MINNESOTA

2025 Minnesota Nutrient Reduction Strategy

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Acronyms and Abbreviations

°F	degrees Fahrenheit
1W1P	One Watershed, One Plan
4R	right source, right time, right rate, right place
ACPF	Agriculture Conservation Planning Framework
AgBMP	Agriculture Best Management Practices Loan Program
BEET	BMP Effects Estimator Tool
BMP	best management practice
BWSR	Board of Water and Soil Resources
cfs	cubic feet per second
chl-*a*	chlorophyll-*a*
CLC	continuous living cover
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
CSW	Construction Stormwater
CWA	Clean Water Act
CWLA	Clean Water Legacy Act
CWLLA	Clean Water, Land, and Legacy Amendment
CWMP	comprehensive watershed management plans
DNR	Minnesota Department of Natural Resources
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FN	flow-normalized
FSA	Farm Service Agency
FWMC	flow-weighted mean concentration
FY	fiscal year
GIS	geographic information system
GLTG	Great Lakes to Gulf
GRAPS	Groundwater Restoration and Protection Strategies
HSPF	Hydrologic Simulation Program-FORTRAN
HTF	Hypoxia Task Force
HUC-4	four-digit hydrologic unit code
HUC-8	eight-digit hydrologic unit code
HUC-10	10-digit hydrologic unit code
HUC-12	12-digit hydrologic unit code
IJC	International Joint Commission
IRRWB	International Red River Watershed Board
L&D	lock and dam
LBCA	lake benefit-to-cost ratio assessment
lbs	pounds
LES	lake eutrophication water quality standards
MAWQCP	Minnesota Agricultural Water Quality Certification Program
MCL	maximum contaminant level
MDA	Minnesota Department of Agriculture
MDH	Minnesota Department of Health
MnDOT	Minnesota Department of Transportation

Met Council	Metropolitan Council
mgd	million gallons per day
mg/L	milligrams per liter
MIDS	Minimal Impact Design Standards
MMP	manure management plan
MNDWIS	Minnesota Drinking Water Information System
MnTap	Minnesota Technical Assistance Program
MPCA	Minnesota Pollution Control Agency
MRTN	maximum return to nitrogen
MS4	municipal separate storm sewer system
MSP	Minneapolis–Saint Paul
MT	metric tons
MTA	metric tons annually
NASS	National Agricultural Statistics Survey
NGO	nongovernmental organizations
nitrate-N	nitrate-nitrogen
NMP	nitrogen management plan
NP-BMP	Watershed Nitrogen and Phosphorus Reduction Planning Tool
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRS	Nutrient Reduction Strategy
PFAS	per- and polyfluoroalkyl substances
PTMApp	Prioritize, Target, Measure Application
QWTREND	Quality of Water Trend
RCPP	Regional Conservation Partnership Program
RES	river eutrophication water quality standards
SDR	State Discharge Restriction
SDS	State Disposal System
SPARROW	Spatially Referenced Regressions on Watershed
SRF	State Revolving Fund
SSTS	subsurface sewage treatment system
SWCD	soil and water conservation district
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
µg/L	micrograms per liter
UMN	University of Minnesota
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WLA	wasteload allocation
WQBEL	water quality-based effluent limit
WQS	water quality standards
WRAPS	Watershed Restoration and Protection Strategy
WRTDS	Weighted Regressions on Time, Discharge, and Season
WWTF	wastewater treatment facility
yr	year

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Executive Summary

Background

Since 2014, the Minnesota Nutrient Reduction Strategy (NRS) has guided the state in reducing excess nitrogen and phosphorus (collectively known as nutrients) in Minnesota's waters, ensuring that in-state and downstream water quality goals are met. Nutrients are important for human and aquatic life; however, when levels become elevated, excessive algae growth, low oxygen levels, toxicity to aquatic life, and unhealthy drinking water can result. A loss of nutrients is also often an economic loss.

The NRS was developed from the work of state, federal, and regional partner agencies and the University of Minnesota (UMN), along with broader input, and describes:

- Nutrient conditions in Minnesota waters
- Sources of excess nutrients
- Goals and milestones for addressing in-state and downstream water nutrient levels
- Science-based solutions to reduce nutrient loss
- The magnitude of changes needed on the land
- Specific strategies for increasing nutrient reduction efforts
- Ways of tracking progress

Reducing nutrients in Minnesota waters also benefits downstream waters, including the Gulf, Lake Winnipeg, and Lake Superior (Figure ES-1). The NRS establishes nutrient reduction planning goals that vary for these three major basins, with the target to reach all goals by 2040 (Figure ES-2).

Figure ES-1-1. Waters in Minnesota drain to the Gulf, Lake Winnipeg, and Lake Superior.

Following 10 years of implementation, the Minnesota NRS implemented planned updates to assess progress in reducing nutrients and better guide the state in meeting its nutrient reduction goals.

The successful implementation of the NRS continues to require broad support, coordination, and collaboration among agencies, academia, local government, and the private sector. State-level support provided to people and organizations at the local level leads to the implementation of more nutrient-reducing practices in both rural and urban areas. Those practices work to improve local waters, with cascading benefits to the waters downstream of Minnesota (Figure ES-3).

Figure ES-1-2. Timeline for achieving nutrient reduction goals for the Mississippi River.

Figure ES-1-3. Overview of how NRS strategies and practices lead to water quality improvements.

Goals and progress overview

Statewide, high phosphorus concentrations cause eutrophication impairments in 686 Minnesota lakes and 50 river reaches. To meet water quality standards, phosphorus in these lakes and rivers should be reduced by an average of 42% from recent conditions. Protecting sensitive lakes from phosphorus inputs remains a high priority for Minnesota.

In-state phosphorus concentrations in lakes, rivers, and streams are generally showing signs of improvement, although 54% of 260 lakes assessed for trends had no trend detected. Of the 119 lakes with detectable phosphorus trends, 86 lakes (73%) showed decreases in phosphorus, while 32 lakes (27%) were increasing between 2007 and 2024.

River phosphorus concentrations have generally decreased or remained stable throughout Minnesota at most of the 61 MPCA river monitoring sites (2008–2022) and at all 15 of the seven-county Twin Cities Metro Area sites (2000–2021). Mississippi River phosphorus concentrations have decreased by over 40% since the 1980s, mostly attributed to reductions from wastewater (see Chapter 4).

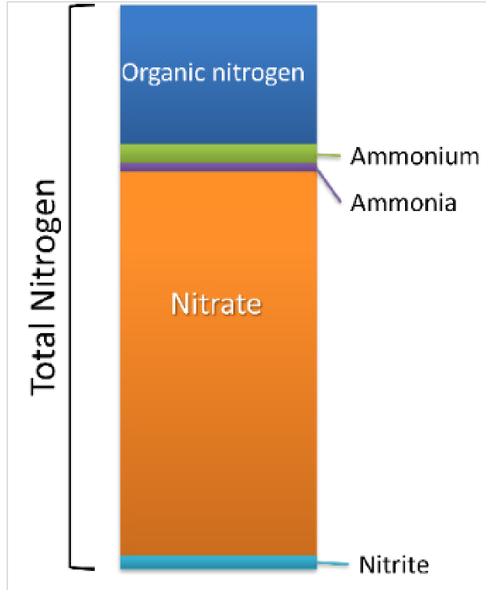
Nitrate is the most dominant form of total nitrogen (TN) in waters that are impacted by human activity (Figure ES-4). High nitrate concentrations can cause drinking water standard exceedances in groundwater and wells. In southern Minnesota, some stream reaches have nitrate levels high enough to potentially harm aquatic life.

If nitrate concentrations are reduced by about 40% in rivers and vulnerable groundwaters in the Mississippi River basin, Minnesota will meet its goals for state-line TN load reductions and most in-state targets for protecting drinking water and aquatic life.

The progress indicators for nitrate concentration show a greater mix of results than for phosphorus.

Between 2008 and 2022, river nitrate concentrations have shown no trend in most (86.5%) of the 52 MPCA-monitored sites across the state. Where trends have been detected, nitrate concentrations have been increasing at five sites (10%) and decreasing at two sites (4%).

Figure ES-1-4. Typical proportions of TN constituents in waters impacted by human activity.

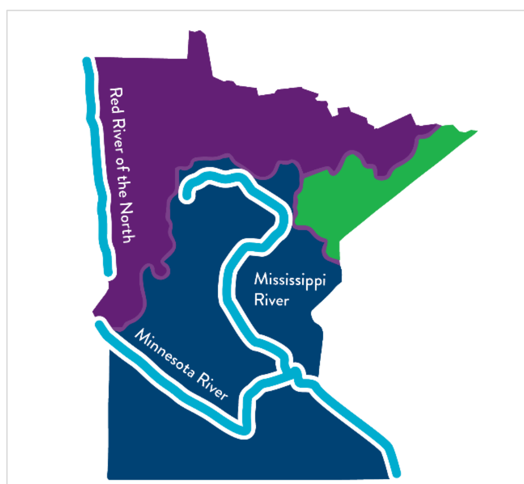


In upper aquifers, which are geologically vulnerable across agricultural and urban parts of the state, nitrate concentration trends (2007–2023) have been decreasing (improving) in 24% of ambient monitoring and domestic wells while increasing (worsening) in 3% of tested wells. However, most wells (73%) show no trend during recent years. More monitoring is needed to better understand groundwater nitrate trends over time.

Mississippi River Basin goals and progress

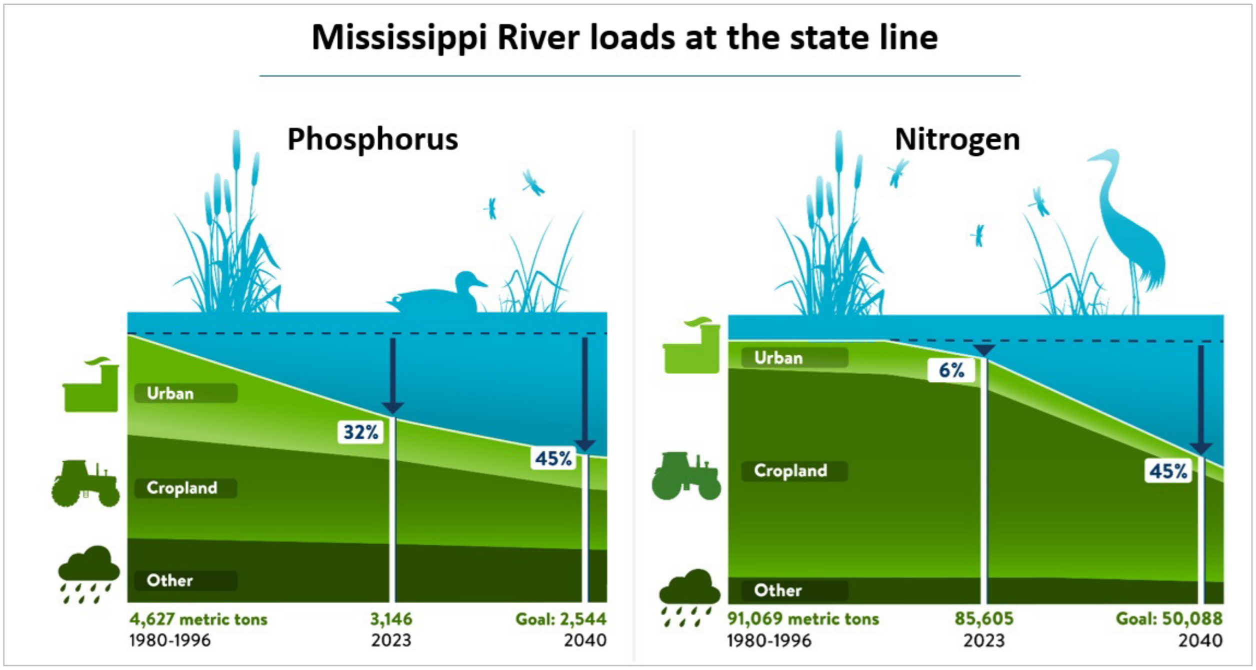
Most of Minnesota's nutrient losses flow out of the state via the Mississippi River Basin (Figure ES-5). Nutrients in the Mississippi River account for 83% of TN loads and 74% of total phosphorus (TP) loads leaving Minnesota. For the Mississippi River, the national-level Gulf Hypoxia Task Force established load reduction goals of 45% for both TN and TP based on average conditions between 1980 and 1996. Minnesota applies the 45% reduction goal at various monitoring points between the Twin Cities and the state line with Iowa.

Figure ES-1-5. Mississippi River Basin within Minnesota (blue), also showing the largest tributary, the Minnesota River.



Minnesota is making progress. Recent estimates based on river monitoring results and validated with best management practice (BMP) adoption information indicate improvement since the baseline period of 1980–1996, with a 32% load reduction in TP and a smaller and less certain load reduction of about 6% in TN (Figure ES-6). About two-thirds of the TP load reduction is attributed to point source wastewater improvements, while the rest is attributed to agricultural and urban nonpoint source reductions.

Figure ES-1-6. Minnesota's annual phosphorus and nitrogen loads in the Mississippi River near the state border during an average flow year in the past (1980–1996), current (2023), and NRS-projected future (2040).



Notes: "Other" includes sources such as atmospheric deposition, nonagricultural rural runoff, streambank erosion, animal feedlots, and septic systems (MPCA 2013).

Lake Winnipeg Basin goals and progress

About 22% of the TP and 13% of TN statewide loads leave Minnesota through the Red and Rainy rivers, contributing to the nutrient enrichment and eutrophication of Lake Winnipeg.

To meet Lake Winnipeg water quality goals, in 2020 the International Red River Watershed Board adopted final load targets for TN and TP in the Red River at the border of the United States of America and Canada. The goals represent load reductions of about 53% and 50% of TN and TP loads, respectively, from the 1996–2000 average. A final target date has not yet been determined by Manitoba, and the Minnesota NRS uses a provisional date of 2040 planning timeframe in the interim. Because relatively few in-state waters in the Red River Basin are impaired by nutrients, the primary water quality drivers for these large nutrient reductions in this part of the state are the goals for Lake Winnipeg.

TN loads in the Red River may have decreased slightly at the Canadian border since the late 1990s baseline period, but more monitoring is needed over time to confirm this trend. TP loads have not shown improvement since the baseline period; more likely, they have increased slightly (7%).

Minnesota also contributes a relatively small amount of nutrients from the Rainy River into Lake Winnipeg, which first flows into Lake of the Woods. The load reduction strategy for the Rainy River in Minnesota is to address nutrient loads through the total maximum daily load for the Lake of the Woods eutrophication impairment, which aims for a 17.3% phosphorus reduction going into the lake. Phosphorus levels in the Rainy River have decreased since 2005 and are now nearing the goal.

Lake Superior Basin goals and progress

About 4% of TN and TP loads leave Minnesota through tributaries flowing into Lake Superior. The NRS references a previously established no-net phosphorus increase goal. The 2025 NRS also identifies a no-net-increase goal for TN loads into Lake Superior. Recent monitoring and modeling suggest that loads from combined Minnesota tributaries average 245 metric tons per year (MT/yr) for TP and 2,670 MT/yr for TN. Further research is needed to better understand nitrogen impacts on nearshore areas as Lake Superior waters warm.

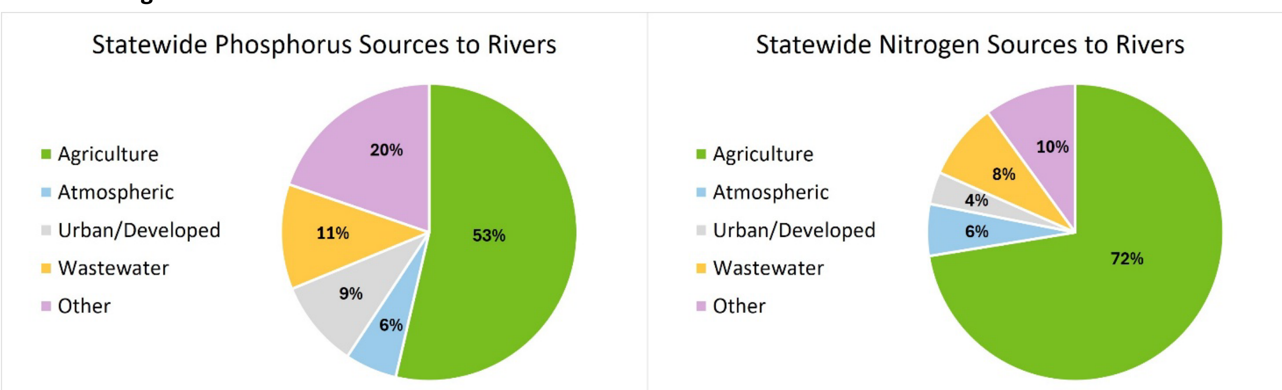
Trend analyses on the largest Minnesota tributary to Lake Superior, the St. Louis River, show a 16% and 14% decrease in TP and TN loads, respectively, between 2011 and 2023. Continued monitoring of tributaries to Lake Superior will verify if the no-net-increase goals for Lake Superior are met.

