Clean Water Council Meeting Agenda
Monday, November 16, 2026
9:00 a.m. to 2:00 p.m.

IN PERSON at MPCA offices in St. Paul with Webex Available (Hybrid Meeting)
****Please allow at least 15 extra minutes to travel due to construction in the area****

9:00 Regular Clean Water Council Business

- **(INFORMATION ITEM)** Council member introductions—please declare any perceived or actual conflict of interest
- **(ACTION ITEM)** Agenda and Minutes - comments/additions and approve agenda
- **(INFORMATION ITEM**) Council updates
  - Council Chair
  - Budget and Outcomes Committee Chair
  - Policy Committee Chair
  - Council staff

9:30 (INFORMATION ITEM) General public comment
Any member of the public wishing to address the Council regarding something not on the agenda is invited to do so as a part of this agenda item.

9:45 (ACTION ITEM) Approve Chloride Deicers Policy Statement
The Policy Committee finalized the draft Chloride Deicers Policy Statement at their October meeting. It is ready for Council approval and inclusion in the biennial recommendations report.

10:00 (ACTION ITEM) Scenario plans for responding to the November budget forecast
The Budget and Outcomes Committee (BOC) will present an updated approach for how to respond to the November budget forecast. Council members are asked to affirm this approach so that the BOC can act accordingly and quickly after the forecast is released.

10:15 (DISCUSSION ITEM) Review of last month, discussion of homework
Last month, we began a two-month arc of review of outcomes—what we mean, what we're looking for, what we track, where it is reported, and what gaps may need to be filled. October focused on setting the stage and showcasing more of the *outputs* and *short-term* outcomes, and homework invited Council members to review more regarding each and look at some of the *long-term* outcomes. Before discussing *intermediate* outcomes, we will take some time for reactions to the content so far and review questions surfaced earlier.

10:30 BREAK

10:45 (INFORMATION AND DISCUSSION ITEMS) Intermediate outcomes from the Clean Water Fund
Rounding out the discussion of outputs and outcomes are three presentations that show some of the work happening now to demonstrate how investment over the last 15 years is producing water quality benefits. These fall into the intermediate or mid-term outcomes category, at a scale between the project level and major river basins.

(Agenda continues on the next page)

Has Minnesota's Legacy Amendment improved lake water quality?
Speakers: Paul Radomski (DNR), Henry Van Offelen (BWSR)
DNR and BWSR staff set out to answer an important question: Is there evidence that the Clean Water Fund investments have made a difference to lake water clarity? Their study shows promising and compelling results, and includes recommendations for how to further accelerate water quality improvements.

Index of Biological Integrity (IBI) scores as an indicator of water quality improvements accelerated by Clean Water Fund investments
Speakers: Glenn Skuta (MPCA)
Using changes in fish and macroinvertebrate IBI scores to illustrate the case, MPCA staff will present on the relationship between outputs and outcomes at the major watershed scale. While the improvements reflect a variety of influences on watershed health, the changes between the first and second 10-year monitoring cycle demonstrate how Clean Water Fund investments are helping to accelerate progress towards the state's clean water goals.

North Dakota State University: Water Quality Trends and Cost-Effective Analysis of Conservation Practices in Minnesota
Speakers: Professor Zhulu Lin, Ashley Crowl
Since 2009, Minnesota has invested substantial resources in conservation practices aimed at reducing nutrient and sediment losses from agricultural lands in an effort to improve water quality. A North Dakota State University study evaluated water quality trends and their relationships to conservation expenditures in 38 headwater HUC-8 watersheds from 2007-2021, finding that conservation spending demonstrated moderate correlations with improvements, indicating that investments are contributing to measurable water quality gains.

12:00 LUNCH

12:30 (DISCUSSION AND INTERACTIVE ITEM) MMB Long-Range Planning: MN 2100 Water Futures
Speakers: Helen Schnoes, Carrie Christensen
Staff from the Long-Range Planning (LRP) team at Minnesota Management and Budget will join the Council for a presentation and discussion about a new water project, MN 2100 Water Futures—an imaginative effort to help Minnesota navigate uncertainty over the coming decades. Built in partnership with water leaders across the State government, this project will launch in 2027 and conclude in 2028with the goal of informing actionable insights for state agencies, local communities, and partners. Council members will participate in a scenario planning exercise as part of this agenda item.

1:45 Wrap up, next steps

2:00 Adjourn *(Steering Committee meets directly after adjournment)*

Executive Summary

When Minnesotans voted for the Clean Water Land and Legacy Amendment in 2008, they did so to protect, restore, and enhance the state's surface water, groundwater, and drinking water. At the time, little was known about the vast majority of waters in the state, and funding to protect and restore waters was largely not there. What was known was that Minnesota was falling behind in tackling its impaired waters challenge, with consequences for communities, the economy, and the environment alike.

Today, as a result of investments provided by the Clean Water Fund, Minnesota now has a wealth of information to understand current conditions and trends, determine how to address issues in scientifically-informed and locally-prioritized ways, and then support local partners to get the work done. In fact, more than two thirds of the Clean Water Funds recommended for the next biennium are for implementation.

And we're seeing that work pay off. Local partnerships are targeting and prioritizing what to work on together. A record number of waters are being delisted from the impaired waters list. High-quality waters remain high-quality, or become further protected from degradation. We're at a point now where implementation and policy actions are truly capitalizing on the research, monitoring, analysis, and planning that has set the foundation for accelerated progress towards the state's clean water goals.

The FY28-29 policy and budget recommendations included in this report will continue that progress, even as water quality challenges remain. In addition to continuing many valuable programs, the Council would like to highlight these major milestones that will be met during the FY28-29 biennium:

- Funding for all 60 watershed partnerships developed through One Watershed, One Plan to implement targeted, high-priority items to restore lakes, rivers, streams, and groundwater in every corner of the state
- Completion of the second-ever round of statewide water quality monitoring to support science-based approaches to clean water and measure positive or negative changes
- Completion of plans designed to protect drinking water sources for all 968 community systems in the state, detailing actions needed to safeguard drinking water at the local level

- Completion of Groundwater Restoration and Protection Strategies for every watershed in the state, informing actions to protect and restore groundwater quality and quantity

Minnesota is fortunate to have made these investments, and their value will continue to be returned to residents and visitors in the years ahead through strategic action on the landscape.

The Council would like to also highlight the following from their funding and policy recommendations:

- Millions more in funding for programs in agricultural watersheds, supporting farmers in adopting changes to their fields, operations, and equipment that improve water quality outcomes
- An expansion of funding for easement programs to permanently protect lands and waters, acknowledging that protection is far cheaper than restoration
- A new program to protect and restore natural shorelines, which are disappearing across the state and play a critical role in maintaining and improving water quality
- A new program to improve water quality outcomes from fields where producers use manure to add nitrogen to soil
- Updates to strategies and identified stressors for 18 watersheds, as well as focused TMDL reports with similar strategies to address 129 non-mercury impairments and 81 mercury impairments
- Hosting of We Are Water in 10 communities across the state, deepening connections and relationships between people and water
- Continuation of increased emphasis on drinking water and groundwater, in southeast Minnesota as well as across the state
- An expansion of policy recommendations to address chloride contamination from road salt deicers
- A new policy targeted at addressing increased interest from large volume water users

Finally, the Council is proud of the way in which input from people across the state shaped these recommendations. They were heavily informed by robust engagement throughout the budget process. From before the drafting of a new evaluation rubric all the way through to the final recommendations, a record number of people shared their input for how to focus

Clean Water Fund investments. The Council hopes you see the influence of the input provided, and that you continue to engage in the years to come. Minnesota voters are the reason this fund exists.

Draft FY28-29 Biennial Recommendations Report Outline

As of November 12, 2026

- Cover page
- Table of Contents
- Legislative Charge and Council Members
- Executive Summary – HIGHLY REVISED
- Glossary
- Introduction
    - Statutory guidance
    - A strategic approach – UPDATED
    - Value of the Clean Water Fund – UPDATED
- Funding Recommendations – UPDATED
- Policy Recommendations – REVISED
- Developing the FY28-29 Recommendations - NEW
    - Public Participation Plan
    - Evaluation rubric
    - Process leading up to the budget recommendations
- Highlighted Programs – UPDATED
- How the State Measures Progress and Provides Oversight
    - Statutory requirements
    - Fishable, swimmable, drinkable standard
    - Strategic indicators – UPDATED
- Cooperation with Tribal Governments on CWF Programs – UPDATED
- Equity Assessment
- Looking to the future – NEW

Reducing Chloride Pollution from Winter De-icing Chemicals

Summarized Policy Statement

The Clean Water Council recommends that the State of Minnesota implement the following actions to reduce chloride pollution from winter de-icing chemicals (salts) in Minnesota's surface water and groundwater while protecting public safety.

Highest Priority Recommendations

While all recommendations are important and interconnected, the Clean Water Council identifies the following as especially critical near-term actions for the legislature to consider:

(1) Implement a granular salt fee for private applicators.

A granular salt fee would create a direct market incentive to reduce unnecessary salt use, encourage innovation and efficiency, and generate sustainable funding for chloride reduction efforts, research, training, and remediation.

(3) Investigate feasible approaches for restoration and remediation.

Minnesota currently lacks a practical strategy for addressing the growing inventory of waters impaired by chloride pollution. Research is needed to identify feasible remediation technologies and long-term management approaches.

(5) Incorporate low salt design standards into building and site development.

Many sites are unintentionally designed in ways that require excessive salt use. Updating development standards can reduce long-term winter maintenance needs while improving safety and reducing costs.

(6) Require Smart Salting for state contracts and facilities.

The State of Minnesota should lead by example by requiring best practices and certified applicators for its winter maintenance activities at public facilities.

(7) Establish an occupational licensure program for winter maintenance professionals.

Similar to Minnesota's pesticide applicator licensing program, winter maintenance professionals should meet standardized training and competency requirements because their work directly affects public safety and environmental health.

Full List of Recommendations

Incentives & Financial Sustainability

(1) Implement a granular salt fee for private applicators.

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(2) Sustain and enhance funding for the MPCA's Chloride Reduction Program including the Smart Salting training and certification program. *Included here for the grant and technical assistance elements of the program*.

Research & Remediation

(3) Investigate feasible approaches for restoration and remediation.

(4) Provide research funds to:

- Develop new technology, best management practices, and alternatives to chloride-containing de-icing chemicals
- Establish understanding of current rate and volume of use, and assess cost of damage to infrastructure.

Standards & Requirements

(5) Incorporate low salt design standards into building and site development.

(6) Require Smart Salting certification and practices for state contracts and facilities.

(7) Establish an occupational licensure program for winter maintenance professionals.

(8) Develop standardized labeling requirements for de-icing chemicals sold in Minnesota.

(9) Expand requirements for proper storage of de-icing chemicals.

Data & Accountability

(10) Expand and strengthen chloride monitoring statewide.

Risk & Liability

(11) Provide liability protection for certified applicators using best practices.

Awareness & Behavior Change

(12) Establish a statewide community-based social marketing campaign.

(2) Sustain and enhance funding for the MPCA's Chloride Reduction Program including the Smart Salting training and certification program. *Included again here for the training program contribution to behavior change*.

These actions are further expanded under the "Recommendations" section.

Additional Considerations

Recommendations 7 (occupational licensure) and 11 (liability protection) are especially important because they address major barriers to behavior change in the winter maintenance industry. Many applicators continue to overapply salt due to liability concerns, inconsistent training standards, and lack of professionalization within the industry. Creating clear standards and protections can support safer and more sustainable practices statewide.

From 2016-2025 a limited liability bill was introduced at the Minnesota Legislature, modeled after a limited liability bill that passed in New Hampshire. Despite many attempts, common ground for the liability language has not been found over the ten-year life of the bill. In light of this, local governments have begun to explore the feasibility of local licensing requirements though a state-level program would ensure consistency and lessen the burden on local governments to deliver a program locally.

Recommendations 2 (MPCA Chloride Reduction Program funding) and 4 (research funding) also represent areas where the Clean Water Council can have particularly strong influence in the near term through funding recommendations and

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program support. Expanding research, technical assistance, and Smart Salting training capacity can deliver immediate and measurable reductions in chloride use while supporting broader long-term implementation of the Council's recommendations.

Problem Statement

Chloride pollution from the application of de-icing salt for winter maintenance of roads, parking lots, and sidewalks disrupts aquatic ecosystems, alters food webs, damages soil, damages infrastructure, and contaminates groundwater and drinking water. Many waterbodies in the state have elevated levels of chloride pollution, with trends continuing upward. Further, a study by the University of Minnesota and referenced in the Statewide Chloride Management Plan found that about 70% to 78% of salt applied in the Twin Cities for winter maintenance is either transported to groundwater or remains in the local lakes and wetlands.

Chloride is considered a "permanent" pollutant because it does not degrade over time through typical environmental processes. Additionally, there is no practical way to remove chloride once it enters a waterbody, so it accumulates over time. As the adage goes, "an ounce of prevention is worth a pound of cure," making source control the most practical and cost-effective strategy. Addressing chloride pollution will require a broad range of knowledge building, behavior change, implementation activities, and policy measures. At the same time, a remediation pathway must be investigated to address the existing and growing inventory of waters impaired by excess chloride.

Winter de-icing salts are among the primary sources of chloride pollution in Minnesota waters. The Minnesota Statewide Chloride Management Plan addresses pollution caused by de-icing chemicals, fertilizers, and water softeners. The Clean Water Council has an independent policy statement related to reducing chloride pollution from water softening to address the Wastewater Treatment Plan (WWTP) pollutant stream.

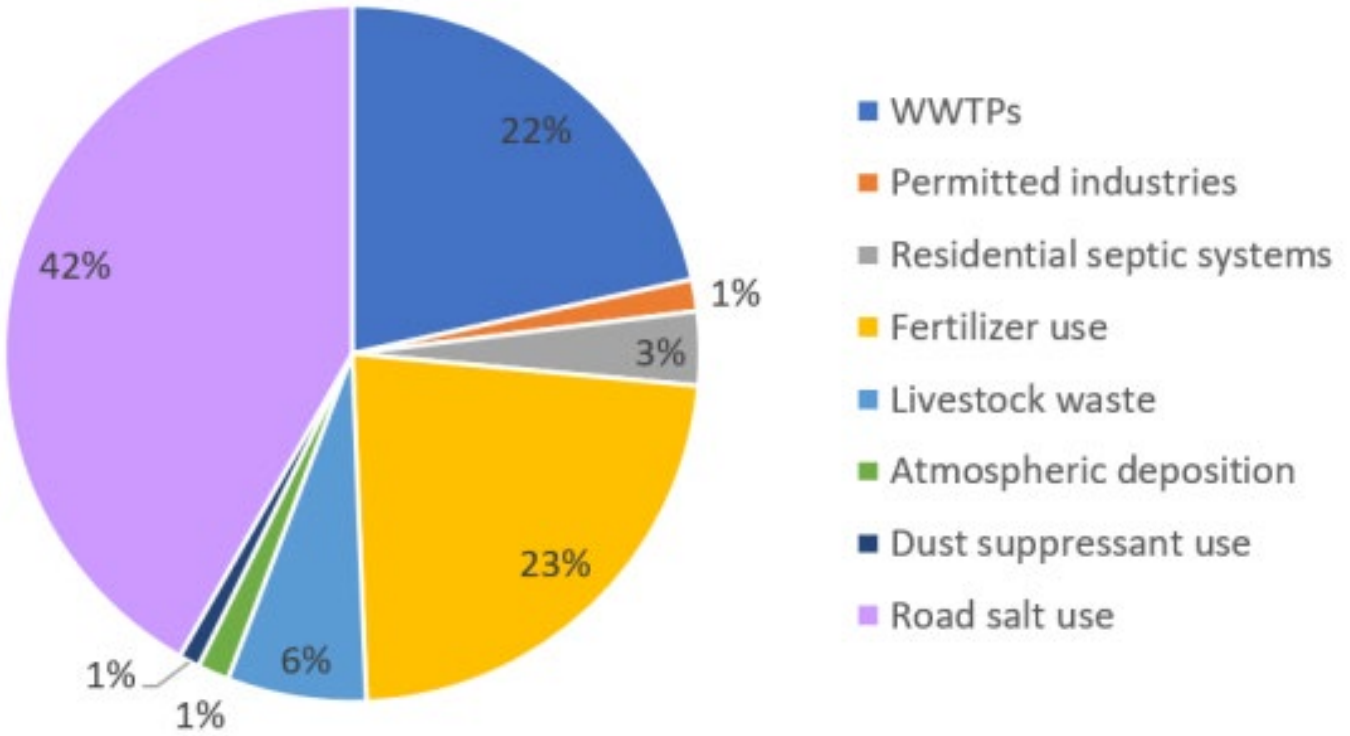


Figure 4: Fraction of annual chloride contributions from major point and nonpoint sources for State of Minnesota (Overbo et al. 2019)

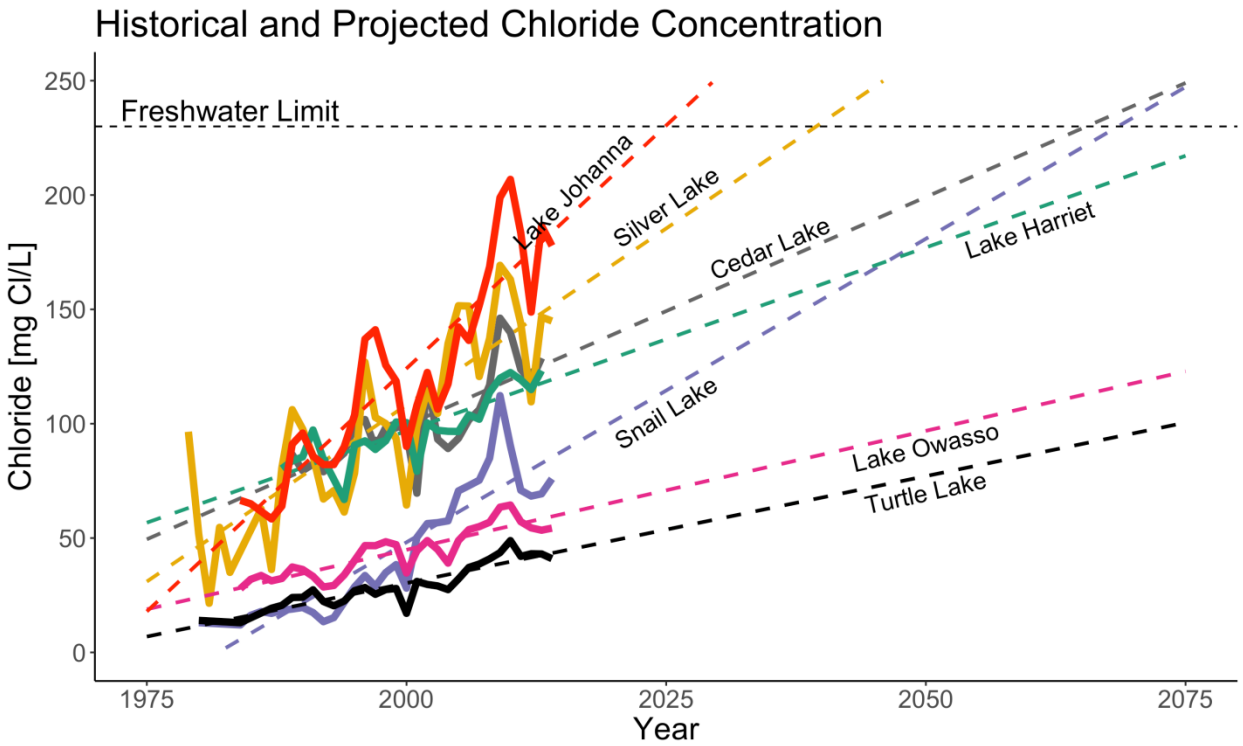
**Please note that Road salt use is actually all de-icing salt applied to roads, parking lots, sidewalks, and trails.*

Statewide, approximately 404,000 tons of de-icer is used annually. It takes just one teaspoon in 5 gallons of water to exceed the water quality standard and become toxic for freshwater fish and other aquatic life under long-term exposure. The de-icing salts applied to hard surfaces eventually wash off and/or infiltrate, contaminating nearby lakes, streams, wetlands, and groundwater.

One ton of salt costs more than its purchase price.

Cost to Buy	**Cost to Society**	**Cost to Water Resources**
$151/ton	$1,900-$4,600/ton	796,178 gallons/ton
Bulk road salt purchase price	Estimated infrastructure damage costs	Water permanently polluted
State Salt Purchase Report (2023-2024 avg.)	MPCA Smart Salting for Roads Manual	Based on 1 teaspoon polluting 5 gallons

The Metropolitan Council published a report (Regional Assessment of Chloride in Select Twin Cities Metro Streams (1999 – 2019) which revealed rising chloride levels in nearly all streams. While the metro has been most heavily studied, chloride pollution is not a metro-only problem. The Minnesota Pollution Control Agency published its Milestones report (Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites) in 2014 which identified significant, largely statewide increases in chloride concentrations. Chloride from de-icing salts has been attributed in part to the impaired waters designations for chloride impaired waters in St Louis, Rice, Jackson, Meeker, Le Sueur, Douglas, Lyon, and Kittson counties. A study of chloride impacts to groundwater predicts groundwater in multiple Twin Cities aquifers is likely to reach chronic chloride exposure thresholds by mid-century due to de-icing salt (McDaris, John R et al. “Documentation and Prediction of Increasing Groundwater Chloride in the Twin Cities, Minnesota.” Ground water vol. 60,6 (2022): 837-850. doi:10.1111/gwat.13227). As of 2026, there are 68 impairments statewide for chloride, and 14 were added in just the last two years.



Graph credit: Freshwater Society

Excess chloride contributes to a phenomenon often referred to as freshwater salinization syndrome, mobilizing heavy metals and creating a chemical cocktail (Kaushal et al., 2022). It leads to direct toxicity and biodiversity loss, macroinvertebrate sensitivity and reduced reproductive success, amphibian mortality, reduced zooplankton populations shifting phytoplankton communities from green algae toward cyanobacteria, density stratification and anoxic conditions which can trigger phosphorus release from sediments.

