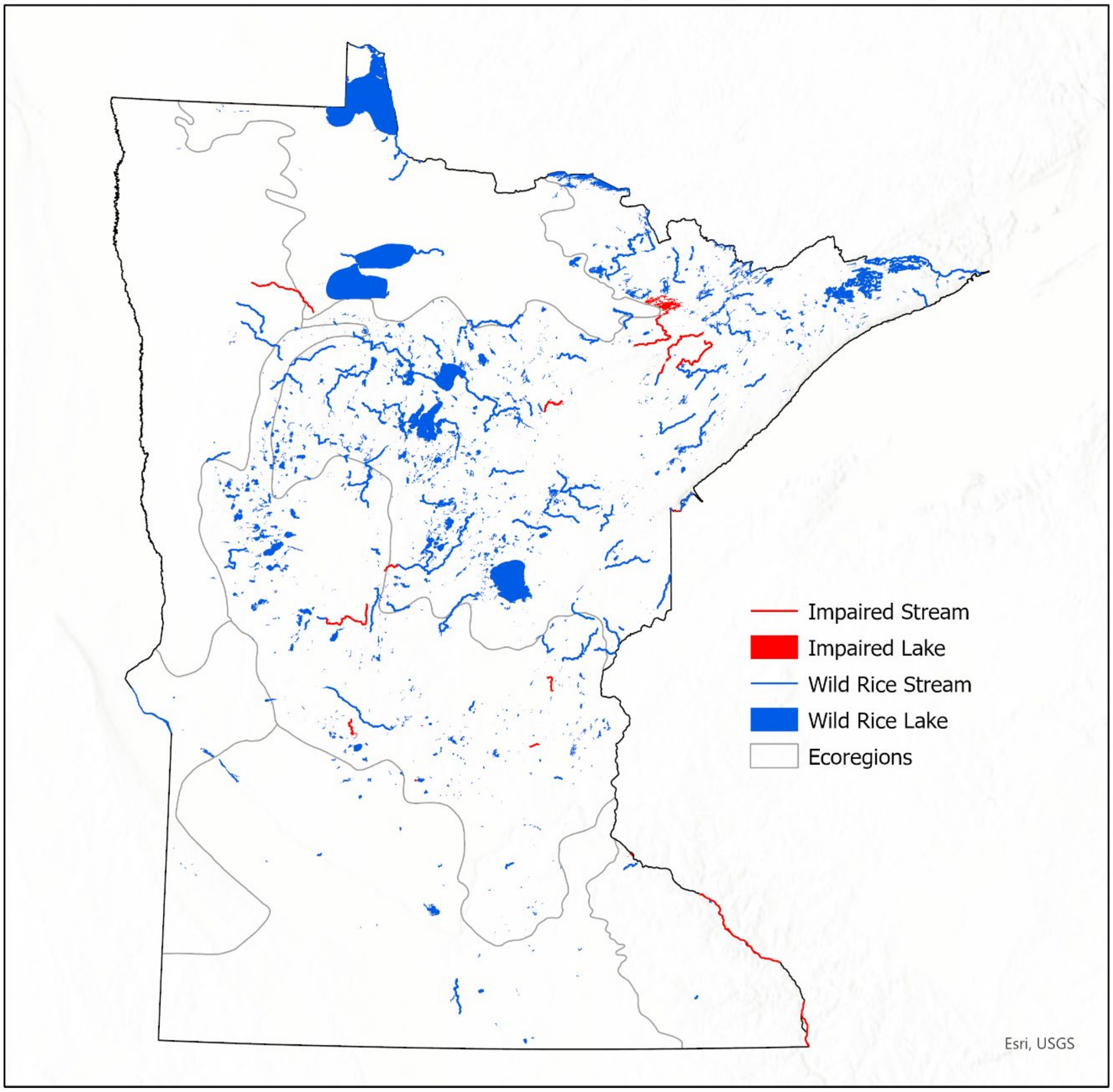
Step 1: Determine whether there is a water used for production of wild rice downstream of the WWTF of interest.

Upon reissuance, determine whether a water used for production of wild rice is located downstream of the permit in review. If not, proceed with reissuance. If a water used for production of wild rice is present, proceed to Step 2.

Wild rice can grow in contiguous or isolated backwater lakes in river floodplains. The impact of a river on floodplain backwaters will be determined on a case-by-case basis. For permitting purposes, flood plain lakes that are separated by land for the majority of the year will not be considered connected to the river. There are several lakes in the flood plain of the Lower Minnesota River (e.g., Fisher and Rice Lakes) that are isolated from the Minnesota River, except during flood flows. Other backwaters are contiguous with river flows and are not separated by land for most of the year. Many of the wild rice beds in Pool 8 of the Mississippi River near La Crescent are impacted by the sulfate of the Mississippi River for much of the year. In this case, WWTFs discharging in the Mississippi River Basin would be assessed for effluent sulfate impacts on wild rice. The cover photo of this document is a contiguous backwater of the Mississippi River near Brainerd.

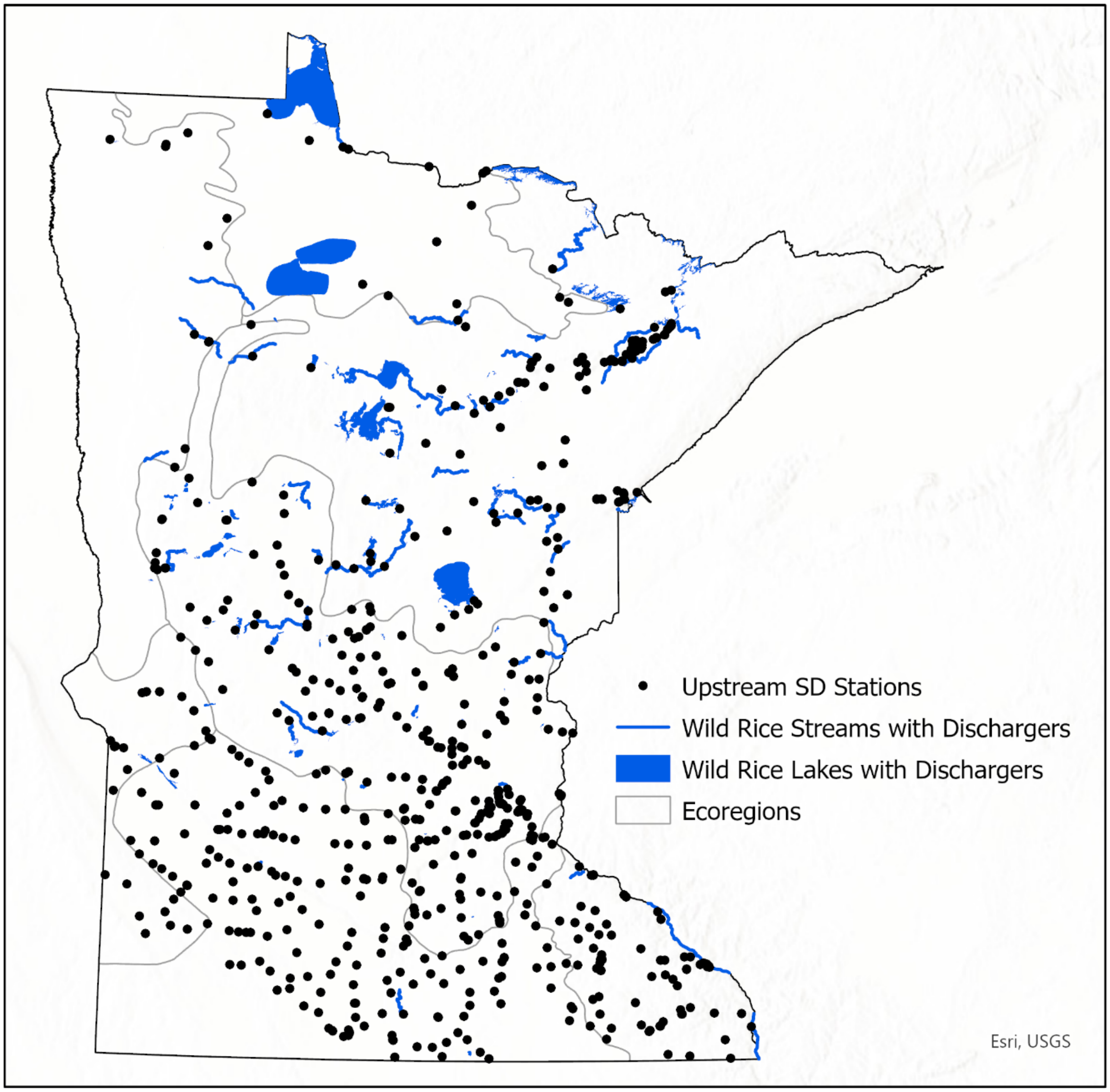
To date, the list of waters used for production of wild rice includes approximately 2,400 waters (Figure 3). This list was based on reviewing multiple sources of information – including various inventories, biological monitoring, and survey databases – to determine where the wild rice beneficial use has been or could be attained. Criteria for the inclusion of additional waters may be developed in a process detailed outside of this document; therefore, the count of waters used for production of wild rice is expected to grow. Since the MPCA assumes that sulfate is generally conservative in river systems, any downstream water used for production of wild rice should be considered unless a boundary condition is established.

Figure 3. Waters used for production of wild rice in Minnesota.



Currently, 35 waters used for production of wild rice are designated as impaired for sulfate on the 2022 impaired waters list (Figure 3). The limit setting process focuses on protecting the first downstream water used for production of wild rice, which will serve to protect all other downstream waters used for production of wild rice for the applicable 10 mg/L sulfate criteria. Not all waters used for production of wild rice have upstream point sources. MPCA data show that 244 of the approximately 2,400 waters used for production of wild rice have at least one upstream surface discharge (SD) station (Figure 4). Thus, the majority of waters used for production of wild rice are not impacted by permitted point sources. A total of 698 SD stations or 576 permittees discharge upstream of at least one water used for production of wild rice (Figure 4). A large number of these waters, 174 of the 244 total (71%), have three or fewer upstream SD stations.

Figure 4. SD stations upstream of waters used for production of wild rice with an upstream point source contribution.

