

# Twenty years of lake nutrient impairment Delistings in Minnesota

Jeff Strom, Amy Timm, Jesse Anderson, and Scott MacLean

According to Minnesota's 2024 inventory of impaired waters, a total of 64 nutrient impaired lakes have been removed ("delisted") from Minnesota's 303(d) [list of impaired waters](#). The first delisting of a nutrient impaired lake in Minnesota occurred 20 years ago, in 2004. This article provides an opportunity to reflect on these successes by providing a brief overview of Minnesota's lake assessment and delisting process, a discussion of some common characteristics of Minnesota's delisted lakes, and the management activities that led to the delistings. Finally, we conclude with a summary of the lessons learned and a look ahead at the future of lake management and delistings in Minnesota.

## Assessment and delisting process

Minnesota's lake eutrophication standards were enacted in 2008, after decades of research and monitoring (summarized in [Heiskary and Wilson, LRM 2008](#)). Minnesota was one of the first states with Environmental Protection Agency (EPA) approved lake nutrient criteria, stratified by ecoregion. From 2002-2022, the Minnesota Pollution Control Agency (MPCA) used these standards to assess approximately 3,500 of the state's 12,000 lake basins greater than ten acres. About 700 (20 percent) of the assessed lakes are impaired by nutrients.

### [A lake nutrient assessment requires:](#)

- Data from a minimum of two years during the past 10 years
- At least eight paired total phosphorus (TP), chlorophyll-a (chl-a), and Secchi transparency measurements collected from June through September.

A lake is considered impaired when mean TP and at least one response variable

(mean chl-a or Secchi transparency) exceeds their respective standards. Once a lake is impaired, additional studies and plans are developed through [Minnesota's Watershed Approach](#) to help guide implementation. A [Total Maximum Daily Load \(TMDL\)](#) study determines the assimilative capacity of the waterbody, and estimates the impairment sources and the reductions needed to meet standards. In Minnesota, approximately 600 lake TMDLs have been completed to address nutrient impairments. Watershed Restoration and Protection Strategy (WRAPS) reports identify high-level strategies to improve water quality at a watershed (HUC 8) level and are completed in conjunction with TMDL reports. Finally, comprehensive local water management plans created through the [One Watershed One Plan](#) and [seven-county metropolitan area surface water management](#) frameworks that identify waterbodies that will be prioritized for focused restoration activities.

The following data and information are needed for a lake to be considered for delisting:

- A minimum of two years of data after the impairment designation date.
- At least eight paired TP, chl-a, and Secchi measurements collected from June through September.
- Mean TP and at least one response variable (chl-a or Secchi transparency) meets the standard.

MPCA consults with local water resource managers to

review restoration practices. The delisting is categorized as due to either "restoration activities" or "unknown reasons" based on this discussion. Of the 64 delisted lakes, 45 lakes (70 percent) have been delisted due to restoration activities, 15 (24 percent) due to unknown reasons, and 4 (6 percent) due to new data and/or the adoption of a new standard. The unknown reasons designation is typically assigned to lakes that have experienced environmental factors (e.g., aquatic invasive species (AIS), fish kills, climate influences) and delistings could not be conclusively tied to restoration activities based on the 'Best Professional Judgement' (BPJ) of MPCA's delisting review team.

## Overview of Minnesota's delisted lakes

Figure 1 provides the location of lake delistings throughout the state. A majority