There is currently no alternative to de-icing salt that doesn't have other tradeoffs in effectiveness, cost, scalability, or other environmental harm. While a variety of products are marketed as safer or more sustainable alternatives, most still contain chloride compounds, perform inconsistently in extreme winter conditions, or introduce their own environmental concerns. Organic additives such as beet juice are commonly blended with salt brine to improve performance at lower temperature and help reduce bounce and scatter, which can lower overall salt use. However, beet juice mixtures can increase biological oxygen demand in nearby waters, contribute nutrients and organic matter to aquatic systems, create odors, and add cost and storage complexity for winter maintenance operators. Other alternatives, such as calcium magnesium acetate or potassium acetate, may reduce chloride impacts but are often significantly more expensive and impractical for widespread use on roads, parking lots, and sidewalks. As a result, the most effective current strategy is not complete replacement of salt, but reducing unnecessary application through smarter winter maintenance practices and targeted use.

In recent years, calls for more enhanced and comprehensive approaches to reducing chloride pollution have gained momentum. The Environmental Quality Board (EQB) identified chloride pollution as an emerging issue in the 2015 Water Policy Report. In September 2025, the EQB published the Groundwater Policy Report and in the chloride section noted gaps and opportunities, specifically, "Implementation of policies that support chloride reduction are needed to move beyond voluntary chloride reduction actions". The Upper Mississippi River Basin Association issued a resolution in 2022 calling for collaboration and progress on chloride pollution. Minnesota Watersheds adopted a resolution in 2024 calling for a regulatory approach to addressing chloride pollution. The Minnesota Cities Stormwater Coalition issued a position statement in 2025 expressing urgency and offering ideas for a comprehensive approach to meet the challenge.

Audience and Purpose

The Clean Water Council has a statutory role to foster coordination and cooperation as part of the Clean Water Legacy Act. These recommendations are intended to inform legislative and regulatory decision-making, guide state and local program development, and support the adoption of best practices across public and private sectors.

This policy statement is intended for the Minnesota Legislature, the Minnesota Pollution Control Agency, other state agencies, and local governments responsible for water quality protection, transportation systems, and land use regulation. It is also directed toward private sector parties, including winter maintenance professionals, commercial applicators, property managers, developers, and de-icing product manufacturers whose decisions influence use across Minnesota. It applies statewide, with particular relevance to developed areas where impervious surfaces and winter maintenance activities are concentrated. While awareness has been increasing, continued progress depends on deepening that awareness across all groups (general public, decision-makers, practitioners, and industry leaders). At the same time, awareness alone is not sufficient to drive the scale of change needed. Progress will require translating awareness into more comprehensive and coordinated action.

The purpose of this document is to recommend a suite of actions to reduce chloride pollution from de-icing chemicals while maintaining public safety and effective winter maintenance. Further, this updated policy statement reflects an inflection point in chloride pollution management in Minnesota. Early efforts have focused on improving operational efficiency and advancing voluntary best practices, yielding measurable reductions in de-icing chemical use, particularly

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among public road authorities. However, chloride concentrations continue to rise in many waterbodies, indicating that additional progress will require a strategic shift beyond operational efficiency improvements in the public sector alone. A more comprehensive approach that integrates standards, incentives, research, accountability, and behavior change is necessary to make meaningful progress in source control and restoration of impaired waters.

Recommendations

1. **Implement a Granular Salt Fee for Private Applicators.** To curb overuse, the costs of infrastructure and environmental damage should be partially shifted to those who overapply salt. A granular salt fee, modeled after the agricultural fertilizer fee, would incentivize more judicious use while generating revenue for and supporting financial sustainability of chloride reduction efforts. Funds could be reinvested in training and certification programs, research and innovation, implementation of best practices, and equipment and facilities upgrades. A fee structure would also enable improved tracking of salt use statewide, supporting benchmarking and accountability.

2. **Sustain and Enhance the MPCA Chloride Reduction Program including the Smart Salting Training Certification program**. The MPCA Smart Salting training and certification program supports a range of audiences involved in de-icing decisions and operations, from private and public winter maintenance professionals who maintain roads, rural roads, parking lots, and sidewalks, to MnDOT, property managers, and community leaders. The Statewide Chloride Management Plan identifies the Smart Salting training program as the top implementation strategy to reduce salt overuse in the winter. Case studies have shown that participating organizations have been able to reduce salt use by 30% to 70%, without compromising safety. Further, the program provides low-interest loans and grants for equipment and retrofit projects.

   The program has been exclusively funded by Clean Water Funds since January 2021. The State should sustain and enhance the MPCA's **Chloride Reduction Program** to support the development and maintenance of tools, resources, policies, trainings and assistance programs to assist communities, private sector applicators, and property managers in their effort to reduce chloride pollution and at least half of the chloride reduction budget should be dedicated to adoption of best practices to reduce chloride from de-icing chemicals.

   Lastly, growing the chloride reduction program in Minnesota is critical as adoption of best practices and other policies in this document could accelerate progress and would put more demand on the training and cost share programs.

3. **Investigate Feasible Approaches for Restoration and Remediation.** While source control is and should remain a top priority, it is prudent to advance a solution to remediate surface water that is or is imminently impaired by chloride. The State should lead a feasibility effort to evaluate remediation options and assess engineering feasibility, cost and scalability, waste management challenges and opportunities, risks, tradeoffs, energy demand, ecosystem impacts, and policy barriers. The goal is to determine if, where, and how chloride remediation can be implemented effectively.

   Case Study: Leveraging Watershed Based Implementation Funding, the Bassett Creek Watershed Management Commission and City of Plymouth studied options for delisting Parker's Lake. The study analyzed two primary alternatives to reduce chloride in Parkers Lake: 1) pumping lake bottom water directly to the sanitary sewer, and 2) pumping lake bottom water, treating it, and returning treated water to the lake. Two different treatment systems were evaluated for this alternative – a small-scale reverse osmosis system (RO) and an ion exchange system (IX). Ultimately, the decentralized treatment systems were cost prohibitive. More information on the study is available at Parkers_Lake_Chloride_Dilution_Extraction_Tech_Memo_final.pdf

4. **Fund Research and Innovation**. The 2016 Twin Cities Metro Area (TCMA) Chloride Management Plan identified a broad range of research needs focused on reducing chloride pollution while maintaining public safety. Key research priorities including improving winter maintenance practices including in technology and equipment;

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evaluating alternative de-icing materials and additives; understanding and tracking chloride fate and transport; evaluating site design and infrastructure approaches; and understanding behavioral, institutional, and policy drivers that influence de-icer application decisions. Lastly, the plan recognizes a need to explore long-term management and potential mitigation strategies for chloride-impacted waters, given that chloride does not break down and accumulates in the environment.

The University of Minnesota's Stormwater Research Program provides an existing framework and strong institutional partner for advancing applied winter maintenance research to support the development and evaluation of new technologies, decision-support tools, and other best management practices that reduce chloride use while maintaining public safety. Expanded research capacity would also help test emerging de-icing products and operational approaches, accelerating the adoption of practical and scalable solutions.

The Forever Green Initiative could serve as a model framework for developing alternatives to chloride-based de-icing chemicals. Innovation in this sector is essential to develop a cost-effective alternative that can perform and is less harmful to the environment.

5. **Incorporate Low Salt Design Standards.** Infrastructure should be designed with winter maintenance in mind. Poor designs with inadequate snow storage, inefficient drainage, and snow removal obstacles drive salt overuse. Design improvements can reduce long term maintenance costs, improve safety, and minimize environmental impacts. The state should incorporate established low salt design principles into building and site development standards, state-funded project requirements, and sustainability frameworks such as the Minnesota B3 (Buildings, Benchmarks, and Beyond) Guidelines. Local communities can incorporate these standards through zoning and ordinances. The biggest opportunity to have this recommendation make an impact is in communities that are still developing.

6. **Require Smart Salting for State Contracts and Facilities.** Require Smart Salting certification, use of best practices, and proper storage of de-icing chemicals for all winter maintenance conducted under state contracts and at state-owned or state-managed facilities. Contract specifications should clearly define performance expectations, documentation requirements, and compliance measures, including calibration of equipment, application rate tracking, and recordkeeping. State agencies should incorporate accountability mechanisms such as incentives, audits, or penalties. By leading through its own operations and procurement standards, the State can set a strong example and accelerate adoption across the private sector.

   A model contract for responsible snow and ice management that embraces best practices to minimize environmental impacts from de-icing chemicals while also maintaining safety and addressing liability risk allocation is available on the MPCA's Chloride Resources website.

   The February 2025 State Salt Purchase Report to the Minnesota Legislature included reporting from seven agencies that own property (MnDOT and leased properties excluded, with about half of agencies not reporting). The average annual purchase for 2023 and 2024 was 1,330 tons. If all the de-icing salt purchased were applied, it could permanently pollute more than a billion gallons and cause $2M to $22M in infrastructure damages annually.

7. **Establish an Occupational Licensure Program.** Establish a statewide occupational licensure program for winter maintenance professionals, or authorize counties to do so, to ensure consistent training and accountability. Licensure should include completion of an approved training program (such as the MPCA's Smart Salting certification program) and periodic continuing education. This approach would professionalize the industry, reduce overuse, and provide assurance to property owners and the public that winter maintenance services are being delivered safely and responsibly.

8. **Develop Standardized Labeling Requirements**. Develop standardized labeling requirements for de-icing chemicals sold in Minnesota to address misleading or incomplete information. De-icers can be labeled as "eco-

friendly" or as an alternative to salt, but they may pose other problems for water quality. The MPCA should convene interested parties from a variety of sectors and lead a process to develop recommendations for new labeling requirements on packages of de-icing chemicals sold in Minnesota. Some key areas to establish requirements for include, but would not be limited to:

- Ingredient disclosure
- Verified environmental and safety claims
- Realistic performance information
- Clear application guidance

Improved labeling would support informed decision-making and reduce unintended environmental harm.

9. **Expand Proper Storage Requirements**. Proper storage of de-icing chemicals is a cost-effective and common-sense measure to reduce pollution.

   Proper storage is required in communities regulated under the MPCA's Municipal Separate Storm Sewer System (MS4) program; the permit requires local controls for proper bulk storage of de-icing chemicals at commercial, institutional, and non-NPDES permitted industrial facilities. The MPCA's Chloride Reduction Model Ordinance Language document provides guidance for creating and implementing an ordinance.

10. **Expand Strategic Chloride Monitoring.** Incorporate strategic chloride monitoring into the Minnesota Pollution Control Agency's surface water and groundwater monitoring programs to better track statewide conditions and identify trends. This should include strategic enhancements to the MPCA's ambient groundwater monitoring network and the Watershed Pollutant Load Monitoring Network to sufficiently capture patterns in high-risk areas and across the state. Enhanced strategic monitoring and reporting of conditions and trends will support early detection of problems in vulnerable waterbodies, evaluate the effectiveness of chloride reduction strategies, and provide the data needed to guide policy, prioritize investments, and engage with interested parties on addressing chloride pollution.

11. **Liability Protection**. Provide liability protection to certified private salt applicators and businesses contracting with them against slip and fall lawsuits who follow established best practices and document their work. The primary goal is to reduce overapplication driven by fear of litigation, encourage adoption of Smart Salting practices, and maintain safety while improving environmental outcomes.

12. **Establish a Statewide Community-Based Social Marketing Campaign.** A coordinated, statewide community-based social marketing campaign is needed to increase awareness and drive behavior change. The MPCA should lead a process to establish a baseline of the public's current knowledge and attitudes, identify gaps, opportunities and roles among interested parties (MPCA's Chloride Reduction Program, Tribal governments, cities, counties, academic institutions, watersheds, non-profits, other state agencies, etc.), support crafting and distributing coordinated messages, and evaluate progress. State leadership can amplify and align existing local efforts. Additionally, the MPCA should further support enhancing chloride pollution awareness into existing programs such as the successful We Are Water program, Eco Experience at the Minnesota State Fair, and supporting the regional Winter Salt Week campaign.

Conclusion

Chloride pollution from de-icing chemicals is a growing threat to Minnesota's water resources. Because chloride accumulates and cannot be feasibly removed, proactive and coordinated action is essential. This policy framework outlines a comprehensive approach that combines incentives, standards, knowledge building, monitoring, research, and accountability. Together, these actions can significantly reduce chloride pollution while maintaining public safety, protecting infrastructure, and preserving Minnesota's freshwater resources for future generations.

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Program name	$1	??	$5	??	$9	Rubric average	Council Priority	Public support
Legacy	0.5		0.75		1			
Stormwater Research	0.5		0.5		0.5			
Voyageurs National Park	0		0.5		1			
Measures, Results, Accountability	0		0.05		0.05			
Working land	0		0.725		1			
Critical Shore	0		0.3625		1			
Wetlands	0		0.3625		1			
PWI	0		0.5		0.75			
AgBMP	0		0.75		1			
FGI	0		0.5		1			
Conservation Drainage	0		0		0.2			
Surface Water & Drinking Water	0		0		0.5			
TOTALS	1	0	5	0	9			



Has the Legacy Amendment Improved Lake Water Quality?

Paul Radomski, DNR
Henry Van Offelen, BWSR
Kris Carlson, DNR

November 16, 2026

CLEAN WATER LAND & LEGACY AMENDMENT

Has the Legacy Amendment Improved Lake Water Quality?

We will show clear evidence that:

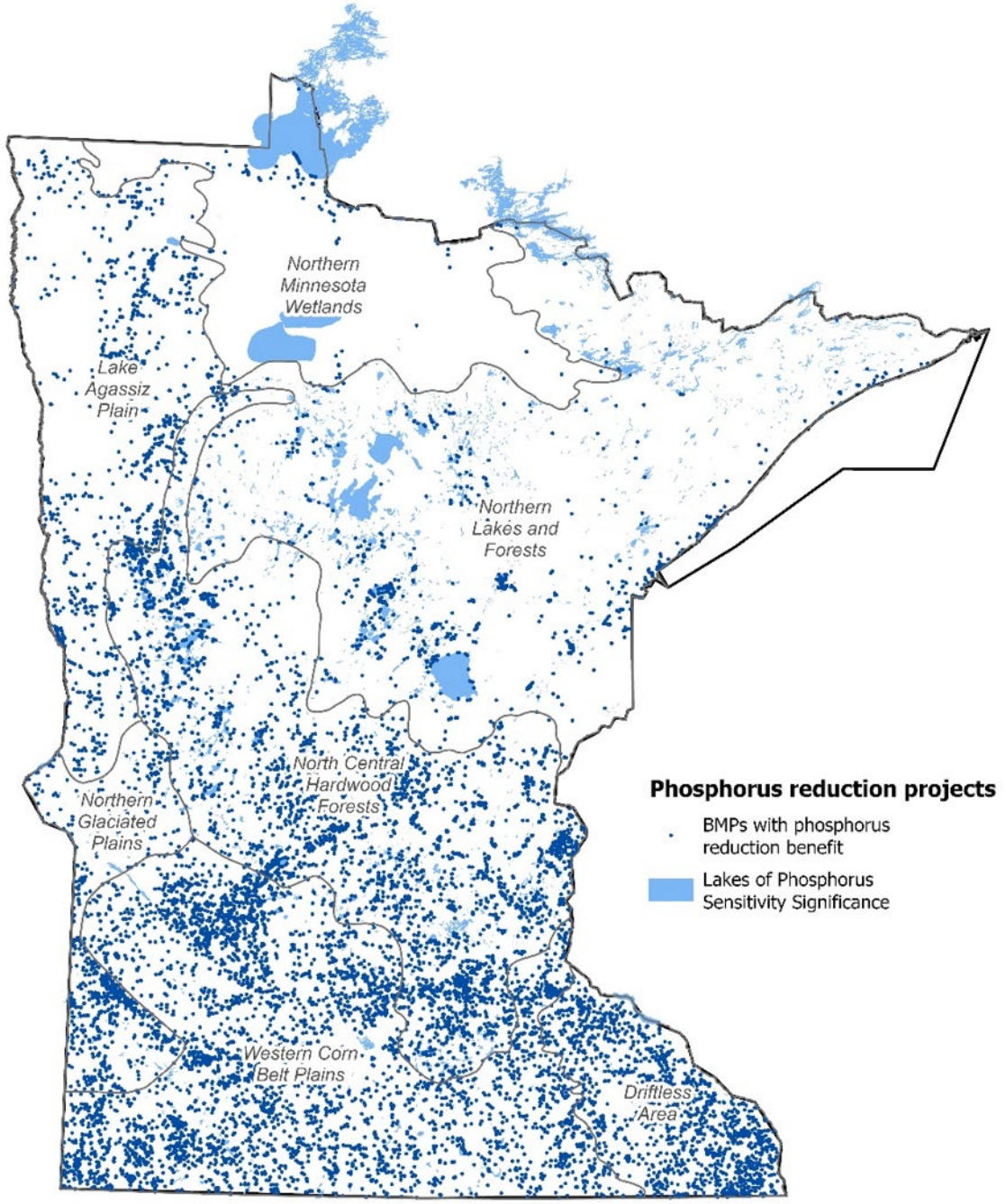
- CWF investments have improved lake water clarity
- The odds of improved water clarity were 2-3 times higher for lakes that exceeded 5% TP load reduction compared to lakes with no projects



Approach used (1 of 4)

BWSR's eLINK data used for load reduction estimates (2013 to early 2026, outliers removed)

- Only used projects with Phosphorus (TP) reduction data that were <u>within 1000' of lakes and streams</u> (n=15,039)





Grassed Waterways

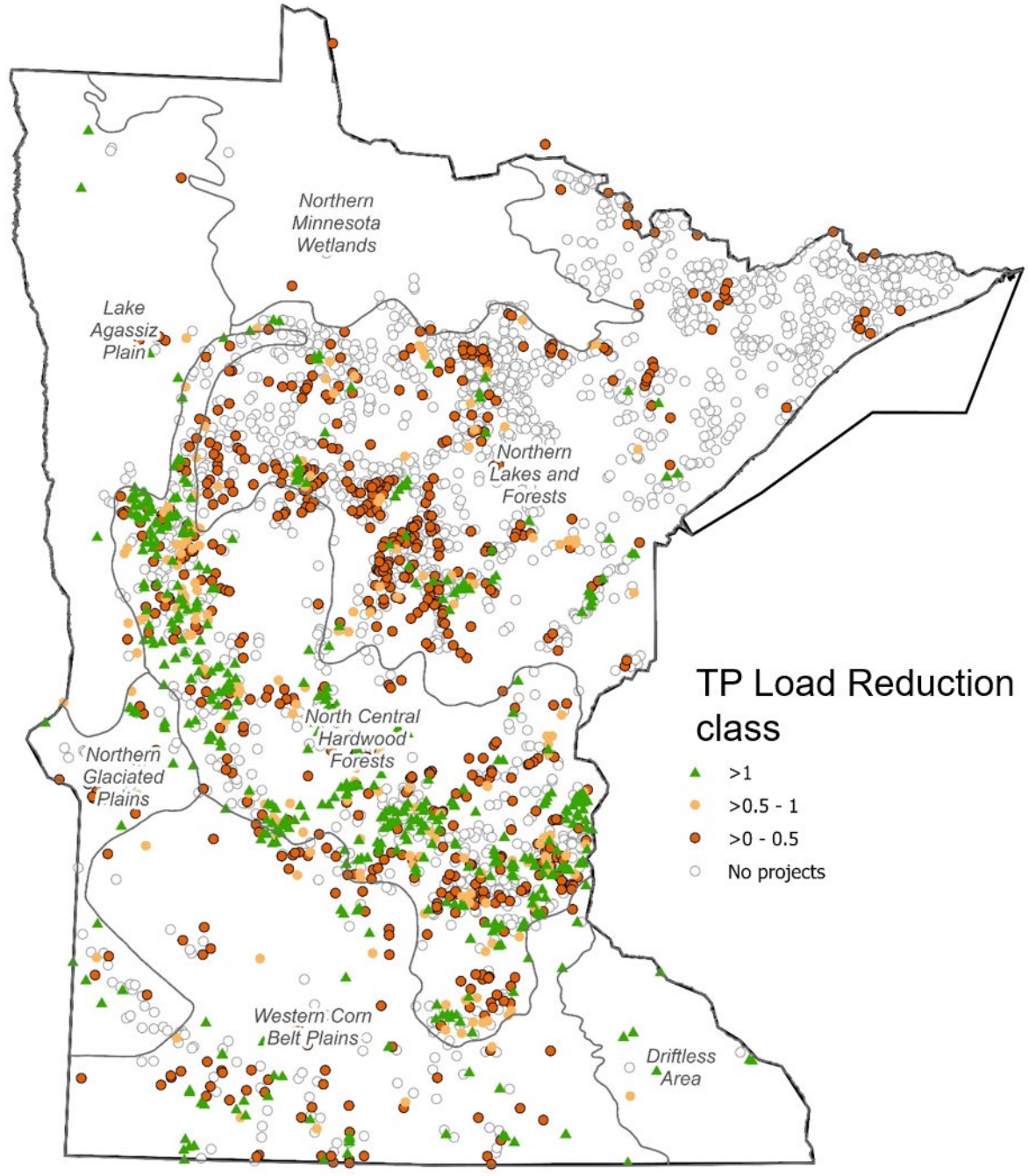
Water and Sediment Control Basin



Approach used (2 of 4)

Classify 3,187 lakes into load reduction classes based on BMP TP Reduction (pounds/year) / Lake 5% TP Load Reduction (pounds/year)

- No projects
- 0 – 0.5 - lakes with zero or minimal load reduction
- 0.5 - 1 - lakes where load reduction less than 5%
- >1 - lakes where load reduction greater than 5%



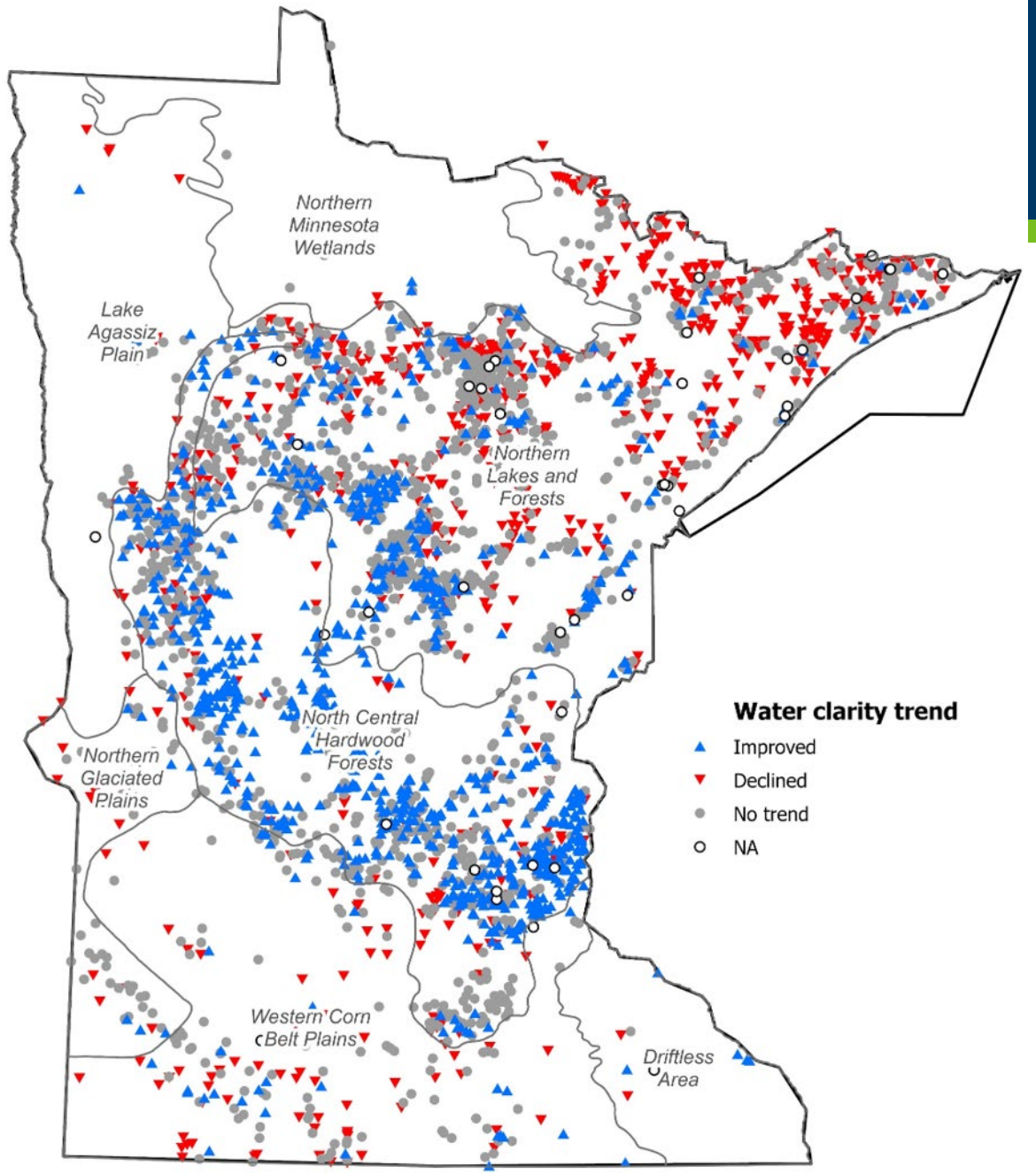
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Sum of P reduction (lbs/year) in 1000ft lake or contributing stream buffer, divided by load reduction goal (lbs/year).