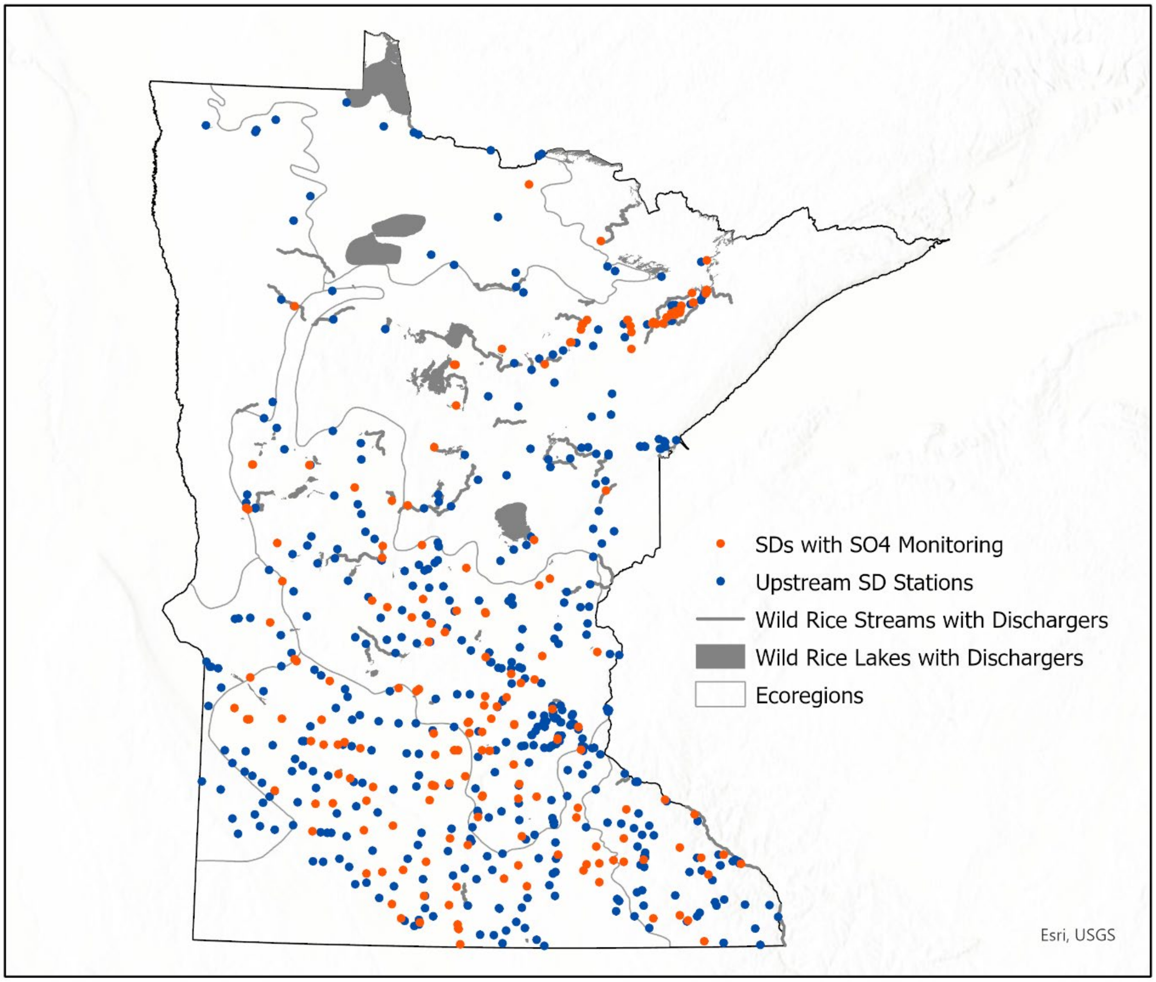


Step 2: Review sulfate effluent data

Determine whether the individual facility in question has sufficient data.

At present, sulfate effluent monitoring data are limited. About 27% of SD stations upstream of a water used for production of wild rice have sulfate effluent data (Figure 5).

Figure 5. Surface discharge stations upstream of waters used for production of wild rice that do (orange) or do not (blue) monitor for sulfate.



Ten samples since the last permit issuance are sufficient for facilities with a continuous discharge. Five samples are sufficient for controlled discharges, like stabilization ponds. If a facility does not have sufficient effluent sulfate data, then follow recommendations in the permit writers' wild rice sulfate effluent monitoring guidance and complete the RP analysis in the next permit cycle.

Step 3: RP analysis for sulfate limits

Federal regulations require that all discharges with the RP to cause or contribute to the exceedance of a state water quality standard are required to receive a WQBEL [40 CFR § 122.44 (d)]. The RP test determines whether a facility will need an effluent limit (Step 4). If a WWTF with sufficient sulfate effluent data is located upstream of a water used for production of wild rice, a RP analysis is required. There are two critical components to the RP analysis step. First, the limit reviewer will determine whether there is a boundary condition between the discharge point and the water used for production of wild rice. If there is a boundary condition, this facility does not have RP. Boundary conditions are defined in greater detail below. Second, if a boundary condition does not separate the discharge and water used for production of wild rice, the RP analysis equation, see below, is used to determine whether this facility has RP. If RP is found, a WLA and limit will be developed (see Step 4).

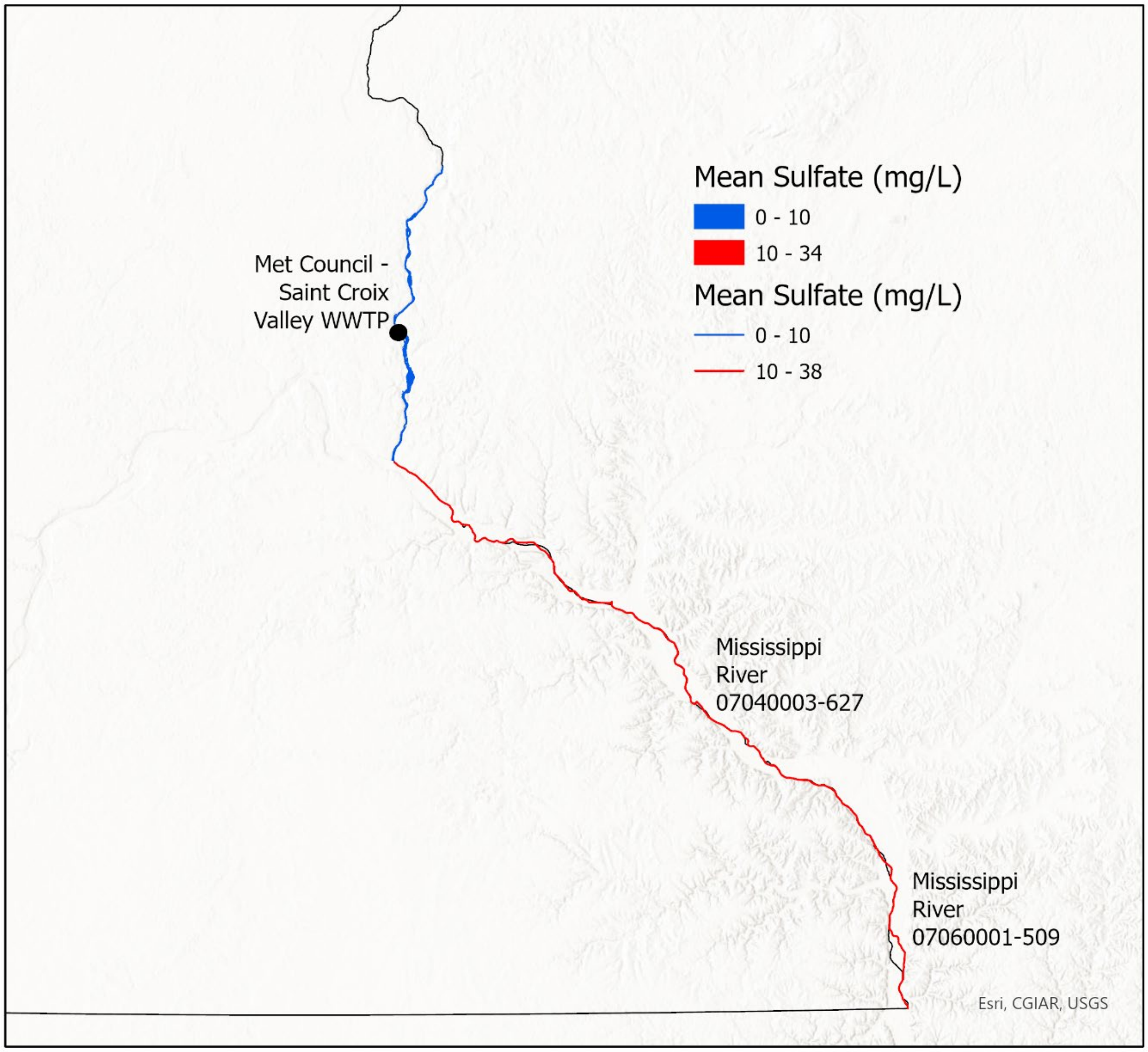
Boundary conditions

When setting effluent limits for toxic pollutants, if the standard is achieved in the local reach, then additional downstream reaches beyond the immediate local downstream reach of the WWTF are not considered. This is considered a “boundary condition” that essentially ends or re-sets the analysis and has been used in both effluent limit setting and TMDLs for multiple pollutants. Occasionally, there are waters between a discharge point and a water used for production of wild rice that have sulfate concentrations less than the water quality standard. This intervening, low-concentration water defines a boundary condition. If the long-term average sulfate concentration in an intervening water is less than the applicable criterion, the empirical data demonstrate that an upstream discharge does not have RP, and the permit should follow permit writer monitoring guidance.

A preliminary evaluation demonstrates that boundary conditions might affect approximately 12% of permits that are upstream of waters used for production of wild rice. Of 576 facilities upstream of at least one water used for production of wild rice (698 SD stations), 70 facilities or 78 SD stations have a water between their outfall and the first downstream water used for production of wild rice with a mean sulfate concentration at or below the standard (10 mg/L). Such a water may be considered a boundary condition. At the time of a permit review, the boundary condition will be evaluated with the reviewer considering factors, such as the sample size and years represented by the data. The reviewer will use best professional judgment in determining whether to implement a boundary condition or pursue another action, like requiring additional data collection. For example, the Metropolitan Council – Saint Croix Valley WWTF (SD 002) discharges effluent to the St. Croix River which flows to the Mississippi River (Figure 6). Multiple WIDs of the Mississippi River are waters used for production of wild rice (Figure 6, red). Since the mean sulfate concentrations of the waters between the Metropolitan Council – Saint Croix Valley WWTF outfall and the confluence of the St. Croix River with the Mississippi River are less than or equal to 10 mg/L, we may consider a boundary condition to exists between this permittee’s SD station and its downstream waters used for production of wild rice.

Figure 6. Example of potential boundary condition.

Flow from the Metropolitan Council – Saint Croix Valley WWTF outfall is generally south-southwest. Mississippi River reaches -627 and- 509 are waters used for production of wild rice.



Reasonable potential analysis (Equation 1)

As a general rule, if a facility discharges upstream of a river or lake that exceeds the wild rice sulfate standard, and that discharge has an effluent concentration greater than the standard, then the facility contributes to the downstream impairment. We use the RP analysis calculation to determine if the facility has the potential to increase the sulfate concentration at the critical flow above the applicable sulfate criterion (Equation 1). If the calculation yields a sulfate concentration below the applicable sulfate criterion, then the current effluent concentration is sufficient to protect the local reach. If the calculation yields a sulfate concentration above the applicable criterion, then the facility has RP to contribute to the impairment. Conservative transport of WWTF sulfate to downstream waters is a reasonable assumption unless the waters contain a slow-moving wetland complex (Berndt et al., 2016). There are some aquatic features, such as lakes or wetlands, that may trap a proportion of sulfate inputs and reduce the downstream impact of a given discharge. Extensive monitoring is typically not available to estimate fate and transport of sulfate downstream of WWTF outfalls. Estimating sulfate transport losses will be done on a case-by-case basis when sufficient monitoring data are available.

