Book 2

Eutrophication Standards for Streams, Rivers, Lake Pepin, and Navigational Pools

Table of Contents

wq-rule4-06f

Table of Figures

Tables

1. Introduction

Nutrient over-enrichment of surface waters, often referred to as eutrophication, is a major water quality problem nationwide and Minnesota is no exception (Exhibit EU-13). Excess nutrients, specifically phosphorus (P) and nitrogen (N), stimulate excessive growth of aquatic plants, including suspended and attached algae and rooted plants. Excessive plant growth affects aquatic recreational and aquatic life uses in lakes, rivers, wetlands, and estuaries. The United States Environmental Protection Agency (EPA) has recognized this and has required the states to develop numeric Water Quality Standards (WQS) to protect surface waters from the effects of excess nutrients.

The development of river eutrophication standards is part of a long-term effort by the states and the EPA to develop eutrophication standards for lakes, rivers, wetlands, and estuaries. For Minnesota this marks the second step in this process, as lake eutrophication WQS were promulgated in the Chapter 7050 rule revision finalized in 2008 (Exhibit EU-31). In Book II of the SONAR developed for that rulemaking the Minnesota Pollution Control Agency (MPCA) provided the details and reasoning used in development of the lake eutrophication standards. The monitoring and research described in that Statement of Need and Reasonableness (SONAR) led to the development of ecoregion-based lake eutrophication standards that employ a causative variable, Total Phosphorus (TP), and two response variables: chlorophyll-a (Chl-a) and Secchi transparency. These standards have been successfully employed in Clean Water Act (CWA) 303(d) assessments, the establishment of National Pollutant Discharge Elimination System (NPDES) permit effluent limits, and provide a sound basis for Total Maximum Daily Load (TMDL) development. The logic and approach that underlay the lake eutrophication standards helps inform the proposed river eutrophication and site-specific WQS for Lake Pepin and Mississippi River navigational pools addressed in the current rulemaking.

Rivers are essential to life in Minnesota and elsewhere in the world. Rivers are used for a wide variety of purposes: drinking water, aquatic community support, aquatic recreation, industrial and agricultural uses, and navigation, including supporting commerce. These uses require good quality water to ensure the use is realized. For example, for drinking water uses, good water quality often implies that only minimal treatment of the water is required to meet that use, in contrast to polluted water that may require extensive and expensive treatment.

Nutrients are naturally a part of aquatic ecosystem functions, but excess nutrients can lead to detrimental effects on aquatic biota (Miltner and Rankin 1998) and other intended uses of the water. Nutrients come from a variety of sources including natural and anthropogenic sources (manmade). Anthropogenic sources include point and nonpoint nutrient sources such as animal wastes, fertilizers, landfills, stormwater, municipal wastewater treatment facility effluent, and industrial wastewater treatment facility effluents (Carpenter et al. 1998). Various activities in a watershed can increase the transport of anthropogenically derived nutrients into streams and rivers (e.g., agricultural activities, development of impervious surfaces, and removal of vegetation). Although a number of nutrients are required for aquatic plant growth (e.g., sulfur, iron, silicon), phosphorus and nitrogen are generally given the most emphasis, as these tend to be limiting nutrients in surface water ecosystems.

Excess nutrients can affect the various uses either directly, e.g. nitrate-nitrogen (N) toxicity to aquatic life, or indirectly, e.g. excessive suspended or attached algal growth that may affect the above uses. In some instances the impact on aquatic recreation and aquatic life uses are self-evident (Figure 1). Since rivers are often a primary source of water to downstream lakes and reservoirs, excessive nutrients transported by the rivers can also contribute to impairments in downstream water bodies. The proposed river eutrophication WQSs are intended to protect aquatic life and aquatic recreational uses of rivers and downstream water bodies. The Mississippi River navigational pools and Lake Pepin share all of the above uses; however, certain uses, including navigation and aquatic recreation use are of particular importance. Aquatic recreation use is the primary emphasis of eutrophication standard development for these two water body types.

Figure 1. Examples of severe blue-green algae (Cyanobacteria) blooms on rivers that contribute to aesthetic, recreational use, and aquatic life impairment. a) Blue Earth River MN July 8, 2002, b) Watonwan River July 25, 2007, c) Pipestone Creek August 5, 2008, d) Minnesota River September 2005.

This book addresses the specific need and reasonableness of proposed eutrophication WQS for rivers and streams, Mississippi River navigational pools and Lake Pepin site-specific eutrophication WQS and also the proposed minor amendment to Minn. R. 7053.0205 to address discharges of total phosphorus in relation to the proposed eutrophication standards. This book also addresses certain requirements of the Administrative Procedures Act (APA) as they specifically relate to the development of the proposed eutrophication standards and economic factors associated with implementing the proposed standards. The discussion provided in this book augments the more general discussion provided in Book 1 of the need and reasonableness of the proposed rule amendments and how the MPCA has generally met the requirements of the APA.

The eutrophication WQS the MPCA is proposing are Class 2, aquatic life, and recreation-based standards. This means the proposed standards are designed to protect rivers for a healthy aquatic community and for aquatic recreation of all kinds, including swimming. While not specifically set in order to protect aesthetic uses, the eutrophication standards will provide improvements in aesthetics. Moreover, as aesthetic qualities are very closely tied to recreational uses when it comes to the trophic condition of lakes and rivers, these uses are closely linked. For example, a river with floating mats of blue-green algae or an extensive blanket of attached algae is unacceptable both recreationally and aesthetically. Aesthetics are specifically addressed under use Class 5, rather than Class 2, and all surface waters are protected for Class 5 uses (Minn. R. 7050.0410 and 7050.0430). The EPA repeatedly emphasizes the importance of states developing nutrient standards that best fit the resources and nutrient source issues in their state. The EPA intends for states to use the national water quality criteria documents (referred to as Ambient Water Quality Criteria or AWQC) for nutrients as guidance in the development of their own proposed nutrient standards (Exhibits EU-11, EU-12, and EU-13). The EPA provides states considerable flexibility, and specifically, the EPA recommended the following three options, in order of preference as guidance to the states (e.g. Exhibit EU-10):

1. Develop nutrient criteria that fully reflect local conditions and protect specific designated beneficial uses, using processes described in EPA's technical guidance. Nutrient standards the states adopt can be either numeric (as proposed by the MPCA) or procedures to translate a narrative standard into a quantitative endpoint.

2. Adopt EPA's Section 304(a) AWQC, either as numeric standards or as procedures to translate a narrative standard into a quantitative endpoint.

3. Develop nutrient criteria protective of designated beneficial uses, using other scientifically defensible methods and appropriate water quality data.

The MPCA used a combination of EPA's options one and three listed above to develop the proposed narrative and numeric river eutrophication WQS (Exhibit EU-1). The numeric standards (Table 1) are the result of a rigorous scientific process that considered multiple lines of evidence as recommended by the EPA. The MPCA's proposed eutrophication standards reflect:

- Localized conditions in Minnesota, including the diversity within the state (created "River Nutrient Regions" using EPA's aggregated Level III ecoregions as a starting point)

- Levels of TP, sestonic Chl-a, and Biological Oxygen Demand (BOD_5) designed to protect a range of designated Class 2 beneficial uses (with a focus on aquatic life uses) and

- Scientifically defensible methods and a very robust and multifaceted Minnesota water quality database upon which, the proposed numeric standards are based

Table 1. Draft river eutrophication standards ranges by River Nutrient Region for Minnesota.

	Nutrient		Stressor	
Region	**TP µg/L**	**Chl-a µg/L**	**DO flux mg/L**	**BOD_5 mg/L**
North	≤50	≤7	≤3.0	≤1.5
Central	≤100	≤18	≤3.5	≤2.0
South	≤150	≤35	≤4.5	≤3.0

As noted above, site-specific eutrophication standards are also being proposed for Lake Pepin and the Mississippi River navigational pools. The Mississippi River navigational pool system in Minnesota runs from Pool 1 near St. Anthony Falls in the northwestern portion of the Twin Cities Metropolitan Area to Pool 8 at the Minnesota, Wisconsin, and Iowa border. These pools have been called out separate from rivers as they are waterbodies formed behind dams, have a maintained navigation channel and depth, cross-section, and water flow-through characteristics differ from that of natural rivers or reservoirs. The SONAR draws heavily from three technical documents: Exhibits EU-1 (rivers), EU-6 (Lake Pepin), and EU-7 (navigational pools). The proposed eutrophication standards for the navigational pools are interrelated, as will be demonstrated. The proposed eutrophication standards for rivers and streams and Mississippi River navigational pools are considered "new" while the site specific WQS for Lake Pepin was developed as a part of the nutrient-impairment study (TMDL) that is underway on the lake. Site -specific WQSs for reservoirs (or lakes with reservoir-like characteristics) are developed consistent with Minn. R. 7050.0222 (Exhibit EU-31).

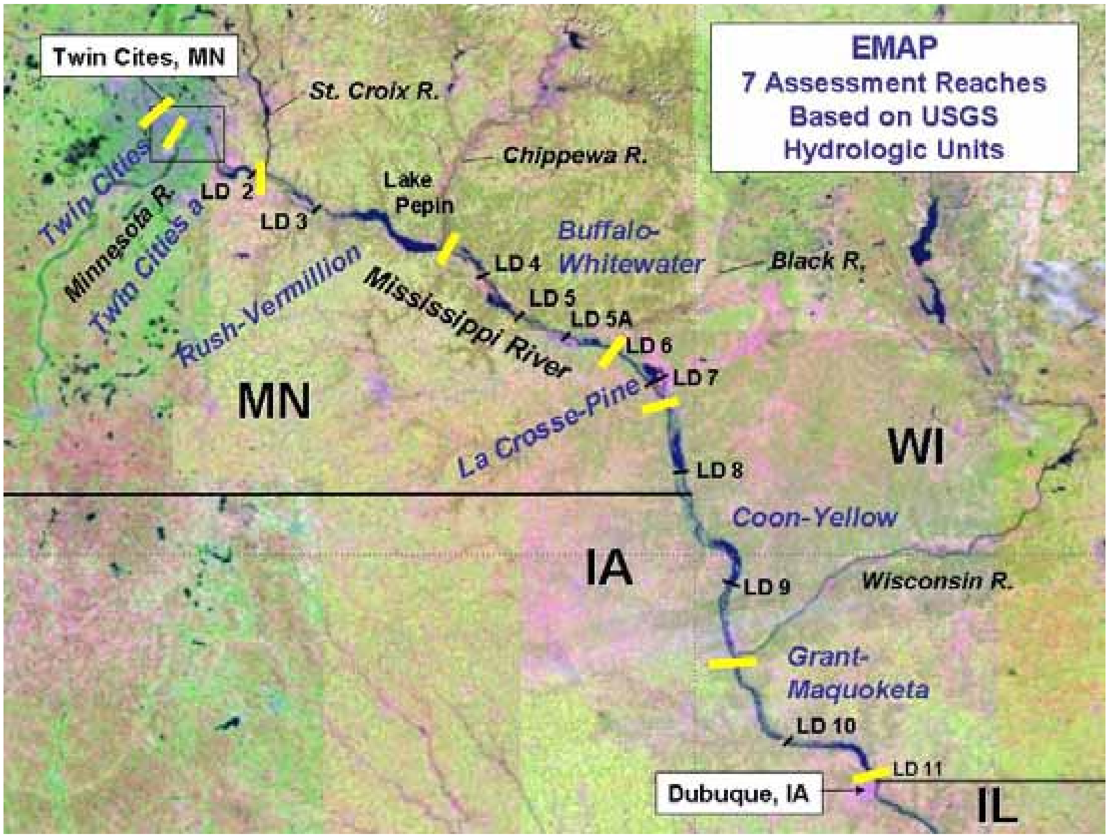


Figure 2. Mississippi River navigational pool system for Lock and Dam 1-11. Lake Pepin occupies most of Pool 4.

The proposed site-specific standards for the navigational pools and Lake Pepin are based on a similar scientific rigor as the river eutrophication standards for the rest of Minnesota, and the details on their derivation may be found in the Technical Support Documents (TSD) (Exhibits EU-6 & 7). In the case of Lake Pepin, these proposed standards reflect years of work, application of model results, feedback from the Lake Pepin TMDL Science Advisory Panel, and consideration of the state of Wisconsin has promulgated eutrophication standards. An important feature of the river, pool, and Pepin standards is interconnectedness of the three waterbody types and need for standards to be supportive and protective of downstream uses (Table 2), which is consistent with the EPA recommendations.

Table 2. Draft eutrophication standards for main-stem rivers, Mississippi River navigational pools, and Lake Pepin. Concentrations expressed as summer averages.

River/Pool	Site	Data source	TP µg/L	Chl-a µg/L
Rivers				
Miss. @Anoka[1]	UM-872	MCES	≤100	≤18
Lake St. Croix[3]	SC-0.3	MCES	≤40	≤14
Minn. @Jordan[1]	MI-39	MCES	≤150	≤35
Pools & Pepin				
Pool 1[2]	UM-847	MCES	≤100	≤35
Pool 2[4]	UM-815	MCES	≤125	≤35
Pool 3[4]	UM-796	MCES	≤100	≤35
Pepin (Pool 4)[5]	4 fixed sites	LTRMP	≤100	≤28
Pools 5-8[6]	Near-dam	LTRMP	≤100	≤35

[1] River eutrophication criteria-based. Based on modeling Upper Mississippi (UM)-872 and Minnesota River (MI) 3.5 criteria will meet Pepin requirements.

[2] Minimize frequency of severe blooms. Upstream criteria provide additional protection for Pool 1.

[3] MN lake eutrophication criteria-based. Based on modeling St. Croix outlet (SC-0.3) would meet Pepin requirements.

[4] Minimize frequency of severe blooms and meet Pepin requirements

[5] TP is consistent with WI standard. Pepin criteria assessed based on lake-wide mean from four monitoring sites.

[6] Minimize frequency of severe blooms; upstream P requirements benefit lower pools. Assumes WI standard of 100 µg/L applies to Pools 5-8

2. Background

A. Eutrophication and River Science

While nutrients are essential to aquatic ecosystems, excessive amounts can have deleterious effects on rivers and streams. The impact of nutrients on aquatic ecosystems and biota through food web alterations depend on a number of factors. For example, turbidity, shading, and water body depth can decrease the impact of nutrients on aquatic systems. In addition, different segments of food webs (*e.g.,* benthos versus seston) may be affected in different habitat types. As a result, the type of habitat (*e.g.,* large versus small rivers) has an impact on how nutrients influence water quality and biological condition in rivers. In large to medium sized rivers, nutrient loading can result in increased production of phytoplankton (measured as sestonic chlorophyll) and microbes. Three important factors that can limit or promote algal growth in medium to large rivers are nutrients, temperature, and light. In these systems, impact of nutrients is moderated by light and residence time (Figure 1). The amount of light reaching aquatic plants can be decreased by shading, turbidity, and depth (Smith et al. 1999 in Exhibit EU-1) with turbidity probably having a larger impact in large to medium rivers. Vertical mixing may also have an impact on light availability, particularly behind impoundments, by moving algae from deeper portions into the euphotic zone. Residence time or flushing rate also affects sestonic chlorophyll where low residence time will cause algae to be transported downstream at a higher rate (Van Nieuwenhuyse & Jones 1996 in Exhibit EU-1). Provided with sufficient light, temperature, and residence time, nutrient loading can cause changes in the food web base by altering growth rate and composition of the planktonic algal community. However, even if these factors are not sufficient to create problematic algal blooms, nutrient enrichment can result in increased microbial production and/or the transport of nutrients downstream to river reaches where the sufficient conditions exist for unwanted algal blooms to occur.

In small rivers, nutrient loading can result in an increase in benthic algae or periphyton (measured as benthic chlorophyll). Benthic algae are those that attach to rocks and other substrates in the river. As in large to medium rivers, temperature, and light are important determinants of algal growth, while turbidity and shading have a moderating effect on the impact of light (Figure 4). Benthic algal production can also be affected by scouring (Lohman *et al.,* 1992 in Exhibit EU-1) and substrate. Sufficient substrate is needed for growth of benthic algae, but this is moderated by scouring. For example, coarse substrates such as bedrock, cobble, and large woody debris provide a stable substrate that allows some forms of benthic algae to be more resistant to scouring. In contrast, fine substrates such as silt and sand are easily scoured (i.e. transported downstream), which will mobilize benthic algae and reduce measurable benthic chlorophyll. As with large and medium rivers, in small rivers if the conditions do not exist for increased algal growth (*e.g.,* if growth is limited by heavy shading or high scouring), nutrients will likely be transported downstream to areas where optimal conditions do exist for high algal productivity.

Regardless of the size of river, once increased algal (sestonic or benthic) and microbial growth occurs, a number of stressors can adversely affect biological condition and recreation quality (Figure 3). A common and severe stress resulting from nutrient enrichment is a change in Dissolved Oxygen (DO) levels in a system. This is often manifested as low DO levels, which can reduce or eliminate populations of aquatic species that do not tolerate low DO. However, DO levels are often more complicated, as enrichment tends to increase DO flux (also referred to as diel range or daily DO range), measured as the difference between the daily high and low values. Enrichment increases the amount of primary productivity in a system which can result in greater levels of DO during daylight hours when algal and plant photosynthesis (oxygen production) is occurring (Exhibit EU-14). Increased nutrients also increase respiration (consumption of oxygen) by algae, plants, microbes, and animals due to greater biomass in the system, which results in greater biological oxygen demand (BOD). This condition is exacerbated at night when photosynthesis is not occurring and respiration by plants, animals, and microbes is occurring (Hynes 1966 in Exhibit EU-1). Decomposition of the increased numbers of algae and plants can also increase the amount of respiration. Increased diel DO range can cause very high DO during the day and very low levels of DO during the night. Not only do low levels of DO cause stress, but the wide diel fluctuation in DO can also stress aquatic organisms (Exhibit EU-1). Low levels of DO can stress aquatic animals and increase availability of toxic substances such as ammonia and hydrogen sulfide (Exhibit EU-14). An additional affect can be fluctuations in pH, which can lead to increases in ammonium hydroxide or toxic metals (Exhibit EU-14).

As a whole, increases in stressors (*e.g.*, low DO, large swings in DO) and changes to food resources and habitat due to increased nutrient loading can have a number of negative impacts on aquatic life and recreation. Increased nutrient loading and subsequent stressors usually result in a loss in species richness and diversity (Carpenter *et al.* 1998, Correll 1998; in Exhibit EU-1). Reductions in DO or increases in DO flux can lead to a shift in a community to organisms more tolerant of low DO. In general, this leads to a reduction or loss of stoneflies, mayflies, caddisflies, walleye, and other sensitive fish species. In addition, there is often an increase in flies, true bugs, and beetles including a number of less desirable forms, such as aquatic worms, larval midges, mosquitoes, moth flies, snails, bullhead, and carp. Broadly these shifts can lead to losses of sensitive, carnivorous, and insectivorous species and an increase in tolerant and generalist (*e.g.,* omnivorous) species (Miltner and Rankin 1998 in Exhibit EU-1). Low DO can also result in fish kills (Correll 1998 in Exhibit EU-1). There is also a positive relationship between nutrient enrichment, bacterial growth, and macroinvertebrate mortality (Lemly 2000; in Exhibit EU-1). This suggests that increased microbial production could increase infection and disease in fish and invertebrates. Nutrient loading and large amounts of algae or macrophytes can also impair recreation quality in rivers (Exhibit EU-14; *e.g.,* swimming, water sports, and fishing). For example, fishing may be harmed by reduced/altered fisheries (*e.g.,* fish kills, reduced numbers of top carnivores, loss of desirable fish species) or by fouling of lines by heavy benthic algal growth.

The conceptual models for medium to large rivers (Figure 3) and small streams (Figure 4) help demonstrate the impact of nutrients on flowing waters. They are also useful for conveying the MPCA's approach to study development and eutrophication standards development. Further details on both are provided in the Reasonableness section of the SONAR.

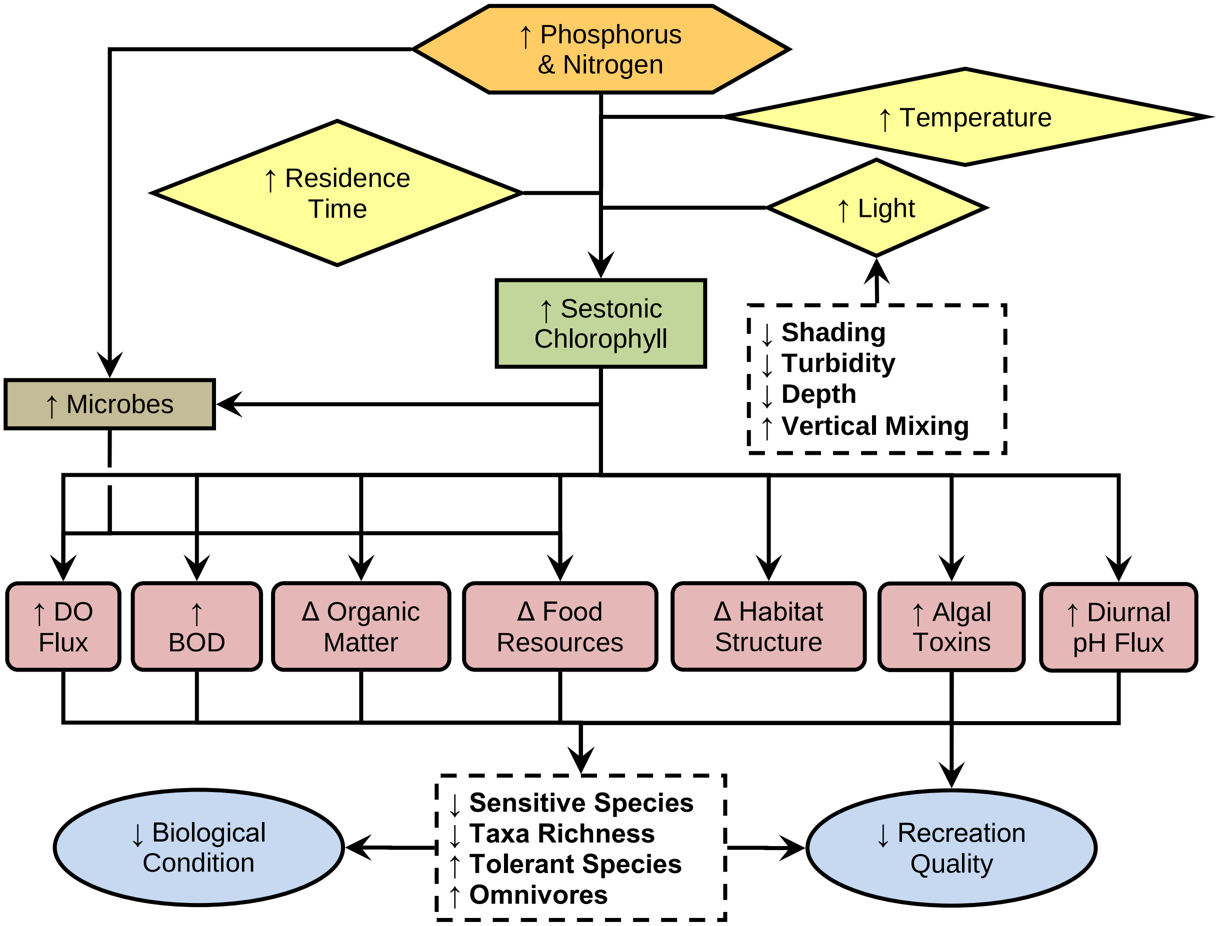


Figure 3. Conceptual model of the impact of nutrient enrichment on biological condition and recreational quality for medium to large rivers.

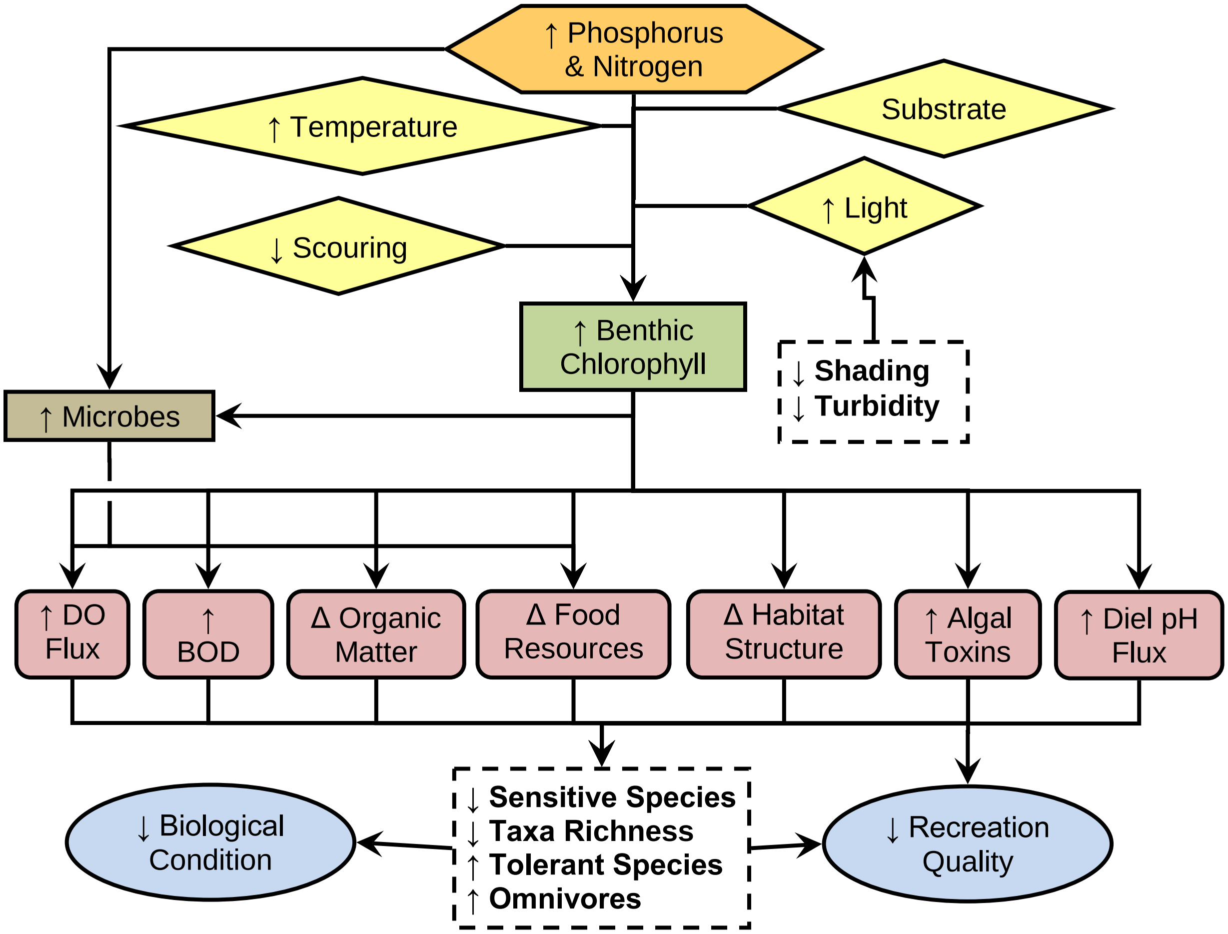


Figure 4. Conceptual model of the impact of nutrient enrichment on biological condition and recreational quality for small rivers.

B. River Eutrophication Standards: A Brief History

The development of river eutrophication standards is part of a long-term effort by the states and United States Environmental Protection Agency (EPA) to develop eutrophication standards for lakes, rivers, wetlands, and estuaries. For Minnesota, this current effort marks the next step in this process, as lake eutrophication WQS were promulgated in the last triennial review, finalized in 2008. In Book II of the SONAR developed for that rulemaking the MPCA provided the details and reasoning used in development of the lake eutrophication standards. The monitoring and research described in that SONAR led to the development of ecoregion-based lake eutrophication standards that employ a causative variable, total phosphorus (TP), and two response variables: Chl-a and Secchi transparency. These standards have been successfully employed in Clean Water Act (CWA) 303(d) assessments, the establishment of NPDES permit effluent limits, and are providing a sound basis for total maximum daily load (TMDL) development. The logic and monitoring that underlay the lake eutrophication standards also informed the proposed site-specific WQS for Lake Pepin and other Mississippi River pools.

As noted, the proposed river eutrophication standards are a part of a long-term process for addressing eutrophication of Minnesota's surface water resources (Exhibit EU-8). MPCA data collection in support of river eutrophication standards development was initiated in 1999 with the aid of nutrient criteria grants from the EPA Region 5. This early work focused primarily on medium to high order rivers. Findings from this work and subsequent grants were published in several MPCA reports to the EPA e.g. Heiskary and Markus 2003 (Exhibit EU-2) and Heiskary 2008 (Exhibit EU-3) and a journal article Heiskary and Markus 2001 (Exhibit EU-4). Subsequent work included data from low order streams, as well (Exhibit EU-1). Collectively, these ten years of study on Minnesota rivers and streams allowed for identification of interrelationships among nutrients, sestonic Chl-a, BOD_5, dissolved oxygen flux and fish and invertebrate metrics as depicted in Figure 3 and Figure **4**. This allowed for development of proposed river eutrophication standards that employ causative (TP) and response variables (sestonic Chl-a, BOD_5, DO flux and pH) that can be used to assess river eutrophication status and protect aquatic life and recreation uses. This provides a parallel approach (for rivers) to the approach that has been successfully used to assess lakes for eutrophication impacts, develop TMDLs, and protect lake uses.

Development of proposed eutrophication standards for the Mississippi River navigational pools and Lake Pepin are somewhat, more recent efforts. Lake Pepin was included on Minnesota's 303(d) impaired waters list in 2004, based on numeric translators of the narrative nutrient standard in Minnesota Rules 7050.0150. The Lake Pepin excess nutrient TMDL was initiated in 2005 and discussion of the need for site-specific numeric standards for the lake was initiated at that time[1]. Ranges of TP and response variables were proposed and discussed at Pepin Science Advisory Panel (SAP) meetings from late 2005 through early 2010. The more recent proposals benefited from completion of a mechanistic model that allowed for simulation of various reduction scenarios (Limno Tech [LTI] 2008) and various related research conducted in support of the TMDL. Details on the development and basis of the proposed Lake Pepin site-specific standards may be found in Heiskary and Wasley (2011; Exhibit EU-6).

As work on this complex system progressed it became evident to the MPCA and the Lake Pepin TMDL SAP that site-specific standards for Pepin needed to be linked with new numeric WQS for the Mississippi River navigation pools, and the major rivers that drive the water quality of Lake Pepin and the pools: Upper Mississippi, Minnesota, and St. Croix Rivers. As a result, the SAP recommended the MPCA move forward with an analysis of data for this overall system with the intent of developing eutrophication WQSs for the rivers, pools, and Lake Pepin. A comprehensive analysis of existing data for the pools and application of the LTI Upper Mississippi River–Lake Pepin mechanistic model allowed for development of new pool-specific criteria as described in Heiskary and Wasley (2010; Exhibit EU-7).

C. River Eutrophication Standards: A Regional Approach

Dividing the nation geographically into zones with similar geological and ecological characteristics called ecoregions is fundamental to the development of the EPA's nutrient AWQC and the MPCA's proposed eutrophication standards. Lake and river characteristics reflect the ecoregion in which they are located. Ecoregions have been mapped by the EPA for the lower 48 states based on overlaying maps of landform, soil type, land use, and potential natural vegetation. Ecoregions are areas where these features and surface water

---

[1] MPCA reports and TSDs used as the foundation for the proposed eutrophication water quality standards specific to the Mississippi River pools and Lake Pepin describe the numeric concentrations for total phosphorus (TP) and response variables as "criteria." As discussed fully in Book 1, prior to adopting narrative statements and numeric standards into rule the term "criteria" reflects the EPA usage as defining the scientific basis and evaluation of data for future water quality standards. In the context of the SONAR for consistency with the terminology in Minn. R. ch. 7050, "criteria" are now described as "proposed water quality standards" or "numeric standards." The TP and chlorophyll-a concentrations being proposed for Lake Pepin are site-specific modifications of the Class 2B Eutrophication standards for lakes, shallow lakes, and reservoirs as authorized in 7050.0222, subp. 4a.

resources are similar. The MPCA added a definition for ecoregions in Minn. R. ch. 7050 in the 2003 rulemaking as follows:

[Minn. R. 7050.0150, subp. 4] *Ecoregion means an area of relative homogeneity in ecological systems based on similar soils, land use, land surface form, and potential natural vegetation.*

The seven Level III ecoregions (Figure 5) that characterize Minnesota's landscapes are:

- 46 **Northern Glaciated Plains (NGP) and** 47 **Western Corn Belt Plains (WCBP)** Corn belt and northern great plains. Rolling plains dominated by moist fertile soils and highly productive cropland
- 48 **Lake Agassiz Plain (LAP)** This region was previously referred to as the Red River Valley ecoregion and lies in the former lake bed of glacial Lake Agassiz.
- 51 **North Central Hardwood Forest (NCHF) and Central Hardwood Forest (CHF).** Mostly glaciated dairy region. Rolling till plains and hills, largely forested, dairy and livestock farming
- 52 **Driftless Area (DA)** Also referred to as "Paleozoic Plateau," this region is in the un-glaciated portion of southeast Minnesota and southwest Wisconsin.
- 50 **Northern Lakes and Forest (NLF)** Nutrient poor largely glaciated upper Midwest and northeast Extensively forested, nutrient-poor soils, cool and moist, limited cropland, short growing season.
- 49 **Northern Minnesota Wetlands (NMW)** Low gradient region dominated by vast wetlands and related forests.

Ecoregions are the framework of choice for developing nutrient criteria as per the EPA technical guidance (Exhibit EU-9). The EPA national nutrient criteria recommendations were developed for 14 "aggregate" ecoregions and those relevant to Minnesota are found in three documents, Exhibits EU-10,-11 and -12. The EPA aggregate ecoregions include one or more "sub-ecoregions," called level III ecoregions. The aggregate ecoregions (Figure 5) and level III ecoregions included in each are:

- **Nutrient ecoregion VI**: Corn belt and northern glaciated plains includes WCBP, NGP, and LAP level III ecoregions
- **Nutrient ecoregion VII**: Mostly glaciated dairy region includes CHF and DA level III ecoregions
- **Nutrient ecoregion VIII**: Nutrient poor largely glaciated upper Midwest and northeast includes NLF and NMW level III ecoregions

As with lakes, there are relatively distinct differences in river water quality in Minnesota among the various ecoregions. Between-region differences in land use, soil characteristics, and geomorphology influence water runoff, nutrient loading, and processing of nutrients in the rivers (Exhibit EU-14). The MPCA has previously described ecoregion-based differences in stream water quality based on representative, minimally impacted streams (McCollor and Heiskary 1993; Exhibit EU-30). Likewise, the EPA has compiled distributions of water quality variables by ecoregion as a part of their "Ambient Water Quality Criteria Recommendations" (e.g., Exhibit EU-10).

Because of the EPA's recommendation to consider regionalization of standards (Exhibit EU-14), distinct regional water quality patterns in Minnesota's rivers (Exhibits EU-11,-12,-13, and-30), and Minnesota's regional approach for applying the lake eutrophication standards the MPCA pursued a regional approach when developing river eutrophication standards. The MPCA's data analysis in support of river eutrophication standards development (Exhibits EU-1, 2 and 3) determined that three regions would provide an appropriate framework for developing and applying river eutrophication standards. We refer to these as River Nutrient Regions (RNR): North, Central, and South and they correspond loosely to the EPA aggregated Level III Nutrient ecoregions with aggregations as follows (Figure 6):

- North – NLF and NMW ecoregions
- Central – CHF and DA ecoregions and
- South – WCBP, NGP, and LAP ecoregions

River-watersheds at the eight digit Hydrologic Unit Code (HUC) level (watersheds on the order of 600-1,400 mi^2) were selected as a primary basis to develop this framework (Heiskary and Parson 2010; Exhibit EU-5). These 81 watersheds, as derived from the Minnesota Department of Natural Resource's (MDNR) major watershed layer, are also a focus of the MPCA's "pour-point" intensive watershed monitoring program and are most similar to rivers from our river nutrient studies. When an eight-digit HUC (HUC-8) is located completely within a RNR or where a vast majority of the watershed is within a single RNR the assignment to that RNR is rather straightforward, (*e.g*. North Fork Crow with 96 percent of its watershed in CHF or South Fork of the Crow River with 75 percent of its watershed in the WCBP). However, when a HUC-8 includes multiple ecoregions the appropriate designation may be less apparent. In these cases, closer inspection was required and HUC-11 (watersheds ~ 30-130 mi^2) maps were incorporated into the mapping coverage to allow for refinement of boundaries. Further details on the mapping approach and a detailed listing of rivers and ecoregion assignments may be found in Heiskary and Parson (2010; Exhibit EU-5).

Minnesota's regional approach is consistent with EPA recommendations as laid out in Exhibits EU-10, -11, and -12, as well as, guidance provided in Exhibit EU-14. Further, EPA's use of "Nutrient Watershed Regions" in the EPA-promulgated rules for Florida's rivers further re-affirms the need to regionalize criteria to "fully reflect local conditions" (Exhibit EU-19a).

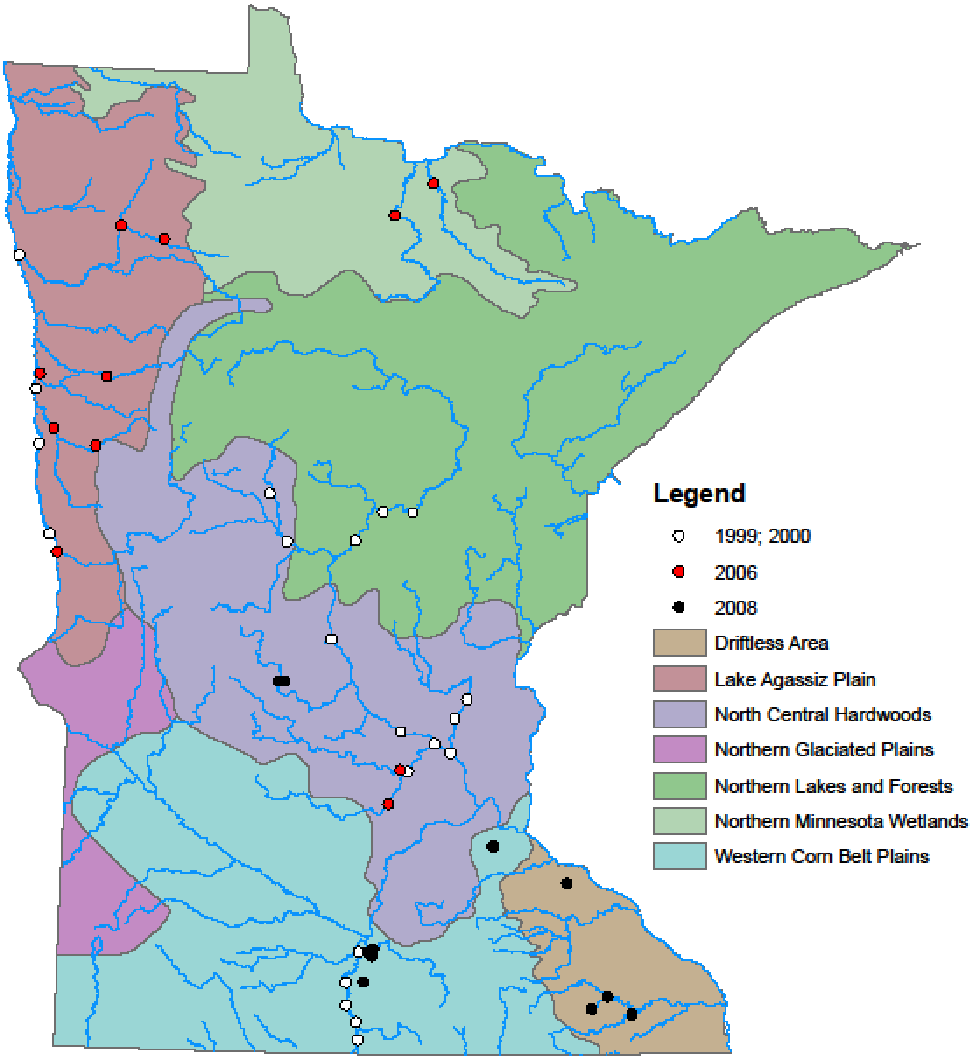


Figure 5. USEPA Level III ecoregions and MPCA River Nutrient Study sites noted. Tables 3 and 4 list river names and site location.

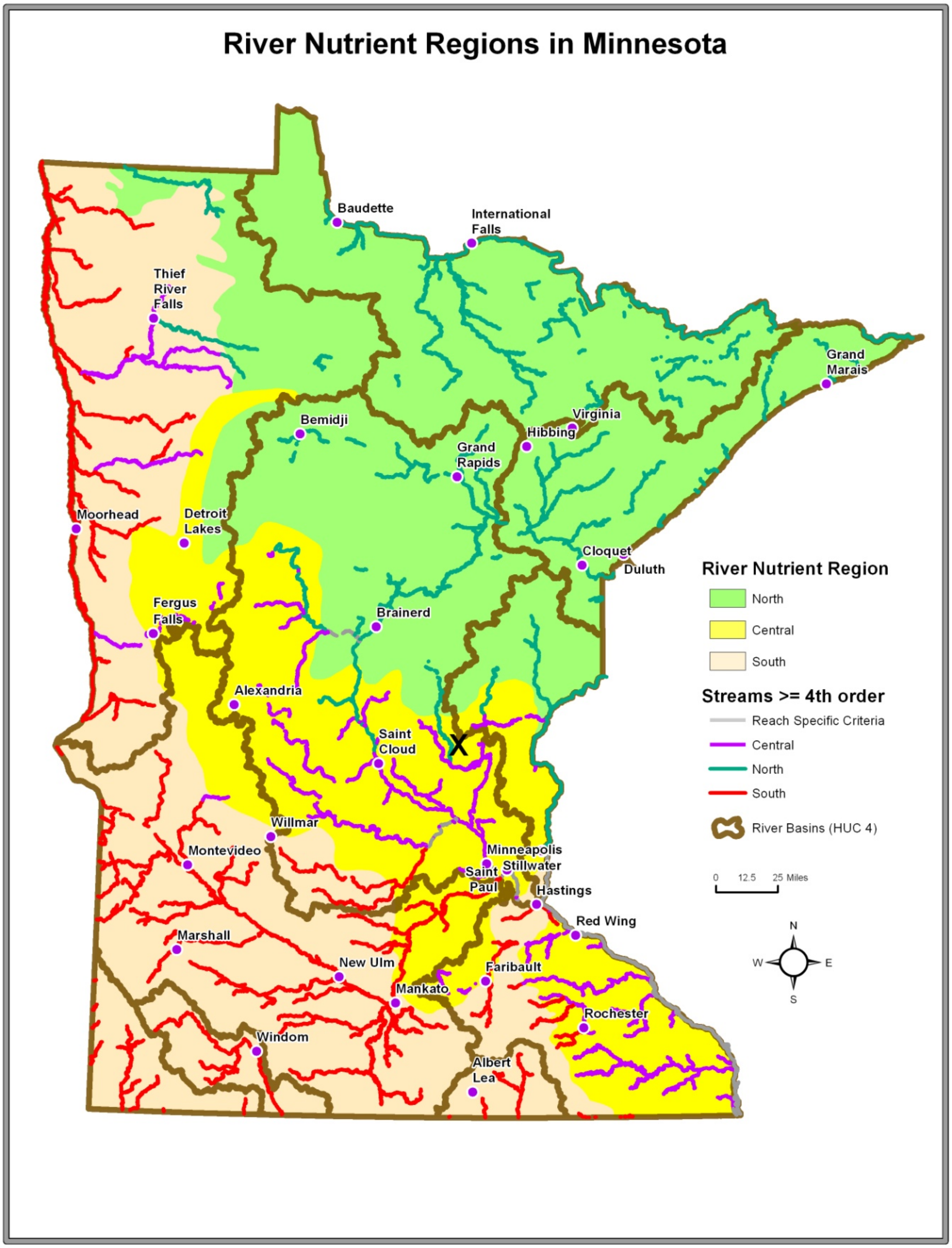


Figure 6. River nutrient region map for Minnesota. Level III ecoregion boundaries and 4th order and higher rivers noted. Rivers are color-coded by RNR.

3. Need for the Proposed Eutrophication Standards

A. Introduction

The EPA has called on states to develop nutrient (eutrophication) standards for lakes, rivers, wetlands, and estuaries. States that have not heeded this directive have found themselves the subject of lawsuits from parties interested in protecting the Nation's surface waters from nutrient over-enrichment. Florida is the most prominent case in this regard, though there have been a variety of lawsuits brought forth in other states as well (*e.g*. Kansas and Wisconsin). [Note – As of January 2011 Wisconsin completed promulgation of lake and river nutrient standards that were approved by EPA]. In Minnesota, environmental advocacy groups (*e.g*., Minnesota Center for Environmental Advocacy [MCEA]) argued for inclusion of river eutrophication standards in the previous triennial rulemaking and supplied recommendations for deriving the standards (Exhibit EU-39).
The impact of excess nutrients on lakes, rivers, wetlands, and estuaries has been clearly established and widely documented. Numeric standards provide one vehicle for addressing this threat to the Nation's waters. As with any other water quality standards, appropriate quantitative measures of eutrophication are needed to determine whether waters are meeting their designated uses, as per the CWA. Numeric standards provide an objective basis for measuring and reporting on condition in 303(d) and 305(b) assessments and provide ecologically meaningful endpoints for TMDL development and NPDES permitting purposes. For Minnesota, promulgation of river eutrophication standards is part of a long-term, broad strategy to address excess nutrients in Minnesota waters (Exhibit EU-8). River eutrophication standards will allow for objective assessments of river condition with respect to excess nutrients. This will complement the 303(d) assessment of lakes for nutrient impairment that have been conducted since 2002. The adoption of river eutrophication standards will also allow a more holistic approach to address nutrient over-enrichment on a watershed basis as the MPCA implements its watershed-based approach for water quality management (MPCA 2004; Exhibit EU-34).

The MPCA's most recent nutrient criteria development plan (MPCA 2008; Exhibit EU-21b) provides a general timeline and approach for addressing river eutrophication water quality standards development. That plan called for the promulgation of lake eutrophication standards in the previous rulemaking (adopted in 2008) and completion of river nutrient standards in the current rulemaking. The plan goes on to describe the general approach and acknowledges work conducted on this from 1999-2006.

The most recent standards rulemaking also included revision of the existing phosphorus effluent rule (Minn. R. ch. 7053, 2008). This rule revision provided a means to further reduce phosphorus pollution from NPDES dischargers under various circumstances. This afforded additional protection to downstream lakes and reservoirs and reduced nutrient loading to rivers.

While the MPCA was able to use numeric translators to allow for 303(d) assessment of lakes, prior to formal promulgation of lake eutrophication standards, this option was not available for rivers, because:

- Science behind river eutrophication and responses of rivers to excess nutrients was not as well developed as it was for lakes
- Critical linkages between excess nutrients and in-river responses (*e.g*., sestonic algae, invertebrates and fish) to excess nutrients were not fully established and
- The EPA had called for the development of numeric nutrient (eutrophication) criteria for rivers.

The above factors and other information argue for the need for numeric standards to reduce the impact of nutrients on rivers, which had been indirectly addressed through related, but not as inclusive or specific, Index of Biological Integrity (IBI) impairments, low DO, elevated pH or related standards. River science, with respect to eutrophication impacts, is now developed to the point where eutrophication (nutrient) criteria can be developed. That science, as compiled from the literature and MPCA monitoring and research, is addressed in several reports (e.g. Exhibits Eu-1,2 and 3) and serves as the technical basis for Minnesota's proposed river eutrophication standards.

In addition to the river eutrophication standards there is a need for site-specific standards for Lake Pepin and the navigational pools on the Mississippi River as expressed in photos taken during the drought of 1988 (Figure 7) and more recently from monitoring in Pepin and Pool 4 (Figure 8). Though Lake Pepin is a natural lake, its characteristics are reservoir-like and as such, the need for the development of site-specific standards is supported by the previously promulgated lake eutrophication standards Minn. R. ch. 7050 (Exhibit 31) (https://www.revisor.leg.state.mn.us/rules/?id=7050.0222). MPCA TMDL guidance "Lake Nutrient TMDL Protocols and Submittal Requirements" (MPCA 2007; Exhibit 32) provides a framework for establishing a site-specific standard and pertinent information that should be considered (e.g. pp. 79-83; http://www.pca.state.mn.us/publications/wq-iw1-10.pdf).