Approach used (3 of 4)

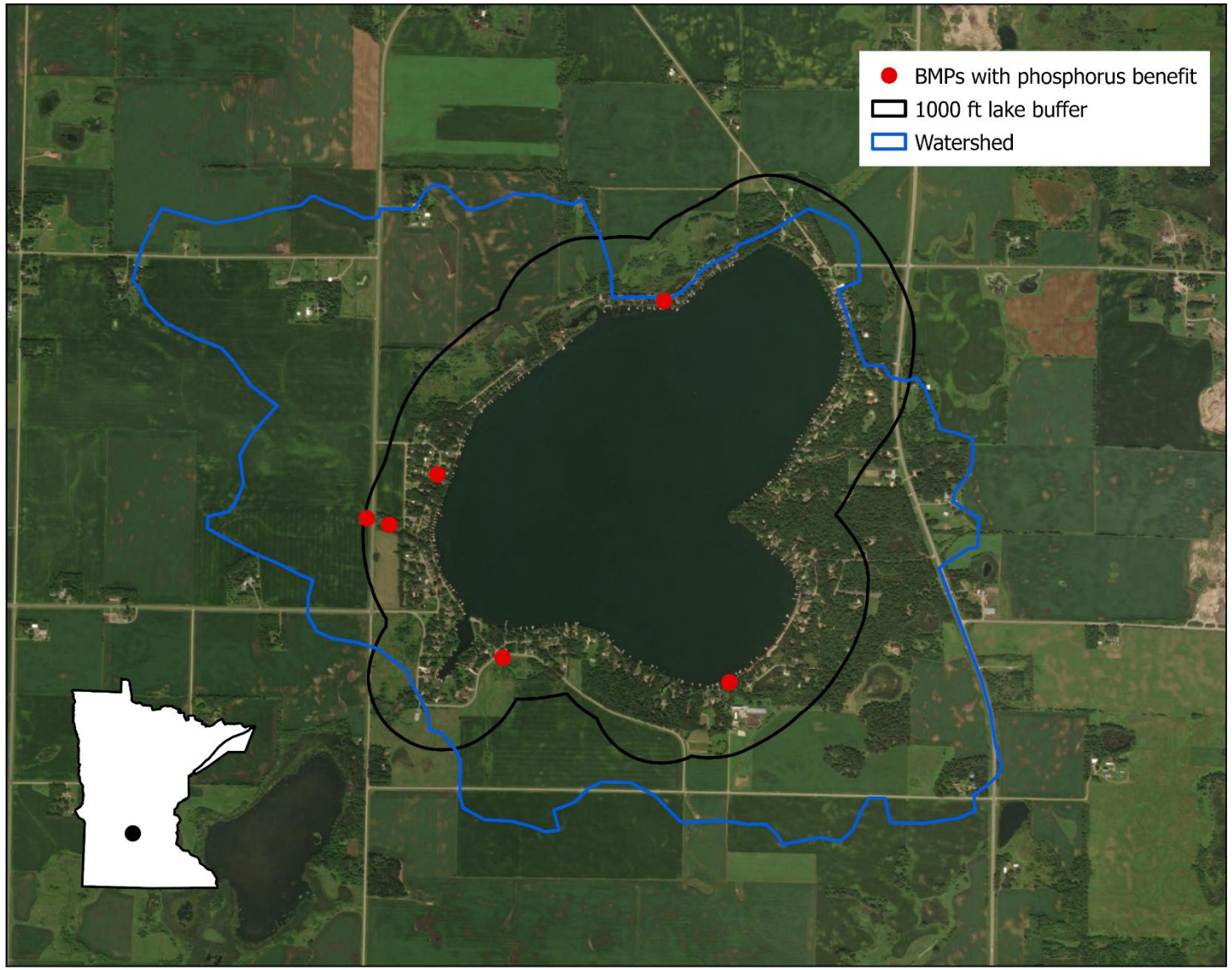
Analyze lake water clarity trends (UMN LakeBrowser 1985-2025; 17 years, 3,145 lakes)

- One-tailed Student t-tests were used determine if the slopes were significantly different from zero in a specific direction
- Three classes - improved, declined, or no trend; (*alpha* = 0.05)



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Example (steps 1-3)



Step 1. BMPs

2 Septic System Improvements

2 Streambank and Shoreline Protection BMPs

2 Water and Sediment Control Basins

Reported BMP TP Load Reduction = 266.5 pounds

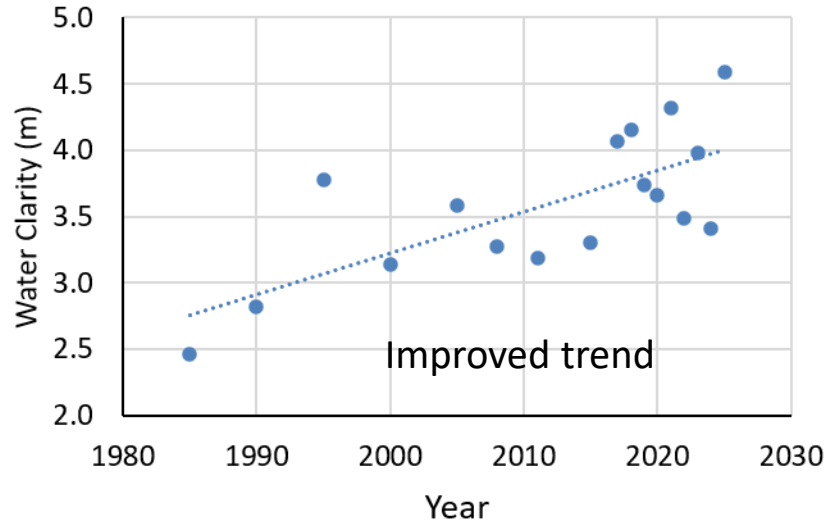
Step 2. Predicted TP Load = 420 pounds/year

Lake 5% TP Load Reduction = 20 pounds

266.5 / 20 = 13.3

Reduction class: >1 (exceeds 5%)

Step 3.



Approach used (4 of 4)

Conduct Odds Ratio Analysis – Was there was a propensity for lakes that exceeded a 5% TP load reduction to have improved water clarity?

1. Simple 2x2 Contingency Table – Unadjusted Odds Ratio
2. Logistic Regression – Adjusted Odds Ratio; accounts for the influence of other variables

A foundational statistical measure used in clinical drug studies



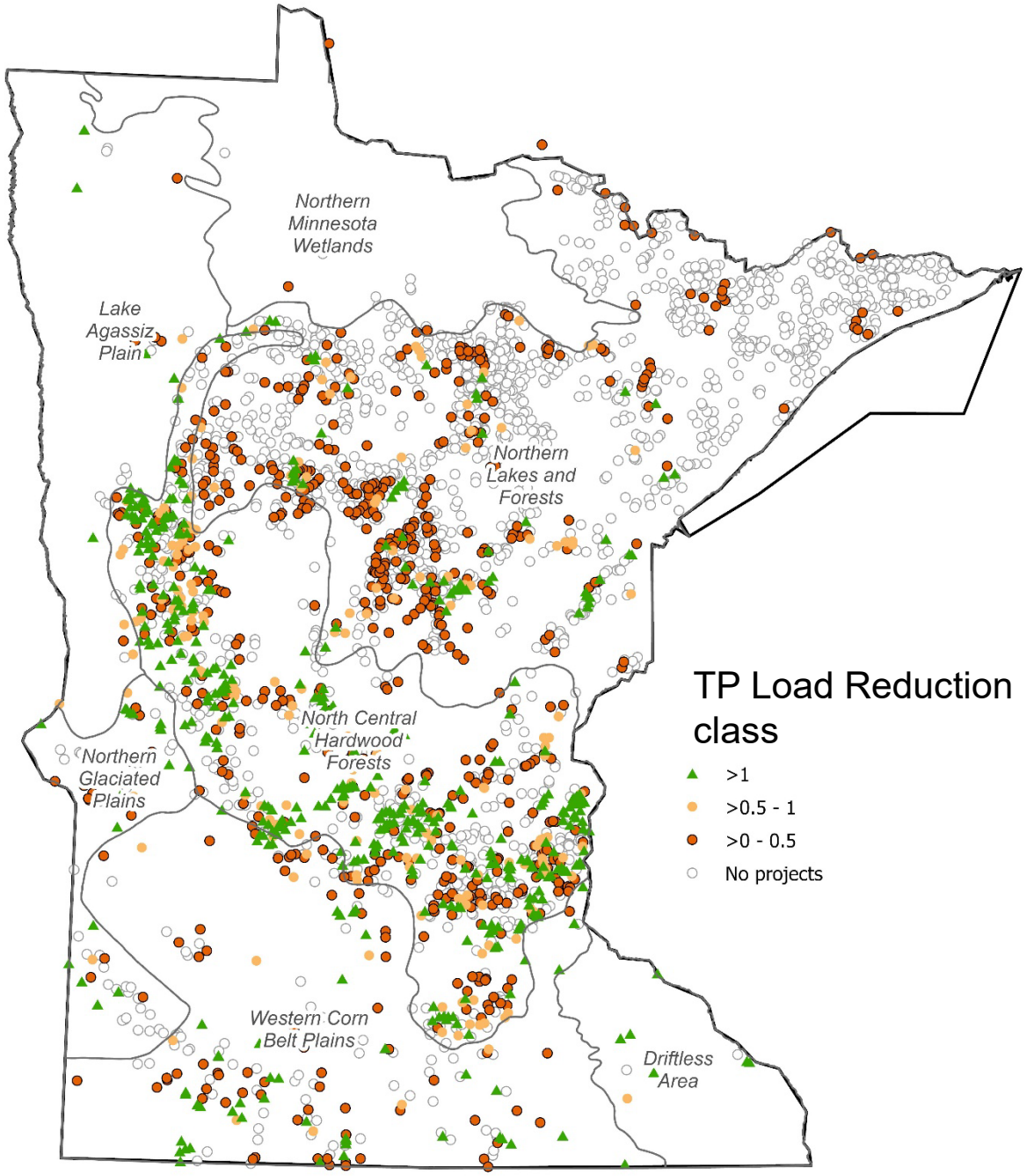
TP Load Reduction class:
BMP TP Reduction / 5% TP Load Reduction

Percent of Lakes (3,187 lakes)

TP Load Reduction class	NCHF	NGP	NLF	WCBP	State-wide
No TP reduction projects	41	48	77	40	60
>0 – 0.5	21	20	17	31	19
>0.5 - 1	10	8	3	5	6
> 1 (exceeded 5%)	28	24	4	24	15

Green:
lakes exceeded 5% reduction

Open circles:
lakes with no projects



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Sum of P reduction (lbs/year) in 1000ft lake or contributing stream buffer, divided by load reduction goal (lbs/year).

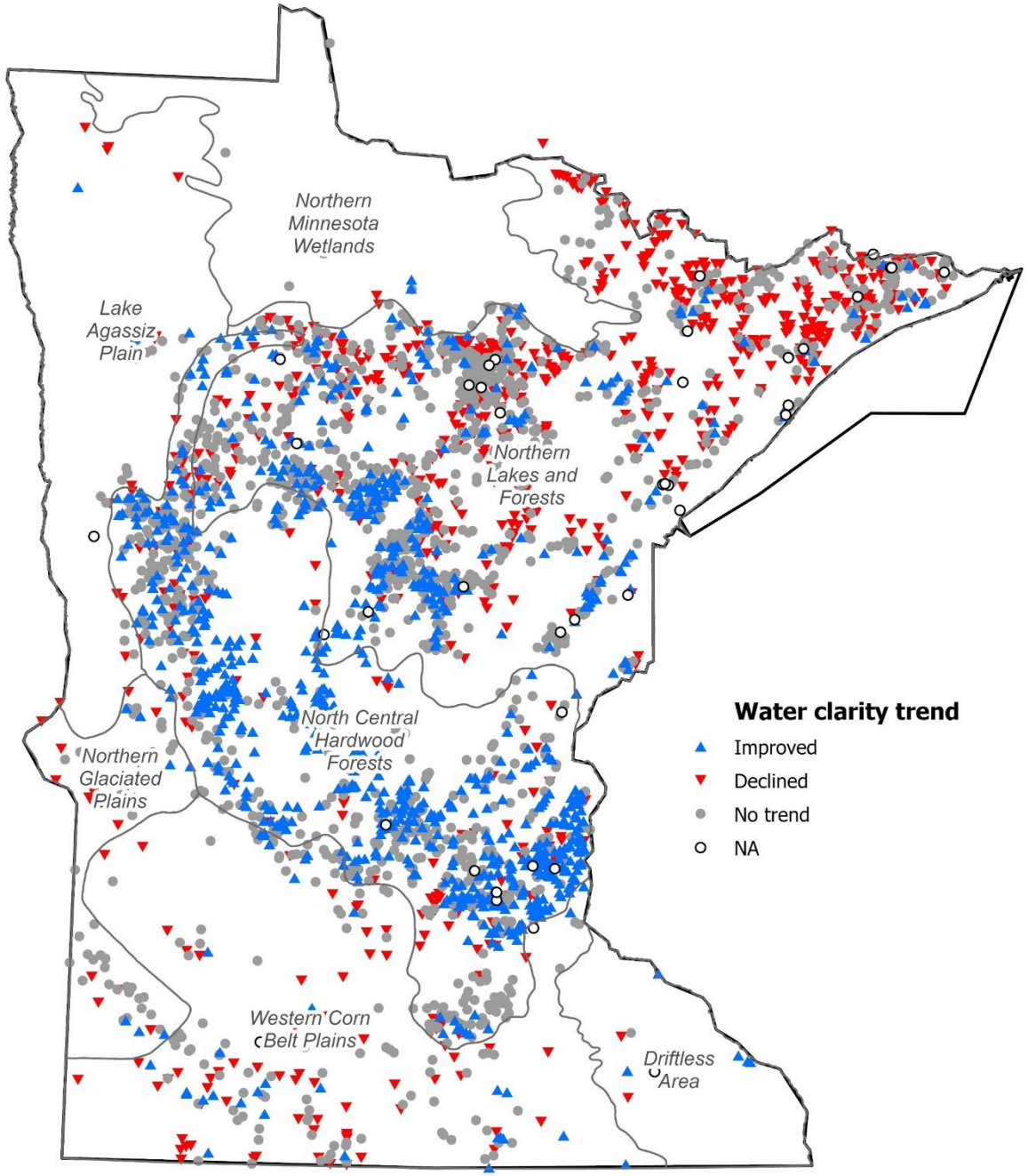
Water Clarity Trends

Percent of Lakes (3,145 lakes)

Water Clarity trend	NCHF	NGP	NLF	WCBP	State-wide
Improved	48	14	18	15	29
Declined	10	29	34	33	24
No trend	42	57	48	46	46

Blue is good:
water clarity improved

Red is bad:
water clarity declined



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Unadjusted Odds Ratio Analysis

2x2 Contingency Table

Unadjusted Odds Ratio:

1.03/0.34 = **3.0**

# of Lakes TP Reduction Class	Water Clarity improved	Water Clarity not improved	Odds favorable/unfavorable success/failure
exceeded 5%	233	227	233/227=1.03
not exceed 5%	687	1998	687/1998=0.34

Interpretation

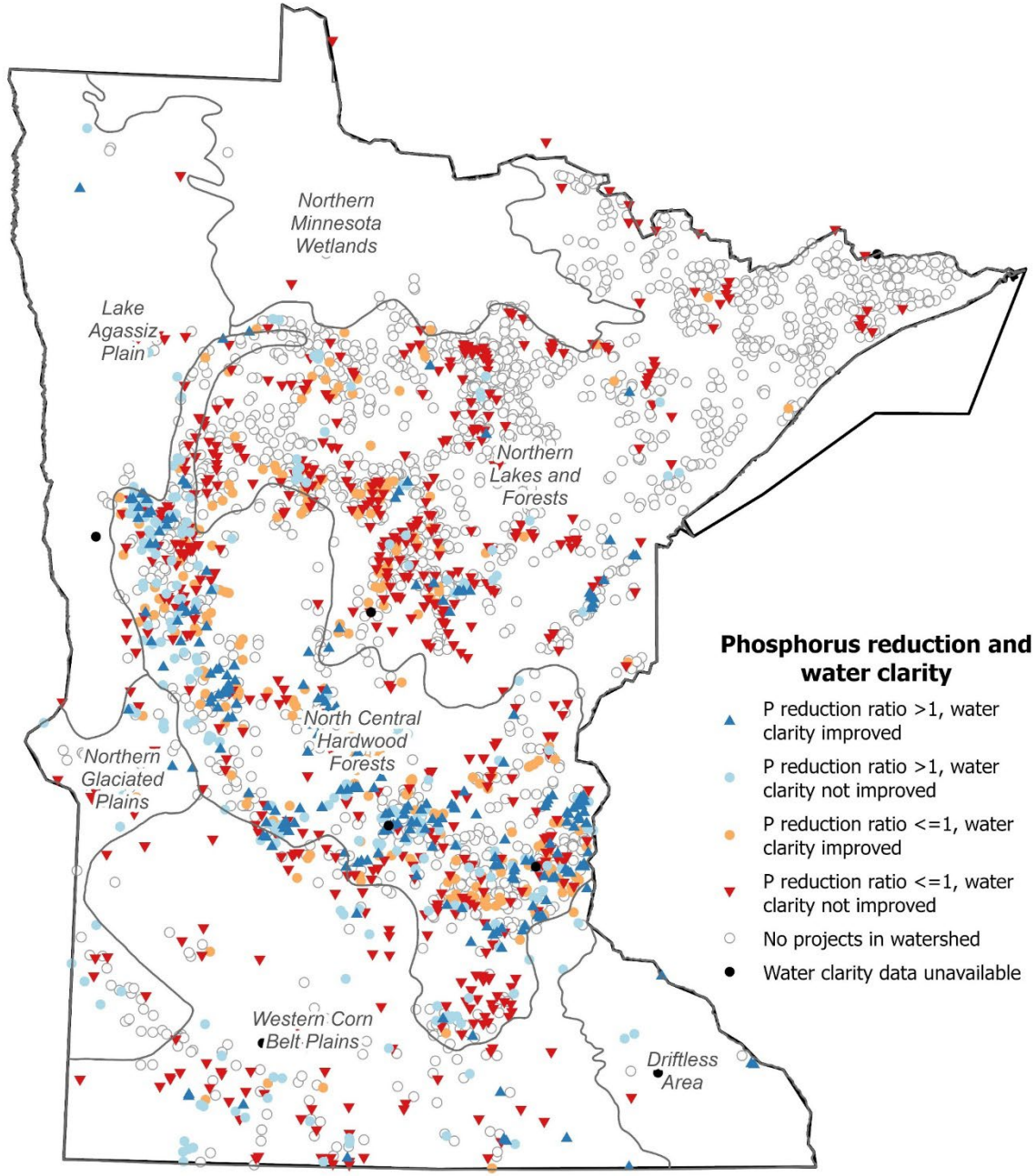
An Odds Rato of 3.0 means that the odds are 3 times higher of improved water clarity for lakes that exceeded 5% TP load reduction compared to those that did not.