Equation 1. Reasonable potential analysis calculation.

$$C_r = \frac{Q_S C_S + Q_e C_e}{Q_r}$$

If Cr is > applicable sulfate criterion, then reasonable potential exists.
Details about variables are covered in the following pages.

$Q_r = Q_s + Q_e$

C_r = Concentration of river at critical flow with WWTF(s) at 70% of average wet weather design flow

Q_s = $365Q_{10}$ annual flow of stream without WWTF(s)

C_s = Baseline concentration of river without WWTF(s)

Q_e = Design flow of WWTF

C_e = Long term effluent concentration, existing concentration limit, proposed concentration from WLA for downstream resource, or concentration target of downstream mass WLA.

Note: No multiplier is used to transform C_e to 95^{th} or 99^{th} percentile concentration since sulfate is an annual average over multiple years. Sulfide concentration in sediment is likely impacted by the long-term concentration of water-column sulfate. The exceedance frequency of Minnesota's sulfate/wild rice standard is interpreted from rule narrative (e.g., not to exceed once in 10 years, Minn. R. 7050.0224).

Receiving water Flow (Q_s) = $365Q_{10}$ flow

The "Q_s" criterion of the equation is the $365Q_{10}$ flow of the river reach of concern (e.g., the lowest average 365 consecutive day flow with a one in ten-year recurrence) The $365Q_{10}$ flow was derived from research used to inform the proposed wild rice sulfate water quality standard revision (Appendix A). Streamflow estimates based on land area ratios of nearby gages, models, or other techniques may be used when streamflow data are unavailable for the river reach of concern. If appropriate, the effluent limit reviewer can subtract out the actual flows of all contributing WWTFs from data in a downstream gauging station. Watershed and TMDL projects will examine all sources and flows while effluent limit reviewers will focus on a relatively low flow year when contributions from WWTFs have the most impact on receiving waters. Higher flow years may be more impacted by sulfate from other sources. In areas with low baseline sulfate, high flow years will dilute the WWTF sulfate concentration in the downstream waterbody of concern. Consideration of receiving water flow for RP determination is consistent with federal regulations [40 CFR 122.44(d)(ii)].

Effluent flow volume (Q_e)

The effluent flow volume (Q_e) is derived from average wet weather design flow (AWWDF) for municipal facilities and maximum design flow (MDF) for industrial facilities. In this way, RP and limit calculations ensure protection up to the design capacity of the facility in question. When MPCA engineers review plans and specifications for WWTFs they focus on the AWWDF as the “design” flow of the facility. Domestic wastewater facilities do not operate at full design capacity for continuous, extended periods of time. Therefore, for municipals WWTFs, “Q_e” is equivalent to 70% of AWWDF which is often similar to average dry weather design flow (ADWDF). **In situations where current average summer effluent flow exceeds 70% of AWWDF, the current average flow for the facility will serve as Q_e**. Flow may be considered on a case-by-case basis for municipal stabilization ponds (Appendix B). For industrial WWTFs, “Q_e” is equivalent to the maximum design flow (MDF). Given their complex nature, the MPCA may use a facility-specific approach for some industrial facilities.

Example: Rochester WWTF/ Rochester Water Reclamation Plant

- AWWDF: 23.85 mgd
- ADWDF: 15.86 mgd
- 70% of AWWDF: 16.70 mgd

In situations where there are multiple facilities upstream of a water used for production of wild rice, Q_e may be the sum of all contributing facilities ($Q_e = \sum Q_e$).

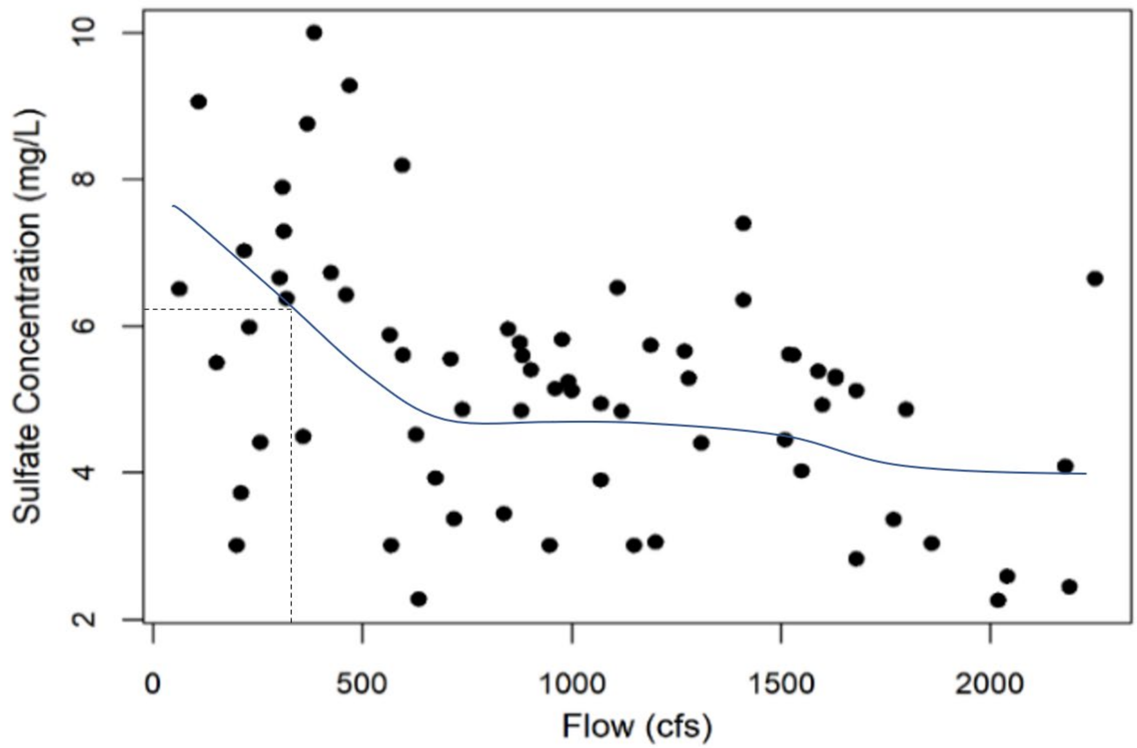
Effluent concentration (Ce)

Step 2 of the decision tree discusses the minimum number of samples required for establishing the effluent concentration (C_e). The average sulfate concentration for the past five years is the appropriate statistical value for $C_{e.}$ A flow weighted concentration is used with multiple facilities.

Current baseline concentration at $365Q_{10}$ flow (Cs)

Effluent limit reviewers will generally examine the available sulfate data for receiving waters upstream and downstream of a given WWTF to determine the long-term average concentrations of sulfate. If sufficient sulfate and streamflow data are available, a flow versus concentration plot is generated to determine the concentration of the receiving stream across all flows (Figure 7). Flow can be plotted in percent exceedance to visualize the impact of point sources during the $365Q_{10}$ flow conditions when contributions from other sources are less dominant.

Figure 7. Locally weighted scatterplot smoothing (lowest) curve to estimate baseline concentration of 6.25 mg/L sulfate at $365Q_{10}$ (350 cfs) flow.



When there are limited ambient sulfate samples on the water used for production of wild rice of interest, an estimated concentration will be used for the upstream, baseline, concentration (C_s) in the RP equation. The current sulfate baseline concentration is essential to the RP calculation and the WLA equation. Some of the rivers that exceed a sulfate/wild rice criterion may have multiple WWTF discharges upstream of the river reach of concern. Estimating the baseline concentration of the river at the $365Q_{10}$ flow minus any point sources is difficult for several reasons. The following options and other methods not specified may be used based on BPJ to estimate the upstream concentration:

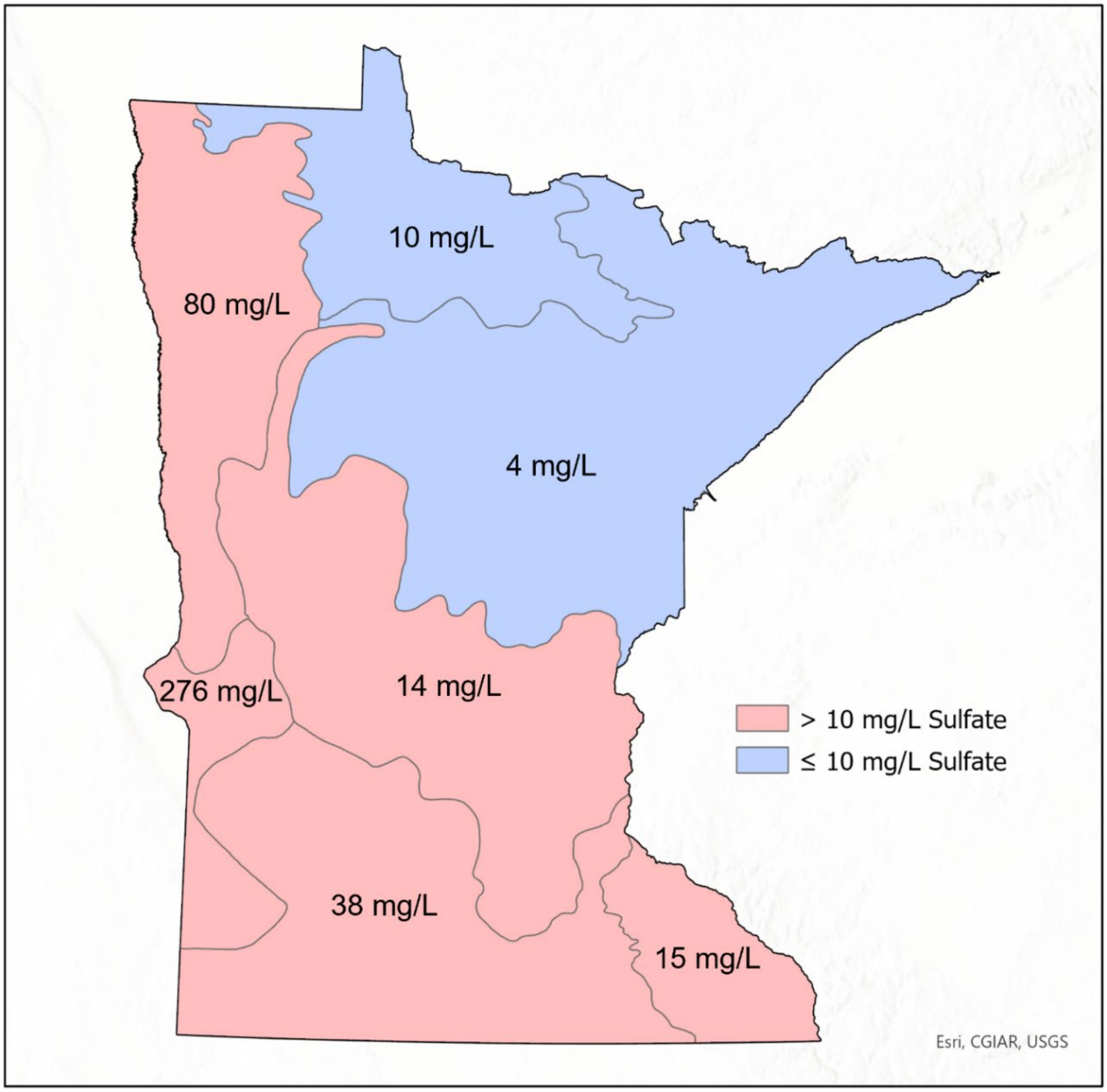
1. Assume baseline concentration is similar to nearby streams without WWTF discharges, see (Figure 8).
2. Estimate concentration based on modeling or mass balance calculations.
   a. Model runs with point sources removed to estimate "current baseline" concentration.
   b. Equation 2: Mass balance approach where assume 100% transport of sulfate from point sources during $365Q_{10}$ flow. This approach is limited in some areas by insufficient sulfate data for the contributing WWTFs and/or river of interest. The monitored mass of the WWTFs is removed from the monitored mass at the $365Q_{10}$ flow to estimate the concentration of the river without the contributing WWTFs. There may be some cases where a mass balance approach reveals that the monitored load at a monitoring station is less than monitored effluent load for the contributing WWTFs. In this situation, transport losses are occurring during the $365Q_{10}$ flow. Situations with significant transport losses will be evaluated on a case-by-case basis.