Priority Management Areas

Priority sources

The state-level nutrient source assessments are based on the averages of two modeling efforts from 2014 and 2024 (Figure ES-7). The priority sources vary greatly across the state and the major river basins (Table ES-1), and priority sources for local waters within each drainage basin are often different than the basin-scale source. Priority sources at the eight-digit hydrologic unit code (HUC-8) scale or smaller are determined through watershed planning efforts.

Figure ES-1-7. The estimated statewide sources of phosphorus (left) and nitrogen (right) to Minnesota rivers, based on the averages of two different source assessments.



Notes: "Other" represents streambank erosion, nonagricultural rural runoff, and forest. Percentages are rounded to nearest percent.

Table ES-1. Priority sources at the major river basin scale within the state of Minnesota, with the highest priority sources in bold.

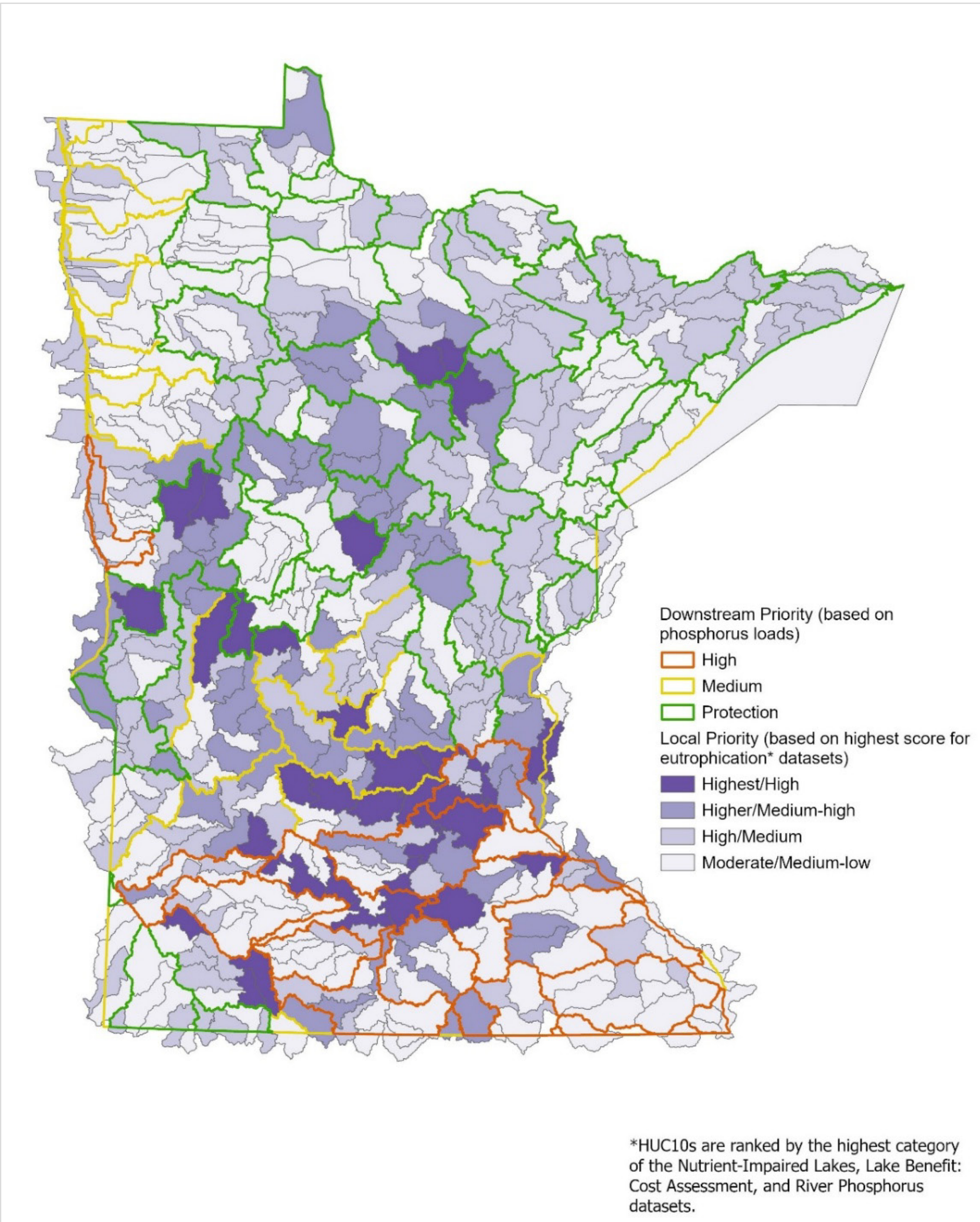
Major basin	Priority phosphorus sources	Priority nitrogen sources
Mississippi River	**Cropland runoff**, wastewater point sources, and streambank erosion	**Cropland leaching loss to tile drainage** and groundwater, wastewater point sources
Lake Superior	**Nonagricultural rural runoff**, wastewater point sources, and streambank erosion	**Nonagricultural rural runoff**, wastewater point sources
Lake Winnipeg	**Cropland runoff**, nonagricultural rural runoff	**Cropland** and other rural runoff and atmospheric sources

Agricultural sources are a priority in the Mississippi River Basin (contributing an estimated 78% TN and 56% TP) and the Lake Winnipeg Basin (51% TN and 53% TP). Conversely, in the more forested Lake Superior Basin, combined sources such as streambank erosion, nonagricultural runoff, and forested lands contribute a higher fraction of the nutrient loads to waters.

Priority watersheds

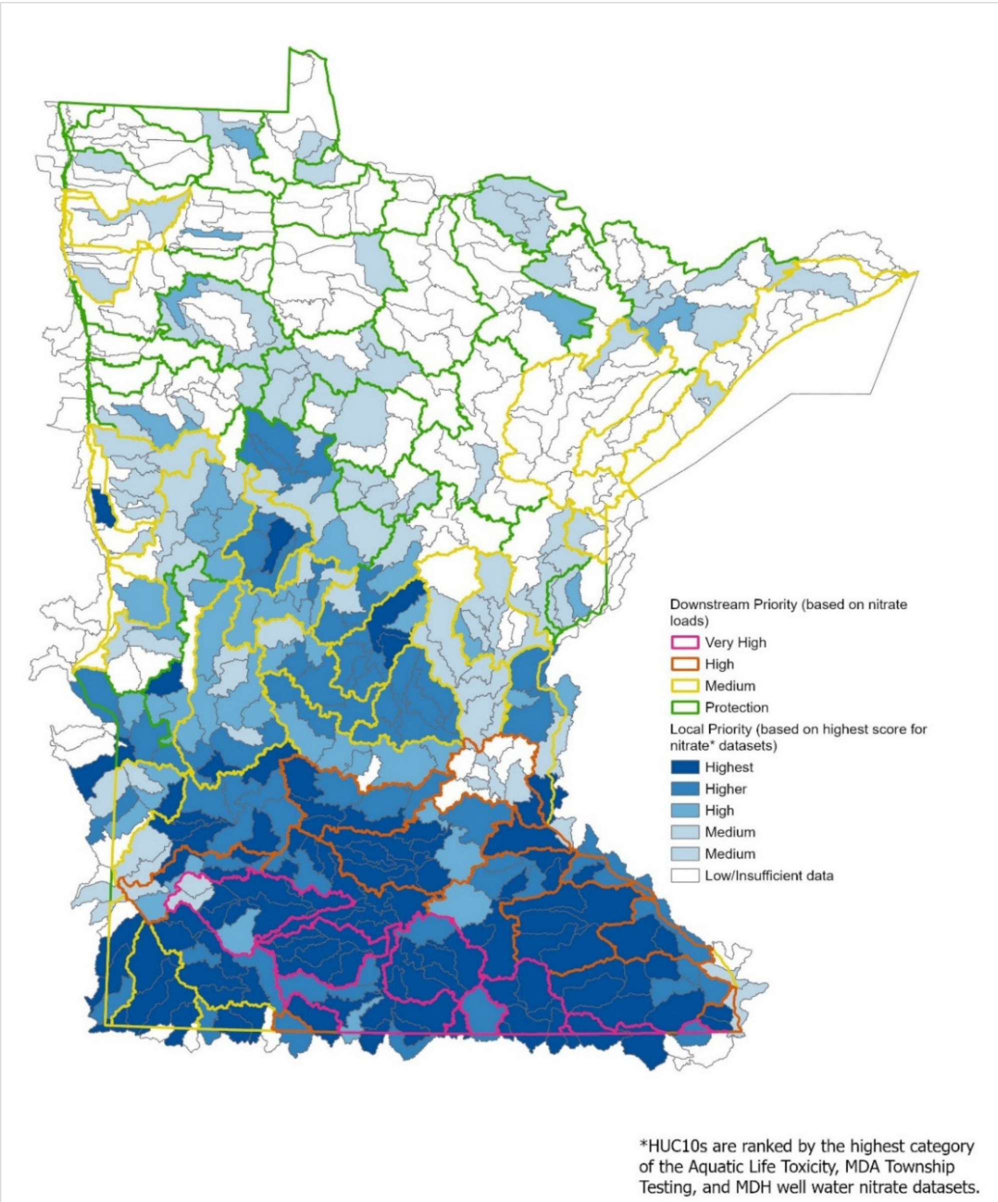
Priority watersheds have either a high nutrient yield (loads normalized to area) that reaches the state line or are considered a high priority for one or more of the in-state nutrient reduction needs. Priority watersheds for phosphorus reduction are more common in the southern half of the state, while phosphorus lake protection needs are more common in the north (Figure ES-8).

Figure ES-1-8. Highest category phosphorus priority watersheds for both protection and restoration, along with the priority watersheds contributing TP loads downstream of Minnesota.



Priority watersheds for nitrogen are mostly in southern Minnesota, as well as in the sandy soil region of central Minnesota that is vulnerable to elevated groundwater nitrate levels (Figure ES-9).

Figure ES-1-9. Highest-category nitrate priority HUC-10 watersheds for drinking water and aquatic life, along with the priority watersheds contributing TN loads downstream of Minnesota.



Nutrient Reduction Strategies

The 2025 NRS documents substantial progress during the past decade. Yet challenges in meeting water quality goals remain, including cost, technology limitations, and federal policy. The cost of reaching NRS goals is estimated to be well above $1 billion annually.

The 2014 NRS identified an aspirational 2040 final goal timeframe, but Minnesota will fall short of meeting NRS goals by 2040 without additional measures in place to accelerate the pace of change. The NRS recommends pursuing steady incremental progress through existing tools while adding initiatives aimed at systemic change that could shift the trajectory. The 2025 NRS builds on foundational advancements already made and identifies where work should be intensified and how success can be achieved (see Chapter 8 for more details).

Watershed-based strategies

Minnesota has a rich history of water planning, which coalesced into the Minnesota Water Management Framework (described in Chapter 6). The framework is organized at the major watershed scale (i.e., HUC-8) and includes five steps:

1. Monitoring, assessment, and characterization
2. Problem investigation and applied research
3. Restoration and protection strategy development
4. Developing comprehensive watershed management plans (CWMPs)
5. Implementation

Steps 1–3 have been completed in all 80 major watersheds in Minnesota, through watershed monitoring that is in its second 10-year cycle, and through the development of Watershed Restoration and Protection Strategies (WRAPS) that are now being updated. The Water Management Framework also includes Groundwater Restoration and Protection Strategies (GRAPS) that address groundwater nitrate. Step 4 is complete for most planning areas, including 54 comprehensive local water plans through the One Watershed, One Plan (1W1P) process and 31 watershed plans in the Twin Cities Metro Area. Step 5 is ongoing.

The NRS identifies HUC-8 watershed outlet load reduction planning targets for both nitrogen and phosphorus that will collectively achieve goals at state lines. These targets can be used with the following NRS tools to plan and implement nutrient reductions for local and downstream waters, as described in Chapter 7:

- Watershed nutrient balance maps show areas with potential cropland surplus nutrients.
- Nutrient reduction efficiencies information for agriculture practices to reduce nitrogen and phosphorus, along with estimated costs per acre.
- River nutrient concentration trends in Minnesota rivers.
- BMP adoption tracking.
- Watershed and lake ecological health scores.
- Treated wastewater effluent nutrient levels throughout Minnesota.
- Modeled estimates of nutrient load reduction from past practices and example scenarios of practice combinations to achieve NRS goals.
- Watershed pollutant load and concentration monitoring results throughout Minnesota.

To meet NRS goals, Minnesota needs to maintain and expand ongoing local conservation practice delivery through comprehensive local watershed planning tailored to local conditions and situations. The Minnesota Water Management Framework will require considerably more support to address the needed landscape-scale changes.

The 2025 NRS recommends that Minnesota invest in developing and strengthening support for the Water Management Framework planning and implementation steps through:

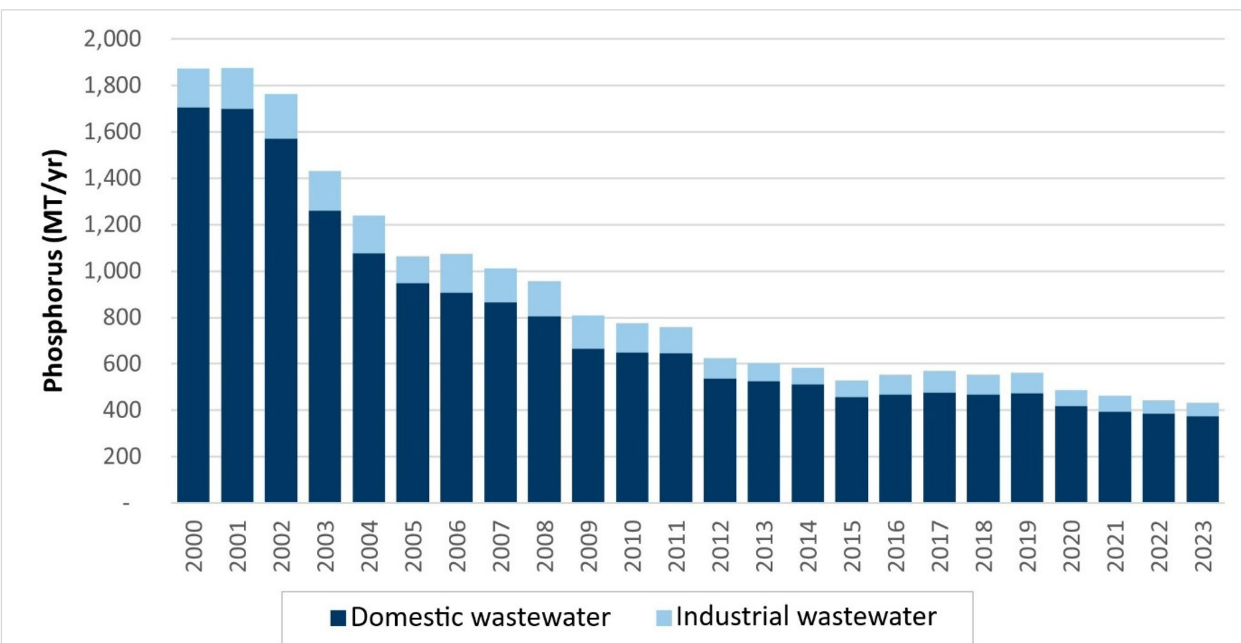
- Increasing workforce capacity and training for local government and private industry staff to help landowners adopt new conservation practices and actions.
- Streamlining practice delivery, reporting, and funding systems to facilitate accelerated practice adoption.

- Making programs that streamline the installation of agriculture practices easy to initiate and fund, especially for drainage water management and treatment practices.
- Strengthening private industry involvement and public-private partnerships.
- Replicating existing successful elements of local and regional soil health programs.
- Expanding opportunities to implement practices that provide multiple ecosystem and economic benefits.
- Reaching absentee landowners with conservation and soil health strategies/incentives.
- Connecting practices and goals identified in the NRS with WRAPS Updates, CWMP through the 1W1P program, Twin Cities Metro Area watershed plans, and GRAPS.
- Increasing support to local watershed organizations for data and analysis, technical training, and tracking and decision-support tools.