Statewide Results – Odds Ratio

Dark Blue is good:
Exceeded 5% and water clarity improved

Red is unfortunate:
Not exceeded 5% and water clarity not improved

Open circles:
No projects



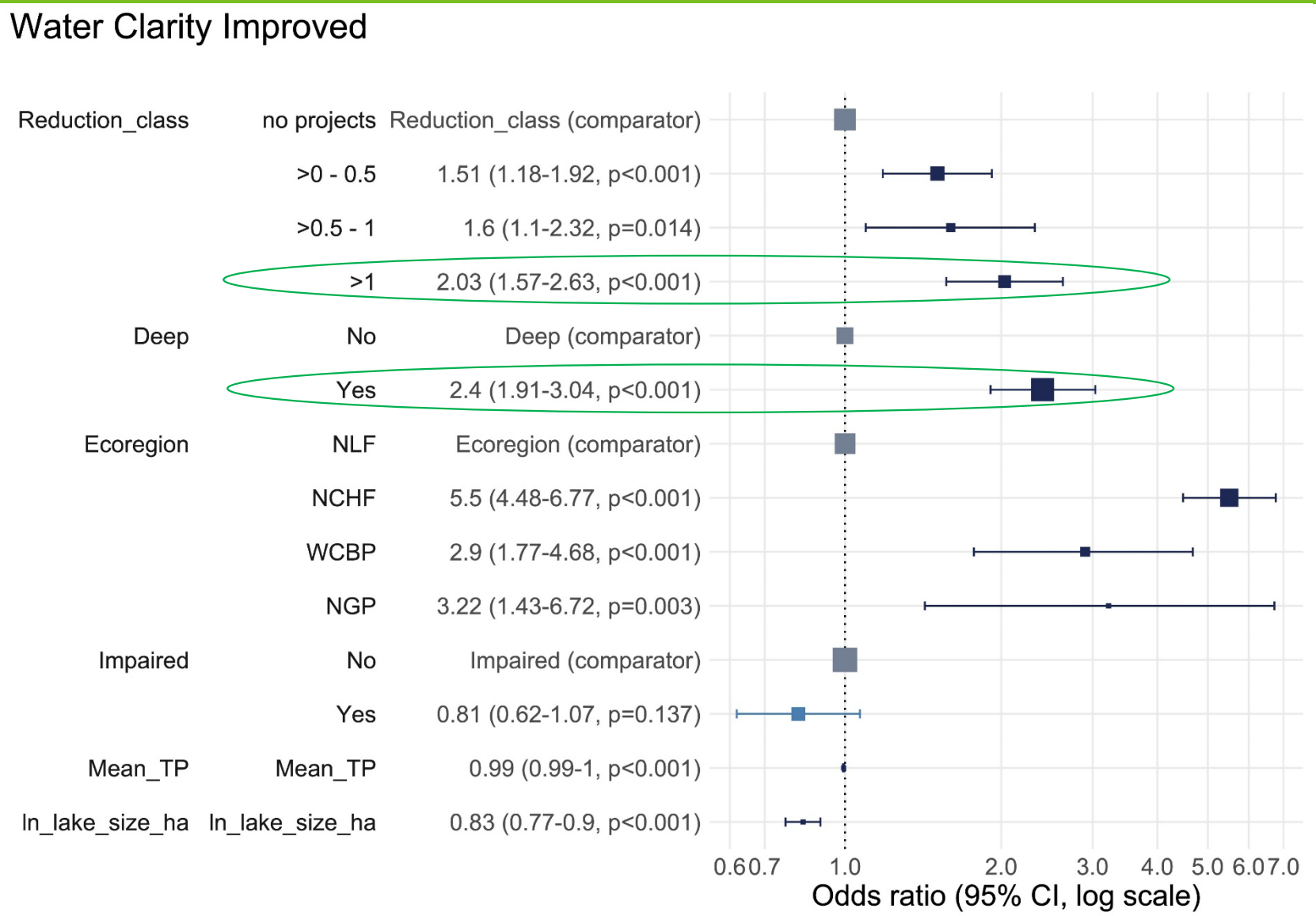
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Phosphorus reduction ratio = sum of P reduction (lbs/year) in 1000ft lake or contributing stream buffer, divided by load reduction goal (lbs/year).

Adjusted Odds Ratio Analysis

Logistic Regression

- The odds were 2 times higher of improved water clarity for lakes that exceeded 5% TP load reduction compared to lakes with no projects



Lessons learned about BMPs recorded in eLink

- Primary purpose of eLINK is a grant tracking not a project tracking application.
- Recording BMPs implemented with CW funds is inherently complicated.
  - Variety of estimators. (PTMApp practice, PTMApp summary, BEET, BWSR calculator, other).

##

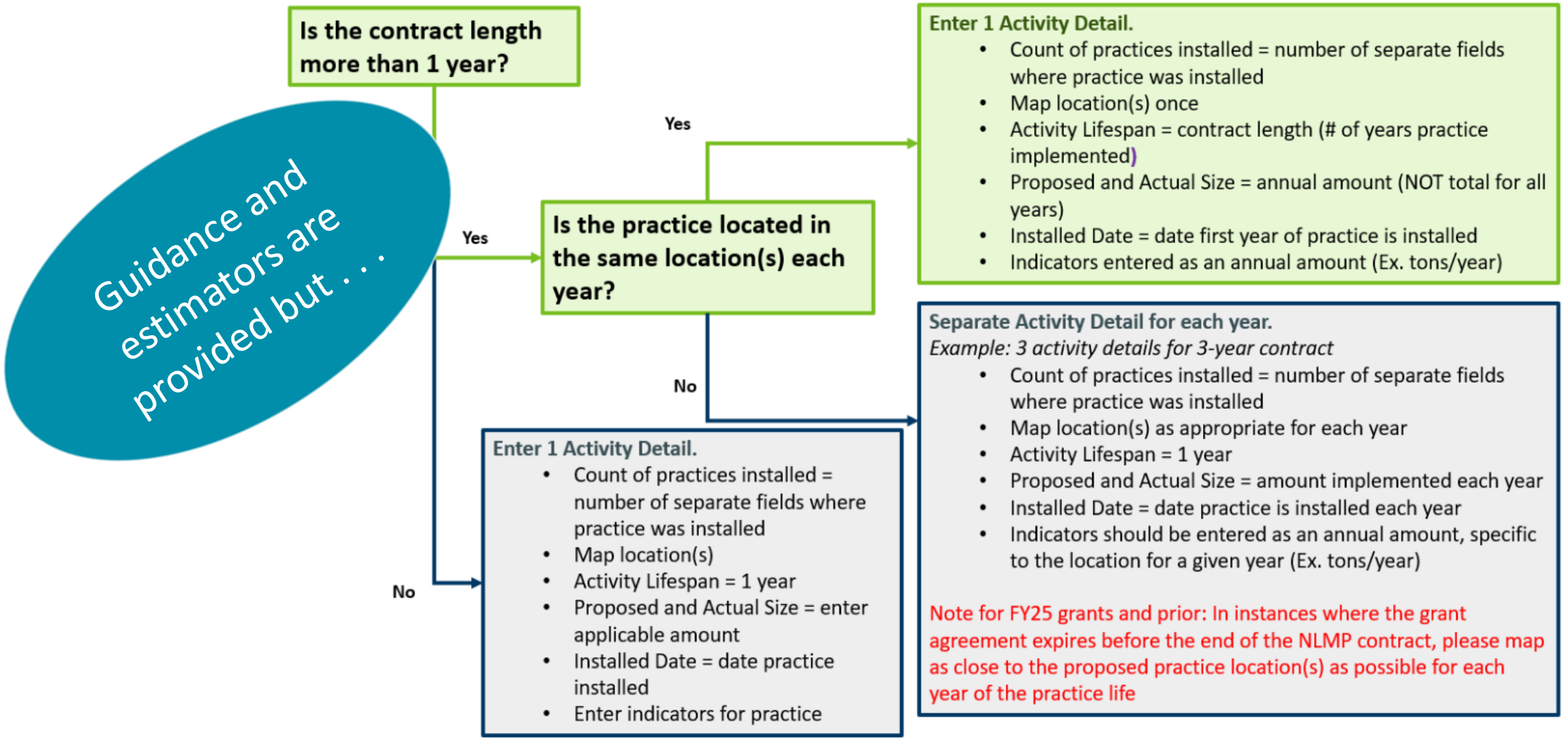
  - Variety of practice types (e.g., Structural with 10-25 year lifespans recorded as a count, non-structural in place for 1 year recorded as acres).
  - Practice outcomes may be part of a treatment train (i.e., double counting possible).

$$

  - Lumped costs for individual practices in one grant activity category (e.g., Ag. Practices).
  - Implementation costs may include “project development” and “technical and engineering”, and implementation costs may occur over multiple years and grants and use multiple funding sources.

Purpose: *This page provides guidance on how to report Nonstructural Land Management Practices (NLMPs) where a contract is implemented over multiple years, and where the practice location may change each year.*

NLMP Reporting Decision Tree:



Future considerations for recording BMP attributes

Can better guidance be provided for recording BMPs in elink?

Would it be better to record BMP outcomes through a different system?

Estimators – Many practices/variations/locations. Many people entering data.

- Simplify load reductions for some practices (e.g., shoreland restoration, use more standardized values per foot).
- Consider recording "acres treated" and whether part of a treatment train.
- Consider standardized cost accounting for each practice (NRCS and PTMApp already do this but costs can still vary widely for some practices). Practices that take years to develop and implement will still be particularly challenging.

Conclusions & Recommendations

- CWF investments are improving lake water clarity
- **The odds were 2-3 times higher of improved water clarity for lakes that exceeded 5% TP load reduction compared to lakes with no TP reduction projects**
- **Strive for higher lake TP load reductions (e.g., >15%)**
- Prioritize BMP investment:
  - Deep lakes rather than shallow lakes
  - High ROI lake
  - Within watershed areas that are or will contribute to TP load to surface water
- Improve BMP load reduction and cost reporting





Thank you

Unadjusted Odds Ratio Analysis

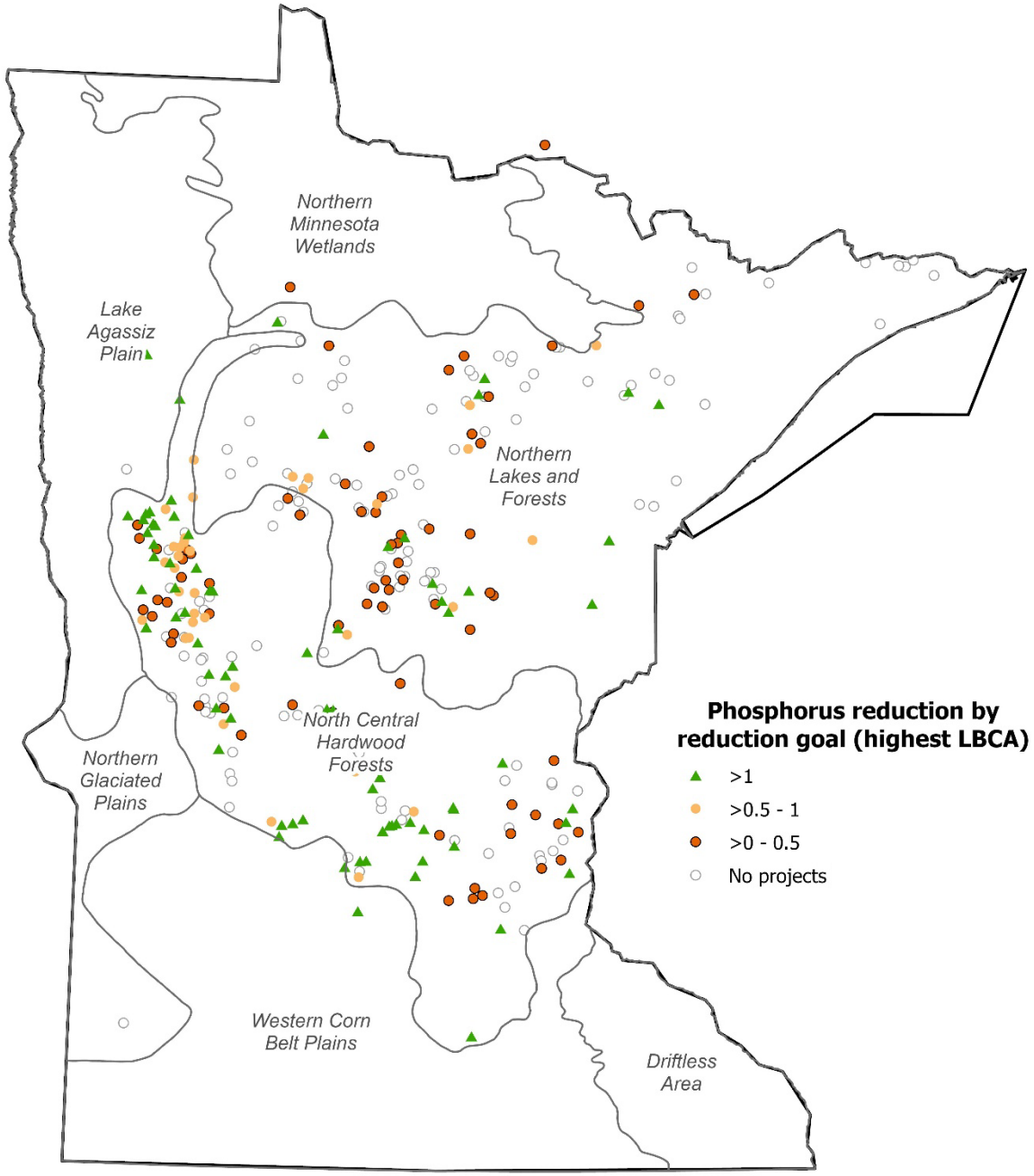
2x2 Contingency Table

- The odds were 3 times higher of improved water clarity for lakes that exceeded 5% TP load reduction compared to those that did not
- Deep lakes had higher odds

Lake Dataset	Odds Ratio	95% CI	P value
All lakes	3.0	2.4 – 3.7	<0.001
Lakes w/o zebra mussels	2.6	2.1 – 3.3	<0.001
Depth Type			
Deep	3.2	2.6 – 4.0	<0.001
Shallow	1.4	0.9 – 2.4	0.160

Number of Lakes with likely high ROI

	5 North Central Counties – Highest LBCA	11 Metro Counties – Highest LBCA
No TP reduction projects	48	18
>0 – 0.5	27	13
>0.5 – 1	8	1
>1 (exceeded 5%)	9	15
Total No. of Lakes	92	47



DEPARTMENT OF NATURAL RESOURCES

Sum of P reduction (lbs/year) in 1000ft lake or contributing stream buffer, divided by load reduction goal (lbs/year). Using Highest LBCA (Lake Benefit: Cost Assessment) lakes only.

Lake Nutrient Impairment Delisting

64 Lakes have been Delisted

- Watershed BMPs – implemented in 93% of the lakes
  - Urban Watershed BMPs (bioretention basins, stormwater, street sweeping, wetland restoration)
  - Ag Watershed BMPs (animal exclusion areas, feedlots, sediment control basins, wetland restoration)
- In-Lake BMPs – applied in 51% of the lakes (alum, carp management)

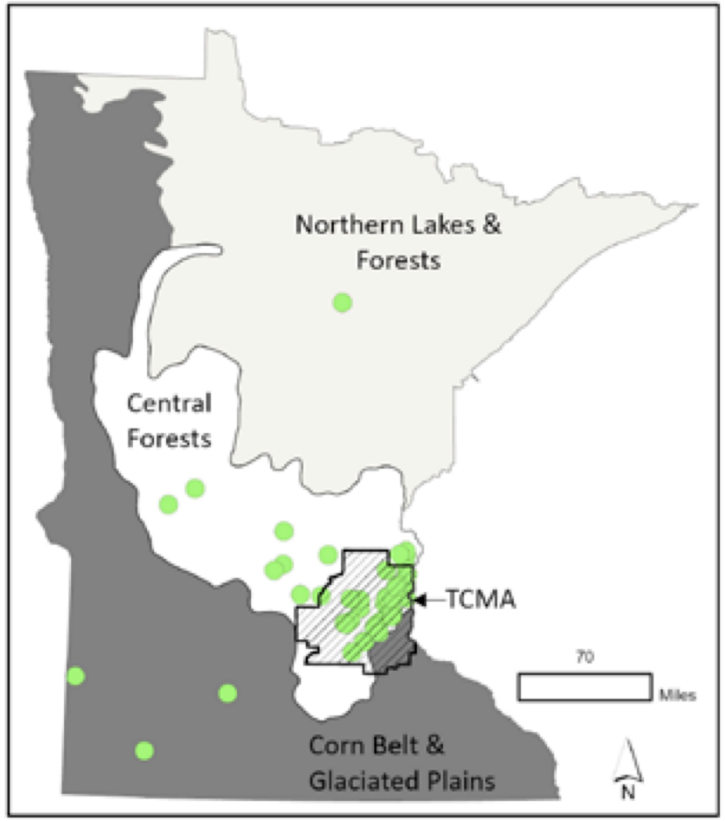


Figure 1. Map of Minnesota's delisted lakes (solid green circles) in relation to ecoregions and the Twin Cities Metro Area (TCMA).

Strom et al. 2024

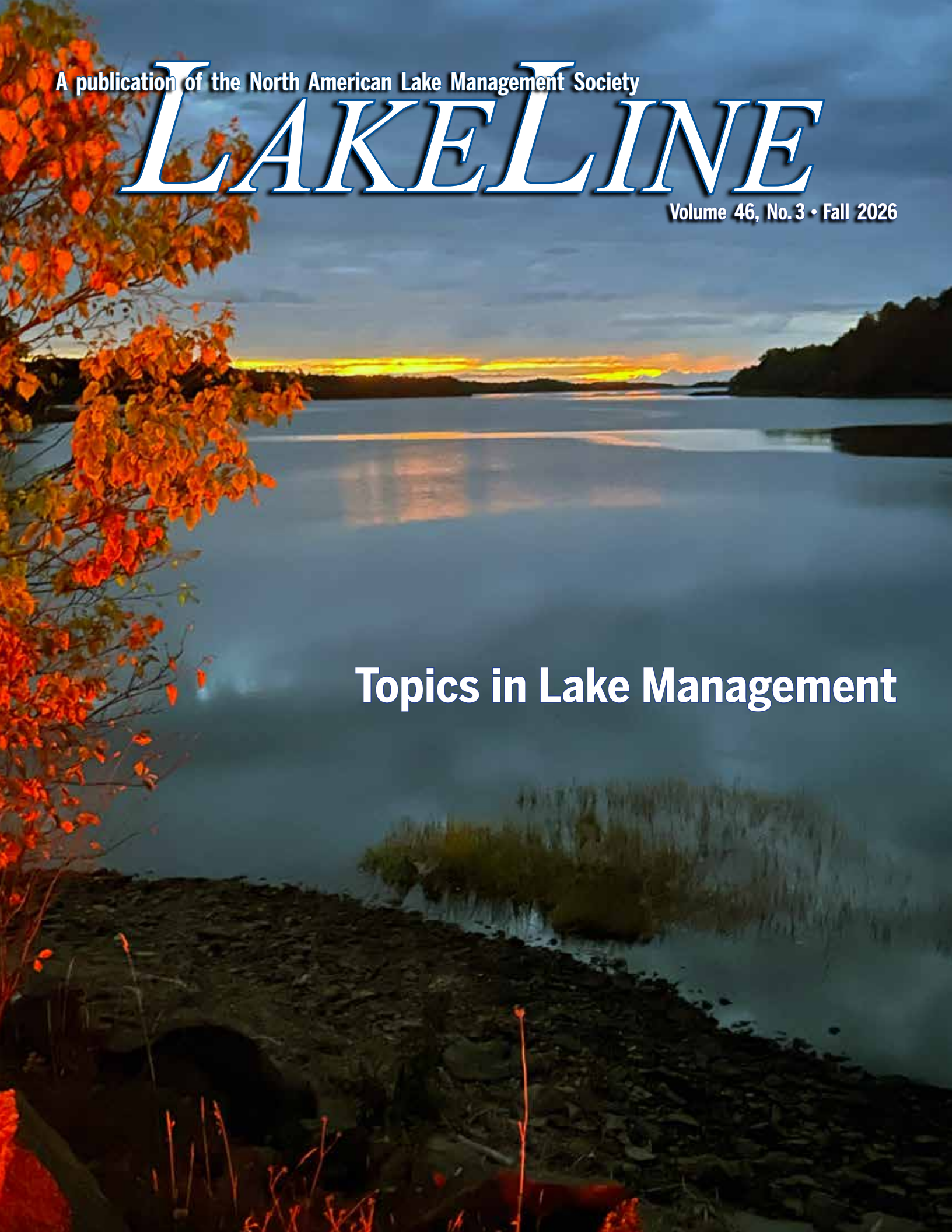
Probabilities, Odds, and Odds Ratio; Oh My!

- Probabilities -> the likelihood of something happening
  - If the probability of success is 0.8, the the probability of failure is 0.2
- Odds -> odds of success are defined as the probability of success divided by the probability of failure [p/(1-p)]
  - In the example, the odds of success are 0.8/0.2 = 4; the odds of success are 4 to 1
- Odds Ratio -> the ratio of the odds of Event A (improved water clarity) in Group 1 (exceeded 5% TP load reduction; reduction class >1) and odds of Event A (improved water clarity) in Group 2 (TP reduction class ≤1).
  - Odds Ratio = $(p_1/(1-p_1)) / (p_2/(1-p_2))$ **Ratio of two odds, so ratio of two ratios, Oh My!**

A publication of the North American Lake Management Society

LakeLine

Volume 46, No. 3 • Fall 2026



Topics in Lake Management

Has Minnesota's Legacy Amendment **improved lake water quality?**

Paul J. Radomski, Kristin Carlson, and Henry Van Offelen

In 2008, Minnesota voters passed a constitutional amendment dedicated to protecting and enhancing outdoor heritage, clean water, parks and trails, and arts and cultural heritage. This "Legacy Amendment" increased the state's sales tax by three-eighths of one percent for 25 years and has raised over $6 billion since 2010. The Clean Water Fund (CWF) was established by the Legacy Amendment, and it receives 33 percent of these revenues. The CWF provides authority, direction, and resources to achieve and maintain water quality standards for state waters. To date, $1.9B has been appropriated from the CWF to protect, enhance, and restore water quality in lakes, rivers, and streams and to protect groundwater from degradation. In addition, local governments and landowners have contributed via cost share match.