Equation 2. Equation to estimate baseline concentration at 365Q_{10} flows.

$$C_s(Baseline\ concentration\ @365Q10\ flow) = \frac{River\ mass@365Q10\ flow - monitored\ WWTF\ mass@365Q10\ flow}{365Q10\ flow\ (includes\ actual\ WWTF\ flows)}$$

Figure 8. Regional baseline sulfate concentrations.

Blue shaded ecoregions have baseline sulfate concentrations of less than or equal to 10 mg/L whereas red shaded ecoregions have baseline sulfate concentrations of greater than or equal to 10 mg/L. Gray lines indicate EPA Level III Ecoregions. Sulfate concentrations noted on the map are the median stream sulfate concentrations in waters without upstream point sources for the given ecoregion; only WIDs wholly within one ecoregion were considered.



Step 4.1: Calculate wasteload allocation and translate it to an effluent limit

When a WWTF has RP to cause or contribute to a downstream impairment, a WLA must be calculated. The WLA will then be translated into an effluent limit. Like the RP calculation (Equation 1), the WLA calculation (Equation 3) will focus on the sulfate criterion. The proposed approach is similar to the approach used to set monthly permit limits for toxics (TSD manual, EPA, 1991). This document will focus on a mass balance-based equation for calculating WLAs. Water quality models and load duration curves can also be used with TMDLs and WRAPS to establish WLAs. The complexity of these techniques is beyond the scope of this document but generally would be favored over the mass balance-based equation as they consider more factors in developing the WLA. Policy and guidance for TMDLs are available on the MPCA webpage (TMDL policy and guidance, MPCA). In unique situations, other limit setting options may be considered. These situations typically involve multiple facilities or a facility with a marginal contribution to the exceedance.

The approach for evaluating WLAs is dependent upon whether the average baseline sulfate concentration at the water used for production of wild rice of interest is above or below the applicable criterion.

Is the baseline sulfate concentration above the applicable standard? Yes → 4.1a
If average baseline sulfate concentration at the water used for production of wild rice is greater than or above the criterion (e.g., 10 mg/L), ELU staff will calculate the WLA individually (4.1a, Figure 2). Calculations may also be performed as a regional batch. However, the resulting WLAs and limits will be derived directly from the water quality standard because there is no assimilative capacity to justify higher WLAs and limits (Appendix D, Example 5).

Is the baseline sulfate concentration below the applicable standard? No → 4.1b
If the baseline sulfate concentration at the water used for production of wild rice is less than the applicable standard, it is recommended that WLAs be evaluated through a watershed analysis. For these watersheds, equivalent limits may not be necessary for all contributing dischargers. A greater sulfate load reduction at one or more large sources may allow for less restrictive limits at much smaller facilities, thereby lessening the pollutant reduction burden for some (Appendix C, Example 4). Tiered pollutant load reduction approaches have been used for decades in Minnesota.

Wasteload allocation calculation: Mass balance approach

The mass balance approach follows the procedures in the USEPA TSD approach for toxics. This section provides sufficient detail for sulfate effluent limit setting staff to complete mass balance equations for wild rice sulfate standards (Equation 3). Given the great diversity of surface waters in Minnesota, it is anticipated that staff may need to use BPJ to modify or complete the general mass balance equation presented in this document. Nonetheless, this equation serves as a starting point to calculating WLAs.

If baseline sulfate is less than the standards (4.1b) and there are multiple facilities upstream of a water used for production of wild rice, WLAs may be evaluated together in a watershed analysis. In this situation, the wastewater treatment design flow (Q_e) could be interpreted as the sum of design flows from all upstream contributing WWTFs (ΣQ_e). The resulting wasteload allocation concentration (WLA_c) can then be translated back into a total mass value, using ΣQ_e. Finally, the gross WLA can be subdivided among contributing WWTFs in a multitude of ways, so long as the total permitted mass does not exceed the gross WLA. See Appendix C, Examples 1-3. The resulting individual WLA, calculated from the total WLA_c, would be translated into individual effluent limits.

Equation 3. General mass balance equation for WLA (some terms of equation defined in previous section).

$$WLA_c = \frac{(Std * (Q_s + Q_e)) - (Q_s * C_s)}{Q_e}$$

WLA_c = Wasteload allocation concentration in (mg/L), which can be translated to mass based on Q_e and WLA_c

Std = Applicable sulfate water quality standard

Q_s = $365Q_{10}$ annual flow of stream

C_s = Baseline concentration of a river without WWTF(s)

Q_e = Design flow of WWTF

Unless noted otherwise, the sulfate criterion (Std) for water used for production of wild rice is 10 mg/L. A site-specific standard can also be substituted as the sulfate standard in Equation 3. Details surrounding this modification of a standard will be described elsewhere and are out of scope for this guidance. **The applicable sulfate criterion is determined by the standard at the nearest downstream water used for production of wild rice to which facilities are shown to have RP (Step 3, Equation 1).**

Developing protective permit limits: Translating WLAs to limits

The conversion of WLAs to limits is based on statistics. The conversion generally results in a calendar month average limit that is not numerically identical to the WLA but will result in attainment of the WLA on an annual basis. The WWTF must comply with the effluent limits for the WLA to be achieved as an average. All effluent limits will be developed to protect the duration and frequency of the wild rice standard and will also consider the variability of the effluent. The permit limits will be expressed as monthly averages to align with standardized monthly data reporting requirements. Daily max and average weekly limits are impracticable for sulfate given that it is assessed as a multi-year average [40 CFR § 122.45(d)]. Concentration limits will be expressed in units of mg/L and mass limits will be expressed as kg/day. Every concentration limit will also be expressed as an equivalent mass limit associated with permitted design flows to conform with 40 CFR § 122.45(f)1.

The equations used to calculate the Average Monthly Limit (AML) can be found on page 100 of the 1991 EPA TSD and are the same equations the MPCA has used for the past 25 years to develop protective permit limits for toxic pollutants (Equation 4, Table 3). The equations simply describe a statistical distribution of a dataset and are not dependent upon any specific pollutant mode of action. To account for the individual facility concentration variability and ensure the facility is discharging at the WLA as a long-term average, the WLA is converted into a Long-Term Average (LTA). Using these equations accounts for effluent variability (coefficient of variation, or CV), when determining effluent limits; to determine the CV the MPCA will require at least five effluent data points over a five-year period or a similarly representative number. Using these equations means that the limit will never be identical to the water quality standard. For example, for a direct discharge to an impaired water the WLA would be 10 mg/L, but the effluent limit would be approximately 13 mg/L as a monthly average (assuming a low effluent variability of CV = 0.2, two effluent samples a month and a 365-day standard duration). These equations are applied to five specific examples in Appendix C and D.

Equation 4. Long term average and average monthly limit equations.

$$LTA = WLA_c * e^{[0.5\sigma_a^2 - z\sigma_a]}$$

$$AML = LTA * e^{[z\sigma_n - 0.5\sigma_n^2]}$$

Table 3. Critical variables for determining a limit.

Acronym	Term	Description
LTA	Long Term Average	Long term average concentration that complies with WLA
CV	Coefficient of variation	Assuming Log-Normal distribution
FM	Frequency of Monitoring	At least five data points or a similarly representative number
Z	Z Factor	1.645, statistical uncertainty factor for a 95% probability
σ_n	Variability factor for 2 samples per month	$\sigma_n = \ln\left(\frac{CV^2}{2} + 1\right)$
σ_a	Variability factor for 2 samples per month	$\sigma_a = \ln\left(\frac{CV^2}{365} + 1\right)$

The final step of the limit setting process requires the effluent limit reviewer to evaluate all applicable regulations and requirements for local and downstream resources to determine the appropriate sulfate limits to be included in the NPDES permit of a given WWTF. The limit reviewer will strive to make the permit as simple as possible, yet be mindful of multiple downstream resources, antidegradation, antibacksliding, and TBELs. After the final limits and requirements are determined by the sulfate effluent limit reviewer, compliance schedules, variances, and/or pollutant management plans will be included, if needed, in the NPDES permit by MPCA permitting staff.

Other limit setting considerations

Most permit reissuances can be evaluated using considerations summarized in the Decision Tree and the following discussion. However, there are other limit setting considerations that will occur less frequently; but nonetheless, are important to document. The following section includes an array of topics that may factor into some limit decisions.

During the limit setting process there are additional considerations to be reviewed including:

- Mass freeze
- Lake considerations
- TMDLs
- New/Expanded

These considerations are further detailed below.

Mass freeze option for facilities that only have RP at design flows

Some waters used for production of wild rice currently meet 10 mg/L with upstream WWTFs discharging at actual flows, well below the facility design flows. At full design flow, these facilities may have RP. The goal of the mass freeze when RP exists is to maintain the current acceptable impact of the WWTFs on the receiving water of concern. The intent of these limits is not to result in new treatment works unless the WWTF expects actual increases in effluent flows. Sulfate effluent limit reviewers will establish mass and/or concentration limits that maintain existing “average” loading from the WWTFs. When flows are increased to 70% of AWWDF or MDF, this same water used for production of wild rice could exceed 10 mg/L in the RP equation. Since the existing actual discharge from WWTF does not have RP, a sulfate mass “freeze” will ensure current conditions are maintained. The current average concentration and mass or modest increase serve as the WLA to establish permit limits that will freeze the WWTF at its current sulfate impact on the river.