Wastewater strategies

The wastewater sector has achieved substantial reductions in phosphorus since 2000, cutting loads in treated effluent by 76% (Figure ES-10). The 2014 NRS outlined a plan to address nitrogen in treated effluent, which contributed about 8% of the statewide nitrogen load to rivers. The first step was monitoring effluent nitrogen levels. Nitrogen monitoring in Minnesota treatment facilities is now widespread. The next steps in nitrogen reduction have begun to be implemented, following MPCA's introduction of a Wastewater Nitrogen Reduction Strategy in the spring of 2024. The strategy is a phased approach that will begin with adding nitrogen limits to wastewater permits for new, expanding, or significantly upgraded facilities. The strategy will also eventually include a state discharge restriction of 10 mg/L TN. Using nitrogen management plans and existing wastewater infrastructure, cities and industry will denitrify and remove nitrogen while aiming to maintain past phosphorus improvements.

Figure ES-1-10. Statewide domestic and industrial wastewater TP annual discharges, 2000–2023.



While this strategy will result in NRS wastewater goals being met, it will require substantial investment in infrastructure. Initially, lower-cost approaches and focusing on facilities that impact streams impaired by nitrate should be emphasized. Over time, higher-cost approaches will likely be needed to reduce nitrate from wastewater discharge, as described in Chapter 4. In addition, Minnesota is working to expand opportunities for nutrient trading across the state to help offset the costs of wastewater nutrient reduction.

Cropland strategies

Nutrient reduction from cropland is especially needed in the following situations:

- Nitrate leaching reduction in areas with vulnerable groundwater under row crop production, including sandy soils, karst geology, and other shallow soils above bedrock.
- Nitrate loss reduction to surface waters in tile-drained lands under row crop production.
- Phosphorus overland runoff reduction in priority watersheds draining into lakes and rivers with eutrophication concerns.

The primary means of reducing nutrient losses from agricultural fields is by installing and adopting practices, often called BMPs, designed to keep nutrients on fields and out of waterways. These practices also include changes to cropping rotations and vegetative cover.

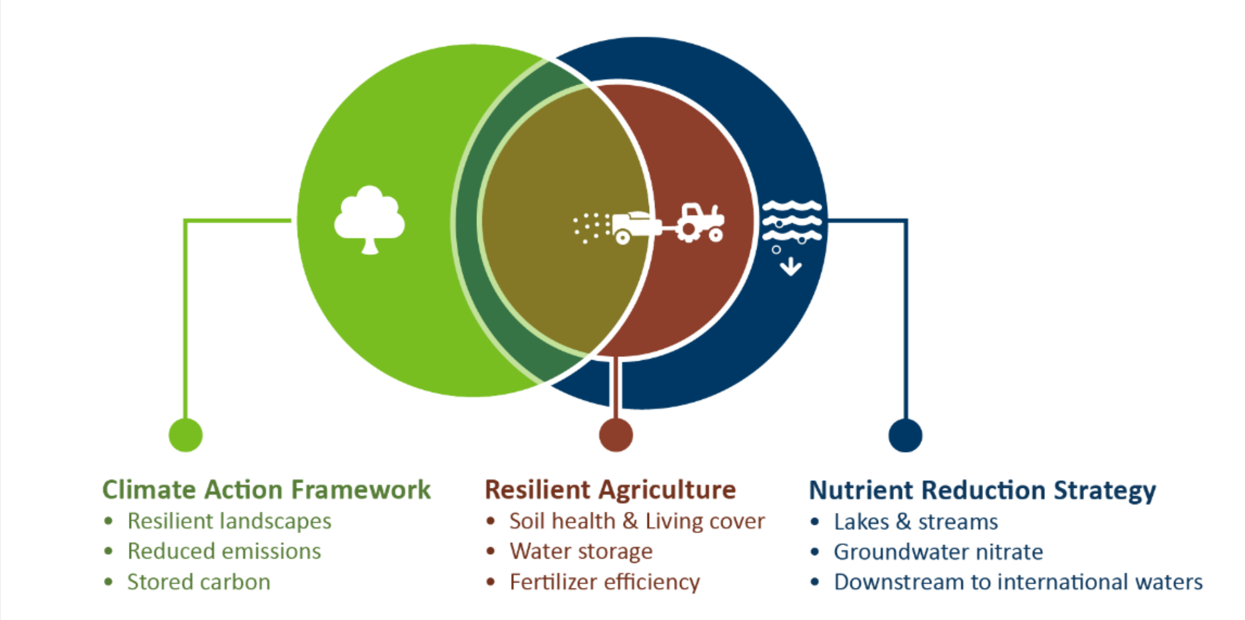
When developing the 2025 NRS, the UMN conducted an extensive literature review of the research on these practices to determine the nutrient reduction effectiveness of practices in Minnesota and locations with similar climates. While no single practice will work on every acre or solve all nutrient loss, most land can use one or more of the 22 practices identified as being able to reduce nitrate losses (by 4% to 94%, depending on the practice) or one or more of the 20 practices identified as being able to reduce phosphorus runoff (by 5% to 75%, depending on the practice).

Besides protecting water quality from nutrient runoff, many of the practices also support co-benefits, such as improved air quality, soil health, carbon storage, long-term agricultural productivity, farm profitability, farm field resilience to precipitation extremes, reduced flooding, and expanded habitat for wildlife and pollinators. Water quality benefits can include improved drinking water, reduced algae in nearby water bodies, and enhanced fisheries and recreation in lakes, rivers, and oceans. Minnesota will build on its recent efforts to develop frameworks for climate action, soil health, and water storage, and associated funding, by promoting practices that help address overlapping ecosystem and agricultural goals (Figure ES-11).

Practices that are effective at protecting water quality and providing other benefits include:

- Conservation crop rotation (i.e., adding small grains like oats or perennials into rotations)
- Perennial crops and pastures as working lands
- Cover crops
- Reduced tillage methods, such as strip-till
- In-field nutrient management (fertilizer and manure precision/efficiency)
- Drainage water recycling (storing and irrigating drainage waters)
- Wetland installation

Figure ES-1-11. Overlapping multiple benefits from strategies aiming for climate action, resilient agriculture, and nutrient loss reduction into waters.



Nutrient reduction efficiencies expected from the UMN review of practices were incorporated into Minnesota's watershed modeling tools to estimate the combined scale of adoption that could potentially reach NRS goals. This confirmed that, while there is no single correct combination of practices to achieve Minnesota's nutrient reduction goals, millions more acres of practices will need to be installed across the state to achieve significant nutrient reductions (Figure ES-12).

Cropland Implementation

Figure ES-1-12. Example scenario showing the magnitude of change needed to achieve nutrient reduction goals in the Mississippi River Basin.

Successful implementation of cropland practices will require building on Minnesota's existing voluntary and regulatory foundations. Continuing implementation of laws, rules, and permits affecting cropland that were adopted during the past decade is expected. Commitment and collaboration among local, state, federal, and private sector organizations, along with individuals, will also be necessary. In addition to the initiatives previously described to strengthen support for the Water Management Framework, the following strategies are emphasized for the cropland sector:

- **Continuous living cover (CLC) campaign**. Nitrogen reduction goals cannot be achieved without transformative changes in crop system rotations and maintaining living cover for more months each year. To accelerate the transition to perennials, pasture, small grains, and harvested cover crops, the NRS recommends creating a work group to develop a CLC campaign to establish the next million acres of CLC.

- **Support and expand existing successful agricultural practice improvement programs**. Minnesota's existing Agriculture Water Quality Certification Program should be expanded to help meet both local and statewide water quality goals. Statewide and local soil health initiatives and the related Minnesota Office of Soil Health programs should continue and expand. The NRS encourages continued work by private industry to promote nitrogen BMPs.

Inter-seeded cover crop (*Source*: USDA, L. Betts)

- **Increase research and development**. Advancing nutrient reduction in croplands requires the continuation of a strong research program. Minnesota will need to invest in studying cropland nutrient reduction techniques, systems, technologies, and co-benefits, as well as support demonstration projects and pilot programs.

Strategies for other sources

Phosphorus reductions from miscellaneous sources are needed to meet TP goals, and, in some cases, the practices used to achieve these reductions will also help meet TN goals.

- **Feedlots.** MPCA's feedlot program has continued to work to minimize the risk to waters from animal holding and manure storage areas and the land application of manure. Recently, permit requirements to reduce nitrate leaching losses were specified for manure management plans, transferred manure, field inspections, early fall manure applications, winter manure applications, and manure application in vulnerable groundwater areas.
- **Septic systems.** As it did in the 2014 NRS, Minnesota's subsurface sewage treatment system program will continue to serve as the primary strategy in the 2025 NRS to reduce nutrient loads from septic systems. The program has made great progress in the past decade.
- **Forests.** Forested areas cover about 33% of Minnesota, and, although intact forests generally do not export many nutrients, factors like past land use practices or timber harvest can mobilize forest nutrients. Forest preservation, peatland restoration, and good timber harvest practices all help minimize nutrient losses to waters in forested areas.
- **Streambank erosion.** Studies of streambank and other near-channel erosion show that it can contribute substantially to river phosphorus loads. To achieve the final in-state and downstream goals for phosphorus, increasing practices to reduce streambank and gully erosion will be needed.

Protection strategies

Protection strategies are needed in watersheds facing development pressures and land use changes. Areas with lakes that are sensitive to relatively small additions of nutrients, including Lake Superior and Minnesota's many high-quality lakes, are important. The Minnesota Water Management Framework requires protection strategies as part of WRAPS development and, therefore, should address the potential for increased nutrient loads at a watershed scale. WRAPS Updates and CWMPs take into account the local needs for water resource protection of waters that are not impaired but have declining water quality trends or are of high value to local communities.

The Minnesota NRS would fail if it met only the large river phosphorus load reduction goals while not also protecting the many lakes that are currently in relatively good condition but remain highly vulnerable to phosphorus inputs.

Tracking progress

Figure ES-1-13. Measuring progress is multifaceted

The NRS provides for accountability, adaptive management, and ensuring that Minnesota stays on the path to progress in achieving healthy waters. Measuring NRS progress depends on tracking the (1) practices and actions related to on-the-ground efforts, (2) water quality in surface water and groundwater, (3) programs on the state and regional levels that affect nutrients, and (4) the changes in people's level of engagement with NRS efforts (Figure ES-13). Tracking is an ongoing, iterative, and interagency process for the NRS.

Since the 2014 NRS, partners have expanded the water quality monitoring data and tools available for following agriculture practice adoption, watershed planning, and strategy development; these are available at the MPCA's NRS website. New ways to track CLC acreage changes will be developed. To increase NRS flexibility and data access, an NRS dashboard will be developed to serve as a central location for the data used for NRS analysis and the tracking tools displaying that data. The dashboard will also be the primary means of communicating NRS progress to NRS partners and the public. Ultimately, the NRS dashboard will facilitate and provide the foundation for the next major update to the NRS.

Assuring progress


Lake Superior

Since the NRS is a multiple-agency strategy with responsibility shared by leadership from several state organizations that use the NRS as a tool for implementing the improvement measures in the strategy, these organizations are responsible for overseeing NRS implementation. The specific agencies identified to lead various initiatives are noted in Chapter 8. These organizations should develop an economic analysis and a strategy for ongoing funding. While Minnesota currently has partial funding for certain NRS implementation measures, much more funding will be needed both before and after the 2034 end date of the Clean Water, Land and Legacy Amendment Clean Water Fund monies.

Accountability to other states and provinces will be maintained through Minnesota's continued involvement on the Gulf Hypoxia Task Force, the International Red River Watershed Board, the International Rainy-Lake of the Woods Watershed Board, and the Great Lakes Commission.

Conclusion

To address the problem of excess nutrients in waters, Minnesota has built a strong foundation consisting of both voluntary and regulatory programs. Many of the programs are relatively new, and the water quality results of those programs are only beginning to emerge.

Water quality may incrementally improve if we pursue a stay-the-course approach without accelerating the pace of progress. However, Minnesota will fall short of meeting all NRS goals by 2040 without putting additional measures in place to accelerate the pace of change and increase the capacity for change. The NRS recommends pursuing both steady incremental progress through existing tools and adding initiatives aimed at systemic change that could shift the trajectory. With over 20 million acres of rural and urban change or refinement needed, the scale is enormous. Meaningful transformation will take time.

The NRS is science-based. However, the NRS is ultimately a strategy about people. It’s about the quality of life for Minnesota’s residents. Because the people of Minnesota care, much progress has already been made to reduce nutrients in waters. In the end, the people of Minnesota will determine what priority to place on NRS efforts, the desired rate of progress, and how much they are willing to invest toward solving our state’s many nutrient-related challenges.

Chapter 1

The First Decade of the Nutrient Reduction Strategy: 2014–2024

1.1 Why was the 2014 Nutrient Reduction Strategy developed?

In 2014, Minnesota introduced a Nutrient Reduction Strategy (NRS) to address the excess nitrogen and phosphorus, collectively known as nutrients, found in the state's waterways. The strategy was developed from the work of state, federal, and regional partner agencies and the University of Minnesota (UMN). The strategy documented and quantified the sources of nitrogen and phosphorus and their levels in Minnesota's water, set measurable goals for reducing nitrogen and phosphorus loads in water bodies both within and leaving the state, and identified a series of strategic actions to help the state accomplish those goals. It also provided a unified resource and platform for the many programs, from the federal to the local level, seeking to reduce nutrient pollution around the state.

1.1.1 The 2014 NRS focused on waters downstream of and within Minnesota

Downstream waters

One reason Minnesota embarked on developing the 2014 NRS was its involvement with other Mississippi River Basin states, federal agencies, and other organizations to develop voluntary nutrient reduction strategies to address hypoxic conditions in the Gulf. The Gulf hypoxic zone, or low-oxygen zone, was first noted in the 1950s, worsened in the 1970s (Rabalais and Turner 2019), and grew to become a regular summer occurrence that reached, at its maximum, over 8,700 square miles in size in 2017 (NOAA 2025). The hypoxic zone is a product of excess nutrient loads entering the Gulf from the cities and farm fields of the Mississippi River Basin. It causes significant environmental impairment to coastal waters and imparts an economic cost to the Gulf region by damaging the fishing, shrimping, recreation, and tourism industries.

Minnesota began working with other states in the Mississippi River Basin in 1997 via the Hypoxia Task Force (HTF) to address the large hypoxic zone in the Gulf. In 2008, the HTF set nutrient reduction goals of 45% nitrogen and 45% phosphorus for each participating state (from a 1980–1996 baseline).

What is Hypoxia?

Hypoxia is a lack of oxygen. Excess nutrients delivered to a water body can lead to the overgrowth of algae. Oxygen is consumed as dead algae decompose, resulting in low dissolved oxygen levels in the water. Hypoxic conditions occur when the dissolved oxygen concentrations in the water column decline to the point that aquatic organisms such as shrimp and crabs cannot survive.

A memo issued by the U.S. Environmental Protection Agency (EPA) on March 16, 2011, urged states to accelerate nutrient reduction and provided "Recommended Elements of a State Nutrients Framework." Minnesota began developing its NRS in 2012, with public review in 2013 and finalization in October 2014.

Figure 1-1. Minnesota's major drainage basins.

Because Minnesota waters also drain to Lake Superior and Lake Winnipeg, the 2014 NRS included existing nutrient goals to protect and improve those water bodies (Figure 1-1). Lake Winnipeg has been experiencing severe harmful algal blooms due to elevated nutrients since the 1990s, and work by the International Red River Watershed Board (IRRWB) in 2011 encouraged surrounding states and provinces to take action to decrease their nutrient contributions.

Lake Superior receives nutrients from tributaries in northeastern Minnesota. To protect the lake from eutrophication, a goal for Lake Superior since 1979 has been no increase in phosphorus.

Minnesota waters

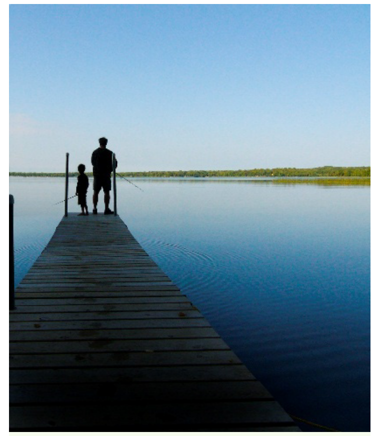
In addition to the need for corrective actions to restore downstream water bodies, a number of driving forces from within Minnesota during the 2010s further inspired the development of the NRS, including:

- Nutrient-related impairments that occurred in hundreds of Minnesota's lakes, reservoirs, and rivers.
- Elevated nitrate that persisted in groundwater, particularly in Minnesota's sandy outwash and alluvial aquifers and the karst region in southeastern Minnesota.
- The growing body of science showing the harmful effects of high nitrate levels on aquatic life.
- The 2008 Clean Water, Land, and Legacy Amendment (CWLLA) to the Minnesota constitution, which provided funding for protecting drinking water sources; protecting, enhancing, and restoring lakes, rivers, streams, and groundwater; and pursuing other goals.
- The development of Minnesota's Water Management Framework, which supports locally led water quality improvement plans, including Watershed Restoration and Protection Strategies (WRAPS) and comprehensive watershed management plans (CWMPs), through programs such as One Watershed, One Plan (1W1P).
- The development of a Nitrogen Fertilizer Management Plan by the Minnesota Department of Agriculture (MDA), drafted in 2013–2014 and finalized in 2015, which represented a blueprint for preventing or minimizing nitrogen fertilizer impacts on groundwater nitrate levels.