The question

Excess phosphorus is a major driver of eutrophication in Minnesota lakes, so implementing best management practices (BMPs) near lakes that reduce the phosphorus load is expected to improve lake water quality, including water clarity. Most CWF lake protection and restoration activities are BMPs implemented primarily on private lands through local soil and water conservation or watershed districts. The BMPs funded by the CWF are recorded within Minnesota's conservation grant tracking system (Minnesota Board of Water and Soil Resources' eLINK), which also includes estimates of total phosphorus reduction resulting from the BMP project or site. The spatial extent of BMPs with phosphorus reduction benefits has been widespread (Figure 1). The BMPs with the greatest total phosphorus (TP) reduction estimates included grassed waterways and swales, streambank and shoreline protection, grade stabilization structures, sediment removal, and water and sediment control basins. Many of these practices have likely reduced the amount of phosphorus released into surface waters.

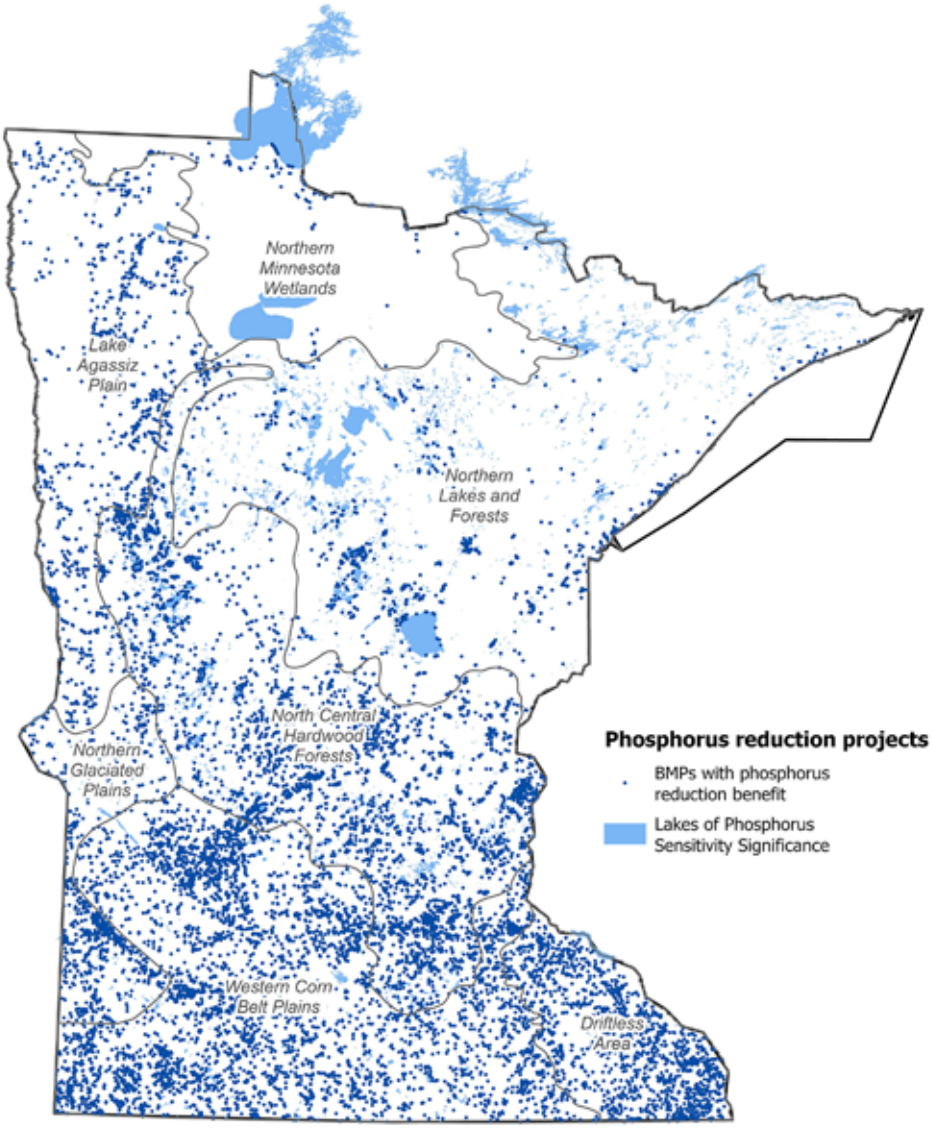


Figure 1. Lakes evaluated and locations with best management practices with phosphorus reduction benefits.

The objective is to assess the cumulative effect of BMPs on lake water clarity for thousands of lakes across the state and answer the question – Is there evidence that the CWF investments have made a difference to lake water clarity? We also provide recommendations to local governments on additional ways to

improve Minnesota lake water clarity. Finally, we outline the lessons learned from using the information from eLINK and provide suggestions to address the data reporting limitations that were found.

The datasets and analyses

Lake water chemistry, morphological data, and TP load were obtained from Minnesota's Lakes of Phosphorus Sensitivity Significance dataset (n = 3,187; Radomski and Carlson, 2018). This dataset is comprised primarily of medium to large fisheries-managed lakes across the state; it under-represents lakes in the northeast and non-fish shallow wildlife lakes statewide. A TP load reduction of 5 percent was estimated for each lake; this was a recommended starting goal provided to local land managers.

The BMP TP reduction estimates were acquired from eLINK, which included both CWF and non CWF projects. Local governments use recommended calculators to estimate TP reduction for their projects. These BMP data included projects implemented between 2013 to early 2026 (n = 15,039); outliers identified by eLINK and projects that didn't have a phosphorus reduction benefit were excluded.

The estimate of TP reduction within 1000 feet of each lake or connected waters within each lake's watershed was summed to estimate the total BMP TP reduction for the lake. For each lake, total BMP TP reduction was divided by the 5 percent TP load reduction estimate. If the resulting ratio was greater than 1, the lake was defined as having exceeded a 5 percent TP load reduction. This ratio was also grouped into TP reduction classes (no TP reduction projects, >0 – 0.5, >0.5 – 1, and >1).

Trends in lake mean summer water clarity values by year were used to evaluate the association between BMP activities and lake water quality. Mean summer water clarity (m) values were obtained from Minnesota LakeBrowser (Page et al., 2019), using all available data years between 1985-2025 (n = 17 years). These data were available for 3,145 of the 3,187 lakes. Lake water clarity trends by year were determined by testing the slope of linear regression lines. One-tailed Student t-tests were used to assess if the slopes were significantly different from zero in a specific direction (water clarity improved, declined, or no trend; *alpha* = 0.05).

Odds ratio estimates were made to test the association between exceeding a 5 percent TP load reduction and lake water clarity improvements. Odds ratio analysis was completed using two methods. First, unadjusted odd ratios were calculated from analyzing 2 x 2 contingency tables consisting of not exceeding and exceeding a 5 percent TP load reduction (TP reduction class ≤1 or >1) and not improved or improved water clarity trend. This approach assesses the strength of the association without controlling for other variables; it assumes that there are no confounding factors affecting the odds.

Second, adjusted odd ratios were estimated by logistic regression, which adjusts the odds ratios to account for the influence of other variables in the model that affect outcomes. The binary response variables were water clarity improved (represented by 1), and water clarity not improved (represented by 0). The following explanatory variables were tested in the regression: TP reduction class (no TP reduction projects, >0 – 0.5, >0.5 – 1, and >1), lake depth class (maximum depth <15 or ≥15 feet), ecoregion (Level 3, USEPA 2006), nutrient impairment status, average summer TP concentration, lake size (natural log transformation of lake surface area in ha), presence of zebra mussels, lake watershed health index (Knudsen et al., 2025), and TP loading sensitivity (Radomski and Carlson 2018).

To select the preferred regression, a top-down, stepwise deletion process and reliance on Bayesian information criterion (BIC) were used. The logistic regression may provide a more accurate assessment of exceeding a 5 percent TP load reduction than the contingency table analysis, as the regression holds all of the other explanatory variables constant in the model, thus isolating the role of the TP reduction class variable from the others.

Questions answered

Statewide, BMPs were implemented near 40 percent of the lakes. Among these lakes, 15 percent had BMPs implemented that resulted in at least a 5 percent TP load reduction. The North Central Hardwoods ecoregion had the highest number (338 lakes) and percentage of lakes (28 percent) that exceeded a 5 percent TP load reduction (i.e., BMP TP reduction/5 percent TP load reduction >1; Table 1, Figure 2).

About half the lakes had no trend in water clarity (Table 2). The remaining lakes were fairly evenly split between an improved or declining water clarity trend. Most of the lakes with improved water clarity were located in the central part of the state; 48 percent of the lakes in the North Central Hardwood Forest ecoregion had an improved water clarity trend (Figure 3). This ecoregion also had the largest number of lakes that both exceeded a 5 percent TP load reduction and had an improved water clarity trend (Figure 4).

Lakes that exceeded a 5 percent TP load reduction were more likely to have improved water clarity compared to lakes that did not. The unadjusted and adjusted odds ratios were similar. Based on the contingency table odds ratio analysis for the complete lake dataset, lakes that exceeded a 5 percent TP load reduction were 3.0 times more likely to have

Table 1. Number and percent of lakes by phosphorus reduction class. Ecoregions are North Central Hardwood Forests (NCHF), Northern Glaciated Plains (NGP), Northern Lakes and Forest (NLF), and Western Corn Belt Plains (WCBP).

	Ecoregion				
Reduction class	NCHF	NGP	NLF	WCBP	Statewide
No projects	497 (41%)	34 (48%)	1304 (7 %)	87 (40%)	1922 (60%)
>0 – 0.5	256 (21%)	14 (20%)	283 (17%)	68 (31%)	621 (19%)
>0.5 – 1	116 (10%)	5 (8%)	45 (3%)	12 (5%)	179 (6%)
>1	336 (28%)	17 (24%)	60 (4%)	52 (24%)	465 (15%)
Total	1205	71	1692	219	3187

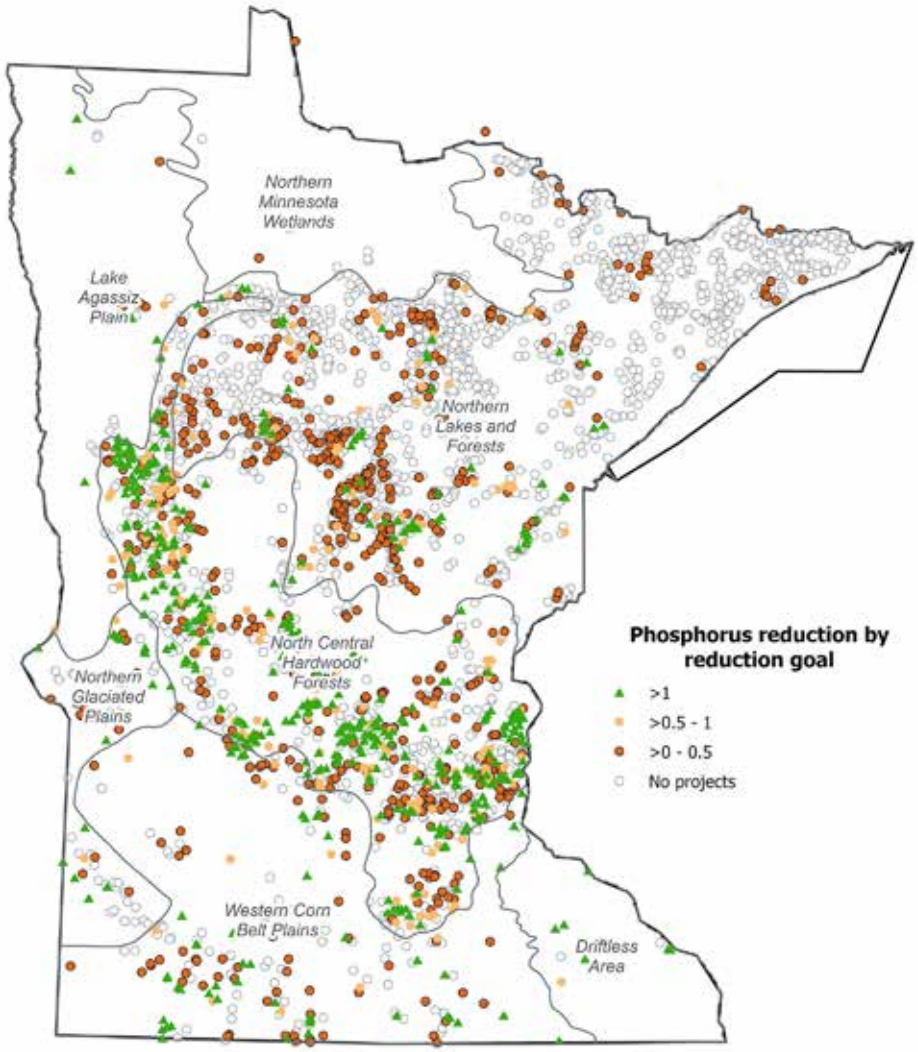


Figure 2. Phosphorus reduction class by lake and ecoregion (n = 3,187 lakes). No projects indicates no phosphorus reduction BMPs were implemented within 1000 feet of each lake or connected waters within each lake's watershed.

Table 2. Number and percent of lakes by water clarity trend and ecoregion.

	Ecoregion				
Trend	NCHF	NGP	NLF	WCBP	Statewide
Improved	578 (48 %)	10 (14 %)	300 (18 %)	32 (15 %)	920 (29 %)
Declined	118 (10 %)	20 (29 %)	561 (34 %)	71 (33 %)	770 (24 %)
No trend	500 (42 %)	39 (57 %)	802 (48 %)	114 (46 %)	1455 (46 %)
Total	1196	69	1663	217	3145

Table 3. Contingency table used to assess association between achieving phosphorus reduction goals (reduction class of >1) and lake water clarity improvements based on all lakes dataset.

Reduction Class	Water Clarity not Improved	Water Clarity Improved	Total
≤1	1998	687	2685
>1	227	233	460
Total	2225	920	3145

Unadjusted Odds Ratio = (233/227)/(687/1998) = 3.0

improved water clarity compared to lakes that did not exceed a 5 percent TP load reduction (Table 3). Lakes without zebra mussels had a similar odds ratio. Other unadjusted odds ratios for subsets of the lake dataset ranged from 1.4 to 3.7 (Table 4). Deep lakes had higher odds than shallow lakes; deep lakes that exceeded a 5 percent TP load reduction were 3.4 times more likely to have improved water clarity compared to lakes that did not. The logistic regression adjusted odds ratio estimated that lakes that exceeded a 5 percent TP load reduction were 2.0 times more likely to have improved water clarity compared to lakes with no TP reduction projects (Figure 5). In terms of percent change, the odds of having water clarity improve for lakes that exceeded a 5 percent TP load reduction were 100 percent higher than the odds with no TP reduction projects when holding all other variables constant. Deep lakes and lakes in North Central Hardwood Forest ecoregion were more likely to have water clarity improvements, whereas larger lakes and nutrient-impaired lakes were less likely to have water clarity improvements.

Lake management implications

Minnesota's Legacy Amendment has improved lake water quality. Lakes meeting a relatively small phosphorus load reduction of 5 percent of the total load had higher odds of improved water clarity. Lakes that exceeded a 5 percent TP load reduction were about two times more likely to have improved water clarity compared to lakes with no TP reduction projects. Other investigations have also found benefits of Clean Water Fund investments for lake water quality. The delisting of numerous nutrient-impaired lakes in Minnesota, for example, is associated with the implementation of lake and watershed BMPs (see Strom et al., 2024).

Several actions can increase the odds of improving Minnesota lake water quality. First, developing a priority lake list to help focus the investment of limited resources will be critical. We recommend that local governments strive for a 15 percent (or greater) reduction in TP loading for these priority lakes, instead of a 5 percent reduction. In addition, we suggest putting more resources into the watersheds of deep-water priority lakes.

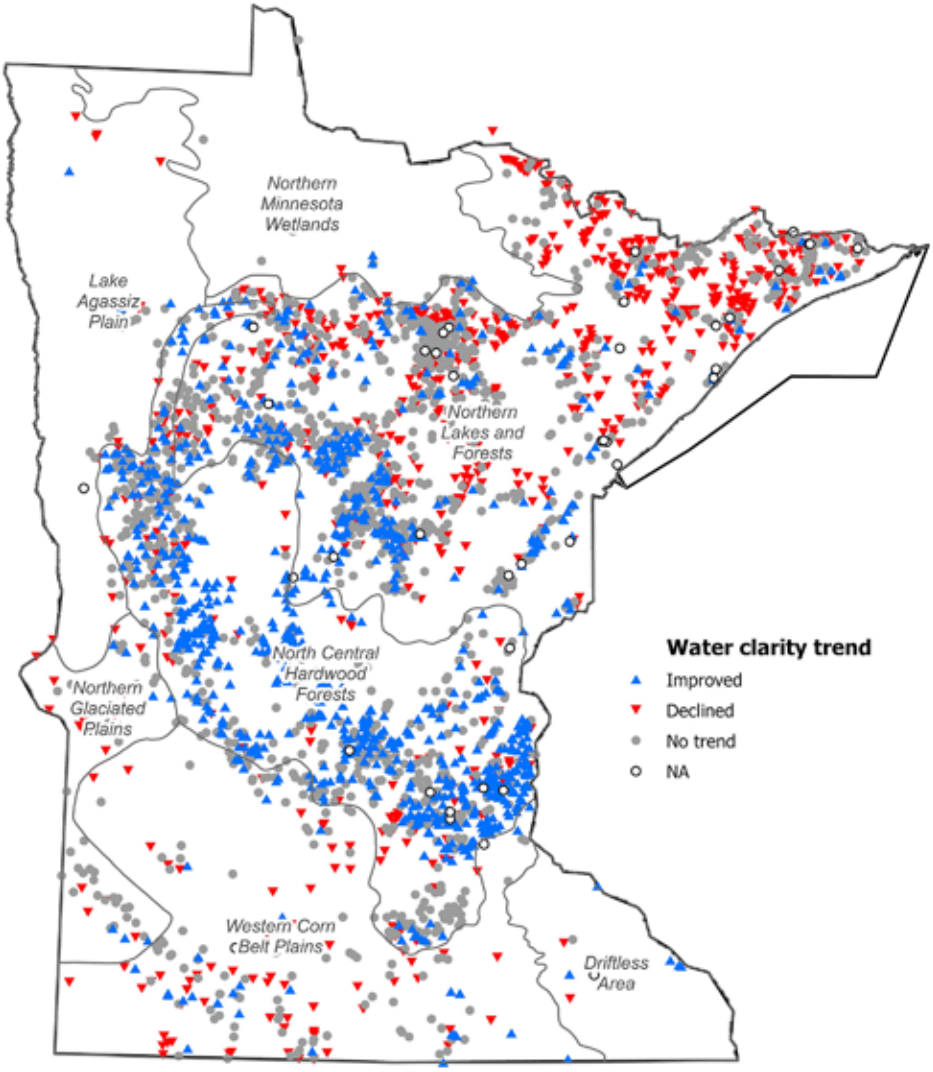


Figure 3. Water clarity trend (improved, declined, no trend, and data not available (NA) by lake and ecoregion (n = 3,145 lakes).

Table 4. Unadjusted odds ratio of improved water clarity for lakes that reached their phosphorus load reduction goals compared to lakes that did not.

Lake Dataset	Odds ratio	95 percent CI	P value
All lakes	3.0	2.4 – 3.7	<0.001
Lakes without zebra mussels	2.6	2.1 – 3.3	<0.001
Depth Type			
Deep	3.4	2.7 – 4.3	<0.001
Shallow	1.7	1.1 – 2.7	0.034
Ecoregion			
NCHF	1.6	1.3 – 2.1	<0.001
NGP	1.4	0.3 – 6.0	0.699
NLF	3.7	2.2 – 6.3	<0.001
WCBP	3.1	1.4 – 6.8	0.006

Prioritizing BMPs in locations that are likely contributing to lake phosphorus load (or would if the land use changed) will also increase the odds of improving (or protecting) water clarity. Finally, a better understanding about benefit:cost ratios will help local governments target lakes and watershed locations to get higher returns on investment. We explored obtaining cost estimates for BMPs, but several challenges currently exist.

Additional guidance to local governments and modifying existing reporting systems is also warranted to improve cost accounting and reporting TP reduction estimates. The eLINK database system was developed to track diverse grant expenditures (e.g., administration, project development, technical and engineering, and BMP implementation) and report outcomes for actions implemented throughout the entire state.

A variety of load reduction estimation tools can be used to enter outcomes associated with an implemented BMP. Additional guidance is needed to increase consistency and accuracy while minimizing the reporting burden to local government staff. The reported costs for individual BMPs were not easily known in many cases because they were combined into one activity category for an entire grant (i.e., agricultural BMPs).

In addition, reporting costs for some practices (e.g., stream restoration) are inherently complicated because expenditures may occur over several years through multiple funding sources and grant periods, where costs may include project development, land acquisition, technical and engineering, and implementation. TP reduction estimates reviewed in this study were highly variable within some BMP types even though there is current guidance to use one of several standardized calculators.

These reported estimates of TP reduction for various BMPs are likely to have biases that are poorly understood; however, these reported estimates are currently the best available data. Additional standardization of TP reduction estimates by BMP type is possible and has merit. For example, it may be prudent for some BMP types to use regional average TP load reductions estimates rather than depend on one of multiple TP reduction calculators.