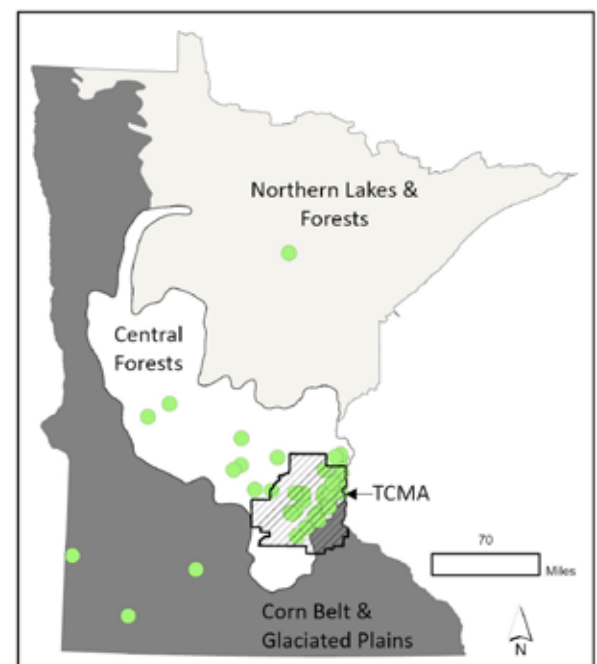


Figure 1. Map of Minnesota's delisted lakes (solid green circles) in relation to ecoregions and the Twin Cities Metro Area (TCMA).

of Minnesota’s delisted lakes are located within the North Central Hardwood Forest (NCHF) Ecoregion and within the Minneapolis-St. Paul Twin Cities Metropolitan Area (TCMA; Table 1). To date, only 27 percent of the lakes delisted due to restoration activities and unknown reasons are outside the TCMA.

Additionally, most of the delisted lakes (83 percent) are located within the jurisdictional boundary of a [Watershed Management District or Organization](#).

These governing entities can levy taxes to finance projects aimed at managing and improving the surface waters within a watershed. The groups are governed by elected and/or appointed board members

from units of government (i.e., counties, municipalities) with land in the watershed.

As shown in Figure 2, the number of delistings in Minnesota has increased in recent years. Of the 64 lakes delisted to date, approximately half occurred in the last two assessment cycles (2022 and 2024). All the delisted lakes were originally assessed as impaired prior to 2015 and a majority (~80 percent) were added to the impaired waters list between 2002 and 2008. Thus, many delisted lakes were among the earliest lake impairment listings and, as a result, some of the first lakes to receive TMDL studies. The average time between impairment listing and delisting for Minnesota’s delisted lakes

has been about 13 years. However, most of the lakes exhibited degraded water quality conditions for several years or even decades before their original impairment listing, and therefore this number does not reflect the true amount of time the lakes were impaired. For many of the impaired lakes the process of listing the waters and developing TMDLs and WRAPS helped kickstart restoration activities that led to their delisting.

Table 1 presents analysis of several common lake and watershed characteristics for lakes delisted due to restoration activities and unknown reasons. Some of the trends and key takeaways of this analysis are:

**Table 1.** Characteristics and features for Minnesota lakes delisted due to restoration activities and unknown reasons.

Category	Lake feature/attribute	Description	Lake count	Percent of total
Location	Ecoregion <sup>1</sup>	NCHF	57	95 percent
		WCBP & NGP	3	5 percent
		NLF	--	0 percent
	Twin Cities Metro Area (TCMA) <sup>2</sup>	within TCMA	44	73 percent
		outside TCMA	16	27 percent
	Watershed Management Authority	yes	50	83 percent
no		10	17 percent	
Lake characteristics	Lake type	shallow/mixed <sup>3</sup>	35	58 percent
		deep/stratified	25	42 percent
	Lake size (acres)	<100	37	62 percent
		100 – 500	18	30 percent
>500		5	8 percent	
Watershed characteristics	Watershed size (acres)	<5,000	46	77 percent
		5,000 – 10,000	8	13 percent
		>10,000	6	10 percent
	Watershed-to-lake area ratio	<10	25	42 percent
		10 – 25	18	30 percent
		25 – 50	8	13 percent
>50		9	15 percent	
Water quality for NCHF ecoregion lakes (N=57)	Mean listing period TP for shallow/mixed lakes <sup>3</sup> (Standard: <60 µg/L)	<90	20	62 percent
		90 – 120	7	22 percent
		>120	5	16 percent
	Mean listing period TP for deep/stratified lakes (Standard: <40 µg/L)	<60	20	80 percent
		60 – 80	3	12 percent
		>80	2	8 percent

1. NCHF = north central hardwood forest; WCBP = western cornbelt plains; NGP = northern glaciated plains; NLF = northern lakes and forest

2. TCMA = 7-county Twin Cities Metropolitan Area which includes Anoka, Ramsey, Washington, Dakota, Scott, Carver, and Hennepin Counties