1.1.2 The 2014 NRS employed a multifaceted approach

With the downstream and in-state nutrient issues noted above, Minnesota developed a comprehensive strategy to reduce nitrogen and phosphorus in Minnesota's lakes, streams, rivers, and groundwater. The intent was to develop a Minnesota strategy that is written and owned by the regional, state, federal, and academic organizations involved with water nutrients.

The 2014 NRS was designed to work in the following ways:



Fishing together in Minnesota.

- **Making nutrient science available** by serving as a repository of information about nutrient sources and delivery to waters.
- **Documenting the degree of action needed** by using the best science available to describe the degree of best management practice (BMP) adoption needed to reach statewide nutrient reduction goals.
- **Addressing both local and downstream needs** to meet nutrient reduction goals for waters within Minnesota and leaving the state.
- **Encouraging different scales of action** at the statewide, major river basin, and subbasin watershed scale, while also connecting to the Mississippi River, the Great Lakes, and the Lake Winnipeg basins.
- **Addressing point and nonpoint nutrients** by focusing on the categories of nutrient sources that contribute the most nutrients to waters.
- **Building from existing state programs and frameworks** by advancing their implementation and including new efforts where needed.
- **Ensuring accountability on progress** by tracking and highlighting efforts and outcomes for stakeholders.
- **Serving as an adaptable, multiple-decade strategy** that evolves to keep up with current science, new findings, previous progress, and innovative approaches.

The 2014 NRS was multidimensional and used for a wide range of purposes, including:

- **Informing other state-level plans and frameworks** addressing nutrients, such as the Minnesota State Water Plan and Clean Water Council strategic plan, and informing major watershed planning and management efforts.
- **Serving as a motivating force** to advance nutrient programs by clarifying goals and solutions.
- **Communicating the big picture** by synthesizing the wealth of data and information to tell the story of nutrients at the state and regional scales, including through UMN Extension Service programs, water summits, state and national conferences, research initiatives, training modules for the Minnesota Board of Water and Soil Resources (BWSR) and the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) staff, and more.
- **Developing watershed decision support tools and visualizations** to help state and watershed organizations plan and implement nutrient reduction and track progress.
- **Connecting the nutrient load reduction** needs with the practices and acreages of new implementation that could achieve those reductions.
- **Qualifying Minnesota to receive federal funds** from programs that require applications showing linkages to the state NRS, such as NRCS initiative monies through the Regional Conservation Partnership Program (RCPP), Mississippi River Basin Healthy Watershed Initiative, National Water Quality Initiative, and EPA-provided Gulf HTF funds.
- **Facilitating interstate collaboration and learning** by sharing information and approaches during meetings among the Mississippi River Basin and Red River Basin states. Minnesota's NRS is one of 12 state strategies in the Mississippi River Basin.

Minnesota's NRS has served the state well by meeting the above-intended purposes during its first decade (2014 through 2024). Minnesota aims to further these uses of the NRS by strengthening existing approaches and addressing new challenges to achieve the final goals. The availability of new information and methods is driving the need for the NRS update in 2025, as described below.

1.1.3 The 2014 NRS was designed to be adaptive

The Minnesota NRS was designed as an adaptive management plan (Figure 1-2). The problem of excess nutrients, including the sources of these nutrients, was assessed as part of the 2014 NRS, which was developed to address those problems. The strategy's implementation was monitored with the intention of evaluating the NRS's recommendations and adjusting where needed. The 2014 NRS set a goal of 10 years for this evaluation and adjustment, with interim assessments along the way. In 2020, the Minnesota Pollution Control Agency (MPCA) published a [5-year NRS progress report] that tracked the advances in meeting NRS goals through changes in water quality, programmatic developments that implemented NRS strategies, and BMP adoptions.

Figure 1-2. The adaptive management cycle.

Source: Williams et al. 2009.

In 2021, the federal EPA received funding from the [Bipartisan Infrastructure Law] to support Gulf HTF states and Tribes with nutrient reduction efforts across the Mississippi River Basin. Minnesota used some of its share of those funds to begin the planned updates of the 2014 NRS to better serve the water quality needs of the state and waters leaving the state. This funding also allowed for more research and updated modeling based on water quality monitoring in Minnesota during the last decade.

Collecting biomonitoring data.

Beginning in late 2022, an NRS revision team began assessing the monitoring data related to the 2014 NRS and the 5-year NRS progress report. Programs and practices put in place to manage nutrients since 2014 were reviewed. Water quality data collected at various locations within the Mississippi River, Lake Winnipeg, and Lake Superior watersheds over the past 10 years were evaluated to see if the changes on the land were appearing yet in the water. Chapters 2 and 3 report on those water quality findings and evaluate the effectiveness of Minnesota's nutrient reduction work. Chapters 4 to 6 evaluate the practices and programs that should be leading to improved water quality, identify opportunities to improve those efforts, and provide recommendations on adjustments needed to ensure future nutrient reduction. Chapters 7 and 8 define what data should be tracked to continue monitoring nutrient reduction and lay out the key actions that will lead to substantial nutrient reductions. Some of the external changes that have increased or hampered nutrient reduction success are described below and in subsequent chapters.

1.2 What changes prompted the 2025 NRS update?

Much has been accomplished during the first decade of NRS implementation, and many changes have occurred. The state's ability to assess these changes has greatly improved. Key changes prompting the need for an update to the 2014 NRS include:

- **Updated water quality data and modeling**. Water quality monitoring has increased over the past 10 years. Models and tools to evaluate spatial and temporal water quality trends have advanced.
- **Updated practice adoption and program data**. State, federal, local, and private programs addressing nutrients have expanded. Some programs have established tracking systems to show how well the adopted practices are reducing nutrients.
- **Updated watershed strategies and planning**. Comprehensive watershed science assessments and planning efforts now cover the entire state of Minnesota. Social sciences and an understanding of the human dimension have advanced.
- **Updated science on nutrient-reducing practices**. Research to better understand the science of nutrient reduction solutions has advanced. Models to predict water quality changes with practices on the land have improved.
- **Updated information about downstream goals**. Nutrient-reduction progress toward goals in the Gulf, Lake Winnipeg, and Lake Superior has been evaluated to determine remaining nutrient reduction needs for these waters.
- **Updated science on climate and other external influences**. Extreme weather events and rapid shifts between these extremes have increased, which affects nutrient management efforts. Changes in land use, cropping system types, soil drainage, and impervious lands can also influence nutrient delivery.

The combined evaluation of this information provided the basis of the NRS updates. Analyses of these changes also helped the state answer the questions of how well Minnesota is doing in reducing nutrients and what else must be done to meet nutrient reduction goals.

1.2.1 Updated water quality data

NRS goals will ultimately be achieved when the long-term average water quality conditions meet the intended goals, and these water quality conditions are sustained over time. Assessing water monitoring results at different scales, on different timeframes, and in different water types is important for understanding progress. Fortunately, Minnesota's water quality monitoring information has greatly increased during the past decade, strengthening opportunities for analyzing trends and comparing recent water quality with baselines and goals. Monitoring results show that although progress has been made, Minnesota must reduce nutrients further to meet in-state and downstream nutrient reduction goals.

Chapter 2 assesses water monitoring results for major river nutrient loads near the state line, and Chapter 3 evaluates water quality progress in lakes, streams, rivers, and groundwater within Minnesota.

Water quality monitoring in rivers, lakes, and groundwater wells is a critical component of NRS evaluation; however, monitoring results do not provide an immediate or perfect picture of progress due to complexities, such as:

- Lag times exist between when changes on the land occur and when those changes can be detected in water.
- Legacy nutrients in soil, lakes, and groundwater can emerge over time.
- The influence of weather and climate is not consistent across a large state like Minnesota.

- River nutrient level monitoring and trend evaluation models have inherent imperfections.
- Watershed characteristics can vary tremendously across river drainage basins and the state.

Because of these complexities, other interim indicators of NRS progress are also needed while waiting for long-term water quality monitoring to provide more definitive results and conclusions. Two other important progress indicators include the scale of newly adopted BMPs intended to reduce nutrient loss to waters and the advances in the large-scale programs and efforts driving that new adoption.

1.2.2 Updated watershed strategies and planning

Several legislative and administrative factors have influenced NRS revisions. Although extensive watershed planning was done in the seven-county Twin Cities Metro Area beginning in 1987, state agencies' development of the Minnesota Water Management Framework in 2013 accelerated watershed-specific scientific assessments across the entire state. This framework helped guide the development of WRAPS and the comprehensive local watershed planning processes implemented through the 1W1P program.

Between the release of the 2014 NRS and the summer of 2023, the WRAPS process was completed in all of Minnesota's 80 major watersheds, providing a wealth of data on water quality and the biological stressors affecting aquatic life in lakes, streams, and rivers in each watershed. Because many of the nutrient-reduction BMPs rely on voluntary implementation by landowners, land users, and residents of the watershed, WRAPS and 1W1P programs also include a focus on the human dimension by building trust, networks, and positive relationships. The watershed planning process to prioritize and implement local nutrient-reducing management actions has begun in all the planning areas designated by the 1W1P program; at the time of this writing, 54 out of 60 plans have been finalized, one was undergoing its 90-day review, and plans for all 1W1P planning areas had begun.

The 2014 NRS provided guidance to both the WRAPS process and the CWMPs developed through the 1W1P program on reducing excess nutrients. These watershed efforts in turn generated extensive data and insight to help apply the NRS and direct how the NRS needs to be adjusted to provide better support when implementing nutrient-reduction efforts. Part of the adaptive management assessment of the NRS included a review of each of the WRAPS and 1W1P documents to learn from those efforts, as described in Chapter 6 and in Appendix 6-3. The NRS revision team also examined how large-scale NRS goals can be integrated into small-watershed-scale planning, including what actions are needed on smaller watershed scales to help meet the combination of local and downstream nutrient-reduction goals. Chapter 6 provides a full description of Minnesota's watershed approach to water management.

1.2.3 Updated science on nutrient-reducing practices

Since the 2014 NRS, considerable research has been completed on nutrient-reducing practices for cropland and urban stormwater. Compiling and reviewing this body of research is important for keeping the NRS up-to-date and providing the most accurate information available.

In partnership with the NRS revision team, the UMN led an effort to update the effectiveness of primary cropland practices to reduce losses of nutrients to waters. These results are included in Chapter 5 and appendices 5-1 and 5-2. The science of achieving wastewater nitrogen reduction from municipal wastewater was also reviewed for the 2025 NRS update, using results from some cities that successfully reduced wastewater nitrogen in cold climates, as reported in Chapter 4 and appendices 4-1 and 4-2.

1.2.4 Updated practice adoption and program data

Over the past decade, considerable progress has been made in understanding the number of land acres treated with nutrient-reducing practices and how that translates into reducing nutrient transport to waters. An important part of the NRS adaptive management approach includes assessing progress by tracking the changes seen on the land and in the programs that implement these changes.

Practice adoption changes

During the past decade, Minnesota has developed systems to track the implementation of nutrient-reducing practices on the land adopted through state and federal assistance programs. These tracking systems are described in Chapter 7. More than four million acres of land have been treated in Minnesota since 2014 through government programs alone, as described in more detail in chapters 2 and 5. Practices adopted without government assistance are often more difficult to accurately track and quantify and may represent sizeable additional implementation efforts.

Minnesota has recently developed tools to model the effects of the aggregated practices across the state on river nutrient load reductions. These models were used to estimate the nutrient load reductions from practices and compare those to river monitoring results, as described in Chapter 2.

Changes in programs

The 2014 NRS highlighted 42 strategies that could reduce excess nutrients. The 2020 NRS progress report evaluated over 36 large-scale programs and other new efforts that were used to implement these strategies between 2014 and 2020 (see Appendix A of the 2020 NRS progress report for descriptions of progress within each program).

Farm along the Root River, MN

In 2024, members of the NRS revision team updated the 2020 assessment of large-scale state, federal, and private industry programs addressing nutrients, and they evaluated a number of additional nutrient-reducing programs, as presented in chapters 4, 5, and 7. Most programs highlighted in the 2014 NRS and the 2020 NRS progress report still existed, and additional programs had been initiated to address nutrient pollution sources. About half of the ongoing programs applying NRS strategies related to cropland nonpoint sources of nutrients, and the others represented strategies affecting nonagricultural sources and feedlots. All but one of the strategies identified in the 2014 NRS were implemented in some way. Chapter 4 describes the strategies and programs most directly affecting urban nutrient sources, and Chapter 5 describes those addressing rural nutrient sources.

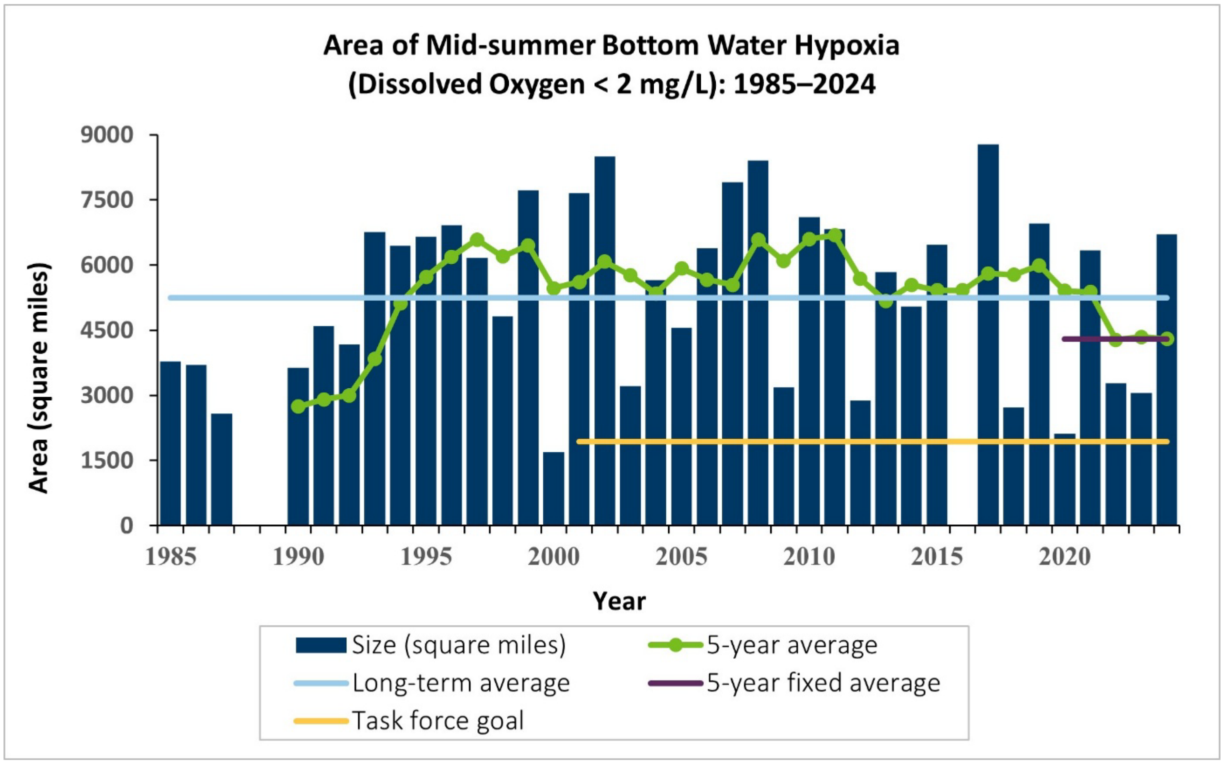
1.2.5 Updated information about downstream goals

Since the 2014 NRS, several updates have been made relating to goals in the Gulf, Lake Winnipeg, and Lake Superior. These updates were an additional source of new information that prompted the 2025 NRS revision.