It is reasonable to conclude that Minnesota Clean Water Fund investments are improving lake quality, even in an environment where the climate is changing, agriculture land use is expanding, and lake development is accelerating. Those investments have resulted in thousands of BMPs in lake watersheds across the state. Minnesota

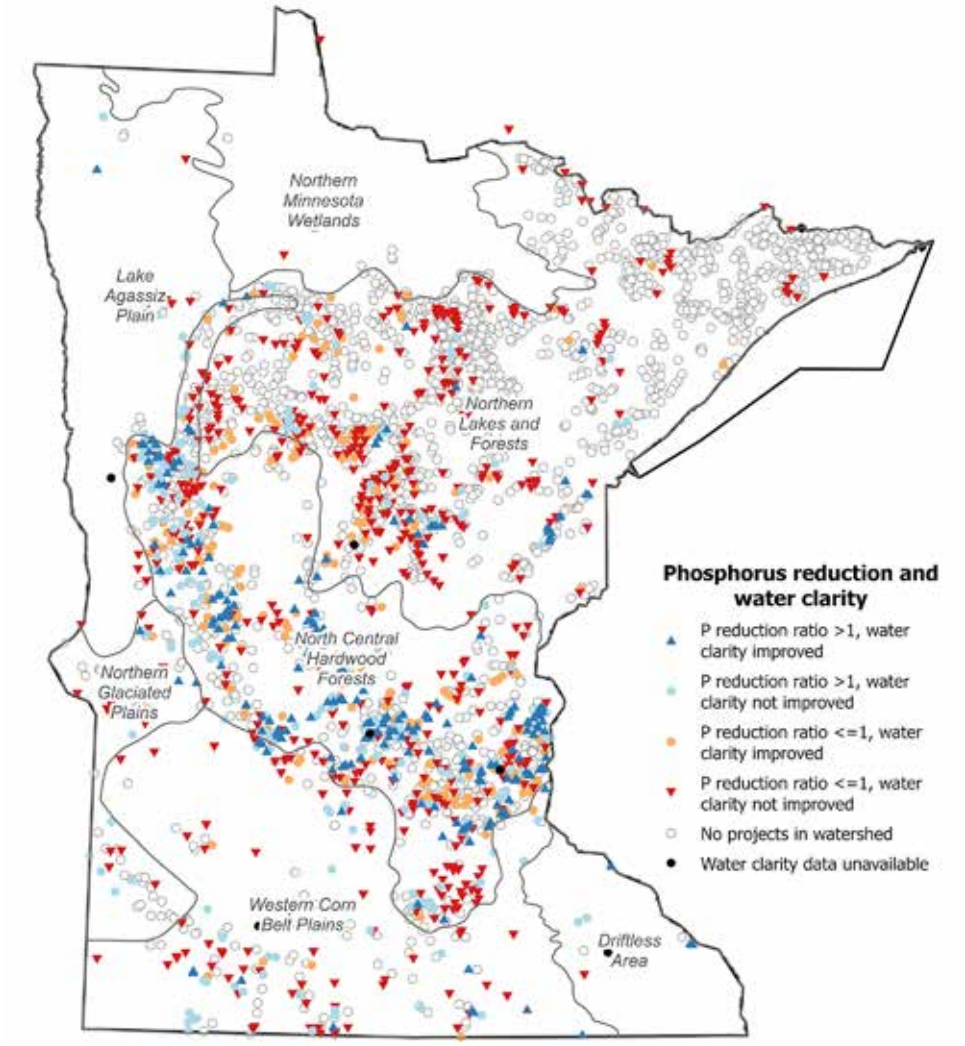


Figure 4. Phosphorus reduction class and water clarity trend by lake and ecoregion (n = 3,145 lakes). No projects indicates no phosphorus reduction BMPs were conducted within 1000 feet of each lake or connected waters within each lake's watershed.

voters passed the Legacy Amendment in the belief that it was important to protect and restore our lakes, which drive our economy and improve our quality of life in Minnesota. Now, we need to analyze the most cost effective BMPs and lake management tools to protect and restore lake health and use that knowledge to improve the return on investment for the citizens of Minnesota (Figure 6).

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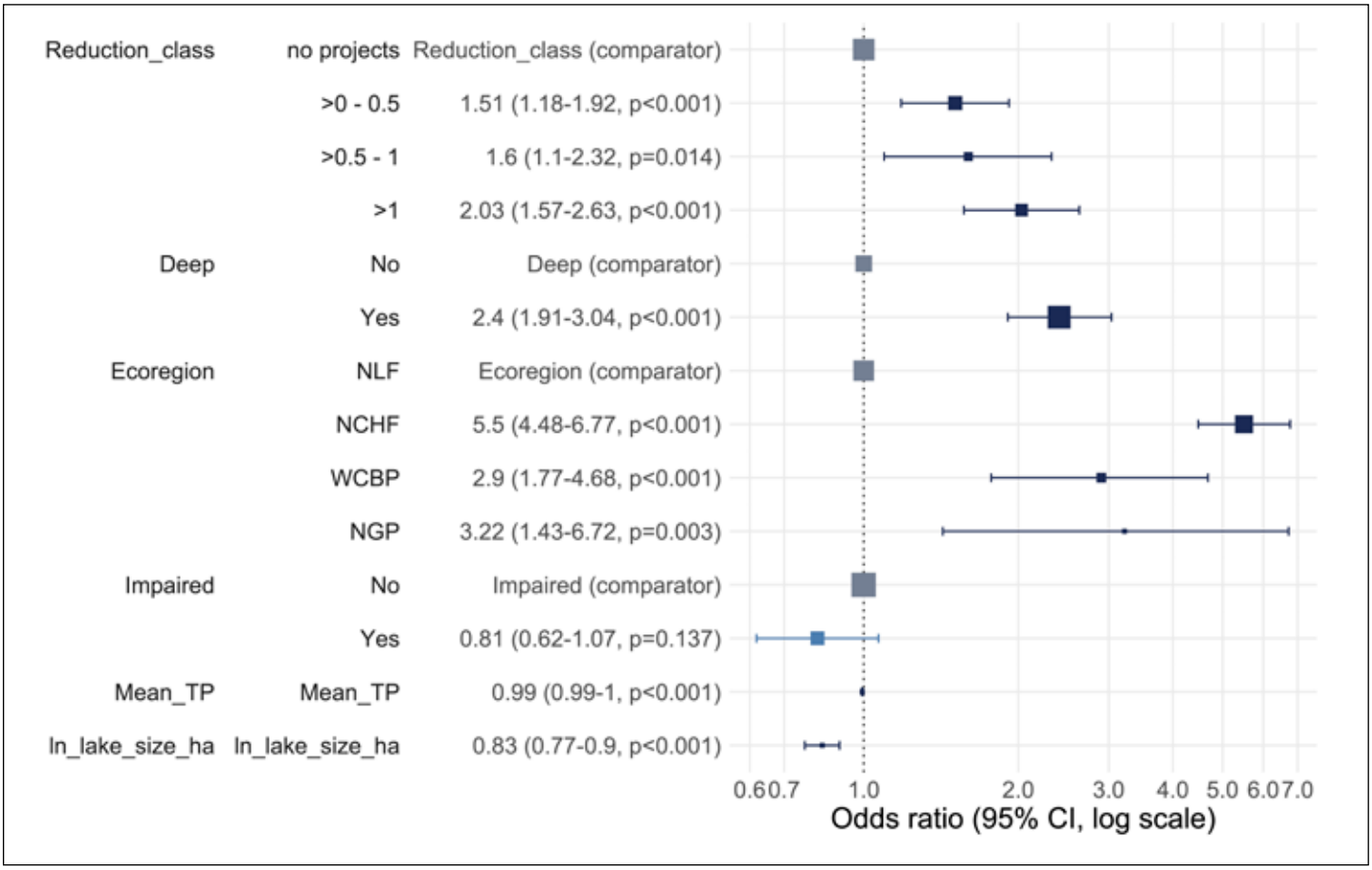


Figure 5 (above). Adjusted odds ratio and 95 percent confidence intervals for explanatory variables from a logistic regression. The squares represent the estimate for the odds ratio, and size of the squares are proportional to the number of observations. The dotted line at 1 represents an odds ratio with no association, and confidence intervals that touch or cross the line are considered to have no difference in likelihood than the associated comparator. Coded variables are phosphorus reduction class (Reduction_class), lake depth class (Deep: Yes or No), ecoregion (North Central Hardwood Forests (NCHF), Northern Glaciated Plains (NGP), Northern Lakes and Forest (NLF), and Western Corn Belt Plains (WCBP)), nutrient impaired (Impaired), and average total phosphorus (Mean_TP), and lake size (natural log transformation of lake surface area in ha; ln_lake_size_ha)

Figure 6 (at right). Clean Water Land and Legacy Amendment logo.

CLEAN WATER LAND & LEGACY AMENDMENT

Errata (October 30, 2026):

Some of the odd ratio results were technically misstated, so the incorrect "more likely" probability statements were replaced with the phrase "higher odds" (the changed text is underlined).

In the last paragraph in "Questions Answered" section:

Based on the contingency table odds ratio analysis for the complete lake dataset, lakes that exceeded a 5% TP load reduction had 3.0 times higher odds to have improved water clarity compared to lakes that did not exceed a 5% TP load reduction (Table 3). Lakes without zebra mussels had a similar odds ratio. Other unadjusted odds ratios for subsets of the lake dataset ranged from 1.4 to 3.7 (Table 4). Deep lakes had higher odds than shallow lakes; deep lakes that exceeded a 5% TP load reduction had 3.4 times higher odds to have improved water clarity compared to lakes that did not. The logistic regression adjusted odds ratio estimated that lakes that exceeded a 5% TP load reduction had 2.0 times higher odds to have improved water clarity compared to lakes with no TP reduction projects (Figure 5). In terms of percent change, the odds of having water clarity improve for lakes that exceeded a 5% TP load reduction were 100% higher than the odds with no TP reduction projects when holding all other variables constant. Deep lakes and lakes in North Central Hardwood Forest ecoregion were more likely to have water clarity improvements, whereas larger lakes and nutrient-impaired lakes were less likely to have water clarity improvements.

I*n the first paragraph in "Lake Management Implications" section:*

Minnesota's Legacy Amendment has improved lake water quality. Lakes meeting a relatively small phosphorus load reduction of 5% of the total load had higher odds of improved water clarity. Lakes that exceeded a 5% TP load reduction had about two times higher odds to have improved water clarity compared to lakes with no TP reduction projects. Other investigations have also found benefits of Clean Water Fund investments for lake water quality. The delisting of numerous nutrient-impaired lakes in Minnesota, for example, is associated with the implementation of lake and watershed BMPs (see Strom et al., 2024).

NDSU

Water Quality Trends and Cost-Effective Analysis of Conservation Practices in Minnesota

Zhulu Lin & Ashley Crowl

Agricultural & Biosystems Engineering Department

Presented at the Minnesota Clean Water Council on November 16, 2026

NORTH DAKOTA STATE UNIVERSITY

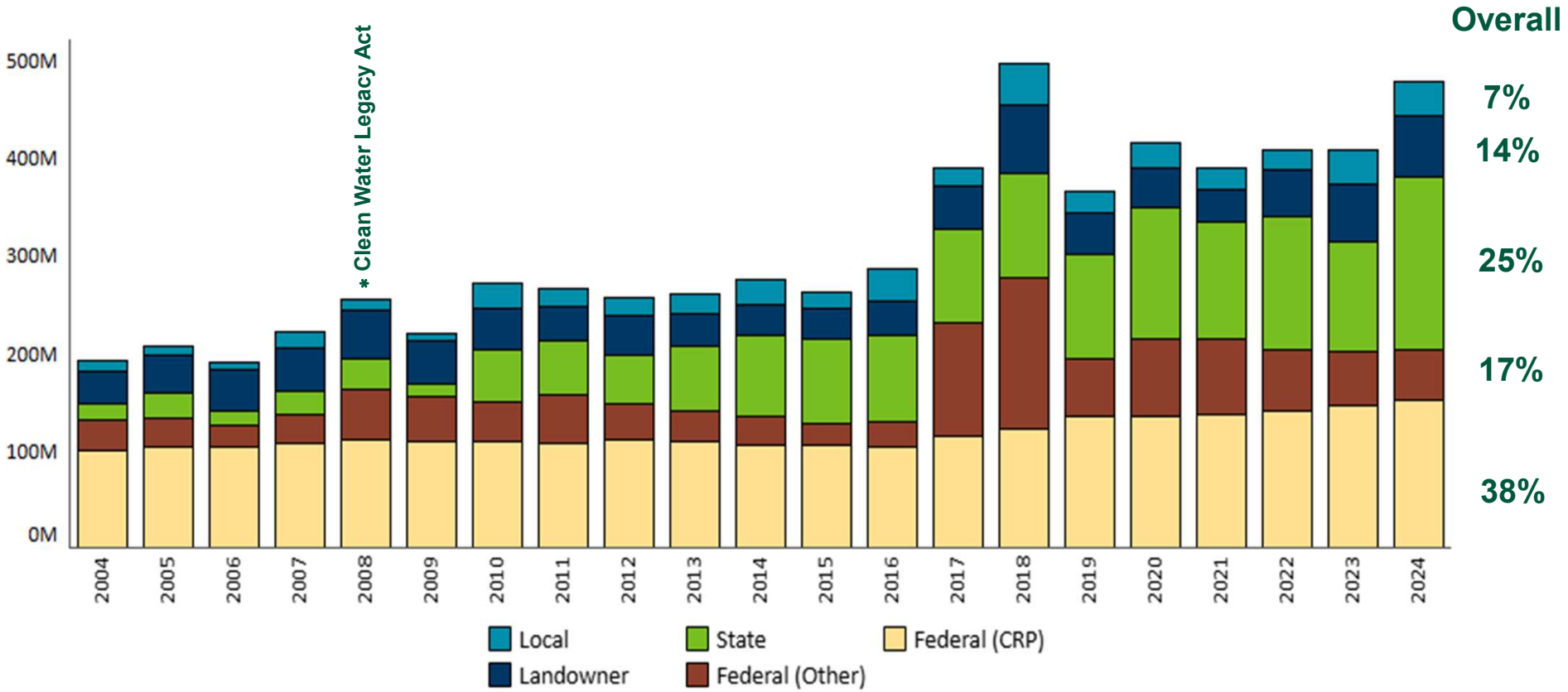
Acknowledgements

- **Funded by the International Water Institute, NDSU ABEN Department & Environmental and Conservation Sciences Graduate Program**
- **Chloe Chen (Northwestern University) and Evelyn Chen (The Meadows School), volunteers**



Dr. Jay Leitch (1948 – 2024)
Barnesville, Minnesota

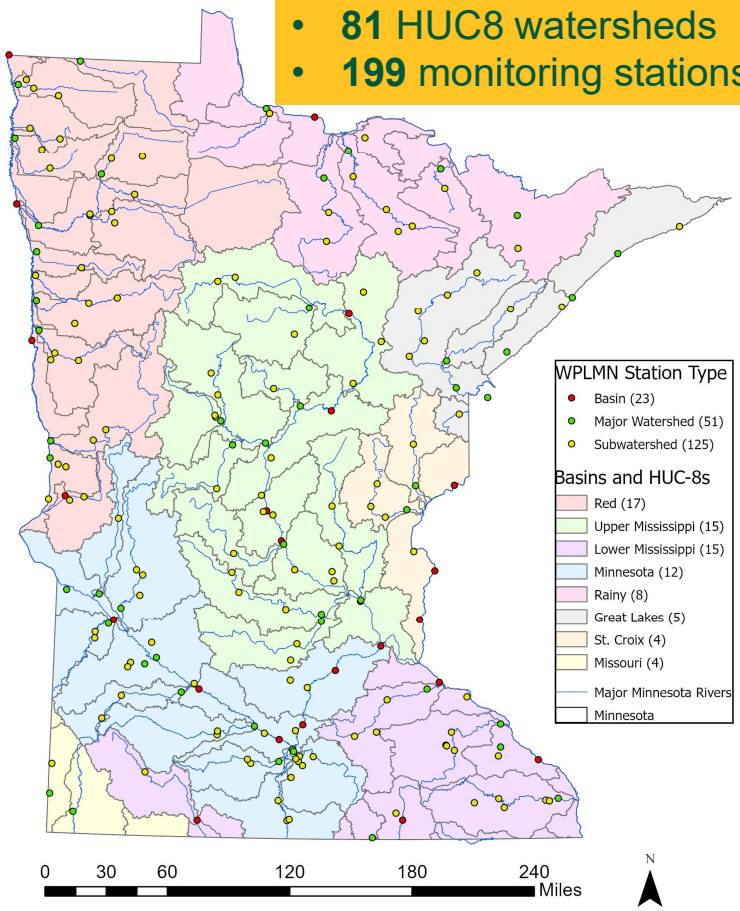
Spending for Water Quality Implementation Projects (MPCA website)



Research Questions

1. **Has Minnesota water quality improved over the last 15 years?**
   - Water quality trends
2. **Has expenditure on conservation practices proven to be cost-effective?**

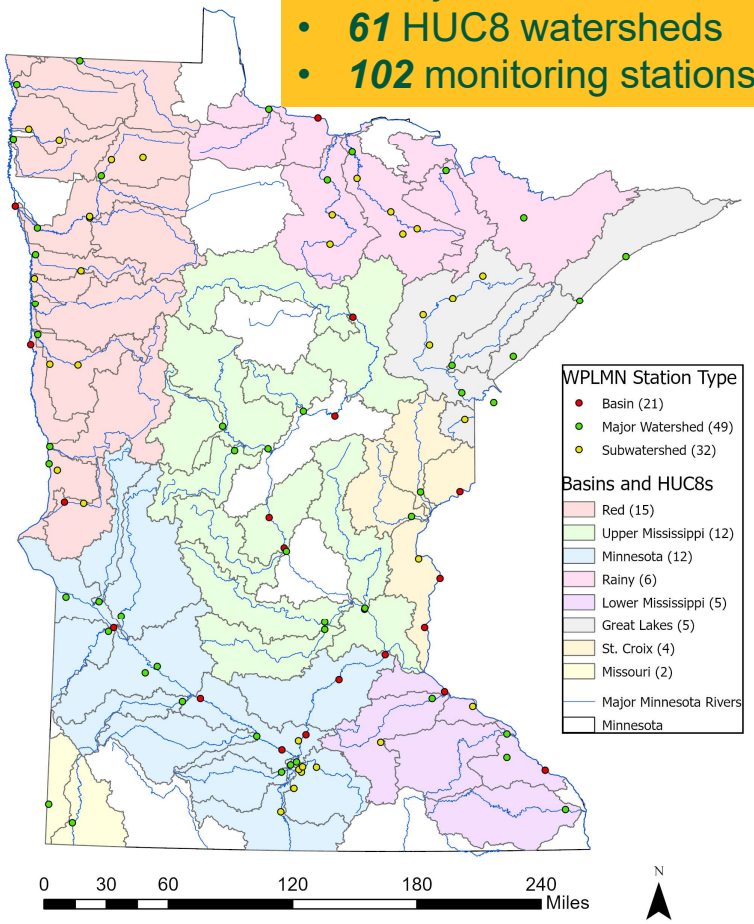
- **8** major basins
- **81** HUC8 watersheds
- **199** monitoring stations



Q1. Trend Analysis

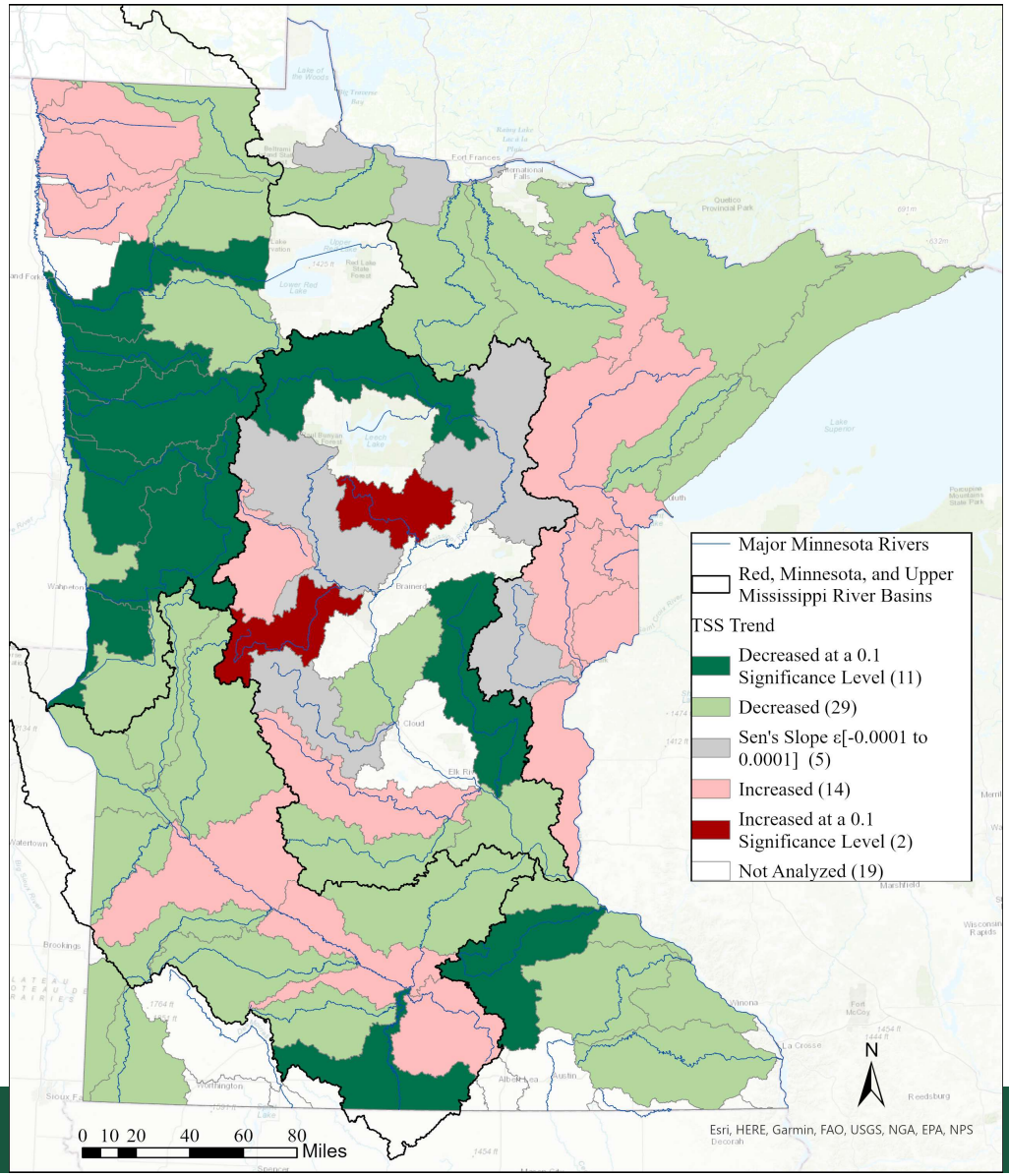
- **Data**
  - Annual flow-weighted concentrations downloaded from the WPLMN website
  - 5 water quality parameters: TSS, TKN, NOx-N, TP, & PO_4-P
  - Stations with 10 years of data or more (2007-2021)
- **Analysis**
  - Mann-Kendall trend test with Sen's slope
  - Implemented in RStudio
  - Tested at a 10% significance level