3. Shallow/mixed lakes are typically defined as having a maximum depth of less than 15 feet and a littoral area greater than 80 percent of the total surface area of the lake

- Slightly more of the lakes are shallow/mixed (58 percent) compared to deep/stratified (42 percent).
- Most of the lakes (92 percent) have surface areas less than 500 acres and a majority (62 percent) are less than 100 acres.
- Approximately 77 percent of the lakes have relatively small drainage areas - less than 5,000 acres.
- Watershed to lake area ratios for 58 percent of delisted lakes are greater than 10 to 1 indicating a mix of surface water and groundwater dominance (Minnesota DNR 2022).
- In general, mean listing period TP concentrations were not far (i.e., within a factor of two) from meeting state standards for shallow/mixed lakes (60 µg/L) and deep/stratified lakes (40 µg/L) in the NCHF ecoregion.

### Management strategies contributing to Minnesota's lake delistings

With the high cost of implementing Best Management Practices (BMPs), it is important to have funding available to partners who are doing the work. In Minnesota, having a completed TMDL study, WRAPS report, and comprehensive management plan can lead to increased opportunities for local, state, and federal funding and grant programs. Minnesota's reported spending on implementation projects to support clean water has more than doubled over the past two decades from just under \$200 million per year in the early 2000s to around \$400 million per year in the early 2020s (source: [Clean Water Fund](#) and [MPCA Healthier Watersheds website](#)). Local partners can leverage water quality implementation programs to help fund management efforts that lead to better water quality and delistings. Detailed information on the total cost of BMPs were typically not submitted by local partners during the delisting process, but a further review of this information could be helpful for water resource managers.

We reviewed all the lake delisting submittals received by MPCA over the past 20 years and grouped the reported management activities into one of two general categories (external/watershed

strategies and internal strategies). Figures 3 and 4 show a breakdown of ten specific management strategy subcategories and the

number of lakes that implemented each strategy. While these categories and subcategories are rather broad, they do

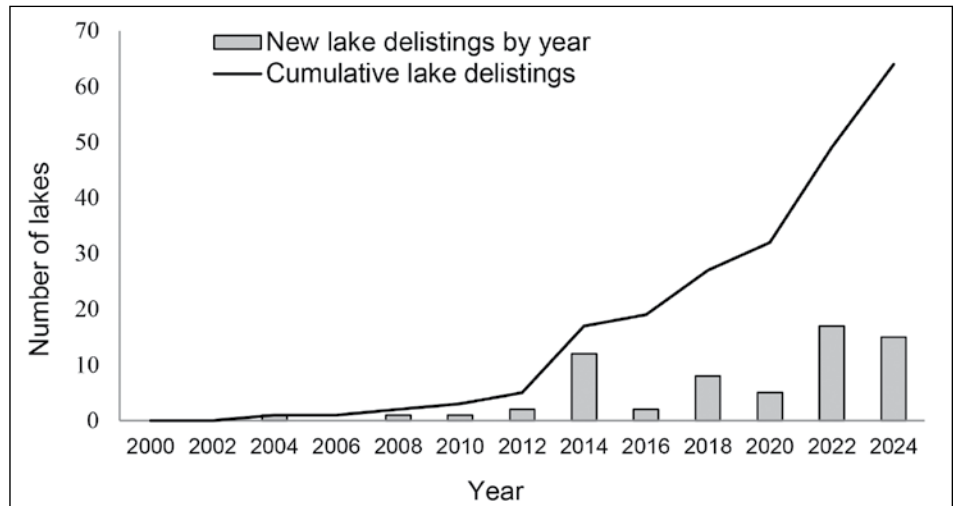


Figure 2. Minnesota lake delistings by year. Minnesota lake assessments and delistings are typically reported to the EPA bi-annually.