Gulf hypoxia

The Gulf HTF monitors the size of the hypoxic zone each summer and tracks the collective nutrient reduction successes of the entire basin. In its 2023 Report to Congress, the HTF noted that the Mississippi River Basin states had met their interim nitrogen reduction goal of a 20% reduction in nitrogen by 2025, but the interim phosphorus goal had not been met. The size of the hypoxic zone has decreased somewhat, especially since 2011, but the average size of the hypoxic zone is still well above the goal (Figure 1-3). Monitoring of the Mississippi River at the Gulf shows progress, but it also shows that very large nutrient reductions are still needed before the hypoxic zone reaches the intended average size of 5,000 square kilometers, or 1,930.5 square miles.

Figure 1-3. Size of the Gulf's hypoxic zone (1985–2024).



Source: NOAA 2025.

Increasing temperatures in the Gulf may create additional challenges to meeting final goals. The Gulf is experiencing rapid warming, with water temperatures increasing at approximately twice the rate of the global oceans between 1970 and 2020 (Wang et al. 2023). In its 2023 Report to Congress, the EPA noted that hypoxic conditions in the Gulf are "likely to worsen if projected climate changes are realized" (EPA 2025). The climate changes documented in that report were based on peer-reviewed literature and Gulf-specific modeling; this work indicates a likelihood that nutrient inputs will increase due to increased precipitation in the Mississippi River Basin, warmer Gulf water temperatures, and more stratification of Gulf waters, resulting in larger and longer-lasting algal blooms.

Lake Winnipeg Basin

Lake Winnipeg, to the north of Minnesota in Manitoba, Canada, is the 10th largest freshwater lake in the world by surface area. The lake has suffered from extensive harmful algal blooms since the 1990s as a result of human nutrient inputs (Schindler et al. 2012). The 2014 NRS referenced the existing (at that time) interim numeric goals for nitrogen and phosphorus load reductions to the Red River and noted that new goals were being developed. In 2020, the International Joint Commission (IJC) and the IRRWB recommended that additional nutrient reduction actions be implemented for the Red River leaving the United States near Emerson, Manitoba. The governments of the United States and Canada adopted loading targets of 1,400 tons/year for phosphorus and 9,525 tons/year for nitrogen for waters at the international border (IJC 2022) but did not set a timeline to achieve them. While historically phosphorus has been viewed as the nutrient limiting algal growth in freshwater, a growing body of research has shown that reducing both nitrogen and phosphorus is often needed to prevent eutrophication (Burton and Armstrong 2020). Chapter 2 discusses what meeting those loading goals means for Minnesota.

The Lake Winnipeg Basin also includes large watersheds from Minnesota and Canada that drain into Lake of the Woods. In 2018, the IJC endorsed and submitted the IRRWB's recommendations for immediate interim phosphorus reductions in Lake of the Woods to the governments of Canada and the United States. Specifically, the IJC endorsed a recommendation that the governments of Canada, Ontario, and Manitoba commit to an 18.4% reduction in phosphorus loads to Lake of the Woods as an interim measure at that time.

Lake Superior

The 2014 NRS identified the streams and rivers draining into Lake Superior to be in good condition, and, in general, protection from additional phosphorus additions, not restoration, was needed to maintain Lake Superior's low nutrient levels. However, since the 2014 NRS, algal blooms have been increasing across Lake Superior. While blooms were recorded in the southern part of the lake beginning in 2012 (Sterner et al. 2020), algal blooms have also been observed along the Canadian shore near the Thunder Bay region since 2019 (Sharma and Culpepper 2024). Blooms seem to be connected to large rainstorms occurring several weeks before the recorded bloom and early spring warmth occurring in bloom areas. A 2020 study (Reinl et al. 2020) found that the types of algae in these blooms most likely originated in tributaries to Lake Superior, were washed downstream via storms, and, when reaching the warmer, brighter conditions of the lake, grew to a high enough abundance to produce a bloom.

Lake Superior's winter ice cover has decreased due to warming winters, and the summer temperatures of Lake Superior's surface waters have also increased (Austin and Colman 2007), which is likely contributing to algal blooms. In a 2025 assessment of Lake Superior conditions, Reinl et al. (2025) noted that stresses to the lake had a larger impact on the nearshore and estuary areas of the lake, as these areas experienced more human use and received watershed inputs of sediment and nutrients. Likewise, because these areas were shallower, warmer, and isolated by currents from the deeper lake waters, pollutants such as nitrogen and phosphorus were more likely to drive algal blooms and other ecological degradation there (Reinl et al. 2025).

Like other boundary waters between Canada and the United States, Lake Superior is overseen by the IJC and governed by the Great Lakes Water Quality Agreement. While this agreement supports the chemical, physical, and biological integrity of the Great Lakes, it did not set numeric goals for nutrient levels within Lake Superior. However, the 2012 version of the agreement stated that the Great Lakes shall be "free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem."

Lake Superior, north side of Shovel Point.

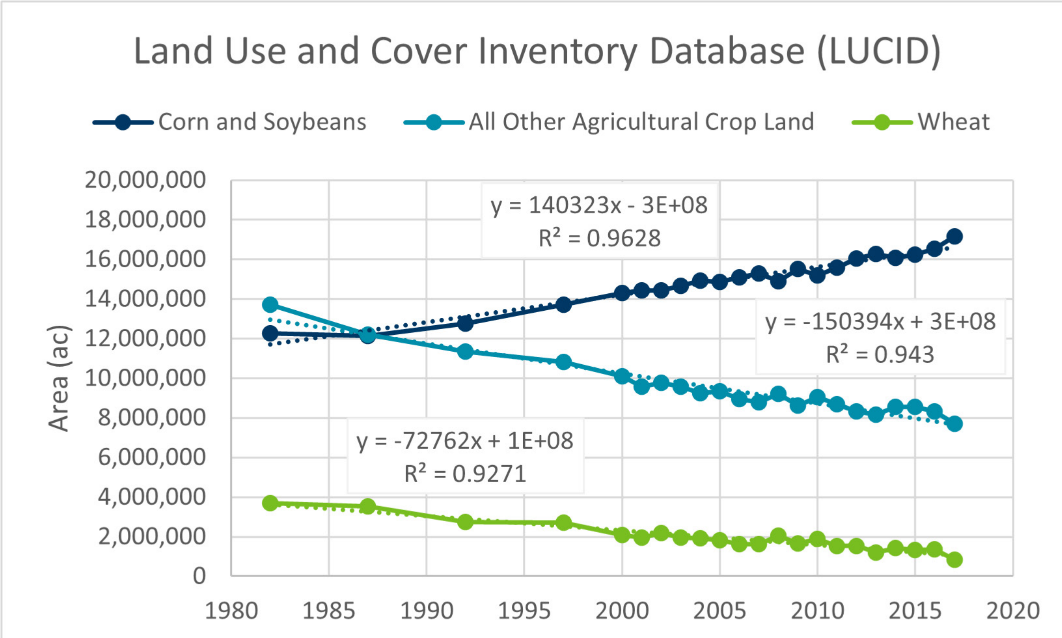
1.2.6 Trends in climate and other external influences

Changes in external influences on nutrient losses have continued during the past decade and need to be periodically considered to see whether these changes should trigger adjustments to the NRS. The 2020 NRS progress report described changes in weather/climate, land use, urban development, wetlands, cropland tile drainage, and irrigated cropland. Those analyses, along with data from more recent years, highlight the added challenges to reducing nutrients from waters.

Because these are long-term trends, the conditions described in the 2020 update are not much different from those of 2025. Many of these topics are covered in depth by other entities; in this document, short summaries will be provided, along with references to additional resources. The following external influences were considered in analyses throughout the NRS.

- **Climate trends**. The Minnesota Department of Natural Resources (DNR) State Climatology Office monitors historical and current weather to address the impact of climate on Minnesota and its citizens. It has documented the following climate trends (DNR 2025a):
  - Warmer and wetter conditions. Between 1895 and 2020, Minnesota has warmed by 3 degrees Fahrenheit (°F), and annual precipitation has increased by an average of 3.4 inches. These changes have become more pronounced since 1970.
  - Heavier rains. Rains have become heavier, and large-area storms are more common. The occurrence of large, heavy rains has significantly increased since 2000, and the trend is expected to continue.
  - Warmer winters. Minnesota winters have become warmer. From 1970 to 2021, the average daily winter low temperatures increased 15 times faster than the summer daily average high temperatures.
- **More frequent weather extremes**. The occurrences of extreme weather events and rapid shifts between these extremes have been increasing. For instance, although the winter of 2022–2023 was one of the snowiest and wettest on record and caused spring flooding, a drought began in May, and the summer of 2023 was one of the driest on record in Minnesota. UMN researchers believe this unstable precipitation pattern will continue into the next century, making extended periods of drought and flash flooding more common and intense (Ford et al. 2021; Roop et al. 2024).
- **Agriculture water management changes**. The U.S. Census of Agriculture indicated that between 2012 and 2022, eight of the top 10 counties in the nation installing new cropland tile drainage were in Minnesota. During that time, tile-drained acreage increased by 25% from 2012 to 2017 and by 2% between 2017 and 2022. Minnesota DNR also reports that irrigation in Minnesota for crop production and noncrop systems has increased over time. In the 1970s, the total water used varied between 10 and 20 billion gallons per year. In the drought years of 1976–1977, Minnesota saw a great interest in installing new irrigation systems, especially those using groundwater as the primary source. By the drought year of 1988, peak reported water use was over 100 billion gallons annually. A steady flow of new large-scale irrigation systems has been installed since then. Currently, there are 7,500 active irrigation water appropriation permits. In recent dry years, such as 2021, permitted irrigation reported using 178 billion gallons of water; in wetter years, such as 2024, only 95 billion gallons was reported used (the 1960–1980 values are from U.S. Geological Survey (USGS) "Estimated use of water in the United States" series, and the 1985–2024 values are from Minnesota DNR water use reports).
- **Less crop diversity**. Analysis of data from the USDA Land Use and Cover Inventory Database indicates that total cultivated cropland and perennial lands have remained largely the same since 1982, but corn and soybean acreages have increased over that timeframe. Decreased production of other crops has offset this, with about half of the offset coming from wheat.

Figure 1-4. Cultivated crop land and perennial land changes (1980–2020).



- **More impermeable lands**. Based on analysis of National Land Cover Database data, impermeable urban lands have slightly increased from 2013 to 2021 (the most recent years for which data were available) from 1.3% to 1.6% of the state's land cover.
- **More people**. The Minnesota State Demographic Center recorded that the statewide population increased from 5.3 to 5.7 million people between 2010 and 2020, increasing wastewater generation and the associated need for wastewater nutrient reduction.

1.3 How was the 2025 NRS update developed?

Most of the same organizations that developed the original 2014 NRS met in late 2022 to initiate a process to revise the NRS, address the changes highlighted in Section 1.2, and include other updates. In addition to updating the strategy with the latest data and science, the organizations sought to develop the following:

- An interactive way for people to access ongoing progress-tracking information.
- New approaches for accelerating the adoption of key nutrient-reducing practices.
- Plans for further integrating large-scale NRS work with Minnesota's Water Management Framework.
- More specific approaches for achieving wastewater nitrogen reduction.
- Estimates of the nutrient reduction amounts that are still needed, along with updated scenarios that could achieve those reductions.
- Stronger NRS linkages to in-state nutrient reduction needs and the relationships between in-state and downstream needs.
- Enhanced communications for increasing awareness of the NRS and its utility.
- A transition from a static NRS document to a flexible, interactive program anchored by the NRS Dashboard.

The NRS revision team intended to achieve these advancements while also retaining most elements of the 2014 NRS, allowing the NRS purposes described in Section 1.1 to continue.

1.3.1 Evaluation and adjustment process

In 2022, leadership from the following organizations that developed the 2014 NRS reconvened to begin the revision process: DNR, MDA, Minnesota BWSR, Metropolitan Council (Met Council), Minnesota Department of Health (MDH), MPCA, NRCS, UMN, and the USGS.

Leaders from these organizations and the Minnesota Environmental Quality Board served on a steering team. Agency technical staff provided expertise through the following six topic-focused technical coordination and advisory teams:

- River loads/goals/sources/priority areas
- Urban nutrients
- Agriculture BMP science
- Agriculture BMP adoption scale-up
- Watershed-scale integration tools and support
- Progress tracking system

Work group focus areas

The focus areas of each work group are described below. At least four components of work were performed by each work group, referred to as NRS building blocks. Groups generally met on an every-other-month schedule during 2023–2024 to share resources, discuss research and data needs, present new findings, evaluate the progress of nutrient reduction, suggest plan adjustments, and review updated NRS content. Work in 2025 focused on writing and refining the topic-specific chapters. The work group members also provided an important link to collaborators within and external to the 10 organizations. Because the NRS is a planning tool for multiple state and federal entities, the work group members served as liaisons to their own agencies and helped to identify how their organizations use the NRS and what revisions would be helpful in their work.

The six primary work groups and lead scientists revising the NRS focused on the following key topics:

1. Water quality goals, conditions, trends, and priorities

An important task of the 2025 NRS is determining how much progress has been made in reducing the nutrient pollution entering Minnesota waters, as well as leaving the state, since 2014. The remaining nutrient load reductions needed to meet goals for state lines and individual watershed outlets were determined using updated models supported by a wealth of monitoring data. Priority watersheds for the nutrient reduction needs downstream of Minnesota were updated, and new priority watershed maps were developed to address various in-state nutrient reduction needs. Also, priority nutrient sources were verified with new data sources. Data from multiple organizations supported these analyses. Chapter 2 discusses updated goals, trends, and priorities for addressing nutrients in major rivers and the needs downstream of Minnesota. In contrast, Chapter 3 covers local (in-state) water quality needs for lakes, streams, and groundwater. Work supporting both chapters can be found in appendices 2-1 through 2-4 and 3-1.

2. Urban nutrients

Urban areas cover a small percentage of land in Minnesota, but they are still an important source of nutrients in waters through municipal and industrial wastewater treatment facilities (WWTFs) and stormwater runoff. This work group reported on past progress with wastewater phosphorus reduction in Chapter 4 and summarized the *Wastewater Nitrogen Reduction and Implementation Strategy* developed in 2023–2024 by MPCA. The strategy also addressed technologies and the costs of wastewater denitrification in cold climates, changes to urban stormwater permitting and management, and the establishment of a stormwater research consortium. As described in Chapter 4, this workgroup identified the necessary resources, reporting, and next steps to continue managing urban nutrients. The full report on how some WWTFs achieved cold-weather wastewater denitrification can be found in appendices 4-1 and 4-2.

3. Agricultural BMP science

UMN researchers led a comprehensive review of the latest science on agricultural nutrient conservation BMPs and continuous living cover (CLC) options in the Upper Midwest. The scientists reported on the efficiency of conservation practices in reducing nutrients to water and provided recommendations on what practices will be most effective in meeting the updated NRS goals. Findings are shared in Chapter 5; the full report of this work can be found in appendices 5-1 and 5-2.

4. Agricultural BMP adoption

The MDA led the effort on the scaling-up of adoption of the most effective BMPs and CLCs across the state to reduce nutrients. This work considered the barriers to BMP adoption, identified existing and new approaches to reducing nutrient losses to waters from cropland areas, and recommended programs for continued development and expansion. This work is summarized in Chapter 5.

5. Watershed integration support and tools

Locally driven frameworks for achieving surface water and groundwater quality goals, first established via watershed planning efforts in the Twin Cities Metro Area, are now in place in every major watershed in Minnesota through WRAPS, the 1W1P program, and/or groundwater restoration and protection strategies (GRAPS). The NRS work group examined nutrient reduction connections between these plans and NRS goals and strategies. Additional local support and watershed tool improvement needs were identified, along with ways that Minnesota's watershed approach can best be used to achieve larger-scale nutrient reductions. This work can be found in Chapter 6 and appendices 6-1, 6-2, and 6-3.

6. Progress tracking system

The NRS belongs to all Minnesotans, and technological advances have allowed data to be more easily shared. In the last 10 years, a large amount of new data and tracking metrics have been made available to enhance long-term progress-gauging efforts. To support shared ownership and accountability, agency partners evaluated the existing progress tracking systems and the remaining tracking gaps. Recommendations were made for a dashboard to provide accessible and timely information about water quality, new practice adoption, and program results as broadly as possible so anyone can see how the efforts to improve our waters are faring. This work is described in Chapter 7.

Concurrent to the NRS updates, a separate work group reviewed solutions and options for addressing high nitrate in southeastern Minnesota aquifers and wells. This work group effort stemmed from a Safe Drinking Water Act Section 1431 emergency petition submitted to the EPA in 2023. The EPA directed Minnesota to develop plans to address immediate drinking water needs and a long-term strategy as well to reduce the causes of nitrate pollution to groundwater. The Minnesota NRS was identified as part of the plan for long-term nitrate reduction, and the NRS revision team reviewed the work group report and recommendations before completing the draft NRS. The report provided specific, detailed recommendations under the following major categories:

- Continue to promote and incentivize policy and programs with the goal of increasing living cover. Many options of BMPs exist to increase the amount of living cover on the landscape. Promote viable market opportunities for small grain farmers as well as hay and pasture-based livestock producers.
- Use existing programs by expanding access and tailoring them to promote nitrate reduction.
- Work at multiple levels in the education system, coordinating messaging and communicating with those who can affect nitrate levels.