- ***8*** major basins
- ***61*** HUC8 watersheds
- ***102*** monitoring stations



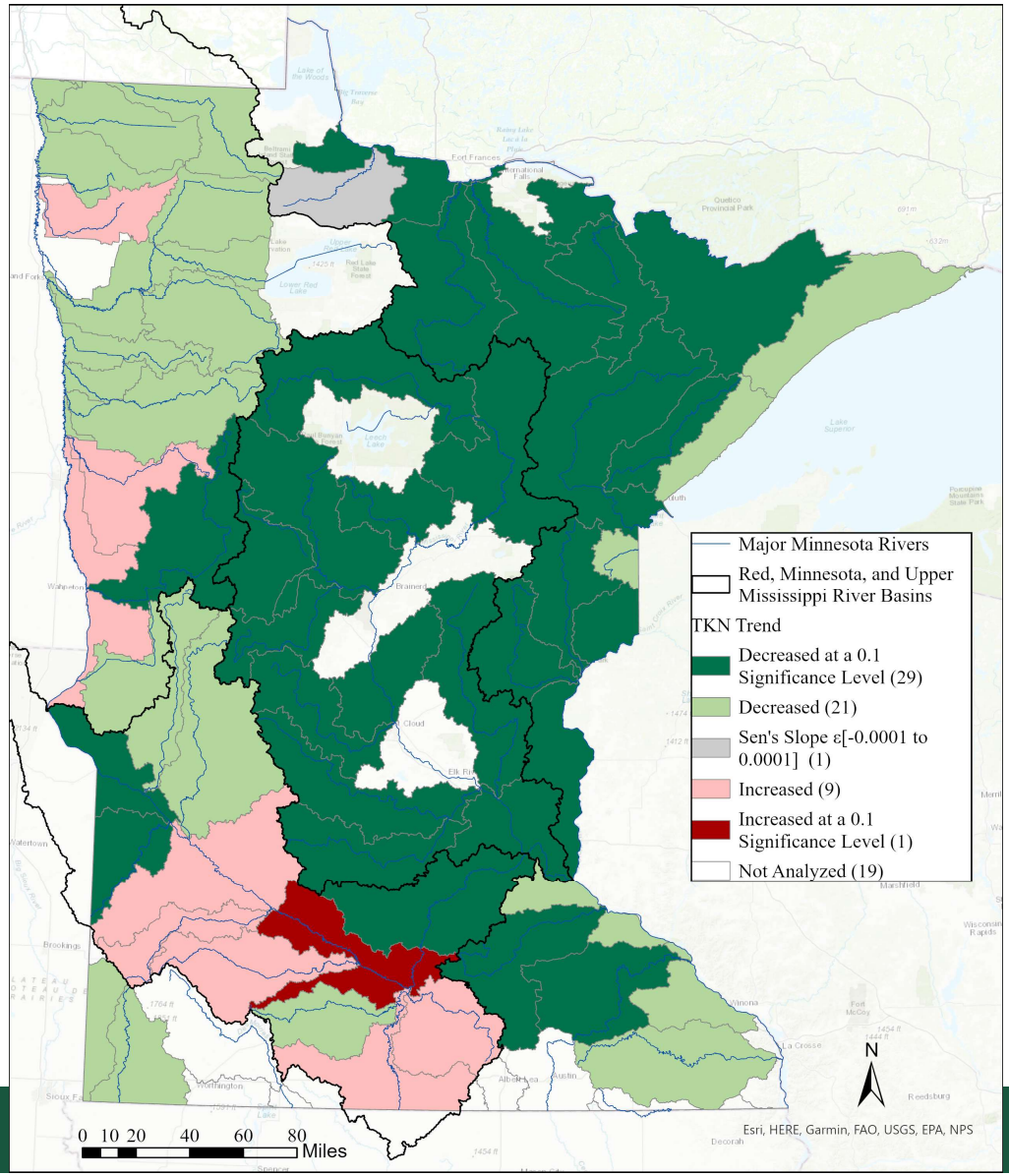
Total Suspended Solids (TSS)

- Decreasing in **66%** of watersheds
- Increasing in **26%** of watersheds
- Not changing in 8.2% of watersheds



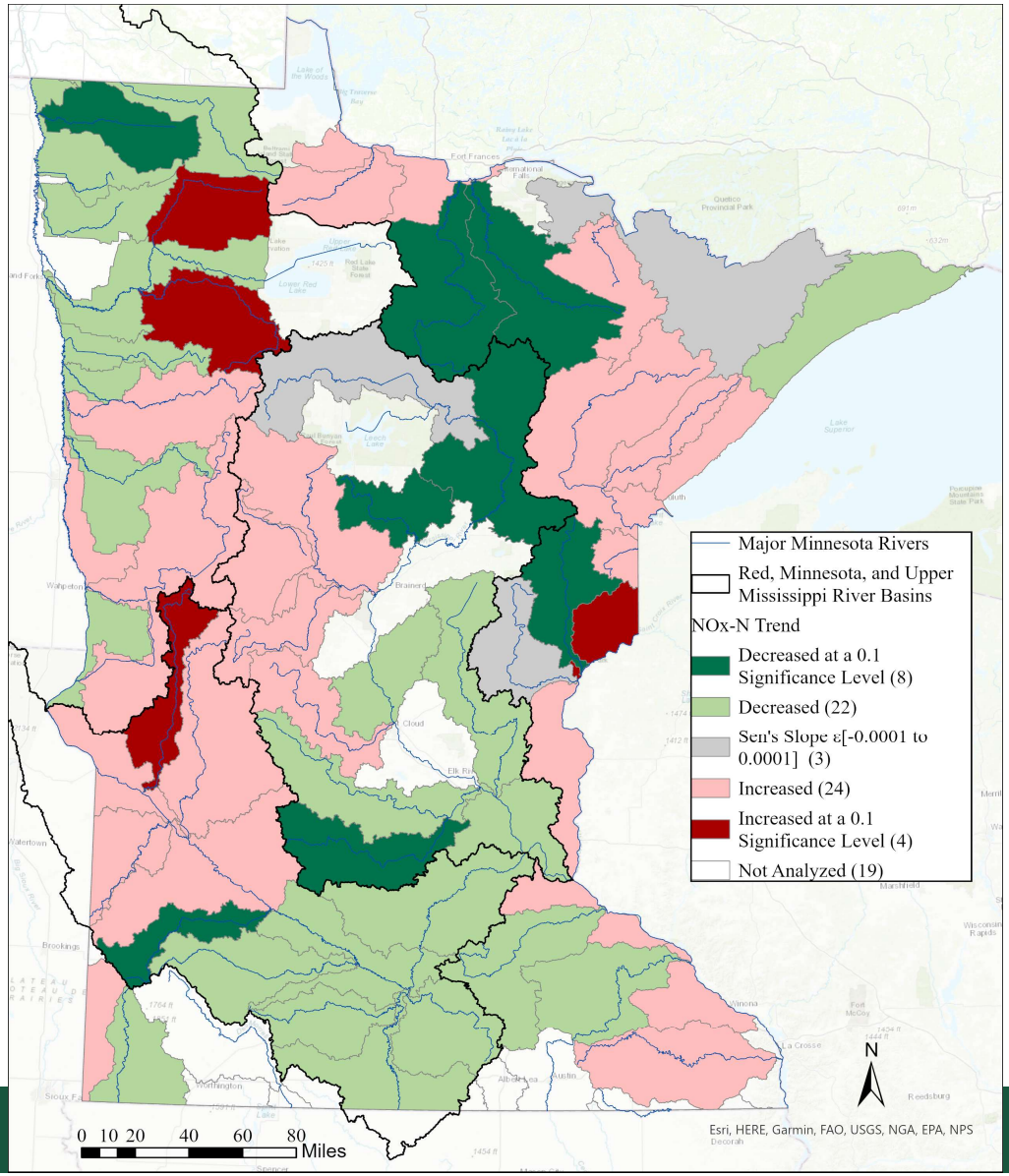
Total Kjeldahl Nitrogen (TKN)

- Decreasing in **82%** of watersheds
- Increasing in **16%** of watersheds
- Not changing in 1.6% of watersheds



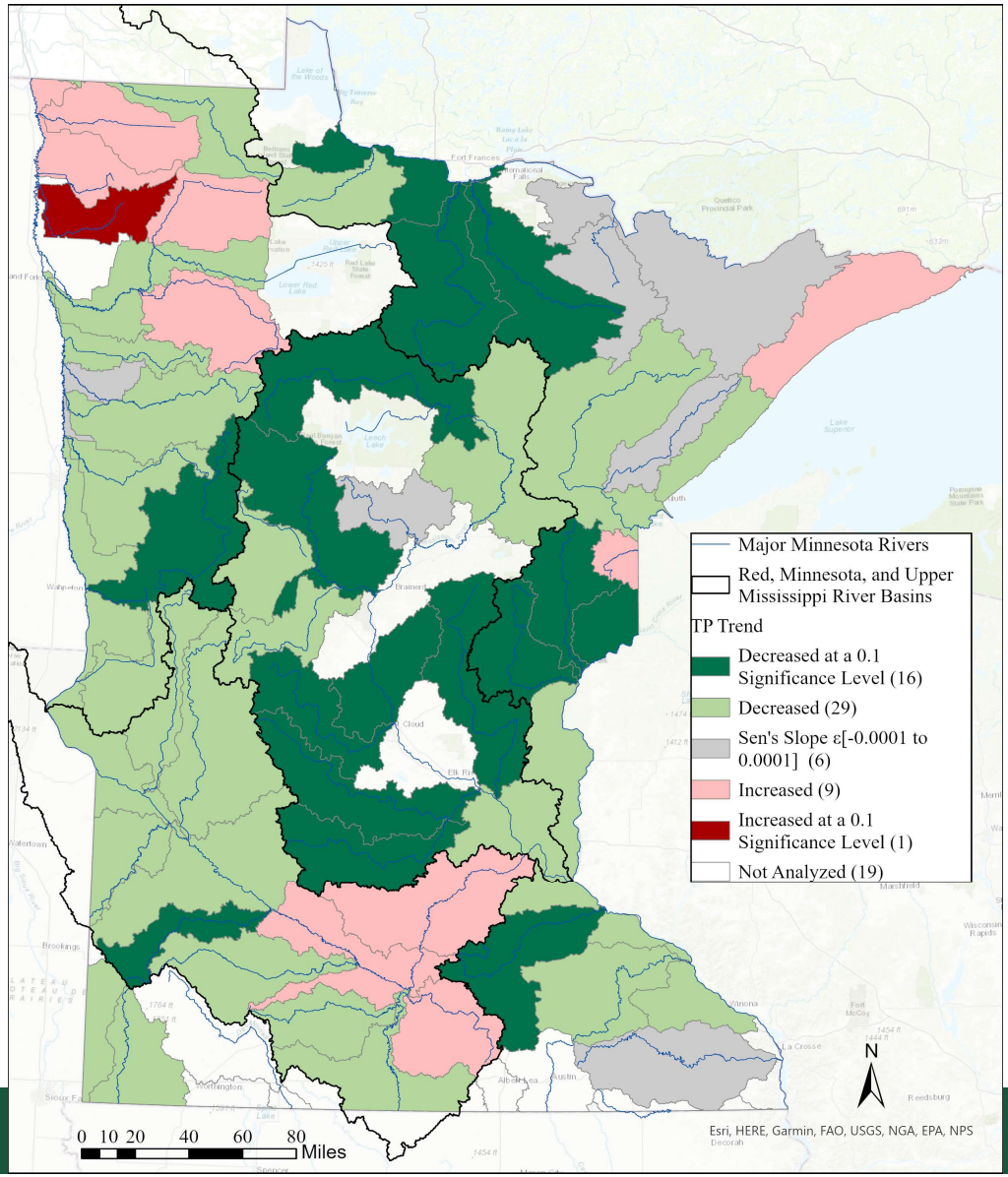
Nitrate + Nitrite (NOx-N)

- Decreasing in **49%** of watersheds
- Increasing in **46%** of watersheds
- Not changing in 5.0% of watersheds



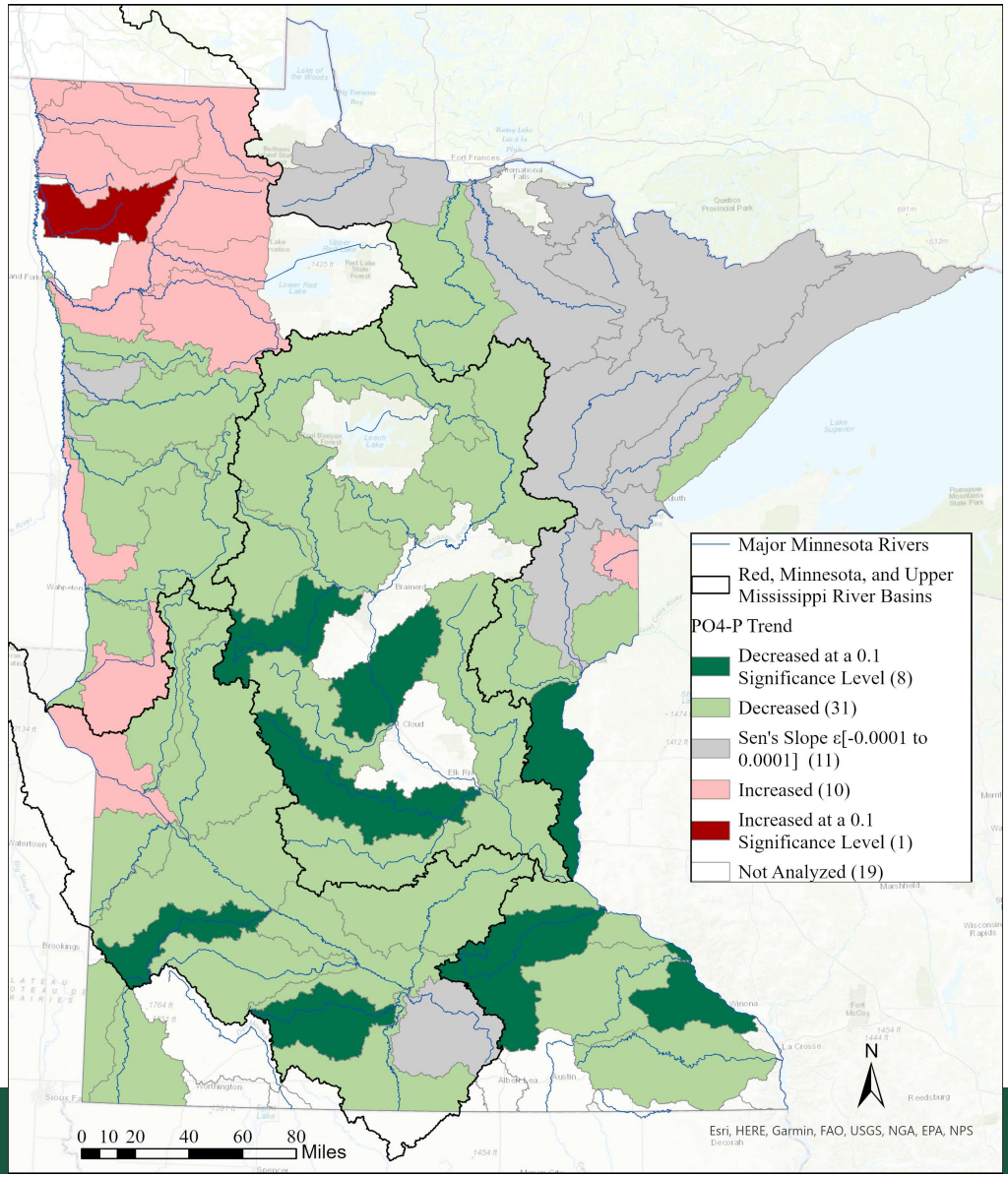
Total Phosphorus (TP)

- Decreasing in **73%** of watersheds
- Increasing in **16%** of watersheds
- Not changing in 10% of watersheds

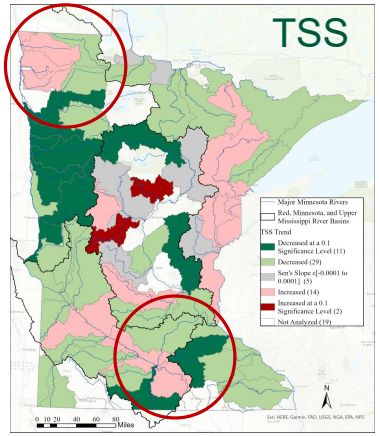


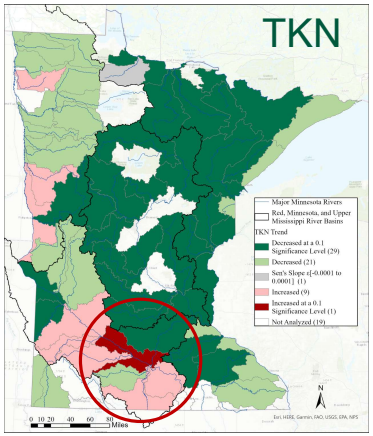
Orthophosphate (PO_4-P)

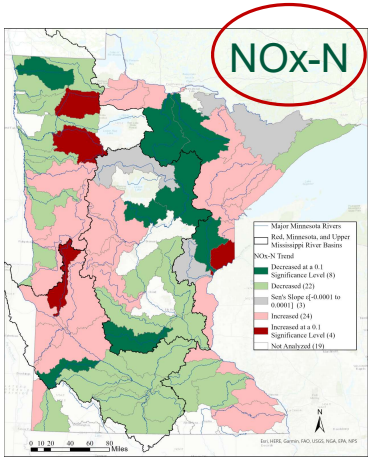
- Decreasing in **64%** of watersheds
- Increasing in **18%** of watersheds
- Not changing in 18% of watersheds

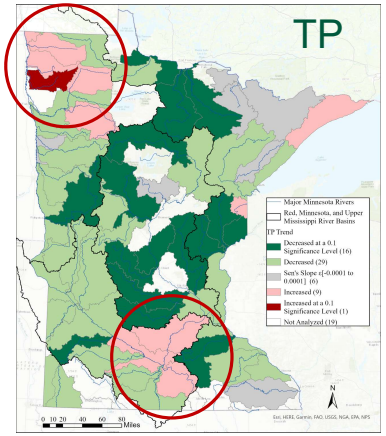


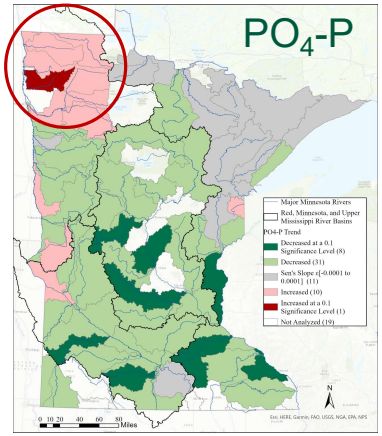
Q1 Conclusions and Recommendations









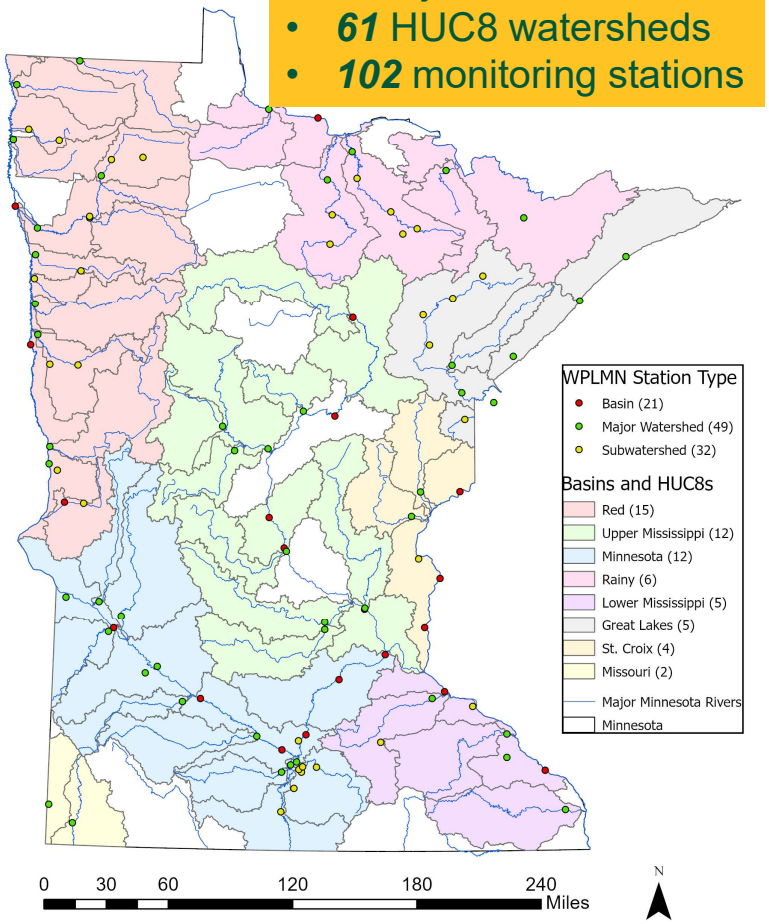


- Surface water quality has overall improved over the past 15 years, except for NOx-N
- Future conservation emphasis and hotspots:
  - NOx-N across the state
  - Downstream watersheds of the Red River Basin and the Minnesota River Basin