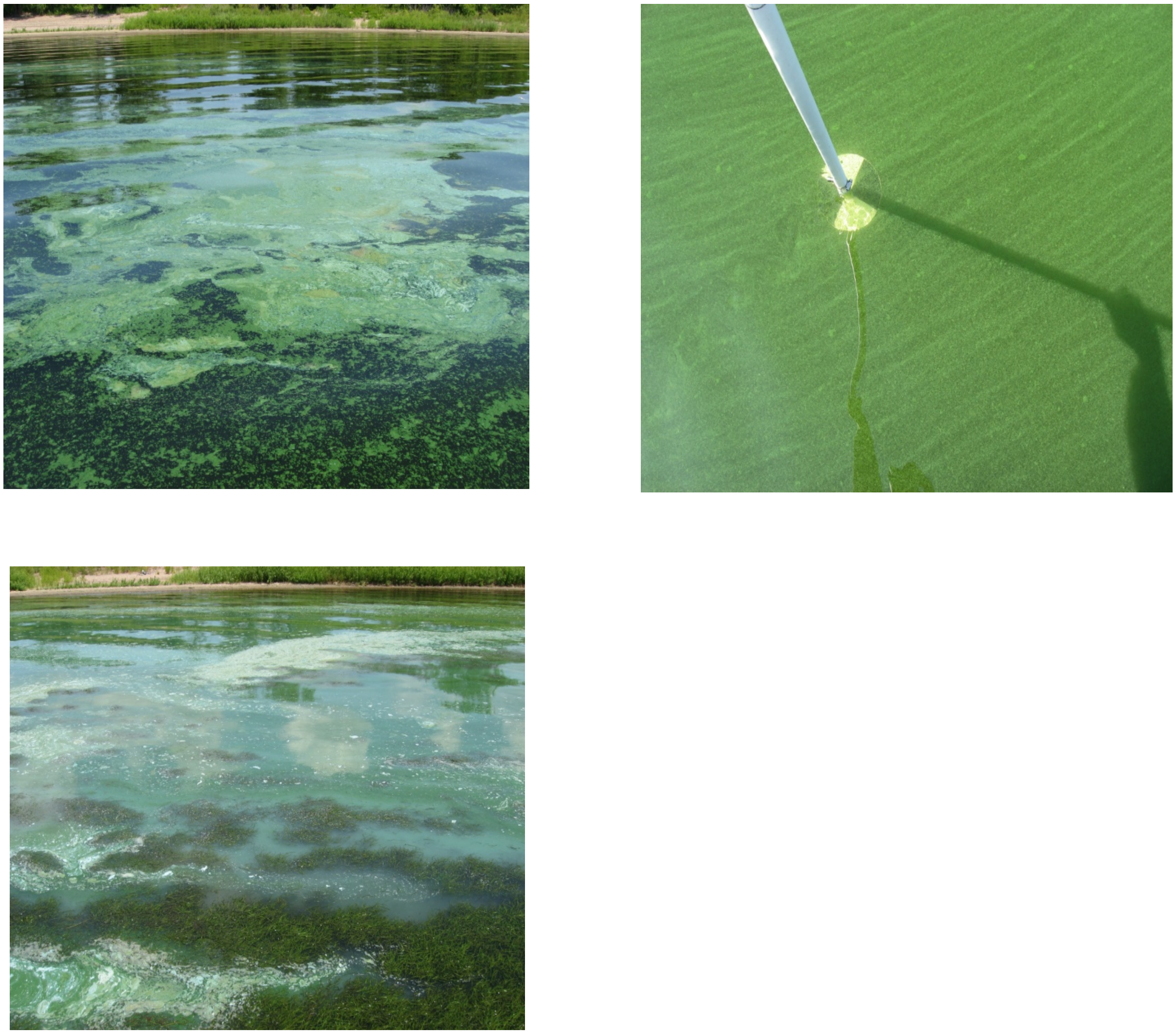
Just as rivers are different from reservoirs and lakes, the man-made navigation locks and dams on the Mississippi River (Figure 2) alter the otherwise free-flowing nature of the river resulting in potentially different relationships among nutrients, chlorophyll-a and biota as a result of increased mixing depth, light limitation, wind-induced mixing, short retention time, habitat alteration and related factors. Within the pools, formed by the locks and dams, aquatic areas are quite variable and range from navigation channels, along the thalweg of the main channel, to contiguous backwaters along the pool margins to isolated backwater lakes (Figure 20). Spring Lake, a shallow floodplain lake, in Pool 2 (Figure 20) is one example of a waterbody that resulted from the damming of the river. In pre-European times, it was a floodplain forest and marsh. The damming of its outlet creek in the 1800's allowed for development of the lake and the installation of Lock and Dam 2 in 1931 resulted in relatively stable water levels. Today the stump-field from the floodplain forest serves as a reminder of its origin.

Pool morphometry, water quality, and habitat vary among the pools as well (Table 15). One of the more significant transitions occurs as water flows through Lake Pepin. Lake Pepin serves to settle suspended sediment, which when combined with the flow from major Wisconsin tributaries (e.g. Chippewa, Black, and Wisconsin) that are low in suspended sediment, results in increased transparency in downstream pools allowing for increased Submerged Aquatic Vegetation (SAV) in contiguous backwaters and other portions of the pools with appropriate substrate and other characteristics necessary for SAV. Processes within Lake Pepin trap particulate phosphorus in the system; however, internal recycling allows for conversion of particulate P to dissolved ortho-phosphorus that may promote downstream algal and SAV growth. All of these unique factors contribute to the need for site-specific eutrophication standards for the Mississippi River Navigational Pools.

Technical reports that address the development of eutrophication site-specific standards for the Mississippi River navigational pools (Heiskary and Wasley 2012; Exhibit EU-7) and Lake Pepin based on the Lake Eutrophication WQS (Heiskary and Wasley 2011; Exhibit EU-6) provide the technical basis for the proposed sites specific WQS and will be referred to later in the SONAR.

Figure 7. Lake Pepin fish kill and severe nuisance algal blooms from summer 1998. Photos provided by John Sullivan, Wisconsin Department of Natural Resources (WDNR)

Figure 8. Severe nuisance blooms in Lake Pepin and Pool 4. Photos from August 2009 provided by Rob Burdis, Minnesota Department Natural Resources (MDNR)



B. EPA Guidance

The EPA reports that excess nutrient loading is one of the leading causes of impairment of the nation's surface waters (Exhibit EU-13). The EPA began a nutrient *Ambient Water Quality Criteria* (AWQC) development program in the 1990s, and moved quickly from 1998 to 2001 to publish a number of documents, including a nutrient strategy (Exhibit EU-9), nutrient criteria recommendations for lakes and rivers (Exhibits EU-10, 11, and 12), technical guidance for states and tribes (EU-14), fact sheets (EU-13), and policy memos (EU-15). More recently, EPA's Science Advisory Board (SAB) has made recommendations to EPA on revisions to river nutrient criteria guidance (SAB 2010; Exhibit EU-18). While the SAB recommendations were not available when MPCA initiated its river eutrophication research and standards development process, the MPCA feels there is merit in many of the recommendations and has since addressed many of the issues raised during the development of its technical approach to river eutrophication standards development.

It is worth mentioning that the latest round of nutrient criteria recommendations from the EPA is not the first time nutrient criteria have been issued by that agency. In a letter dated April 20, 1973, EPA recommended that the MPCA adopt TP standards for both flowing water and lakes by 1983 (Exhibit EU-16). The recommended TP values for free flowing streams was 200 µg/L and for lake 50 µg/L. The recommended values were a little more lenient than the criteria in the support document attached to the letter, which were 100 µg/L for free flowing streams, 50 µg/L in any stream where it enters a reservoir or lake, and 25 µg/L in any reservoir or lake. The support document stressed that these numbers were strictly guidance to states, and the criteria adopted could be more or less stringent depending on the local conditions in each state. The support document also discusses issues relevant today, such as the need to address situations when standards cannot be met and the variability in trophic condition among lakes and rivers.

The EPA expects states to adopt nutrient criteria into their state WQS and rules (e.g. see Exhibit EU-15). Over the period from 1998-2008 states have begun to adopt nutrient WQSs, albeit slowly (Exhibit EU-17). The EPA has indicated a willingness to step in and promulgate nutrient standards for any state that fails to take action on their own – as was the case in Florida (e.g. Exhibits EU-15 and EU-17).

RTAG and External Meetings and RTAG Review of Draft Standards

As EPA started to develop nutrient AWQC for the nation, they also formed Regional Technical Assistance Groups (RTAG), also called "regional nutrient teams" (Exhibit EU-9). The RTAGs consist of state and tribal representatives that met with staff from EPA and other federal agencies to develop more refined and localized nutrient criteria for use in future WQSs using approaches described in the EPA technical guidance (Exhibit EU-14). Minnesota, along with Wisconsin, Michigan, Ohio, Indiana, and Illinois are a part of the EPA Region 5 RTAG. Steven Heiskary is Minnesota's representative on this group (Exhibit EU-17).

The EPA designated a regional nutrient coordinator for each of the 10 EPA regions. The most current listing may be found in Exhibit EU-17. Their function was to facilitate the collection and analysis of local nutrient data, provide technical assistance to the states on criteria development, report progress to EPA Headquarters in Washington D.C., and award financial assistance. The EPA encouraged states to have their RTAG provide a technical review of proposed state nutrient standards.

The MPCA data-driven and ecoregion-based approach is recognized as a model by EPA (Exhibit EU-28). The MPCA initiated studies to support eutrophication standards development, developed lake eutrophication standards, and used them in lake programs and impairment assessments ahead of most other states (EU-17). The MPCA's experience with lakes helped to jump-start criteria development efforts for rivers with initial EPA-funded studies dating back to 1999. Initial studies in 1999 and 2000 led to a publication (Exhibit EU-4) that began to lay out Minnesota's approach to understanding the impact of nutrients on streams and served to shape our overall approach. Subsequent monitoring and research served to further refine our approach and expand linkages among nutrients and aquatic biota (Exhibits EU-1, EU-2, and EU-3).

The MPCA has shared this experience with EPA Region 5 RTAG, the North American Lake Management Society (NALMS), at water quality standards forums, and other meetings on numerous occasions. Example outreach includes: NALMS meetings in November 2003, Mississippi Hypoxia meeting in St. Louis in November 2005, Minnesota Water Resources meetings (2008, 2009, and 2011), the All States National Criteria meeting in Dallas, Texas in February, 2006, the National Park Service sponsored Mississippi River Forum meetings in fall 2010 (Exhibit EU-29), the Upper Mississippi River Basin Association "Nutrient Workshop" in August 2011, and the Upper Mississippi River Conservation Committee in March 2012.

State Nutrient Criteria Development Plans

The EPA proposed a simple two-step process for the states to follow that would culminate in the adoption of nutrient standards by the state (Exhibit EU-9). Step 1 was for each state to submit a nutrient criteria development plan to EPA that described how the state proposed to develop nutrient criteria and a schedule for adoption. Step 2 was the promulgation and adoption of the nutrient criteria into the state's rules as WQS. The MPCA submitted a final plan for EPA's consideration in April 2003 and that plan was approved by EPA Region 5 (EPA R5) (Exhibit EU-21a). The plan has undergone periodic updating since the most recent major revision of the plan is Exhibit EU-21b (summer 2008). In its plan, the MPCA outlined:

- A strategy for developing eutrophication standards for lakes and rivers
- The causal (TP) and response variables (sestonic Chl-a and BOD_5) for which standards will be proposed
- A description of the MPCA's approach and data utilized to arrive at the proposed standards (Attachment I to the plan) and
- A timetable for adopting the standards

The EPA approved Minnesota's 2003 plan in a letter dated May 5, 2003, (Exhibit EU-21a) and EPA has approved the 2008 update as well (Exhibit 21c). In Exhibit EU-21a, the EPA reiterates the possibility of promulgating nutrient standards for Minnesota, if the MPCA fails to meet the terms agreed upon in the plan. The MPCA is lagging behind the schedule provided in the 2003 and 2008 plans for adoption; however, is well along in the rulemaking process as evidenced by the completed TSD (Exhibit EU-1) and the supporting SONAR. The MPCA has remained in close communication with EPA Region 5 and since EPA prefers states complete their own adoption process, EPA has not indicated it plans to take action at this time. The 2008 nutrient criteria development plan update reiterates the MPCA's intention to adopt the proposed eutrophication standards in this rulemaking.

EPA Nutrient (Eutrophication) Criteria

The EPA developed nutrient Ambient Water Quality Criteria (AWQC) recommendations under the authority of Section 304(a) of the Clean Water Act. The EPA's nutrient criteria are unlike essentially all other 304(a) criteria. Most EPA 304(a) AWQC developed over the years are for toxic substances. Because nutrients are not regulated in the same fashion as toxic substances, the data and methods used to establish nutrient criteria are very different from the data and methods EPA uses to develop criteria based on the toxicity of a substance to aquatic life, humans, or wildlife. Nutrient criteria are based on trophic condition monitoring data from lakes, reservoirs, and rivers across the nation. Toxicity-based criteria are based mostly on laboratory derived, toxicity test data for aquatic organisms. Also, EPA's nutrient criteria are regional, specifically tailored to ecoregions, whereas most EPA 304(a) AWQC are applicable nation-wide with the same consideration of using local to regional data to refine the national criteria when scientifically defensible.

C. A Tool to Protect Very Valuable Resources

The proposed river eutrophication standards will complete an ongoing process of developing protections for Minnesota waters. Because of the importance of Minnesota's water resources to the state's environment and economy, the MPCA has been working to control phosphorus for many years. In 1996, the MPCA developed a comprehensive phosphorus strategy with seven action steps for phosphorus reduction and control. These action steps apply to both point and nonpoint sources of phosphorus and are in various stages of implementation (Exhibit EU-8).

- Develop education/outreach information on environmental impacts of phosphorus
- Co-sponsor basin-wide phosphorus forums

- Use basin management as the main policy context for implementing the phosphorus strategy
- Broadly implement Minnesota's point-source phosphorus controls
- Broadly promote lake protection activities
- Address phosphorus impacts on rivers
- Modify water-quality standards if necessary

With lake eutrophication standards and a revision to Minnesota's effluent P rule addressed in the 2008 triennial rulemaking, this left development of river eutrophication standards as a last major step in this strategy. The proposed numeric river eutrophication WQSs are needed to facilitate water quality assessments and watershed protection management. They will support improved development of nutrient Total Maximum Daily Loads (TMDLs) and implementation of water quality-based effluent limits in NPDES permits, so beneficial uses like healthy aquatic communities and recreational use are maintained and restored. Perhaps most importantly, they will create state - and community-developed environmental baselines that allow us to manage more effectively, measure progress, and support broader partnerships based on nutrient trading, Best Management Practices (BMPs), land stewardship, wetlands protection, voluntary collaboration, and urban storm water runoff control strategies. The progress of states and territories in setting numeric nutrient WQS is extremely important to help address nutrient pollution.

Numeric river eutrophication standards will facilitate more effective and efficient program implementation. River standards will complement existing lake standards and allow for easier development and adoption of site-specific standards where needed (e.g. reservoirs). Numeric standards have a number of key advantages over narrative standards alone:

- provide a direct measure of nutrient impacts to surface water (expands on use of other standards: IBIs, pH, and DO)
- easier and faster development of TMDLs
- quantitative targets to support trading programs
- easier to write protective NPDES permits
- increased effectiveness in evaluating success of nutrient runoff minimization programs and
- measurable, objective water quality baselines against which to measure environmental progress

D. Excess Nutrients are a Leading Cause of Water Pollution

The MPCA needs to develop eutrophication standards for rivers to address a major cause of water impairments. These impairments show up as a reduced or lost ability for waterbodies to support their beneficial uses, such as healthy fish populations or recreation. Dodds and Welch (2000; in Exhibit EU-1) note, *"Nutrient criteria for streams may be needed to avoid direct toxicity, taste and odor, alterations in biotic integrity, and interference with recreation."* Walker *et al.* (2006; in Exhibit EU-1) summarize a variety of reasons for addressing excess nutrients in streams as well as important factors to consider in the process. Many of their ideas touch on areas the MPCA has addressed in the development of the proposed amendments and they bear further mention as follows:

> *"Excessive nutrient levels may allow excessive increases in algae and other primary producers, which may in turn, prevent streams from meeting their designated uses. The adverse effects of either high nutrient levels or the nuisance growth of primary producers include:*
>
> *1) Impairment of the aquatic life use; whereby*

- *Daily fluctuations in oxygen concentrations and pH values may negatively impact aquatic life;*
- *Toxicity may result if high ammonia levels (e.g., > 1 mg/L NH_3-N) contribute to high nitrogen levels;*
- *Blue-green algal blooms may release toxic compounds (e.g., cyanotoxins);*
- *A loss of diversity and other changes in the aquatic plant, invertebrate, and fish community structure may result;*
- *Extremes in stream pH are stressful and can even be deadly to aquatic organisms. High pH levels increase the toxicity of some substances, such as ammonia, whereas low pH levels can make heavy metals in stream sediment more mobile.*

2) Negative impact on the drinking water and community water supply use:

- *Methemoglobinemia (blue-baby syndrome) may affect infants if nitrate levels >10 mg/L;*
- *Potentially carcinogenic disinfection by-products (trihalomethanes (THMs)) may form during treatment of drinking water from eutrophic waters;*
- *Diatoms and filamentous algae can clog intake screens and filters in water treatment plants;*
- *Decay of algae may lead to taste and odor problems of drinking water;*
- *Treatment costs may rise for waters drawn from eutrophic sources by requiring more backwashing, etc.*

3) Degradation of the aesthetic and recreational use

- *Unsightly algal growth is unappealing to many swimmers and other stream users;*
- *Slippery streambeds caused by heavy growths of algae on rocks are difficult to walk on;*
- *Fishing lures may become tangled in algae and macrophytes and boat propellers may get tangled by aquatic vegetation."*

A primary basis for the proposed eutrophication standards for rivers is quantifying protections for aquatic life communities, with fish and invertebrates as representative aquatic biota. However, the goals for the standards are to meet both of the key beneficial uses for Minnesota's Class 2 WQS of ensuring healthy aquatic environments for "propagation and maintenance of fish and aquatic life" and protection of "aquatic recreational uses." While an emphasis has been placed on ensuring healthy aquatic environments the standards will also serve to maintain and enhance aquatic recreational uses.

In contrast to the statewide river eutrophication standards, the proposed site-specific standards for the navigational pools and Lake Pepin emphasize attainment of aquatic recreational uses – somewhat akin to the lake eutrophication standards. This is in part because of how the pools and Lake Pepin are used (e.g. swimming, wading, and boating) and linkages with TP, Chl-a and aquatic life cannot be made for the pools and Lake Pepin in the same fashion that has been done for rivers (the MPCA lacks appropriate data and linkages are not well demonstrated to date). However, fisheries data that has been summarized for Lake Pepin and the pools (Exhibit EU-6 and EU-7) indicate a diverse and robust fishery is present in these waterbodies and hence efforts to reduce TP and Chl-a will serve to further enhance aquatic life uses.

The EPA's goals for eutrophication standards can be drawn directly from the USEPA's National Nutrient Policy (USEPA 2007; Exhibit EU-15): *"High nitrogen and phosphorus loadings, or nutrient pollution, result in harmful algal blooms, reduced spawning grounds and nursery habitats, fish kills, oxygen-starved hypoxic or "dead" zones, and public health concerns related to impaired drinking water sources and increased exposure to toxic microbes such as Cyanobacteria."* Nutrient problems can be exhibited locally or much further downstream leading to degraded estuaries, lakes and reservoirs, and to hypoxic zones where fish and aquatic life can no longer survive.

The most widely known examples of significant nutrient impacts include the Gulf of Mexico and the Chesapeake Bay. For these two areas alone, 35 states contribute to the excess nutrient loadings. There are also known impacts in over 80 estuaries/bays, and thousands of rivers, streams, and lakes. The significance of this impact has led the EPA, states, and the public to come together to place an unprecedented priority on public partnerships, collaboration, better science, and improved tools to reduce nutrient pollution.

Nutrient pollution is widespread. A recent United States Geological Survey (USGS) study (Dubrovsky and Hamilton 2010; Exhibit EU-33) notes, *"Nutrients can occur naturally in water (referred to as background), but elevated concentrations usually originate from man-made sources, such as fertilizers, manure, and septic system effluent. All five nutrients studied – nitrate, ammonia, total nitrogen, orthophosphate and total phosphorus—exceed background concentrations at more than 90 percent of 190 sampled streams draining agriculture and urban watersheds."* This USGS study goes on to state that stream biological condition (based on algal, macroinvertebrate and fish communities) declined with increasing nitrogen and phosphorus.

Virtually every state and territory is impacted by nutrient-related degradation of its waterways. All but one state and two territories have Clean Water Act Section 303(d) listed impairments for nutrient pollution. States have listed more than 10,000 nutrient and nutrient-related impairments. Fifteen states have more than 200 nutrient-related listings each. For these reasons, EPA Regions have identified nutrient pollution reduction as a priority for EPA. Minnesota has more than 400 nutrient-impaired lakes on its 303(d) list and a vast majority of these are a result of excess loading of nutrients from streams in the watershed. In the case of some large-scale TMDLs such as Lake Pepin, the in-lake impairment can be shown to be a direct product of excess nutrient and algal loading from upstream tributaries (Heiskary and Wasley 2011; Exhibit EU-6).

E. EPA Direction to States to Adopt Standards

The proposed amendments are needed to respond to the EPA direction to states to adopt nutrient standards. The EPA (2000a; Exhibit EU-14) notes, "*A directly prescriptive approach to nutrient criteria development is not appropriate due to regional differences that exist and the lack of a clear technical understanding of the relationship between nutrients, algal growth, and other factors (e.g., flow, light, and substrate). The approach chosen for criteria development must be tailored to meet the specific needs of each state or tribe."* The section on Reasonableness provides details on the MPCA's approach to river eutrophication WQS development and how the approach is consistent with the EPA direction and guidance.

F. Narrative Standards

Eutrophication standards have many unique qualities that set them apart from most other Class 2 numeric standards. The proposed river eutrophication standards (Table 1):

- By necessity are developed through a completely different process as compared to other Class 2 standards
- Include "causal" (TP) and "response" (Chl-a, BOD_5 and diel DO flux) variables
- Vary by River Nutrient Region
- Are implemented as summer season averages rather than 4-day or 30-day averages
- Are aimed at protecting aquatic life and recreational uses, and are also aimed at protecting aesthetic uses and
- Need to protect rivers and streams with water quality better than standards and accommodate rivers and streams that cannot meet the standards due to natural causes

These facts create a need to supplement the numeric eutrophication standards with narrative statements that provide information and guidance on these aspects. The MPCA is proposing language to accompany the numeric standards to cover these issues.

The narrative statements proposed for addition in Minn. R. 7050.0222 subp.4b (Class 2B river eutrophication standards) are quoted below.

> [Minn. R. 7050.0222 _Subp. 4b._ ***Narrative eutrophication standards for Class 2B Rivers and streams.***
>
> A. _Eutrophication standards are compared to data averaged over the summer season or as specified in subpart. 4. Exceedance of the total phosphorus and either sestonic chlorophyll-a, biochemical oxygen demand (BOD_5), diel dissolved oxygen flux or pH standard is required to indicate a polluted condition for assessment and implementation purposes._
>
> B. _Rivers and streams that exceed the phosphorus levels but that do not exceed either the chlorophyll-a (seston), five day biochemical oxygen demand, diel dissolved oxygen flux, or pH levels meet the eutrophication standard._
>
> C. _A polluted condition also exists when the chlorophyll-a (periphyton) concentration exceeds 150 milligrams/meter^{2}more than one year in ten._
>
> D. _It is the policy of the MPCA to protect all rivers and streams and navigational pools from the undesirable effects of cultural eutrophication. Rivers, streams and navigational pools with a baseline quality better than the numeric eutrophication standards in subpart 4 must be maintained in that condition through the strict application of all relevant federal, state, and local requirements governing nondegradation, the discharge of nutrients from point and nonpoint sources, and the protection of river and stream resources, including, but not limited to:_
>
> _(1) the nondegradation requirements in parts 7050.0180 and 7050.0185;_
> _(2) the phosphorus effluent limits for point sources, where applicable in chapter 7053;_
> _(3) the requirements for feedlots in chapter 7020;_
> _(4) the requirements for individual sewage treatment systems in chapter 7080;_
> _(5) the requirements for control of stormwater in chapter 7090;_
> _(6) county shoreland ordinances; and_
> _(7) implementation of mandatory and voluntary best management practices to minimize point and nonpoint sources of nutrients._
>
> E. _Rivers, streams, and navigational pools with a baseline quality that is poorer than the numeric eutrophication standards in subpart 4 must be considered to be in compliance with the standards if the baseline quality is the result of natural causes. The commissioner shall determine baseline quality and compliance with these standards using summer-average data and the procedures in part 7050.0150, subpart 5. Natural causes is defined in part 7050.0150, subpart 4, item N._

The above narrative standards language is quite similar to that used in the lake eutrophication standards. Item D is patterned directly after language used for lakes.

G. Proposed Water Quality Standard for Excessive Attached Algae in Rivers

To complement the river eutrophication standards for sestonic, water column algae in streams where the algal community is dominated by periphytic algae that grow on rocks and other substrates, the MPCA is proposing a water quality standard to meet the standards prohibiting excess algal growth and slime (Minn. R. 7050.0150).

Because water column algae require time to develop, they are less common in headwater, shallow, shaded, 1st and 2nd order streams; in these areas, periphyton are more common and the main focus will be the attached algae rather than water column algae. However, in larger shallow un-shaded streams, attached algae can still be a problem in mid-summer when flows are low.

Sampling attached algae is very different from collecting water column samples because of the scattered nature of the occurrence of attached algae. Small gravel, sand, and silt does not provide adequate attachment sites and are too unstable for algal growth, so the focus will be on riffle areas. While some rocks may have excess attached algae, it is unlikely that all rocks in the sampling area will have attached algae. Therefore, it is important that monitoring protocols establish an unbiased sampling approach, selecting substrate for sampling that is generally characteristic of rocks in the sampling area. Periphyton monitoring data is expressed as the amount of chlorophyll for a given area of stream bottom (i.e., mg Chl/m^2).

In Montana streams, Suplee *et al* (2008) determined through public surveys that as benthic algal biomass increased, desirability for recreation decreased. Mean biomass levels of ≥ 200 mg Chl/m^2 were determined to be excessive, while mean levels ≤ 150 - 200 mg Chl/m^2 were determined to be desirable. Welch *et al* (1988) found a biomass range of 100 – 150 mg Chl/m^2 represents a critical level for aesthetic nuisance. Biggs (2000) stated that biomass levels > 150 – 200 mg Chl/m^2 are very conspicuous in streams, are unnaturally high, and would compromise the fishery and recreational value of rivers.

Work by Miltner (2010a) suggests maintaining periphyton below 150 mg Chl/m^2 would be protective for aquatic life uses as well. In this work, he recommends that biomass remain below 107 mg Chl/m^2 for protecting high-quality waters and less than 182 mg Chl/m^2 to ensure minimum DO remains >4.0 mg/L.

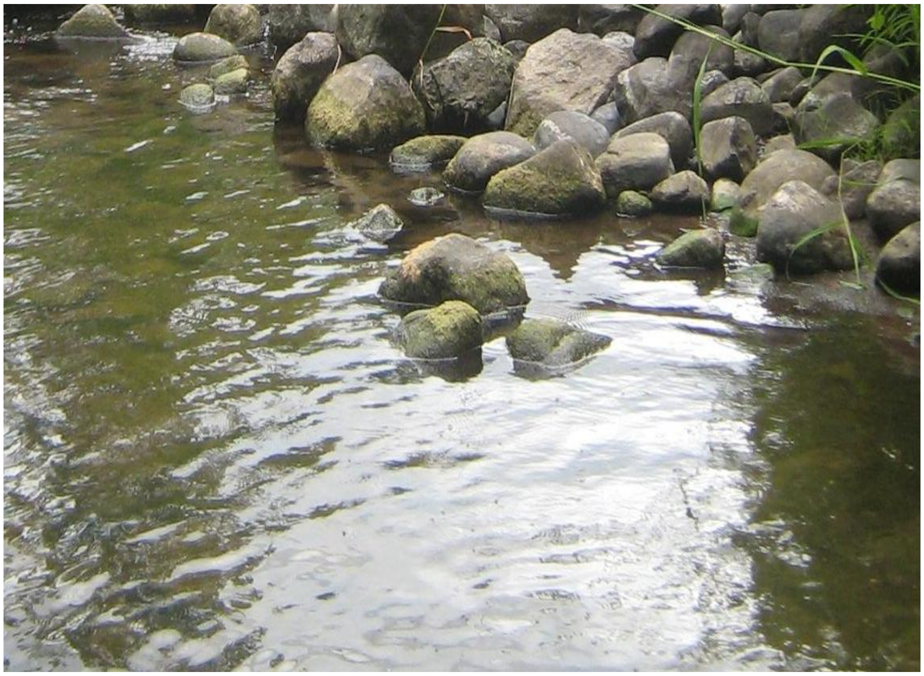
Suplee *et al* (2008b) also provide examples of photographs from Montana for excellent quality, diatom-dominated streams, and poor-quality filamentous green algal [*Cladophora*] - dominated streams (Figure 23). Their study showed a clear demarcation in algal type as biomass increased from 150 mg Chl/m^2 to 200 mg Chl/m^2.

In addition to the photos from Montana, below are examples of stream collection site photos from different locations in Minnesota:

Photograph of periphyton conditions at the North Branch of the Sunrise with measurements on the same day.

Stream name	STORET station ID	Date	Substrate type	Periphyton Chl a mg/m^2
North Branch Sunrise River	S003-472	7/16/2009	Wood/ cobble	187

Photograph of periphyton conditions at Rock Creek with measurements on the same day.



Stream name	STORET station ID	Date	Substrate type	Periphyton Chl a mg/m^2
Rock River	S005-532	7/16/2009	cobble	203

There are several national sampling protocols available for assessing the periphyton in wadeable streams, including the US Geological Survey (USGS) Field Manual Open-File Report 02-150. Field collectors will use the method described in the USGS National Field Manual for rocky habitat, with MPCA protocol modifications developed under consultation with USGS staff, so there is consistency among results. Collection for periphyton biomass is limited to rock substrate because of the difficulty of collecting a representative sample on other substrates or in deeper stream depositional habitats.

Sampling may be across one riffle or up to five different riffles in the sampling area, depending on the width of the stream – apparent excessive algae should average more than 1/3 of the width of the riffle or riffles. Periphyton sampling should occur during the algal growing season of June through September.

Collection Methodology

1. Collections will be made on a minimum of two cobbles (maximum of five) and on at least two riffles. Collect one additional set at each location for field replicate. Carry to a processing location on the stream bank to collect the periphyton from the rock. (USGS reference 4.3.1. section, SG-92 #2 p. 16). Rock substrate smaller than 45 mm diameter will not be sampled.

2. Place a flexible mask, such as a plastic water bottle cap, open side down on the growing surface of a cobble to delineate and protect the periphyton to be collected. Cut with a utility knife or scissors any coarse stems around the perimeter of the cap. While holding the cap in place, use a grout brush to remove all the periphyton around the cap. Then use a stiff-bristled small brush and a squirt bottle of

clean water and scrub all of the periphyton that was protected under the cap into a clean stainless steel bowl. (USGS reference 4.3.1. section, SG-92 #3-5 p.16)

3. Repeat #2 on remaining four cobbles, and transfer the slurry into an amber bottle. Place the bottle on ice and keep in the dark until delivered to the lab for filtering. If field filtering, homogenize the sample and note the volume filtered. Freeze the filter until delivery to lab. (USGS reference 4.3.1. section, SG-92 #6 p.17)

4. Repeat on second set for a field replicate.

Proposed Periphyton Water Quality Standard

Some states use biomass levels in their water quality standards or water assessments, centering on 150 mg Chl a/m^2, and other states use percentage of stream covered by excess algae. We are proposing to combine those two approaches to ensure the excess algal problems are both significant in amount and coverage. Therefore, in implementing the periphyton standard the periphyton algal biomass standard would need to be exceeded over greater than one-third of the stream. In making this determination, the monitoring site would be evaluated visually to determine the aerial coverage of periphyton in representative reaches. If luxuriant periphyton growth exists on over one-third of the stream, periphyton sampling would ensue and be compared to the periphyton algal biomass standard. There must be at least two exceedances of the periphyton algal biomass standard in a ten-year period for a site to not meet the periphyton water quality standard.

Once an impairment of the periphyton threshold is identified, the next step will be to determine the cause of the excess periphyton growth. This step is needed before a TMDL study can be initiated, since a TMDL would focus on the stressor(s) causing the impairment. Since there are many factors that go into the determination of periphyton biomass, e.g. lack of shade, substrate quality, nutrient loading from the watershed, the approach that will work the best is utilizing the EPA's Stressor Identification Guidance Document (USEPA/822/B-00/025) (Cormier et al. 2000). This document contains an introduction to the Stressor Identification [SI] process, and walks through the SI steps of listing candidate causes, identifying approaches to analyze the evidence, characterizing causes, and iteration options. No linkage between NPDES dischargers or other potential pollution sources and specific stressors causing the excess periphyton biomass will be assumed until the stressor list is established.

H. Conclusion

Numeric eutrophication standards are needed for the following reasons:

- Nutrient enrichment has a negative impact on aquatic life and aquatic recreation, and impacts downstream waterbodies.
- Rivers and streams are extremely important and valuable resources to the state and numeric standards will be an important tool to help protect these resources from impairment due to excess nutrients.
- Adopted numeric standards, as opposed to thresholds in guidance, will have greater legal standing, greater visibility, and enhanced accessibility. This should encourage their use by other state agencies, consultants, local governments, watershed management districts and other organizations.
- The EPA expects states to adopt river eutrophication standards and has indicated its intent to promulgate standards for those states that do not (e.g., Exhibit EU-15).
- The river eutrophication standards will complement the lake eutrophication standards and allow for more comprehensive protection of Minnesota's lakes, reservoirs, and rivers.

In conclusion, the numeric standards for rivers and navigational pools proposed to be adopted into rules are needed to protect these waters from the threat of eutrophication and further serve to protect downstream water bodies.

4. Reasonableness of the Proposed Eutrophication Standards

A. Introduction and EPA Guidance

The criteria development process leading to the data acquisition and state-specific approaches for proposing water quality standards described in EPA guidance (Exhibit EU-14) can be divided into the following iterative steps:

1. Identify water quality needs and goals with regard to managing nutrient enrichment problems.
2. Classify rivers and streams first by type and then by trophic status.
3. Select variables for monitoring nutrients, algae, macrophytes, and their impacts.
4. Design sampling program for monitoring nutrients and algal biomass in rivers and streams.
5. Collect data and build database.
6. Analyze data.
7. Develop numeric criteria based on reference condition and data analyses.
8. Implement nutrient control strategies.
9. Monitor effectiveness of nutrient control strategies and reassess the validity of nutrient criteria.

Three general approaches for criteria setting are discussed in Exhibit EU-14: (1) identification of reference reaches for each stream class based on Best Professional Judgment (BPJ) or percentile selections of data plotted as frequency distributions; (2) use of predictive relationships (e.g., trophic state classifications, models, and biocriteria); and (3) application and/or modification of established nutrient/algal thresholds (e.g., nutrient concentration thresholds or algal limits from published literature).

According to the guidance, initial criteria should be verified and calibrated by comparing criteria in the system of study to nutrients, Chl-a, and turbidity values in waterbodies of known condition to ensure that the system of interest operates as expected. A *weight of evidence approach* that combines any or all of the three approaches above is recommended as a means of producing criteria of greater scientific validity**.** Selected criteria and the data analyzed to identify these criteria are also comprehensively reviewed by a panel of specialists in each EPA Region, and initial criteria are refined as needed based on the results of the calibration and review.

Since the completion of the MPCA's numerous field studies and publication of draft Technical Support Documents (TSDs) (e.g. Exhibit EU-1) the EPA has provided some additional guidance. Exhibit EU-20 was developed in response to the Science Advisory Board's review of EPA nutrient criteria guidance (Exhibit EU-18). It provides states with a framework for establishing stressor-response relationships as a basis for deriving nutrient criteria. The studies that provide the basis for the MPCA's proposed standards were designed and carried out over a period from 1999-2008. Although the MPCA could not restructure its entire data collection and analysis approach in order to reflect the additional EPA guidance, the MPCA has been able to use a similar approach to develop the proposed standards. The MPCA used an approach similar to EPA's more recent guidance (Exhibit EU-20) to collect and compile data, tier data analysis, focus on establishing interrelationships (e.g., Figure 3), apply appropriate statistical tests, and to use weight-of-evidence approach in selecting criteria values. Further details are provided later in the SONAR.

The MPCA used a systematic approach to develop river eutrophication WQSs. The approach emphasized linkages among nutrients, algae, dissolved oxygen (DO), and stream biota consistent with the conceptual models (Figure 3 and Figure 4). Initial efforts in 1999 and 2000 focused on representative, medium to large rivers. The rivers (sites) selected for study reflected a range of stream and landscape types including predominately forested watersheds in northern Minnesota (Crow Wing), mixed land uses in central Minnesota (Rum and Mississippi) and more highly agricultural watersheds (Crow and Blue Earth). Subsequent studies in 2001, 2006, and 2008 augmented this database with additional streams, broader geographic representation, and increased amounts of biological data.

A draft technical support document (TSD) that summarized findings from previous studies and documents (e.g. Exhibits EU-2, EU-3 and EU-4) and included proposed river eutrophication standards for TP and response variables, was provided to EPA Region 5 and Region 5 RTAG members for review and comment in 2009. Three states elected to comment on the draft report (Michigan, Ohio, and Indiana). Region 5 forwarded the draft TSD to EPA Headquarters (EPA HQ) for review as well. EPA HQ contracted with Dr. Walter Dodds (Kansas State University), Dr. Michael Paul (Tetra Tech Inc.), and Dr. Jan Stevenson (Michigan State University) and each provided detailed comments on the technical approach and draft criteria (Exhibits EU-22a, -23a, and -24a, respectively). RTAG and EPA HQ reviewer comments and suggestions were used to refine the technical approach and presentation resulting in Exhibit EU-1. MPCA responses to comments are included in Exhibits EU-22b, -23b and -24b, and integrated into the overall TSD (Exhibit EU-1). Dr. Lester Yuan, principal author of the EPA stressor-response document (USEPA 2010b), provided a more recent review of Exhibit EU-1 and noted, “You all have done a huge amount of work and analysis and put together a coherent rationale for nutrient criteria.” (Exhibit EU-44).

The development of the proposed river eutrophication standards is described in detail in Exhibit EU-1. This publication discusses the sources and types of data used to develop first the nutrient criteria then the proposed eutrophication standards, how the data were analyzed, and the uses the standards are designed to protect. The reasonableness section of the SONAR will provide a technical summary of that process, and many topics covered in the SONAR are addressed in more detail in Exhibit EU-1. To avoid repetition, citations to this exhibit will be kept to a minimum, but its relevance throughout can be assumed. Literature references as used in this portion of the SONAR are drawn from Exhibit EU-1, unless noted otherwise. A list of references is included at the end of the SONAR to allow the reader to follow-up on any specific articles referenced in the SONAR.

B. Definitions

The MPCA is proposing a number of definitions to provide a consistent understanding of the terms used in the proposed amendments. The new definitions that are being added for “biochemical oxygen demand”, “diel flux”, “periphyton”, “seston”, “River Nutrient Regions”, and “stream order” are based on the common understanding of the terms in the field and the standard usage of the terms in related scientific documents. The following are commonly understood explanations of technical terms discussed in the SONAR.

Biochemical oxygen demand or ”BOD” - Refers to the procedure for determining the amount of dissolved oxygen needed by biological organisms to break down the organic material present and for the oxidation of inorganic constituents. BOD is established at certain temperatures and for specified timeframes. The proposed amendments identify the most commonly used technique, the BOD_5, which refers to the oxygen demand that occurs over a period of five days.

Diel flux - Refers to the daily (also referred to as diurnal) change in a constituent like dissolved oxygen or pH; whereby there is a distinct daily cycle in the measurement. Diel dissolved oxygen flux means the difference between the maximum daily dissolved oxygen concentration and the minimum daily dissolved oxygen concentration.

Periphyton - Refers to algae attached to submerged surfaces in a water-body. In rivers or streams these algae are typically found attached to logs, rocks or other substrates, but when dislodged they become part of the seston. The term periphyton is used in the eutrophication standards in conjunction with chlorophyll-a, and is distinct from sestonic algae.

River Nutrient Regions - Refers to a system of classifying rivers according to regions of the state for purposes of applying the river eutrophication standards. The river nutrient regions are identified in a document incorporated by reference in Minn. R. ch 7050. A more complete discussion of the Agency's development of the river nutrient regions is provided in the Reasonableness section of this SONAR.

Sestonic algae - Refers to algae suspended in the water column, also referred to as phytoplankton. The term seston or sestonic algae is used in the eutrophication standards in conjunction with chlorophyll-a, and is distinct from periphyton.

C. Data Supporting the Proposed Numeric Eutrophication Standards: Technical Overview

The conceptual models (Figure 3 and Figure 4) provide an overview of the MPCA's approach to study design, monitoring, and the linkages we sought to establish connections between TP and response variables. Exhibit EU-20 and Exhibit EU-18 recommend the use of conceptual models to demonstrate interconnections and help define linkages; in addition, this can ensure good study design and that appropriate data are collected. The various steps/procedures and data employed to derive the numeric criteria (basis for proposed numeric standards) as summarized in this section are drawn primarily from Exhibit EU-1. Literature sources, more complete details, database, and data analysis may be found in Exhibit EU-1. As the various studies that were conducted from 1999-2008 built-upon one another so did the steps used to derive the standards. The major steps or approaches used are summarized below.

- Linear regression described basic interrelationships among total phosphorus (TP), total nitrogen (TN), sestonic chlorophyll-a (Chl-a), biochemical oxygen demand (BOD_5), and dissolved oxygen (DO) flux based on the river nutrient datasets. Most relationships exhibited high R^2 values and were highly significant.
- Spearman correlation analysis provided an initial basis for identifying relationships among TP, TN, sestonic chlorophyll and DO flux and fish and invertebrate metrics. This provided a basis for identifying responsive metrics for each of these variables and helped to focus subsequent analyses.
- Scatterplots were used to visualize relationships among the more responsive metrics and the stressors and begin threshold identification. Statewide interquartile ranges for the biological metrics were used to place metric values in perspective and help discern where an important shift in the metric may be occurring relative to the stressor gradient.
- More advanced statistical techniques: quantile regression and changepoint analysis, which are well suited to the often wedge-shaped plots that are common with field-collected biological data, were employed. Based on the previous analyses emphasis was placed on some of the more responsive metrics: fish and invertebrate taxa richness and sensitive species. These techniques were applied to both the river nutrient dataset and the much larger biomonitoring datasets. Threshold concentrations were produced for statewide, wadeable vs. nonwadeable, and on a region-specific basis.

- Reference condition analysis was conducted to provide an additional line of evidence and to further place threshold values in perspective.
- A comprehensive review of the literature was conducted and literature-based thresholds were used to provide further perspective on this issue.
- Threshold concentration ranges were placed in context with ecoregion-based frequency distributions compiled by MPCA for representative, minimally-impacted streams (McCollor and Heiskary 1993; Exhibit EU-30) and interquartile (IQ) ranges from EPA criteria manuals (Exhibits EU-10,-11, and-12).

All of the above was used to move from broad ranges for criteria setting to region-specific criteria. The information gathered by these related efforts provided the basis for deriving the criteria and represents a multiple lines of evidence or "weight of evidence" approach as referred to by the EPA (Exhibit EU-14). This type of approach is consistent with EPA Science Advisory Board (SAB) recommendations for river nutrient criteria development (Exhibit EU-18).

The MPCA conducted several years of focused field studies to develop a comprehensive database of river nutrient profiles and related "response" factors with an emphasis on medium to large rivers (typically 4th – 6th order rivers with watersheds of 1,000 mi^2 or greater). This database is referred to as the "River Nutrient (RN) Database." The river nutrient study in 1999 and 2000 focused on medium to large rivers that were representative of several Minnesota ecoregions (Table 3). Subsequent years of study expanded on this dataset and included a variety of rivers representing various ecoregions and basins that are representative of Minnesota's stream resources (Table 4). Sample size and representativeness was increased further by inclusion of biomonitoring datasets (later referred to as the "Biomonitoring (BM) Database"), which were subject to statistical analysis. A third dataset was developed by assembling TP, Chl-a, BOD_5, and pH data from EPA's environmental data system called STORET (STOrage and RETrieval) and is herein referred to as the "STORET" dataset.

A detailed listing of all monitoring sites, river morphometric characteristics, drainage area and stream order is provided in Exhibit EU-1. A listing of sites and example pictures (Table 3 and Table 4) provide context for the following discussion. Detailed explanation of field methods, data reduction methods, and data summaries from these studies are presented in Exhibits EU-1 and EU-3. Summer-mean RN data were the basis for establishing many of the interrelationships described in the next section.

Table 3. River study sites for 1999-2006. Site ID numbers and study years noted. Example pictures at right.

Basin / River	Station ID	Study Year(s)
Rainy		
Big Fork	BF-46	2006
Little Fork	LF-21	2006
Red		
Red	RE-536	2000
Red	RE-452	2000
Red	RE-403	2000
Red	RE-298	2000
Red Lake	RL-1	2006
Red Lake	RL-75	2006
Wild Rice	WR-1	2006
Wild Rice	WR-200	2006
Buffalo	BUFF-10	2006
Buffalo	BUFF-01	2006
Otter Tail	OT-1	2006
Minnesota		
Blue Earth	BE-100	2000
Blue Earth	BE-94	1999, 2000
Blue Earth	BE-73	1999, 2000
Blue Earth	BE-54	1999, 2000, 2001
Blue Earth	BE-18	1999, 2000
Upper Miss.		
Crow Wing	CWR-72	1999, 2000, 2001
Crow Wing	CWR-35	1999, 2000
Mississippi	UM-1056	2000
Mississippi	UM-1029	2000
Mississippi	UM-1004	1999
Mississippi	UM-965	1999
Mississippi	UM-953	1999, 2000
Mississippi	UM-895	1999, 2000
Mississippi	UM-872	1999, 2000, 2001, 2006
Rum	RUM-18	1999, 2000, 2001, 2006
Rum	RUM-34	1999, 2000
Crow	CR-0.2	1999, 2000
Crow	CR-23	1999, 2000, 2006
North Fork	CRN-2.33	1999, 2000, 2001, 2006
South Fork	CR-44	2001, 2006

Big Fork

Wild Rice

Rum (RUM-18)

Crow (CR-23)

Blue Earth (BE-54)

Table 4. River study sites for 2008. Example pictures at right

Basin/ River	Bio Field #	STORET Site #
Lower Miss.		
N. Branch Root	08LM012	S004-825
S. Branch Root	08LM002	S004-829
Bear Creek	08LM014	S004-827
Wells Creek	08LM127	S001-384
Vermillion River	08LM114	S000-896
Minnesota		
Maple River	08MN003	S002-427
Rice Creek	08MN004	S002-431
Le Sueur River	08MN035	S003-860
Big Cobb	08MN005	S003-446
Upper Miss.		
Getchell Creek	00UM039	S003-289
Sauk River	08UM025	S000-284


North Branch Root


Bear Creek


Vermillion


Wells


Maple

Dataset Development

Several different datasets were used to develop nutrient criteria and define proposed WQSs from biological information (Table 5). The purpose of these multiple datasets was to examine different patterns between regions in the state, stream size, and different nutrient data sources. Patterns among northern, central, and southern regions were assessed to determine if different criteria should be proposed for these areas of the state. Differences between stream sizes were also assessed to determine if different criteria were justified for these stream classes. This is important because differences in the presence or effect of the sestonic chlorophyll could result in different responses by biological communities. Different sources of nutrient data were also examined to determine if a similar relationship was observed between nutrient enrichment and the response of the biological community. Similar threshold concentrations developed from these many datasets also provided greater confidence in the final criteria used as the foundation for the standards.

Three sets of data were used to develop water quality threshold concentrations from fish and invertebrate data: River Nutrient study, STORET, and Biomonitoring data. The names for these datasets refer to the source of the water quality data. Some of these datasets were large enough to partition by stream size and region in order to examine these patterns. The STORET and Biomonitoring datasets were divided by region (North, Central, and South) and the biomonitoring dataset was further divided by stream size (wadeable, nonwadeable). Stream size class was determined by watershed area with streams with drainages <500 mi^2 considered **"wadeable"** whereas those >500 mi^2 were considered **"nonwadeable"**. The regional classification for the biomonitoring dataset was based on Level III ecoregions (see Figure 5).

The River Nutrient dataset is from a study specifically assessing the impact of nutrients on Minnesota streams. From the River Nutrient dataset, total phosphorus, total nitrogen, chlorophyll-a, BOD_5, and DO flux was assessed against biological data. The River Nutrient data consisted of both wadeable and nonwadeable streams although this dataset consisted largely of nonwadeable streams. These sites were located throughout the state of Minnesota and included sites from different ecoregions. Due to the relatively small size of the dataset, it could not be assessed regionally or by stream size.

The STORET dataset came from the EPA's environmental data system called STORET. The STORET data comes from a variety of sources including agencies and individuals. The STORET dataset included total phosphorus, chlorophyll-a, and BOD_5 data. Nutrient data from STORET were downloaded from EPA's STORET site. Water quality data was only used if:

- Measurements made from June to September
- Appropriate sampling and lab techniques were used and
- Water quality measurements made within five years of biomonitoring sampling

Water quality data from the biomonitoring data set came from water chemistry grab samples that were collected at the same time as biological monitoring. Only total phosphorus was available from this dataset; however, because of the large size of the dataset and the fact that water quality sampling occurred concurrent with biological sampling it was a useful dataset.

For all three datasets, the biological data used in the analyses came from data collected as part of the MPCA biomonitoring activities. Sites identified as channelized (*i.e.,* >50% of reach channelized) during biological sampling were excluded from the analyses, to reduce the effects of habitat modification on the analytical results. To avoid anomalous biological samples, sites that were sampled for biology during high flows were also not included in analyses. The proposed standards were developed for warmwater streams so data from coldwater streams were also removed from all datasets.

Table 5. Numbers of collections in each dataset used to assess relationships between water quality and biological measures (*Most sites are nonwadeable).

Data Source	Region	Stream Size	WQ Variable	Fish	Invertebrates
STORET	North	All	BOD_5	25	10
STORET	Central	All	BOD_5	33	26
STORET	South	All	BOD_5	53	38
River Nutrient	Statewide	All*	BOD_5	22	16
River Nutrient	Statewide	All*	DO Flux	25	20
River Nutrient	Statewide	All*	Chlorophyll-a	31	25
River Nutrient	Statewide	All*	TP	31	25
Biomonitoring	North	Wadeable	TP	346	277
Biomonitoring	North	Nonwadeable	TP	81	49
Biomonitoring	North	All	TP	427	326
Biomonitoring	Central	Wadeable	TP	315	247
Biomonitoring	Central	Nonwadeable	TP	53	32
Biomonitoring	Central	All	TP	368	279
Biomonitoring	South	Wadeable	TP	230	161
Biomonitoring	South	Nonwadeable	TP	49	29
Biomonitoring	South	All	TP	280	190

Reference condition analysis provided a complimentary approach and was consistent with EPA guidance. Central to the reference condition analysis is the identification of stream sites that are least or minimally disturbed using an *a priori* measure of condition independent of the water quality parameters of interest. These models should not be based on water quality or biological parameters, but rather should employ land use and other measures of human activity in a watershed or stream reach. Minnesota has developed an index to measure the degree of human activity in a watershed upstream of stream monitoring site and within the stream monitoring reach called the Human Disturbance Score (HDS). Further details on HDS development may be found in Exhibit EU-1.