Outreach during development

Besides state and federal organization interactions, outreach to the broader Minnesota community occurred through several avenues. Early in the revision process, updates were given at conferences, trainings, invited presentations, and soil and water conservation district (SWCD) events. As the revisions progressed and information on specific findings became available, informational webinars were hosted by MPCA and the other participating agencies to provide details on the science underlying the NRS. Other methods, such as special conference sessions, were used to invite Minnesotans to "follow along" in the process of assessing past progress and updating the NRS. Additional input was solicited through a public review process in summer 2025, and those comments were used to guide the final development of the NRS.

Chapter 2

Nutrient Reduction for Downstream Waters – Progress and Priorities

Key Messages

Chapter 2 provides an update on the goals, progress, and priorities related to nutrient reduction in major rivers leaving Minnesota and draining to three large bodies of water: (1) the Gulf via the Mississippi River, (2) Lake Winnipeg via the Red River, and (3) Lake Superior via various Minnesota tributaries. Groundwater nitrate goals are also described in this chapter because one of these goals connects to the goals for river loads. The key messages in this chapter include:

- **In-state and downstream nutrient reductions are both important**. The 2025 NRS includes the amount of nutrient reduction needed for waters within Minnesota as well as Minnesota's share of the nutrient reduction needed for downstream waters.
- **Results from multiple organizations tell a more complete story**. The 2025 NRS's river load monitoring evaluation uses monitoring results from the MPCA, USGS, Met Council, and Manitoba Conservation and Water Stewardship/Environment Canada to provide a more complete understanding of monitoring and trend results.
- **It's complicated**. The information presented in Chapter 2 is complex because of the numerous options for analyzing changes in water quality, the varied monitoring sites and timeframes used, the variability in weather and climate, and the diverse organizations and models involved.
- **Overall improvement observed**. Minnesota is making progress toward the goals, especially with phosphorus, based on river load monitoring results available through 2023. However, river load monitoring and associated trend analysis results can change given additional years of data. Maintaining long-term monitoring efforts at key sites is critical.
- **More work is needed**. Much more work is needed before reaching goals for both phosphorus and nitrogen loads leaving the state. The best estimates of the remaining nutrient load reductions needed to meet goals at the state lines are 35,517 metric tons per year (MT/yr) of total nitrogen (TN) and 602 MT/yr of total phosphorus (TP) in Minnesota tributaries to the Mississippi River. The reductions still needed from all combined Red River Basin tributaries in Minnesota are 3,486 MT/yr of TN and 538 MT/yr of TP.
- **Mississippi River phosphorus load monitoring shows improvement**. TP loads have decreased (improved) by 32% in the Mississippi River since the 1980–1996 baseline period. An additional 13% of baseline TP loads still needs to be reduced before achieving the 45% reduction goal. The biggest reasons for the observed phosphorus reduction include improved municipal and industrial wastewater treatment, followed by decades of implementing conservation practices on cropland and installing urban stormwater runoff improvements.
- **Northern Minnesota phosphorus load monitoring shows mixed results**. Rivers in the northern part of the state show a mix of phosphorus load change results. The Red River at the Canadian border has not shown improvements with TP since the late-1990s baseline. Modeling suggests

that a majority (66%) of nutrients at this site originate in the Dakotas and Manitoba, but Minnesota is also a large contributor. Farther east, the Rainy River and St. Louis River have shown indications of recent phosphorus load decreases.

- **Mississippi River nitrogen load monitoring is trending in the right direction**. TN loads in the Mississippi River by the state line appear to be modestly headed in the right direction compared to the 1980–1996 baseline, but it is too soon to be certain about this improvement. Monitoring indicates a 6% load reduction since baseline. An estimated 39% reduction from baseline loads is still needed to achieve the 45% reduction goal. An encouraging TN load trend is a 32% decrease in the Minnesota River at Jordan, the largest nitrogen-contributing tributary to the Mississippi River.
- **Red River nitrogen load monitoring**. TN loads in the Red River have decreased by an estimated 9% at the Canadian border since the late-1990s baseline. An additional 42% reduction is estimated in the Red River before final goals are met.
- **River flow variability complicates trend analyses**. Recently, repeated periods of wet years followed by dry years have affected load monitoring results. These effects are not the same in the Red River and Mississippi River basins because weather patterns vary across the state. Changes in river flow can make long-term progress difficult to achieve and detect. NRS analyses accounted for changing flow regimes and found that reductions in nutrient loads at primary monitoring sites were evident when adjusting or normalizing for river flow variability, except for phosphorus in the Red River at Emerson. Understanding river nutrient loads with and without adjustments to account for varying river flows is important for long-term NRS progress evaluation, and both types of results are described in Chapter 2.
- **Modeled load reductions from added practices align reasonably well with monitoring results**. Agricultural BMP adoption through government programs is tracked, and the effects of those newly added practices were estimated. Wastewater discharge monitoring results are also tracked. Since the early 2000s, the combined benefits of these two source reduction efforts have indicated a 27% TP and a 5% TN modeled reduction across the Mississippi River Basin—percentages that are close to the reductions indicated by monitored results.
- **Priority phosphorus sources were verified**. Based on the original 2014 NRS nutrient source assessment and a supplementary source analysis in 2024, the largest contributors of phosphorus loads were found to vary by large-scale basin, as follows:
  - Mississippi River Basin: (1) cropland runoff, (2) wastewater point sources, and (3) streambank erosion.
  - Lake Winnipeg Basin: (1) cropland runoff, (2) wastewater point sources, and (3) streambank erosion.
  - Lake Superior Basin: (1) nonagricultural rural runoff, (2) wastewater point sources, and (3) streambank erosion.

  Statewide, agricultural cropland runoff contributes about 53% of TP load to rivers. Another 20% comes from the combination of streambank erosion, nonagricultural rural runoff, and forest runoff. Municipal and industrial wastewater combined with urban stormwater contributes an estimated 21% of TP, and the remaining 6% is estimated to be from atmospheric deposition directly into waters.
- **Priority nitrogen sources were verified**. The largest contributors of TN loads were found to vary by large-scale basin, as follows:
  - Mississippi River Basin: (1) cropland via tile drainage and leaching to groundwater and (2) wastewater point sources.
  - Lake Winnipeg Basin: (1) cropland, (2) nonagricultural rural runoff, and (3) atmospheric deposition.

- Lake Superior Basin: (1) nonagricultural rural runoff and (2) wastewater point sources.

  The priority nitrogen sources for local waters within each drainage basin will differ from the basin-scale source. Across the state, agriculture contributes an estimated 72% of the TN loads to rivers, wastewater contributes the second highest amount at 8%, and the rest of the sources contribute the other 20%. Most (83%) TN flows through the Mississippi River drainage; therefore, the sources in that basin have the most influence on statewide sources.

- **Priority watersheds for nutrients leaving Minnesota were reassessed**. River nutrient loads that flow out of watersheds to the state lines were re-evaluated to determine priority watersheds for reducing contributions to waters downstream of Minnesota. The highest-priority watersheds for both nitrogen and phosphorus are found in the southern part of the state. However, many medium-priority watersheds are found in northern Minnesota.
- **Watershed nutrient load reduction needs were calculated**. For each eight-digit hydrologic unit code (HUC-8) watershed in the state, watershed outlet load reduction targets for TN and TP were developed through modeling to show how nutrient load reductions from anthropogenic sources in each watershed could potentially, in aggregate, enable the final goals at state lines to be met.

2.1 Introduction

The Minnesota NRS includes goals for nutrient reduction at multiple scales, including protecting and restoring nutrient-sensitive waters within the state and in waters downstream of Minnesota. At its largest scale, the NRS nitrogen and phosphorus reduction needs relate to goals for the Gulf, Lake Winnipeg, and Lake Superior. Identifying and integrating downstream needs and objectives with nutrient reduction goals at watershed scales is an important part of the NRS for water quality improvement and protection.

This chapter primarily focuses on annual nutrient *load*, which is the total amount of a pollutant being transported by water over a 1-year period, often expressed as MT/yr or pounds per year (lbs/yr). Nutrient *concentrations*, on the other hand, affect local water quality goals, such as drinking water and the biological health of local lakes and streams, so these are described in Chapter 3 (“In-State Nutrient Reduction Needs and Priorities”). Note that groundwater nitrate is discussed in chapters 2 and 3 because elevated nitrate concentrations in groundwater not only contribute to the major rivers’ nitrogen loads when the groundwater flows into surface waters through springs and baseflow (Chapter 2), but nitrate also poses a concern for local drinking water sources (Chapter 3).

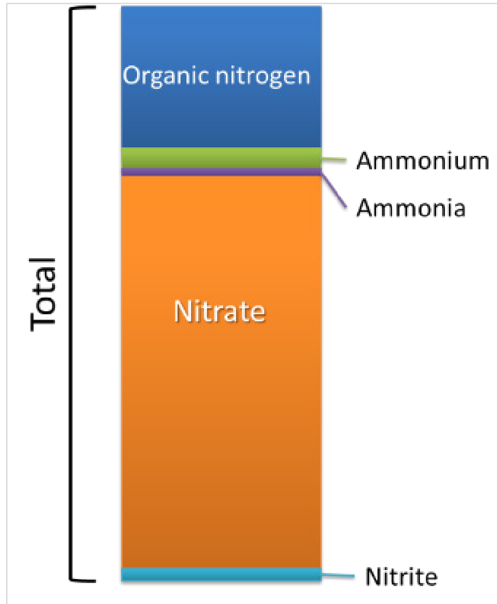
This chapter emphasizes the goals and progress evaluation related to major river nutrient load reduction goals and describes the level of effort still needed at the basin and watershed scales to collectively achieve goals for waters downstream of Minnesota.

2.1.1 Defining TP and TN

The goals for waters downstream of Minnesota are typically based on TP and TN annual loads. Phosphorus in the NRS refers to TP (particulate plus dissolved forms). The term “phosphorus” is used to more generically describe the total amount of phosphorus in waters, and “TP” is used when referring to a specific load or concentration amount.

“TN” includes both organic and inorganic (e.g., nitrite, nitrate, ammonium) nitrogen forms. The NRS uses terms TN and nitrogen synonymously, and nitrate refers to the combination of nitrite and nitrate. TN is used when describing downstream loads, and “nitrate” (the primary dissolved form of TN) is used when referring to in-state concerns associated with nitrogen (Figure 2-1). When referencing a specific concentration or trend, nitrate in the NRS refers to laboratory analyses that include nitrite plus nitrate.

Figure 2-1. Forms of nitrogen that constitute TN in rivers impacted by human sources of nitrogen.



2.2 Goals for major river basins and groundwater

Nutrient reduction goals (phosphorus and nitrogen) in the 2025 NRS are included for the Minnesota portions of three major river basins (Figure 2-2). Data from the Minnesota DNR Watershed Suite indicate that these major river basins occupy the following approximate percentages of the state: Mississippi, 58.3%; Red and Rainy River, 34.3%; and Lake Superior, 7.3%.

- **Lake Superior Major Basin** (including the Minnesota portions of the Lake Superior tributary watersheds).
- **Lake Winnipeg Major Basin** (including the Red River and Rainy River basins, with emphasis on the Red River Basin and pollutant delivery to the Canadian border at Emerson, Manitoba).
- **Mississippi River Major Basin** (including the Missouri River, Cedar River, and Des Moines River basins that ultimately flow into the Mississippi River south of Minnesota).

The 2025 NRS also includes groundwater nitrate reduction goals because high-nitrate groundwater baseflow can enter major rivers and contribute to overall nitrogen loads. Specifically, groundwater nitrate reduction goals are established to reduce the TN load in the Mississippi River Basin and to support the groundwater protection goal established by Minnesota in 1989.

The 2025 NRS goals build on the final 2014 NRS goals, which were based on load reduction goals stated previously in applicable plans or policies. Some of those plans or policies have been modified or updated, as summarized in Table 2-1 and described in the following section.

Figure 2-2. Minnesota's river basins within the three headwater major river drainages to the Mississippi River and Gulf, Lake Winnipeg, and Lake Superior basins.

Table 2-1. TP and TN river load goals and timelines in the original 2014 NRS and the updated 2025 NRS, along with groundwater nitrate goals.

Water body	Nutrient	Original 2014 NRS goals	Updated 2025 NRS goals
Lake Superior MN tributaries	TP	Maintain protection goals; no net increase from 1979 conditions	No increase above 245 MT/yr average (combined MN tributaries)
	TN	Maintain protection	No increase above 2,670 MT/yr average (combined MN tributaries)
Lake Winnipeg (Red River at Canada border)	TP	Achieve reductions identified through international efforts with Manitoba (interim milestone: 10% by 2025)	Reduce to 1,400 MT/yr average load (all states). ~50% reduction from late 1990s (1996–2000)
	TN	Achieve reductions identified through international efforts with Manitoba (interim milestone: 13% by 2025)	Reduce to 18,687 MT/yr average load (all states). ~53% reduction from late 1990s (1996–2000)
Mississippi River	TP	Achieve 45% TP reduction by 2040 (from 1980–1996 baseline)	Same as original
	TN	Achieve 45% TN reduction by 2040 (from 1980–1996 baseline)	Same as original
Groundwater (statewide)	Nitrate	Meet 1989 Groundwater Protection Act goals	Meet 1989 Groundwater Protection Act goals, and reduce groundwater nitrate baseflow into major rivers to enable achieving TN load reduction goals at state lines

2.2.1 Lake Superior goals

The 2014 NRS phosphorus goal stemmed from the Great Lakes Water Quality Agreement of 1978, amended by a protocol signed on November 18, 1987. The 2014 NRS identified a no-net phosphorus increase goal from 1979 phosphorus levels. Some potential concerns about nitrogen reaching Lake Superior were described in Chapter 1. With algal blooms appearing to increase (Reinl et al. 2020; Sterner et al. 2020; Sharma and Culpepper 2024), waters warming in Lake Superior (Austin and Colman 2007; Anderson et al. 2024), and nitrate concentrations increasing in offshore waters of Lake Superior historically and in recent decades (Sterner et al. 2007; Dove and Chapra 2015), there is reason to be cautious with nitrogen additions to Lake Superior.

Until further study of nitrogen impacts can be completed, a no-net-increase nitrogen goal has been added for the 2025 NRS update for Lake Superior, replacing the previous qualitative protection goal. Nitrogen cycling and storage in Lake Superior are not well understood (McDonald et al. 2010). More study is needed to determine the impacts of adding more nitrogen to the lake.

Currently, the offshore waters of Lake Superior are considered overwhelmingly phosphorus-limited (Dove and Chapra 2015), but less is known about nitrogen effects in nearshore shallower/warmer waters. It is possible that nitrogen behaves differently in nearshore and deep-water areas, and that separate criteria will need to be developed to best protect water quality in Lake Superior (Reinl et al. 2025). As more studies show how nitrogen behaves in and affects Lake Superior, this goal can be changed in the future to better fit the lake's needs.

The load monitoring results for Minnesota's tributaries to Lake Superior are insufficient to quantify the nutrient loads to Lake Superior during the baseline reference year of 1979. For the 2014 NRS, USGS's SPAtially Referenced Regression on Watershed (SPARROW) modeling results, representing 2002 conditions, were used to estimate nutrient loading into Lake Superior. Because the land uses in this major basin had not changed substantially since the late 1970s, the SPARROW model load results were believed to reasonably approximate baseline loads. An approximate goal of 248 MT/yr of phosphorus was proposed to represent "holding the line" at 1979 TP conditions.

Since the 2014 NRS, the monitoring of Minnesota tributaries has greatly improved, along with Hydrologic Simulation Program – FORTRAN (HSPF) modeling results calibrated to monitoring data. The aggregated loads of Minnesota tributaries to Lake Superior from the most recent HSPF-modeled 10-year averages are 245 MT/yr for TP and 2,670 MT/yr for TN. The newly modeled HSPF TP load is very close (within about 1%) to the original 2014 NRS baseline loads of 248 MT/yr, which were based on SPARROW. As a result, the newly HSPF-modeled TP and TN loads of 245 and 2,670 MT/yr, respectively, will now serve as a baseline reference point for evaluating changes in aggregated loads from combined Minnesota tributaries into Lake Superior.