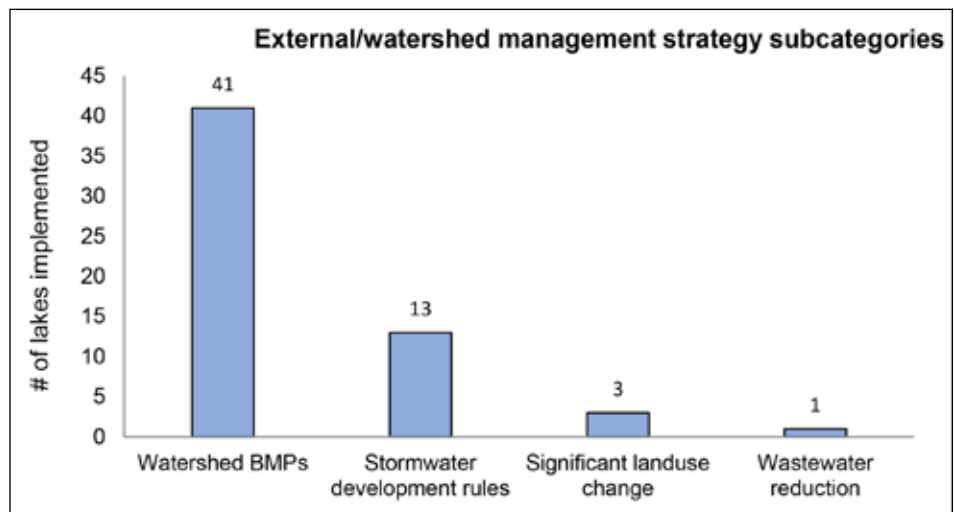


Figure 3. Types of external/watershed management strategies implemented for lakes delisted due to restoration activities.

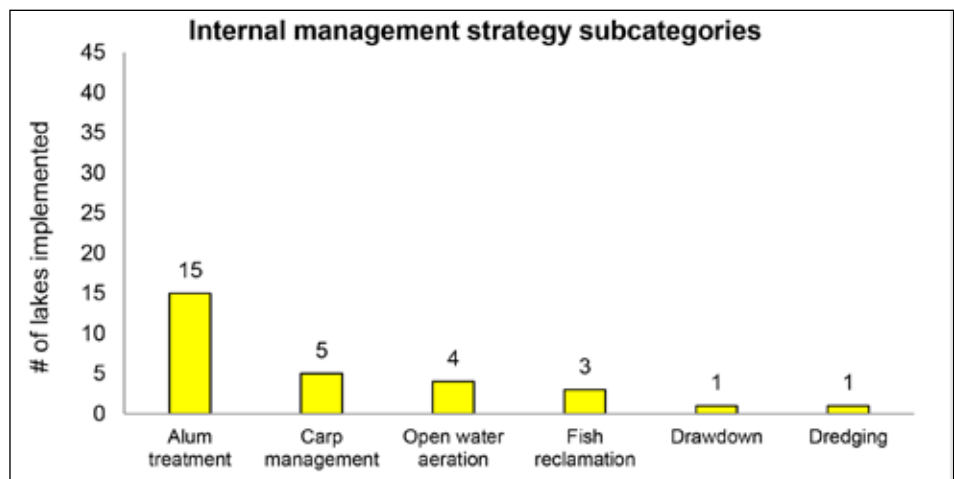


Figure 4. Types of internal management strategies implemented for lakes delisted due to restoration activities.

allow us to evaluate what specific strategy, or combination of strategies, have been most effective for delisting lakes. Common BMPs cited include:

- Urban watershed BMPs - raingarden and bioretention basins, stormwater ponds, shoreline stabilizations and restorations, increased street sweeping, iron enhanced sand filters, stormwater development rules, and wetland restorations and enhancements
- Agricultural watershed BMPs - cattle exclusion, feedlot runoff improvements, improved manure management, septic system upgrades, water and sediment control basins, grassed waterways, reduced tillage, wetland restorations, critical area plantings, and shoreline and streambank restorations
- Internal BMPs – aluminum sulfate (alum) treatments, carp management, open water aeration, and fish reclamation (i.e., rotenone treatment)

Watershed BMPs (both urban and agricultural) were by far the most common strategy subcategory implemented and were noted in 41 of the 45 lakes delisted due to restoration activities. Internal strategies were used on 23 of the 45 lakes (Figure 5). There were only three instances in which internal management was the only strategy cited by local partners. All three of these lakes have very small drainage areas and watershed-to-lake area ratios less than

five to one. In general, the 15 delisted lakes treated with alum showed an immediate improvement in water quality conditions, often helping push the lake to meet water quality standards. A similar response was noted in some of the lakes in which biomanipulation techniques (i.e., carp management and fish reclamation) were used, particularly in shallow lakes with small drainage areas. In most cases (20 of 23 lakes), the local partners indicated that internal management strategies followed and/or were paired with a thorough investigation of external loading sources and implementation of watershed BMPs to reduce nutrient loads entering the lake.