TP, chlorophyll-a, and BOD_5 from the summer index period and from 1990-2012 were queried from STORET. Average values of these measures were determined for Assessment Units (AUIDs) and associated with HDSs to yield the values used in the reference condition analysis. AUIDs were classified as “reference” or “non-reference” and cumulative distributions were developed by parameter and region, when adequate data were available.

Correlations among Nutrients and Biological Indicators: Spearman Correlation and Scatterplots

The measurement of diel fluctuation of dissolved oxygen (DO), temperature, pH, and specific conductivity at select river nutrient study sites was an integral part of our approach for understanding how nutrients, sestonic algae, DO and related factors may affect stream metabolism and overall stream health (Figure 3). Diel DO fluctuation, also referred to as daily DO range, has been used as an indicator of nutrient over-enrichment by other states (*e.g*. Ohio) in their river nutrient criteria development efforts (Miltner 2010; Exhibit EU-25). Measurements targeted mid-late summer when river flow is often stable and water temperature reaches its peak for the year. Lower flow allows for longer water residence time which, when combined with warm temperatures, favors sestonic algal growth. Warm temperatures also reduce DO solubility and the combined effects of large DO diel swings (because of algal photosynthesis and respiration), warm temperatures, and related factors stress stream biota. Details on sonde deployment and related factors are found in Exhibits EU-1, EU-2, and EU-3. Sonde deployment varied among the three years as follows: 2000 5-8 days, 2006, 12-15 days, and 2008 4-9 days (Table 6). A data summary from these studies (Table 6) provides the reader with the range of values encountered and differences among sites and years, which is of value as these measures are discussed in more detail herein. River names that correspond to site designations are in Table 3 and Table 4.

Table 6. 2000, 2006, and 2008 diel monitoring sites. Summary of dissolved oxygen (DO), pH, temperature, specific conductivity, and sonde deployment dates.

River/site		**DO**	mg/L		**pH**	SU		**Temp.**		C	**Cond.**	umhos	
2000	Diurnal dates	Min DO	Max DO	Mean Flux	Min pH	Max pH	Mean flux	Min.	Max.	Med.	Min.	Max.	Med.
CWR-70	8/16 - 8/22	5.8	10.5	4.3	8.0	8.8		18	24	20	290	302	298
CWR-35	8/16 - 8/22	6.5	9.5	2.5				17	23	20	374	394	389
UM-1056	8/10 - 8/15	6.2	7.5	0.5	8.1	8.3		22	25	24	285	295	290
UM-872	8/10 - 8/15	4.5	10.0	3.5	8.3	8.8		26	29	27	380	400	389
RUM-34	8/8 - 8/14	6.3	12.0	4.2	8.1	8.6		22	26	25	297	338	323
RUM-18	8/9 - 8/14	6.0	12.8	4.1	8.4	9.3		22	27	25	260	360	332
CR-23	8/9 - 8/14	5.5	13.0	5.1	8.1	8.8		23	28	26	590	680	651
CR-03	8/9 - 8/14	5.5	13.5	6.1	8.4	8.8		23	28	26	510	620	575
BE-73	8/3 - 8/7	6.5	16.0	6.7	8.0	8.5		22	25	23	530	630	590
BE-54	8/3 - 8/7	6.5	15.0	6.3	7.9	8.5		22	25	24	555	630	588
RE-536	8/15 - 8/22	7.0	9.0	1.4	8.2	8.4		19	26	22	400	650	547
RE-452	8/15 - 8/22	6.5	7.7	0.5	8.2	8.3		21	26	22	500	580	548
2006													
BF-46	7/26 - 8/9	6.1	10.4	2.4	8.2	8.8	0.2	21	29	24	264	297	277
LF-21	7/26 - 8/9	6.4	9.1	0.9	8.0	8.3	0.2	21	28	24	310	342	320
RL-1	7/25 - 8/8	5.1	8.2	1.1	7.9	8.4	0.2	23	27	25	284	297	289
RL-75	7/25 - 8/8	5.0	10.0	1.8	7.7	8.2	0.2	21	28	24	284	294	288
WI-3	7/25 - 8/8	6.3	9.1	1.6	8.3	8.5	0.1	22	32	26	546	612	590
WR-200	7/25 - 8/8	5.1	9.8	2.7	8.1	8.4	0.2	20	32	25	491	573	559
Buff-10	7/26 - 8/7	4.9	11.4	4.4	7.7	8.3	0.3	17	28	22	402	689	626
Buff-01	7/26 - 8/8	5.3	10.2	3.0	8.3	8.7	0.2	22	29	26	528	666	615
OT-1	7/26 - 8/7	6.2	10.9	2.5	8.3	8.8	0.2	23	32	27	408	467	428
UM-872	7/26 - 8/10	5.8	18.2	6.8	8.3	9.1	0.3	25	32	28	173	468	394
RUM-18	7/26 - 8/10	5.5	12.9	4.3	8.2	9.4	0.4	23	31	26	260	371	332
CR-23	7/27 - 8/9	4.0	16.4	6.5	7.9	8.9	0.5	24	32	28	493	685	612
2008													
S. Branch Root	8/21 - 8/28	8.4	13.8	3.8	7.7	8.2	0.2	14	21	17	587	608	599
N. Branch Root	8/21 - 8/28	7.7	13.4	4.1	7.7	8.1	0.2	16	23	19	482	586	575
Bear Creek	8/5 - 8/14	6.7	12.2	3.9	7.7	8.1	0.3	17	24	21	527	567	555
Vermillion River	8/11 - 8/20	7.2	10.6	2.5	7.9	8.3	0.2	15	25	19	520	597	587
Wells Creek	8/21 - 8/26	8.7	10.7	1.0	8.2	8.3	0.1	12	22	17	452	578	477
Maple River	8/5 - 8/13	6.7	13.5	4.7	8.2	8.8	0.4	20	28	24	436	547	502
Rice Creek	8/5 - 8/13	4.8	12.9	5.6	8.2	8.9	0.4	18	28	23	488	588	503
Big Cobb	8/5 - 8/13	6.4	11.7	4.0	7.9	8.6	0.3	20	29	24	489	512	523
Le Sueur	8/5 - 8/13	6.5	12.5	2.9	6.0	8.6	0.7	17	32	24	355	1010	515
Sauk	8/11 - 8/14	6.6	11.3	3.2	8.0	8.5	0.4	20	23	22	443	574	546
Getchell	8/11 - 8/14	2.2	7.2	3.2	7.7	8.2	0.3	20	23	22	595	631	611
Wells (repeat)	8/11 - 8/14	9.5	11.3	1.2	8.0	8.3	0.1						
Minimum	**2 days**	**2.2**	**7.2**	**0.5**	**6.0**	**8.1**	**0.1**	**12**	**21**	**17**	**173**	**294**	**277**
Maximum	**15 days**	**8.7**	**18.2**	**6.8**	**8.4**	**9.4**	**0.7**	**26**	**32**	**28**	**595**	**1010**	**651**
Median	**8 days**	**6.2**	**11.3**	**3.5**	**8.1**	**8.5**	**0.2**	**21**	**28**	**24**	**443**	**574**	**523**
25th %	**6 days**	**5.4**	**9.9**	**2.4**	**7.9**	**8.3**	**0.2**	**18**	**25**	**22**	**304**	**383**	**361**
75th %	**13 days**	**6.5**	**13.0**	**4.3**	**8.2**	**8.8**	**0.3**	**22**	**29**	**26**	**515**	**625**	**588**
Count	**35**	**35**	**35**	**35**	**34**	**34**	**23**	**35**	**35**	**35**	**35**	**35**	**35**

D. Development of Numeric River Eutrophication Standards

A systematic approach was used to derive the river eutrophication standards. Multiple datasets as described in Exhibit EU-1 were used to establish interrelationships among nutrients, algae, dissolved oxygen, and aquatic biota. The conceptual model (Figure 3) provides a “road map” for the overall process.

Relationships among nutrients and chlorophyll

Initial studies in 1999 and 2000, as documented in Exhibits EU-3 and-4, demonstrated significant, consistent, and positive relationships between TP and sestonic chlorophyll in Minnesota rivers (excluding the Red River). The significant relationship between TP and chlorophyll is consistent with a worldwide study conducted by Van Nieuwenhuyse and Jones (1996; in Exhibit EU-4) and a Canadian study by Basu and Pick (1996; in Exhibit EU-4). In each of these studies, linear regressions (log-log) of TP and total chlorophyll (Chl-T) exhibited significant R^2 values of 0.72 and 0.76 respectively.

These studies also prompted our initial emphasis on total chlorophyll (Chl-T) rather than Chl-a (e.g. Heiskary and Markus 2001). Chl-T is a measure of the living and dead algal biomass and is derived as the sum of Chl-a and pheophytin (e.g. Table 12 in Exhibit EU-1). We later transitioned to use of Chl-a as the basis for data analysis and criteria development, as indicated by direct reference to Chl-a. Chl-a represents the “living” algal biomass and is more routinely used in eutrophication assessment and modeling. This placed an emphasis on viable algae, which is consistent with Minnesota’s lake eutrophication criteria.

Predictable and significant relationship between TP and chlorophyll-a were integral to development of Minnesota’s lake eutrophication standards. The TP and chlorophyll relationship for medium to large Minnesota rivers is also highly significant but is different from the relationship for lakes (Figure 9). While both exhibit a high R^2 the lake relationship indicates that lakes produce greater Chl-a per unit TP than do rivers. For example, at a TP of 100 µg/L the predicted Chl-a for lakes is ~50 µg/L, whereas for rivers it is ~25 µg/L. The 95 percent confidence interval (CI) for lakes is slightly smaller than that for rivers. However, in terms of the 95 percent prediction interval (PI) the lake and river equations are relatively similar (Figure 9).

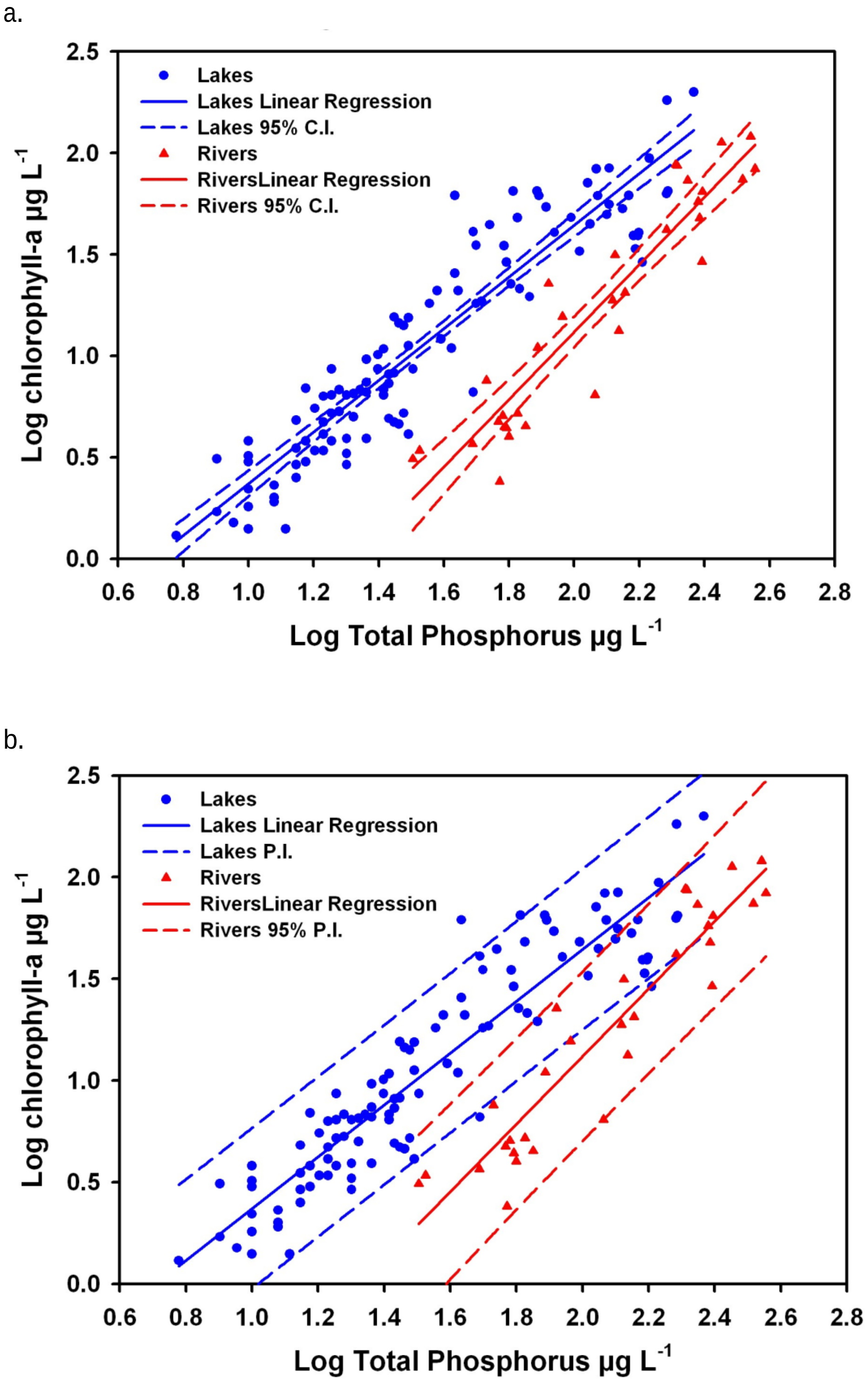


Figure 9. Total phosphorus and chlorophyll-a relationships for Minnesota rivers as compared to lakes. Confidence interval (a) and prediction interval (b) noted for each regression equation. Lake equation from Heiskary and Wilson (2008).

The expansion of the datasets since the original studies in 1999 and 2000 and observed variability in Chl-a relative to TP, led us to include data from all summers where river nutrient-related monitoring had been conducted to develop a more robust relationship between TP and chlorophyll. A linear regression was developed based on log-transformed data for nonwadeable rivers (which were the primary focus for river nutrient criteria development) and a high R^2 value (0.81) was noted (Figure 10). With this analysis we shifted emphasis to corrected Chl-a (corrected for pheophytin) as the parameter to be used for criteria establishment, since corrected Chl-a allows for more consistent linkage with previous work on lakes and Minnesota's promulgated lake standards.

Exhibit EU-1 provides additional regression analyses to help define the relationship among TP and sestonic Chl-a. For example, flow has a significant effect on sestonic chlorophyll levels, whereby the amount of sestonic chlorophyll is greater in drier years or years with lower flows. In some cases, higher discharge appears to be responsible for relatively low levels of chlorophyll. Regardless of discharge, most sites with TP greater than 150 µg/L have sestonic chlorophyll levels above 40 µg/ L indicating that annual variation in discharge only has a moderate effect on the levels of chlorophyll in nonwadeable rivers and is most pronounced at very high flows (Exhibit EU-1).

Other factors that cause variation in the relationship between TP and Chl-a include turbidity, stream size, and anomalous features (*e.g.,* impoundments). Based on Figure 10 all wadeable sites fall on or below the regression line. For sites below the regression line this implies they produce less sestonic Chl-a per unit TP as compared to nonwadeable (larger, higher order) sites. As noted previously, algal production in these shallow, low-order sites is in the form of periphyton rather than seston. Other effects on chlorophyll noted previously (Exhibit EU-4) include extreme turbidity. For example, the very nutrient-rich Red River main-stem sites often do not have high levels of sestonic chlorophyll due to the high turbidity (Exhibit EU-3).

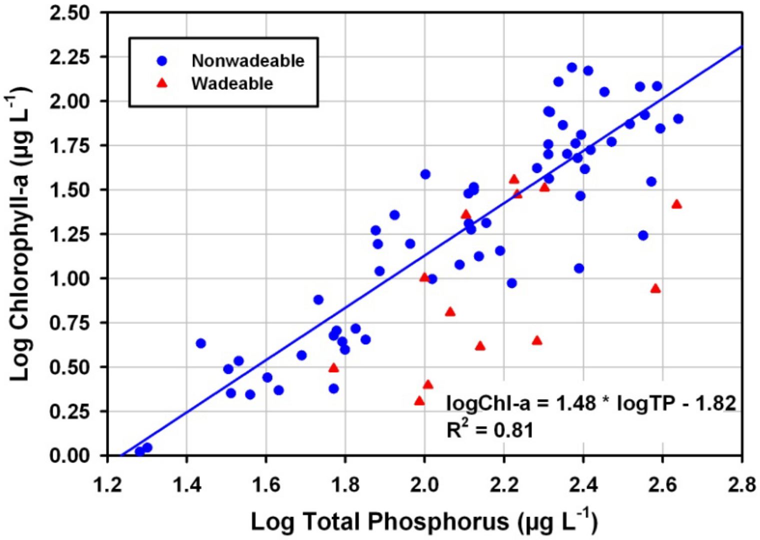


Figure 10. Relationship between log transformed TP and chlorophyll-a for River Nutrient Study data. (least squares regression line based on nonwadeable river sites; nonwadeable streams: n=63; wadeable streams: n=13).

TP and total Kjeldahl Nitrogen (TKN) are highly correlated based on the River Nutrient data (Figure 11). This was anticipated since sestonic algae comprise much of the organic N in the TKN measurement. TP and TN (TN=TKN + nitrate N) are not highly correlated (Figure 11) however, because nitrate N accounts for much of the TN as TN exceeds 2-3 mg/L (Figure 11). A significant linear relationship between TKN and Chl-a was noted based on the 1999 and 2000 River Nutrient data (Exhibit EU-4) and was re-affirmed in subsequent study. There was no linear relationship between TN and Chl-a based on the combined 1999, 2000, 2006 and 2008 data (Figure 12). This is primarily because of nitrate-N, which contributes to the elevated TN (Figure 11). In general, based on the RN sites TKN is the majority of TN at concentrations less than about 1.5-2.0 mg/L (Exhibit EU-1). As TN increases above 2.0 mg/L, nitrate-N is an important contributor to TN and often exceeds TKN concentration when TN exceeds ~3-4 mg/L (Figure 11). The lack of relationship between TN and chlorophyll is particularly evident in wadeable streams and is a function of low sestonic chlorophyll and high concentrations of nitrate-N in these systems. In general, elevated nitrate-N is found primarily in the highly drained watersheds of the Western Corn Belt Plains ecoregion (Exhibit EU-1).

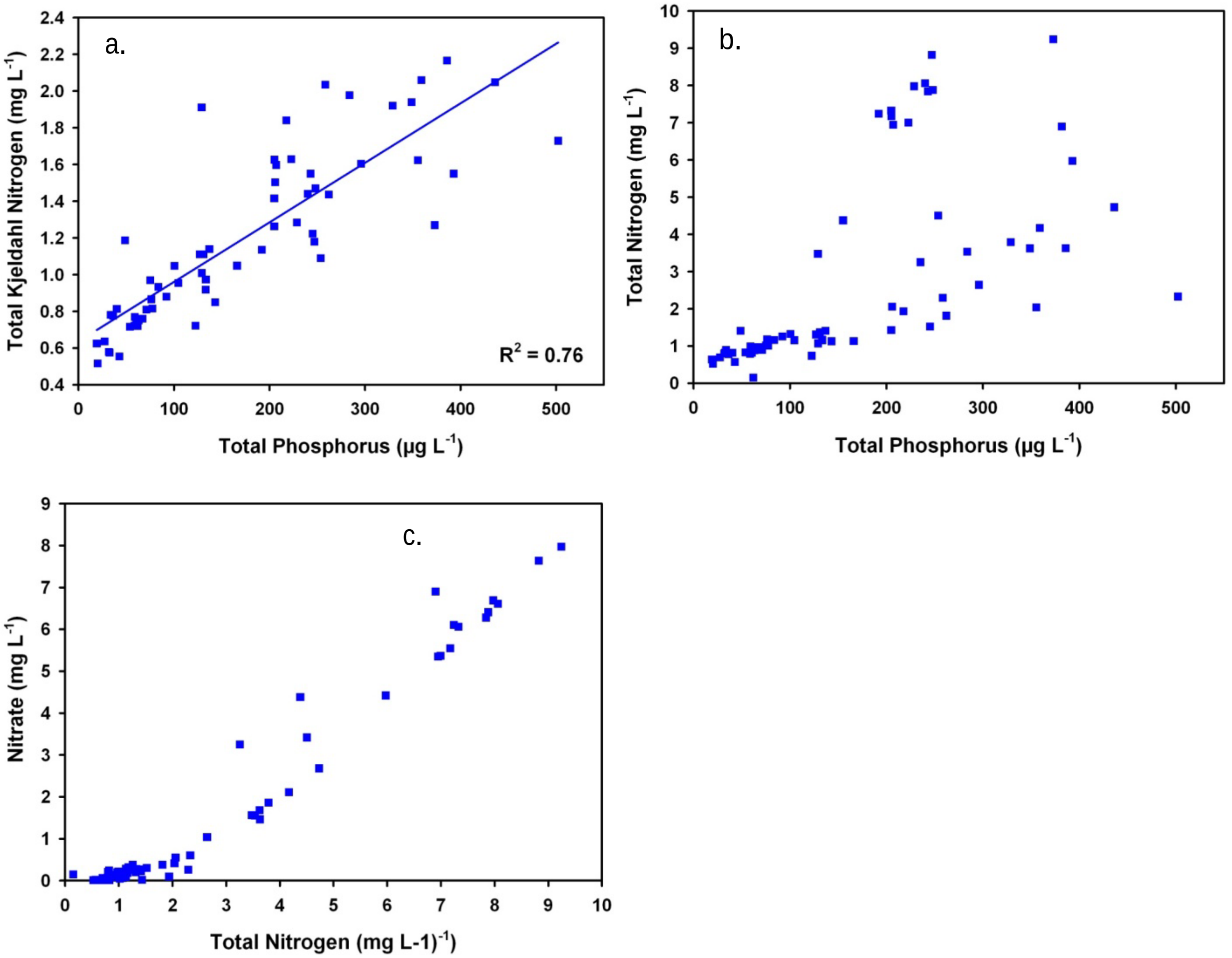


Figure 11. Relationship among a) TP and TK, b) TP and TN, and c) nitrate-N and TN based on River Nutrient Study data (watersheds > 500 mi2, Red River sites removed; a) n = 63, b) n= 65, c) n=66).

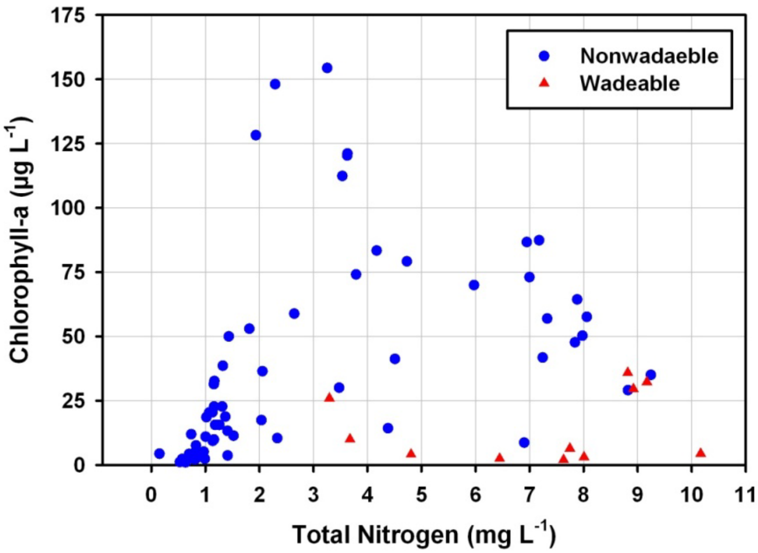


Figure 12. Relationship between total nitrogen and chlorophyll-a using River Nutrient Study data (nonwadeable streams: n=66; wadeable streams: n=11).

Correlations between Nutrients and Biological Indicators: Spearman Correlation and Scatterplots

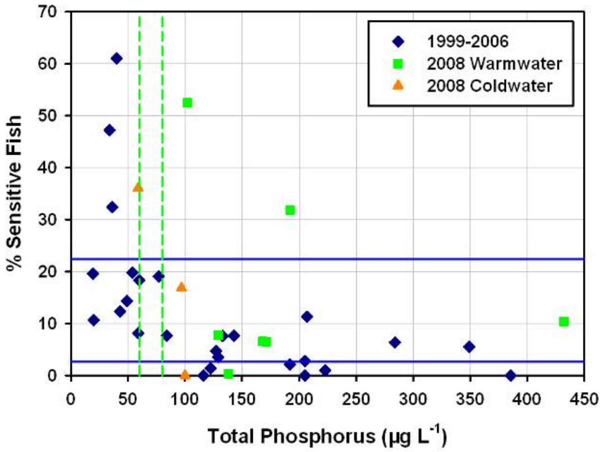
Because eutrophication of rivers can alter biological community composition and decrease biotic integrity, we have placed our emphasis on making associations among excess nutrients and impacts on stream biota (Exhibit EU-1). The generally described mechanism for impact of nutrients on streams is stimulation of excess primary productivity, which can degrade habitat, alter food resources, and deplete DO (Wang *et al.* 2007). This is demonstrated in the conceptual model (Figure 3). Miltner and Rankin (1998; in Exhibit EU-1) found a deleterious effect on fish communities when TN and TP levels exceeded natural background in lower order streams but found no affect in higher order streams. At that time, they indicated that not much is known about the response of fish communities in large rivers to the cascade of effects caused by an imbalance of nutrients. Rankin *et al.* (1999) adds, “nutrients, while essential to the functioning of healthy aquatic ecosystems, can exert negative effects at much lower concentrations by altering trophic dynamics, increasing algal and macrophyte production (Sharpley *et al.* 1994), increasing turbidity (via increased sestonic algal production), decreasing average dissolved oxygen (D.O.) concentrations, and increasing fluctuations in diel D.O. and pH”. Rankin *et al.* (1999) adds, “Such changes, caused by excessive nutrient concentrations resulting in shifts in species composition away from functional assemblages of intolerant species, benthic insectivores, and top carnivores (*e.g.*, darters, insectivorous minnows, redhorse, sunfish, and black basses) typical of high quality warmwater streams towards less desirable assemblages of tolerant species, niche generalists, omnivores, and detritivores (*e.g.*, creek chub, bluntnose minnow, white sucker, carp, and green sunfish) typical of degraded warmwater streams.” Miltner (2010; Exhibit EU-25) notes, in his rationale for deriving nutrient criteria for small Ohio rivers, that the macroinvertebrate communities were related to benthic chlorophyll-a and both minimum DO and 24 hour DO range (=diel flux).

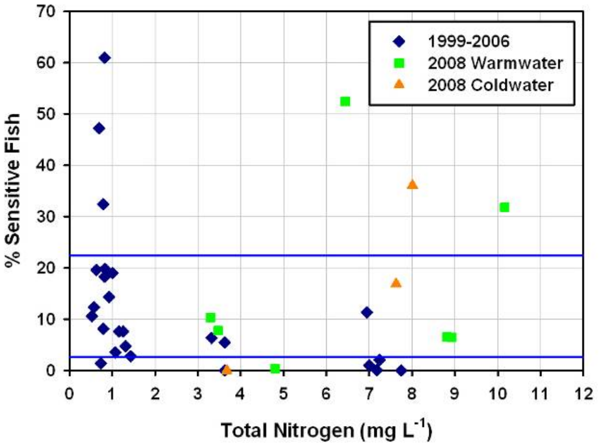
Correlations among TP, TN, chlorophyll, and DO flux were firmly established based on early work (*e.g.*, Exhibits EU-3 and -4). An additional emphasis of the 2000, 2006, and 2008 studies was to explore how various biological metrics (*e.g.*, fish and invertebrate metrics) correlated with TP, TN, sestonic chlorophyll, and DO flux. Spearman correlation (R_S) analysis provided an overall summary for the four primary variables and how they relate to a variety of chemical, physical and biological measures (Table 15; Exhibit EU-1).

Strong correlations were evident for many of the biological metrics relative to the four primary variables based on data from 1999, 2000 and 2006 studies. The majority of the biological metrics exhibit inverse (negative) correlations with nutrients, chlorophyll, and DO flux. In some instances, the correlation coefficients (R_s) of the biological variables are higher than many of the chemical and physical variables relative to the four primary variables. Among the more prominent biological measures, as shown by high R_s were: number of invertebrate taxa, number of Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa, fish IBI, number of sensitive fish taxa, percent sensitive fish, and relative abundance of amphipods.

Some fish and invertebrate metrics exhibit strong positive relationships with nutrients, chlorophyll, and/or DO flux. These positive relationships are observed in metrics that increase with greater stress and include number of tolerant invertebrate taxa, omnivorous fish (number of taxa and percent of community), and others as noted in Exhibit EU-1. Where positive relationships are observed, there is a less consistent response among the four variables, in contrast to the negative (inverse) relationships. For example, the number of invertebrate taxa exhibits a strong negative correlation with all four variables. Certain invertebrate feeding and functional groups also exhibit strong correlations; however, these vary from negative to positive dependent on the primary variable they are associated with, and include number of clinger taxa, number of collector / gatherer taxa and to a lesser degree number of collector/filterer taxa.

The Spearman correlation analysis provided a basis for a more detailed examination of select biological metrics relative to the four primary variables. For this purpose, scatterplots were used to examine the relative relationship among various biological metrics and TP, TN, Chl-a, and DO flux. Among the most responsive metrics were invertebrate taxa richness, % sensitive invertebrates, % sensitive fish, and % piscivorous fish. While numerous examples were pursued in Exhibit EU-1, a subset is provided here to demonstrate use of this technique (Figure 13). Distribution statistics for the various metrics were used as a basis to suggest where important shifts in the various metrics may be occurring, with an emphasis on those values that fall into the lower and upper quartiles for the respective metric.





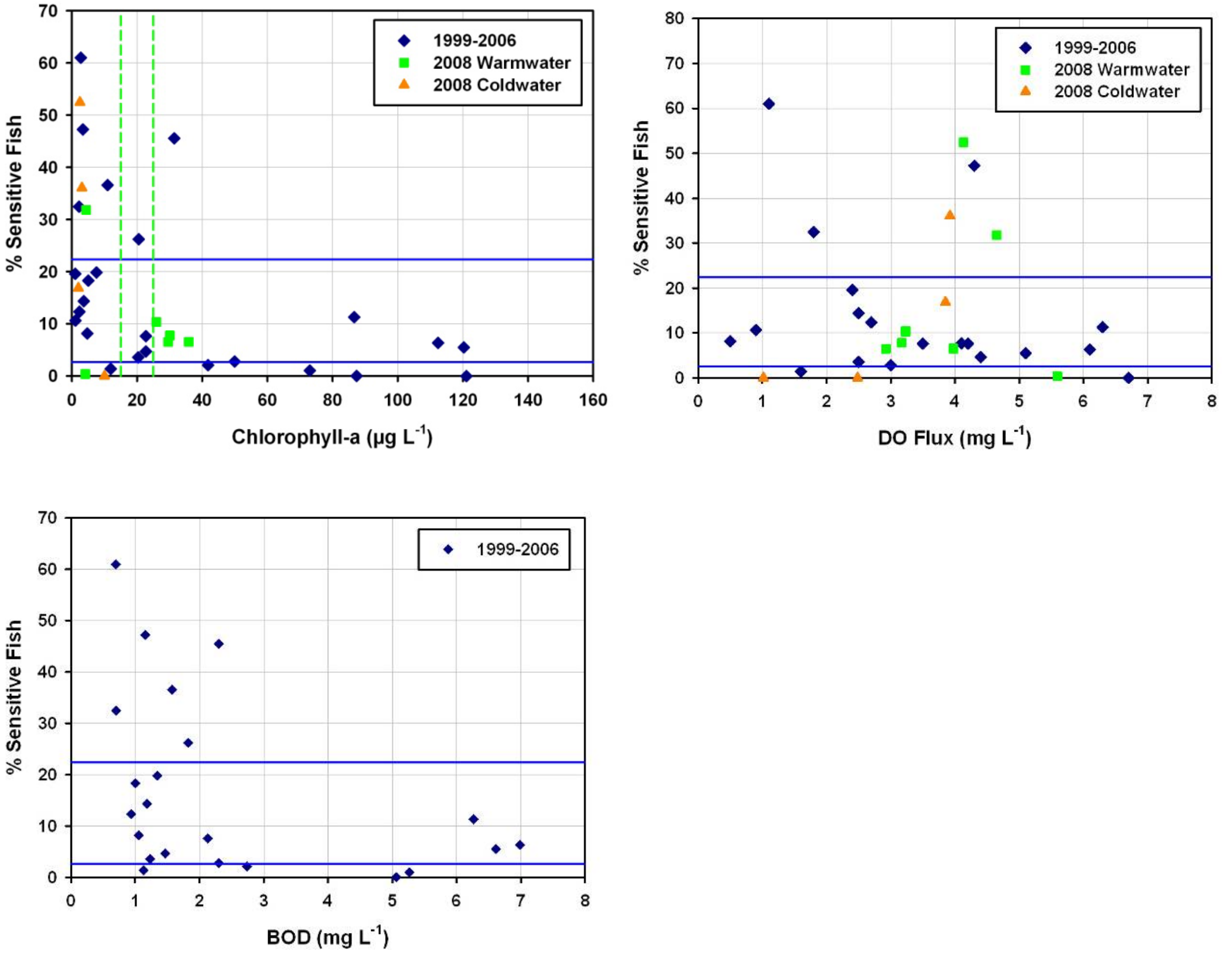


Figure 13. Fish metric relative to TP, TN, chlorophyll-a, DO flux and BOD5 (% sensitive fish used in this example). 25th – 75th percentiles (blue horizontal lines) for nonwadeable rivers noted. Green vertical bar represents a shift in metric distribution (fit by eye).

Visual inspection of relationships and shifts in the distribution of the metric (% sensitive fish in this case), relative to changes in TP, were useful for defining the relationship between two variables (Figure 13). This exercise was repeated for several biotic metrics and observations (Exhibit EU-1). With respect to % sensitive fish, shifts in the distribution of the metric occurred over a range from 60-80 µg/L TP. At TP ~ 100 µg/L or more, percent sensitive fish comprised 10 percent or less of the catch and metric values begin to fall below the 25th percentile. Based on the 1999-2006 data the percent sensitive fish fall to 10 percent or less as TN exceeds ~1.0-1.5 mg/L (Figure 13); however, there were a few exceptions among the 2008 warmwater and coldwater sites. Number of sensitive fish taxa exhibited the highest inverse relationship for the fish metrics, while percent omnivore fish was among the highest positive relationships relative to Chl-a. As chlorophyll-a increases above 15-25 µg/L, percent sensitive fish comprise 10 percent or less of the catch and above 40 µg/L values fall below the 25th percentile (Figure 13). Sensitive fish exhibit a wide range of values at DO flux less than about 4 mg/L; however, as DO flux increases above ~4.5 mg/L, sensitive fish decline to 10 percent or less of the sampled population (Figure

13). As DO flux increased above 4.5 mg/L, tolerant species increased as a portion of the total and values were above the 75th percentile for this metric (Exhibit EU-1).

BOD_5 is an important measure of the potential stress on a biological community as there is a well-documented relationship between BOD_5 and biological condition. There is a strong relationship between sestonic chlorophyll and BOD_5 presumably due in part to the increase in organic matter available to heterotrophs because of algal death and algal respiration. Mallin *et al.* (2006; Exhibit EU-40) acknowledge a highly significant relationship among sestonic Chl-a and BOD_5 and note that BOD_5 can be increased in some waterbodies by direct stimulation of heterotrophic microbial flora by anthropogenic nutrient loading. The increase in BOD_5 can lead to lower DO levels and greater diel DO flux and may indicate a shift in the food resources in the system. These responses lead to declines in biological condition and data from Minnesota indicates that there is a strong response of biological metrics to increases in the BOD_5. Many biological metrics indicated a negative shift in biological condition at ~2-3 mg/L BOD_5 (Exhibit EU-1).

Identification of Nutrient Threshold Concentrations: Quantile Regression and Changepoint Analysis

The use of field-collected biological data in developing chemical criteria is often difficult due to complex relationships among chemical and physical measures and the biota. A relatively new analysis method, called quantile regression, has been used as a tool to identify threshold concentrations and to develop criteria to protect aquatic life. Quantile regression is well suited for the wedge-shaped plots that are common with biological monitoring data (Terrell *et al.* 1996, Koenker & Hallock 2001, Cade & Noon 2003, Bryce *et al.* 2008; in Exhibit EU-1). These wedge-shaped plots are the result of the limitation of biological attributes (*e.g.,* taxa richness) by the variable of interest on the outer or upper edge of the wedge (Figure 14; Bryce *et al.* 2008). Limitations to biological measures inside the wedge are caused by other unmeasured variables (Figure 14). Further explanation and limitations of quantile regression are found in Exhibit EU-1.

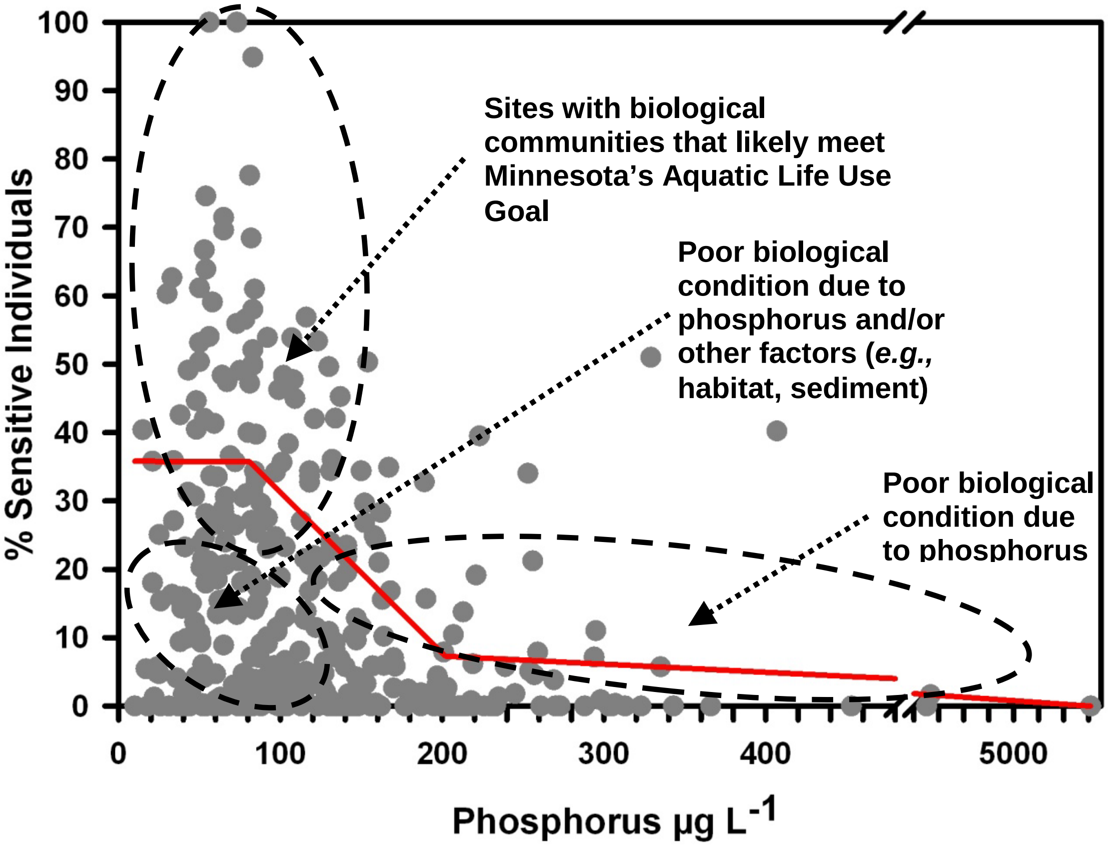


Figure 14. Relationship between phosphorus and the percent of sensitive fish for central streams with additive quantile regression smoothing line (red line). This is an example of the typical wedge-shaped data to which quantile regression is suited.

Regression tree or changepoint analysis is another technique that can be used to identify thresholds where biological condition declines in data with unequal variance. This analysis splits that data into groups where the sites within that group are more homogeneous (De'ath & Fabricius 2000 in Exhibit EU-1). For example, groups may have different mean values of the response variable. The location of the splits or nodes indicates a change between groups that may suggest a threshold has been crossed.

The relationships between different water quality variables and biological measures were assessed with the above statistical approaches. Water quality variables assessed included nutrients (e.g., phosphorus) and proximate stressors (e.g., chlorophyll-a, BOD_5 and DO flux). Proximate stressors provide a more direct determination of the impact of these variables on biological condition as they have a direct influence on the composition and health of biological communities. The impact of nontoxic levels of nutrients has an indirect impact on the biology (i.e., cause variable → response variable → biological impact) so the causal association between biological health and phosphorus levels may be less clear. However, the use of methods including quantile regression and changepoint analysis allow the assessment of these causal associations. In addition, an understanding of how phosphorus influences proximate stressors allowed the determination of phosphorus concentration thresholds. In this analysis, we used quantile regression and changepoint analysis to identify biological threshold concentrations for various water quality variables. These values were used in conjunction with water quality relationships to determine phosphorus levels that will be protective of aquatic life goals.

Before quantile regression and changepoint analyses were performed, it was necessary to select appropriate response measures or biological metrics. The selection of a subset of metrics was made using several methods. Spearman rank correlations were examined to identify metrics with a strong relationship between the total phosphorus and biological metrics (Exhibit EU-1). Some of the metrics that were significantly correlated were eliminated due to the redundancy of metrics and the relevance of the metrics to nutrient enrichment (i.e., can a mechanism between nutrient enrichment and the response in that metric be identified). Eight metrics were selected for fish and six metrics for invertebrates (Table 7).

Table 7. Fish and invertebrate metrics used to develop concentration thresholds

Fish Metrics	Invertebrate Metrics
% Sensitive	Total Taxa Richness
% Darter	Collector-filterer Taxa Richness
% Simple Lithophils	Collector-gatherer Taxa Richness
% Tolerant	EPT Taxa Richness
% Insect	Intolerant Taxa Richness
% Piscivore	% Tolerant
Taxa Richness	
% Intolerant	

A number of patterns can be observed between nutrients and the biological metrics (Brenden *et al.* 2008) although the relationship between biology and nutrients is often wedge shaped (Wang *et al.* 2007). In the Minnesota datasets, a distinct wedge with breakpoint(s) was most commonly observed. This dataset shape was associated with a sufficient disturbance gradient. The “upper plateau” generally, occurs at low levels of nutrients (stressors) and is characterized by high variability in the biological metric. The steep portion of the wedge occurred at moderate levels of the nutrient or stressor and indicated that a threshold had been crossed and that biological condition was declining. At higher levels of nutrients or stressors there were generally low biological metric scores indicating that the response variable had largely reached bottom and was not declining or declining at a much slower rate. Additive Quantile Regression Smoothing (AQRS) and changepoint analyses were both effective with this type of dataset. The fit of the quantile regression and the ability of the changepoint analysis to identify thresholds were assessed and analyses with a poor fit or those not identifying relevant thresholds were omitted. For some datasets, no analysis was appropriate, as a gradient sufficient for these analyses was not evident in the available datasets. For example, the southern region often had too few sites with low disturbance and did not show a good relationship between the nutrient or stressor and the biological metrics. This suggests that most streams in this region are enriched and that additional data is needed from less enriched streams in the region to undertake an analysis.

The next step involved application of quantile regression and changepoint analyses and is described in detail in Exhibit EU-1. These techniques are well-suited to the often wedge-shaped plots that are common with field-collected biological data. Based on the previous analyses emphasis was placed on some of the more responsive metrics. These techniques were applied to both the river nutrient dataset and the much larger biomonitoring datasets. These techniques and the expansion to additional datasets are consistent with SAB recommendations to EPA (Exhibit EU-18) and EPA’s recent guidance (Exhibit EU-20). Quantile regression and changepoint analysis were also recommended by EPA reviewers (Exhibits EU-23a and -24a).

Threshold concentrations were produced for statewide, wadeable vs. nonwadeable streams, and on a region-specific basis for BOD_5, DO flux, Chl-a, TP, and TN using the two analysis methods (*i.e.,* AQRS) and changepoint) from the available datasets. Further details and limitations are addressed in Exhibit EU-1. A summary of statistics for quantile regression- and changepoint-derived ranges for threshold nutrient and stressor concentrations from the various stream classes are presented in Table 8.

Table 8. Summary statistics for threshold concentrations for total water quality variables developed from fish and invertebrate biomonitoring data using quantile regression and changepoint analyses (see Exhibit EU-1, Appendix IV for the raw threshold concentration values used to calculate these statistics; # T.C. = number of the threshold concentration values used to calculate statistics, RN = River Nutrient Study Data, STOR = STORET Data, BM = Biomonitoring Data).

Region	Range	Mean	Median	25th %ile	75th %ile	#T.C.
BOD_5 (mg^{-1})						
North (STOR)	-	-	-	-	-	0
Central (STOR)	1.5-4.1	2.8	2.2	2.1	3.8	7
South (STOR)	1.7-5.1	3.8	4.3	3.1	4.5	14
Statewide (RN)	1.9-3.9	2.9	2.5	2.5	3.7	5
DO Flux (mg^{-1})						
Statewide (RN)	3.0-4.9	3.6	3.3	3.1	3.8	4
Total Chlorophyll (μg^{-1})						
Statewide (RN)	11-62	31	31	21	35	11
Total Phosphorus (μg^{-1})						
North (BM)	33-154	72	68	44	91	26
North Nonwadeable (BM)	27-29	28	29	28	29	3
North Wadeable (BM)	33-126	66	64	48	81	22
Central (BM)	81-209	140	142	110	164	24
Central Nonwadeable (BM)	75-144	105	102	86	121	14
Central Wadeable (BM)	81-290	143	148	108	164	23
South (BM)	66-411	258	310	145	373	17
South Nonwadeable (BM)	131-199	165	165	148	182	2
South Wadeable (BM)	50-411	225	273	115	318	18
Statewide (RN)	42-233	135	136	98	168	15
Total Nitrogen (mg^{-1})						
Statewide (RN)	1.4-3.7	2.5	2.5	1.9	3.1	2

The threshold concentrations were developed from different biological metrics and biological groups, which have different responses to nutrients and stressors. As a result, the 25th percentile of these values is likely to be more relevant to the development of protective aquatic life criteria. A mean or median statistic would likely be under protective because the concentration threshold would be exceeded for approximately half of the biological metrics. The 25th percentile is appropriate because it accounts for the error that is associated with these estimates and is therefore not under protective.

A significant difference ($P = <0.0001$) between the mean threshold concentrations was identified for the different regions and river sizes. Due to an unequal number of threshold concentrations in the different groups, a Dunn's multiple comparison test was performed to determine among which groups significant differences between the mean threshold concentrations were present (SigmaPlot ver. 11; Systat Software 2008). The most obvious differences were among the regional TP threshold concentrations with criteria values increasing from north to south. The threshold concentrations for both northern river size classes were significantly different from the central and southern wadeable rivers (Figure 15). The southern wadeable streams were also significantly different from the central nonwadeable river class. In addition, threshold concentrations for nonwadeable rivers were lower than those for wadeable rivers. However, there were no significant differences between the mean total phosphorus concentration thresholds between nonwadeable and wadeable rivers within any of the regions (Figure 15). This suggests that different criteria may not be needed for different stream sizes although regionalizing criteria is justified. It is likely that a smaller proportion of wadeable streams will have poor biological condition resulting from eutrophication, but there is no indication that these streams are not affected by eutrophication. As a result, wadeable streams should not be excluded from nutrient standards. The relatively low number of threshold concentrations that could be determined for nonwadeable rivers also increases the importance of the values determined for the wadeable rivers. The low number of threshold concentrations was at least partly driven by the relatively small number of nonwadeable rivers from which data was available.

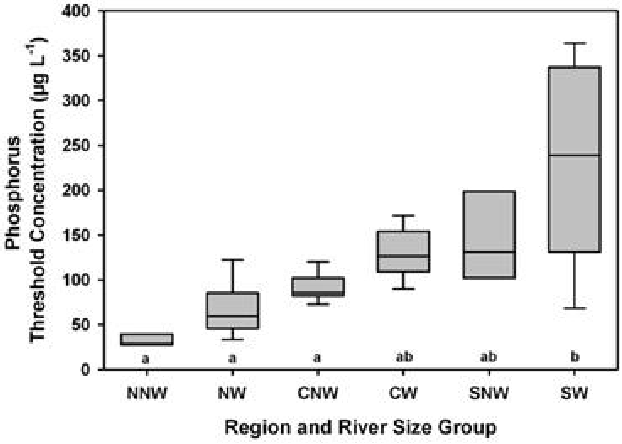


Figure 15 Box plots of phosphorus threshold concentrations for the three regions and two river sizes using 1st breakpoint or midpoint additive quantile regression smoothing and changepoint threshold concentrations (description of box plots: solid line = median, upper and lower bounds = 75th and 25th percentiles, whisker caps = 10th and 90th percentiles; n values: North Nonwadeable (NNW) = 5, North Wadeable (NW) = 25, Central Nonwadeable (CNW) = 15, Central Wadeable (CW) = 23, South Nonwadeable (SNW) = 3, Southern Wadeable (SW) = 22). Region and river size groups with significantly different ($p<0.05$) mean threshold concentrations are indicated by different letters below each box plot as determined by a Kruskal-Wallis ANOVA on Ranks with Dunn's multiple comparison test. See Exhibit EU-1 for raw threshold concentration values used to generate box plots.