2.2.2 Lake Winnipeg Basin goals (Red and Rainy River basins)

The Manitoba Water Stewardship Division developed the Lake Winnipeg Action Plan in 2003, which served as the source of the 2014 NRS's milestone/provisional goals for TN (13% reduction by 2025) and TP (10% reduction by 2025) from a late-1990s baseline. The 2014 NRS noted that the International Red River Basin Water Quality Committee had suggested revisions to Red River nutrient reduction goals and that the NRS would be updated to reflect the final recommended goals.

In September 2019, the IRRWB agreed to pass along the proposed loading targets for the Red River at the United States/Canada boundary to the IJC. In December 2019, the MPCA sent a letter of support for the IRRWB's proposed nutrient reduction targets. The IJC held two public hearings in 2020 and decided to fully support the IRRWB's proposed load targets of 9,525 MT/yr for TN and 1,400 MT/yr for TP at the Red River in Emerson. The final targets for the Red River in Emerson combine nutrient additions from both the Dakotas and Minnesota.

Manitoba's load goals for Lake Winnipeg do not emphasize a percent load reduction from a specific baseline period; rather, they focus on the final goal load amounts to be achieved in the Red River at Emerson, as represented by a 5-year rolling average. These goals represent load reductions of about 53% and 50% of the 20,067 MT/yr and 2,787 MT/yr average TN and TP loads, respectively, that were measured during the late 1990s (1996–2000 average annual loads). Manitoba and the IJC have not yet determined a target end date for the goals. The Minnesota NRS uses a provisional date of 2040 to achieve the final Red River goals until the Manitoba Water Stewardship Division establishes a final goal timeframe.

Minnesota also contributes a relatively small amount of the nutrients to Lake Winnipeg that do not flow through the Red River at Emerson, but instead flow from the Rainy River into Lake of the Woods. Lake of the Woods drains into the Winnipeg River and a long series of multiple flowage lakes before entering Lake Winnipeg. The initial emphasis and load reduction strategy for the Rainy River in Minnesota is to address nutrient loads through the total maximum daily load (TMDL) for Lake of the Woods eutrophication. The goal is to achieve total in-lake phosphorus concentrations of 30 micrograms per liter (µg/L), which is a reduction from the average concentrations of 36 µg/L determined from limited monitoring in 1999 and 2005–2006 and from an average of 39.8 µg/L found more recently (2005–2014). The Lake of the Woods TMDL aims for a 17.3% reduction in phosphorus loads going into Lake of the Woods. At the time of the TMDL development, Minnesota contributed about 64% of the load (432.5 MT/yr from Minnesota and 241 MT/yr from Canada). A 17.3% phosphorus reduction from Minnesota's 432.5 MT/yr is a reduction of 74.8 MT/yr.

2.2.3 Mississippi River (Gulf) goals

The Mississippi River/Gulf HTF developed the 2008 Gulf Hypoxia Action Plan, which set a 45% reduction goal for each HTF member state. Minnesota adopted a nutrient reduction goal proportional to the load reductions needed for the Gulf as a whole, aiming to reduce the 1980–1996 baseline TN and TP loads by 45%. Minnesota's 2014 NRS established a 2040 target year for reducing its part of nutrients headed to the Gulf. Subsequently, the Gulf HTF identified a 2035 target goal achievement date for the Mississippi River at the Gulf. Minnesota's 2025 NRS continues to use the original 2040 timeframe for the 45% load reduction goals.

The Mississippi River near Brainerd, MN

The 2014 NRS and the 2025 NRS include specific load goals for combined Minnesota watersheds that eventually drain into the Mississippi River. This entire drainage basin of the Mississippi River from Minnesota includes the Mississippi River loads and the loads from the Cedar, Des Moines, Missouri and Root rivers. A final goal amount of 50,088 MT of TN and 2,544 MT of TP was identified in the 2014 NRS; this goal amount continues in the 2025 NRS for the Minnesota contributions to tributaries within the Mississippi River Basin. Multiple monitoring sites and modeling can be used to assess progress toward those goals.

2.2.4 Groundwater nitrate goals

The groundwater nitrate goal in the 2014 NRS referred to the goals outlined in the 1989 Groundwater Protection Act. This law applies statewide but, in the context of the NRS, pertains mostly to the Mississippi River Basin. The 1989 Minnesota Groundwater Protection Act's degradation prevention goal states:

"It is the goal of the state that groundwater be maintained in its natural condition, free from any degradation caused by human activities. It is recognized that for some human activities, this degradation prevention goal cannot be practicably achieved. However, where prevention is practicable, it is intended that it be achieved. Where it is not currently practicable, the development of methods and technology that will make prevention practical is encouraged."

Because the groundwater nitrate discharging into rivers and streams contributes a substantial amount of the TN load to the Mississippi River (~31% as noted in the 2014 NRS) and affects the health of in-state waters, the 2025 NRS establishes a groundwater nitrate reduction goal that aligns with the remaining reduction needs for Mississippi River TN. Based on monitoring through 2023, this reduction percentage is estimated to be about 39% but is subject to change as monitoring continues over time. The timeframe for adopting practices to achieve this goal is aligned with the 2040 final goal date. However, river monitoring efforts will not fully reflect such reductions until several decades after changes are implemented on the land due to the slow groundwater transport times to rivers (Alexander and Alexander 1989; Kuehner et al. 2025).

The groundwater nitrate planning goal for reducing discharges into the Mississippi River is expected to concurrently bring the average nitrate concentrations in high-nitrate wells (those exceeding 10 milligrams per liter [mg/L]) down from approximately 16 mg/L to below the health risk limit of 10 mg/L. Therefore, local actions on the land to reduce groundwater nitrate for drinking water purposes will generally align with actions needed for downstream needs and vice versa. Groundwater monitoring results are presented in Chapter 3, as they are associated with well water nitrate conditions.

2.2.5 Applying the major basin goals to specific river monitoring sites

The major river basins and groundwater goals (percent reduction) described above are applied to water quality results measured at specific long-term river monitoring sites near state lines (Table 2-2) to help track progress over time. Long-term monitoring results for all monitoring sites are provided in detail in Appendix 2-1, which was written using the monitoring and modeled annual river loads provided by MPCA, USGS, the Met Council, and Manitoba Water Stewardship Division.

At certain monitoring sites, such as the Red River at Emerson site, a high fraction of the load is coming from other neighboring states. The Mississippi River at La Crosse (Lock and Dam 7) monitoring site receives flow from much of the Mississippi River Basin in Minnesota, but not all. The La Crosse site captures 87% of TN and 84% of TP that originate in Minnesota. The remaining 13% of TN and 16% of TP flow into Iowa from the Des Moines, Cedar, and Missouri rivers on the southern border of Minnesota and reach the Mississippi River further downstream south of Minnesota.

Table 2-2. Average river loads: baselines and goals (in MT) at the primary NRS state-line monitoring sites.

River and location(s) [a]	Pollutant	Fraction of load from MN	Baseline load	Average loads upon reaching final goals (all states)	Average loads upon reaching final goals (MN watersheds only)
Mississippi River (La Crosse L&D 7)	Phosphorus	81.4%	4,976 [b]	2,737	2,228
	Nitrogen	77.7%	97,996 [b]	53,898	41,879
Mississippi River (Red Wing L&D 3)	Phosphorus	97.5%	3,664 [c]	2,022	1,971
	Nitrogen	95.5%	73,447 [c]	41,790	39,909
Red River (Emerson, Manitoba)	Phosphorus	34.1%	2,787 [d]	1,400	477
	Nitrogen	39.9%	20,067 [d]	9,525	3,800
Lake Superior (MN tributaries sum)	Phosphorus	100%	245 [e]	245	245
	Nitrogen	100%	2,670 [e]	2,670	2,670

Notes:

L&D = lock and dam

[a] Monitoring site details are described in Section 2.2.

[b] Per the 2014 NRS, based on a baseline period of 1980–1996. Monitored loads were not available for the 1980s at La Crosse; so, to calculate the baseline for 1980–1996, the 2014 NRS relied on a combination of actual and estimated loads based on relationships between the Red Wing and La Crosse loads.

[c] 1980–1996 average loads over baseline period using the Weighted Regressions on Time, Discharge, and Season (WRTDS) non-normalized loads (sections 2.4.1 and 2.5.1).

[d] 1996–2000 average loads over the approximate baseline period using the non-flow-normalized WRTDS loads from a WRTDS run on November 13, 2024. The IRRWB does not emphasize a specific baseline, but rather focuses on the loads needed to reach the final goal (1,400 and 9,525 MT/yr).

[e] Lake Superior nutrient loads from Minnesota tributaries were unknown in 1979. "Baseline loads" in the 2014 NRS were calculated from SPARROW model loads. More monitoring in recent years has enabled MN to model loads in tributaries to Lake Superior more accurately using the HSPF model. "Loads upon reaching final goal" are based on recent aggregated watershed HSPF model loads (10-year averages of the most recent model for each modeled watershed). See Appendix 2-1 for the HSPF model loads.

Appendix 2-1: A Comprehensive Review of Data, Progress, and Recommendations

Appendix 2-1 is a technical report that presents assessments of monitoring and modeling data near major river basin outlets and state lines and identifies progress toward meeting the milestones and goals of the 2014 NRS. Chapter 2 of the 2025 NRS uses several of the results from Appendix 2-1, but much additional information is included in this appendix. Appendix 2-1 includes the following key sections:

- **Appendix 2.1, Section 2**. Evaluates the flow-weighted mean concentrations (FWMCs) and the loads determined from TN and TP monitoring data. Much of this section is composed of evaluations of baseline and recent conditions for FWMCs, non-normalized loads calculated using FLUX32 and the WRTDS, and flow-normalized loads calculated using WRTDS. Section 2 also includes evaluations of flow-FWMC and flow-load relationships, assessments of in-state and out-of-state nutrient load contributions, and an assessment of progress toward achieving milestones and goals established in the 2014 NRS. Many of the analyses from Appendix 2.1, Section 2, are discussed in Chapter 2.
- **Appendix 2.1, Section 3**. Evaluates loads and yields determined from TN and TP modeling data. This section focuses on the evaluation of simulated loads and yields at watershed outlets and at state lines. Section 3 also includes estimates of annual yields at the basin scale (e.g., Minnesota River, Rainy River) and the identification of priority watersheds for restoration and protection. The analyses of simulated loads and yields in Appendix 2.1, Section 3, are not discussed in Chapter 2 because Chapter 2 focuses on monitoring data.
- **Appendix 2.1, Section 4**. Evaluates the monitored and modeled loads together to identify which datasets are best for assessing progress. This section compares baseline, current, milestone (proposed), and 2040 goal loads. The exploratory analyses in Appendix 2.1, Section 4, are not discussed in Chapter 2.

The Appendix 2-1 report itself has 12 appendices. Appendices A through D present 73 charts of FWMCs and loads determined from monitoring data collected at 21 monitoring sites. Several of the charts in appendices A through D are reproduced in Chapter 2. The other appendices present flow-corrected trends (Appendix E), linear regressions of FWMC and flow (Appendix F) or FWMC and load (Appendix G), in-state and out-of-state load fraction (Appendix H), subwatersheds bisected by the state line (Appendix I), model results (Appendix J), evaluation of monitored versus modeled loads (Appendix K), and a brief summary of pertinent climate change studies (Appendix L).

Load reductions from all contributing states are important for meeting the downstream goals. The SPARROW model was used to estimate the load fraction from Minnesota and from other states (Appendix 2-1, tables 47–48), as represented in Table 2-2. Section 2.3 describes the monitoring site locations and other details.

An in-depth analysis of river nutrient load results, as performed by Tetra Tech consultants and completed in 2025, is included in its entirety in Appendix 2-1, with the most important river nutrient load information incorporated into this NRS chapter (see box for more details on Appendix 2-1).

2.3 Evaluating river nutrient load progress

Progress toward river nutrient goals has been tracked over time to determine if strategies are successful and how much additional work is needed. Long-term monitoring results provide important indications of progress toward goals. Multiple decades of monitoring are needed to discern trends that are complicated by nutrient transport lag times, legacy nutrients from historic practices, weather and climate variability/change, and other inherent statistical uncertainties.

River nutrient change assessments for the Minnesota NRS are quite complex because the results can be shown in many different ways:

- Monitor water quality changes in rivers OR model practice changes on lands.
- Use simplistic modeling approaches that focus on one or two main factors OR complex models that account for many factors.
- Use flow-normalized (sometimes referred to as FN) methods OR non-flow-normalized methods.

- Focus on the in-state water needs (concentrations) OR focus on downstream needs (loads).
- Include other neighboring state contributions OR isolate only the Minnesota tributaries.
- Assess recent changes in the river OR assess longer timeframes from baseline years.

The 2025 NRS uses multiple combinations of the above options to assess indications of river nutrient changes. Estimates of load reduction change are calculated from both river monitoring (changes in the water) and practice adoption (changes on the land). The 2025 NRS relies on methods that directly measure or estimate the impact of Minnesotans' actions on river nutrient levels. The 2025 NRS also includes complementary indicators that reflect outcomes from a combination of Minnesotans' actions and the effects of climate and weather patterns and changes.

2.3.1 River load monitoring: indicators of change

River nutrient data are collected throughout the year by multiple monitoring programs in Minnesota. These data are used to calculate annual river total nitrogen and phosphorus loads. Converting the monitored nutrient concentration data to annual nutrient loads requires the use of computer models that include factors such as the flow of water and time (see the "Modeling loads" box below for specific model details). The calculated load changes are driven by changes in river flows and nutrient concentrations.

To make the best use of previous and ongoing efforts to statistically assess river nutrient trends, the 2025 NRS analysis incorporates results generated through the work of four organizations:

- **USGS**. Results include Mississippi River monitoring, including Weighted Regressions on Time, Discharge, and Season (WRTDS) analysis of loads at Lock and Dam 7 near La Crosse, Wisconsin, and at Lock and Dams 4 and 8 near major tributaries from Wisconsin. Additionally, USGS analyzes trends of the St. Louis River at Scanlon using WRTDS.
- **Met Council Environmental Services**. Conducts long-term monitoring of major rivers entering and leaving the Twin Cities Metropolitan area (mid-range and long-term trends); includes an NRS emphasis on WRTDS load calculations at the Mississippi River sites Lock and Dam 3 (Red Wing) and the Anoka and the Minnesota River site at Jordan. This NRS includes results updated from previous reports at the Met Council's Regional River Water Quality Report website.
- **MPCA**. Loads are calculated across Minnesota, with FLUX32 and WRTDS analyses of the monitored data at the Mississippi River Winona site and Manitoba's monitoring data at the Red River site in Emerson, Manitoba.
- **Manitoba Conservation and Water Stewardship/ Environment Canada.** Monitoring results for the Red River at Emerson, Manitoba.

Modeling loads

WRTDS, developed by the USGS, is a modeling tool for analyzing and describing long-term water quality trends in rivers and streams. The model develops load estimates by using weighted regressions; considering the influence of time (long-term trends), discharge (flow rate), and season (seasonal variations) on water quality concentrations; and using a flow-normalized approach to remove the effect of year-to-year variations in streamflow.

FLUX32 is a Windows-based interactive software developed by the U.S. Army Corps of Engineers and the MPCA. FLUX32 can examine and evaluate data and flow and calculate the loads (material fluxes) in streams.

Section 2.2 in Appendix 2-1 summarizes the available monitoring data from each of these organizations.

A period of a few years typically does not provide enough information about changing nutrient loads. Long-term monitoring and statistical analyses are needed to best assess river nutrient load changes. Even with the best approaches, it is often difficult to understand how recent changes made on the land affect water quality. When decades of monitoring are combined with statistical model trend analyses, indications of the direction and magnitude of water quality change often become more evident.

Monitoring and trend results may also vary depending on the specific nutrient parameter assessed, monitoring site, timeframe evaluated, and the models and trend assessment methods used. Looking at multiple indicators produces more complex results, but the results tell a more robust story about what is happening in rivers. The 2025 NRS emphasizes certain combinations of indicators more than others, as decided through conversations with a multiple-organization river loads work group and as summarized below. Section 2 in Appendix 2-1 includes a more comprehensive description of the monitoring results and analyses; the discussions in Section 2 in Appendix 2-1 are supported by tables and charts in Appendix 2-1, appendices A through G.

Which nutrient parameters?

Most in-state standards and goals pertain to nitrate and phosphorus concentrations, whereas the goals for waters downstream of Minnesota are typically based on TN and TP annual loads. Annual nutrient loads are the primary 2025 NRS focus in Chapter 2. Dissolved constituents of nitrogen and phosphorus (i.e., nitrate and orthophosphate concentrations) are more important for local in-state water concerns (see Chapter 3). Because the transformations of nitrogen and phosphorus forms commonly occur in water (e.g., cycling between organic and inorganic forms), the TN and TP parameters are generally the best indicators affecting long-term algae growth potential in downstream receiving waters, as compared to only looking at dissolved forms of nitrogen and phosphorus.