Example: The current effluent from the WWTF has 10 kg sulfate/day which equates to a sulfate concentration of 8 mg/L in a local water used for production of wild rice during the critical $365Q_{10}$ flow. Based on the current design of the WWTF, the WWTF could discharge 60 kg/day which equates to a sulfate concentration of 12 mg/L in a local river during the critical $365Q_{10}$ flow. The sulfate effluent reviewer examined the existing sulfate data and concluded, based on BPJ that an increase of sulfate from 10 kg/d to 30 kg/d would still achieve 10 mg/L in the water used for production of wild rice. The effluent limit setter establishes a 42.0 kg/day calendar month average mass cap based on the translation of the 30 kg/d WLA to an effluent limit to prevent the water used for production of wild rice from exceeding 10 mg/L. If the facility increases its actual flows, it will need to treat for sulfate to meet the mass limit.

Sulfate limits for lakes

Many of the waters used for production of wild rice in the state are lakes. A case-by-case analysis will be completed for setting effluent limits upstream of lakes with sulfate/wild rice impairments. The preceding section provides a process for setting sulfate effluent limits for WWTFs upstream of waters used for production of wild rice that are rivers or streams. The MPCA has historically worked to avoid WWTF discharges upstream of lakes to minimize the impact of phosphorus on lakes. Nonetheless, there are some WWTF outfalls upstream of lakes. The simpler method for setting effluent limits for lakes is establishing annual flow-weighted mean concentration (FWMC) targets for tributaries. Computer models are a more complex tool to set sulfate effluent limits for WWTFs upstream of a lake. Tributary and lake monitoring are essential to building lake water quality models. Sulfate monitoring throughout a watershed may indicate limited sulfate transport losses. If no data are available, conservative transport will be assumed.

TMDLs

Total maximum daily load (TMDL) studies are developed for waters that are on Minnesota’s impaired waters list. A TMDL is a pollutant load budget that defines the maximum amount of pollution a water can receive and still attain standards. Generally, if a TMDL WLA is available at the time of permit issuance, effluent limits will be directly derived from this WLA or reviewed for compatibility. At the moment, the MPCA has not completed any TMDLs for wild rice sulfate; and therefore, there are no wild rice sulfate TMDL WLAs to inform WQBELs.

Nonetheless, the MPCA anticipates that when permits are reviewed prior to issuance, many will have RP for downstream impaired waters used for production of wild rice. Federal regulations require that if a permit has RP, limits must be included in the permit, and these limits must be sufficient to attain the standard.[2] Therefore, when the MPCA determines that a facility has RP to cause or contribute to a downstream water used for production of wild rice, a permit associated with this facility must also

[2] 40 CFR 122.44 (d)(1)

contain a sulfate WQBEL. Variances, compliance schedule, or perhaps other implementation tools may be used to provide time and flexibility. However, these tools are not the subject of this document.

Some TMDLs may include WLAs for facilities discharging below the sulfate criterion as part of a total accounting system for all sources of sulfate upstream of a water of interest. In circumstances where the discharge concentration is below the applicable water quality standard, the facility would not have RP, and an additional effluent limit would not be necessary to ensure that the discharge is consistent with the assumptions of the TMDL WLA.

Effluent limit reviewers will seek to have WQBELs developed in a manner as consistent as possible with future TMDLs. It is likely that similar methods, assumptions, and data for WQBELs and TMDLs will lead to compatible outcomes for WWTF restrictions. In some cases, however, additional data or more sophisticated TMDL modeling, not available at the time of the effluent limit review, may result in different TMDL WLA and limit outcomes. These results could lead to different limits compared to those expressed in the preceding permit. Modifications will be made accordingly to ensure future limits are consistent with the TMDL. If the limit has not yet become final or enforceable, a modification to a less restrictive numeric limit value will not constitute backsliding. However, reducing the stringency of a WQBEL is restricted by state and federal antibacksliding regulations if the facility has already demonstrated consistent compliance with an earlier WQBEL.[3,4]

New and expanded facilities

Annually, MPCA receives 10 to 15 requests to review new or expanded permit proposals. A fraction of this number is fully realized; and therefore, new or expanded permits are relatively rare. Nonetheless, it is reasonable to expect that new or expanded wastewater treatment plant permits will occur in the future. Some of these proposals may be upstream of waters used for production of wild rice.

State and federal regulations restrict new or expanded dischargers. Federal regulations require that permittees with RP be required to receive WQBELs.[5,6] If the pollutant loading is from a new source or new discharger and it would cause or contribute to an excursion of the wild rice sulfate standard, then the new or expanded discharger needs a pollutant load allocation to allow for the discharge. WLAs could be a component of a TMDL, or they could be developed through a watershed permitting analysis. In many situations, the larger issue is a general lack of assimilative capacity. There are three ways, perhaps more, that assimilative capacity could be developed.

1. **Effluent limits for large sources in the watershed** – If effluent limits for large sources in the watershed were to be implemented through a permit, this may provide assimilative capacity and, therefore, sufficient remaining pollutant load allocations to allow for a new source or discharge.
2. **Variances** – A variance is a temporary modification of a water quality standard. Typically, variances are implemented through NPDES wastewater permits. Permits with variances would contain final WQBELs based upon the WQS at the time of issuance. However, the final WQBEL would not be enforceable. Instead, the variance would identify the highest attainable condition

[3] Minn. R. 7053.0275 Antibacksliding.
[4] 40 CFR 122.44(2)(i)
[5] 40 CFR 122.4(i)
[6] 40 CFR 122.44 (d)(1)(i-iii)

(HAC) reflected as both an interim effluent limit, applicable during the course of the variance term, and also a series of actions that the permittee could take to ensure that they were making progress towards attainment of the final effluent limit. So far, Minnesota has implemented variances through individual permits. It may be possible to implement variances in other ways, but this is out of scope for this document. The variance serves to modify the underlying WQS for the term of the variance, which in turn, provides assimilative capacity, and sufficient remaining pollutant load allocation.

3. **Site specific standards (SSS)** – If a site-specific standard were developed and adopted at a concentration above current levels, this could allow for more assimilative capacity and pollutant load allocation. A SSS may also change the outcome of a reasonable potential analysis if it is conducted after the SSS has already been developed. For example, if a SSS is adopted and a new or expanded facility is expected to operate at a concentration below that standard, the facility would not have reasonable potential. In turn, a WQBEL or a pollutant load allocation would not be required for that facility. Another possibility is the new or expanded facility could discharge above the SSS if the downstream water used for production of wild rice has sufficient assimilative capacity for the proposed facility.

New facilities may also be allowed when dilution is present which could be achieved through two means; first, if the proposed discharge is at a concentration lower than the downstream standard, and/or second, if the downstream water used for production of wild rice has a sulfate concentration less than the standard. Depending on the nature of the permit and the amount of assimilative capacity, a new or expanded permit may be issued with sulfate effluent limits to ensure continued protection of downstream waters.

Finally, all new or expanded sources of sulfate loading upstream of waters of interest need to satisfy state and federal antidegradation rules. Permittees wanting more information on antidegradation should be advised to read MPCA's guidance in addition to state and federal rules.[7, 8,9]

References

MPCA, 2022. Guidance manual for assessing the quality of Minnesota surface waters for determination of impairment: 305(b) report and 303(d) List: 2022 assessment and listing cycle. MPCA St. Paul, MN 78 pp.

U.S. EPA, 1991. Technical support document for water quality-based toxics control. EPA/505/2-90-001, PB91-127415, 335 pp.

Berndt, Michael E., Wes Rutelonis, and Charles P. Regan. "A comparison of results from a hydrologic transport model (HSPF) with distributions of sulfate and mercury in a mine-impacted watershed in northeastern Minnesota." Journal of environmental management 181 (2016): 74-79.

[7] Antidegradation Guidance, 2019, MPCA
[8] Minn. R. 7050.0250- 7050.280
[9] 40 CFR 131.12

Appendices

Appendix A. Justification of $365Q_{10}$ flow for RP analysis

In order to calculate WQBELs, one must consider the magnitude, duration, and frequency of the standard that is being protected. The wild rice standard has a numeric magnitude (10 mg/L) and a narrative frequency defined in rule. Rule language indicates that the 10 mg/L sulfate standards is, "applicable to waters used for production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels."[10] Research indicates that sulfate in the water column can affect sediment chemistry, even outside of the growing season. Sulfate needs to be controlled year-round. However, research also indicates that wild rice is not susceptible to short duration pulses of sulfate. Because the duration and frequency are defined in narrative, MPCA must make a reasonable numeric interpretation.

The MPCA will use a one-in-ten-year annual low flow statistic ($365Q_{10}$) to define the critical in-stream condition. The "365-day ten-year low flow" or "$365Q_{10}$" is the lowest annual average flow with a one-in-ten-year recurrence interval. The $365Q_{10}$ is comparable to the recurrence interval used for other water quality standards, such as general toxics ($7Q_{10}$) and ammonia ($30Q_{10}$) in the sense that a one-in-ten-year recurrence interval is used; however, the averaging period is expanded to an annual (365 day) period to reflect the annual average duration for the wild rice sulfate standard. A $365Q_{10}$ is derived using the same methods to derive a $7Q_{10}$. The guidelines regarding the period of record for flow data and estimating a $7Q_{10}$ apply equally to determining a $365Q_{10}$, as described in part 7053.0135, subp. 3. The $365Q_{10}$ calculation methodology would apply to streams and rivers. A one-in-ten-year flow recurrence interval, or equivalent value, calculated with a model would apply to lakes, wetlands, and reservoirs. Because of the lack of flow through some water bodies, an isolated water body without inflows or outflows would have a one-in-ten-year flow of zero. The flow rate will be calculated using calendar-year time intervals to be protective of the annual average duration of the standard. The 2017 wild rice rulemaking technical support document used a science-based approach to justify an annual average duration and a one in ten-year frequency.[11]

Appendix B. Special considerations for municipal pond facilities.

Many smaller communities in Minnesota have stabilization pond WWTFs. These facilities are allowed to discharge seasonally in spring and fall. Relatively little sulfate effluent monitoring is currently available for stabilization ponds. Stabilization pond dischargers, upon reissuance, will be instructed to monitor according to the permit writers' guidance.

When evaluating limits, there are two basic approaches for establishing sulfate limits for stabilization ponds with sufficient effluent data.

1. **Reasonable potential calculation assumptions.** For the RP and WLA calculation, flow will be equivalent to 70% of AWWDF. Assume that this flow is spread over the year even though ponds

[10] Minn. R. 7050.0224, subp. 2.