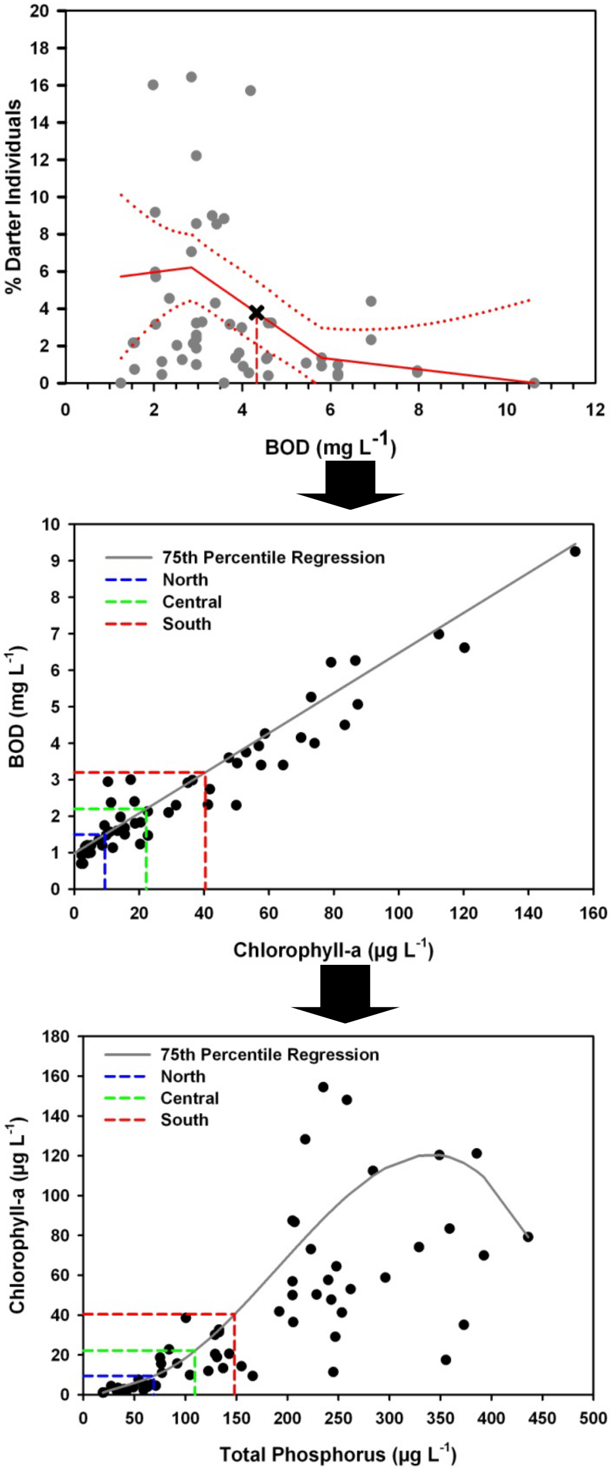
The relationship between biology and total nitrogen was also examined; however, the relationships were not strong and only a few threshold concentration values could be identified (see Table 8). These relationships are often complicated by a covariance with phosphorus (Figure 11b). Additional work would be needed to determine if eutrophication-based standards are appropriate for nitrogen. Research has indicated that nitrogen is often a limiting or co-limiting nutrient in freshwater systems (Dodds 2006, Dodds & Cole 2007 in Exhibit EU-1), which suggests that nitrogen can contribute to eutrophication in Minnesota streams.

Threshold concentrations developed using the causal association between TP and the decline in biological metrics should be considered cautiously in a "multiple lines of evidence" approach because they may be under protective of biological condition. There are a number of factors that reduce or mitigate the effect of nutrients on aquatic life in streams (e.g., shading and low residence time). As a result, some streams may support relatively high levels of nutrients with minimal impact to aquatic life.

These streams may shift the outer edge of the wedge in the nutrient-biological metric plots to the right. This shift will cause the concentration threshold to increase and may not be reflective of protective nutrient levels for streams without characteristics that mitigate the effects of nutrients on these systems. Therefore, analyses linking proximate stressors (e.g., BOD_5 and DO flux) to biological condition are a better determination of protective concentrations. These stressor concentrations still need to be linked to nutrient levels, since nutrients are a major cause of these stressors. Nutrient levels can be associated with levels of stressors using a series of regressions. Using BOD_5 threshold developed from the AQRS and changepoint analyses and 75th percentile quantile regressions for water quality variables, nutrient levels to protect aquatic life can be determined. The equation for the 75th percentile quantile regression fitted to Chl-a and BOD_5 data is provided in Eq. 7 (Exhibit EU-1). Smoothing spline regressions do not generate an equation, however the total phosphorus and Chl-a values for the fitted smoothing splines quantile regression are provided in Table 10. Unfortunately, sufficient DO flux information was not available to determine regional patterns of the impact of this stressor on the biology.

The threshold concentrations for TP developed using AQRS and changepoint analysis were similar to those derived from the serial regression of BOD_5 → Chlorophyll-a → total phosphorus (Figure 16). The 25th percentile of value from AQRS and changepoint analysis for the north was 44 µg/L and 41-78 µg/L for the serial regressions. The lower values for AQRS and changepoint analysis may be caused by the somewhat limited disturbance gradient, which resulted in lower values from the changepoint analysis. Specifically changepoint analysis may be responsive to the initial decrease in the biological metric because there is a limited disturbance gradient. When a more complete disturbance gradient is present, the changepoint often falls in the middle of the area where the metric score is most rapidly declining. The greatest difference between values was observed in the central region where the 25th percentile of TP concentration was 110 µg/L for AQRS and changepoint analysis and 83-121 µg/L for the serial regressions. As discussed previously these differences may be the result of mitigating conditions in some streams shifting the response pattern to the right in the AQRS and changepoint analyses. Southern region TP values were close with 145 µg/L for AQRS and changepoint analysis and 129-193 µg/L for the serial regressions. However, there was considerable variability in threshold concentration values (Table 8) so the results from AQRS and changepoint analyses should be treated with caution.

The use of different metrics and statistical approaches resulted in a range of concentration thresholds for a given stream class (Table 8). This range represents variability between these datasets and some of the uncertainly around these thresholds. In general, these statistical methods identify areas along a gradient of nutrients where there is a change in the biological community. These thresholds are typically not specific enough for these methods to identify the exact concentration where the community will shift or violate biological goals. Some of this variability comes from sampling variability and others come from natural differences between streams. Even though we controlled some of this natural variability through a stream classification, natural variability still exists. However, these methods do identify relatively consistent concentration ranges within stream classes, which indicate that these methods are effective tools for determining where a negative and unwanted change in the community occurs along a nutrient gradient. As a result, a number of statistics (e.g., range, mean, and quartiles) from these threshold concentrations rather than a single value are considered as part of the “multiple lines of evidence” approach used here for nutrient criteria development.



BOD_5 (25th Percentile)

North	Central	South
1.5*	2.1	3.1

Chlorophyll-a

North	Central	South
10(5)	21(13)	39(28)

Total Phosphorus

North	Central	South
72(41)	107(83)	149(129)

Figure 16 Interpolation of phosphorus levels protective of aquatic life use goals using the relationships between BOD, Chl-a, and TP. BOD thresholds established using the 25th percentile of threshold concentration values for each region. Regressions for BOD → Chl-a and Chl-a → TP were fit using 75th smoothing splines quantile regressions. The first value was interpolated from the RN data and the value in parentheses was determined using the STORET dataset. *The threshold values for BOD5 were based on the maximum values observed in this region with this the RN dataset.

Summary of Criteria Development and Synthesis with Elements of Water Quality Standards

Weigel and Robertson (2007; in Exhibit EU-1) summarize the difficulties in understanding relationships between stream biota and nutrients based on the observations of several researchers, as follows:

> *"One of the greatest impediments to understanding biotic–nutrient relations is that biota may not respond to nutrient enrichment in the same way that they react to other stressors (Yoder & Rankin 1995, Karr & Chu 1999). Nutrients can provide a subsidy rather than a stressor effect on assemblages (Odum et al. 1979). Furthermore, environmental variables are often highly correlated, making it difficult to differentiate correlations from cause–effect relations (Miltner & Rankin 1998, Wang et al. 2003, Dodds & Oakes 2004). If the effect of the controlling factor is strong, the response should vary little, whereas if the effect of the controlling factor is weak or absent, the response may vary greatly with effects of other controlling factors (e.g. light, habitat) (Garvey et al. 1998)."*

Exhibit EU-1 provides further discussion and observations from researchers charged with development of river eutrophication criteria. A summary of threshold concentrations from our analysis, literature-based thresholds, and typical ecoregion-based ranges are provided in Table 9.

Examination of the threshold concentrations derived from both fish and invertebrate data reveals a number of apparent patterns. There was a gradient of increasing threshold concentrations from north to south. The north-south criteria gradient may be due to differences in the biological communities between regions and may also reflect differences in land use, soils, and geomorphic patterns across the state (*i.e.,* ecoregions). This suggests that statewide nutrient criteria may not be appropriate due to the range of criteria developed using quantile regression and changepoint analyses across the state (Table 8), and that these criteria should be regionalized. Regional patterns in modern-day water quality (*e.g.,* TP and BOD; Table 9) and estimated background TP (Smith *et al.* 2003) further reinforce regional patterns and differences between threshold concentrations from wadeable and nonwadeable streams were not consistent across regions. The causes of this pattern are not clear, but it is possible that natural differences in nutrient concentrations are partially responsible for differences in the native species pools present in these regions. For example, southern fauna are better suited to more enriched conditions than are the northern fauna. Regardless of the cause of the pattern, these results suggest that regionalized nutrient criteria are appropriate. There was little difference between threshold concentrations developed for the two taxonomic groups (*i.e.,* fish and invertebrates), suggesting that both taxonomic groups respond to nutrients and related stressors and can be used together to develop nutrient criteria. Observed thresholds from basic regressions (Table 10) and ranges for phosphorus criteria developed from quantile regression and changepoint analysis, using fishes and invertebrates, were within or near the range of thresholds reported in the literature (Table 9b).

Table 9 Summary statistics: a) for total phosphorus, chlorophyll-a and BOD$_5$ derived from quantile regression and changepoint analyses (BM = Biomonitoring data, RN = River Nutrient data, STOR = STORET data); b) based on recommended literature ranges; c) Minnesota ecoregion-based interquartile ranges based on representative minimally impacted streams; and d) regional reference conditions.

a. Summary statistics

Region	25th %ile AQRS & Changepoint	# T.C.
Total Phosphorus (µg L^{-1})		
North (BM, all sizes)	44	26
Central (BM, all sizes)	110	24
South (BM, all sizes)	145	17
Chlorophyll-a (µg L^{-1})		
Statewide (RN, all sizes)	21	11
BOD (mg L^{-1})		
North (STOR, all sizes)	-	0
Central (STOR, all sizes)	2.1	7
South (STOR, all sizes)	3.1	14

b. Literature-based criteria ranges.

TP range	Notes from literature	Source (state)
<170 µg/L (headwater)	"significantly higher fish IBI as compared to streams with higher TP"	Miltner & Rankin 1998 (OH)
<120 µg/L (wadeable)	# of sensitive fish sp. was significantly higher than streams with higher TP	Miltner & Rankin 1998 (OH)
~90 µg/L	macroinvertebrate changepoint; generally poor metric values above this TP	Robertson *et al.* 2006 (WI)
<100 µg/L	exceptional IBI	Rankin *et al.* 1999 (OH)
100-200 µg/L	good IBI	
60-150 µg/L	biota impaired above this range	Weigel & Robertson 2007 (WI)
<60 µg/L	fish IBI fair or better and invert. taxa richness >40	Weigel & Robertson 2007 (WI)
70 µg/L	Median TP for streams without macroinvertebrate impairments (mean=60 µg/L)	Hill & Devlin 2003 (VA)
100 µg/L	threshold identified by shift in algal community to Cyanobacteria 1 study)	Carleton *et al.* 2009 (MN)
100 µg/L	Median TP for streams with macroinvertebrate impairments (mean=280 µg/L)	

c. Typical (interquartile) ranges based on: a. representative, minimally-impacted Minnesota streams (McCollor & Heiskary 1993), b. STORET summary of all stream TP and c. USEPA ecoregion-based criteria summaries (Heiskary et al. 2010).

Region (basis)	TP (a) µg/L	TP (b) µg/L	TP (c) µg/L	BOD$_5$ (a) mg/L	Chl-a [1] µg/L TP(a)-based	Chl-a [1] µg/L BOD$_5$-based
North (NLF, NMW)	40-70	33-70	32-70	1.0-1.7	3-10	1-13
Central (NCHF)	70-170	77-225	40-200	1.6-3.3	10-40	11-42
South (WCBP, NGP)	185-320	147-308	170-403	2.4-6.1	50-80	26-93

1. Estimate based on TP and Chl-a (loess) and BOD$_5$ and Chl-a regressions

d. 75th percentile values by nutrient region for reference sites from STORET (Table 17 in Exhibit EU-1) (TP = total phosphorus, Chl-a = Chlorophyll-a, BOD$_5$ = Biochemical Oxygen Demand).

Region (basis)	TP µg/L	Chl-a µg/L	BOD$_5$ mg/L
North (NLF, NMW)	61	3	2.0
Central (NCHF)	139	5	2.0
South (WCBP, NGP)	302	19	-

E. Proposed River Eutrophication Standards: Summary

The multiple lines of evidence approach the MPCA has used, is well supported in the literature and by the EPA reviewers (e.g. Exhibit EU-22a). Stevenson *et al.* (2008), for example, describe how algae and phosphorus relationships, threshold analysis and frequency distributions can guide development of nutrient criteria. In their example they focus on benthic algal growth; however, they acknowledge that this approach could be applied to other stream biota as well. In summary they note – *"In conclusion, multiple analytical approaches can and should be used when developing nutrient criteria to provide the diversity of information that justify criteria to stakeholders and increase the probability of successful management actions."* EPA guidance (Exhibit EU-14, page 95) recommends a weight-of-evidence approach as well, which may include identification of reference reaches and percentiles, use of predictive models, and/or published nutrient or algal thresholds.

As such, the MPCA has used successive levels of data analysis to characterize datasets, interrelationships among variables (e.g. Figure 17) and supporting information to move from potential ranges for eutrophication criteria to region-specific criteria. Basic steps are summarized as follows, with each step building on previous analyses - allowing for a refinement in the selection of criteria values (i.e., move from general criteria ranges to region-specific criteria):

- Assessed linkages among nutrients, sestonic Chl-a, BOD_5 and diel DO flux (Figure 9). These provide a basis for describing interrelationships and predicting changes in potential "response variables" (*e.g.,* Chl-a) as a function of changes in causal variables (*e.g.,* TP and TN)
- Demonstrated relationships among these variables and select fish and invertebrate metrics based on the River Nutrient dataset by means of Spearman rank correlation, plotting data (*e.g.* Figure 13), and review of plotted data for thresholds or shifts in distribution of responsive metrics
- Expanded the analysis to include biomonitoring data sets and statistical analyses including quantile regression (e.g. Figure 14) and changepoint analysis
- Results from these various techniques allowed us to assemble a range of potential values from which the MPCA developed criteria for the causative variable (TP) and several response variables (*e.g.,* sestonic chlorophyll-a).
- Relationships among nutrients, stressor variables, and the biology was further assessed by determining the levels of chlorophyll-a and total phosphorus associated with the BOD_5 threshold concentrations;
- Reviewed thresholds put forth in the literature to provide further perspective on this issue.
- Concentration ranges were placed in context with ecoregion-based frequency distributions compiled by MPCA for representative, minimally-impacted streams (Exhibit EU-30), STORET summary of Minnesota streams (Figure 24), and IQ ranges from EPA criteria manuals (Exhibits EU-10, 11 and 12), which are summarized in Table 9;
- The draft total phosphorus criteria and water quality relationships were used to determine the probabilities of attaining stressor criteria if the total phosphorus criteria are met.

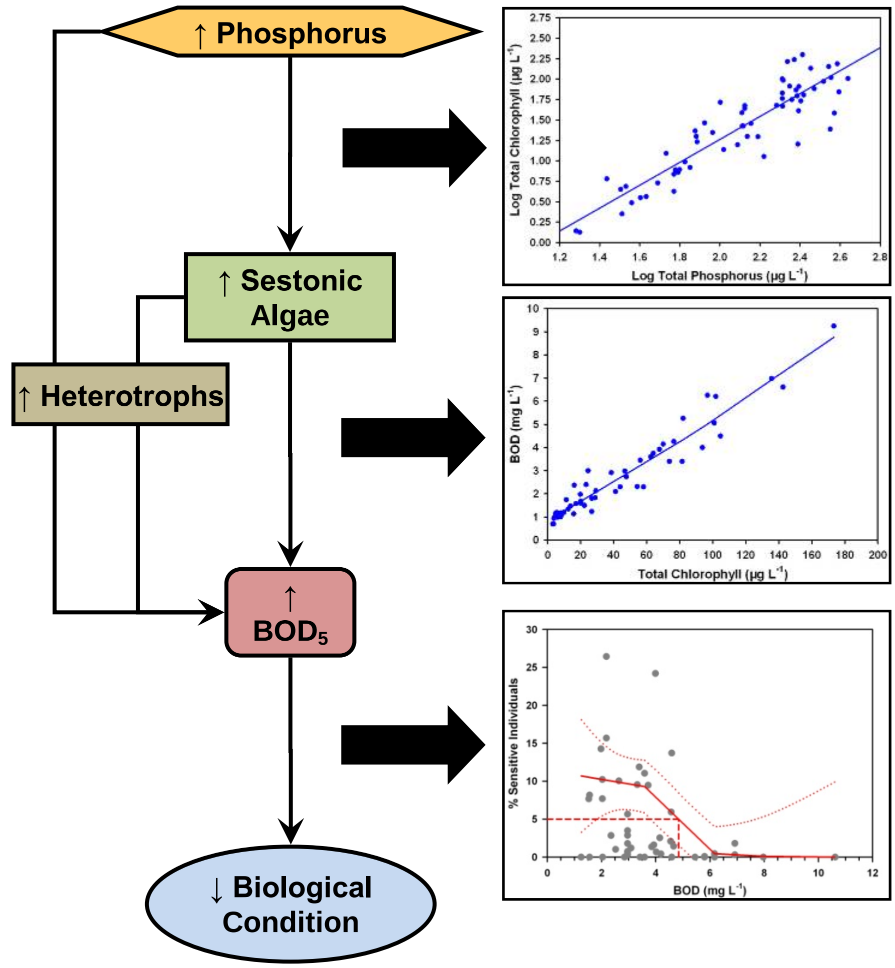


Figure 17 Conceptual model with empirical data that supports the relationships between nutrient enrichment and biological impairment.

The multiple lines of evidence, as described above, provide the basis for selection of ecoregion-based criteria. This approach does not use reference condition, a recommended approach in early EPA guidance (e.g. USEPA 2000a-c), as a primary basis for criteria selection. Rather, the datasets and summaries provided in that guidance help place proposed criteria in perspective with the overall distributions for each ecoregion. Our approach emphasized the threshold concentrations developed from the biomonitoring data using quantile regression and changepoint analysis (Table 8). Further, we began with selection of TP criteria, since TP had the largest number of threshold concentrations developed for each RNR. Once selected, we sought protective response variables based on Table 8, the serial regressions (Table 10), and tried to ensure there was good correspondence between TP and the primary response variable Chl-a (Table 10).

The North RNR rivers drain landscapes dominated by forest and wetland land uses. These rivers, by comparison to their counterparts in the Central and Southern regions, have minimal anthropogenic impacts relative to excess nutrients. Example rivers from the River Nutrient dataset include Big Fork, Little Fork, and upper reaches of the Crow Wing River (Table 3). Nutrient and Chl-a concentrations in these rivers are quite low and are well within the typical range for the Northern region (Exhibit EU-1). TP threshold concentrations as derived from quantile regression and changepoint analysis averaged 72 µg/L, with an IQ range of 44-91 µg/L. The 25th percentile values (implies 75% are higher) for the North overall, nonwadeable, and wadeable are 44, 28, and 48 µg/L respectively. Of these, the overall and wadeable have the highest number of threshold concentrations. In contrast, the nonwadeable had only five thresholds. Based on these data, a criteria value of 50 µg/L is proposed. 50 µg/L is well within the IQ range based on representative minimally impacted Minnesota streams and USEPA's criteria summary for the northern ecoregions (Table 9) and is near the median for the North RNR based on Figure 24. This TP is also below most reported thresholds from the literature (Table 9). A criterion of 50 µg/L is also protective of the majority of the metrics tested and will provide protection to aquatic life in this region.

The corresponding Chl-a for TP=50 µg/L, ranges from 5-6 µg/L based on the 75th quantile regressions (Table 10). Based on the BOD threshold, established using the 25th percentile of concentration thresholds for this stressor and interpolated TP and Chl-a (Figure 16), the corresponding range of Chl-a values is 5-10 µg/L. Maintaining Chl-a at 10 µg/L or lower should minimize risk of reduced invertebrate taxa richness and percent and number of sensitive fish species (Figure 13 Figure 14). Based on the aforementioned data and predictive relationships a value of 50 µg/L was selected, which is protective of the majority of the metrics tested (Table 8). The recommended response criteria are ≤7 µg/L for Chl-a, 1.5 mg/L for BOD5 ≤, and ≤3.0 mg/L DO flux ≤3.0 mg/L. These values should minimize the risk of reduced invertebrate taxa richness, loss of sensitive fish species, and replacement by tolerant fish species. These levels may also minimize the risk of excessive periphyton accumulations as well. Focusing on the 75th percentile values (implies 75% of predicted values are at or below the threshold for the given TP) for the water quality relationships (at a TP of 50 µg/L) ensures a 75 percent likelihood of achieving the response criteria when the TP criterion is met.

The Central RNR, which consists of the NCHF and DA ecoregions, is a transitional area between the forest and wetland dominated North and agriculturally dominated South RNR (Exhibit EU-1). While land uses have changed toward increased developed land in recent years, the CHF and DA land use percentages are quite different from those of the NLF and NMW ecoregions, which are dominated by forested and wetland (water) landuse. Because of differing soils, landform, and landuse, streams draining the Central RNR landscapes are more nutrient-rich than North RNR streams (Table 9). TP threshold concentrations, as derived from quantile regression and changepoint analysis, averaged 140 µg/L and an IQ range of 110-164 µg/L (Table 8). The 25th percentile TP for Central overall, nonwadeable, and wadeable were 110, 86, and 108 µg/L respectively (Table 8). Based on the 25th percentile BOD thresholds and interpolated TP and Chl-a (Figure 16) the corresponding range of TP values is 83-121 and Chl-a values is 13-21 µg/L. Based on the aforementioned data and predictive relationships, a TP value of 100 µg/L was selected, which is protective of the majority of the metrics tested (Table 8). Selection of this value acknowledges that the 25th percentile TC for nonwadeable steams was based on a large number of thresholds and was lower than the nonwadeable value and was protective of the majority of the metrics tested (Table 8). In addition, 100 µg/L is well within the range for Minnesota minimally impacted streams (IQ=70-170 µg/L) and USEPA's criteria summary for the central region (40-200 µg/L).

The corresponding Chl-a for TP=100 µg/L, was 18 µg/L based on the 75th quantile regressions (Table 10). Corresponding BOD values range from 1.8-1.9 mg/L and DO flux was 3.9 mg/L. Using the 75th percentiles for the response variables (Table 10) and 25th percentile threshold concentrations, we propose values less than or equal to 18 µg/L (Chl-a), 2.0 mg/L (BOD), and 3.5 mg/L (DO flux). In addition, TP of 100 µg/L or lower should also minimize the risk of dominance by blue-green algae (Figure 17 in Exhibit EU-1), which can negatively affect aquatic recreational uses.

The South RNR, which consists of the WCBP, NGP, and LAP ecoregions, is characterized by agricultural land uses with cultivated landuse being the dominant land use across all three ecoregions (Exhibit EU-1). These landuses are an inherent reflection of the soils, landforms, and potential natural vegetation characteristic of these ecoregions, which result in more nutrient-rich streams in this RNR as compared to the North or Central RNRs (Table 9). TP threshold concentrations, as derived from quantile regression and changepoint analysis, averaged 258 µg/L and an IQ range of 145-373 µg/L (Table 8). The 25th percentile TP values for South overall, nonwadeable, and wadeable were 145, 148, and 115 µg/L respectively (Table 8). Based on the BOD threshold, established using the 25th percentile of concentration threshold for this stressor and interpolated TP and Chl-a (Figure 16), the corresponding range of TP values is 129-193 and Chl-a values is 28-39 µg/L. Based on the aforementioned data and predictive relationships a TP value of 150 µg/L was selected, which is protective of the majority of the metrics tested (Table 8).

The corresponding Chl-a for TP=150 µg/L, ranges from 36-39 µg/L based on 75th quantile regressions (Table 10). Corresponding BOD values range from 2.5-2.7 mg/L and DO flux is 4.8 mg/L. Using the 75th percentiles for the response variables (Table 10), we propose values less than or equal to 35 µg/L (Chl-a), 3.0 mg/L (BOD), and 4.5 mg/L (DO flux).

While the South RNR TP criterion is relatively “high” compared to literature values (Table 9), it is consistent with the regional differences exhibited by modern-day water quality as demonstrated by MCPA and EPA data summaries and estimates of background stream TP (Smith *et al.* 2003 in Exhibit EU-1). Smith et al. (2003) estimate background stream TP for the North, Central and Southern regions of Minnesota at 15, 25 and 55 µg/L, which translates to about a three-fold difference between the North and South. The criteria (Table 1) exhibit a similar relative difference. Also, this three-fold difference between the North and South is similar to the difference in lake TP criteria for the NLF ecoregion as compared to the WCBP/NGP ecoregions (Heiskary & Wilson 2008). Lastly, 150 µg/L is at the 25th percentile for the South RNR (Figure 24). Based on a comparison with reference and non-reference South RNR sites, 150 µg/L is near the median for reference and is below the 25th percentile for non-reference sites (Figure 18). The use of the 25th percentile (overall) or 75th percentile (reference), as a basis for establishing criteria, is consistent with early EPA nutrient criteria guidance (Exhibit EU-10).

Table 10 Predicted values of chlorophyll-a (Chl-a), biochemical oxygen demand (BOD_5), and Diel DO flux based on a range of total phosphorus (TP) values. Predicted values are based on interpolation of 50th and 75th percentile quantile regression spline fits using nonwadeable and wadeable streams

TP	Chl-a (RN) (TP à Chl-a)		Chl-a (STOR) (TP à Chl-a)		BOD_5 (RN) (TP à BOD_5)		BOD_5 (STOR) (TP à BOD_5)		DO Flux (RN) (TP à DO Flux)	
	50th	75th	50th	75th	50th	75th	50th	75th	50th	75th
50	3.3	5.2	3.8	6.2	1.0	1.3	1.2	1.4	2.5	3.0
100	11.4	18.2	12.4	18.4	1.4	1.9	1.5	1.8	3.5	3.9
150	25.6	39.1	25.2	36.1	2.1	2.5	2.2	2.7	4.3	4.8
200	42.4	63.2	39.3	55.3	2.9	3.2	2.9	3.9	5.0	5.6
250	58.5	85.8	51.9	72.2	3.6	3.9	3.7	5.0	5.3	5.9
300	70.3	102.1	60.1	82.8	4.2	4.5	4.2	5.9	5.4	6.0
350	74.8	108.1	61.1	82.9	4.4	5.2	4.5	6.1	5.1	5.5
400	67.4	97.4	51.7	68.6	4.1	5.8	4.1	5.5	4.0	4.1

A comparison of the proposed criteria with the STORET-based reference and non-reference condition provides a useful perspective (Figure 18). For the North RNR, a TP of 50 µg/L is more protective than the reference 75th percentile. This is also the case for the Central RNR 100 µg/L proposed criteria. For the South RNR, a TP of 150 µg/L is below the median for the reference and below the 25th percentile for non-reference. This indicates that while this value may seem high, it is actually more protective than values generated from a reference-based approach, as suggested in EPA guidance documents. Further comparisons for BOD and Chl-a are included in Exhibit EU-1.

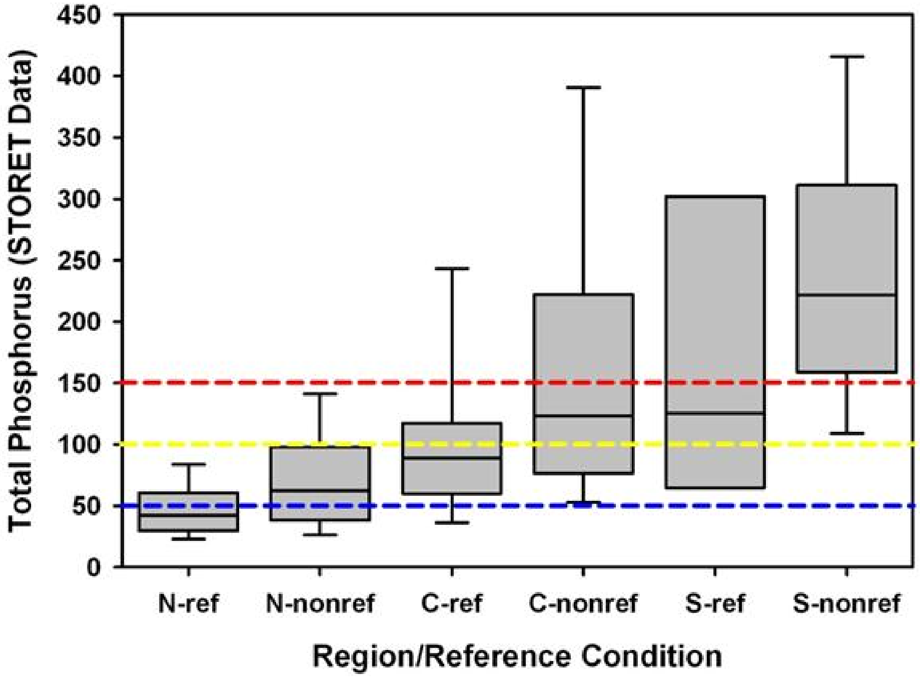


Figure 18 Box plots of total phosphorus (µg L-1) concentrations by region for reference and non-reference AUIDs (description of box plots: solid line = median, upper and lower bounds = 75th and 25th percentiles, whisker caps = 10th and 90th percentiles; blue dashed line = north region draft criterion, yellow dashed line = central region draft criterion, red dashed line = south region draft criterion).

Summary of Criteria Development and Synthesis with Elements of Water Quality Standards

The RNR-based TP and Chl-a proposed WQSs are presented in Table 1, including numeric standards for both the "causative" variable TP and "response" variable Chl-a as consistent with EPA guidance (e.g. Exhibit EU-13). In addition to sestonic Chl-a, two additional response variables are proposed: DO flux and BOD_5, with RNR-based standards for each. DO flux ranges recognize that values between ~2-4 mg/L are fairly typical, variability in biotic metric values is common over this range and that marked declines in metrics occurs as DO flux exceeds ~4.5-5.0 mg/L (Figure 13). Miltner (2010; Exhibit EU-25) makes a case for a slightly higher DO flux (range) threshold of 6 mg/L; whereby *"daily DO range>6.0 carries a significant risk of minimum concentrations falling below the established DO water quality standard of 4 mg/L"* (Exhibit EU-25). However, Minnesota's Class 2B DO standard is 5 mg/L and thus keeping DO flux <5.0 mg/L should minimize the risk of instantaneous DO measures <5.0 mg/L. In addition to these "response" variables, other potential water quality parameters with WQSs could be considered. Elevated pH, for which there is existing water quality standards of "not <6.5 nor >9.0" for Class 2B waters is one such parameter. Summary results from the RN diel monitoring (Table 6) indicated that maximum pH was >9.0 in some of the monitored streams. Impaired biology, as reflected by poor fish and invertebrate metric scores, IBI, etc. could be viable "response" variables to incorporate as a part of river eutrophication assessments.

The MPCA's proposed WQS were developed in a regional context and are to be applied to rivers within each RNR as described in Exhibit EU-5. Minnesota's regional approach is consistent with EPA recommendations (Exhibits EU-10, -11 and -12), as well as, guidance (Exhibit EU-14). Further, EPA's use of "Nutrient Watershed Regions" in the recently promulgated rules for Florida's rivers, further re-affirms the need to regionalize criteria to fully reflect local conditions (Exhibit EU-19a).

Some stream reaches require site-specific standards within the context of the River Nutrient Regions (Figure 6). These reaches occur when two similar order (sized) rivers from two different RNRs meet prior to discharging to a major downstream, higher order river. Exhibit EU-5 notes *"In a few instances where two HUC-8s meet prior to entering the major mainstem river (e.g. North Fork and South Fork Crow Rivers) "blended" or site-specific standards are recommended and these reaches are noted on the RNR map. "*

Where/when, such sites are identified; the TP site-specific WQS will be the midpoint between the values from the two contributing RNRs. The corresponding "stressor" WQSs will be the midpoint between the WQS in Table 11. With this approach, the stressor values should be in the range of predicted values based on TP as noted in Figure 16 and Table 10. This approach and values as noted in Table 11 should be applicable in other instances where this may occur. The Assessment Unit Identifications (AUIDs) identified (to date) are as follows:

- Crow Wing River from confluence of Long Prairie River to the mouth - Below the confluence with the Long Prairie (below Motley) the CHF ecoregion influence increases and the relative ecoregion composition at Pillager is ~66% CHF and ~34% NLF. The melding of these two HUC 8 watersheds and observed data at Pillager, argued for a site-specific standard (intermediate between Northern and Central RNR) for the final reach of the Crow Wing River. This extends from the Long Prairie confluence to the mouth at the Mississippi and includes AUIDs 07010106-507 (Long Prairie R to Seven Mile Creek), 07010106-506 (Seven Mile Cr to Gull River) and 07010106-501 (Gull R to Mississippi River). These three AUIDs are a single assessment unit for purposes of applying the site-specific river eutrophication standard (Table 11).
- North Fork of the Crow – The North Fork above the confluence with the South Fork, is in Central RNR and the South Fork is in the South RNR. The final ~25 mile reach of the Crow River from the confluence of the North Fork (~1,477 mi^2) and South Fork (~1,279 mi^2) to the mouth at the Mississippi River (considered part of North Fork HUC) represents a "blending" of the two 8-digit HUCS; whereby ~62% drains from the CHF ecoregion and ~38% from WCBP ecoregion. This final reach (AUID 07010204-502) does not fit "cleanly" into either the Central or South so a site-specific standard is proposed for this AUID (Table 11).

Table 11. Draft river eutrophication standards ranges by River Nutrient Region for Minnesota and site-specific values for specific river AUIDs.

	Nutrient	Stressor		
Region	TP µg/L	Chl-a µg/L	DO flux mg/L	BOD_5 mg/L
North	≤50	≤7	≤3.0	≤1.5
Central	≤100	≤18	≤3.5	≤2.0
South	≤150	≤35	≤4.5	≤3.0
Crow Wing River (AUIDs 07010106-507, -506, & -501)	≤75	≤13	≤3.5	≤1.7
Crow River (AUID 07010204-502)	≤125	≤27	≤4.0	≤2.5

As previously described, WQS include beneficial use classifications and numeric and narrative standards directed at meeting those uses. Current use classifications for the designated use of aquatic life protection are differentiated by cold water (Class 2A), cool-warm water (Class 2B) communities, and Limited Resource Value Waters (LRVW) (Class 7). Recreation is also addressed under Class 2, with Class 7 waters having less protection. Proposed river eutrophication standards protect the beneficial uses of aquatic life and recreation. The standards were regionalized by RNR to account for regional differences in river and stream condition. This classification scheme does not require different application as done currently for cold-water communities or Limited Resource Value Waters. The third element of WQS, nondegradation, is discussed in the Implementation section

F. Proposed Lake Pepin Site-Specific Standards

Every other year, the CWA, Section 303 (d), requires states to assess the quality of their waters against WQSs to develop a list of impaired waters. Lake Pepin was assessed for “nutrient impairment” as a part of the 2002 303(d) lake assessment. Since numeric lake eutrophication standards were not available at that time, ecoregion-based numeric translators were used to interpret the narrative standards that referred to excess algal growth and associated impairment. Lake Pepin was assessed based on the following data collected between June through September from 1991-2000: total phosphorus (TP) =198 (±4) µg/L (n=160), chlorophyll-a (Chl-a) = 25 (±1) µg/L (n=158), and Secchi= 1.0 (±0.3) m (n= 240). Since there were no specific translators for the ecoregion where Lake Pepin was located (Driftless Area), translators from the adjacent two ecoregions that comprise much of Pepin’s watershed (Figure 19) were used in the assessment. Based on the assessment, Lake Pepin’s TP was well above the CHF and WCBP thresholds, while chlorophyll-a and Secchi exceeded CHF thresholds. As a result, Pepin was placed on Minnesota’s 2002 303(d) list.

A central task of the Lake Pepin Total Maximum Daily Load (TMDL) was development of a site-specific eutrophication standard for chlorophyll a (Chl-a), transparency and phosphorus concentration that provides adequate protection of aquatic recreational use. This task evolved over time as more knowledge was gained on Lake Pepin and its interrelationship with upstream navigation pools and the major tributaries that drive the overall system. Recognizing the complexities and linkages of Lake Pepin, upstream navigational pools, and major tributaries the Lake Pepin TMDL Science Advisory Panel (SAP) recommended that the MPCA develop eutrophication standards for Lake Pepin and Pools 1-8. The SAP further acknowledged that these waterbodies differ sufficiently from typical lakes and rivers to warrant site-specific standards. They recommended that Lake Pepin and navigational pool eutrophication standards should be integrated into the statewide river eutrophication WQS development and hence each will be addressed in the SONAR and rulemaking.

Data analysis and modeling revealed that transparency in Lake Pepin was regulated more by suspended organic and inorganic solids, rather than Chl-a (i.e. algae, as is the case in most lakes). This led the SAP to recommend that transparency be addressed through the "turbidity TMDL" that was underway and included Pools 2 and 3 and the upper segment of Lake Pepin. A site-specific Total Suspended Solids (TSS) standard was developed and approved by the EPA in 2010 for these waters (Exhibit EU-36). Meeting the requirements of this TMDL will result in a level of transparency that is supportive of aquatic recreational and aquatic life uses. The Lake Pepin site-specific TP and Chl-a standard will serve to reduce the algal component that affects Lake Pepin transparency.

The Lake Pepin TSD (Exhibit EU-6) was prepared in support of the development of a site-specific eutrophication standard for Lake Pepin. The report includes:

- Basic background information on Lake Pepin and previous efforts to establish goals for the lake
- An up-to-date analysis of data for the lake, which focuses on the 22 years of data (1985-2006) used in the development of the Upper Mississippi River-Lake Pepin (UMR-LP) model and recent data that has been collected by the Long Term Resource Monitoring Program (LTRMP) for the period 2006-2009
- Analysis of data from recent low-average flow years to further describe relationships between the Mississippi River and upper and lower segments of Lake Pepin
- Review of model predictions for various years and reduction scenarios that contribute to criteria development and
- Summary of proposed site-specific standard for Lake Pepin

A brief summary of the data analysis and findings is presented here. The TSD (Exhibit EU-6) provides further details.

Lake Pepin is a natural lake on the Mississippi River (Figure 19). The lake formed about 10,000 years ago behind an alluvial fan of the Chippewa River in Wisconsin, which dammed the Mississippi River after outflow from Glacial Lake Agassiz was diverted northward and ceased to scour sediments deposited by the Mississippi's tributaries (Wright *et al.* 1998 in Exhibit EU-6). It has a surface area of about 40 square miles and a mean depth of 18 feet. Lake Pepin is characterized by two somewhat distinct segments. The upper (inflow) segment accounts for about 40 percent of the lake by area (~10,700 acres) but only about 28 percent by volume because it is very shallow (mean depth ~12 feet) and is more "river-like" in nature. The lower segment is somewhat deeper (mean depth ~22 feet) and accounts for about 72 percent of the lake by volume and is more "lake-like" as compared to the upper segment.

Lake Pepin's watershed is about 48,634 square miles, includes the Upper Mississippi, St. Croix, and Minnesota Rivers, and drains about 48 percent of Minnesota and a portion of Wisconsin (Figure 19). This results in a watershed-to-lake ratio of about 1,225:1. This large watershed area promotes short water residence times that range from six to 47 days, with an average of 16 days. Because of its shallowness and small volume residence time in the upper segment is very short, often less than 2-3 days, which limits its ability to process phosphorus from the river. Lake Pepin's watershed drains several ecoregions (Figure 19) and since water quality varies among these regions (Table 9), no single ecoregion can characterize Lake Pepin or its watershed, a fact that further reinforces the need for site-specific standards.

Development of water quality goals for Lake Pepin date to the early 1990s when a Phosphorus Cooperators Group conducted extensive research on Lake Pepin and actively pursued this question. That work and recent efforts, in support of the Lake Pepin TMDL and development of the Upper Mississippi River-Lake Pepin (UMR-LP) model (LTI 2007 in Exhibit EU-6) resulted in a range of goals (Table 12) being discussed and/or adopted (as was the case with the Phosphorus Cooperators Group Chl-a goal of 30 µg/L; Heiskary 1993; in Exhibit EU-6). Considerations used in previous efforts provide a general framework for developing site-specific standards for the lake. Since that time we have the benefit of over 15 more years of data collection, sediment diatom reconstruction, and numerous other projects (Metropolitan Council Environmental Services (MCES) 2002; in Exhibit EU-6) that advance our knowledge of Lake Pepin.

Ecoregion-based lake eutrophication WQSs promulgated in 2008 provide some context for Lake Pepin site-specific standards development. More important than the actual numeric standards is the approach used in their derivation, given the unique nature of Lake Pepin. Heiskary and Wilson (2008; in Exhibit EU-6) describe the weight-of-evidence approach that considers user perceptions, nuisance bloom frequency, ecological endpoints and interrelationships among TP, chlorophyll-a, and Secchi. Lake Pepin site-specific standard consideration can also benefit from recent efforts to draft eutrophication standards for Minnesota's rivers (Exhibit EU-1). Recognizing the complexities and linkages of Lake Pepin, upstream navigational pools and major tributaries the Lake Pepin TMDL SAP recommended that the MPCA develop eutrophication standards for Lake Pepin and Pools 1-8, further acknowledging these waterbodies differ sufficiently from typical lakes and rivers to warrant site-specific standards. The SAP recommended further that Lake Pepin site-specific eutrophication standards be integrated into statewide river eutrophication standards development.

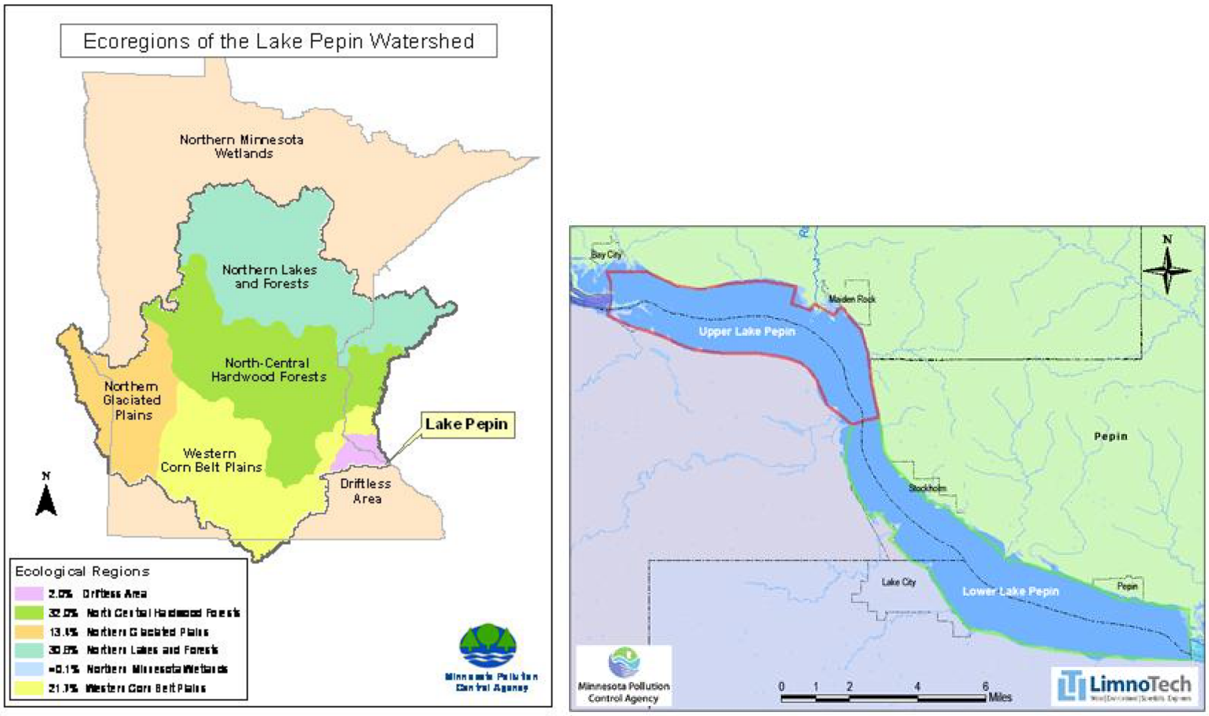


Figure 19 Lake Pepin morphometry and watershed: (a) Map of watershed and ecoregion composition and (b) map of lake with upper and lower segments noted. The Chippewa River, which formed Lake Pepin, enters immediately southeast of the city of Pepin WI.

Table 12. Lake Pepin 303(d) listing, current, and historical values and draft criteria/standards ranges.

	2002 303(d) listing [1]	Recent 10-year mean [2]	2009 means	Criteria & goal ranges [3]	Diatom-inferred P from c1900-1960 [4]
TP µg/L	198	171	152	80-120	~110-140
Chl-a µg/L	25	30	32	28-32	--

[1]. 1991-2000
[2]. 2000-2009
[3]. Represents draft values discussed or proposed at various points in overall process.
[4]. Estimate #1 (Engstrom and Almendinger 2000 in Exhibit EU-6))

The LTI UMR-LP model for Lake Pepin provides a basis for predicting in-lake response based on current and future loading scenarios and can help guide establishment of numeric standards for Lake Pepin and upstream waters. Two model runs evaluated potential in-lake endpoints and required upstream conditions under low-average flow (a) and all summers (b) (Table 13). These model runs, as they inform criteria selection for Pepin, are addressed in this report while implications for upstream pools and tributaries are addressed in Exhibit EU-6. Of the two model runs, the one based on all years is most consistent with how assessments will be conducted (i.e. averaging data across the ten most recent years, irrespective of flow).

Table 13. LTI UMR-LP model runs for: (a) average to low flow summers used in model development and testing: 1987, 1990, 1992, 1998, 2000, and 2006 and (b) all years: 1985-2006. Results are modeled, see footnotes for scenario details. Model details provided in LTI (2008). TP in mg/L and Chl-a in µg/L.

a.) average-low flow

	Total phosphorus								
Scen.	**St. Croix**	**Minn**	**LD1**	**LD2**	**LD3**	**upper LP**	**lower LP**	**overall LP**	**outlet LP**
2	0.036	0.293	0.118	0.227	0.175	0.161	0.160	0.160	0.167
4	0.029	0.145	0.095	0.173	0.133	0.120	0.113	0.116	0.114
17	0.029	0.145	0.095	0.127	0.102	0.095	0.093	0.094	0.096
20	0.029	0.147	0.094	0.163	0.127	0.117	0.115	0.116	0.120
21	0.029	0.140	0.094	0.124	0.100	0.096	0.098	0.097	0.103
Chlorophyll-a (mean)									
Scen.	**St. Croix**	**Minn**	**LD1**	**LD2**	**LD3**	**upper LP**	**lower LP**	**overall LP**	**outlet LP**
2	15	64	51	44	35	39	28	33	20
4	12	32	41	38	32	37	28	32	21
17	12	32	41	36	30	33	25	29	19
20	12	48	41	41	34	40	30	34	22
21	12	48	41	39	32	36	28	31	21
Chl-a Days > 50									
Scen.	**St. Croix**	**Minn**	**LD1**	**LD2**	**LD3**	**upper LP**	**lower LP**	**overall LP**	**outlet LP**
2	1	64	54	41	13	28	5	10	0
4	0	21	30	31	12	27	3	8	0
17	0	21	30	26	4	9	0	0	0
20	0	43	30	25	7	22	4	7	0
21	0	43	30	20	7	9	1	2	0

b.) all years

	Total phosphorus								
Scen.	**St. Croix**	**Minn**	**LD1**	**LD2**	**LD3**	**upper LP**	**lower LP**	**overall LP**	**outlet LP**
2	0.045	0.285	0.110	0.215	0.170	0.158	0.152	0.154	0.155
4	0.036	0.141	0.088	0.161	0.126	0.116	0.110	0.112	0.110
17	0.036	0.141	0.088	0.122	0.100	0.095	0.092	0.093	0.093
20	0.036	0.148	0.088	0.152	0.121	0.113	0.109	0.111	0.111
21	0.036	0.139	0.088	0.120	0.099	0.095	0.093	0.094	0.096
Chlorophyll-a									
Scen.	**St. Croix**	**Minn**	**LD1**	**LD2**	**LD3**	**upper LP**	**lower LP**	**overall LP**	**outlet LP**
2	13	45	38	34	27	31	23	26	17
4	11	22	31	29	25	29	22	25	17
17	11	22	31	28	23	26	20	23	16
20	11	40	31	35	29	33	25	28	19
21	11	40	31	34	27	30	24	26	18
Days > Chl-a 50									
Scen.	**St. Croix**	**Minn**	**LD1**	**LD2**	**LD3**	**upper LP**	**lower LP**	**overall LP**	**outlet LP**
2	2	38	29	19	6	16	2	4	0
4	0	8	14	16	5	17	1	3	0
17	0	8	14	13	2	7	0	0	0
20	0	35	14	18	5	14	2	3	0
21	0	35	14	14	4	9	1	1	0

Scen 02, Historical tributary loads, Direct point sources at permitted (AWWDF x 1.0 mg/L); **Scen 04**, Direct point sources at permitted (AWWDF x 1.0 mg/L), Cannon and Minnesota 50% reduction for TP, TSS and chl-a, St. Croix and Upper Miss 20% reduction for TP, TSS and chlorophyll-a; **Scen 17**, Direct point sources at reduced (AWWDF x

0.3 mg/L), Nonpoint same as 04; **Scen 20**, Same as 04 but MN River response based on HSPF model for Lower MN (see Larson 2010 for HSPF details)**Scen 21**, Same as 17 but MN River response based on HSPF model for Lower MN

Total phosphorus – A site-specific standard of 100 µg/L is proposed for Lake Pepin. Several factors suggest that 100 µg/L, while a very aggressive goal for Lake Pepin, may be a realistic target to use as a site-specific WQS. A summary follows.