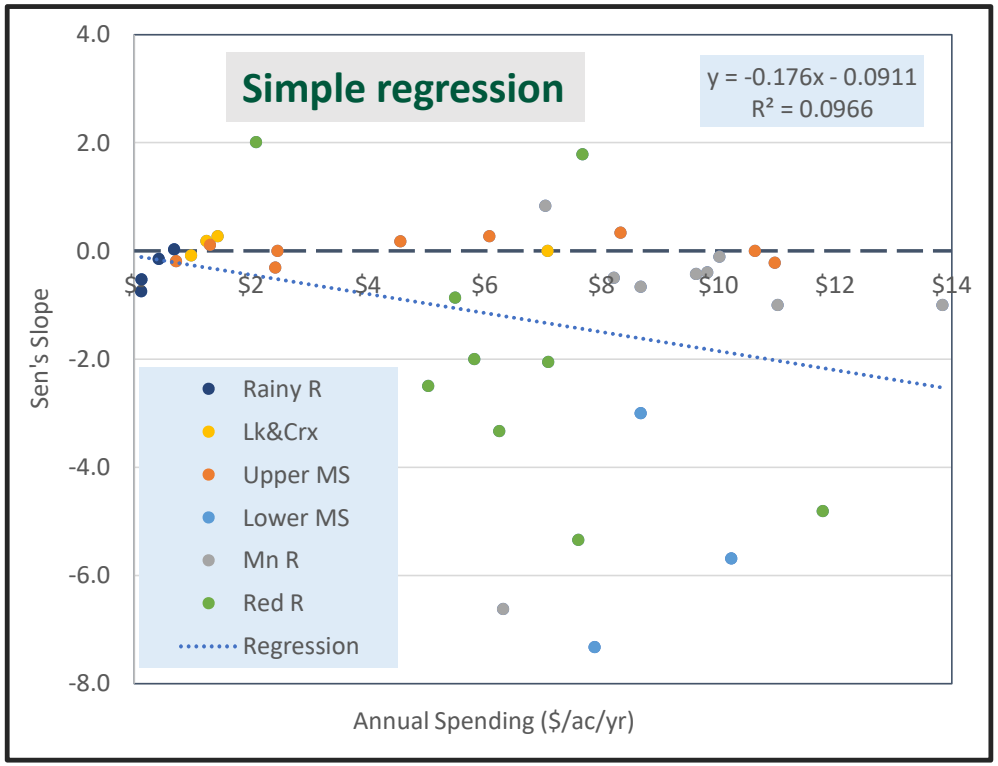
Q2. Cost-Effectiveness Analysis

- **Simple linear regression**
  - Sen's slope (degree of trend) vs. annual spending per acre ($/ac/yr)
  - Limited to 38 ***upstream*** HUC8 watersheds only
- **Mixed-effects regression**
  - Control for natural and human factors, e.g., locations, topography, soils, land use, climate, time, upstream vs. downstream
  - Concentration vs. funding sources
  - Applied to all *61* HUC8 watersheds with 10 years of data or more

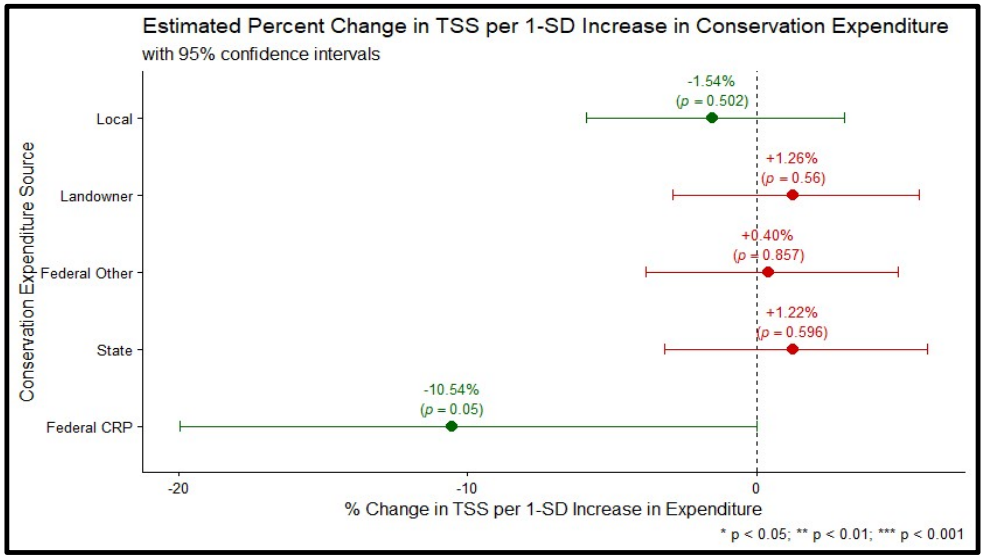
- ***8*** major basins
- ***61*** HUC8 watersheds
- ***102*** monitoring stations



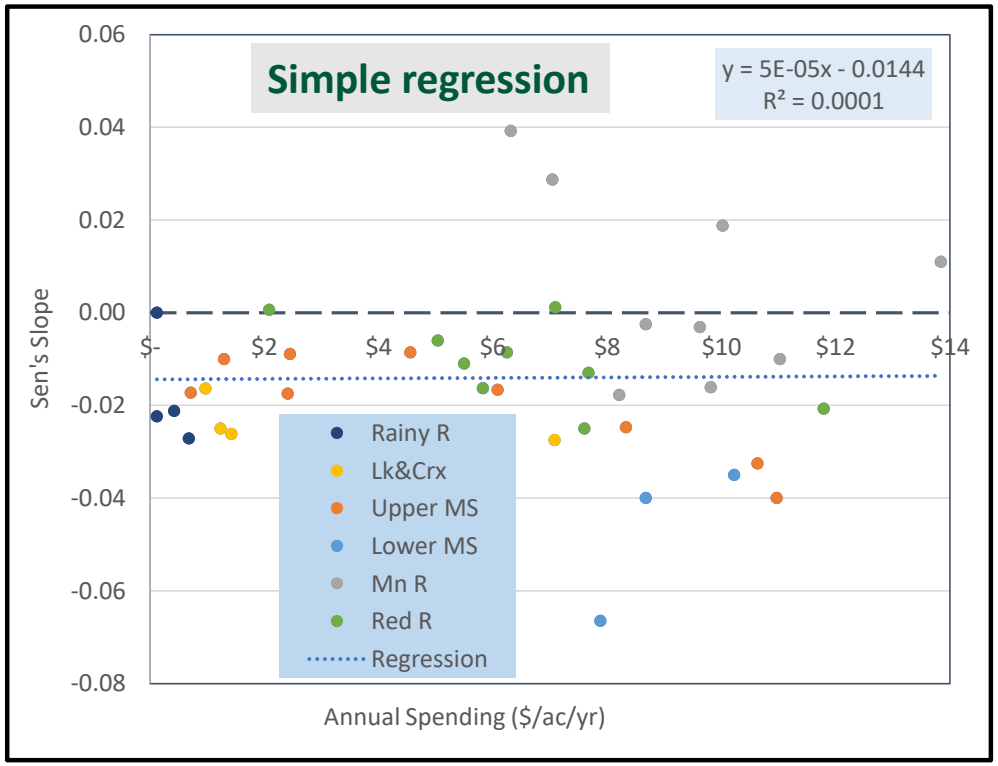
Total Suspended Solids (TSS)



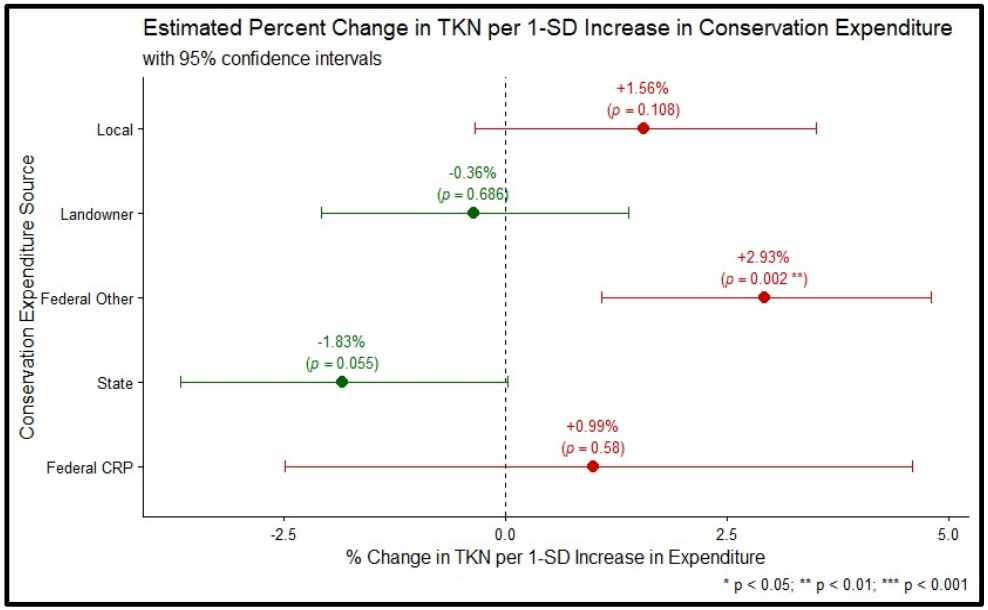
Funding Sources



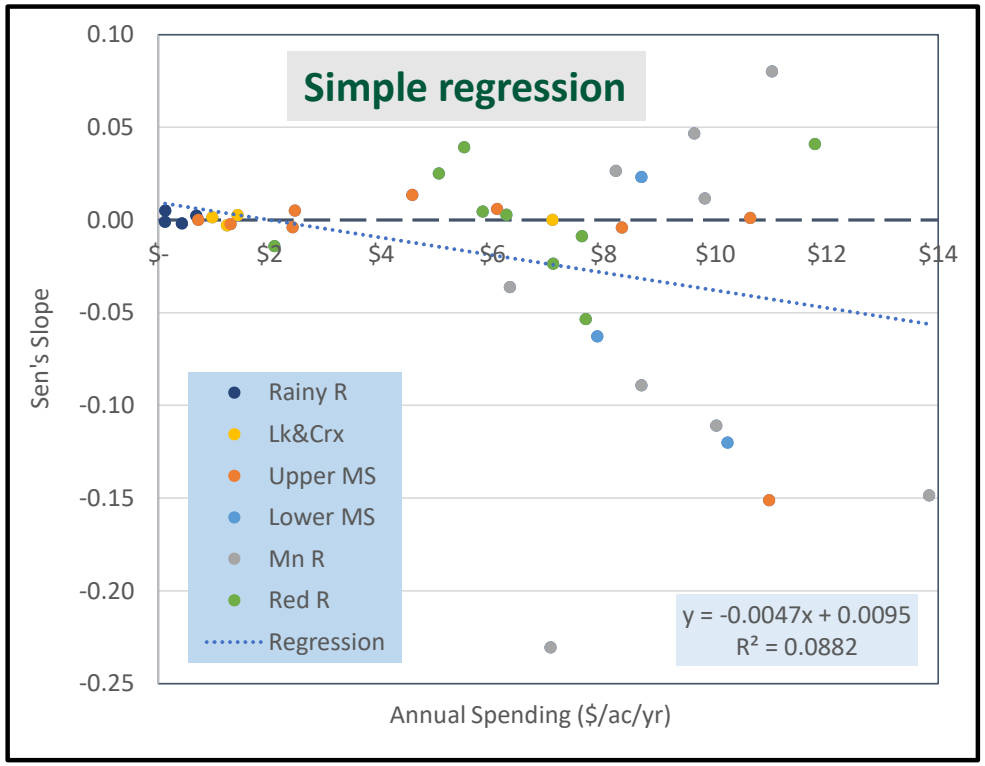
Total Kjeldahl Nitrogen (TKN)



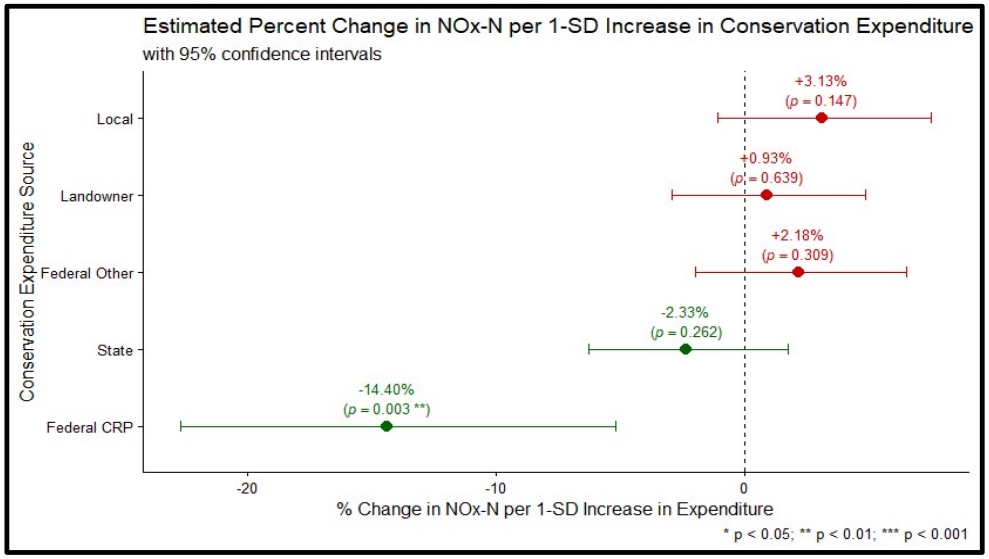
Funding Sources



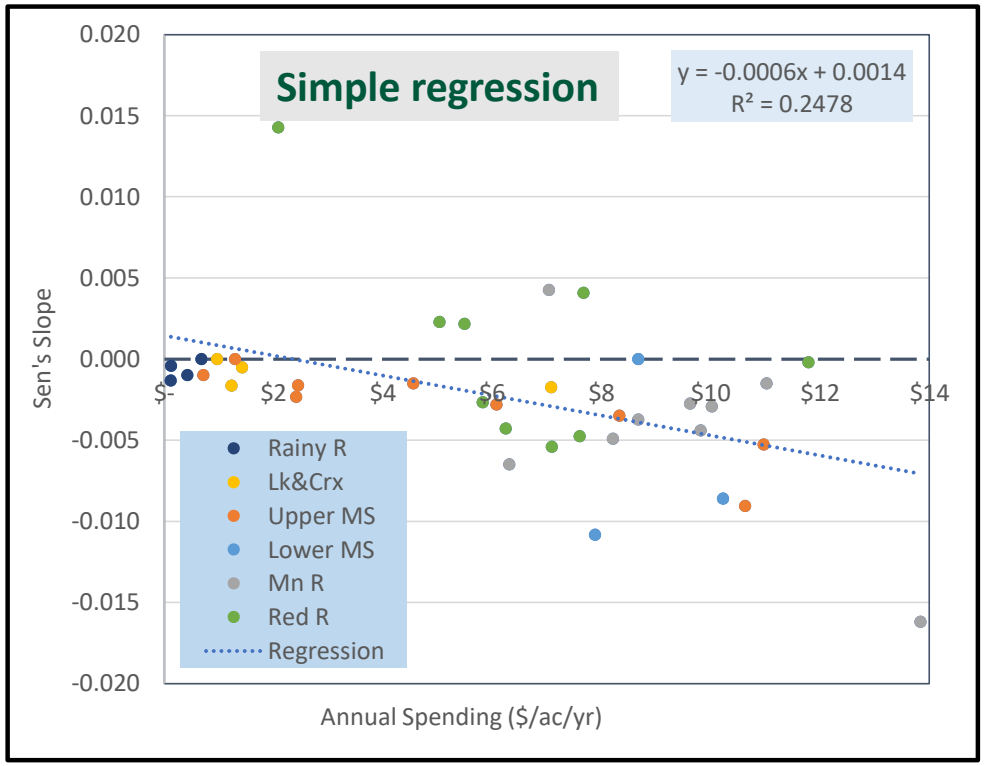
Nitrate and Nitrite (NOx-N)



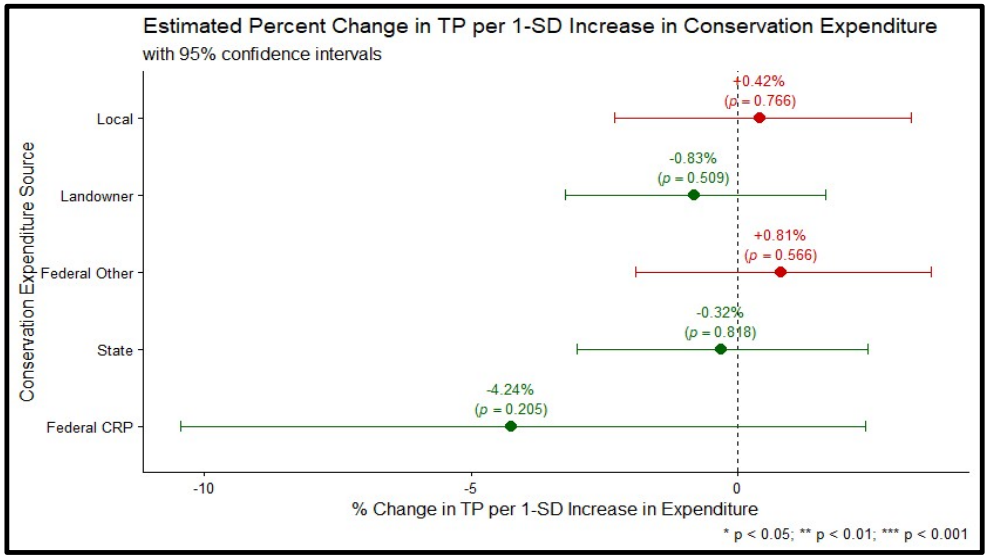
Funding Sources



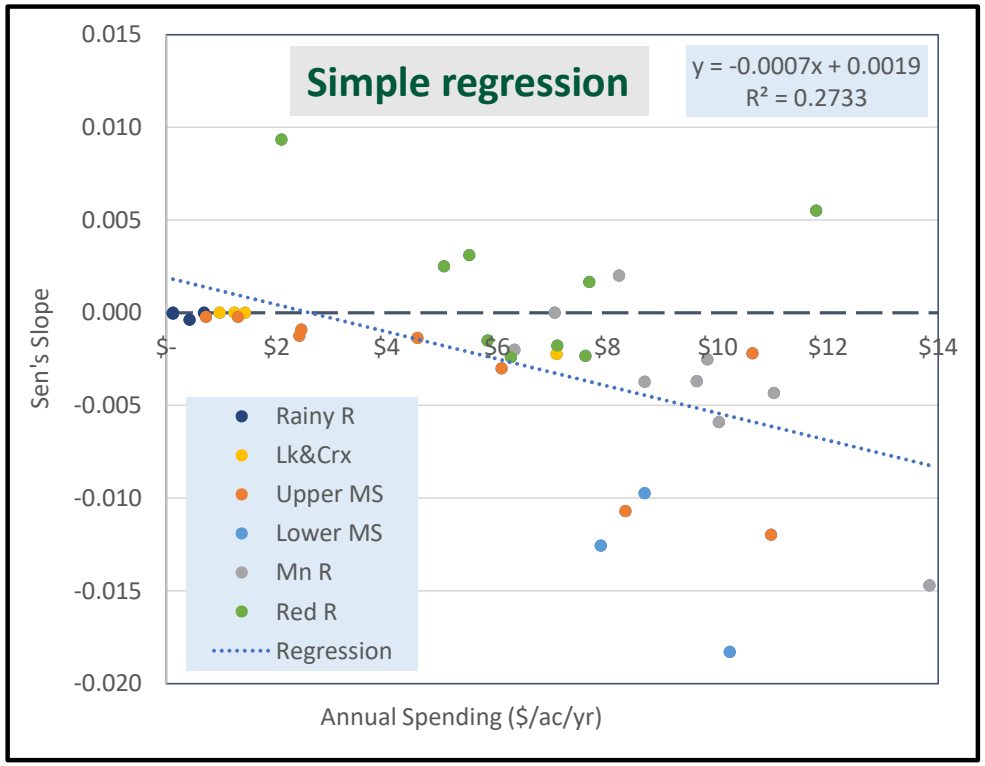
Total Phosphorus (TP)



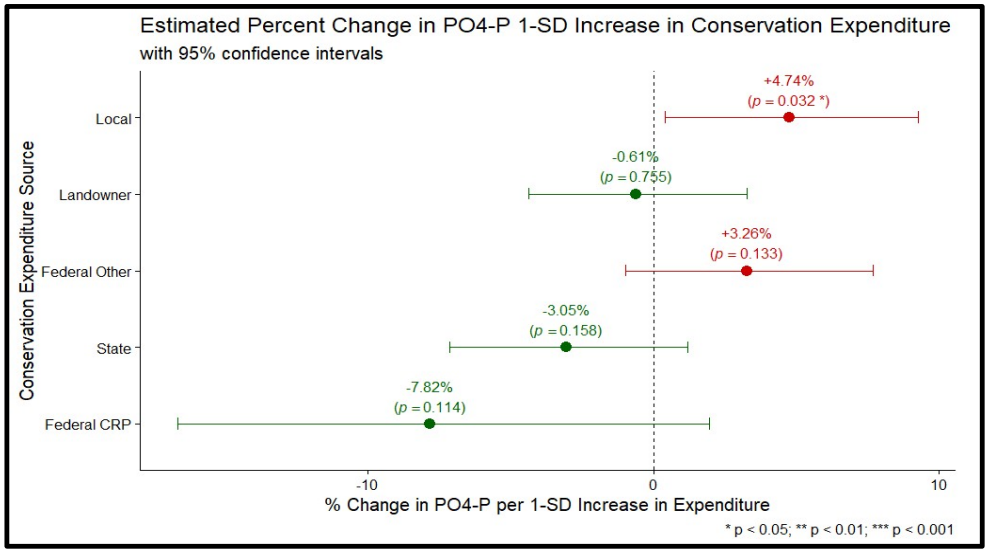
Funding Sources



Orthophosphate (PO_4-P)



Funding Sources



Q2 Conclusions and Future Work

- Conservation expenditure on water quality implementation projects over the last 15 years was more cost-effective from state and federal CRP funding sources than from other sources.
- They were generally more effective in reducing phosphorus concentrations than in reducing suspended solids and nitrogen concentrations.
- Future work to improve the mixed-effects models
  - Regroup local and landowner expenditure with their respective funding sources.
  - Account for CRP types IF such data are available.
  - Conduct robustness checks and sensitivity analysis.

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Thank you!

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