[11] The technical support document from the 2017 rulemaking (pp 91-97) provides the rationale for using an annual duration and a one in ten-year frequency.

can only discharge during spring and fall. This technique is possible since the standard is an annual average rather than a “do not exceed” standard averaged over a short duration such as a 4-day average.

2. **Mass freeze option.** In some watersheds current performance of the stabilization facilities is adequate, but increased loads have RP. Slight adjustments in permit language or a mass freeze will minimize the impact of ponds especially in situation where actual flows are stable or declining.

Appendix C. Hypothetical examples with low baseline sulfate

The hypothetical examples in this section focus on limit-setting for a range of facilities in a watershed with low baseline sulfate. In this watershed (Figure 9), baseline sulfate for the entire watershed is assumed to be 3 mg/L based on monitoring of streams without upstream WWTFs. The example will show the analysis going through the decision tree for each WWTF (Figure 2). Tables 4 and 5 list the facility and water-quality information needed to determine if and what sulfate limits are necessary. For the purposes of this example, all mine discharges will be considered as the functional equivalent of a direct discharge; a final agency decision on any functional equivalent analysis would be included for review during the permit’s public comment period.

Example 1 focuses on a discharge with no downstream water used for production of wild rice. Example 2 covers a discharge upstream of a water used for production of wild rice that is not found to have RP. The concentration after discharge is low enough to not cause an exceedance of the standard. Example 3 focuses on a lobe of the watershed in which two facilities have RP, and thereby require limits. Finally, Example 4 is similar to Example 3, except that limits for some dischargers could be set at levels that could allow for achievable limits with another dischargers.

Figure 9. Watershed with low baseline sulfate concentration. Map accompanies Examples 1, 2, and 3.

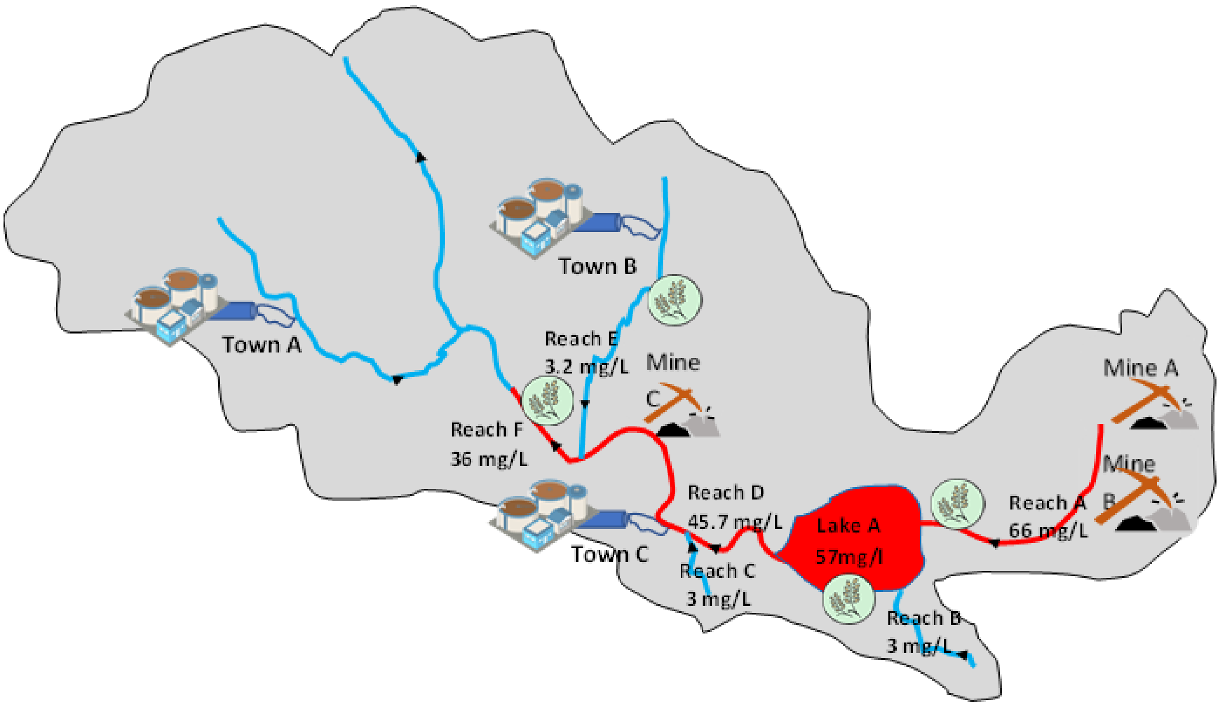


Table 4. Facility sulfate discharge information for low baseline sulfate examples.

Facility	Design flow mgd	Critical Flow 70% for WWTFs mgd (Q_e)	Actual flows	Mean sulfate mg/L (C_e)	Count of sulfate samples	Sulfate mass
Town A	12	8.4	10	Not monitored	0	--
Town B	1	0.7	0.5	24	24	63.7
Town C	0.4	0.28	0.23	50	15	53.0
Mine A	20	20	14	400	16	30,280
Mine B	10	10	7	300	12	11,355
Mine C	5	5	4	600	19	11,355

Table 5. Ambient water quality data (low baseline sulfate example, map in Figure 9).

Surface water	Upstream sulfate sources	Mean sulfate mg/L (C_s)	$365Q_{10}$ flow (mgd) with dischargers (Q_r)	$365Q_{10}$ flow (mgd) without dischargers (Q_s)	water used for production of wild rice
Reach A	Mine A and Mine B	66	121.0	100	Yes
Reach B	-	3	20.0	20	No
Lake A	Mine A and Mine B	57	141.0	120	Yes
Reach C	-	3	20.0	20	No
Reach D direct ungaged	-	3	70.0	70	No
Reach D	Mine A, Mine B, Town C, Mine C	46	235.2	210	Yes

Surface water	Upstream sulfate sources	Mean sulfate mg/L (C_s)	$365Q_{10}$ flow (mgd) with dischargers (Q_r)	$365Q_{10}$ flow (mgd) without dischargers (Q_s)	water used for production of wild rice
Reach E	Town B	3.2	70.0	69.5	Yes
Reach F	Mine A, Mine B, Town C, Mine C	36	305.2	279.5	Yes

Example 1. Town A – no downstream water used for production of wild rice (Figure 2, Decision Tree 1, outcome A)

1. Is there a water used for production of wild rice downstream?

   No → No water used for production of wild rice downstream.

   Outcome A: Proceed with permit reissuance.

Example 2. Reach E and Town B – data available, no reasonable potential (Figure 2, Decision Tree 3b, Outcome B)

1. **Is there a water used for production of wild rice downstream?**

   Yes → the receiving water of the facility (Reach D) is a water used for production of wild rice.

2. **Does the facility have sulfate effluent data?**

   Yes → Facility has 24 effluent sulfate results.

3. **Reasonable potential**

   3a. Is there a boundary condition between the discharge and the water used for production of wild rice?

   No → Ambient water quality data are not available between the Town B discharge and the nearest downstream water used for production of wild rice. Data are not available from which to determine a boundary condition. Therefore, the limit setter must use Equation 1 to calculate RP. Go to Step 3.b.

   3b. Does Town B have reasonable potential?

   No → At the $365Q_{10}$ flow, the sulfate concentration of the downstream water used for production of wild rice (Cr) was calculated to be 3.2 mg/L (Table 6, Equation 1). Because 3.2 mg/L is less than 10 mg/L, the Town B does not have reasonable potential.

$$C_r = \frac{Q_s C_s + Q_e C_e}{Q_r}$$

   Outcome B: Follow permit writers' monitoring guidance. Reach E will be monitored by MPCA in watershed monitoring framework.

Table 6. Results of Step 3b. reasonable potential determination for Town B and water used for production of wild rice at Reach E.

Variable	Description	Value	Unit
C_r	Concentration of river at critical flow ($365Q_{10}$) with WWTF at 70% of average wet weather design flow	3.2	mg/L
Q_s	$365Q_{10}$ annual flow of stream without WWTF(s)	69.5	mgd
C_s	Concentration of reach E without WWTF(s)	3	mg/L
Q_e	Design flow of Town B WWTF	0.7	mgd
C_e	Long term effluent concentration	24	mg/L
Q_r	$Q_s + Q_e$ total flow in the river	70.2	mgd

Variable inputs for Equation 1, Example 2.

Example 3. Reach A, Mine A and Mine B – Multiple facilities have RP. Baseline is less than the standard. WLAs/Limits are calculated through watershed analysis. (Decision tree 4.1b, Outcome C)

1. **Is there a water used for production of wild rice downstream?**

   Yes → the receiving water of the facility (Reach A) is a water used for production of wild rice.

2. **Does the facility have sulfate effluent data?**

   Yes → both facilities have more than 10 sulfate samples: Mine A n=16, Mine B n=35

3. **Reasonable potential**

   3a. Is there a boundary condition between the discharge and water used for production of wild rice?

   No → There are no waters between the point of discharge and the water used for production of wild rice that have average concentrations less than the water quality standards (10 mg/L, sulfate).

   3b. Does Mine A and B have reasonable potential to cause or contribute to wild rice sulfate impairment?

   Yes → Both facilities have reasonable potential, given that both discharges raise the downstream river concentration (C_r) to 87 mg/L, which is greater than the water quality standard (Table 7).

$$C_r = \frac{Q_s C_s + Q_e C_e}{Q_r}$$

   Move to determine wasteload allocation.

Table 7. Terms of Equation 1 for Example 3, for determination of rasonable potential. In this example the flow-weighted mean average concentration is expressed as $\sum Q_e$ and $\sum C_e$, respectively.

Variable	Description	Value	Unit
C_r	Concentration of river at critical flow with WWTF at 70% of average wet weather design flow	87	mg/L
Q_s	$365Q_{10}$ annual flow of stream without WWTF(s)	100	mgd
C_s	Concentration of river without WWTF(s)	3	mg/L
$\sum Q_e$	Design flow of Mine A and B	30	mgd
$\sum C_e$	Long term effluent concentration flow weighted mean of both facilities	367	mg/L
Q_r	$Q_s + Q_e$	130	mgd

4. **Limit determination**

4.1b Concentration of baseline is less than applicable standard. A watershed limit analysis is used to calculate the WLA.

WLA allocation calculation: use the general mass balance equation for WLAs (Equation 3), shown below. Some terms of this equation are defined above (Table 8).

$$WLA_c = \frac{(Std * (Q_s + Q_e)) - (Q_s * C_s)}{Q_e}$$

Table 8. Wasteload allocation calculations – Equation 3 applied to Example 3.

Variable	Description	Result	Unit
Std	Sulfate water quality standard for waters used for production of wild rice	10	mg/L
Q_s	$365Q_{10}$ annual flow of stream without WWTF(s)	100	mgd
C_s	Concentration of river without WWTF(s)	3	mg/L
$\sum Q_e$	Design flow of Mine A and B	30	mgd
WLAc	WLA concentration need to meet the sulfate standard	33.3	mg/L

4.2 Convert WLA to limit. Use the LTA to AML calculation to determine the sulfate Limits (Equation 4), as well as the sulfate discharge data (Table 9).