1. Based on sediment-diatom inferred TP 100 µg/L is above pre-European TP. However, pre-European P has not been the primary basis for establishing Minnesota's lake eutrophication standards. A value of 100 µg/L is well within Lake Pepin's range of diatom-inferred TP for c1900-1960 (Est. #1 and #2, Figure 14 in Exhibit EU-6). This is an important period as it included: establishment of the lock and dam system, major land clearance for agriculture, initial urbanization of the seven county metropolitan area, centralization of municipal wastewater and can serve as somewhat of a "modern-day" benchmark. Mississippi River water-quality was not pristine during this time period; however it can be argued that excess sediment loads from land clearance and organic material from untreated wastewater were the primary factors impacting water quality and aquatic life uses during this era based on accounts by Anfinson (2003; in Exhibit EU-6). A similar timeframe was used by the St. Croix Basin Water Resources Planning Team when proposing water quality goals for Lake St. Croix *"….The subcommittee determined that the third management option (c1940s) would be a reasonable goal in improving the water-resource conditions in Lake St. Croix (Davis 2004; in Exhibit EU-6)."*
2. In a short residence time system, like Lake Pepin, inflow TP strongly influences in-lake TP (Table 13).
3. Based on data from typical streams (without major point sources) for each of the contributing ecoregions (Table 11), 100 µg/L is in the range of an ecoregion-based estimate of inflow TP (80-100 µg/L), which further suggests that while it is an aggressive goal it is in the range of what might be anticipated within the context of the ecoregions drained by the lake.
4. Limiting the frequency of nuisance blooms is important to achieving aquatic recreational uses in lakes. Summer-mean TP of 100 µg/L limits the frequency of blooms (>50 µg/L Chl a) to <10 days per summer (equates to <10% of summer). Model runs for scenarios with overall Lake Pepin TP near 100 µg/L indicate frequencies <2 days based on low-average flow and all summers (Table 13). TP of 100 µg/L also should keep percent blue-greens to 16 percent or less over most years/scenarios (Table 14). Summer-mean Chl-a will not decrease substantially at 100 µg/L, as compared to current levels (Table 13). However, the likelihood of reduced summer-mean Chl-a increases at 100 µg/L as compared to TP in the 150-200 µg/L ranges.
5. A summer-mean TP of 100 µg/L should be protective of downstream navigational pools 5-8 as well (Exhibit EU-7).
6. The state of Wisconsin completed promulgation of TP standards for rivers and lakes as of December 2010. Their standard for medium to large rivers in Wisconsin, which would include the Mississippi River, is 100 µg/L (state of Wisconsin Natural Resources Board 2010; Exhibit EU-27). Sullivan (WDNR 2010, personal communication; in Exhibit EU-6) and Baumann (WDNR 2010, personal communication) indicated this is Wisconsin's intended numeric standard for Pepin as well (Exhibit EU-6).
7. The Minnesota Legislature in the 87th Legislative Session required the MPCA to coordinate with WDNR in establishing a phosphorus standard for Lake Pepin (Minnesota Legislature 2011; Exhibit EU-43). The proposed Lake Pepin eutrophication standard and steps taken in its development meet this requirement.

Chlorophyll-a – A site-specific standard of 28 µg/L, measured as a lake-wide summer average for the most recent 10-years, is proposed for Lake Pepin. Lake Pepin chlorophyll-a concentrations vary as a function of river flow (flushing rate), turbidity (light limitation via inorganic suspended solids and dissolved organic carbon), river-borne chlorophyll-a (algae), and TP. This is in contrast to typical glacial lakes in Minnesota where chlorophyll-a can be routinely predicted based on in-lake TP (Figure 9) and where river-borne algae is considered an insignificant source. During high flow summers, flushing rate and turbidity are the primary limiters of the amount of chlorophyll-a produced in Pepin and upstream. During average to low flow summers flushing rate and turbidity decline in significance, while river-borne algae and TP increase in significance. All of these factors can contribute to some degree to the variability in chlorophyll-a response even when years of somewhat similar flow are considered.

The 28 µg/L summer-mean goal was proposed at the onset of the Pepin TMDL model development as a desirable target (LTI 2007 in Exhibit EU-6). It relates back to the 30 µg/L goal proposed by the Phosphorus Cooperators Group, which was to be applied between flow ranges of 4,578 cfs (as measured at Prescott) to 20,000 cfs and desires to minimize nuisance blooms. Achieving 28 µg/L Chl a or lower across the range of all flows (years) should help assure that 30 µg/L is achieved in low to average flow years (Table 13).

1. The UMR-LP model predicts that nuisance algal blooms (Chl-a >50 µg/L) are unlikely to occur when summer-mean Chl-a is at or below 28 µg/L based on four summers and flow ranges tested (Exhibit EU-6).
2. Force and Macbeth (2002; in Exhibit EU-6) in conclusions of their user perception study note, “With a mean concentration of 34.1 µg/L for samples taken when recreational suitability was rated as 3 (swimming and aesthetic enjoyment slightly impaired because of algae levels), it appears that the water quality goal of less than 30 µg/L was a good approximation of acceptable water quality in Lake Pepin based on volunteers’ ratings of recreational suitability.”
3. Achieving 28 µg/L as a whole-lake average in Pepin ensures low Chl-a at the outlet of Pepin (Table 14) and should be protective of aquatic recreational uses in downstream Pools 5-8.

Table 14. Minnesota’s lake eutrophication standards and related metrics for adjacent ecoregions and proposed Lake Pepin site-specific standards.

Ecoregion – lake type (use classification[1])	TP (µg/L)	Chl-*a*	% nuisance blooms[2]	%blue-green biomass & impact
CHF – Aquatic Rec. Use – Deep (Class 2B)	40	14	0-5%	moderate
WCBP&NGP – Aquatic Rec. Use - Shallow (Class 2B)	90	30	30-45%	moderate-high
Lake Pepin	100	28	0-8%	8-16% low-moderate

[1] Aquatic life and recreation use class as defined in Minn. R. 7050.0140, subp. 3 and Minn. R. 7050.0222 (Minnesota Rules Chapter 7050 2008). Class 2A is used for waters supporting a cold water fishery and refers specifically to lakes that support natural populations of lake trout. Stream trout refers to all other designated (managed) trout lakes. Class 2B is designation for waters supporting cool or warm water fishery and is the default classification for the majority of Minnesota’s lakes.
[2] Defined as >30 µg/L for CHF and WCBP ecoregions and >50 µg/L for Pepin; percent of summer based on Heiskary and Wilson (2005) and Figures 18 and 19 and Table 8 this document.

G. Proposed Mississippi River Navigational Pool Standards

The need for the proposed site-specific standards and a physical description of the Mississippi River navigational pools (Figure 2) was provided in the Introduction and Needs section of the SONAR. A detailed description of the setting of the pools and their linkage to major upstream tributaries, analysis of data from the pools, and proposed site-specific WQS are provided in Exhibit EU-7. This effort is linked to development of site-specific WQS for Lake Pepin, which is described in detail in Exhibit EU-6. A summary, drawn from these two documents, is presented here; however, both should be referred to for more detailed information on the development of site-specific WQS for these resources

The Mississippi River (pools) offers abundant opportunity for hunting, wildlife observation and a host of water-based activities, including swimming, fishing, and pleasure boating (Exhibit EU-7). Much of the river in Minnesota below Lake Pepin is part of the Upper Mississippi River National Wildlife and Refuge system, which allows for a wide variety of uses. A recreational boating study conducted by the MDNR, WDNR, United States Fish and Wildlife Service (USFWS), and United States Army Corp of Engineers (USACE) in 2003 provides some insights into recreational uses of the pools. MDNR (2004; in Exhibit EU-7) notes that the reach from Pool 4 to Pool 9 contains nearly 130,000 acres of boating water and a substantial number of facilities (public and private) that help support water-based recreation on the pools. Estimated usage exceeds one-million-boat hours during the summer period. This is a very high level of usage and boating intensity (boats per acre of water) on the Mississippi River is at a level similar to Minnesota's non-metropolitan lake regions. One finding of the study was that boaters spend about equal amounts of time in the main channel area, side channel and backwater areas. As an activity group, anglers spend most of their time in side channels and backwaters, while pleasure boaters spend most of their time in the main channel (MDNR 2004). Various MDNR fishery studies indicate a healthy and diverse fishery that is widely used. In summary, Pools 1 to 8 on the Mississippi are highly used by a variety of people, for a wide variety of purposes and many of these uses are enhanced by good water quality (Exhibit EU-7).

Habitats within the pools are quite variable. Using Pool 8 as an example (Figure 20b) it is evident that depth may vary substantially among the various habitats; whereby channel areas are somewhat deeper while backwaters may be quite shallow. For Pool 8, 75 percent of the pool is two meters or less in depth. Given the wide array of aquatic areas in the pools (*e.g.* Figure 20) and that each area provides one or more opportunities for aquatic recreation it was difficult to decide on the specific focus for the standards and which data should be used in standards development and assessment of the pools. Upon review of various data sets and monitoring site locations from Metropolitan Council Environmental Services (MCES), LTRMP), WDNR, and MPCA it was determined the WQS should focus on the water quality as measured in the main river channel and near-dam area of each pool. Data collected near the dam (e.g. MCES site at UM-815.6 immediately above Lock and Dam 2) or the various LTRMP or WDNR sites located at or immediately below the dam serve to integrate the upstream water quality of the pool (e.g. Lock and Dam 8 in Figure 20). As such, these sites provide a reasonable basis for evaluating water quality relationships, characterizing pool water quality, establishing the numeric standards, and eventually assessing compliance – with a focus on aquatic recreational use.

Summary of Proposed Site-specific Water Quality Standards for Mississippi River Navigational Pools

Mississippi River navigation pools 1-8 represent a unique waterbody-type with a blend of characteristics found in free flowing rivers, navigational canals, shallow lakes, and shallow reservoirs. Morphometry and residence time varies and ranges from "river-like" in Pool 1 to "lake-like" in Pool 4 and for most pools is on the order of one to two days under average to low flows (Table 15). Long-term datasets from

MDNR's LTRMP, MCES, and WDNR on Pools 1-8 were used to characterize water quality status and trends and were the primary basis for defining pool-specific eutrophication standards. These data demonstrate the range of TP, Chl-a, and interrelationships of these variables for the main-stem rivers and Pools 1-8 (Table 16 Table 17)

Flow, water residence time, and non-algal turbidity have a strong influence on Chl-a production in medium to large rivers (Exhibit EU-3) and are significant in Lake Pepin (Exhibit EU-6). The Mississippi River pools are no different in this regard. Soballe *et al.* (2002; in Exhibit EU-7) note in their examination of LTRMP data from 1993-1996 *"…chlorophyll-a concentrations were highest in summers of 1994-95, when river stage was near the seasonal norm. Slower water velocities and longer retention times may have increased phytoplankton productivity during that period of time."* Johnson and Hagerty (2008; in Exhibit EU-7) further reinforce these concepts noting, *"Chl-a concentration in large rivers are generally determined by light availability (largely determined by TSS), nutrient availability, and current velocity. Light availability is tied directly to depth which is highly managed in this system to maintain navigation."* They go on to state the difficulty in predicting Chl-a because the relations among these factors are not well understood and the potential effect of zebra mussels and Asian carp in the future.

Summer-mean TP and Chl-a data from Pools 1-3 were compared to the LOESS-based river nutrient regression (Figure 21). Pool 1, with low non-algal turbidity exhibits higher Chl-a per unit TP as compared to the river nutrient regression. Pool 2 Chl-a varies somewhat independently of TP. High non-algal turbidity from the Minnesota River contributes to low Chl-a per unit TP in Pool 2 during many summers. Pool 3 Chl-a response is well within the 90th Prediction Interval (PI) for the river regression. Lake Pepin, as previously demonstrated (Exhibit EU-7), also yields lower Chl-a per unit TP as compared to the lake and river regressions. The response in Pools 5-8 is rather variable and is likely driven more by residence time, mixing depth, light limitation, interactions with contiguous backwaters, zooplankton grazing (Burdis *et al.* 2007; in Exhibit EU-7), and submerged aquatic vegetation.

There is a very significant relationship between mean and maximum Chl-a based on MCES and LTRMP data (Figure 22). A Chl-a concentration of >50 µg/L has previously been used to characterize "nuisance blooms" for Lake Pepin and Spring Lake (Exhibit EU-6). This presumes blue-green algae are the dominant form contributing to the "bloom." Based on data from Pools 1-8 the risk of encountering nuisance blooms can be minimized if summer-mean Chl-a remains <30-35 µg/L (Figure 22).

Figure 20. Mississippi River Pools 1-11: (a) Map with assessment reaches as defined by EMAP; (b) Example of the varied habitats in Mississippi River Pools based on Pool 8. Land cover maps from 2000. Source: USGS, Upper Midwest Environmental Sciences Center website; (c) major tributaries and MCES monitoring sites

a. **b.**

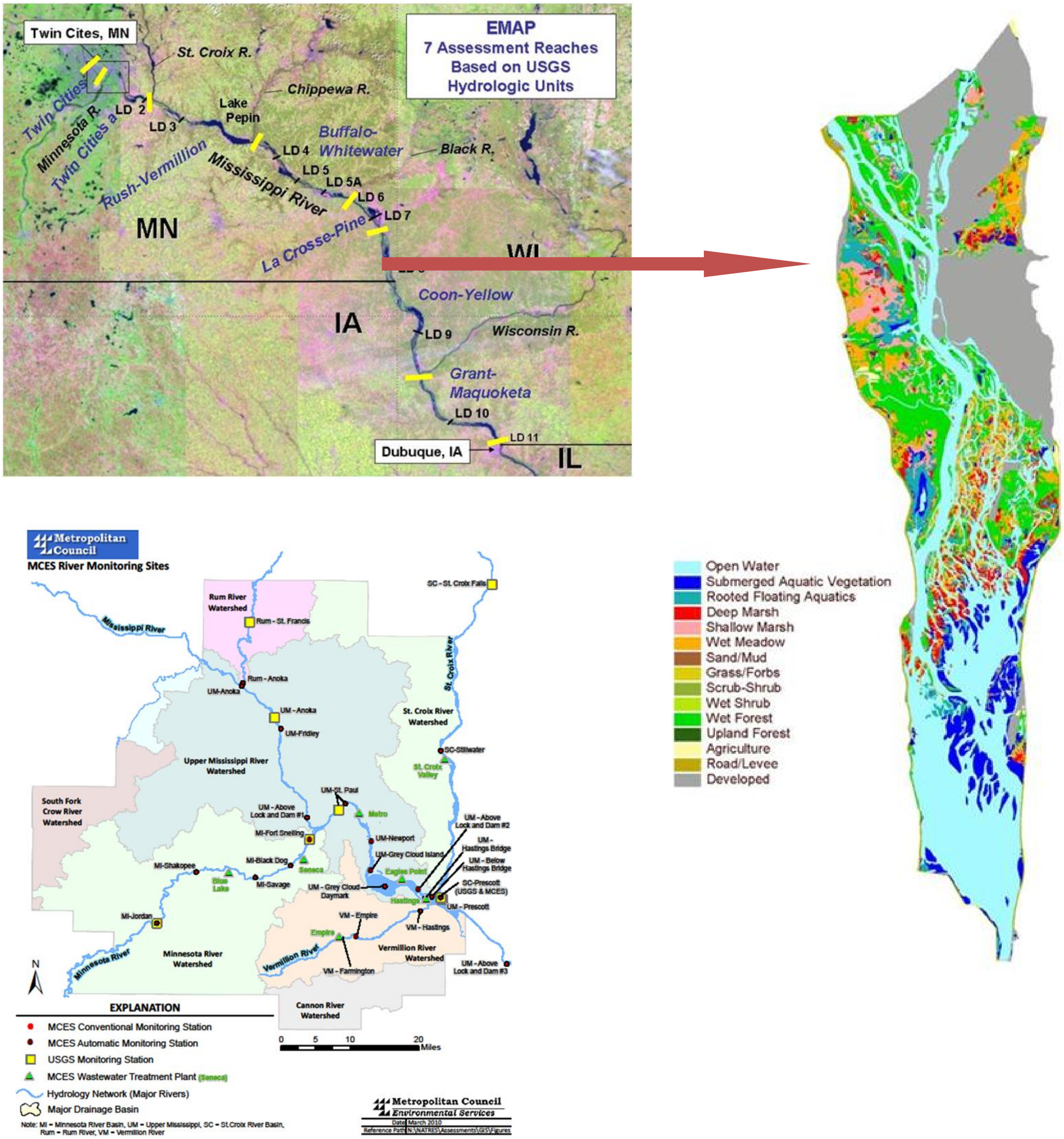


Table 15. List of dams that form Pools 1-8 on Upper Mississippi River. Residence time estimated based on average to low flow and volume of pool (details in Exhibit EU-7).

Lock Name or Number	River Mile	Pool Length (mi)	Drainage Area (sq. mi)	City	Began Operation	Mean depth m	Res. Time days
Lower St. Anthony Falls	854.1	0.6	19,680	Minneapolis MN	1958		
1	847.7	6.4	19,684	St. Paul, MN	Rebuilt 1938	6.0	<1-2
2	815.2	32.5	36,990	Hastings, MN	1931	2.5	2-8
3	796.9	18.3	45,170	Red Wing, MN	1938	2.7	1-4
4	752.8	44.1	57,100	Alma, WI	1935	5.2	7-28
5	738.1	14.7	58,845	Minneiska, MN	1935		0.8-1.7
5A	728.3	9.8	59,105	Winona, MN	1936		0.4 – 0.9
6	714.2	14.1	60,030	Trempealeau, WI	1936		0.5 – 1.1
7	702.5	11.7	62,340	Dresbach, MN	1937		0.9-1.9
8	679.1	23.4	64,770	Genoa, WI	1937	1.8	1-2

Table 16. Summer-means for period 2001-2009 based on MCES data. Chlorophyll measured by spectrometry. Chl-a represents viable chlorophyll (corrected for pheophytin) and Chl-T is uncorrected chlorophyll as measured by trichromatic method (DOP=dissolved ortho-P).

Pool (Location)	**River Mile**	**TP mean**	**DOP mean**	**Chl-a mean**	**Chl-T mean**
		µg/L	µg/L	µg/L	µg/L
Anoka	UM-871.6	115	46	38	41
Pool 1	UM-847.7	97	26	46	50
Pool 2	UM-839.1	153	44	49	57
Pool 2	UM-831.0	188	78	45	53
Pool 2	UM-826.7	181	78	41	49
Pool 2	UM-815.6	197	81	45	53
Pool 3	UM-796.9	158	65	40	49
Jordan	MI-39.4	221	53	95	104
Savage	MI-8.5	256	63	73	86
Ft. Snelling	MI-3.5	239	75	61	73
SC Falls	SC-23.3	53	10	28	30
Lake outlet	SC-0.3	39	13	18	18

Table 17. Summer-means for Pools 5, 7 & 8: 2001-2008 based on LTRMP data. Spectrophotometric corrected and fluorometric Chl-a values noted.

Pool	River mile	TP µg/L	Chl-spec µg/L	Chl-fluor µg/L
Pool 5	M738.2	169	32	31
Pool 7	M701.1	163	35	34
Pool 8	M679.2	157	23	23

Figure 21. Summer-mean MCES pool data (2001-2009) overlain on RNR-based Loess regression. Dashed lines are the 95th and 5th percentile quantile regressions (i.e. 90th prediction interval).

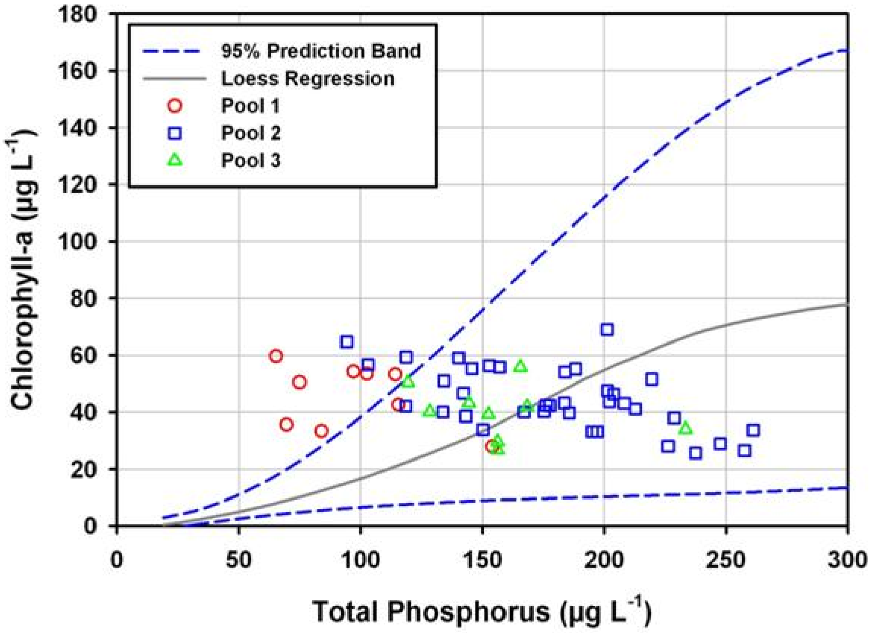
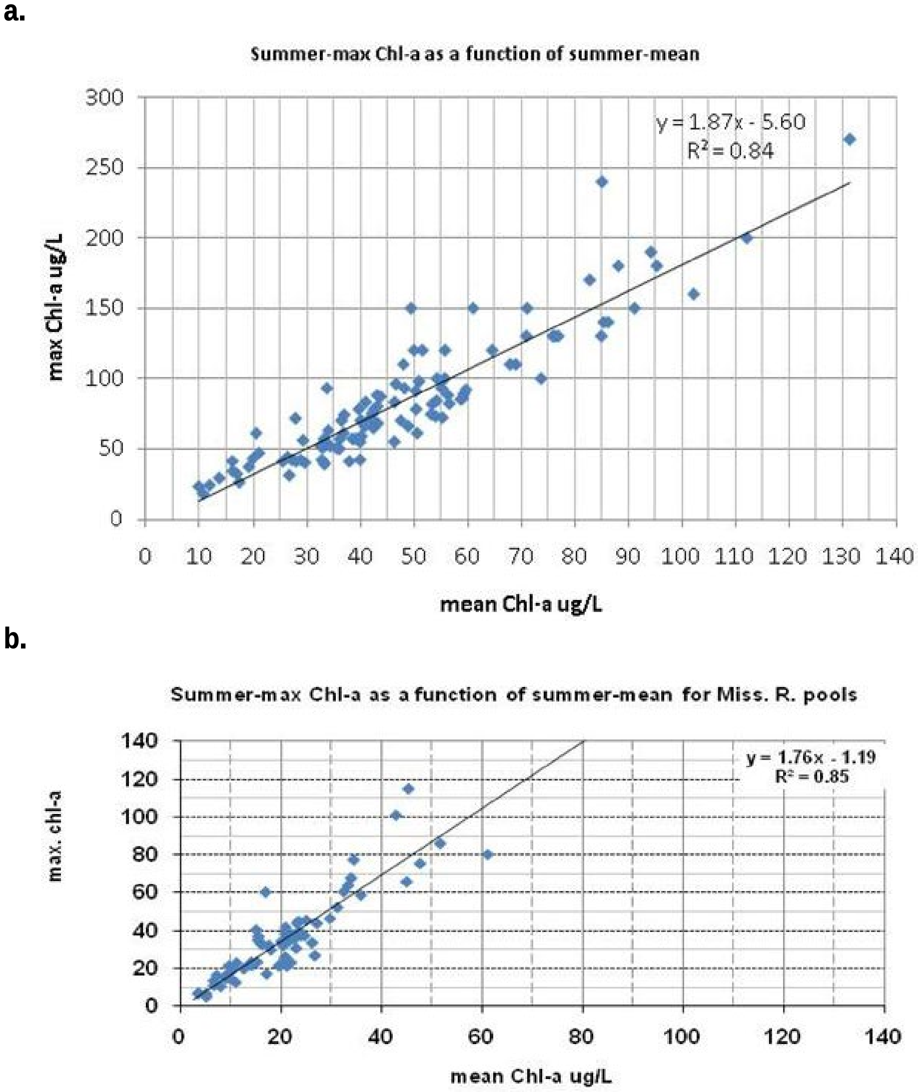


Figure 22. Maximum Chl-a as a function of summer-mean chlorophyll-a. Based on (a) MCES data for rivers and Pools 1-3 and (b) fixed station LTRMP data by spectrometry for Pools 3, 4, 5, 7 and 8.



The lower pools (5-8) do not exhibit a strong relationship among TP and Chl-a – in part, because summer-mean TP remains above 100 µg/L (Table 17) and because of the previously noted factors. In general, Chl-a is quite variable in Pools 5, 7 and 8 and about 2/3^{rds} of Chl-a samples are <30 µg/L (Exhibit EU-7). Long-term summer-mean Chl-a ranges from 23-35 µg/L (Table 17). Given the lower Chl-a in these pools (as compared to upper pools) and lack of relationships among TP and Chl-a it is reasonable to focus attention (nutrient reduction) on the main-stem rivers and upper pools, which exhibit much stronger relationships and where a majority of the excess algal biomass is produced. Ideally, standards that result in reductions of Chl-a and are protective of aquatic recreational uses in the main-stem rivers and the upper pool(s) of this system will be protective of Lake Pepin and the downstream pools. The LTI model projections serve to support this approach (Table 13). To achieve reductions in TP and Chl-a in Lake Pepin and be protective of lower pools 5-8, reductions must be made at the major inflows to this system. LTI UMR-LP model runs for low-average flow years and all years (Table 13) help place potential reductions in perspective. As noted previously, through efforts by the Phosphorus Cooperators Group and as a part of the Lake Pepin TMDL, a primary focus for protecting aquatic recreational use in Lake

Pepin has been to minimize the frequency of nuisance blooms. Over the history of working on this issue nuisance blooms have been defined in terms of various levels of Chl-a ranging from >40 µg/L to >60 µg/L (Heiskary and Walker 1995 and MCES 2002; in Exhibit EU-6). In more recent work on the Lake Pepin TMDL, a level of >50 µg/L was adopted for defining nuisance blooms and used as a metric in the UMR-LP model (Table 13). Previously proposed in-lake goals to achieve this are ~100 µg/L TP and ~30 µg/L Chl-a (expressed as summer-means; Table 13).

Based on the UMR-LP model: scenarios 4 and 17 for Upper Mississippi (UM)-847 and SC-0.3 and scenarios 20 and 21 for Mississippi River (MI)-3.5 (Table 13) inflows to the system need be in the range of:

- Mississippi (UM-847) – TP ~90-100 µg/L and Chl-a ~20-30 µg/L;
- St. Croix (SC-0.3) – TP ~30-36 µg/L and Chl-a ~11-12
- Minnesota (MI-3.5) – TP ~140-150 µg/L and Chl-a ~32-40 µg/L

The state of Wisconsin has adopted 100 µg/L TP criteria for medium to large rivers (Exhibit EU-27), which would include the Mississippi River. For Minnesota, the Mississippi River at Anoka is considered part of the Central RNR (Figure 6) and Minnesota's proposed WQS are 100 µg/L for TP and <20 µg/L for Chl-a. The MPCA's proposed TP standards are in the LTI UMR-LP model-predicted range of what may be required, while the proposed Chl-a is actually much lower than the model projection. This suggests that the MPCA's proposed WQS (Table 2) are protective of both the Mississippi and Minnesota Rivers and downstream resources (e.g. Lake Pepin) as well.

The requirements for the St. Croix River are very close to the values required by the Lake St. Croix TMDL. In that TMDL the endpoints are consistent with Minnesota's lake eutrophication WQS for the NCHF ecoregion: TP <40 µg/L and Chl-a <14 µg/L. Given there is a reduction in both TP and Chl-a from Lake St. Croix to the mouth of the river (Exhibit EU-7), the Lake St. Croix WQS are adequately protective for Pool 3 and Lake Pepin.

Model-predicted reductions (Table 13)) for the Minnesota River are quite large given the long-term mean TP is ~250 µg/L and chlorophyll ~85-95 µg/L. However, model-predicted TP and Chl-a are in the range of the proposed standards for the South RNR (Table 1). Likewise the model-predicted Chl-a (32 µg/L) is in the range of the proposed RNR-based Chl-a standard (<40 µg/L; Table 1). The Minnesota River at Jordan achieved a TP near 150 µg/L during the low flow summers of 2008 and 2009 (Exhibit EU-7); however, Chl-a was well above the model-predicted values (Table 13). Since the model scenarios assume reductions in TP, TSS and Chl-a for the various sites - upstream reductions in Minnesota River Chl-a is essential to achieving downstream Lake Pepin and lower pool WQS.

These reductions are generally consistent with the values required to meet the Lower Minnesota River Low DO TMDL. Work on the Lower Minnesota River began in 1985 when a Wasteload Allocation (WLA) study established Biochemical Oxygen Demand (BOD) limits for the facilities in the lower 22 miles of the Minnesota River. The WLA Study also established a 40 percent BOD reduction goal for the Minnesota River upstream of Shakopee. A TMDL report completed in 2004 targeted the 40 percent reduction by reducing high phosphorus loading upstream of the metropolitan area. TP was targeted because it causes excessive algal growth, which in turn produces BOD because of algal decomposition. High BOD leads to low dissolved oxygen during low flow conditions in this reach of river. Based on scenario 7 in the Minnesota River simulation of watershed hydrology and water quality for conventional and toxic organic pollutants (HSPF) model the recommended low flow goals for this reach were: TP = 0.131 mg/L, Chl-a =

56 µg/L and BOD = 3.61 mg/L (Gunderson and Klang 2004; in Exhibit EU-7). [Note: Chl-a of 56 µg/L at MI-39 (near Jordan) translates to ~40 µg/L at MI-3.5 (near Fort Snelling) because of settling losses].

The emphasis of the Lower Minnesota TMDL report is on wastewater treatment facilities, although agriculture, noncompliant subsurface treatment systems and stormwater each play a role in the reduction efforts. In 2005, a watershed permit, dealing exclusively with phosphorus, was issued for continuously discharging wastewater treatment facilities. It requires a 51 percent reduction in total phosphorus by 2015. Options for achieving this include phosphorus trading between point sources or a five-month seasonal concentration-based (e.g. 1 mg/L) or mass-based limit. The wastewater treatment facilities have met their 2010 interim target of a 35 percent reduction in total phosphorus.

Proposed site-specific pool standards consider proposed river eutrophication WQS (Table 2), linkages among rivers, pools and Pepin, downstream transport of TP and algae, TP and Chl-a relationships, and desire to minimize the frequency of nuisance blooms (Chl-a > 50 µg/L). Related considerations include LTI model projections for the Lake Pepin TMDL, existing upstream TMDLs (e.g. Minnesota River low DO and Lake St. Croix TMDLs), and numeric standards adopted in Wisconsin. The standards for the pools and Lake Pepin have an aquatic recreation use focus (Table 2), while the river standards (Table 1) have an aquatic life use focus. The Mississippi, Minnesota, and St. Croix River standards (Table 2) have a downstream protection focus as well.

H. Proposed Water Quality Standard for Excessive Attached Algae in Rivers

To complement the river eutrophication standards for sestonic algae, in streams where the algae community is dominated by periphytic algae that grow on rocks and other substrate, the MPCA is proposing a water quality standard to meet the standards prohibiting excess algal growth and slime (Minn. R. 7050.0150). The proposed periphyton water quality standard is designed to augment the proposed sestonic water quality standard in shallow, 1st and 2nd order streams. These streams typically do not have residence times sufficient to grow sestonic algae but could be susceptible to excessive attached filamentous algae or diatoms.

Rivers shall have an algal biomass not to exceed 150 mg Chl-a/m^2 and not to exceed one-third (1/3) of the stream width, to avoid nuisance algal biomasses that interfere with aquatic recreation designated uses. Dodds et al. (1997), Dodds & Welch (2000), Welch et al. (1988), and Suplee et al (2008) provide excellent literature reviews and biomass recommendations. More recently, work by Miltner (2010) suggests maintaining periphyton below 150 mg Chl-a /m^2 would be protective for aquatic life uses as well. In this work, he recommends that biomass remain below 107 mg/m^2 for protecting high-quality waters and less than 182 mg/m^2 to ensure minimum DO remains >4.0 mg/L. This further reinforces that a value of 150 mg Chl-a/m^2 is reasonable for protection of aquatic life and recreational uses. Suplee et al (2008) also provides example photographs for excellent quality, diatom-dominated streams, and poor-quality filamentous green algal [*Cladophora*] - dominated streams. Their study showed a clear demarcation in algal type as biomass increased from 150 mg Chl-a/m^2 to 200 mg Chl-a/m^2, mediated by nitrogen concentrations (Figure 23). Those studies we have noted here, as well as numerous studies cited in Exhibit EU-1, serve to support the 150 mg Chl-a/m^2 as proposed.

Figure 23 Examples of varying amounts of periphyton in streams as compared to periphyton Chl-a measurements. Taken from Suplee et al. (2008)

Photo A – very low biomass (44 mg/m^2)

Photo B – at the biomass breakpoint (152 mg/m^2)

Photo C – impaired stream (202 mg/m^2) biomass

I. Implementation

Once the proposed WQS promulgation is complete, the WQS must be integrated into the water quality assessment and permitting functions of the MPCA. It is reasonable to include a discussion of implementation of the WQS within the SONAR. This discussion will provide an overview of the proposed implementation in the MPCA's 303(d) assessment process and implementation in the National Pollutant

Discharge Elimination System (NPDES) permit system. In each case there will be guidance documents that will provide greater detail. In this section implementation in the assessment process will be addressed, while NPDES implementation will be addressed in Section 5 of the SONAR.

River Eutrophication Numeric Standards

The approach used for developing the river eutrophication standards bears similarity to Minnesota's lake eutrophication standards. Similarities include:

- We established relationships among the causative variable TP and response (stressor) variables. For medium to large rivers a significant relationship was established for sestonic (phytoplankton) chlorophyll-a, which was equally strong as that for lakes (Figure 9).
- For the river eutrophication standards, we made further linkages with BOD_5 and DO flux. In turn, we established linkages made among these cause and response variables and stream biology.
- We used a modified ecoregion-based approach that acknowledges that rivers may drain multiple regions. The regions were termed "River Nutrient Regions" (RNR). Ecoregion-based data summaries from MPCA (minimally impacted stream sites) and EPA ecoregion-based data distributions were used to place draft standard ranges in perspective with the overall population of rivers for the region.
- We conducted an extensive review of the literature, which contributed to the approaches taken and served as a basis of comparison for criteria developed elsewhere. We used multiple lines of evidence to yield draft ranges of standards and ultimately select the final proposed values.
- We propose a summer index period (June-September) for data collection and assessment. A minimum of two summers of data with six samples per summer will be required for assessments.
- For a river reach (AUID) to be deemed nutrient impaired it must exceed the RNR-based TP and one or more of the response variables: sestonic chlorophyll-a, BOD_5, diel DO flux or the pH standard.

Similar to the previous adoption of lake eutrophication standards, proposed river eutrophication standards will be implemented based on causal and response factors. For lakes the response is measured in terms of summer-mean chlorophyll-a or Secchi transparency. Minnesota has extensive experience in implementing this cause and response approach as a part of its 303(d) assessment of lakes. Implementing this approach in biennial assessments from 2002-2008 (using numeric translators) and in 2010 (using numeric WQS) more than 450 lakes have been assessed as impaired to date. Based on draft river eutrophication assessments conducted as a part of Exhibit EU-1, we are confident the proposed standards will be appropriate for identifying nutrient-impaired stream reaches and identifying those stream reaches that fully meet standards and are supportive of aquatic life use relative to nutrients.

Implementing river eutrophication standards via impaired waters assessments will be generally similar to the approach used for lakes. River sites (reaches or AUIDs) subject to assessment will be monitored about 6 to 8 times each summer for a minimum of two summers. All available data from the most recent 10-year period will be used in the assessment. For some rivers, the assessment will be based on two years of targeted intensive watershed monitoring, while for others there may be multiple years of data available within the 10-year period. TP, sestonic chlorophyll-a, and BOD_5 will be averaged for the entire period and compared to the RNR-based standards. Diel DO flux and pH data are used as well but data are managed and assessments are done in a different manner as described below.

Exhibits EU-1 and EU-3 provide details on methods for collecting instrumented DO data for the calculation of diel DO flux. Measurements will be taken over a minimum of three days and daily flux values will be calculated based on the daily maximum DO-daily minimum DO. These daily flux values are averaged based on the number of days of measurement. Table 6 provides an example of how data can be assembled for assessment purposes. The resulting DO flux measurement is then compared to the WQS (Table 1) to determine if this standard is met or exceeded.

Since pH assessments are based on the existing pH WQS, assessments should be done in accord with the existing methodology. Should the pH data exceed the pH standard this can be used in conjunction with the other WQS (stressor variables; Table 1) that make up the river eutrophication standards to determine whether the river reach (AUID) meets or does not meet WQS.

AUIDs that exceed the causative variable – TP and one or more of the response variables: Chl-a, BOD_5, diel DO flux, or pH are impaired and the AUID will be included on Minnesota's 303(d) list and appropriate steps, as described in TMDL guidance, would be taken to address this impairment. The TMDL will seek to restore the impaired reach and that will typically require that upstream reaches be included in TMDL development. We assume that achievement of the TP WQS will result in the response variables being met.

An example assessment using recent data from MPCA's watershed outlet monitoring sites is provided in Exhibit EU-1 (Appendix Table I-4). The assessed river sites had a sufficient number of observations and data for the causative variable: TP and one or more of the response (stressor) variables: Chl-a and BOD_5. Based on this example, most North RNR streams meet the proposed WQS. Both the Kettle and Rapid Rivers slightly exceed TP but are below the response WQS. In the Central RNR the Cannon, North Fork of the Crow, and Sauk Rivers exceed the proposed WQS, while the Leaf, Otter Tail, and Red Lake Rivers meet them. The Mississippi at Anoka and Rum Rivers are very close to the proposed WQS and would likely warrant closer inspection of data and/or continued monitoring. In the South RNR, most of the rivers exceed proposed WQS including the Minnesota, Blue Earth, Le Sueur, Des Moines, Redwood, South Fork of the Crow and Shell Rock. The Pomme de Terre, Mustinka, and Watonwan Rivers all meet stressor variables - though each exceeds the proposed TP standard.

We conducted a draft analysis to determine how proposed eutrophication standards compare to biological criteria (IBIs). STORET data for TP, Chl-a, and BOD_5 was obtained for AUIDs and matched to biological monitoring sites where both fish and invertebrates were sampled (Table 18). AUIDs with exceedances of the proposed WQS (cause and one or more response) were compared to biological condition. AUIDs that met the proposed eutrophication WQS were not assessed in this analysis as it could not be determined with available data if another stressor was responsible for the biological data not meeting the biocriteria. A total of 33 AUIDs had sufficient biological and water quality data to perform this analysis (Exhibit EU-1, Appendix). Based on this data, a simple determination was made if proposed eutrophication standards and biological criteria were in agreement for each AUID. Determinations of "Agree" were made if one or both biological groups (i.e., fish and invertebrates) indicated impairment and "Disagree" if both biological groups did not indicate impairment. Some AUIDs were given the determination of "More information needed" if the IBI score for one or both of the biological groups was within the confidence bounds of the biocriterion (i.e., near the biocriteria threshold). [Some caution should be exercised with this analysis as in some cases the data were not sufficient to meet the minimum data requirements for assessment.] In addition, this analysis is not equivalent to the comprehensive assessment approached employed by the MPCA; under a true assessment of reach attainment, other evidence may be part of the determination of attainment or nonattainment. In general, there was good agreement between the biological and nutrient assessment (Figure 25). Overall, they were in agreement in 79 percent of cases with an additional 15 percent possibly agreeing (i.e., more information was needed to make a determination). In only 6 percent of cases (2 AUIDs) did the IBIs indicate that biology was meeting designated aquatic life uses, but the proposed eutrophication WQS were exceeded. A single AUID in the North region indicated eutrophication impairment, but the biological measures were mixed in this AUID (Roseau R., Table 18). Ten AUIDs in the Central region exceeded the draft eutrophication standards and of these eight AUIDs indicated biological impairment and two did not. In the South region, 22 AUIDs exceeded the draft eutrophication WQS and all indicated biological impairment or possible impairment (within confidence interval,Table 18). Approximately 42 percent of the 33 AUIDs were wadeable reaches (i.e., <500 mi^2) and included AUIDs with drainage areas as small as 19 mi^2 and several below 100 mi^2.

Downstream protection is an important consideration in WQS implementation (e.g., Exhibit EU-19b). This means that proposed river eutrophication standards need to be protective of the assessed water and downstream waters. In the case of eutrophication, the downstream waters of concern would typically be lakes, reservoirs, or mainstem pools on major rivers. Based on a long history of lake restoration and watershed projects, the MPCA is confident the proposed river eutrophication standards will be protective of downstream uses. We offer various lines of evidence in this regard.

1. One basis for this assertion is comparing the proposed WQS to the stream TP values used in the Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) model. The MINLEAP model (Wilson & Walker 1989; in Exhibit EU-1 is used as a basis for predicting in-lake TP for minimally impacted lakes on an ecoregion basis. The model was regionally calibrated. It is routinely used to help define in-lake goals for lake and watershed restoration projects. The regionally calibrated stream values that serve as the basis for calculating TP loading in MINLEAP for the NLF and NCHF ecoregions are respectively 52 µg/L and 148 µg/L. These values represent typical stream TP from minimally impacted watersheds within that ecoregion (calibrated to specific characteristics of the region; see Wilson and Walker 1989 for more detail). The model-predicted TP represents the "expected" TP for a lake (given its size, depth and watershed area). Since the proposed WQS are equal to or lower than the MINLEAP stream TP values, they should be protective of downstream lakes (based on this comparison). A similar comparison cannot be made for the WCBP and NGP ecoregions because the stream inflow TP was highly calibrated to account for excessively high storm-event TP and internal recycling in the shallow lakes of these ecoregions.
2. For further perspective, about 50 percent of Northern RNR streams have TP <50 µg/L (Figure 24) and 75% <70 µg/L, which suggests that stream TP is relatively low over much of the Northern RNR. In the few instances where Northern RNR stream TP is elevated and contributes to a downstream impairment, the TMDL would establish the required stream TP to ensure in-lake WQS are met. If that TMDL-derived value were < 50 µg/L, it would take precedent over the adopted eutrophication standards. For the Central and South RNRs, over 60 percent and 70 percent respectively, of the stream AUIDs have TP above the proposed WQS, which further suggests the proposed WQS should be protective of downstream resources.
3. Lake nutrient TMDLs will define the steam inflow P needed to meet the TMDL and protect the resource. Erdmann (2012, Exhibit EU-55) conducted a review of lake and inflow TP requirements for 16 lakes across eight EPA-approved TMDL projects. All 16 lakes were within the NCHF

ecoregion and required stream inflows ranged from 41 µg/L to 215 µg/L, with an interquartile range of 45-92 µg/L. Erdmann noted that the five lakes with very low inflow TP were located directly on the Clearwater River and had high flushing rates (low water residence time), which limited their ability to process the incoming load. This review indicates that no single value (stream TP criterion) could be protective of all downstream resources; rather the TMDL for impaired lakes and reservoirs will define the needed inflow concentration.

4. A further review determined the extent of nutrient impaired lakes and their watersheds for Minnesota (Figure 26). This mapping indicates that a majority of Minnesota (by area) is included in a nutrient-impaired lake watershed. The subsequent TMDL for each lake will dictate the reductions (stream inflow) required to meet WQS for each lake.
5. The linkage among the proposed river, navigational pool, and Lake Pepin eutrophication standards is addressed in Exhibits EU-5 and 6 and is summarized in Table 2. These standards are protective of the specific resource as well as downstream resources. For example, if upstream criteria are achieved in the Upper Mississippi, Minnesota, and St. Croix Rivers Lake Pepin criteria will be met. In turn, downstream navigational pool criteria should be attained as well.

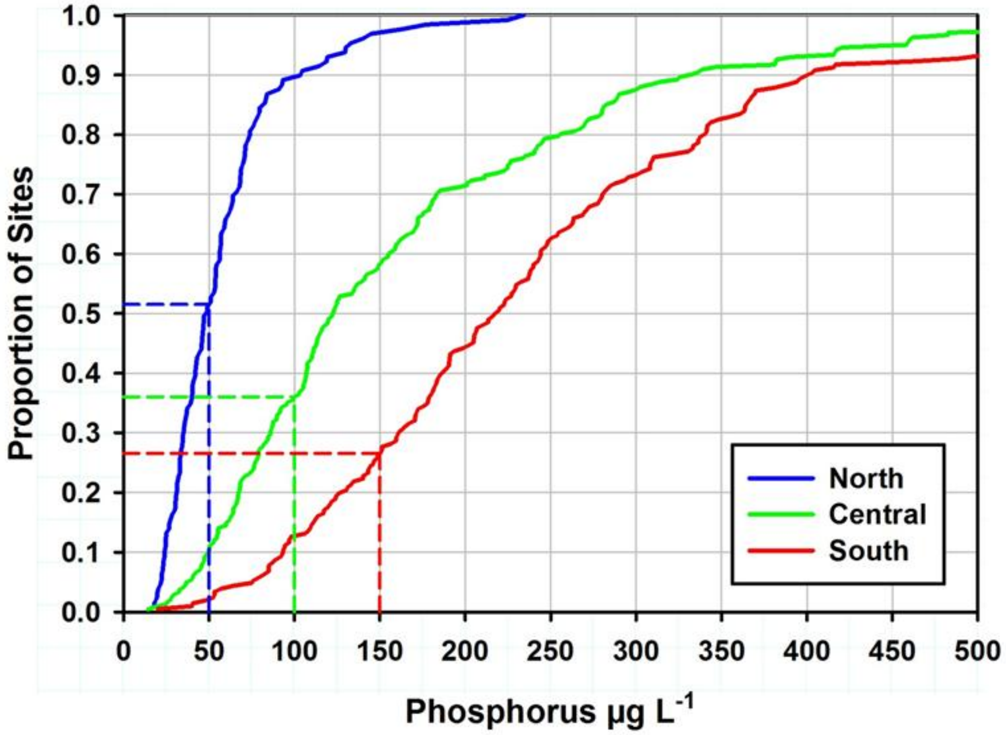


Figure 24. Cumulative distribution functions for stream total phosphorus concentrations by RNR. Mean summer (June through September) concentrations for AUIDs from 1995-2009 data drawn from STORET. North= 128 AUIDs, Central=239 AUIDs, and South=206 AUIDs. Dashed lines interpolate the proportion of sites meeting or not meeting the draft total phosphorus criteria for each RNR.

Table 18. Comparison of draft WQS to preliminary biological criteria using WQ data from STORET (means and # of measurements in parentheses). [Notes: DA = drainage area; Inv = Invertebrates; yes = site impaired for biology; no = site not impaired for biology; ? = above biological criteria but within confidence interval; nd = no data; na = not assessable). Note: Some AUIDs have too few Chl-a or BOD_5 measurements (<10 records during the index period) for assessment, but were still included in this analysis.] Values in bold with grey exceed proposed WQS.