### Lessons learned

Over the last five to ten years, Minnesota has experienced an encouraging upward trend in lake impairment delistings. While it's important to celebrate this achievement, it's also important to reflect on the management efforts that made this possible and share stories with others that are working to improve water quality in their lakes. Below is a summary of the key themes and lessons learned from 20 years of lake delistings in Minnesota.

- Many of Minnesota's delisting successes have been urban and suburban lakes in the TCMA with smaller drainage areas that were relatively close to meeting water quality standards when they were placed on the impaired waters list.
- External/watershed management strategies were implemented in 93

percent of the lakes delisted due to restoration activities and were a critical component of the restoration process.

- Internal management strategies were applied in 51 percent of the lakes delisted due to restoration activities and, with the exception of a few lakes, were paired with external/watershed BMPs.
- There were no "quick fixes" or "silver bullets" to improving water quality. In most cases, multiple BMPs and strategies were needed for delisting.
- All of Minnesota's delistings took several years, and in most cases over a decade, to achieve the necessary nutrient reductions to meet water quality standards.
- Strategic planning, significant funding from multiple sources, and strong partnerships between citizen groups, local units of government, and state agencies were needed to make it all happen.
- In Minnesota, the assessment, TMDL, and delisting process serves as a helpful tool to identify problems, establish nutrient reduction goals, and kickstart restoration efforts.

### Looking ahead

For a positive delisting trend to continue, significant improvements will need to be made to some of the state's more challenging impairments (e.g., bigger lakes, lakes with large drainage areas, and lakes in rural/agricultural settings—as exhibited by Lake Shaokatan (see Perleberg et al., 2023)). It is also important to continue to prioritize protection of high-quality waters (i.e., non-impaired lakes) due to the effort and cost of restoring waterbodies after they've become impaired. Finally, as threats to waterbodies increase (e.g., AIS, climate change, new emerging contaminants) collaboration amongst water managers and agencies will continue to be important to collect data and develop the tools and resources needed to assess and manage these threats. Fortunately, Minnesota has a long history of supporting state and local agencies with funding to monitor, assess, restore, and protect the state's abundant and diverse

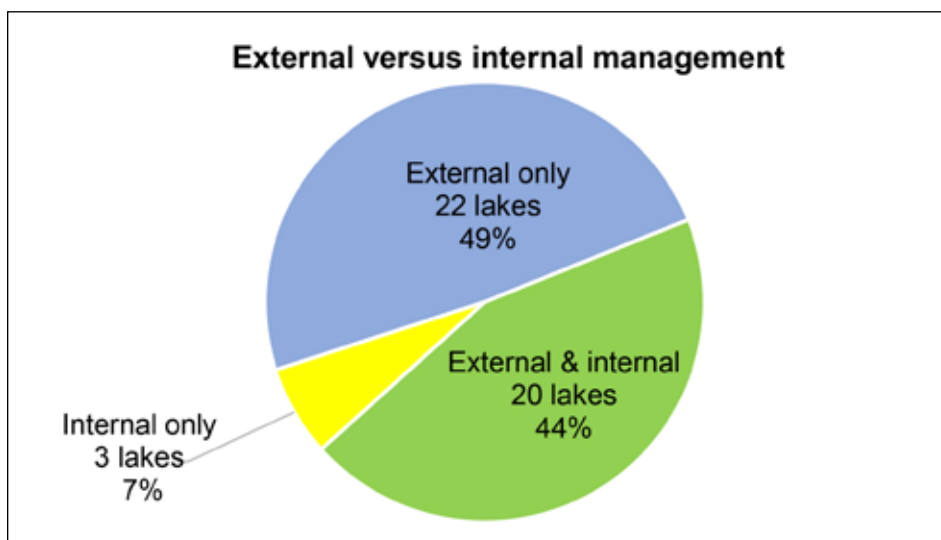


Figure 5. External versus internal management strategies applied in the 45 Minnesota lakes delisted due to restoration activities.

lake resources. We are proud of our accomplishments but recognize the hard work of lake management is on-going and evolving.