Table 9. Conversion of WLA to monthly average mass and concentration limits for Mine A and B.

Acronym	Variable	Description	Mine A	Mine B
WLA	Wasteload allocation	mg/L	33.3	33.3
CV	Coefficient of variation	Assuming Log-Normal distribution	0.33	0.23
FM	Frequency of monitoring	At least five data points or a similarly representative number	2 x Month	2 x Month
Z	Z Factor	statistical uncertainty factor for a 95% probability	1.645	1.645
VAR	Sample variance	$\frac{\sum(x-\bar{x})^2}{n-1}$	0.106	0.050
StdDev	Standard deviation	$\frac{\sum x^2 - \frac{1}{n}(\Sigma x)^2}{n-1}$	0.325	0.223
σ_n	Variability factor for 2 samples per month	$\sigma_n = \ln\left(\frac{CV^2}{2}+1\right)$	0.054	0.025
σ_a	Variability factor for 365-day standard duration (chronic)	$\sigma_a = \ln\left(\frac{CV^2}{365}+1\right)$	0.0003	0.0001
LTA	Long term average	$WLA_c * e^{[0.5\sigma_a^2 - z\sigma_a]}$	33.3	33.3
AML mg/L	Calendar month ave. conc. limit mg/L	$LTA * e^{[z\sigma_n - 0.5\sigma_n^2]}$	48.8	42.7
AML kg/d	Calendar month ave. mass limit[a]	AML *MDF *3.785	3690.8	1615.9

[a] 40 CFR 122.45(f)

Outcome C: Reissue permit with average monthly concentration and mass sulfate limits, as specified in Table 9.

Example 4. Reach D, Town C and Mine C

In Example 4, it is assumed that limits are implemented at Mine A and B (Equation 3) resulting in water quality improvements in Lake A (Figure 10). Baseline is less than the water quality standard. A watershed analysis is again used to evaluate limits for Town C and Mine C (Table 10). Town B is also upstream of the reach D exceeding 10 mg/L, but Town B's immediate discharge to Reach E does not exceed 10 mg/L (see Example 2 above). Town B was excluded from this example since it doesn't have RP in the first downstream water used for production of wild rice.

1. **Is there a water used for production of wild rice downstream?**

   Yes → The receiving water of the facility (Reach D) for both Mine C and Town C is a water used for production of wild rice (Figure 10). Proceed to decision tree question 2.

2. **Does the facility have sulfate effluent data?**

Yes → Both facilities have more than 10 sulfate samples: Mine C (N=19) and Town C (N=15, Table 4).

3. **Reasonable potential**

3a. Is there a boundary condition between the discharge and water used for production of wild rice?

No → There is no river reach between the outfalls and the water used for production of wild rice with average sulfate concentrations less than 10 mg/L (Figure 10).

3b. Does Town C and Mine C have reasonable potential to cause or contribute to an exceedance of the wild rice sulfate water quality standard?

Is the projected sulfate concentration at $365Q_{10}$ flow greater than the applicable standard in the water used for production of wild rice, when the facility is at design flow (70% of AWWDF for municipals)? Equation 1, reprinted below, is used to make this determination.

$$C_r = \frac{Q_{s1}C_{s1} + Q_{s2}C_{s2} + \sum Q_e \sum C_e}{Q_r}$$

Table 10. Equation 1 values to make reasonable potential determination for Town C and Mine C (Example 4).

Variable	Description	Value	Unit
C_r	**Concentration of river at critical flow with WWTF at 70% of average wet weather design flow**	**20.3**	**mg/L**
Q_{s1}	$365Q_{10}$ annual flow of Lake A	120	mgd
Q_{s2}	$365Q_{10}$ annual flow of Reach C + Direct D without WWTF(s)	90	mgd
C_{s1}	Lake A outlet Input concentration based on limits from Mine A and B	9	mg/L
C_{s2}	Reach C + Direct D without WWTF(s)	3	mg/L
$\sum Q_e$	Design flow of Mine C and Town C	5.28	mgd
$\sum C_e$	Long term effluent concentration flow weighted mean of both facilities	572	mg/L
Q_r	Total flow of upstream and effluent (Q_s (Direct D + Reach D) + $\sum Q_e$)	215.28	mgd

Yes → Both facilities have reasonable potential as C_r is greater than the water quality standard (10 mg/L). The flow weighted mean concentration calculated at the 365Q10 flow (C_r = 20.3 mg/L, Table 10) is greater than the sulfate standard (10 mg/L,**).** Move to setting effluent limits for sulfate**.**

4. **Calculate WLA and translate it to an effluent limit.**

4.1 Is the baseline sulfate concentration above the applicable standards?

No → Baseline sulfate (C_s) is 9 mg/L from lake A and 3 mg/L from reach 3 which are both less than the standard (10 mg/L).

4.1b Calculate WLA through watershed analysis.

WLA allocation calculation: use the general mass balance equation for WLAs (Equation 3, reprinted below), reprinted below. Design flow (Q_e) is represented as the sum of both Town C and Mine C. The wasteload allocation concentration (WLA_c) is calculated to be 141.25 mg/L (Table 11, Table 12). This is the flow weighted mean average concentration needed from both facilities. Individual facility WLAs may be different than this value, so long as the sum does not exceed 141.25 mg/L sulfate.

$$WLA_c = \frac{(Std * (Q_s + Q_e)) - (Q_s * C_s)}{Q_e}$$

Table 11. Results of applying Equation 3 to Example 4.

Variable	Description	Value	Unit
Std	Sulfate standard	10	mg/L
$\sum Q_s$	365Q10 annual flow of stream without WWTF(s) • Lake A 120 mgd • Reach C 20 mgd • Direct D 70 mgd	210	mgd
$\sum Q_e$	Design flow of Mine C and Town C	5.28	mgd
C_s Avg.	Flow weighted concentration • Lake A 9 mg/L • Reach C 3 mg/L • Direct D 3 mg/L	6.7	mg/L
WLAc	**WLA concentration needed to meet the sulfate standard**	**141.25**	**mg/L**

Figure 10. Watershed map for use in Example 4.

Figure 10 demonstrates sulfate reductions in Reach A and Lake A, as a result of limits implemented through Example 3 for Mine A and B. Though limits achieve the standard in Reach A and Lake A further downstream in Reach D predicted sulfate is above the standard of 10 mg/L.

Table 12. Sulfate Wasteload allocation calculations in Table 11 broken down between two permittees.

Calculation	Facility	WLA_C (mg/L)	Flow (mgd), Q_e	WLA Mass (kg/d)
Current	Town C	50	0.28	53
	Mine C	600	5	11,335
Adjusted to meet WLAc	Town C	50	0.28	53
	Mine C	146.4	5	2,770
	Total/combined	141.25[a]	5.28	2,823

[a] The Concentration for the WLA was adjusted down until the sulfate mass WLA of 2,823 kg/d was meet. WLAc value (141.25 mg/L) is a gross flow-weighted mean concentration value calculated in Table 11. This value is the product of Town C with a high allowable concentration (50 mg/L) at 0.28 mgd flow and Mine C with a lower allowable concentration (23.8 mg/L) at a much higher flow (5 mgd).

4.2 Convert the WLA to a limit.

Use the LTA to AML calculation to determine the sulfate Limits (see page 20), as well as the sulfate discharge data.

Outcome C: reissue permit with calculated sulfate effluent limits, as provided in Table 13.

Table 13. Results of applying TSD calculation to Example 4.

Acronym	Description	Detail / Equation	Town C	Mine C
WLAcw	Wasteload Allocation concentration weighted	Long term average concentration that complies with WLA weighted	50	146.4
CV	Coefficient of variation	Assuming Log-Normal distribution	0.211	0.081
FM	Frequency of Monitoring	Sampling frequency at facility Sigman (n =2 sampler per month)	2 x month	2 x month
VAR	Sample variance	$\frac{\sum(x-\bar{x})^2}{n-1}$	0.043	0.007
StdDev	Standard Deviation	$\frac{\sum x^2 - \frac{1}{n}(\Sigma x)^2}{n-1}$	0.209	0.081
Z	Z Factor	Statistical uncertainty factor for a 95% probability	1.645	1.645
σ_n	Sigma-n Variability factor for 2 samples per month	$\sigma_n = \ln\left(\frac{CV^2}{2}+1\right)$	0.02	0.003
σ_a	Variability factor for 365-day standard duration (chronic)	$\sigma_a = \ln\left(\frac{CV^2}{365}+1\right)$	0.0001	0.00002
LTA	Long Term Average	$WLA_c * e^{[0.5\sigma_a^2 - z\sigma_a]}$	50.0	146.4
AML mg/L	Average Monthly Limit	$LTA * e^{[z\sigma_n - 0.5\sigma_n^2]}$	64.5	160.9
AML Kg/d	Mass Limit	AML *MDF *3.785	68.4	3044.5

MDF - Town C = 0.28 mgd and Mine C = 5 mgd. These values are the same as variable Q_e, for Equation 3.

Appendix D. Hypothetical Example 5 (High baseline sulfate)

Example 5. Watershed with high baseline concentration and no dilution.

In Example 5 is facilities discharge upstream of a water used for production of wild rice in a watershed (Figure 11) where baseline sulfate is above the standard. In this example, the limits are calculated in a batch (Table 14, Table 15). However, because baseline is above the standard, there is no assimilative capacity or dilution. Each one of these limits could have been calculated independently, at time of reissuance, rather than simultaneously in a batch, and the values of the limits would be identical.

Figure 11. Watershed map for Example 5 (high baseline sulfate).