AUID	River Name	DA (mi^2)	Chl-a (µg/ L)	BOD_5 (mg/ L)	TP (µg/ L)	Fish	Inv	Overall
NORTH								
09020314-501	Roseau	1397	**22.9 (3)**	**2.75 (2)**	**126 (51)**	no	?	?
CENTRAL								
07040002-502	Cannon	1296	16.2 (20)	**2.56 (20)**	**190 (37)**	no	yes	yes
07040002-542	Cannon	96	15.5 (6)	**5.00 (20)**	**730 (36)**	?	yes	yes
07010204-502	Crow	2637	**70.8 (40)**	**4.27 (33)**	**309 (90)**	yes	yes	yes
07010204-503	N.F. Crow	1340	**55.1 (24)**	**3.33 (27)**	**248 (61)**	yes	yes	yes
07010206-596	Hardwood Creek	29		**5.44 (2)**	**246 (23)**	yes	yes	yes
07010202-501	Sauk	1038	**27.5 (22)**	**2.49 (7)**	**171 (75)**	no	no	no
07010202-505	Sauk	570	**30.0 (2)**		**158 (62)**	yes	yes	yes
07030004-587	Snake	974	**23.9 (4)**	**2.08 (20)**	**100 (42)**	no	yes	yes
07040004-507	S.F. of Zumbro	312	**24.0 (16)**	**2.24 (15)**	**209 (58)**	no	no	no
07040002-560	Waterville Creek	19		**3.55 (11)**	**278 (21)**	yes	?	yes
SOUTH								
07100001-503	Beaver Creek	170	**70.8 (3)**	2.07 (48)	**186 (87)**	yes	yes	yes
07020009-507	Blue Earth	1539	**67.7 (15)**	**4.55 (15)**	**237 (16)**	?	yes	yes
07020009-515	Blue Earth	1385	**85.8 (35)**	**4.59 (35)**	**306 (35)**	yes	yes	yes
07040002-509	Cannon	952	31.6 (15)	**4.15 (12)**	**371 (43)**	yes	no	yes
07020012-516	Carver Creek	74	66.9 (46)		**352 (86)**	?	no	?
07020009-503	Center Creek	92	34.3 (19)	**5.80 (12)**	**371 (105)**	?	yes	yes
07100001-533	Des Moines	480	**166.0 (2)**	**6.92 (49)**	**280 (50)**	yes	yes	yes
07100001-501	Des Moines	1182	**196.2 (2)**	**7.77 (49)**	**323 (50)**	yes	yes	yes
07020009-502	Elm Creek	191	**57.8 (20)**		**193 (128)**	yes	yes	yes
07100001-527	Heron Lake Outlet	450	**139.7 (1)**	**10.96 (80)**	**388 (101)**	yes	yes	yes
07020011-501	Le Sueur	1109	**41.4 (56)**		**279 (109)**	yes	no	yes
07020011-504	Little Cobb	128	**66.3 (56)**		**257 (73)**	yes	nd	yes
07020004-509	Minnesota	8056	**52.8 (18)**	**4.02 (18)**	**205 (18)**	no	yes	yes
07020007-501	Minnesota	15102	**72.7 (77)**	**4.57 (15)**	**252 (70)**	?	?	?
07020007-505	Minnesota	11280	**69.9 (48)**		**259 (100)**	?	?	?
07020002-501	Pomme de Terre	651	**42.0 (10)**	2.96 (10)	**198 (84)**	yes	yes	yes
07020006-501	Redwood	697	**79.1 (29)**	3.39 (26)	**328 (29)**	no	yes	yes
07020006-509	Redwood	610	**93.7 (12)**	**5.08 (4)**	**449 (83)**	nd	?	?
07020012-521	Rush	402	**42.9 (4)**	3.18 (4)	**230 (74)**	yes	?	yes
07020012-662	Sand Creek	93	**72.1 (88)**	**4.19 (11)**	**345 (53)**	yes	nd	yes
07080202-501	Shell Rock	187	**78.1 (25)**	**6.17 (19)**	**508 (51)**	?	yes	yes
07010205-508	S.F. Crow	1167	**69.8 (24)**	**5.45 (26)**	**407 (64)**	yes	yes	yes

	#	%
yes	**26**	**79**
?	**5**	**15**
no	**2**	**6**

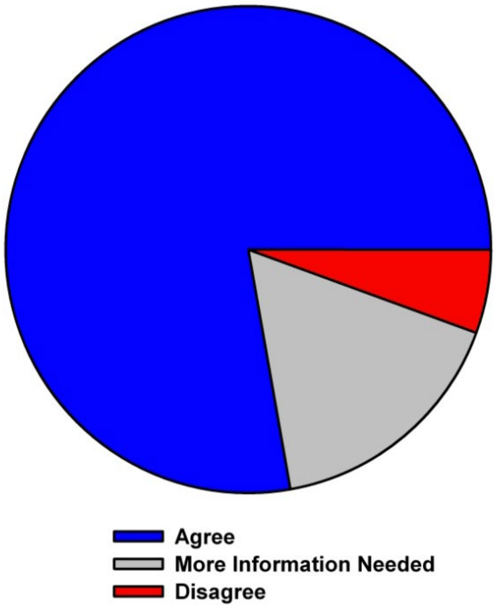


Figure 25 Draft comparison of river eutrophication impairment assessment based on proposed criteria as compared to assessments based on preliminary biological criteria. Thirty-three AUIDs were assessed based on data from STORET as described in Table 18

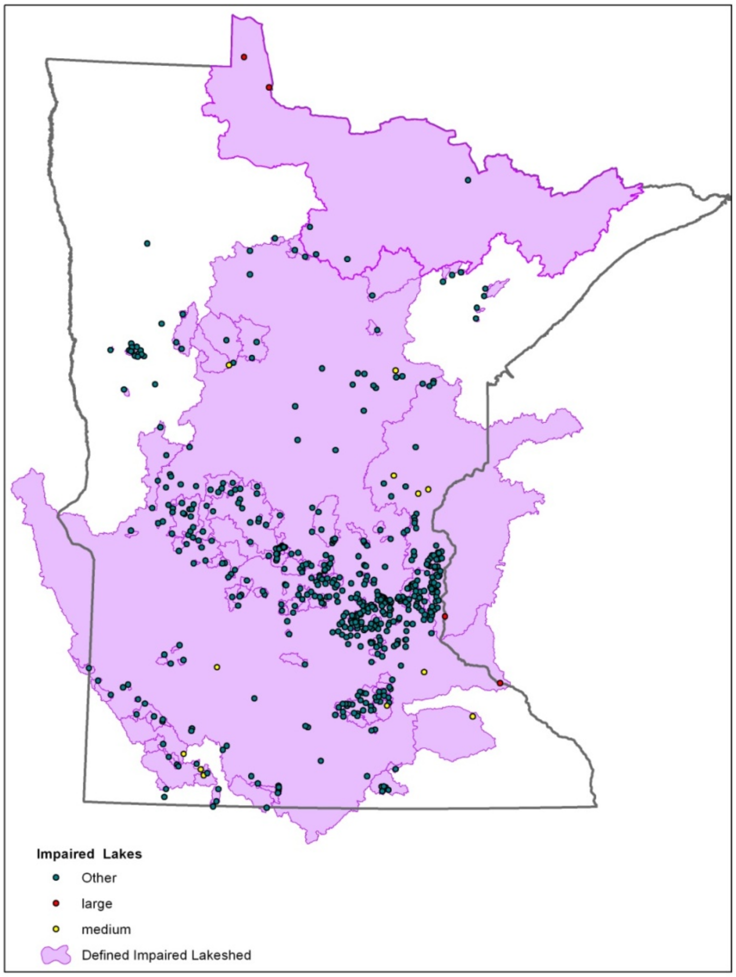


Figure 26. Nutrient impaired lakes (~520 lakes) and extent of their watersheds. Lake Pepin (Upper Miss., Minn., and St. Croix Basins) and Lake of the Woods (Rainy Basin) TMDLs have largest influence on an area basis. Map current as of October 2012.

Lake Pepin and Navigational Pool Standards

The Lake Pepin and navigational pool standards were developed in a Mississippi River context. Achieving these standards will require phosphorus and chlorophyll reductions upstream of Lake Pepin, in specific watersheds (Lower Minnesota River, Crow River, Sauk River, etc.). The proposed Lake Pepin standards cannot be considered in isolation to imply that P reductions anywhere upstream of the lake will have the desired impact. The main biological activity affecting Lake Pepin trophic status is not taking place in the lake, but instead upstream of it. In particular, reductions upstream of the MCES's Wastewater Treatment Plants (WWTPs) are needed to achieve the proposed WQS. The Lake Pepin site-specific standard is not a stand-alone goal to be pursued in isolation. Rather, it belongs to a set of goals (standards) for the Mississippi River system that if pursued systematically in unison, will achieve the desired results.

Flow directly influences residence time and plays a significant role in Chl-a production in Lake Pepin and the overall system (Exhibit EU-6). Previous efforts to establish a Chl-a goal for Lake Pepin emphasized summers of low to average flow when Lake Pepin exhibited more "lake-like" conditions. While low to average flow summers remain an important focus in modeling and data analysis, site-specific standards are applicable across all summers to ensure aquatic recreational use is supported in all years. This issue becomes more acute as we seek to harmonize river, pool, and Lake Pepin standards, since the proposed WQS will be applicable across all summers and data from both low-flow and high-flow summers contribute to 303(d) assessments (Exhibit EU-6). With this in mind, site-specific standards for Lake Pepin and Mississippi River navigational pools will be applied across all summers with assessments using summer-means based on the most recent 10 years, consistent with other 303(d) assessments. An exception to the use of the complete 10-year record would be if a significant trend were noted that could be associated with specific point and nonpoint source reductions conducted as a part of TMDL implementation. In that instance, a shorter record (a minimum of two summers) could be used to assess use-support. This exception is consistent with the 303(d) assessment guidance and TMDL (Exhibit EU-32). Since the Long Term Resource Monitoring Program (LTRMP) fixed site network was the primary data set used to support the listing of Lake Pepin and site-specific standards development it is anticipated the LTRMP be the primary data source for assessing progress on the TMDL. This implies data collection will continue at the four fixed sites, with one in the upper segment and three in lower segments along the thalweg of the lake (Figure 19).

Consistent with lake eutrophication criteria, both the causative (TP) and response variable (Chl-a) need to be exceeded for the pool (assessment reach) to be listed on the 303(d) list. While we have not examined the relationship between Chl-a and pH in the pools, there is adequate information for rivers to suggest that elevated Chl-a may result in elevated pH. Thus, consistent with the draft river eutrophication criteria, elevated pH could be used as an additional response variable for pool eutrophication standard assessment. Since pH is an existing ambient WQS in Minn. R. ch. 7050, the values and method for applying that standard is in rule and guidance already.

A summary of recent MCES and LTRMP data (Table 16 Table 16) provides perspective on the water quality of river and pool sites in the Mississippi River system and allows for a comparison with the proposed site-specific standards. Based on MCES data, the Mississippi River near Anoka (UM-872) and the Minnesota River near Jordan (MI-39) are above the proposed values and would be deemed impaired. TMDLs for these AUIDs should provide the roadmap for needed upstream reductions. Meeting the proposed standards in these two reaches should result in attainment of downstream pool and Lake Pepin eutrophication standards. Lake St. Croix, near Prescott WI (SC-0.3) is slightly above the proposed standards and the Lake St. Croix TMDL will address this. Lake Pepin values for the most recent 10 years remain above the site-specific standards as well. Pool 2 also exceeds the proposed standards. Pools 5-8 are currently attaining the proposed Chl-a WQS; meeting eutrophication standards upstream will further benefit these pools. As upstream nutrient TMDLs are developed and implemented, there will be a reduction in phosphorus loads to Pools 5-8. These reductions will provide additional protection for the pools.

The proposed standards will protect aquatic life in rivers and pools (Table 2), while also protecting aquatic recreation in Lake Pepin and protecting downstream aquatic life and recreational uses in Pools 5-8. They are consistent with Wisconsin's nutrient standards for large rivers and Lake Pepin. This is important given a mandate from the 2011 Minnesota First Special Session that directed the MPCA to coordinate with Wisconsin in establishment of a phosphorus standard for Lake Pepin (Exhibit EU-43). The EPA is also supportive of a consistent standard between the two states.

In summary, proposed eutrophication standards consider linkages among rivers, pools and Lake Pepin, downstream *transport of TP and algae, TP and Chl-a relationships, and desire to minimize the frequency of nuisance* algal blooms (Chl-a > 50 µg/L). Related considerations include Limno Tech Inc. (LTI) Upper

Mississippi River – Lake Pepin mechanistic model projections for the Lake Pepin TMDL (Table 13) and existing upstream TMDLs (e.g. Minnesota River Low DO and Lake St. Croix TMDLs).

Future Site Specific Standards

While Minnesota Rules Chapter 7050 already provides the authority to develop site-specific Class 2 standards for reservoirs, rivers, pools or any waterbody (existing Minn. R. 7050.0222, subp. 8), the MPCA believes it is important and reasonable to mention site-specific considerations in the context of the current rulemaking. Additionally, it recognizes the possibility that site-specific standards for rivers may need to be needed as we gain more experience implementing the standards.

Reservoirs have many unique characteristics that can cause them to react somewhat differently to nutrient loading as compared to natural lakes and the lake eutrophication WQS rulemaking considered this and indicated that site-specific WQS would likely be required. While the MPCA has incorporated Lake Pepin and navigational pool (Table 2) and river-reach (AUID) site-specific WQS (Table 11) in this current rulemaking, any future river eutrophication-related site-specific WQS would be proposed for adoption through a standard administrative update. This update would most likely be in association with a NPDES permit or a TMDL.

Periphyton Standard

Periphyton can be sampled by using artificial substrates or on naturally occurring substrates; Aloi (1990) recommends natural substrates. There are several national sampling protocols available for assessing the periphyton in wadeable streams (Standards Methods Committee 2001 and the US Geological Survey Open-File Report 02-150). We recommend that the method as described in the USGS National Field Manual be used so there is consistency among results (Exhibit EU-36; Hambrook-Berkman & Canova 2007).

For assessment purposes, sampling should occur during the algal growing season of June through September and no more than one year in ten should exceed 150 mg Chl-a/m^2. Appropriate sampling areas are those where light penetration reaches the area being sampled.

The MPCA's stream condition monitoring program will incorporate periphyton collection when nuisance periphyton growth is observed. For assessment purposes, sampling should occur during the algal growing season of June through September. This sampling should be conducted during the first year of the two-year intensive watershed monitoring so that a second sampling may be undertaken during the second sample season, if the first exceeds 150 mg Chl-a/m^2. If both collections, with field duplicates, exceed 150 mg Chl-a/m^2, along with photo documentation of the visible nuisance condition, this is evidence that impairment due to "nuisance algal growth" is occurring at that site.

Appropriate sampling areas are those where light penetration reaches the sampling area. Collection for periphyton Chl-a, as a response variable, is limited to rock substrate due to the difficulty of collecting a representative sample in stream depositional habitats without losing cells. This is an acceptable approach because streams that are limited to sand and silt beds are often already impaired for sediment instability system-wide. Also, more direct nutrient enrichment impairments will often be seen downstream in these systems based on elevated sestonic Chl-a and this impairment will be addressed along with sediment in watershed scale TMDL approaches. The recommended field approach follows the USGS sampling protocol as defined in Exhibit EU-36 with some adaptations developed by MPCA for assessment use as noted in MPCA assessment guidance.

Once an impairment of the narrative eutrophication standard, as represented by the periphyton criteria, is identified, the next step will be to determine the cause of the excess periphyton growth. This step is needed before a TMDL study can be initiated, since a TMDL would focus on the stressor(s) causing the impairment. Since there are many factors that go into the determination of periphyton biomass, as has been discussed above, the approach that will work the best is utilizing the EPA's Stressor Identification Guidance Document (USEPA/822/B-00/025) (Cormier *et al.* 2000) at the following web link: http://www.USEPA.gov/waterscience/biocriteria/stressors/stressorid.pdf. This document contains an introduction to the Stressor Identification (SI) process, and walks through the SI steps of listing candidate causes, identifying approaches to analyze the evidence, characterizing causes, and iteration options.

Rivers Not Able to Meet Standards Due to Natural Causes

Some rivers can never attain the proposed eutrophication standards due to natural causes. Rivers determined to be unable to meet standards due to natural causes will not be considered in violation of the eutrophication standard. As is the case with other water quality standards, the MPCA is proposing the following language for 7050.0222, subparts 2b and 3b:

> *Narrative eutrophication standards for Class (2A/Class 2Bd) Rivers and streams*
>
> *C. Rivers and streams with a baseline quality that does not meet the numeric eutrophication standards in 7050.0150, subpart 5a are in compliance with the standards if the baseline quality is the result of natural causes. The commissioner must determine baseline quality and compliance with these standards using summer average data and the procedures in part 7050.0150, subpart 5.*

The key to this concept is determining whether the trophic condition in a given river is the result of natural causes alone, or the result of the combination of natural nutrient loading plus loading from human activities in the watershed. The determination will require river-specific monitoring data, historical information, watershed data, and other relevant information. Input from local organizations and units of government and the public would be very important as well.

Protecting Rivers with Better Quality than Water Quality Standards

Another major concern with proposing eutrophication WQS is that the numeric standards are adequately protective of high water quality - which is the quality better than the standard necessary to meet the beneficial use. We anticipate this being accomplished by appropriate implementation of nondegradation language, the third element of WQS. As with other WQS there is an expectation that the proposed river eutrophication standards are not "degrade down to" standards; rather waters that are currently meeting standards would be expected to continue to do so. The combination of the eutrophication standards and nondegradation language should assure this occurs, except in certain circumstances where a nondegradation review results in the allowance of some degradation that is necessary for important social or economic development.

As was the case for the lake eutrophication standards the MPCA is proposing to include a strong non-degradation policy statement with the numeric standards as follows:

> *"It is the policy of the MPCA to protect all rivers and streams from the undesirable effects of cultural eutrophication. Rivers and streams with a quality better than the numeric*

> *eutrophication standards in subpart 4 must be protected from unnecessary degradation through the strict application of all relevant federal, state, and local requirements governing nondegradation, the discharge of nutrients from point and nonpoint sources, and the protection of river and stream resources, including, but not limited to:"*
>
> (1) nondegradation requirements in parts 7050.0180 and 7050.0185
> (2) phosphorus effluent limits for point sources, where applicable in chapter 7053
> (3) requirements for feedlots in chapter 7020
> (4) requirements for individual sewage treatment systems in chapter 7080
> (5) requirements for control of stormwater in chapter 7090
> (6) county shoreland ordinances and
> (7) implementation of mandatory and voluntary best management practices to minimize point and nonpoint sources of nutrients"

It is reasonable to list, in rule, examples of the requirements the MPCA has in mind to prevent an increase in nutrient loading to high quality streams and rivers. In streams and rivers where a decline in water quality can be documented due to anthropogenic nutrient sources, but the stream or river is still "better than standards" management of nutrient loading may be needed to halt the decline in water quality. What is listed in the proposed rule are existing provisions and treatment requirements already adopted and in place. The nondegradation policy statement establishes no new authority for the MPCA or any other government entity; rather it relies on existing provisions in Minn. R. 7050.0180 and 7050.0185 and provisions in other existing rules, as well as local ordinances.

J. Change to Minn. R. 7053.0205

As part of the amendments to the eutrophication standards, the MPCA is also making a corresponding change to stream flow considerations when setting effluent limits (Minn. R. 7053.0205, subp. 7). This change is needed to account for the seasonal nature of the proposed river eutrophication standards.

Minn. R. ch. 7053 pertains to the establishment of effluent limits and Minn. R. 7053.0205 establishes the general requirements for discharges to waters of the state. Subpart 7 provides conditions for the consideration of minimum stream flow in the process of setting effluent limits. In this rulemaking, the MPCA is proposing to add a new item C to the requirements to address discharges of total phosphorus in relation to the proposed eutrophication standards.

River eutrophication WQS are based on a long-term summer average. All summer days and thus all summer flows are equally weighted when calculating a long-term summer average for assessments. Evaluating a single summer river flow such as $7Q_{10}$ to establish effluent limits is not consistent with the definition of "average". All available flow data will be considered when establishing effluent limits for river eutrophication WQS.

The MPCA is also proposing to consider all sources of phosphorus to given receiving water along with the propensity of the water to grow algae when setting effluent limits. The MPCA staff has identified this aspect of the existing rules as an area of confusion because the current rule is not explicit about what factors can be considered when developing phosphorus effluent limits. The added provision is a reasonable clarification of how the existing process for setting effluent limits is conducted. Exhibit EU-45 includes implementation guidance for river eutrophication standards. The guidance spells out specific procedures and considerations MPCA staff will use to set effluent limits based the river eutrophication standards.

K. Reasonableness Conclusion

The MPCA, as the state agency responsible for implementing the Clean Water Act in Minnesota, is charged with identifying the beneficial uses of the state's waters and ensuring those uses are protected and (where impacted) restored. In accomplishing this charge, the MPCA relies on federal guidance, national research, and Minnesota-specific data to identify the conditions in Minnesota waters that are protective of beneficial uses.

Research from around North America (including Minnesota) has documented linkages between phosphorus, in-stream chlorophyll-a and impairment of the aquatic life and recreation beneficial uses of rivers and streams. The MPCA considered that research and its own Minnesota-specific studies in developing the proposed river eutrophication standards, and the site-specific standards for Lake Pepin and the Mississippi River navigational pools.

The MPCA's approach of focusing the standards development effort on medium to high order streams (typically 4th order and higher) was reasonable given the data available in Minnesota, and the scientifically established relationships between river eutrophication and aquatic life and recreation impacts in these sizes of streams (as exhibited through excess Chl-a, DO flux, excess BOD_5 or violation of the pH standard). Most of the streams included in the River Nutrient dataset (1999-2008) have watershed areas of 500 mi^2 or greater (most >1,000 mi^2), are generally considered non-wadeable, and include many prominent and highly utilized (from Aquatic Life Use Support (ALUS) and Aquatic Recreational Use Support (ARUS) standpoints) Minnesota rivers. Detailed River Nutrient data sets included nutrients, sestonic Chl-a, water chemistry, diel DO measurement, and fish and invertebrate collections. The RN data were complemented with statewide biological data sets that provided statewide coverage of both high and low order streams, a comprehensive basis for establishing interrelationships among nutrients, DO, algae and aquatic life and ultimately appropriate proposed river eutrophication standards.

The conceptual models (Figure 3, Figure 4) provide an overview of the focus of the MPCA's research and the linkages the MPCA established. The MPCA's approach used multiple lines of evidence to develop the river eutrophication standards that are protective of aquatic life use (Table 1). This approach is well supported in the literature, including the EPA nutrient criteria guidance manual for rivers and streams (Exhibit EU-14) and more recent SAB and EPA guidance (Exhibits EU-18 EU-20). EPA reviewers also were supportive of this approach (Exhibits EU-22a, EU-23a, and EU-24a).

As the various studies from 1999-2008 built-upon one another, so did the steps used to derive the proposed standards. The major steps or approaches that were used are summarized below.

- Linear regression described basic interrelationships among TP, TKN, sestonic Chl-a and DO flux based on the river nutrient datasets. Most relationships exhibited high R^2 values and were highly significant.
- Spearman correlation analysis provided an initial basis for identifying relationships among TP, TN, Chlorophyll and DO flux and fish and invertebrate metrics. This provided a basis for identifying responsive metrics for each of these variables and helped to focus subsequent analyses.

- Scatterplots were used to visualize relationships among the more responsive metrics and the stressors and begin threshold identification.
- More advanced statistical techniques, quantile regression and changepoint analysis, which are well suited to the often wedge-shaped plots that are common with field-collected biological data, were employed. These techniques were applied to both the River Nutrient dataset and the much larger biomonitoring datasets.
- Threshold concentrations were produced for statewide, wadeable vs. nonwadeable, and on a region-specific basis (Table 8).
- A comprehensive review of the literature was conducted and literature-based thresholds were used to provide further perspective on this issue (Table 9).
- Threshold concentration ranges were placed in context with ecoregion-based frequency distributions compiled by MPCA for representative, minimally-impact streams (Exhibit EU-30), a compilation of stream TP data from STORET (Figure 24), and IQ ranges from EPA criteria manuals (Exhibits EU-10-11,-12).
- All of the above were used to move from broad criteria ranges to region-specific criteria as defined in Table 1.

Data from STORET and previous MPCA (Exhibit EU-30) and EPA ecoregion-based summaries were used to place the TP values in perspective for Minnesota. Based on MPCA's data summary for Northern RNR streams about 60 percent have TP <55 µg/L (Figure 24). These percentages are similar to that reported by EPA. Based simply on TP this suggests that ~60% of Northern RNR stream-sites will likely comply with the proposed standards. However, once the response variables are considered it is likely a higher percentage will meet the standards. The data summary (Figure 24) indicates that about 35 percent of the Central RNR stream sites are <100 µg/L, which suggests that, dependent on a streams response to TP (sestonic Chl-a), many stream-sites (AUIDs) in the Central RNR may be deemed impaired for nutrients. The data summary suggests about 30 percent of the South RNR stream sites have TP <150 µg/L (Figure 24). Maps in Exhibit EU-1 indicates that all 8-digit HUCS in the South RNR have one or more stream sites with TP >150 µg/L, which implies that most 8-digit HUCS in that RNR may have one or more stream sites deemed impaired for nutrients, again dependent on response variables. Developing these standards in a regional context recognizes the gradient in land use, landform, soil type and potential natural vegetation that characterizes Minnesota's heterogeneous landscape and is consistent with EPA guidance that supports standards development on an ecoregional basis (e.g., Exhibits EU-10,-11,-12, and -13).

In addition to the RNR-based river eutrophication standards, site-specific standards are proposed for the Mississippi River navigational pools 1-8 and Lake Pepin. Numeric standards for the pools and Pepin focus on aquatic recreation use support, in contrast to the ecoregion-based river standards that focus on aquatic life use support. Regardless of the water-body focus, an essential feature of the MPCA's entire approach for eutrophication standards for the major rivers, pools, and Lake Pepin is that all of the proposed standards support one another, so that all resources are adequately protected from the impact of excess nutrients. This critical goal was built into the overall process and resulted in the proposed WQS (Table 2).

In addition to the ecoregion-based eutrophication standards, the MPCA is proposing a criterion to address the impact of nuisance levels of periphyton that can limit aquatic life and aquatic recreational uses of Minnesota streams. This proposed criterion of 150 mg Chl-a/m^2 is well supported in the literature (e.g. Exhibit EU-14) and provides a sound basis for defining impairment from excess periphyton.

The combination of the ecoregion-based eutrophication standards and the numeric translator for nuisance levels of periphyton represent Minnesota's eutrophication WQS for rivers. These proposed standards are intended to be protective of aquatic life and aquatic recreational use relative to eutrophication impacts. In developing these proposed standards, the MPCA followed a reasonable and well-established scientific approach that considered relevant guidance, studies, and Minnesota-specific data, while focusing on the important responsibility of protecting Minnesota's waters from the impacts of nutrient pollution.

5. Specific Rulemaking Activities Relating to the Proposed Eutrophication Standards

A. Comparison to other standards

Other States, Native American Bands, and Canadian Provinces

In the development of the proposed WQS, the MPCA has conducted benchmarking with other entities to benefit from others knowledge and experience. This benchmarking also helps to fulfill the requirements of Minn. Stat. § 14.131, which requires an evaluation of a proposed rule in relation to corresponding federal regulations, and Minn. Stat. §116.07, subd.2 (f), which requires that the MPCA evaluate each proposed standard in relation to corresponding requirements of the federal government and also the standards of bordering states and other states within EPA Region V.

> *§116.07, subd.2*
>
> *(f) In any rulemaking proceeding under chapter 14 to adopt standards for air quality, solid waste, or hazardous waste under this chapter, or standards for water quality under chapter 115, the statement of need and reasonableness must include:*
>
> *(1) an assessment of any differences between the proposed rule and:*
>
> *(i) existing federal standards adopted under the Clean Air Act, United States Code, title 42, section 7412(b)(2); the Clean Water Act, United States Code, title 33, sections 1312(a) and 1313(c)(4); and the Resource Conservation and Recovery Act, United States Code, title 42, section 6921(b)(1);*
>
> *(ii) similar standards in states bordering Minnesota; and*
>
> *(iii) similar standards in states within the Environmental Protection Agency Region 5; and*
>
> *(2) a specific analysis of the need and reasonableness of each difference.*

Under Minn. Stat. §116.07, subd. 2, (f), the MPCA is required to evaluate the differences between the proposed standards and the standards of EPA, Wisconsin, Michigan, Iowa, North Dakota, South Dakota, Indiana, Illinois and Ohio. Such an evaluation is challenging due to the geographic context of the proposed river eutrophication standards – a context that is needed to reflect the diversity of Minnesota's ecoregions and water resources. The evaluation is further complicated by the fact that many states are developing but have not yet formally proposed river eutrophication standards; where that is the case, the MPCA's analysis relied on the most recent standard development information or draft criteria available from that state.

The following discussion presents the MPCA's analysis of the similarities and differences between the river eutrophication standards proposed in this rulemaking and the standards of EPA, Region 5 states, and adjacent states as of fall 2011

In addition to the statutory obligation to consult with other states and the federal government, EPA has directed states to adopt numeric nutrient standards on their own or face possible promulgation by EPA (e.g., Exhibit EU-10 and EU-20). In response to this expectation, the MPCA has communicated extensively with other states to ensure that Minnesota's proposed river eutrophication standards are consistent with other states' approaches. Many states are likely to use a similar sequence of steps to those Minnesota has taken leading up to the adoption of eutrophication standards. Those steps include:

1. Gather state-specific nutrient, trophic condition, and water clarity (e.g. Secchi or turbidity) data, and biological and other data in streams, rivers, and lakes.
2. Analyze the data to find relationships between nutrients and response, such as changes in biological communities or water quality.
3. Identify nutrient (TP and possibly nitrogen) "thresholds" or levels that show a significant shift in biological or water quality response and
4. Select numeric standards or draft nutrient standards based on a combination of data-driven thresholds, and policy decision on the function of nutrient standards in the state.

Based on progress reports given by many states at an EPA-state nutrient criteria conference held in Dallas, Texas in February 2006, many states were in steps 1, 2, and 3. A few have adopted numeric criteria or standards since 2006 and several have some type of narrative eutrophication standard. A recent national summary on state adoption of numeric nutrient standards for the period 1998-2008 (EU-17) indicates that as of 2008 seven states have adopted numeric standards for one or more waterbody type and 18 states adopted numeric standards for one or more parameters for selected individual waters in a waterbody type. The seven that have adopted numeric standards for at least one waterbody type include Vermont, Rhode Island, New Jersey, Delaware, North Carolina, Minnesota, and Oregon. Of these seven only two: Oregon and Minnesota have adopted these standards since the baseline date of 1998 (approximately the initiation of the national nutrient criteria program). A summary of the status of nutrient standards development for select states follows, with an emphasis on Region V and neighboring states.

Illinois is gathering nutrient data for rivers and streams. They have compared nutrient levels to indices of biotic integrity (IBI) measured in streams. Measured nutrient levels are high and they feel that nutrients are very rarely the limiting factor for algae blooms in streams; according to their work, poor habitat is more likely the primary cause of poor IBI scores. In February 2007, Illinois indicted they planned on adopting nutrient standards by fall of 2009; however that deadline was missed and Illinois does not yet have nutrient standards. Illinois is currently considering a site-specific approach to nutrient standards for lakes because of the small number of natural lakes and the prevalence of reservoirs in the state. More recently, EPA Region 5 has had discussions with Illinois on the need for Water Quality (TP)-Based Effluent Limits (WQBELs) based on numeric translation of existing narrative WQS. This correspondence underscores the continued insistence by the EPA on the need to address nutrient over-enrichment through NPDES permit setting and WQS development.

In Indiana, the U.S. Geological Survey is helping standards developers assemble nutrient data and look for thresholds of effects at various nutrient levels in both streams and lakes. They have been monitoring lakes for a long time, and they have developed some preliminary TP criteria for Indiana lakes. Similar to Minnesota, Indiana plans to adopt state-developed nutrient standards rather than the EPA-suggested nutrient criteria; the state hoped to begin rulemaking in 2009. As of 2011, data analysis continued and standards were not yet promulgated.

Back in 2006, Michigan was on a very fast track to propose and adopt nutrient standards for both lakes and streams. They planned to be in rulemaking in 2008; however, a moratorium on new rulemaking is currently in effect in Michigan and the Michigan Department of Natural Resources (DNR) has been unable to promulgate new rules. When rulemaking is again allowed, Michigan is planning to adopt state-developed standards rather than the nutrient criteria suggested by EPA. Michigan DNR enlisted the help of Michigan State University faculty and students to assemble and analyze nutrient data for both streams and lakes. They have used several regression techniques to identify TP and total nitrogen “break points”, or levels at which they see a definite biological response. They are seeing TP/bio-response thresholds at 15, 40, and 80 µg/L TP for streams and rivers depending on their size and location, and response thresholds of about 10, 20, and 30 µg/L TP for lakes. The TP thresholds for rivers are in the range of what the MPCA is proposing for the Northern and Central RNRs. Michigan has not decided at this time if these thresholds will become the proposed standards.

Ohio EPA submitted draft standards for control of nutrient enrichment of streams (Exhibit EU-26) to EPA Region 5 in November 2010. The proposed approach includes calculation of “trophic index criteria” that are used to determine the applicability of water quality standards for TP and dissolved inorganic N (i.e. nitrate-N). The draft standards also consider aquatic life use and habitat quality (Qualitative Habitat Evaluation Index - QHEI). A range of proposed TP concentrations are as follows: 60 µg/L for exceptional warmwater habitat; 160 µg/L for warmwater habitat and poor to moderate QHEI; 300 µg/L for all other aquatic life uses and QHEI scores. The 60 µg/L and 160 µg/L TP concentrations are quite similar to Minnesota’s proposed WQS for the Northern and Southern RNRs (Table 1). The nitrate-N criterion is 3.0 mg/L for all classes. Periphyton Chl-a and minimum DO and DO range are considered as well in calculating a trophic index criterion for a stream. A 24-hour DO range (similar to diel DO flux) of 7.0 mg/L or less is sought for most streams, with 6.0 mg/L or less for high quality streams. These DO range values are slightly higher than Minnesota’s proposed values (Table 1). Further details on the approach, assignment of effluent limits and water quality trading options are included in Exhibit 25. Some of the technical basis for the proposed standards may be found in Exhibit EU-25.

Wisconsin ended their data acquisition and analysis phase in 2006-2007. Wisconsin DNR drafted numeric standards for lakes, rivers, and streams and promulgated them in a 2009-2010 rulemaking. The nutrient standards were approved by the WI Natural Resources Board in fall of 2010. The state legislature allowed them to move forward and the new rules were approved by EPA at the end of December 2010. The TP values for named rivers (listed in rule) are 100 µg/L and 75 µg/L for all other unnamed streams (Exhibit EU-27; WDNR 2010). Waters impounded on rivers or streams with a mean annual retention time of <14 days, based on the previous 30 years, shall meet the river and stream standard that applies to the primary stream or river entering the impounded water (Exhibit EU-27).

The ecoregional characteristics of the Northern and Central RNRs of Minnesota extend into Wisconsin (Figure 5). Wisconsin’s 100 µg/L TP standard for named rivers is equivalent to Minnesota’s proposed standard for Central RNR rivers. Having a similar standard for the two states should prove advantageous as the two states address eutrophication issues on shared border waters. Wisconsin’s 75 µg/L standard for all unnamed rivers is slightly higher than Minnesota’s proposed TP standard for Northern RNR rivers.

The Grand Portage Reservation adopted water quality standards applicable to lakes, rivers, and wetlands within the reservation in 2006. Fond du Lac Band of Lake Superior Chippewa adopted water quality standards in 1998. A review of applicable documents for each indicated these Bands do not have numeric nutrient standards for lakes, rivers, or streams.

North Dakota, South Dakota, and Iowa have not promulgated numeric lake or river nutrient standards as of December 2008 based on Exhibit EU-17. This continued to be the case as of the fall of 2011 based on oral correspondence with each of the states. Data analysis is underway in each state and each appears to be making progress.

Some other states and governments outside of EPA Region 5 or adjacent states have adopted numeric or narrative nutrient standards or are taking other actions to reduce nutrient loading. Information about a few states, Canada, and Canadian provinces, that appear to be more advanced in the process, is summarized below.

California is using a risk-based approach to define beneficial uses, and is focusing on "response" variables in setting standards (Chl-a in this case); level I is no risk, level II is possible risk and level III is definite risk to beneficial uses. Level I or II Chl-a criteria are 5 µg/L for cold water fish and 10 µg/L for warm water fish. Level II or III Chl-a criteria are 10 µg/L for cold water fish and 20–25 µg/L for warm water fish.

Florida was among the states that had not developed numeric standards as of 2008 (EU-17). The state had done extensive data collection and analysis but had not promulgated standards. This inaction led to a lawsuit that eventually required EPA to develop and promulgate lake, river, and estuarine standards for Florida. The EPA drafted the standards (EU-19a) and review and public comment occurred throughout 2010. The final rule was adopted on November 15, 2010, in compliance with a court-ordered deadline. The "Nutrient Watershed" Region-based river TP and TN values are summarized in Table 19. Details on their derivation may be found in Exhibit EU-19b.

Table 19. TP and TN criteria promulgated by USEPA for Florida rivers (USEPA 2010a)

Florida "Nutrient Watershed Region"	TP µg/L	TN µg/L
Panhandle West	60	670
Panhandle East	180	1,030
North Central	300	1,870
West Central	490	1,650
Peninsula	120	1,540

The Florida Department of Environmental Protection (DEP) has since proposed numeric standards (Exhibit EU-51a) and the standards were approved for adoption by the Environmental Regulation Commission on December 8, 2011. Florida DEP sought legislative approval in 2012. The river TP and TN criteria were the same as those proposed by the EPA (Table 19). Florida DEP also proposed "nutrient response variables" to aid in interpretation and identification of impaired surface waters (Exhibit EU-51b). They also included language that allows for development of Site Specific Alternative Criteria, which are applied where natural background conditions or man-induced conditions cannot be controlled (Exhibit EU-51a). Details on application of the criteria, use of nutrient response variables (e.g., 20 µg/L Chl-a as a geometric annual mean), and the resulting listing decisions (categories) are summarized in "Identification of Impaired Surface Water" (Chapter 62-303; Exhibit EU-51b). [Note - USEPA and Florida

DEP were in negotiations on final status of criteria and rule language at the time Minnesota's SONAR was being developed, so final criteria and their application may vary from what is reported herein.]

Maine implemented a narrative standard in 1986 requiring a "stable or declining (improving) trophic status" for its lakes. This standard, in effect, does not allow changes in the land use in the watershed of a lake that may adversely affect the trophic status of the lake. More recently, Maine has proposed nutrient criteria for surface waters of the state (Exhibit EU-48a). The Maine proposal is rather detailed and includes TP criteria and "response indicator" criteria including Secchi transparency and water column Chl-a (all waters), percent of substrate covered by algal growth (non-impounded rivers and streams), and patches of bacteria and fungi (all rivers and streams). In addition, they acknowledge that existing WQS for DO, pH, and aquatic life may be also used as response indicators. The response criteria are used in conjunction with TP in a weight of evidence approach. The proposed rule also includes procedures for assessment and 303(d) listing, application of criteria in NPDES permits, a procedure for developing site-specific criteria.

EPA Region 1 provided a review of the proposed rule to Maine DEP (Exhibit EU-48b). The EPA review poses some re-organization of language and seeks some clarification on the application of the criteria. They also encourage Maine to consider measurement of all applicable response criteria in instances where TP is exceeded but response data are not sufficient for listing purposes. The EPA states "*In conclusion, we think your approach, when combined with our recommended technical edits to the rule, is consistent with the Clean Water Act and its implementing regulations*."

Massachusetts has emphasized low-level P removal at Publicly-Owned Treatment Works (POTWs). Fifty-six of Massachusetts' 116 POTWs that range in size from 0.02 to 350 Million Gallons per Day (MGD) have TP effluent limits ranging from 0.1 to 1.0 mg/L. Those with limits more stringent than 1 mg/L break down as follows:

0.1 mg/L – four plants
0.2 mg/L – six plants
0.75 – 1.0 mg/L – 34 plants; 11 of these are slated for upgrades to meet an effluent limit of 0.2 mg/L and two to meet a limit of 0.1 mg/L

Massachusetts is implementing its requirements such that limits lower than 1.0 mg/L are applicable from April through October; in this case, a 1 mg/L limit applies the rest of the year. Massachusetts is looking at multi-point chemical addition and sand filtration as well as new and innovative treatment technologies that they feel will achieve TP effluent concentrations in the 0.05 to 0.1 mg/L range. Massachusetts has developed site-specific criteria for total nitrogen, which they use to help restore impaired estuaries. They also use historical information to establish "background" conditions and use models to develop the site-specific targets and nitrogen reductions needed to achieve the target.

Montana recently proposed ecoregion-specific nutrient criteria for streams (Montana DEQ 2011; Exhibit EU52a). The proposed criteria bear some similarities to Minnesota's proposed WQS (Table 1). Montana proposes a list of "core indicators" that include TP and TN, a benthic diatom index, DO delta (equivalent to DO flux of 5.3 mg/L), BOD_5 (8.0 mg/L), a macroinvertebrate index, and benthic algae biomass (Chl-a <120 mg/m^2). They present assessment methodology to demonstrate how the values should be applied in the assessment process (Exhibit EU-52b). A decision matrix demonstrates how the core indicator values are used to determine 303(d) impairment and as a basis for diagnosing stream condition.

Oklahoma adopted a TP numeric standard of 37 µg/L for their scenic rivers, which they apply as a 30-day geometric mean.

Tennessee has worked extensively on nutrient criteria for small streams. They have associated total nitrogen and TP to negative changes in streams. They use the 90th percentile values from reference sites as a basis for impairment determinations. Application of Tennessee's original narrative nutrient standard was successfully challenged in court as being overly broad. In addition, Tennessee failed in their first attempt to adopt numeric nutrient standards. They have refined their narrative standard and are using numeric "translators" to identify nutrient levels that cause harm.

Canada has a long been interested in the impact of nutrients on surface waters and has sought to reduce nutrient loading to lakes and rivers. However, to date we are not aware of promulgated eutrophication or nutrient standards for the provinces adjacent to Minnesota (Manitoba and Ontario).

The Province of Manitoba has long expressed interest in reducing nutrient loading to Lake Winnipeg. This is of particular interest to Minnesota as the Red River is one of the largest tributaries to the lake. The Province, along with Environment Canada and other partners, has drafted a "Science framework for developing long-term, ecologically sensitive nutrient objectives for Lake Winnipeg and its tributaries (Manitoba Water Stewardship and Environment Canada 2010; Exhibit EU-47)." While the framework does not present promulgated water quality standards for the lake, it clearly establishes the interest and intent to do so. The MPCA remains abreast of these discussions and is working with the Province and Environment Canada as requested on this issue.

Environment Canada has proposed "agri-environmental performance standards" based on collaboration with Agriculture and Agri-Foods Canada. These non-regulatory standards were envisioned to be chemical or biologic targets that confer good environmental condition (Chambers et al. 2008). The standards are comprised of "Ideal Performance Standards" and "Achievable Performance Standards." The EPA 25th percentile approach was one of the approaches used to develop the standards. Recommended Ideal Performance TP Standards for five eco-zones are as follows: (a) Atlantic Maritime 12-24 µg/L, (b) Mixed-wood Plains 24 µg/L, (c) Prairies and Boreal Plain transition 101 µg/L, (d) Prairies 87 µg/L and (e) Montane Cordilera 19 µg/L. As a part of this, they make a comparison with existing provincial guidelines or objectives.

The significance of the Canadian work relative to MPCA's proposed WQS is three-fold: (1) Environment Canada recognized a need to regionalize their standards (objectives) and proposed values ranging from 12 to 101 µg/L; (2) the provincial river TP objectives for the two provinces adjacent to Minnesota, Manitoba (Prairie and Boreal Plains) and Ontario (Mixed-wood Plains), are 50 µg/L and 30 µg/L respectively, which are near the proposed TP for the North RNR (55 µg/L)and (3) the eventual development of WQS for Lake Winnipeg will provide a basis for determining needed P reductions from the Red River and this could influence future assessments of the Red River.

Literature-Based Nutrient Standards Guidance as Compared to Minnesota's Proposed River Eutrophication Standards

It is worth mentioning that the EPA's latest effort (late 1990s to present-day) to encourage nutrient criteria development is not the first time they have encouraged the states to address this issue. In a letter dated April 20, 1973, the EPA recommended that the MPCA adopt TP standards for both flowing water and lakes by 1983 (Exhibit EU-16). The recommended TP values were 200 µg/L for free-flowing streams and 50 µg/L for lakes. The recommended values were a little less restrictive than the criteria in the support document attached to the letter, which were 100 µg/L for free flowing streams, 50 µg/L in any stream where it enters a reservoir or lake, and 25 µg/L in any reservoir or lake. The support document stressed that these numbers were strictly guidance to states, and the criteria adopted could be more or less stringent depending on the local conditions in each state. The support document also discussed issues relevant today, such as the need to address situations when standards cannot be met and the variability in trophic condition among lakes. It is interesting to note that the recommended TP value 100 µg/L, is equivalent to Minnesota's Central RNR value and the 50 µg/L recommendation, which emphasized downstream protection, is very close to the Northern RNR value (Table 1).

The South RNR proposed TP standard is on the "high" end of reported literature values (Table 9). However, it is consistent with the regional differences exhibited by modern-day river TP concentrations (Table 9 and Figure 24) and estimates of background stream TP. Smith et al. (2003; in Exhibit EU-6) estimated background (pre-European settlement) stream TP for the North, Central and Southern regions of Minnesota at 15, 25, and 55 µg/L, which translates to about a three-fold difference between the North and South. This three-fold difference is similar to the difference in the lake TP standards for the NLF ecoregion as compared to the WCBP/NGP ecoregions (Heiskary & Wilson 2008). In addition, the proposed South RNR TP standard is lower (i.e. more restrictive) than the EPA-adopted standard for some of the Florida "Nutrient Watershed Regions" (Table 19); Exhibit EU-19a) and is lower than Ohio's proposed TP criterion for warmwater streams with moderate to poor habitat (Exhibit EU-26).

The EPA issued 304(a) criteria recommendations (e.g., EU-10,-11, and -12) as a part of the overall effort to develop nutrient criteria for lakes and rivers. The general approach for deriving these criteria included acquiring and statistically summarizing available data from various databases including STORET (EPA's water quality database) and the National Water Quality Assessments ((NAWQA) (USGS's water quality database)) for the period 1990-1999. Data were summarized and criteria recommendations were published for each of the 14 aggregated level III ecoregions. The EPA recommendations that apply to Minnesota's aggregated nutrient ecoregions are summarized in Table 20. This three-fold difference in the MPCA proposed standards for the North and South RNR) is much less than the among-region difference in reference condition as indicated in the EPA criteria manuals.

The EPA's stated expectation for the use of their recommended values was as starting points to identify more precise numeric levels for nutrient parameters needed to protect aquatic life, recreation, or other uses on site-specific or subregion-specific conditions. The EPA further stated that states and tribes might also develop standards using other scientifically defensible methods and appropriate water quality data or simply adopt EPA's recommended water quality criteria in their water quality standards (summarized from Exhibits EU-10, -11, and -12). The MPCA has adhered to EPA's expectations by considering the EPA-recommended values and approach in MPCA's effort to develop river eutrophication standards for Minnesota. As the previous two sections have demonstrated, the fact that the MPCA's proposed standards vary from the EPA's recommendations reflects state-specific data and conditions, and result from a scientifically defensible approach to eutrophication standard development. The MPCA's approach is consistent with the EPA's cumulative guidance on this topic that ranges from the ambient water quality criteria recommendations of c 2000 (e.g., Exhibit EU-10) to the more recent document in 2010 on use of stressor-response relationships to derive criteria (Exhibit EU-20). In addition to the proposed TP WQS noted in Table 20, MPCA has also proposed response variables as a part of the overall river eutrophication standards for Minnesota (Table 1).

Table 20 USEPA 304(a) TP Criteria (µg/L) for Aggregated Level III Ecoregions. Criteria based on 25th percentiles for Nutrient Ecoregion VIII (Exhibit EU-12), Nutrient Ecoregion VII (Exhibit EU-11) and Nutrient Ecoregion (Exhibit EU-10).

Nutrient Ecoregion & Minnesota RNR	Aggregate ecoregion TP reference condition	Range of Level III ecoregions ref. conditions	Minnesota proposed RNR-based TP WQS
VIII (NLF & NMW; North RNR)	10	6-40	50
VII (NCHF & DA; Central RNR)	33	21-80	100
VI (WCBP, NGP & RRV; South RNR)	76	63-118	150

B. Comments Received Specific to the Eutrophication Standards

The MPCA published Requests for Comment in the *State Register* to solicit comments and information regarding the MPCA's proposed amendment of the state WQS on July 28, 2008, and March 2, 2009. As described and cited as administrative exhibits (A-1, A-2, etc.) in Book I, a number of individuals and organizations submitted specific comments regarding the MPCA's intentions during the public comment period. The following are the MPCA's responses to the comments that pertained to river, navigational pool, or Lake Pepin eutrophication standards.

A-6 Wayne Goeken, Red River Watershed Management Board; September 24, 2008

This comment acknowledges the Board's interest in the upcoming rulemaking, their active monitoring programs, and potential impact on the Red River and Lake Winnipeg. Both the Red River and Lake Winnipeg are referenced in technical support documents for the proposed rule. No MPCA action needed other than to provide routine notification of rulemaking and associated timelines for comment.

A-10 Warren Formo, Minnesota Agricultural Water Resource Coalition, September 26, 2008

This comment inquired about the scope of the upcoming rule making and questioned the need to develop numeric water-quality standards for nutrients and their impacts on rivers – in the absence of strong cause and effect. The commenter also states that the development of such standards is an unreasonable allocation of resources.

The MPCA disagrees with the comments regarding the need for the standards and the reasonableness of allocating resources to development of such standards. States are required by the EPA to develop nutrient WQSs for lakes, rivers, estuaries, and wetlands and adopting river eutrophication standards is part of the MPCA's comprehensive strategy to address nutrient over-enrichment in Minnesota's waters. Recent developments in Florida, Wisconsin and other states underscore the importance of states developing these standards to protect their water resources, avoid costly litigation, and avoid the potential for the EPA to develop them if states do not.

As for the comment about establishing a cause and effect relationship to support the numeric WQS, the MPCA agrees and has clearly established such relationships in the technical support documents and in proposed rule language.

A-11 Jeremy Geske and Kevin Paap, Minnesota Farm Bureau, September 26, 2008

These are the same comments as received in A-10.

A-12 Steve Nyhus, Flaherty and Hood, and David Lane for Minnesota Environmental Science and Economic Review Board (MESERB), September 26, 2008

These comments question the linkages the MPCA made relative to fish, invertebrates, algae, and nutrients as a basis for developing proposed eutrophication standards for rivers. The letter also included broader questions on the overall methodology or approach for developing the proposed standards, suggesting it may not be "scientifically defensible." MESERB went on to ask that MPCA defer actions on river nutrient standards development until some identified broader issues were sorted out by EPA. In particular, EPA Region III was noted with respect to peer review relative to nutrient TMDLS in Pennsylvania that made use of biological data and statistical approaches.

The MPCA disagrees with the comments and has firmly established that the approach used in the standards development is technically sound. This is clearly documented in the technical support documents. One of the primary documents, "Minnesota Nutrient Criteria Development for Rivers (2009 draft version)" was reviewed by EPA Region V and Headquarters. Headquarters requested technical review by three noted experts in the field: Dr. Walter Dodds, Dr. Michael Paul, and Dr. Jan Stevenson. All three reviewers supported the MPCA's general approach and supplied useful comments that were addressed in a revision to that document (Exhibit EU-1) or through direct responses to their comments (Exhibits EU-22b, 23b, and 24b). Interestingly, two of the reviewers, Dodds and Paul, were cited in the MESERB letter with respect to comments on nutrient levels and periphyton. Also, EPA Region III completed a response document for nutrient and sediment TMDLs in Pennsylvania that addressed concerns brought forth in a letter from MESERB to the EPA administrator.

MPCA staff has met with Mr. Nyhus and Mr. Lane since that time to discuss criteria development and resolved some of the issues raised in their comment letter.

A-13 Supplemental information from Steve Nyhus, Flaherty and Hood, and David Lane for Minnesota Environmental Science and Economic Review Board (MESERB), October 2008

These comments were additional information to the comments presented in A-12 and no further response is needed.

A-14 Minnesota Center for Environmental Advocacy (MCEA), Kris Sigford, September 26, 2008

These comments were supportive of river-nutrient criteria development but went on to request that the MPCA develop and apply numeric translators for the narrative standard prior to promulgation of numeric river nutrient standards. Their supporting argument referred to the length of the rulemaking process and their concern about the MPCA not meeting the proposed timeline for river nutrient development as submitted to EPA as part of overall nutrient criteria development plan. The MCEA also provided suggestions for criteria values and cited literature in support of these values. Much of this material was previously assembled by MCEA when they requested the MPCA to expand the scope of the 2007-2008 water quality standards rulemaking, which included promulgation of lake eutrophication standards, to also include river standards. In the latter instance, the hearing examiner ruled against this inclusion.