## References

Heiskary, S., & Wilson, B. 2008.

Minnesota's approach to lake nutrient criteria development. *Lake and Reservoir Management*, 24(3), 282-297. Minnesota Department of Natural Resources (DNR). 2022. Minnesota DNR Hydrology Standard Deliverables for Watershed Planning. [https://resources.gisdata.mn.gov/pub/gdrs/data/pub/us\\_mn\\_state\\_dnr/env\\_lake\\_hydrology/metadata/Minnesota%20DNR%20Lake%20Hydrology%20Standard%20Deliverables%20for%20Watershed%20Planning.pdf](https://resources.gisdata.mn.gov/pub/gdrs/data/pub/us_mn_state_dnr/env_lake_hydrology/metadata/Minnesota%20DNR%20Lake%20Hydrology%20Standard%20Deliverables%20for%20Watershed%20Planning.pdf)

Perleberg, D.J., J.P. Anderson, and A.R. Streitz. 2023. The recovery of a shallow lake within an agricultural landscape of Minnesota – in interdisciplinary approach to understanding change. *Lake and Reservoir Management*, 39(4), 311

**Jeff Strom** is a TMDL Writer and Lakes and Eutrophication Expert in MPCA's Watershed Analysis and Modeling Unit (Watershed Division). Jeff has over 15 years of public and private sector



experience in surface water monitoring, assessment, and management. His primary roles at MPCA include interpretation of surface water quality data, lake eutrophication modeling, studying pollutant sources and transport, authoring TMDL and lake protection reports, and assisting in collaborative efforts with other state and federal agencies. [jeff.strom@state.mn.us](mailto:jeff.strom@state.mn.us)

**Amy Timm** is a Watershed Project Manager with the MPCA in St. Paul, MN. Amy has 14 years of experience in monitoring, assessment, nutrient modeling, and management of lakes and watersheds. Her role



is to work with the various watershed partners to create TMDLs, WRAPS, review water plans, and aid partners. [amy.timm@state.mn.us](mailto:amy.timm@state.mn.us)

**Jesse Anderson** is a Research Scientist with the Minnesota Pollution Control Agency in Duluth, Minnesota. For over 25 years he has worked in surface water quality monitoring, assessment, research, and TMDLs. He is an active member of NALMS and an Associate Editor for *Lake and Reservoir Management*. He can be contacted at [jesse.anderson@state.mn.us](mailto:jesse.anderson@state.mn.us)



**Scott MacLean** is a Watershed Unit Supervisor with the Minnesota Pollution Control Agency in Mankato, Minnesota. Scott has over 20 years of experience working for local units of government and the State of Minnesota in surface water quality monitoring, data analyses, BMP implementation, TMDLs, and WRAPS. Scott currently supervises eight staff in Southwest Minnesota who perform stressor identification on biological impairments, develop WRAPS and TMDLs, and work closely with local partners to protect and restore Minnesota's water resources. [scott.maclean@state.mn.us](mailto:scott.maclean@state.mn.us)



*(Upcoming issues, continued from p. 4 . . .)*

related to this subject, consider submitting a draft to *LakeLine* for possible inclusion in the fall issue.

**Draft articles for the fall issue of *LakeLine* are due by September 15, 2024, for publication in October 2024.**

Please contact Amy Smagula, *LakeLine* Editor, with any questions, or to propose an article for one of the above-listed themes.

Do you have a topic that doesn't match a theme? That's ok, we can include the article in any of these issues, or use it to build a themed issue.

Amy can be reached at [lakeline@nalms.org](mailto:lakeline@nalms.org)

**In-Situ** | water simplified.

## Stay on Top of HABs

Multiparameter water quality instruments, easy-to-use telemetry and our lightweight Rugged Buoy combine for a cost-effective HAB monitoring system you can count on.

[in-situ.com/sw-habs](http://in-situ.com/sw-habs)