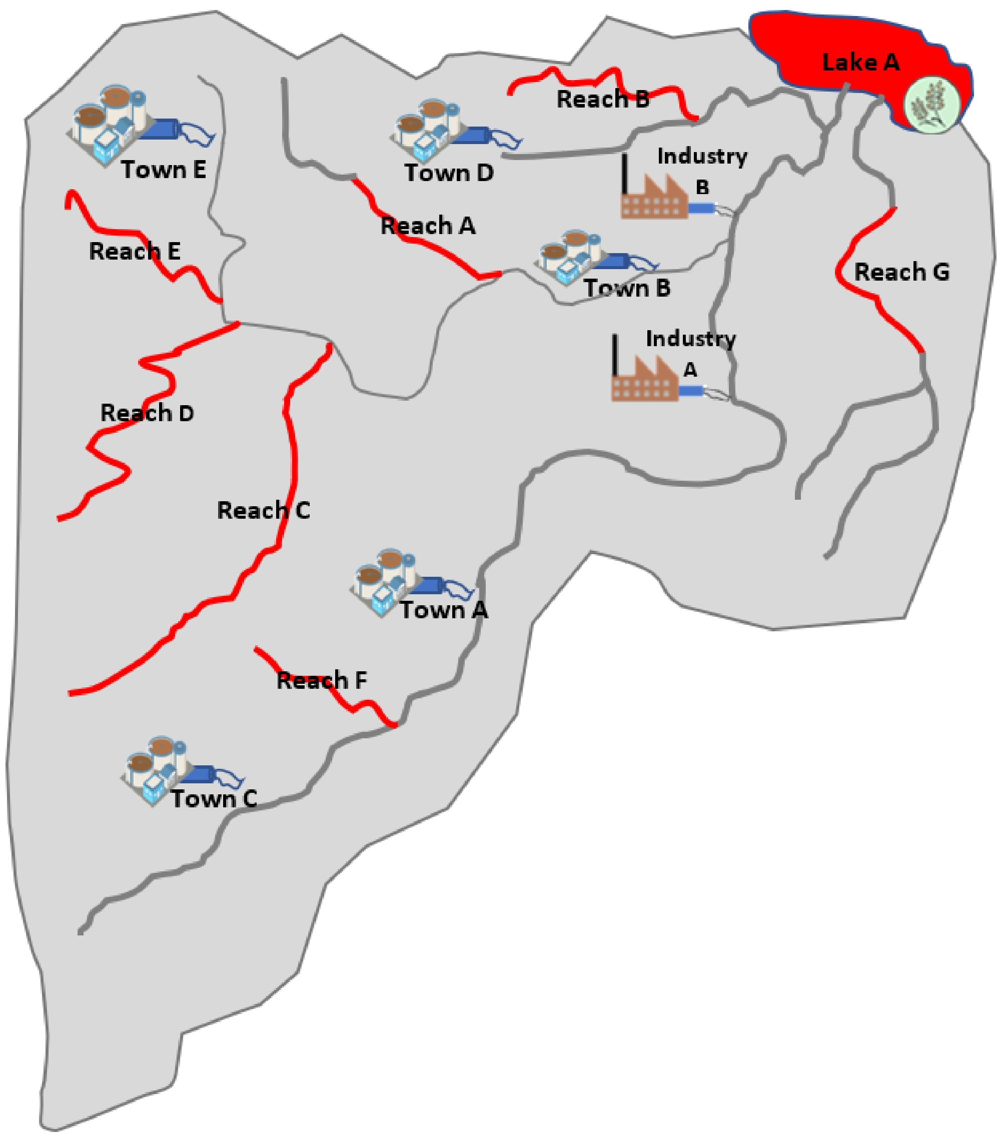


Table 14. Facility information for low baseline sulfate example.

Facility name	Design flow mgd	Critical flow[1] (Q_e)	Mean sulfate mg/L (Ce)	Sulfate count	Std Dev	CV	Sulfate loading kg/yr	Facility type
Town A	0.339	0.2373	-	-	-	-	30,811	WWTF Pond
Town B	0.471	0.3297	269	102	0.39	0.40	71,751	WWTF
Town C	0.185	0.129	-	-	-	-	13,196	WWTF
Town D	0.48	0.336	593	102	0.16	0.16	184	WWTF
Town E	0.033	0.023	-	-	-	-		WWTF Pond
Industry A	1.53	1.53	363	93	0.07	0.07	648,95	Industrial
Industry B	2.44	2.44	515	5	1.2	0.6	25,878	Industrial

Based on 2010-2020 discharge values

[1] 70% AWWDF for municipal WWTFs, MDF for industrial facilities

Table 15. River information low baseline sulfate example.

River reach	Mean sulfate mg/L (Cs)	365Q10 mgd	WWTF Upstream of reach
Reach A	547		None
Reach B	708		None
Reach C	246		None
Reach D	256		None
Reach E	666		None
Reach F	198		None
Reach G	313		None
Lake A	249	202	All

1. **Is there a water used for production of wild rice downstream?**

   Yes → Lake is downstream of all facilities and is listed as a water used for production of wild rice.

2. **Does the facility have sulfate effluent data?**

   Yes → Town B, Town D, Industry A and Industry B**, move on to Step 3**

   No → Town A, Town C, and Town E

   Outcome B: Follow permit writers' monitoring guidance for sulfate.

3. **Reasonable potential determination**

   3a. Is there a boundary condition between the discharge and water used for production of wild rice?

   No → In all cases there is not a boundary condition between the discharges and Lake A.

   3b. Does the facility have reasonable potential?

   Yes →

   a. Is discharge concentration above the sulfate standard (Town B, Town D, Industry A, and Industry B)?

Yes → All facilities with sulfate monitoring discharge over the standard and have sufficient data (Table 14, C_e).

b. Is the projected sulfate concentration at $365Q_{10}$ flow in Lake A above the applicable standard in the water used for production of wild rice of concern when the facility is at design flow (70% of AWWDF for municipals)? This was determined by using the RP calculation mass balance approach using Equation 1, Table 16.

$$C_r = \frac{Q_s C_s + Q_e C_e}{Q_r}$$

Table 16. Reasonable potential calculations for Example 5.

Acronym	Description	Town B	Town D	Industry A	Industry B	Unit
Q_r	Q_S + Q_e total flow in the lake	197.5	197.3	198.5	199.4	mgd
C_r	**Concentration of water at critical flow with wastewater at 70% of average wet weather design flow**	**241.1**	**241.6**	**241.9**	**244.4**	**mg/L**
Q_s	$365Q_{10}$ annual flow of Lake without WWTF(s)	197	197	197	197	mgd
C_s	Concentration of the Lake without wastewater	241	241	241	241	mg/L
Q_e	Critical Design Flow (70% AWWDF or 100% MDF)	0.471	0.336	1.53	2.44	mgd
C_e	Long term effluent concentration to	269	593	363	515	mg/L

Yes → The calculated C_r concentration value (Cr) for each facility is above the sulfate standard (Table 16).
Move on to Step 4.1

c. Is the baseline sulfate concentration above the applicable standard?

Yes → Baseline sulfate concentration is above applicable sulfate standard.
Move on to Step 4.1a

4. Calculate WLA and translate it to an effluent limit.

4.1a Calculate WLA individually:

WLA allocation calculation: use the general mass balance equation for WLAs (Equation 3, Table 17), reprinted below. Design flow (Q_e) is represented the critical design flow (70% AWWDF of the Town WWTFs facilities and 100% of the MDF of the industrial facilities). In situations where the baseline concentration (C_s) is higher than the water quality standard, the baseline concentration used in the equation will be set to the level of the standard, in this case 10 mg/L (Table 17). In the case of Appendix D, Example 5, if C_s in the equation was set at 241 mg/L, the resulting WLA would be a negative value reflecting the total upstream reductions necessary to attain the water quality standard, including reductions from all point and nonpoint sources. This approach, of setting the baseline at the standard, has been used in Minnesota to calculate WQBELs for other water quality parameters for decades.

$$WLA_c = \frac{(Std * (Q_s + Q_e)) - (Q_s * C_s)}{Q_e}$$

Table 17. WLA concentration calculations for Example 5.

Acronym	Description	Town B	Town D	Industry A	Industry B	Unit
WLAc	**WLA concentration needed to meet the sulfate standard**	**10**	**10**	**10**	**10**	**mg/L**
Std	Sulfate standard	10	10	10	10	mg/L
Q_s	$365Q_{10}$ annual flow of Lake without WWTF(s)	197	197	197	197	mgd
Q_e	Critical Design flow	0.471	0.336	1.53	2.44	mgd
$C_{s\ (uncorrected)}$	Estimated concentration of Lake A without WWTF(s)	241	241	241	241	mg/L
$C_{s\ (corrected)}$	Maximum baseline concentration level set at applicable criterion	10	10	10	10	mg/L

Move on to Step 4.2

4.2 Calculate convert WLA to limit:

Use the TSD calculations to determine the final recommended limits for Town B, Town D, Industry A, and Industry B. See Table 18 below.

Table 18. Conversion of WLA to effluent limit for Example 5, as directed by decision tree box 4.2.

Acronym	Description	Detail/Equation	Town B	Town D	Industry A	Industry B
WLA	Wasteload Allocation	Equation 3, Step -4.1a, Table 17	10	10	10	10
CV	Coefficient of variation	Assuming Log-Normal distribution	0.4	0.16	0.07	0.6
FM	Frequency of Monitoring	At least five data points or a similarly representative number	2x Month	2x Month	2x Month	2x Month
VAR	Sample variance	$\frac{\sum(x-\bar{x})^2}{n-1}$	0.151	0.024	0.005	1.6
StdDev	Standard Deviation	$\frac{\sum x^2 - \frac{1}{n}(\Sigma x)^2}{n-1}$	0.388	0.156	0.070	1.250
Z	Z Factor	Statistical uncertainty factor for a 95% probability	1.645	1.645	1.645	1.645
σ_n	Variability factor for 2 samples per month	$\sigma_n = \ln\left(\frac{CV^2}{2}+1\right)$	0.078	0.012	0.024	0.166
σ_a	Variability factor for 365-day standard duration (chronic)	$\sigma_a = \ln\left(\frac{CV^2}{365}+1\right)$	0.0004	0.0007	0.00001	0.001
LTA mg/L	Long Term Average	$WLA_c * e^{[0.5\sigma_a^2 - z\sigma_a]}$	10.0	10.0	10.0	9.8
Q_e	Critical Design flow	See Table 17 above (mgd)	0.471	0.336	1.53	2.44
AML mg/L	Average Monthly Limit	$LTA * e^{[z\sigma_n - 0.5\sigma_n^2]}$	15.8	12.0	10.8	19.2
AML kg/d	Mass Limit	AML *MDF[1] *3.785	28.7	21.4	62.8	177.5

[1] MDF is equivalent to Q_e

Appendix E. Water used for production of wild rice watersheds with large numbers of upstream WWTFs

There is a wide range in number of SD stations upstream of a given water used for production of wild rice in Minnesota. Figure 4 shows all SD stations upstream of at least one water used for production of wild rice. The number of SD stations upstream of a given water used for production of wild rice ranges from one to about 578. Two reaches of the Mississippi River both have over 500 upstream SD stations (Figure 12). The next largest count of upstream SD stations for a water used for production of wild rice is 53. Waters used for production of wild rice with high numbers of upstream dischargers and within high sulfate concentration ecoregions pose challenges for limit setting. For instance, the two Mississippi River reaches with over 500 upstream SD stations appear to have a baseline sulfate concentration that exceeds 10 mg/L. Thus, no dilution is available to offset the potential sulfate effluent limits of the many upstream facilities. This situation may result in considerable costs for permittees and necessitate the pursuit of variances for them. Compliance with limits by all 500 upstream facilities will not result in the Mississippi River achieving 10 mg/L sulfate, due to the very high baseline sulfate concentration of the Minnesota River and other tributaries. Initial estimates project a reduction from 35 mg/L to 27 mg/L sulfate in the Mississippi River near Winona if all upstream wastewater contributions were totally removed.

Figure 12. Counts of upstream SD stations for waters used for production of wild rice with at least 10 upstream SD stations.