The MPCA chose not to propose numeric translators for river nutrients in 2002. A primary reason for this is that the science behind river eutrophication standards was not fully developed or accepted at that time. The MPCA argued that development of numeric translators would require the same level of effort as promulgation of river nutrient standards and hence this short-term step was not practical; instead, the MPCA has moved forward to propose the numeric standards that are a subject of this current rulemaking. As for the information submitted by MCEA to the MPCA regarding proposed standards, much of this literature has been incorporated in the MPCA's technical support documents, although the

MPCA's conclusion on the needed and reasonable values of the standards differs from MCEA's. MPCA staff has also discussed these issues with MCEA and Dr. Bauer in the 2008 timeframe.

A-21 Minnesota Farm Bureau, Jeremy Geske & Kevin Paap, October 13, 2008

Same as A-10

A-22 Coalition of Greater Minnesota Cities, Wayne Wolden, October 6, 2008
This comment identifies the same references to the Pennsylvania TMDL and nutrient-criteria development approach and issue as were identified in comment letter A-12. The MPCA's response is addressed in A-12.

A-28 MCEA, Kris Sigford, April 14, 2009
This comment addresses eutrophication standards for rivers. Included with this were some literature references and a review of the overall issue by Dr. Candice Bauer. The comments reinforce the MCEA's suggestion for total phosphorus and total nitrogen standards to protect against river eutrophication and downstream impairments, and suggest the need for a nitrate-N standard to prevent nitrate toxicity to aquatic life.

While the MPCA does not agree with the precise approach and thresholds proposed by Dr. Bauer, the MPCA does agree on the need for TP and chlorophyll-a criteria. Some of the concepts and literature used in Dr. Bauer's arguments were incorporated into the MPCA's technical support documents as well. As for total nitrogen, the MPCA conducted various statistical test to determine if Minnesota-specific data suggested the need for TN standards to protect against river eutrophication. Such a need was not identified by MPCA and the Agency focused on TP as the stressor leading to river eutrophication since TP is the primary nutrient that limits the growth of excessive amounts of suspended algae (chlorophyll-a) in Minnesota rivers and streams. This and other reasons for the MPCA's proposed approach to river eutrophication standards are addressed in the technical support documents.

Finally, the MPCA is collaborating with EPA Region 5 and other states in the development of a nitrate-N aquatic life standard. The results of additional toxicity testing currently underway in Illinois are needed before such a standard can be proposed.

A-30 MESERB, David Lane, April 17, 2009
In this comment letter MESERB includes specific review comments on documents that were posted on the MPCA webpage in support of the March 2, 2009 *State Register* notice, where the MPCA issued its intent to adopt eutrophication standards for rivers. The primary technical document referred to was: "Relation of Nutrient Concentrations and Biological Response in Minnesota Streams: Applications for River Nutrient Criteria Development. March 2008." This document is included as Exhibit EU-2 (Heiskary 2008). It should be noted that this document was developed in partial fulfillment of an EPA nutrient criteria grant to the MPCA and it represented the MPCA's approach as of 2008. Minnesota's approach was refined considerably over the subsequent two years when the principal technical support document for the river eutrophication criteria was developed and submitted for EPA review: "Minnesota Development of Nutrient Criteria for Rivers" (Exhibit EU-1; Heiskary *et al.* 2010). The MPCA believes this refinement addresses many of the concerned raised in the MESERB comment letter; however, here follows brief responses to specific comments on pages 2 and 3 of the MESERB submittal:

- The MPCA's analysis has addressed low-, medium- and high-order streams; the primary emphasis was been on medium- to high-order streams in the original work. Data from low-order streams was later included from the hundreds of biomonitoring sites across the state. The MPCA has also proposed a periphyton-based numeric translator that will be useful for addressing excessive benthic algae that may be problematic in low-order streams.

- The MPCA switched emphasis from total chlorophyll to chlorophyll-a (two slightly different analytical measures of algal photosynthetic pigment).
- The MPCA's selection of thresholds (standards) was based on extensive statistical analysis and multiple datasets.
- There was reference in the comments to the use of metrics and the 25th percentile as a basis of selecting thresholds. The MPCA agrees that this approach is not sufficient in isolation to identify thresholds. In the case of the proposed river eutrophication WQS this approach was not used in isolation; it was used initially to provide perspective on significant changes in a metric. The MPCA subsequently included advanced statistical approaches in the standards development effort. The resulting proposed standards do not rely solely on the 25th percentile as a means for selecting thresholds.
- MESERB's comment s included an issue with DO flux as a measure of stress. The MPCA has since refined the analysis of this metric and has retained it as one of the measures of stream response to excess TP included in the proposed standards.
- The MESERB comments expressed concern about the analysis based on correlations with field data. Again, this was a step in a larger process and the MPCA incorporated additional lines of evidence in subsequent work to develop the proposed standards.
- The last comment refers to the "uniqueness" of each high-order river, which implied that it is difficult to establish nutrient criteria that apply to multiple rivers and therefore site-specific criteria and individual modeling of each system is required. The MPCA disagrees with this and believes that the current approach does consider the range in responses that may be encountered across a wide variety of rivers and streams.

Pages 4-6 of the comment letter addresses issues related to periphyton (attached algae) in contrast to sestonic (suspended) algae. Several reports in the literature were noted and examples provided of where excess periphyton was to be addressed via nutrient reductions. Since the time of these comments, the MPCA has included a numeric translator value for interpreting Minnesota's narrative standard on "excess algal or slime growth." Waters deemed as impaired through this translator will not immediately move into a TMDL; rather the sites will be included in a "stressor ID" process that would determine potential causes of the excess periphyton. This approach does not immediately presume that nutrients are the principal cause of the impairment.

Page 7 commented on macrophytes as a potential indicator for impairment. Since the MPCA had not proposed macrophytes as a potential indicator, it is a non-issue.

Pages 7-11 discuss the use of macroinvertebrates and statistical approaches for TP threshold development. The comments reference studies in EPA Region III that involved the use of conditional probability analysis and discuss some analysis by Hall and Associates that suggest alternate endpoints. Since this statistical technique was not used by MPCA in development of Minnesota's proposed standards, no further comment is needed.

Page 11-14 discusses canopy enhancement as an approach to achieve reduction in periphyton. This could very well be an option for some Minnesota streams with excessive periphyton and that is what the stressor ID process is intended to discern.

The summary on pages 14-15 re-caps previous observations in the memorandum and was based on findings in the 2008 MPCA report (Exhibit EU-2). The MPCA believes that the refinements in the MPCA's approach, as documented in Exhibit EU-1, which occurred subsequent to the comment letter, addressed many of the concerns noted in the summary. It is also important to note that MPCA staff has met with Mr. Lane since the issuance of this memorandum and further addressed issues raised in the memorandum. Finally, in the case of the comment suggests that site-specific criteria should be developed for each river individually-the MPCA respectfully disagrees.

A-31 Minnesota Corn Growers, Doug Albin, April 16, 2009
This comment was in reference to the previously noted MPCA request for comments. The principal comment questioned development of river nutrient criteria in general and more specifically the need for strong cause and effect if standards were to be developed. This comment was the same as A-10.

6. Statutory Requirement for Consideration of Economic Factors

Minnesota Stat. § 14.131 requires that this SONAR include information about the impact of the proposed rule amendments on the regulated community, regulatory entities and other affected parties. A discussion of how the MPCA has generally addressed the economic impact of all of the proposed amendments is provided in Book 1 and a specific discussion of the economic impact of the proposed eutrophication standards are provided in part 6 of this Book. The following discussion addresses each of the statutory requirements to the extent that they specifically relate to the proposed eutrophication standards.

A. Classes of Persons Affected by the Proposed Amendments, including those Classes that will Bear the Cost and those that will Benefit

Essentially all the citizens of Minnesota could be affected by, and benefit from, the proposed eutrophication standards for rivers and streams, navigational pools and Lake Pepin. Some of the benefits to people in general are intangible, such as just the notion that Minnesota will remain a land of valuable lake and river resources. A more tangible benefit will be a continued robust water-orientated tourism and recreational industry in Minnesota, which the proposed standards will help protect. The many people that fish, swim, boat, and simply enjoy the aesthetic quality of these resources will benefit. Counties, cities and other local governments could benefit from the proposed standards by increased tax revenues, increased tourism dollars, added jobs, and related benefits. In addition, river and lake property owners could see a real monetary benefit if the water quality improves; and, to the contrary, they may see a monetary loss if the water quality declines.

Krysel *et al.* (2003; Exhibit EU-50) conducted an analysis of the economic impact of water quality on property values in the Mississippi River Headwaters region. In their work, they clearly demonstrated the impact of good water quality on lake property values. In summary they state, *"Using the estimated hedonic equations from the MN model, the implicit prices of water quality was determined and calculations were made to illustrate the changes in property prices on the study lakes if a one-meter change in water clarity would occur. Expected property price changes for these lakes are in the magnitude of tens of thousands to millions of dollars. The evidence shows that management of the quality of lakes is important to maintaining the natural and economic assets of this region."* While this work was conducted specifically on lakes, there is little reason to believe that improved river, navigational pool, and Lake Pepin water quality (e.g. reduced algal blooms, improved transparency, and healthy aquatic communities) would not be beneficial to riparian property values. This benefit would logically be extended to communities cities along these waterbodies as well, whereby increased fishing, boating, and recreational use could be anticipated in river reaches with good water quality as compared to very poor water quality. For example, the severe blue-green algal blooms and fish kills in the summer of 1988 (Figure 7) severely limited usage of the Mississippi River and Lake Pepin in Lake City, Red Wing, and other communities in this area and this had a direct economic impact on the communities. For example, the Lake City Marina chose to install aerators to overcome the severe algal scums and odors that had rendered the harbor unusable that summer (Exhibit EU-54).

Rivers protected for use as a domestic drinking water supply (Class 1) are important community resources. Class 2A and 2Bd rivers are also Class 1 waters. The proposed eutrophication standards do not address drinking water uses directly, and drinking water uses are not discussed in this book of the SONAR. However, similar to aesthetics, the proposed eutrophication standards will help protect drinking water uses where applicable, because of the benefits of reducing excess algae. Certain algae species, when numerous, can impart unpleasant tastes and odors to drinking water. Generally, the less eutrophic the drinking water source, the less extensive and less costly water treatment needs to be to provide safe and good tasting and smelling finished water to the public. A good example of this was the announcement by the City of St. Paul in February 2006, of costly improvements to the city's drinking water treatment system to reduce or eliminate the city's occasional taste and odor problems (for costs see Section 5F). St. Paul's drinking water, much of which comes from the Mississippi River via a conduit, travels through the Vadnais chain of lakes prior to withdrawal for treatment, which provides river and lake algae the opportunity to impart unpleasant tastes or odors to the water. The cities of Minneapolis and St. Cloud also draw drinking water from the Mississippi and along with St. Paul, they collaborate on a surface-water protection program that seeks to ensure the quality of this important resource is protected.

State agencies with a responsibility for programs involving lakes and rivers should benefit from the eutrophication standards. In particular, the Minnesota Department of Natural Resources (MDNR) that has the responsibility to enhance and manage the sport fishery and protect rivers, pools, and Lake Pepin, will benefit because the standards will give them an added tool to carry out their mission. Sport fish, emphasized in MDNR fishery management, should benefit from reduced TP (Figure 3), in contrast to omnivorous and rough fish, which are favored under high nutrient concentrations.

Wastewater treatment facilities and stormwater NPDES permittees (*i.e.* municipalities) will be among those that bear costs of the proposed amendments. However, in many instances, lake and reservoir nutrient TMDLs already require phosphorus reductions from upstream discharges and the proposed river WQS may not add significantly to current requirements. The costs to NPDES dischargers are discussed in more detail in 6F below.

B. Estimate of the Probable Costs to the Agency and Other Agencies of Implementing and Enforcing the Rule Amendments, and any Anticipated Effect on State Revenues

Promulgation of the proposed eutrophication standards will result in additional work for MPCA staff responsible for setting, implementing, and communicating phosphorus effluent limits. Staff needs, workloads, and overall costs will increase during the first round of permit issuances following promulgation. Over time, the demand for resources will level off as limits are implemented and downstream water quality needs are addressed. The increased demand for staff time will be somewhat offset by the fact that existing lake eutrophication standards are equal to or more restrictive than the proposed river eutrophication standards. In most cases, existing limits to address lake or reservoir water quality will be sufficient for the proposed river standards. It is likely that not promulgating the proposed eutrophication standards would also result in additional work and overall costs to the Agency. Recent history has shown that not having numeric-river eutrophication standards greatly increases the likelihood that individual permits will be challenged through legal channels. The application of phosphorus effluent limits based on narrative standards and/or downstream lake or reservoir standards often leads to the receipt of many comments and requests for contested case hearings during permit public notice periods. The defense of these permit decisions is extremely resource intensive. The ability to include in permits phosphorus effluent limits based on the proposed river eutrophication standards will result in better water quality across Minnesota. The MPCA expects that state revenues could be positively impacted by the role of the standards in helping to protect rivers from eutrophication, which in turn maintains Minnesota as an attractive destination for water oriented tourism. Costs to the MPCA are discussed in detail in Section 6.C – E below.

The process of assessing rivers for possible impairment due to excess nutrients will be initiated in the first assessment cycle following promulgation of the standards. The MPCA is currently gathering data that will allow river eutrophication assessments to take place in several watersheds. River eutrophication assessment will require additional staff effort (time) during the overall 303(d) assessment process. Assessment protocols will be described in guidance and are anticipated to be consistent with the approach that is currently being used to design monitoring strategies for nutrients. These protocols and experience gained from the initial assessment will serve to refine the river eutrophication assessment process and should lead to less staff time needed in future cycles.

MDNR was consulted as the proposed river eutrophication standards were developed and has played a prominent role in navigational pool and Lake Pepin standards development. The MPCA does not believe any other state or federal agency will incur any significant added costs in the future due to the proposed eutrophication standards.

C. Determination of Whether there are Less Costly or Less Intrusive Methods for Achieving the Rule Amendment's Purpose

There are options open to the MPCA that would at least partially achieve the goal of improving the State's ability to protect rivers, which the MPCA rejected in favor of the proposed combination of numeric and narrative eutrophication standards. It is conceivable that the rejected options could be somewhat less costly and less intrusive, but the MPCA believes that it is equally possible that these options might be even more costly than the proposed approach. The two most logical options are:

1. Enhance or expand the narrative nutrient standard now in Minn. R. 7050.0150, subp. 5
2. Adopt numeric standards for certain named rivers statewide, but continue to use the narrative standard to protect the remaining rivers.

The MPCA does not believe that either of these options would be as effective as the proposed numeric standards in satisfying the need for standards specifically designed to protect rivers and pools from eutrophication. The EPA has concurred with the MPCA and supported the previous adoption of numeric lake eutrophication standards and the current rulemaking effort for numeric river eutrophication standards in Minnesota.

The first option, expanding the existing narrative standard, is essentially a “do-nothing” option. This option would not advance the ability of the MPCA, local governments, citizens or other parties to actively protect rivers or pools. This would most likely lead to EPA promulgating nutrient standards for Minnesota, as was the case in Florida and/or a lawsuit from environmental advocacy groups that would eventually require the state of Minnesota or the EPA to promulgate river eutrophication standards. This might also prompt EPA to request that Minnesota translate narrative standards into WQBELs on a permit-by-permit basis, as was case for Illinois (e.g., Exhibit EU-49). This step would lead to much uncertainty as to the outcome for the permitted facility as well as an increased workload for the MPCA NPDES permit program.

The second option is a “combination” approach; *i.e.*, adoption of numeric standards for select rivers, but not all rivers. The MPCA believes that this option could result in substantial added costs for the MPCA. A requirement that the MPCA must develop a site-specific standard for each and every unnamed river would mean incurring the expense of gathering data and developing the site-specific standard, and possible costs associated with unnecessary delays in taking action. This process could also result in delays in issuance of NPDES permits for rivers that lack standards and would likely lead to permit-by-permit numeric translation of the narrative standard. In addition, it could be a strong disincentive to protect rivers with un-promulgated standards from eutrophication because of the costs and time needed to treat each one case-by-case. Numeric standards for all rivers, tailored by River Nutrient Region, will be more visible and allow for more timely and equitable issuance of NPDES permits, and provide a basis for protection as needed.

D. Describe any Alternative Methods for Achieving the Purpose of the Proposed Rule Amendments that the Agency Seriously Considered and the Reasons why they were Rejected in Favor of the Proposed Amendments

As discussed in the previous section, the MPCA has considered other mechanisms for addressing eutrophication. However, in the course of developing the proposed amendments the MPCA has conducted a long and public process to provide opportunities for the development of alternative proposals. The proposed numeric standards have been under development for several years and are supported by more than ten years of data collection. The proposed numeric standards and associated narrative statements have continued to evolve over the four years this rulemaking has been in development, including changes made as result of public comments (e.g. Lake Pepin TMDL SAP comments on integrating Pepin, pool, and river criteria). The MPCA has been on a path to adopt numeric standards for rivers for some time, to meet EPA requirements and to further the state’s ability to protect and restore rivers from the negative water quality impacts of eutrophication. Except as discussed in the previous section, the MPCA does not consider that it has rejected any alternatives that would achieve the purpose of the proposed rule amendments. The proposed amendments are the most reasonable option the MPCA identified for meeting the stated need in a way that reflects Clean Water Act requirements and EPA guidance, the MPCA’s water program goals, and the interests of the affected community.

E. Estimate of the Probable Costs of Complying with the Proposed Rule Amendments, Including Costs Borne by Categories of Affected Parties

The probable costs of the proposed eutrophication standards are discussed in part 6 of this Book.

F. Estimate of the Probable Costs of not Adopting the Proposed Rule Amendments, Including Costs Borne by Categories of Affected Parties

If the proposed rule amendments are not adopted, the issue of river eutrophication standards will not disappear for Minnesota. Instead, the two most likely scenarios are:

1) The EPA would require the MPCA to translate the existing narrative standards into water quality based effluent limits on a permit-by-permit basis (as EPA has directed Illinois to do), or
2) The EPA would step in and promulgate nutrient criteria for Minnesota itself (as was the case in Florida).

Either of these two actions has the potential to increase uncertainty, and possibly litigation over nutrient-related issues, which would increase the costs borne by affected parties. For example, municipalities and businesses that are developing wastewater treatment systems must conduct extensive planning and design activities to meet standards. Without clarity about the specific eutrophication standards that a facility must meet (clarity that the proposed river eutrophication standards provide in part because they provide the numeric translation of the narrative standards) the planning process would have to be determined on a case-by-case basis, which is certainly more complicated and potentially more expensive.

An unlikely, but theoretically possible scenario would be that the EPA would not take either course and no entities would sue the MPCA to promulgate river eutrophication. (This scenario is unlikely because of the national priority and public concern regarding river eutrophication.) However, if the status quo were to remain in Minnesota, the consequences of not adopting the amendments would be a possible monetary loss to certain groups. Lake and river-shore property owners, resort and marina owners and communities that depend on rivers, pools, or Lake Pepin for income (e.g. tourism) or as a component of their property value would be negatively affected by a decline in water quality.

In addition, those groups or entities that rely on rivers for drinking water consumption or industrial process or cooling water could be impacted should the quality of rivers decline. Without the proposed standards, those groups or entities would incur additional costs to treat the water to remove excessive algae that contribute to taste, odor, and other problems for both drinking water purveyors and industrial users. The cities of St. Cloud, Minneapolis, and St. Paul are among three of the larger cities in Minnesota that draw water from the Mississippi River for drinking water. This water must undergo extensive treatment to make it suitable as drinking water. Excessive amounts of algae can contribute to taste and odor problems and add to the overall cost of treating the water.

St. Paul Regional Water Services (SPRWS) has extensive experience in addressing excess phosphorus and algae in the water from the river and the lakes (e.g. Vadnais Chain of Lake) that comprise its overall system. Three general categories of treatment/projects are as follows (Blackstone, J. 2012, personal communication):

1. Treating river water – In this project SPRWS seeks to reduce P and algae from the river prior to its entry into the overall system. For this purpose, ferric chloride is used to help remove excess P and algae from the water. This required construction of a dosing station near the intake and annual operation and maintenance to carry out this treatment. Capital cost is estimated at $153,000 and annual O&M is estimated at $4,300.

2. Internal recycling of P in the lake system also contributes to algal blooms and taste and odor problems in the finished water. SPRWS has addressed this through hypolimnetic oxygenation in Vadnais Lake. Capital cost is estimated at $800,000 and annual O&M is estimated at $150,000.
3. Several watershed projects have been undertaken as well in an effort to improve the quality of runoff that enters the chain of lakes. Project costs are not included here but it is relevant to mention this as a part of the comprehensive solution SPRWS has undertaken to ensure that good quality water is delivered to its customers.

Reductions in river phosphorus and algae concentrations should prove beneficial to all municipalities and industries that draw water from rivers for drinking water and other uses and should have a beneficial impact on their costs to treat the water.

Finally, the MPCA believes there could be an intangible "cost" to Minnesota if the standards are not adopted. Because Minnesota and the quality of life of its citizenry is so closely identified with water, it is not far-fetched to assume that, as rivers, pools and Lake Pepin continue to degrade, there could be both a tangible and intangible cost to the state.

G. Differences between the Proposed Rule and Existing Federal Regulations and the Need for and Reasonableness of Each Difference

The proposed river eutrophication standards and approaches used in their development are consistent with federal guidance and are expected to meet EPA approval. Since EPA has not provided specific nutrient criteria recommendations, but rather guidance for the development of such standards by the states and tribes, there are not federal river eutrophication regulations specific to Minnesota against which the proposed rule can be compared. With that said, Section 4A of this Book discusses how the MPCA's proposed river eutrophication standards compare to EPA guidance, and Sections 2 and 3 of this Book explain the need for and reasonableness of the proposed river eutrophication standards.

H. Consideration and Implementation of the Legislative Policy under Minn. Stat. §§ 14.002 and 14.131

Minnesota Statutes §§ 14.002 and 14.131 require state agencies, whenever feasible, to develop rules that are not overly prescriptive and inflexible, and rules that emphasize achievement of the MPCA's regulatory objectives while allowing maximum flexibility to regulated parties and to the MPCA in meeting those goals.

While numeric standards are generally prescriptive by nature and definition, because river standards are unique in several respects, greater flexibility is built into these standards than into most numeric standards (see Section 1.6). First, separate standards have been developed for three River Nutrient Regions, the Mississippi River navigational pools, and site-specific standards for Lake Pepin. This was done to accommodate the regional patterns, uses, and varying impact of nutrients on these resources. Secondly, accompanying the numeric standards are narrative statements that provide important information on how the numeric standards are to be interpreted and implemented, plus again the consideration that site-specific standards may be considered. These provisions provide clarity in the application of river eutrophication standards, including the interpretation of the narrative standards, while incorporating the flexibility needed to ensure appropriate protection of diverse Minnesota rivers and streams to protect and restore beneficial uses.

I. Additional Notification of the Public under Minn. Stat. §§ 14.131 and 14.23

Minn. Stat. §§ 14.131 and 14.23 require the MPCA to include in its SONAR a description of its efforts to provide additional notification to persons or classes of persons who may be affected by the proposed rule, or the MPCA must explain why these efforts were not made. The MPCA provides a discussion in Book 1 of its general efforts to notify persons who may be affected by the proposed amendments.

The MPCA developed several TSDs, in support of this rulemaking, and made them available on the rulemaking website http://www.pca.state.mn.us/qzqh5e3. The proposed WQS and technical approach to their development have been shared in various formal and informal venues with interested parties. The MPCA conducted a number of additional activities to provide public engagement specific to the proposed river eutrophication standards. The MPCA has shared its approach to river, Mississippi River navigational pool and Lake Pepin eutrophication standards development in numerous forums including the National Park Service-sponsored Mississippi River Forum on two occasions in 2010 (EU-29), Minnesota Water Resources Conference in 2009 and 2011, and at Lake Pepin TMDL stakeholder meetings. In addition, the MPCA maintains a special mailing list of the parties interested in eutrophication and includes them in stakeholder and public notice activities throughout the rulemaking process.

J. Agency Determination Regarding Whether Cost of Complying with Proposed Rule in the First Year after the Rule takes Effect will Exceed $25,000

The Administrative Procedures Act was amended in 2005 to include a section on potential first-year costs attributable to the proposed amendments (Minn. Stat. § 14.127, subd. 1 and 2). This amendment requires the Agency to "*determine if the cost of complying with a proposed rule in the first year after the rule takes effect will exceed $25,000 for:*

- *Any one business that has less than 50 full-time employees, or*
- *Any one statutory or home rule charter city that has less than ten full-time employees*."

The MPCA's complete discussion of this required statutory determination in relation to all of the proposed amendments, including the proposed river eutrophication standards, is provided in Book 1.

7. Economic Review of the Eutrophication Standards

A. Introduction

The MPCA's discussion of the benefits resulting from the adoption of the river eutrophication water quality standards are discussed in Book 1 under the general discussion of the need for the amendments and also in the discussion of the statutorily required questions in part 5 of this Book. The MPCA's detailed discussion of the economic effect of the proposed eutrophication standards, specifically the costs associated with them is provided below.

The discussion is divided according to the type of discharge that will be affected by the proposed standards. Nonpoint (unregulated) discharges are those discharges that are not associated with a distinct outfall or source. For this consideration of costs, nonpoint sources are discharges of pollutants from agricultural and un-regulated urban stormwater sources. The second area of discussion is the economic effect on point sources of pollutant discharge. These are the permitted municipal and industrial wastewater dischargers as well as permitted stormwater discharges from industrial, construction, and municipal activities.

B. Economic Impact to Unregulated Sources of Pollutants

Promulgation of the river eutrophication water quality standards is not expected to result in any additional costs or redirection of resources to address unregulated sources of pollutants, unless a river segment is found to be impaired (i.e. not supporting designated uses) due to non-attainment of the river eutrophication standards and listed on the 303(d) impaired waters list.

While many municipalities obtain NPDES Stormwater permits, there are a number of smaller cities and townships with significant impervious surface areas, which can affect their local surface water resources, but are not regulated by the NPDES Stormwater Program. Currently cities smaller than a population of 10,000 residents and not connected to a U.S. Census Bureau Urbanized Area are not required to have stormwater permits and BMP requirements. Cities with populations greater than 5,000 may need NPDES Stormwater permits in the future, if they discharge to impaired waters. The local governments may also have stormwater management programs and proactively seek grants from state agencies (Board of Water and Soil Resources and the MPCA) to address surface water protection; however, the MPCA has no direct authority over these local units of government and their effectiveness in reducing phosphorus run-off. Activities taken in response to new or revised WQS is voluntary for these municipalities.

The Minnesota Department of Agriculture (MDA) has already developed voluntary best management practices (BMPs) to minimize transport of phosphorus and sediments from agricultural lands. The MDA's BMPs are intended to minimize soil loss and reinforce the use of buffer areas between cultivated or pastured areas and adjacent watercourses, which will in turn, minimize the amount of nutrients entering streams and rivers from agricultural non-point sources. The BMPs are voluntary for producers and have the potential to reduce nutrient-related surface water impacts and avoid impairment.

The potential for future costs or redirection of resources that would affect nonpoint sources would stem from a determination of impairment and the listing of river segments on the 303(d) impaired waters list. When water is impaired and subsequently listed, the Clean Water Act requires that a Total Maximum Daily Load (TMDL) study be developed to identify the sources of the impairment and reduce loading to attain water quality standards, and thereby restore the water to support designated uses. In that case, the MPCA would incur costs to complete the TMDL (either directly or by passing funds through to a local partner) to address the river eutrophication impairment. Local partners or cooperating state or federal agencies may also incur costs to participate in the TMDL development.

Once the TMDL was complete, an implementation plan would be developed and initiated to undertake the activities needed to restore water quality. To reduce unregulated sources of pollution, water quality management agencies (e.g. MPCA, MDA, Board of Water and Soil Resources, cities, watershed districts, soil and water conservation districts, federal agencies) may provide cost-share funding to install BMPs to reduce the pollution loading, or (in the case of local agencies) may undertake projects directly. Landowners, such as agricultural producers or homeowners, may also contribute to the cost of BMP installation as a condition of receiving cost-share grants to install additional BMPs or pay the complete cost for BMP installation.

To date the MPCA has not listed rivers for nutrient impairments; however numerous lakes have been listed and this experience can provide insights into the potential cost of developing and implementing river eutrophication TMDLs. To arrive at the estimates the MPCA consulted with MPCA TMDL staff in the St. Paul and the Regional Offices, MDA, and University experts in BMPs.

C. Initial Costs to the MPCA Associated with the Promulgation of Proposed Standards

Implementation of the proposed river eutrophication standards would require the support of MPCA monitoring, assessment, effluent limit setting, permitting, and compliance/enforcement activities, as well as TMDL program support to address waters that do not attain the proposed standards. For example, the MPCA will incur costs to gather the necessary cause (total phosphorus) and response data (chlorophyll-a, BOD_5, and/or diel dissolved oxygen flux) to determine if a river is attaining the eutrophication standards. The most likely scenario would be for the MPCA to increase collection of total phosphorus and chlorophyll-a data at existing and new monitoring sites. Sample collections would be made in conjunction with sites monitored as a part of the MPCA’s watershed monitoring approach. Since water sample collections would be made regardless of the proposed new standards (so that rivers could be assessed for compliance with existing water quality standards (e.g., dissolved oxygen)), no additional labor costs are anticipated. There would be additional costs for chlorophyll-a laboratory analysis, which is not routinely measured at river sites.

Other entities or organizations that monitor Minnesota’s rivers and streams, e.g., watershed districts or water management organizations, may encounter some additional laboratory costs associated with collecting data to assess compliance with the new water quality standards. However, these groups may be eligible for state grant dollars to help subsidize these expenses (e.g., surface water quality assessment grants). There would most likely be no additional expenditures for staff or field work, as this work would be integrated into existing monitoring activities.

The MPCA would also see an increase in the amount of monitoring data that needs to be reviewed and an increase in the effort to assess monitored river reaches for attainment of the new standards. However, based on the MPCA's current staffing and framework for reviewing monitoring data and conducting assessments, the additional resources needed for the assessments could be absorbed into current workloads and budgets.

The proposed numeric standards will require an additional reasonable potential analysis for all permits with sufficient data and concern about phosphorus in their effluent. Following the analysis, effluent limits will subsequently be developed to not only to address impaired waters but also to insure the protection of existing water quality for those rivers already meeting standards. It is expected that staff needs, workloads and costs will increase during the first round of permit issuances following promulgation. The increased demand for staff time will be somewhat offset by the fact that existing lake eutrophication standards are equal to or more restrictive than the proposed river eutrophication standards. In most cases, existing limits to address lake or reservoir water quality will be sufficient for the proposed river standards.

It is likely that not promulgating the proposed eutrophication standards would also result in additional work and overall costs to the Agency. Recent history has shown that not having numeric river eutrophication standards available greatly increases the likelihood that individual permits will be challenged through legal channels. The application of phosphorus effluent limits based on narrative standards and/or downstream lake or reservoir standards often leads to the receipt of many comments and requests for contested case hearings during permit public notice periods. The defense of these permit decisions is extremely resource intensive. The ability to include in permits phosphorus effluent limits based on the proposed river eutrophication standards will result in better water quality across Minnesota.

D. Costs to the MPCA for 303(d) Impaired Waters Listing and TMDL Study

A consequence of the assessment of surface water monitoring data is that waters will be identified that do not meet the proposed river eutrophication standards. Waters not meeting standards are included on the 303(d) list that identifies waters in need of a TMDL study, as mandated by the CWA. The TMDL study is a process that determines the sources of the pollutant and necessary reductions needed to return the waters to attainment. The TMDL study is followed by the development of an implementation that identifies the actions needed to achieve the pollutant reductions specified by the TMDL.

In response to federal and state statutory requirements including the federal Clean Water Act and state Clean Water Legacy Act (Minn. Stat. ch. 116D), the MPCA has developed a major watershed approach to water quality restoration and protection. Since 2006, the MPCA and its partner agencies have used a statewide watershed approach to prioritize and integrate monitoring and assessment, TMDL plans, and restoration and protection activities. All of Minnesota's 81 major watersheds will be addressed over a repeating 10-year cycle.

To support the watershed approach and other restoration and protection activities in Minnesota, the state's voters approved a sales tax increase through the Clean Water, Land, and Legacy Amendment, providing 25 years of constitutionally-dedicated funding for clean water, habitat, parks and trails, and the arts. Approximately $85 million is appropriated each year by the Legislature from the new Clean Water Fund to support our monitoring, TMDL development and implementation activities.

The MPCA believes it can accommodate river eutrophication impairment listings within this approach and the existing monitoring and assessment budget as it implements the major watershed approach. For example, the Clean Water Fund provides the funds necessary for the MPCA to achieve economies of scale in not only our monitoring, but in developing watershed restoration and protection strategies that will include the TMDLs and protection plans for most all river and lake impairments in each of the 81 watersheds of the state.

It is important to note that the major watershed approach will not directly address sections of the Mississippi, Minnesota, and Red Rivers that cross multiple major watershed boundaries and include drainage areas from border states. However, much work has already been done on some of these waters, e.g., Lake Pepin assessment and modeling, which will lay the foundation for future work in these watersheds and should serve to minimize future costs.

E. Costs of TMDL Implementation and Restoration Activities

Costs to the Minnesota Pollution Control Agency

As described above, the new Clean Water Fund, as well as Clean Water Act Section 319 grants are used to implement restoration and protection activities. In FY10-11, a total of $93.5 million was appropriated from the Clean Water Fund for restoration and protection activities. In FY12-13, another $104.1 million was appropriated for this work, which includes grants and loans to install best management practices for unregulated sources of pollutants from agriculture and rural sources, as well as infrastructure for regulated wastewater and stormwater sources. More information on projects supported by the Clean Water Fund can be found at http://www.legacy.leg.mn/funds/clean-water-fund.

Grants and loans to implement TMDLs and control runoff from unregulated sources are administered largely by the Minnesota's Board of Water and Soil Resources, along with a smaller portion from the Minnesota Department of Agriculture. For regulated wastewater and stormwater, project funding is administered by the Public Facilities Authority. Cities, counties, watershed management organizations, and soil and water conservation districts are the primary recipients of this grant and loan support. These local contractors lead BMP implementation, education/outreach, and other activities related to TMDL implementation as well as protection activities for high quality waters.

The addition of the river eutrophication standards will increase the number of impairments throughout the state, but will not have an effect on either the amount of money received through the Clean Water Fund or Section 319 grants for restoration activities. This will require additional prioritization of projects to ensure that impairments are addressed in a cost-efficient manner and where possible, combining efforts to address multiple pollutants (impairments). For example, watershed-scale work conducted to implement turbidity TMDLs may be directly beneficial to river eutrophication TMDLs. In addition, there may be opportunity to combine river eutrophication TMDLs with lake eutrophication TMDLs that may be underway. Both of these options will serve to minimize the cost of implementing TMDLs.

Costs to other State Agencies

As mentioned above, the Minnesota Department of Agriculture, Board of Water and Soil Resources, Department of Natural Resources, Public Facilities Authority, and Minnesota Department of Health collaborate closely with the MPCA to implement restoration activities and this collaboration efficiently utilizes largely Clean Water Fund-supported resources from all Agencies. For example, the MDA is involved with education and outreach to producers and other agricultural groups in response to publication of voluntary BMPs and is expected to continue to use existing staff resources to implement restoration activities. However, future costs and staffing needs may increase for MDA and other agencies in order to direct more resources to an increase in the number of eutrophication-related impaired watersheds.

Costs to Address Unregulated Sources: Stormwater and Agricultural Runoff

The river eutrophication standards, through the increase in the number of impaired waters, will not have a direct economic effect on municipalities with unregulated stormwater or agricultural producers. While adoption of the proposed standards will lead to the identification of additional river impairments, unregulated sources of pollutants that includes some urban stormwater, agricultural runoff, and other unregulated sources are not required to take action to achieve TMDL requirements – implementation of BMPs to achieve TMDL reductions are voluntary. There are also several sources of funding and subsidies available to implement BMPs. The following discussion identifies areas of cost and benefits to municipalities and agricultural producers expected because of the adoption of the proposed eutrophication standards.

Agricultural producers in impaired watershed, specifically those with cropland in sensitive areas near surface waters or with connections to surface waters, may need to implement BMPs. BMPs seek to minimize the transport of soil and nutrients to surface waters. These may range from reduction in fertilizer application rates, timing of applications, installation of buffer strips, or taking cropland out of production. Targeting the more expensive BMP's (e.g., taking cropland out of production) to the most sensitive parcels of land would allow for efficient use of available cost share funds. In the case of many lower-cost BMP's, preserving top soil or minimizing fertilizer application may not be cost prohibitive to the producer and may in fact save the producer money.

The highest cost for unregulated source phosphorus reduction occurs when farmland is removed from production in order to establish a riparian buffer, waterway, or wetland. With farmland prices at record highs, it is particularly costly at present to purchase easements for land retirement. Land costs exceeding $4,000/acre, together with practice establishment costs, will probably limit the scope for land-removal practices for now. The cost of totally removing cropland from production can be reduced by substituting a perennial crop such as alfalfa for row crops in areas exporting high loads of phosphorus. However, local markets are often lacking for bulky crops such as hay or biomass. Federal (Natural Resources Conservation Service) and state (Board of Water and Soil Resources) programs may be available to subsidize such practices to a limited extent.

Municipalities with unregulated stormwater in impaired watersheds may also need to implement BMP's. These BMP's seek to minimize the amount of runoff from impervious surfaces, encourage infiltration, and reduce the transport of soil and nutrients to surface waters. There is extensive guidance on urban BMP's and in impaired watersheds; cost-share dollars may be available as well to promote adoption of the BMP's.

It is important to realize that many of the waters likely to be included on the impaired waters list because of the adoption of the proposed river eutrophication standards are likely to coincide with current listings for turbidity impairment. Some turbidity TMDLs have been completed, several geographically large TMDLs are nearing completion, and many more will follow in the next several years. Two consequences of this are:

(1) No added cost of remediation activities because of river eutrophication TMDL studies. Since much nonpoint source phosphorus is attached to sediment, models and data prepared for turbidity TMDLs are partially transferable to river eutrophication impairment studies and
(2) Reduced marginal cost to agricultural producers in order to meet new TMDL requirements prompted by the proposed eutrophication standards. This is because the existing requirements of turbidity TMDLs will account for much of the unregulated phosphorus reduction that will be required to respond to eutrophication TMDLs.

The fact that turbidity impairments and eutrophication impairments are linked can reduce model development costs, data acquisition costs, and stakeholder involvement costs, as the needs of the eutrophication TMDL can be achieved by building on past efforts. The linkage between turbidity impairments and eutrophication impairments can also reduce the cost of removing sediment-attached phosphorus through such practices as rain gardens, porous pavement, conservation tillage, grass buffers, terraces, or grass waterways. Costs incurred to control sediment also serve to provide nutrient load reductions at no additional cost. In addition, efforts to develop restoration and protection strategies on a major watershed scale, will also lead to economies in modeling, stakeholder processes, and even BMP implementation.

However, there are significant agricultural sources of phosphorus that cannot be addressed solely through the sediment-reduction efforts already in use to meet turbidity TMDL goals. These include:

- Cropland that has high or very high levels of phosphorus because of repeated manure applications. Such areas will merit additional measures for erosion control and nutrient application rate-reduction. Manure and fertilizer application rate-reduction will pay for itself unless soil test levels are brought below agronomic thresholds, a situation that can be avoided through careful attention to soil test values.
- Cropland areas exporting soluble phosphorus through drainage tile. Recent monitoring data from the Minnesota River indicate that a high proportion of total phosphorus export from agricultural fields can be through tile drainage losses of soluble forms of phosphorus. This situation may arise in areas of very high soil phosphorus, or where heavy manure applications are made without adequate nutrient credits being given.

In both of these cases, reduction of nutrient application rates to agronomic levels is a logical, cost-free and potentially cost-saving first step to addressing this problem.

Information is available to examine annual costs per acre in implementing BMPs for soil and nutrient preservation and can be obtained from past implementation projects and BWSR resources http://www.bwsr.state.mn.us. The MPCA has estimated BMP costs for some commonly used practices: minimum tillage at $14/acre, stream buffers at $200/acre, and conservation easements in the Conservation Reserve Program at $100/acre/year (as derived from: Yellow Medicine Watershed District 2005 (MPCA approved) *South Branch Yellow Medicine River Fecal Coliform Total Maximum Daily Load Report;* available at: http://www.pca.state.mn.us/xggx950). Certainly, these costs will vary over time and among locations in the state but these figures provide a good starting point for framing costs. Since these standard BMPs may yield multiple benefits it may be difficult to assign costs specifically to any single impairment (e.g., sediment, nutrient, or bacteria) when multiple impairments may be addressed by individual BMPs.

F. Regulated Source Costs, Implementation, and Point-nonpoint Trading

Overview and Implementation

Regulated sources, also referred to as point sources, include several sources that are regulated through the NPDES permits. The sources addressed in this section include municipal wastewater, industrial wastewater, urban stormwater, and Concentrated Animal Feeding Operations (CAFOs). The costs of implementation of the river eutrophication WQS varies substantially among these source categories with essentially no additional costs for CAFOs to substantial capital and operation and maintenance costs for some large wastewater dischargers. Most regulated wastewater and stormwater sources in Minnesota discharge to streams or rivers (Exhibit EU-45). Implementation of river eutrophication standards will require consideration of applicable effluent limits for many of these regulated sources when their permits are re-issued or revised. With respect to municipal wastewater, the economic evaluation most directly applies to mechanical facilities that discharge continuously. Stabilization ponds are generally small discharges that are not allowed to discharge during a portion of summer (June-September).

Municipal Wastewater

Currently, most total phosphorus (TP) effluent limits required for riverine discharges are technology-driven limits (typically 1 mg/L) that were implemented based on the long-standing effluent P rule that called for P limits for discharges “to or affects a lake.” The Phosphorus Strategy in the late 1990’s called for P limits in facilities that were new or expanding (Exhibit EU-8). These effluent limits were generally designed to reduce nutrients to receiving waters without a specific in-stream target for the immediate watershed. The Minn. R. ch 7053 revision in 2008 essentially served to codify the strategy. In 2009, the Minnesota Center for Environmental Advocacy sent EPA Region 5 a petition to remove the state’s NPDES program delegation, stating that conditions in federal law were not appropriately being addressed. Namely, the MCEA alleged that reasonable potential for TP was not being adequately determined in many permits, and as a result, Water Quality Based Effluent Limits (WQBELs) were not being implemented. In an effort to resolve this petition, the Phosphorus Decision Tree” was developed in 2010 with a more detailed emphasis on federal regulations and the implementation of WQBELs where necessary (Exhibit EU-46). Increasingly, WQBELs are being assigned for downstream lakes or reservoirs such as Lake St. Croix, Lake Byllesby, and Lake Pepin. Once the river eutrophication standards are adopted, the MPCA will determine if a given WWTP at current discharge limits has the “reasonable potential” to cause or contribute to an exceedance of the river eutrophication standards in downstream rivers. Existing limits are likely to be sufficient in rivers where the proposed river eutrophication standards are currently met. Where water quality standards are exceeded WQBELs for TP will be required where point sources cause or contribute to an exceedance of the proposed river eutrophication standards.

Implementation of lake and reservoir eutrophication standards in 2008 have resulted in WQBELs for point sources that discharge upstream of lakes and reservoirs (hereafter lakes). The process of setting effluent limits for river eutrophication standards will be similar to what the MPCA has developed for settling limits for facilities discharging directly to or upstream of lakes. MPCA adopted eutrophication standards for lakes in 2008 and has refined its process for setting effluent limits for facilities upstream of lakes since that time. Approximately 80 percent of dischargers in lake watersheds, currently discharge upstream of lakes that exceed lake eutrophication standards (“nutrient impaired” lake). However, many of these discharges are located far upstream of the impaired lake (as is the case for many of the dischargers in Lake Pepin’s watershed) and determination of WQBEL can be difficult absent a completed

TMDL and wasteload allocation. In instances where TMDL studies have been completed, river eutrophication standards and wasteload allocations provide the basis for TP WQBELs for upstream discharges.

The process for setting effluent limits for river eutrophication standards is unique from the established process of setting effluent limits for more "traditional" pollutants such as conventional pollutants and toxics. Several of the unique factors associated with calculating effluent limits for river eutrophication standards include:

- the cause variable TP and one response variable need to exceed river eutrophication standards to be considered impaired or not meeting the water quality standard
- the seasonal averaging period for river eutrophication standards applies to all summer days over multiple years (typically assessed over a 10 year period) so there is not a critical flow consideration such as a $7Q_{10}$ for river eutrophication standards as with conventional pollutants and toxics
- Staff that establish effluent limits need to determine downstream impacts since phosphorus is relatively conservative in rivers, and non-point reductions must be considered for many watersheds for river eutrophication standards to be achieved.

Fortunately, the MPCA has developed a watershed framework that will collect important monitoring data essential for calculating effluent limits once the river eutrophication standards are adopted. MPCA will be able to set WQBELs from data sets of cause (TP) and response (e.g., elevated Chl-a) variables for medium to large rivers that are most similar to the primary sites used in river eutrophication standards development. The MPCA will also utilize river reaches upstream of these sites if adequate monitoring data exists, but the amount and quality of data must be sufficient to allow for proper WQS evaluation. Additional monitoring of smaller streams will be required in some cases to complete TMDLs and prepare for future permit cycles. The multitude of discharges within a watershed will be considered when implementing river eutrophication standards.

In most watersheds that currently exceed the proposed river eutrophication standards, reductions in TP loading will be necessary from non-point sources in order to meet the new river eutrophication standards in addition to point source reductions. The MPCA will project reductions in non-point sources based on modeling when calculating effluent limits. In many of the watersheds that exceed river eutrophication standards in southern, western and central Minnesota, all dischargers could essentially meet water-quality standard (WQS) end-of-pipe and the river would still not meet river eutrophication standards because of the contribution from non-point sources. Current lake eutrophication TMDLs employ a similar balanced approach to achieve WQS. Reductions in point sources will be a component to achieving the river eutrophication standards in these watersheds, but it will not be the only reduction needed. Additional consideration will be made in setting effluent limits based on an understanding of transport losses of TP within the watershed. Analysis of flow duration curves and composition of contributing sources will be imperative to identify the significance of point sources discharges to meeting water quality standards in a given watershed. A more detailed example of how river eutrophication standards implementation is expected to occur may be found in Exhibit EU-45.

Costs to Municipal Dischargers

Background

Studies in Minnesota and elsewhere indicate that the cost of phosphorus reduction from wastewater treatment facilities depends heavily on two factors: the influent TP concentration and the size of the facility as measured in millions of gallons of flow per day (MGD). An evaluation of Minnesota wastewater facilities from the mid-1990s indicated that annualized costs (operation and maintenance plus fixed costs) for TP removal range between $10/lb. and $26/lb. for most facilities ($151/lb. for an anomalous facility - Vermillion WWTP). These costs were estimated for influent concentrations averaging 5 mg/L TP. At influent concentrations twice that level, costs declined by more than half, to $3/lb. TP to $7.50/lb. TP (MPCA 1997, page 42). Cost estimates from another study of point-nonpoint source trading in Minnesota (Faeth 2000) were in a similar range.

A study of six small Texas communities, ranging in population from 360 to 14,900 persons, confirms that unit costs of phosphorus removal vary inversely with community size (Kepinger *et al.* 2004). The removal cost per pound was lowest for Stephenville, the largest community, at $13.97/lb., and greatest for Iredell, the smallest community, at $331/lb. TP. Chemical precipitation with alum was the treatment method evaluated. The cost of pollutant removal is not simply a "given" of technology, since it can be influenced by policies.

The most common phosphorus removal technique currently practiced by both mechanical and stabilization pond wastewater treatment facilities in Minnesota is chemical coagulation and precipitation with metal salts of aluminum or iron, typically as alum and ferric chloride, respectively. Mechanical facilities use alum or ferric chloride (and possibly polymer), which is typically fed into the wastewater flow path prior to or at entry points into the primary or secondary clarifiers to provide for mixing, coagulation, and then settling of the phosphorus into the sludge blanket of the clarifiers (Exhibit EU-41a). The phosphorus is then removed from the clarifiers with the waste sludge, and the sludge is later applied to farm fields as a soil amendment to be utilized by crops.

Operators for stabilization pond systems introduce alum into the secondary pond, typically by using a pontoon boat that is equipped with a small storage tank that drips the alum into the pond water surface near the boat's propeller to mix the chemical with the wastewater. The phosphorus then settles into the sludge blanket of the pond bottom.

A series of memoranda provide estimates of municipal Wastewater Treatment Facilities' (WWTF) costs of P removal to concentrations varying from 1 mg/L to 0.1 mg/L. Cost estimates are provided for a range in size of WWTFs and include a range (low, average, high) of costs for total capital, annual capital and annual operations and maintenance. Specific cost details and supporting literature are found in Exhibits EU-41a-d. The analysis also differentiates among mechanical facilities and stabilization ponds. In addition to these analyses (Exhibit EU-41a-d), cost estimates were provided in the 2007 SONAR in support of Minn. R. ch 7053 (Exhibit EU-53).

The MCPA reviewed a number of references to determine the best method to provide the cost estimates for chemical removal of phosphorus and these details are included in Exhibit EU-41a-d. Removal costs vary dependent on facility size, influent P concentration, permitted effluent P, and related factors. For example, estimated individual facility total capital costs for alum addition for P removal to 1 mg/L in mechanical facilities with a design flow of 0.2-0.5 MGD may range from 0.2-0.71 ($ million) with annual operation and maintenance from 0.04-0.12 ($ million). Comparable individual facility capital and O&M costs for WWTF of 40-110 MGD would be 10-15 ($ million) and 2.6-11.0 ($ million), respectively. Individual facility capital cost for stabilization ponds, ranging from 0.024-0.672 MGD were estimated at 0.042-0.235 ($ million) annual O&M from 0.0044-0.0535 ($ million). Further detail and cost ranges are included in Exhibits EU-41a-c.

The MPCA is using two policies to favor lower costs of phosphorus abatement. First, the MPCA has attempted to reduce the cost of additional TP removal by timing permit revisions to coincide with a significant hydraulic expansion. This has the effect of greatly reducing the capital outlays required for phosphorus removal. Since annualized capital costs are frequently about half of total costs, this leads to substantial cost savings. For example, the MPCA has estimated that if a 1 mg/L TP limit had been imposed on the MCES Metro Plant in 1993, the cost of phosphorus removal would have been about $20/lb. TP. By timing the requirement to coincide with a major hydraulic expansion, the estimated cost was reduced to $5.75/lb. TP.

Another way of reducing unit costs of wastewater phosphorus removal is to encourage pollutant trading among facilities. Since the MPCA is in the process of adopting a pollutant trading rule, this is a relevant consideration. As discussed above, WWTFs vary considerably in their unit cost of pollutant removal. Under pollutant trading, low-cost facilities would be able to generate pollutant trading credits by generating reductions beyond permit requirements. These credits could then be sold to a higher cost facility. The policy of pollutant trading is likely to reduce overall costs by concentrating reduction costs in the largest, lower cost facilities. Both parties to the trade would be better off than without the trade. For example, the Texas study cited above concluded that the six communities studied could save a potential $185,000 annually through point-point pollutant trading.

As phosphorus reduction requirements increase, unit cost of control increases. The costs cited above are in the range needed to achieve the recent benchmark of 1 mg/L TP effluent concentration. However, as TMDLs lead to requirements for still greater reductions, to as low as 0.1 mg/L TP, more expensive treatment methods such as membrane filtration are likely to be required, perhaps in combination with biological or chemical removal capability as a supplement or backup technology. The Wisconsin Department of Natural Resources (WDNR) estimated the cost of achieving 0.1 mg/L TP with advanced filtration technology would range from $240/lb. TP to $304/lb. TP. The WDNR anticipates that point-nonpoint source pollutant trading will be used to allow wastewater treatment facilities to purchase phosphorus reduction credits in the range of $10 to $45/lb. TP from nonpoint sources, rather than investing in costly upgrades to advanced filtration (WDNR 2010).

The MPCA anticipates that ultra-low TP limits will be necessary in some regions ($\leq$ 0.1 mg/L) but are expected to be the exception statewide. The need for an ultra-low limit will be dependent on both the magnitude of the reduction necessary to meet standards, and on the proportion of load contribution for a given discharger. Where point sources constitute a minor portion of the overall load and where the load reduction potential from a point source is nominal, ultra-low limits are not likely.

Mechanical facility cost estimates

In addition to the general costs cited above the MPCA has made detailed estimates of chemical treatment cost for mechanical facilities based on a tiered approach: A- meet 1.0 mg/L, B – meet 0.8 mg/L and C – meet 0.1 mg/L. The approach assumes the facility is already meeting 1 mg/L and continues to use alum as the phosphorus removal chemical. Since the facility is already meeting the 1.0 mg/L costs, it can be assumed the chemical feed system, the chemical storage tank, incremental costs of clarifier improvements, and any sludge treatment and handling improvements to the facility have already been completed. Therefore, the Tier B cost estimates assume there will be no (zero) capital costs. The Tier B costs, as presented, are the incremental additional O & M costs for adding more alum (and possibly polymers) and added costs of associated solids handling to reduce the effluent total phosphorus concentration to 0.8 mg/L. Exhibit 41c also provides estimates for removal to 0.5 mg/L, which was drawn largely from the literature.

Literature references were used to develop the Tier B costs (Table 21) (Exhibit EU-41c) and were updated to 2010 based on the Engineering News Record (ENR) (2010) approach. Table 21 includes one annual O & M cost amount for a specific design flow. These costs should be considered an average value for a facility at the design flow indicated. It is not likely that two different facilities with similar design flows will have the same operation and maintenance (O & M) costs, but it would be more likely the two O & M costs would fall into a range plus or minus some percentage around that cost value, due to differing individual facility site-specific conditions. The reasons for these cost differences could be: chemical costs may vary slightly around the state depending on the local supplier or distance of delivery costs, costs of individual facility bio-solids treatment (energy use) and ultimate disposal may vary (depending on haul distance to application sites).

Table 21. Tier B cost estimates for reducing phosphorus from 1.0 to 0.8 mg/L

Tier B: Additional Cost Estimates for Reducing Total Phosphorus form 1.0 to 0.8 mg/L

Design Flow (MGD)	Annual O & M Costs ($)
.02	$ 25,000
1.5	$ 57,000
5.0	$ 180,000
10.0	$ 352,000
15.0	$ 516,000
20.0	$ 690,000
30.0	$ 1,026,000
40.0	$ 1,363,900
75.0	$ 2,546,700
315.0	$ 10,657,300

The costs estimates for Tier C assume that the existing treatment facility is already treating to 0.8 mg/L and will be upgraded by adding or expanding treatment units as needed. These estimates also assume that land is available at the existing site for any new treatment units, and do not include costs for additional land at the facility sites. These estimates also assume that there are not significant at-grade or sub-grade issues (examples would be old buried structures or piping) that need correction for these improvements to be constructed at the example facilities.

Literature and past design and operating experience for municipal wastewater treatment facilities in Minnesota with TP effluent limits below 0.5 mg/L, indicate that higher metal salt dosages and effluent filtration will be required (Exhibit EU-41c). Additional treatment/process components can include expanded or enhanced single or multi-point chemical addition with metal salts (aluminum or iron based), new settling units, new effluent pumping stations (site-specific if a gravity location for filters is not available) and filtration units including deep-bed granular media filters and/or microfiltration processes. It is also important to note that there are example municipal wastewater treatment facilities currently operating in the United States that are producing effluent with total phosphorus concentrations of less than 0.1 mg/L.

Table 22 provides cost ranges (low and high) around the average values for a specific design flow. The average values were calculated using a number of values from references in EU-41c and are not simply a calculated average value using only the low and high costs respectively for an example design flow of a possible facility. This range considers that two individual facilities with the same design flow will likely have somewhat different capital (construction) and O & M costs. Remember that the cost estimates for Tier C assume the facility is already meeting a 0.8 mg/L total phosphorus effluent limit (Tier B). To arrive at total costs for a WWTF that moves through all three tiers, the Tier C costs need to be added to the initial cost to treat to 1 mg/L and Tier B costs as appropriate.

Table 22. Tier C cost estimates for reducing phosphorus from 0.8 to 0.1 mg/L

Tier C: Additional Cost Estimates for Reducing Total Phosphorus from 0.8 to 0.1 mg/L (in $ million)

Design Flow (mgd)	Total Capital Costs (Low)	Total Capital Costs (Avg)	Total Capital Costs (High)	Annual O & M Costs (Low)	Annual O & M Costs (Avg)	Annual O & M Costs (High)
0.2	0.760	1.660	2.600	0.008	0.060	0.110
1.5	1.120	3.530	6.480	0.105	0.210	0.320
5.0	2.460	7.780	16.480	0.145	0.525	0.905
10.0	3.100	11.930	25.750	0.365	0.950	1.535
15.0	3.640	16.680	36.000	0.400	1.255	2.110
20.0	4.280	21.250	44.800	0.905	2.155	3.400
30.0	24.929	38.849	52.770	0.749	2.459	4.170
40.0	33.190	50.795	68.400	1.925	5.042	8.160
75.0	59.840	83.595	107.350	2.174	6.527	10.880
315.0	182.369	310.017	450.865	8.035	20.953	45.695

Stabilization ponds

Under current MPCA NPDES permitting practices, based on Minnesota Rules 7053, the MPCA has assigned TP effluent limits of 1 mg/L, but has not assigned an effluent limit to date below 1 mg/L for municipal, controlled-discharge pond systems (also referred to as stabilization ponds or lagoons). Since the MPCA lacks direct experience with setting limits <1 mg/L for stabilization ponds, we relied on recent literature that addressed this topic. Two documents available in the literature conflict on their conclusions whether or not it is possible to add technology to an existing stabilization pond system to meet a 0.1 mg/L phosphorus effluent limit. A summary of each follows:

1. CH2MHILL (2010) prepared cost estimates for adding required treatment units to meet a 0.1 mg/L total phosphorus effluent limit at the one large Utah municipal continuous discharge lagoon facility, and one "model" Utah municipal, continuous-discharge lagoon facility. These cost estimates were prepared assuming the existing lagoon facilities would continue to be used to reduce $CBOD_5$ and TSS, and the facilities would need to add power substations, pumping, dual stage chemical addition (before clarification and before filtration), clarifiers, pumping, and deep bed granular media filtration, which would result in substantial costs to the facility.

2. Strand Associates, Inc. (2008) concluded that it would be very difficult for a Wisconsin municipal "lagoon-based" wastewater treatment plant (similar term to stabilization pond system) to achieve phosphorus effluent concentrations of 0.5 mg/L, 0.25 mg/L or 0.05 mg/L. Their cost estimates assumed the lagoons would be <u>abandoned and new mechanical treatment facilities would be required.</u>

Since the MPCA is not aware of a pond system (in the U.S.) that is operated and meeting a 0.1 mg/L limit and given conflicting opinion in the recent literature we cannot state whether it is possible to add treatment units to stabilization pond systems to meet a 0.1 mg/L TP effluent limit. As such, "typical" cost estimates are not provided. It is not currently the intent of the MPCA to require an existing municipal stabilization pond system to be abandoned in order to meet a 0.1 mg/L total phosphorus effluent limit. The MPCA believes it is appropriate to continue the current practice of assigning 1 mg/L total phosphorus effluent limitations for controlled discharge stabilization pond systems, and also maintain the current standard boiler-plate NPDES permit language that designates discharge windows be limited to spring and fall discharge periods to minimize impacts from the stabilization pond systems effluent on Minnesota rivers.

Costs to Industrial Dischargers

During initial development of the river eutrophication standards, various wastewater treatment plants were identified as discharging into receiving streams, which may be affected by the adoption of river eutrophication standards. Industrial facilities included in that list were grouped into specific industrial categories consistent with the protocol used by the EPA in establishing technology base limits for industrial wastewater dischargers. Facility information available from various sources was used to establish existing operating conditions, as well as current design conditions, for each category. No projections were made for facility expansions since that type of growth is dependent on local, regional, and national economic factors beyond the scope of this rulemaking process.

Treatment technologies currently used to remove total phosphorus (TP) from industrial wastewater treatment plant discharges are similar to those used by municipal facilities. Many industrial plants use iron salts (precipitation/settling) for removal of TP. When amenable to biological treatment, enhanced biological TP removal is also available for industrial facilities that have organic influents.

<u>Cost estimate limitations</u>

The MPCA has made a reasonable effort to determine the cost of the river eutrophication standards on industrial point sources. However, the actual future costs may vary according to a number of factors, including:

1. adequacy of existing facilities
2. outdated and worn out structures and equipment
3. additional land requirements

4. “At-grade” or sub-grade deficiencies needing correction for future improvements

MPCA staff also made assumptions about the number, type, and size of discharges to be impacted. These assumptions are based on previous experience with evaluating the economic effect of the previous rule revisions regarding statewide wastewater treatment plant requirements for TP removal to 1 mg/L. As such, these costs are to be used only as a gross estimate of statewide costs for all industrial sectors identified (in total) and regulated by Minnesota’s NPDES/SDS program. Facility specific data and information is not available to determine actual implementation measures for any individual WWTP. Hence, the estimates provided for this discussion cannot be used to project actual site-specific costs for any particular facility.

This cost estimate was prepared for continuous discharge NPDES/SDS permitted industrial facilities. The costs for industrial facilities with trading agreements or other controlling documents for discharges of total phosphorus are not included in this analysis. The costs associated with controlled discharge ponds are also not included because of the lack of good information, as was the case for municipal stabilization ponds. A listing of references and sources used to develop cost estimates is provided in Exhibit EU-42.

Basis of cost estimates

MPCA staff compiled cost estimates from: (1) search of national public domain literature on estimating costs for TP removal at various WWTPs; (2) information collected from suppliers and consultants on WWTPs that have completed construction of TP removal facilities, and; (3) information collected from suppliers and consultants on prepared cost estimates for contemplated future TP removal related construction projects (Exhibit EU-42).

To meet a TP effluent limitation of 0.1 mg/L, the MPCA assumed that all treatment plants would add treatment units to the end of their existing wastewater treatment facilities. Additional treatment components include expanded/enhanced multi-point chemical precipitation (w/ metal salts) in combination with additional settling, deep-bed granular media filters, and/or microfiltration processes. Table 23 provides a summary by industry sector. All planning level capital costs estimates are based on, or were converted to, March 2011 dollars using the *Engineering News-Record Cost Index.* Planning level annualized capital cost estimates are based on a 20 year life cycle cost (n = 20 years) and a discount rate of 8 percent. A wide range in capital costs is evident across the sectors analyzed and this relates to strength of effluent and related factors.

Table 23. Planning Level Cost Estimates for Industrial Facilities to meet 0.1 mg/L TP effluent limit.

Industry Sector	Estimated Design Flow MGD*	# of Plants in Sector	Capital Costs per Facility ($ Million)	Annualized Capital Cost per Facility ($ millions)	Annual O/M per Facility ($ millions)	Total Annual Cost per Facility ($ millions)
Ethanol Plants	0 to 0.2 (range)	6 (no TP trading)	0 to 2	0 to .2	0.0 to 0.1	0 to 0.3
Contact Cooling (food processing)	0.55	1	2.5 to 4	0.26 to 0.41	0.02 to 0.12	0.28 to 0.53
Egg Processing Facility	.8	1	3 to 5.5	0.31 to 0.56	0.03 to 0.2	0.34 to 0.76
Dairy Processing	0.14	1	0.7 to 2	0.07 to 0.2	0.02 to 0.1	0.09 to 0.3
Rendering Plant	0.15	1	0.7 to 2	0.07 to 0.2	0.02 to 0.1	0.09 to 0.3

Industry Sector	Estimated Design Flow MGD*	# of Plants in Sector	Capital Costs per Facility ($ Million)	Annualized Capital Cost per Facility ($ millions)	Annual O/M per Facility ($ millions)	Total Annual Cost per Facility ($ millions)
Poultry Processing Plant	2.3	1	0	0	0.09 to 0.3	0.09 to 0.3
Corn Wet Milling Plant	4.3 (peak)	1	10 to 20	1.02 to 2.04	0.2 to 0.5	1.22 to 2.54
Meat Processing	2	1	5 to 11	0.51 to 1.12	.09 to 0.3	0.6 to 1.42
Petroleum Refining	5.2 (peak)	2	11 to 23	1.12 to 2.34	0.2 to 0.6	1.32 to 2.94
Total (all plants)			**44 to 103**	**4.48 to 10.44**	**0.87 to 3.42**	**5.35 to 13.83**

*Assumed influent design value prior to discharge to advanced/tertiary treatment systems (following existing primary and/or secondary treatment).

Municipal, Construction, and Industrial Stormwater (NPDES Permits)

MPCA administers three types of National Pollutant Discharge Elimination System/State Disposal System (NPDES/SDS) permits for stormwater: municipal, industrial, and construction. Most permits issued are general permits, with a few issued as individual permits (e.g., Minneapolis and St. Paul municipal stormwater permits). The foundation of stormwater permits are Best Management Practices (BMPs), which are implemented using varied approaches. The approaches for the implementation of BMPs range from “Maximum Extent Practicable” (MEPs) and “Stormwater Pollution Prevention Plans” (SWPPPs) for municipal stormwater permits, to “no exposure” and “adaptive management controls” for industrial stormwater permits (see *Stormwater Program* at http://www.pca.state.mn.us/stormwater).

Addressing excess nutrient discharges from stormwater is an important consideration for these permits. The addition of river eutrophication standards will have some impacts on these permits and permit holders at the time they are implemented.

- Reducing phosphorus, or more generally, a requirement to control all nutrients, is already included in the BMPs. The BMPs also include management objectives based on controls that are consistent with the seasonal application of the river eutrophication standards and thus the summer index period for the standards should not result in additional expenses to permittees.
- The phosphorus benchmark value used in industrial stormwater permits of 1 mg/L is already being applied to stormwater permits. However, this value may not be stringent enough in some receiving waters to meet the future river eutrophication WQS. The existing stormwater permits already have language describing when a more stringent Water Quality-Based Effluent Limit (WQBEL) may be required, and application of WQBELs may increase in future reissuance of permits after the adoption of the more stringent river eutrophication WQS. The few industrial sectors that have been assigned phosphorus monitoring requirements or effluent limits in their stormwater permits may have to implement more BMPs based on more stringent benchmarks and revised limits. The MPCA does not have complete monitoring data at this time to assess how many permittees may need to change their current practices in order to meet the proposed river eutrophication standards. The MPCA expects that for some permittees, there will be some increase in the cost of treating industrial stormwater for phosphorus.
- The effect of the river eutrophication standards on future general municipal stormwater permits and costs to permittees is the possibility of more municipalities needing individual stormwater

permits (see *Stormwater Programs and Impaired Waters* at http://www.pca.state.mn.us/r0pga8a). The EPA provided estimates of costs to small cities to implement MS4 permits in a range of $1,206 for one acre up to $8,709 for five acre sites, with administrative costs averaging about $937 per municipality (Federal Register, vol. 64. No 235. Dec. 8, 1999 available at http://www.epa.gov/npdespub/regulations/sw2-part1.pdf. The EPA review, which included estimated monetary benefits of broadly controlling stormwater pollutants in citizen's willingness-to-pay for fishable, boatable, and other surface water uses, showed that the benefits of stormwater management exceeded cost estimates.

- The MPCA's estimates of costs for a new industrial permittee to implement a storm water permit over five years were about $9,616 (see *Fact Sheet for the National Pollutant Discharge Elimination System/State Disposal System Multi-sector General Permit for Industrial Stormwater Activity,* November 2010 http://www.pca.state.mn.us/index.php/view-document.html?gid=14929). It is important to note that less costly BMP options are also available for industrial stormwater management that can be tailored to the stormwater system and help to minimize costs.
- Construction stormwater permittees are also affected and will likely incur costs when their site discharges within one-mile of an impaired water. This is the case for new permittees and current permit holders that need to regularly review their SWPPPs for new requirements related to MPCA's Special Waters List that includes impaired waters. Additional requirements found in the permit appendices (B9, C1, and C2) mean quicker stabilization of exposed soils, temporary settling basins, and treatment of 1 inch of runoff from new impervious surface, instead of just ½ inch. This final condition doubles the size of permanent BMPs, and requires that ½ inch of runoff be infiltrated where possible.

Costs to Confined Animal Feeding Operations

CAFOs can also be sources of nutrient discharge. CAFO owners are required to follow an approved manure management plan and to prevent feedlot runoff of manure. These prevention measures are included in the cost of doing business for operations of 1,000 animal units or greater, and these CAFOs account for a large share of certain livestock types – hogs, dairy, and poultry. As a result, the proposed eutrophication standards will not have an economic effect on this sector of agricultural producers.

8. Conclusion

The MPCA's proposed river eutrophication standards are based on over 10 years of chemical and biological data collection, data analysis, and reporting on the condition of Minnesota's rivers. A systematic approach was proposed and targeted data collection efforts were first initiated in 1999, with assistance from the EPA through nutrient criteria grants. By 2008 the MPCA had detailed chemical, physical and biological datasets for over 30 river reaches distributed across Minnesota. These data were augmented with fish, invertebrate, and chemical data from hundreds of MPCA's biological monitoring sites. Combined, these data provided the basis for applying sound statistical procedures that allow for identification of a range of thresholds that provided the basis for selection of criteria deemed to be protective of aquatic life uses. A weight-of-evidence approach based on tiers of statistical analysis, extensive literature review, characterization of regional patterns in chemistry and biology all contributed to the proposed WQS.

The Lake Pepin proposed site-specific standard and Mississippi River navigational pool proposed WQS are built on a similarly strong foundation. In the case of Lake Pepin, data date back to 1988 and there is a long history of collaborative work among the states of Minnesota and Wisconsin, USACE, regulated dischargers, the environmental community, and the University of Minnesota on issues related to Lake Pepin. This data collection, analysis, model development, and overall collaboration contributed to the WQS that was developed. WQS development for the pools was a more recent effort; however it relied on many of the same partners and existing data from their long-term monitoring networks.

The river, navigational pool, and Lake Pepin proposed WQS are intended to complement one another and provide a holistic approach for addressing nutrient over-enrichment that may impair uses in these resources. The proposed standards will be protective of downstream uses, which were taken into account along with aforementioned factors.

The proposed standards are:

- Broken out by three river nutrient regions that are based broadly on aggregated level 3 ecoregions but acknowledge that rivers may flow through one or more ecoregions
- Consistent with EPA guidance to states on the development of nutrient standards using local data and consideration of regional patterns
- Designed with a basis of WQS implementation linkage of cause (total phosphorus) and response (stressor) variables and
- Protective of Class 2 beneficial uses (and sub-uses within Class 2) with an emphasis on aquatic life uses in rivers and aquatic recreational uses in Lake Pepin and the Mississippi River Pools

The MPCA has established in this SONAR that the proposed river eutrophication standards are needed for the following reasons:

- To protect Minnesota's valuable water resources
- To address a leading cause of impaired waters
- To address the EPA expectation that states develop river nutrient standards and
- To supplement the existing narrative aquatic nuisance standard and provide a numeric translator

The MPCA has established in this SONAR that the proposed river eutrophication standards are reasonable for the following reasons:

- The proposed standards can be implemented with currently available wastewater treatment technologies and stormwater management practices.
- The proposed standards reflect the great natural variability of river characteristics and response to nutrients.
- The ability to protect high quality rivers from eutrophication through existing nondegradation policy
- Provide an allowance that recognizes not all rivers can achieve the standards due to natural causes
- The implementation of eutrophication standards is different than other Class 2 standards and
- Site-specific standards are an available alternative to implementation of the general WQS that may be needed for some stream reaches.

Based on the foregoing, the proposed eutrophication standards are both needed and reasonable.

9. References

Anfinson, J. 2003. The River We Have Wrought: A History of the Upper Mississippi. University of MN Press, Minneapolis MN 365 p.

Aloi, J. 1990. A critical review of recent freshwater periphyton field methods. Can. J. Fish. Aq. Sci. 47:656-670.

Basu, B. and F. Pick. 1996. Factors regulating phytoplankton and zooplankton biomass in temperate rivers. Limnol. Oceanogr. 41(7):1572-1577.

Bauman, J. 2010. Personal communication to Special Assistant to Director Bureau of Watershed Management. Wisconsin Department of Natural Resources.

Blackstone, J. 2012. Engineer, St. Paul Water Regional water Services. Personal communication to Steven Heiskary, MPCA, February 2012.

Brenden, T.O., L. Wang and Z. Su. 2008. Quantitative identification of disturbance thresholds in support of aquatic resource management. Environ. Manage. 42:821-832.

Brick, C. and J. Moore. 1996. Diel variation of trace metals in the upper Clark Fork River, Montana. Environ. Sci. Technol. 30(6):1953-1960.

Bryce, S., G.A. Lomnicky, P.R. Kaufmann, L. McAllister and T.L. Ernst. 2008. Development of biologically based sediment criteria in mountain streams of the western United States. N. Am. J. Fish. Manage. 28:1714-1724.

Burdis, R.M. and J.K. Hirsch. 2007. Summary of Zooplankton in Lake Pepin Upper Mississippi River System 1993-2006. Completion Report 2006D7 prepared for the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. July 2007.

Cade, B.S. and B.R. Noon. 2003. A gentle introduction to quantile regression for ecologists. Front. Ecol. Environ. 1(8):412-420.

Carleton, J.N., R.A. Park and J.S. Clough. 2009. Ecosystem modeling applied to nutrient criteria development in rivers. Environ. Manage. 44:485-492.

Carpenter, S., N. Caraco, D. Correll, R. Howarth, A. Sharpley and V. Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications. 8(3):559-568.

Chambers, P., R. Brua, D. McGoldrick, B. Upsdell, C. Vis, J. Culp and G. Benoy. 2008. Nitrogen and phosphorus standards to protect ecological condition of Canadian streams in agricultural watersheds. National Agri-Environmental Standards Initiative. Environment Canada Technical Series 2008.

CH2MHILL. 2010. Final Report: Statewide Nutrient Removal Cost Impact Study. Prepared for Utah Division of Water Quality. October 2010.

Correll, D. 1998. Role of phosphorus in the eutrophication of receiving waters: A review. J Environ Qual. 27(2):261-266.

Cross, W., B. Johnson, J. Wallace and A. Rosemond. 2005. Contrasting response of stream detritivores to long-term nutrient enrichment. Limnol. Oceanogr. 50(6):1730-1739.

Cross, W., J. Wallace, A. Rosemond and S. Eggert. 2006. Whole-system nutrient enrichment increases secondary production in a detritus-based ecosystem. Ecology. 87(6):1556-1565.

Davis, P. 2004. St. Croix Basin phosphorus-based water quality goals report on the recommended water quality goals of the St. Croix Basin. St. Croix Basin Water Resources Planning Team

De'ath, G. and K.E. Fabricius. 2000. Classification and regression trees: A powerful yet simple technique for ecological data analysis. Ecology. 81(11):3178-3192.

Dodds, W.K. 2006. Eutrophication and trophic state in rivers and streams. Limnol. Oceangr. 51(1):671-680

Dodds, W.K. 2002. Freshwater ecology: concepts and environmental applications. Academic Press, San Diego. 569 p.

Dodds, W.K. and J. Cole. 2007. Expanding the concept of trophic state in aquatic ecosystems: It's just the autotrophs. Aquatic Sciences Research Across Boundaries. 69(4):427-439.

Dodds, W. and R. Oakes. 2004. A technique for establishing reference nutrient concentrations across watersheds affected by humans. Limnol. Oceanogr. 2:333-341.

Dodds, W. and E. Welch. 2000. Establishing nutrient criteria in streams. J. N. Am. Benthol. Soc. 19(1):186-196.

Dodds, W., V. Smith and B. Zander. 1997. Developing nutrient targets to control benthic chlorophyll levels in streams: a case study of the Clark Fork River. Water Res. 31(7):1738-1750.

Elwood, J., J. Newbold, A. Trimble and R. Stark. 1981. The limiting role of phosphorus in a woodland stream ecosystem: effects of P enrichment on leaf decomposition and primary producers. Ecology. 62(1):146-158.

Engineering News Record (ENR). 2010. Published Cost Indexes. March 4, 2004, July 28/August 4, 2008, August 25/September 1, 2008, November 9, 2009, December 21, 2009, and December 6, 2010.

Faeth, Paul . 2000. Fertile Ground: Nutrient Trading's Potential to Cost-Effectively Improve Water Quality, World Resources Institute, Washington D.C.

Garvey, J., E. Marschall and R. Wright. 1998. From star charts to stoneflies: detecting relationships in continuous bivariate data. Can. J. Fish. Aq. Sci. 64(12):1816-1827.

Gunderson, L and J. Klang.2004.Lower Minnesota River Dissolved Oxygen Total Maximum Daily Load Report. MPCA St. Paul MN May 2004

Hambrook Berkman, J.A. and M.G. Canova. 2007. Algal biomass indicators (ver. 1.0). U.S. Geological Survey Techniques of Water-Resources Investigations book 9, chap. A7, section 7.4, August, available online only from http://pubs.water.usgs.gov/twri9A/.

Heiskary, S. 1993. Lake Pepin Water Quality Goal Setting Section 9. Mississippi River Phosphorus Study. MPCA St. Paul, Minnesota.

Heiskary, S. 2008. Relation of Nutrient Concentrations and Biological Responses in Minnesota Streams: Applications for River Nutrient Criteria Development. Minnesota Pollution Control Agency, St. Paul, MN. 60 p.

Heiskary, S. and H. Markus. 2001. Establishing relationships among nutrient concentrations, phytoplankton abundance, and biochemical oxygen demand in Minnesota, USA rivers. Lake Reserv. Manage. 17(4):251-262.

Heiskary, S. and H. Markus. 2003. Establishing relationships among in-stream nutrient concentrations, phytoplankton abundance and composition, fish IBI and biochemical oxygen demand in Minnesota USA rivers. Minnesota Pollution Control Agency, St. Paul, MN. 100 p.

Heiskary, S. and K. Parson. 2010. Regionalization of Minnesota's rivers for application of river nutrient criteria. Environmental Analysis and Outcomes. MCPA. St. Paul MN.

Heiskary, S., W. Bouchard, Jr. and H. Markus. 2010. Minnesota nutrient criteria development for rivers. Minnesota Pollution Control Agency, St. Paul, MN. 177 p.

Heiskary, S. and W.W. Walker, Jr. 1988. Developing nutrient criteria for Minnesota lakes. Lake and Reserv. Manage. 4:1-9.

Heiskary, S. and D. Wasley. 2011. Lake Pepin Site Specific Eutrophication Criteria. MPCA St. Paul MN

Heiskary, S. and D. Wasley. 2012. Mississippi River Navigational Pool Eutrophication Criteria. MPCA St. Paul MN

Heiskary, Steven. A and William W. Walker, Jr. 1995. "Establishing a Chlorophyll a Goal for a Run-of-the-river Reservoir." Lake and Reservoir Management 11(1): 67-76.

Heiskary, S. and B. Wilson. 2005. Minnesota lake water quality assessment report: Developing nutrient criteria. MPCA St. Paul MN

Heiskary, S. and B. Wilson. 2008. Minnesota's approach to lake nutrient criteria development. Lake Reserv. Manage. 24:282-297.

Hill, J. and G. Devlin. 2003. Associations between biological, habitat, and ambient data in upland western Virginia ecoregions. Virginia Department of Environmental Quality, West Central Regional Office, Roanoke, VA.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution.
Great Lakes Entomol. 20(1):31-39.

Hynes, H.B.N. 1966. The biology of polluted waters. Liverpool University Press, Liverpool, UK. 202 p.

Johnson, B. and K. Hagerty (eds.). 2008. Status and trends of selected resources of the Upper Mississippi River System. A synthesis report of the Long Term Resources Monitoring Program. USGS, Upper Midwest Sciences Center. LaCrosse WI

Karr, J.R. and E.W. Chu. 1999. Restoring life in running waters. Island Press, Washington D.C. 206 p.

Keplinger, Keith, and James Houser, Alex Tanter, Larry Hauck and Larry Beran. 2004. Cost and Affordability of Phosphorus Removal at Small Wastewater Treatment Plants, Small Flows Quarterly, Fall

Koenker, R. and K.F. Hallock. 2001. Quantile Regression. J. Econ. Perspect. 15(4):143–156.

Lemly, A. and R. King. 2000. An insect-bacteria bioindicator for assessing detrimental nutrient enrichment in wetlands. Wetlands. 20(1):91-100.

Lohman, K., J. Jones and B. Perkins. 1992. Effects of nutrient enrichment and flood frequency on periphyton biomass in northern Ozark streams. Can. J. Fish. Aq. Sci. 49(6):1198-1205.

McCollor, S. and S. Heiskary. 1993. Selected water quality characteristics of minimally impacted streams from Minnesota's seven ecoregions. Minnesota Pollution Control Agency, St. Paul, MN.

Miltner, R.J. and E.T. Rankin. 1998. Primary nutrients and the biotic integrity of rivers and streams. Freshwat. Biol. 40:145-158.

Miltner, R.J. 2010. A method and rationale for deriving nutrient criteria for small river and streams in Ohio. Environ. Manage. DOI 10.1007/s00267-010-9439-9.

Minnesota Pollution Control Agency. 1997. Pollutant Trading for Water Quality Improvement: A Policy Evaluation," MPCA, St. Paul, MN.

Odum , E., J. Finn, and E. Franz. 1979. Perturbation theory and the subsidy-stress gradient. Bioscience. 29(6):349352.

Ohio USEPA. 1996. Justification and rationale for revisions to the dissolved oxygen criteria in the Ohio water quality standards. MAS/1995-12-5. Ohio Environmental Protection Agency, Columbus, OH. 25 p.

Rankin, E. 1989. The Qualitative Habitat Evaluation Index [QHEI]: Rationale, methods, and application. Ohio Environmental Protection Agency, Columbus, OH.

Robertson, D., D. Graczyk, P. Garrison, L. Wang, G. Laliberte and R. Bannerman. 2006. Nutrient concentrations and their relations to the biotic integrity of wadeable streams in Wisconsin US Geological Survey, Reston, Virginia.

Sharpley, A., S. Chapra, R. Wedepohl, J. Sims, T. Daniel and K. Reddy. 1994. Managing agricultural phosphorus for protection of surface waters: issues and options. J. Environ. Qual. 23:437-451.

Smith *et al.* 1999. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems.

Smith R., R. Alexander, and G. Schwartz. 2003. Natural background concentrations of nutrients in streams and rivers of the conterminous United States. Environ. Sci. Technol. 37(14):3039-3047

Soballe, D. J. Fischer, L. Hodge-Richardson, T. Clemment. 2002. Limnological monitoring on the Upper Mississippi River system, 1993-1996: Long Term Resource Monitoring Program Onalaska Field Station. USGS Upper Midwest Environmental Sciences Center. La Crosse WI.

Stelzer, R., J. Heffernan and G. Likens. 2003. The influence of dissolved nutrients and particulate organic matter quality on microbial respiration and biomass in a forest stream. Freshwat. Biol. 48(11):1925-1937.

Stevenson, R.J., B.H. Hill, A.T. Herlihy, L.L. Yuan and S.B. Norton. 2008. Algae-P relationships, thresholds, and frequency distributions guide nutrient criteria development. J. N. Am. Benthol. Soc. 27(3):783-799.

Strahler, A. 1957. Quantitative analysis of watershed geomorphology. Trans. Am. Geophys. Union. 38:913–920.

Strand Associates, Inc. 2008. Report for Municipal Environmental Group, Wisconsin – Opinions of Probable Cost for Achieving Lower Effluent Phosphorus Concentrations at Wastewater Treatment Plants in Wisconsin. August 2008.

Sullivan, J. 2010. Mississippi River Water Quality Specialist, Wisconsin Department of Natural Resources, Personal communication to Steve Heiskary, MPCA.

Suplee, M.W., V. Watson, M. Teply and H. McKee. 2008b. How green is too green? Public opinion of what constitutes undesirable algae levels in streams. J. Am. Water Resour. Assoc. 44(6):1-17.

Systat Software. 2008. SigmaPlot for Windows. Chicago, Ill.

Terrell, J., B. Cade, J. Carpenter and J. Thompson. 1996. Modeling stream fish habitat limitations from wedge-shaped patterns of variation in standing stock. Trans. Am. Fish. Soc. 125(1):104-117.

USEPA. 1998. Development of index of biotic integrity expectations for Lake Agassiz Plain ecoregion. US Environmental Protection Agency, Washington D.C.

USEPA. 2000a. Nutrient criteria technical guidance manual. USEPA-822-B-00-002. United States Environmental Protection Agency, Washington, D.C. 152 p.

USEPA. 2000b. Ambient water quality criteria recommendations: Rivers and streams in nutrient ecoregion VII. USEPA-822-B00-0018. USEPA Office of Water, Washington D.C.

USEPA. 2000c. Ambient water quality criteria recommendations: Rivers and streams in nutrient ecoregion VI. USEPA-822-B00-0017. USEPA Office of Water, Washington D.C.

USEPA. 2001. Ambient water quality criteria recommendations: Rivers and streams in nutrient ecoregion V. USEPA 822-B-01-014. U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 2007. USEPA Memo from Geoffrey Grubbs to Water Directors, etc. Nutrient Pollution and Numeric Water Quality Standards, May 25, 2007.

USEPA. 2010a. Water quality standards for the State of Florida's Lakes and Flowing Waters. Accessed at: http://www.regulations.gov/search/Regs/home.html#docketDetail?R=USEPA-HQ-OW-2009-0596

USEPA. 2010b. Using stressor-response relationships to derive numeric nutrient criteria. Off. Sci & Tech. Off of Water. USEPA Washington DC USEPA-820-S-10-001

Van Nieuwenhuyse, E. and J. Jones. 1996. Phosphorus-chlorophyll relationship in temperate streams and its variation with stream catchment area. Can. J. Fish. Aq. Sci. 53(1):99-105.

Walker, J., C. Zipper, L. Shabman and T. Younos. 2006. A Literature Review for Use in Nutrient Criteria Development for Freshwater Streams and Rivers in Virginia. SR28-2006. Virginia Water Resources Research Center, Blacksburg, VA.

Wang L. *et al.* 2003. Watershed, reach, and riparian influences on stream fish assemblages in the Northern Lakes and Forest Ecoregion, USA. Can. J. Fish. Aquat. Sci. 60(5):491-505.

Wang L., D. Robertson, and P. Garrison. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implications to nutrient criteria development. Environ. Manage. 39(2):194-212.

Weigel, B. and D. Robertson. 2007. Identifying biotic integrity and water chemistry relations in nonwadeable rivers of Wisconsin: Toward the development of nutrient criteria. Environ. Manage. 40(4):691-708.

Welch, E., J. Jacoby, R. Horner and M. Seeley. 1988. Nuisance biomass levels of periphytic algae in streams. Hydrobiologia. 157(2):161-168.

Wilson, C. and W. Walker. 1989. Development of lake assessment methods based upon the aquatic ecoregion concept. Lake Reserv. Manage. 5(2):11-22.

Wisconsin DNR. 2010. Chapter NR 102. Water Quality Standards for Wisconsin Surface Waters. Department of Natural Resources. Madison WI.

Wright, H. E., K. Lease and S. Johnson, 1998. Glacial River Warren, Lake Pepin, and the environmental history of southeastern Minnesota. In C.J. Patterson (Ed), Contributions to Quaternary Studies in Minnesota. Minnesota Geological Survey Report of Investigations 49, Minneapolis, MN: 131-140.

Yoder, C. and E. Rankin. 1995. The role of biological criteria in water quality monitoring, assessment and regulation. MAS/1995-1-3. Ohio USEPA. Cleveland OH. 55 p.

10. Exhibit List

EU-1. Minnesota River Nutrient Criteria Development for Rivers. Heiskary, S., W. Bouchard, Jr. and H. Markus. 2010. MPCA

EU-2. Relation of Nutrient Concentrations and Biological Responses in Minnesota Streams: Applications for River Nutrient Criteria Development. Heiskary, S. 2008. MPCA 60 p.

EU-3. Establishing relationships among in-stream nutrient concentrations, phytoplankton abundance and composition, fish IBI and biochemical oxygen demand in Minnesota USA rivers. S. Heiskary and H. Markus. 2003. MPCA. 100 p.

EU-4. Establishing relationships among nutrient concentrations, phytoplankton abundance, and biochemical oxygen demand in Minnesota, USA rivers. S. Heiskary and H. Markus. 2001.
Lake Reserv. Manage. 17(4):251-262.

EU-5. Regionalization of Minnesota's rivers for application of river nutrient criteria. Heiskary, S. and K. Parson. 2010. MCPA.

EU-6. Lake Pepin Site Specific Eutrophication Criteria. Heiskary, S. and D. Wasley. 2011. MPCA

EU-7. Mississippi River Navigational Pool Eutrophication Criteria. Heiskary, S. and D. Wasley. 2012. MPCA

EU-8. Phosphorus Strategy Task Force Report. Water Quality Division. MPCA. June 1996.

EU-9. USEPA National Strategy for the Development of Regional Nutrient Criteria.
USEPA 822 R-98-002. 1998.

EU-10. USEPA Rivers and Streams in Nutrient Ecoregion VI, NGP, WCBP, and LAP.
USEPA 822 B-00-017. 2000

EU-11. USEPA Rivers and Streams in Nutrient Ecoregion VII, CHF, and DA.
USEPA 822 B-00-018. 2000

EU-12. USEPA Rivers and Streams in Nutrient Ecoregion VIII, NLF, and NMW.
USEPA 822 B-01-015. 2001

EU-13. USEPA Fact sheet, Ecoregional Nutrient Criteria, December 2001

EU-14. USEPA Nutrient Criteria Technical Guidance Manual, Rivers and Streams.
USEPA-822-B00-000. 2000.

EU-15. USEPA Memo from Benjamin Grumbles to Water Directors, etc. Nutrient Pollution and Numeric Water Quality Standards, May 25, 2007.

EU-16. USEPA Policy as it Relates to the Phosphorus Objectives for the Nation's Receiving Waters.
April 20, 1973 USEPA Region V letter to MPCA.

EU-17. State Adoption of Numeric Standards (1998-2008) USEPA-821-F-08-007

EU-18. Science Advisory Board Recommendations to USEPA on river nutrient criteria guidance. Final draft April 2010.

EU-19a Water Quality Standards for the State of Florida's Lakes and Flowing Waters.
October 2010 (USEPA 2010a).

EU-19b Technical support Document for UEPA's Proposed Numeric Nutrient Criteria for FL Inland Surface Fresh Waters (USEPA 2010b)

EU-20. Using Stressor-response Relationships to Derive Numeric Nutrient Criteria
November 2010 (USEPA 2010b).

EU-21a. USEPA approval of MPCA 2003 Nutrient Criteria Development Plan: 2003. May 5, 2003 Jo Lynn Traub USEPA R5 Water Division letter to Mike Sandusky.

EU-21b. Minnesota's Plan for Development of Nutrient Criteria: 2008 update to USEPA R 5 (July 2008)

EU-21c. USEPA R5 approval of MPCA 2008 Nutrient Criteria Development Plan Update. Timothy Henry, Acting Director Water Quality Division letter to Mike Sandusky August 22, 2008.

EU-22a. USEPA Headquarters review of "Minnesota Nutrient Criteria Development for Rivers."
Draft October 21, 2009. by Dr. Walter Dodds, December 14, 2009 for USEPA.

EU-22b. MPCA response to Dr. Walter Dodds comments: June 21, 2010.

EU-23a. USEPA Headquarters review of “Minnesota Nutrient Criteria Development for Rivers.” Draft October 21, 2009. by Dr. Michael Paul, February 9, 2010 for USEPA.

EU-23b. MPCA response to Dr. Michael Paul comments: June 7, 2010

EU-24a. USEPA Headquarters review of “Minnesota Nutrient Criteria Development for Rivers.” Draft October 21, 2009. by Dr. Jan Stevenson, February 22, 2010 for USEPA.

EU-24b. MPCA response to Dr. Jan Stevenson comments: June 21, 2010

EU-25. A Method and Rationale for Deriving Nutrient Criteria for Small Rivers and Streams in Ohio. Miltner, R.J. 2010. Environ. Manage. 45:842-855.

EU-26. Criteria for control of nutrient enrichment in streams. Ohio USEPA working draft submitted to USUSEPA Region 5: November 4, 2010.

EU-27. Phosphorus water quality standards for Wisconsin rivers, streams, various types of lakes, reservoirs, and Great Lakes; as included in WI Chapter NR 102 (WDNR November 2010)

EU-28. USEPA Nutrient Criteria Technical Guidance Manual, Lakes and Reservoirs. USEPA-822-B00-001. 2000.

EU-29. Announcement for presentation draft river eutrophication criteria at National Park Service Mississippi River Forum: October 15, 2010. Lark Weller, MNRAA Water Quality Coordinator, NPS

EU-30. Selected water quality characteristics of minimally impacted streams from Minnesota’s seven ecoregions. S. McCollor and S. Heiskary.1993. MPCA, St. Paul MN

EU-31. Minn. R. Ch. 7050

EU-32. MPCA TMDL guidance “Lake Nutrient TMDL Protocols and Submittal Requirements”

EU-33. Dubrovsky, N. and P. Hamilton. 2010. Nutrients in the Nation's streams and groundwater: National Findings and Implications: U.S. Geological Survey Fact Sheet 2010-3078, 6p.

EU-34. Minnesota's Water Quality Monitoring Strategy 2004 to 2014: A Report prepared for the U.S. Environmental Protection Agency. August 2004

EU-35. Total Suspended Solids-Submersed Aquatic Vegetation Site-Specific Standard South Metro Mississippi River Public Notice Draft January 2010. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/lower-mississippi-river-basin-tmdl-projects/project-south-metro-mississippi-turbidity.html

EU-36. Hambrook-Berkman, J. and M. Canova. 2007. Ch. 7.4 Algal Biomass Indicators. U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A7, section 7.1, February, accessed Feb. 11, 2011 from http://pubs.water.usgs.gov/twri9A7/

EU-37. Minnesota Water Sustainability Framework. 2011. Developed by University of Minnesota Water Resources Center. http://wrc.umn.edu/watersustainabilityframework/index.htm

EU-38. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. 2004. A Legislative Report developed by Barr Engineering for MPCA. http://www.pca.state.mn.us/index.php/about-mpca/legislative-issues/legislative-reports/detailed-assessment-of-phosphorus-sources-to-minnesota-watersheds-2004-legislative-report.html?menuid=&redirect=1

EU-39. MCEA submittal requesting promulgation of river nutrient standards in 2007-2008 triennial rule revision.

EU-40. Mallin, M, V. Johnson, S. Ensign, and T. Macpherson. 2006 Factors contributing to hypoxia in rivers, lakes and streams. Limnol. Oceangr. 51 (1, Part 2): 690-701.

EU-41a. Cost estimates for municipal facilities using chemical phosphorus removal to meet a 1 mg/L effluent limit. Memo to Steve Heiskary, EAO Division MPCA. From Randy Thorson Municipal Division. MPCA August 4, 2011.

EU-41b. Cost estimates for municipal stabilization pond facilities using chemical phosphorus removal to meet a 1 mg/L effluent limit. Memo to Steve Heiskary, EAO Division MPCA. From Randy Thorson Municipal Division. MPCA August 16, 2011.

EU-41c. Cost estimates for municipal facilities with design flows from 0.2 MGD to 315 MGD using chemical phosphorus removal to meet a 0.8 mg/L or 0.1 mg/L effluent limit. Memo to Steve Heiskary, EAO Division MPCA. From Randy Thorson Municipal Division. MPCA October 28, 2011.

EU-41d. Municipal stabilization pond facilities using chemical phosphorus removal to meet a 0.15 mg/L or 0.1 mg/L effluent limit. Memo to Steve Heiskary, EAO Division MPCA. From Randy Thorson Municipal Division. MPCA November 21, 2011.

EU-42. Potential Cost to Industrial Point Source Dischargers Attributed to Adoption of a 0.1 mg Total Phosphorus (TP) per Liter Water Quality Standard. Scott Knowles, MPCA.

EU-43. Coordination of Minnesota and Wisconsin phosphorus standard: Lake Pepin.
11-3661 - 87th Legislative Session (2011-2012), Sec. 31

EU-44. Dr. Lester Yuan, USEPA, May 5, 2011 e-mail communication to Steve Heiskary

EU-45. Implementation of river nutrient standards. November 2011. Dennis Wasley and Steve Weiss, EAO, MPCA.

EU-46. Phosphorus decision tree and narrative. March 2010. Dennis Wasley, EAO, MPCA

EU-47. A Science Framework for Developing Long-term, Ecologically Sensitive Nutrient Objectives for Lake Winnipeg and its Tributaries. A draft for discussion at the November 2010 Nutrient Objectives Workshop. Manitoba Water Stewardship and Environment Canada. October 27, 2010 (draft).

EU-48a. Nutrient Criteria for Surface Waters in Maine. 06-096 Chapter 583. Maine Department of Environmental Protection (DEP). November 2011

EU-48b. USEPA Region 1 Response to Maine DEP Rule 06-096 Chapter 583

EU-49. USEPA Region V Letter to Illinois EPA. January 21, 2011

EU-50. Krysel et al. 2003. Lakeshore property values and water quality: evidence from property sales in the Mississippi Headwaters Region. Submitted to the Legislative Commission on Minnesota Resources.

EU-51a. State of Florida Chapter 62-302. Surface Water Quality Standards. 2011.
Florida Department of Environmental Protection. Approved for adoption by Environmental Regulation Commission. December 8, 2011.

EU-51b. Chapter 62-303. Identification of Impaired Surface Waters. Parts 62-303.150-62-303.720.
Florida Department of Environmental Protection. 2011.

EU-52a. Assessment Methodology for Determining Wadeable Stream Impairment Due to Excess Nitrogen and Phosphorus Levels. Appendix B & C. Montana Department of Environmental Quality. December 2011.

EU-52b Water Quality Assessment Method. Montana Department of Environmental Quality.
November 28, 2011

EU-53. Statement of Need and Reasonableness. Book II of III. In the Matter of the Proposed Revisions of Minn. R ch 7050 Relating to the Classification and Standards for the Waters of the State. The Proposed Addition of a New Rule Minn. R ch.7053, Relating to Point and Nonpoint Source Treatment Requirements. MPCA, 2007.

EU-54. The Lake City Graphic, “City doing something about stagnant water” June 30, 1988 and “Aerators making harbor sweeter” July 7, 1988.

EU-55. Total phosphorus concentrations in lakes and their inflows: a review of approved Minnesota lake nutrient TMDLs. Memorandum to Steve Heiskary Environmental Analysis and Outcomes Division.
From: John Erdmann, Metro Watershed, Regional Division, MPCA. October 8, 2012.

EU-55. Total phosphorus concentrations in lakes and their inflows: a review of approved Minnesota lake nutrient TMDLs. Memorandum to Steve Heiskary Environmental Analysis and Outcomes Division.
From: John Erdmann, Metro Watershed, Regional Division, MPCA. October 8, 2012.

EU-56. Angradi, T. 2013. An exploratory analysis of Indiana and Illinois biotic assemblage data in support of state nutrient criteria development. USEPA ORD Duluth MN, January 24, 2013.

EU-57. Engineering News Record (ENR). Cost Indexes, page 19. December 6, 2010.

EU-58. CH2MHILL. Final Report: Statewide Nutrient Removal Cost Impact Study.
Prepared for Utah Division of Water Quality. October 2010.

EU-59. Strand Associates, Inc. Report for Municipal Environmental Group, Wisconsin – Opinions of Probable Cost for Achieving Lower Effluent Phosphorus Concentrations at Wastewater Treatment Plants in Wisconsin. August 2008.

EU-60. Faeth, Paul . 2000. Fertile Ground: Nutrient Trading's Potential to Cost-Effectively Improve Water Quality, World Resources Institute, Washington D.C.

EU-61. Keplinger, K., J. Houser, A. Tanter, L. Hauck and L. Beran. 2004. Cost and Affordability of Phosphorus Removal at Small Wastewater Treatment Plants, Small Flows Quarterly, Fall: 36-49.