Which monitoring sites?

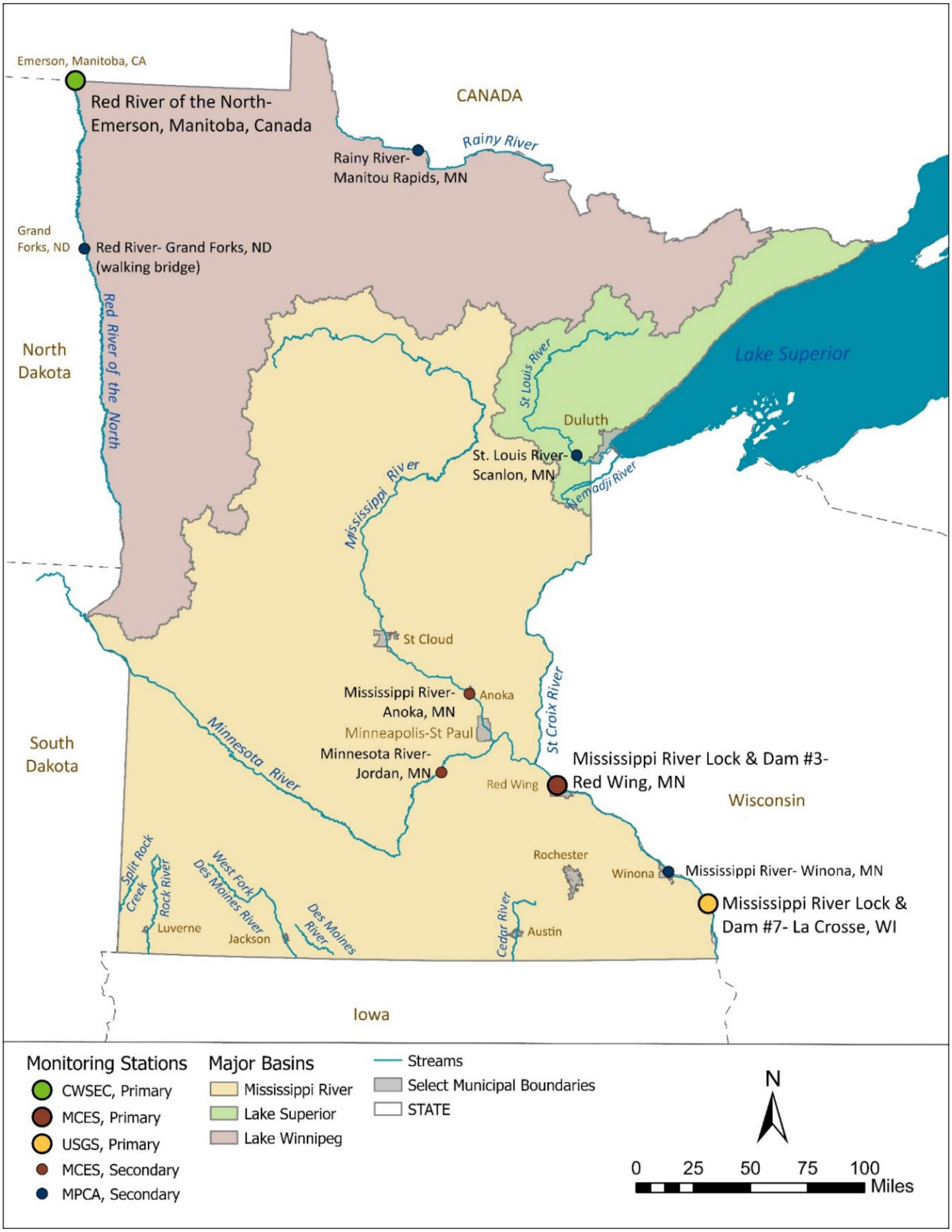
Monitoring sites were selected to represent the combination of the largest rivers, the longest monitoring records, and the closest proximities to a state line. Primary sites were selected to best indicate the load changes on the major rivers since the baseline periods and to identify the remaining load reduction needs. Other secondary and supplemental monitoring site locations were also assessed to provide a fuller picture of trends on major rivers. Sites were selected based on discussions with a multiple-organization NRS technical team focusing on river loads.

This chapter focuses mostly on the results from primary sites; secondary sites are mentioned to help understand the more complete picture of major river trends. Primary and secondary monitoring site locations are shown in Figure 2-3; Appendix 2-1 includes detailed monitoring results and analyses, primarily within Appendix 2-1, Section 2 and appendices A through G.

The watersheds contributing nutrients to monitoring sites have different fractions coming from neighboring states. For example, the Mississippi River at Red Wing is mostly affected by nutrients coming from within Minnesota (Figure 2-4), whereas the Mississippi River at La Crosse includes additional Wisconsin tributaries (Figure 2-5). The Red River at Emerson (Figure 2-6) has the largest fraction of nutrients coming from neighboring states/provinces for a Minnesota monitoring site.

The Mississippi River near Minneapolis, MN

Figure 2-3. Primary and secondary monitoring site locations used for major river nutrient loads evaluation for the 2025 NRS.



Timeframes evaluated

The MPCA, Manitoba, USGS, and the Met Council initiated river monitoring at different times, affecting the timeframes used in the 2025 NRS to evaluate load change (Table 2-3)—the first years of analysis ranged from 1976 to 1994. Most load analyses used data collected through 2023, the most current data available at the time of this writing. Load analysis results take time to process, calculate, and verify following each year of monitoring.

Progress evaluation for the Mississippi River described in this chapter compares the recent loads to a baseline period. The baseline period for the Mississippi River is 1980–1996, consistent with the Gulf HTF baseline.

The baseline for the Red River is only generally described by the IRRWB as the late 1990s, as their focus is more on the specific load upon reaching the final goal rather than an ongoing calculation of percent reduction. For the 2025 NRS, the baseline is considered to be 1996–2000, which is a representative period for loads in that late 1990s timeframe.

While the no-increase goal for Lake Superior began in 1979, the load monitoring for Minnesota's tributaries to Lake Superior has been the most complete since 2008. The 2025 NRS uses the most recent decade of available modeling calibrated to the river load monitoring results to represent the baseline for the Lake Superior tributaries.

Figure 2-4. Mississippi River at Red Wing (Lock and Dam 3) drainage area.

Figure 2-5. Mississippi River at La Crosse (Lock and Dam 7) drainage area.

Figure 2-6. Red River at Emerson drainage area.

Table 2-3. Primary and supplemental monitoring sites used for the 2025 NRS river loads analyses.

Basin[a]	Site	NRS site use	Monitoring period examined	Analysis methods	Notes
MR	Mississippi River La Crosse (Lock & Dam 7) – USGS	Primary site: used to evaluate river load changes near MN's state line with Iowa	1992–2023	WRTDS annual FN loads and non-FN loads analyzed by USGS	This site captures most of the nutrients coming from MN; 78% of TN loads are from MN, and 22% are from WI and other states. Loads are similar to results downstream at Lock & Dam 8, which has a shorter history of consistent monitoring.
MR	Mississippi River Red Wing (Lock & Dam 3) – Met Council	Primary site: longest monitoring record of the Mississippi River. Drainage area mostly in MN	1976–2023	WRTDS FN loads and non-FN loads	Monitoring began at this site before the start of the 1980–1996 baseline period (1980). The site is upstream of a large lake (Lake Pepin) and large Mississippi backwaters; so, it is not influenced by nutrient transformations in those waters. This is an excellent site for evaluating MN's effects on Mississippi River nutrient loads.
MR	Mississippi River Winona – MPCA	Secondary site: site relatively close to state border	Phosphorus: 1982–1993 & 2001–2023; nitrogen: 1981–1993 & 2009–2023	WRTDS FN loads and non-FN loads	Because this site has a 7- and 15-year gap in TP and TN data, respectively, it is not as good for trends as other Mississippi River sites. Yet, Winona is in a good downstream location with monitoring data back to the baseline period, which enables comparison of baseline to recent data.
MR	Minnesota River Jordan – Met Council	Secondary site: very important site with the highest nutrient-loading tributary to the Mississippi River and a long-term monitoring record	1979–2023	WRTDS FN loads and non-FN loads	Baselines were calculated in the 2025 NRS and compared to the more recent decade (i.e., 1980–1996 vs. 2014–2023). This basin has extensive tile drainage, so the nitrogen response times, or lag times, are generally shorter than in other parts of the Mississippi River Basin that have high groundwater contributions.
MR	Mississippi River Anoka – Met Council	Secondary site: used to evaluate north of Twin Cities Metro & upstream of Minnesota River confluence	1976–2023	FLUX32 loads and FWMC	This site has much lower nutrient levels than the Mississippi River further downstream after the confluence with the Minnesota River and tributaries in southeastern MN and southwestern WI.
MR	Black River and Chippewa River (WI tributaries) – USGS	Supplemental sites: WI tributaries to the Mississippi River at La Crosse	1992–2022	WRTDS modeled annual loads and FWMC	These loads can be used to help explain differences between the Mississippi River Red Wing and La Crosse sites and to better understand MN vs. WI nutrient contributions at La Crosse. This is not emphasized in the 2025 NRS.
MR	Cedar River (Austin), West Fork Des Moines River (Jackson),	Supplemental sites: tributaries to the Mississippi River further downstream of La	2008–2009 through 2022	FLUX32 modeled loads and FWMC	These sites are not directly comparable with the 2014 NRS loads noted for these watersheds, as the 2014 NRS had insufficient historical monitoring to determine reliable baselines in these

Basin[a]	Site	NRS site use	Monitoring period examined	Analysis methods	Notes
	Missouri River (Rock & Split Rock rivers), Root River – MPCA	Crosse; used when evaluating the complete Mississippi River drainage areas from MN			rivers. Changes over time at these sites are included in Appendix 2-1 but not in Chapter 2 of the 2025 NRS.
LW	Red River Emerson – Environment Manitoba	Primary site: represents Red River leaving MN and the Dakotas	1994–2023	WRTDS loads and trend analyses performed by MPCA on Manitoba monitoring results	While less than 40% of the load at this site is from Minnesota, this site aligns with river load goal evaluations established by Manitoba.
LW	Red River Grand Forks – MPCA	Secondary site: Red River	2007–2022	FLUX32 modeled loads and FWMC	Results are included in Appendix 2-1; some discussion is in Chapter 2 of the 2025 NRS.
LW	Rainy River Manitou Rapids – MPCA	Secondary site: upstream of Lake of the Woods, which has phosphorus-related TMDL	2010–2022	FLUX32 modeled loads and FWMC	Limited number of load analysis years at this site. Results included in Appendix 2-1; some discussion is in Chapter 2 of the 2025 NRS. Relatively small amounts of phosphorus exiting Lake of the Woods will reach Lake Winnipeg but are not quantified.
LS	St. Louis River Scanlon – MPCA	Secondary site: largest MN tributary for Lake Superior	1976–2023; but most reliable for 2008–2023	WRTDS analysis by USGS	This site is upstream of the largest city (Duluth) in the MN tributaries to Lake Superior.
LS	Nemadji River, South Superior – MPCA	Supplemental site: high phosphorus concentrations in this river, largely from eroded streambank soils	2009–2022	FLUX32 modeled loads and FWMC	The river flows through WI before flowing into Lake Superior's south shore where algae blooms have been reported. Results are included in Appendix 2-1 but not in Chapter 2 of the 2025 NRS due to a limited number of load monitoring years.
LS	Other MN tributaries to Lake Superior – MPCA	Supplemental sites: needed for assessing total aggregated loads to Lake Superior	2007/2008/ 2009 to 2022	FLUX32 modeled loads and FWMC	Not included in the 2025 NRS or appendices directly but used for periodic updates to HSPF-modeled loads reported in 2025 NRS.

Notes:
FN = flow-normalized; FWMC = flow-weighted mean concentration
[a] LS = Lake Superior; LW = Lake Winnipeg; MR = Mississippi River

Adjusting for flow variability

The flow-normalized (also known as flow-adjusted) approaches use statistical analyses to determine load and concentration trends after separating out the influence of year-to-year river flow variability. Such methods are used to better separate the water quality effects caused by human land use changes from those caused by variability in precipitation and weather patterns and corresponding river flows.

Such flow-normalized approaches provide the best statistical indicator of progress that aligns with the original intent of the NRS. That intent was to reduce the loss of nutrients to waters during both wet and dry periods through the direct actions of people on the land, thereby achieving nutrient reduction goals based on the range of weather and climate conditions experienced during baseline periods.

The primary flow-normalization method used to evaluate river nutrient load trends in the 2025 NRS is via the USGS's WRTDS model. The USGS, Gulf HTF, and HTF states have increasingly relied on WRTDS to estimate nutrient load changes using flow-normalization (see the HTF's 2023 Report to Congress). In collaboration with the USGS, the Minnesota 2025 NRS uses WRTDS at major river long-term monitoring sites. This approach provides the best indicator of monitoring-based progress affected by direct actions to control nutrient losses to waters.

The 2025 NRS estimates progress by comparing the average WRTDS calculated loads for the baseline period to the most recent flow-normalized load from 2023. The Gulf HTF baseline loads are also determined by using an average of loads over the baseline period, which is 1980–1996 for the Gulf. The 2023 flow-normalized load during this end year (2023) integrates data throughout the period of evaluation, with an increased influence of the previous seven years of data. Therefore, 2023 does not represent a single year but rather the endpoint of the flow-normalized load trend lines.

The method of comparing the long-term baseline average loads with the WRTDS flow-normalized loads in 2023 did not allow testing for statistical significance. Rather, to indicate whether load changes were statistically significant, additional trend analyses were performed in WRTDS over specific timeframes selected by the organization conducting the analyses. Several timeframes were evaluated in WRTDS, including (1) the most recently available monitored year that was within the baseline period, through the last year available (2023) and (2) the time of the original NRS (2014) through 2023. WRTDS outputs the statistical significance of each trend for each timeframe. In the 2025 NRS, statistical significance is considered a p-value at or above 0.05.

The WRTDS baseline versus the 2023 flow-normalized load results are also compared with a flow-weighted mean concentration (FWMC), which is the annual load divided by the annual river flow volume. The FWMC is not the same as flow-normalization trend results and is not as powerful; rather, it provides a commonly used and understood measure to evaluate long-term change that is less driven by year-to-year precipitation variability as compared to looking at non-flow-normalized loads.

Non-flow-normalized approaches to evaluating change

Several statistical methods can be used to evaluate load changes without trying to separate more direct human nutrient load influences from weather and river flow variability. Instead, such results reflect a combination of changes driven by urban and rural areas and changes in precipitation and river flow. These methods reflect the actual amount of nitrogen and phosphorus in the water sent downstream each year without smoothing out trends for river flow variability.

One of the statistical methods employed in the 2025 NRS is the 5-year rolling average of annual TP and TN loads using available flow and water quality data. A 5-year average period is one of the ways that the Gulf HTF evaluates loads, along with Manitoba and the IRRWB. These averages are the arithmetic mean of the calculated annual loads for the previous five consecutive years; for example, a 5-year rolling average representing the year 1993 is the arithmetic mean of the annual loads from 1989, 1990, 1991, 1992, and 1993. Both extreme wet and dry periods have occurred during recent years, often lasting for three to seven years, which affects the 5-year rolling averages.

For each primary and secondary monitoring site, the 2025 NRS river loads work group determined how the 2025 NRS would use the site results and the analysis methods, as described in Table 2-3 above.

Different analysis methods for the sites are partly due to a limited staff capacity to assess every site with preferred methods, such as the WRTDS.

2.4 TP loads: progress near the state lines

Water quality monitoring results were evaluated to assess changes in TP conditions since the baseline periods. The purpose of the analyses and results described below was to assess the conditions and changes most directly applicable to the major river state-line 2025 NRS goals and approaches. Results from each of Minnesota's three major drainages are discussed separately, using the approaches and monitoring locations described in Section 2.2. The progress for TP and TN loads is discussed in sections 2.4 and 2.5, respectively.

2.4.1 Mississippi River: TP load progress near the state line

Two primary monitoring sites were evaluated for the Mississippi River progress indicators: La Crosse (Lock and Dam 7) and Red Wing (Lock and Dam 3). Results from two secondary monitoring sites, the Mississippi River at Winona and the Minnesota River at Jordan, were also included (Figure 2-7).

Flow-normalized load progress indicators

Figure 2-7. Locations of primary (large circles) and secondary (smaller circles) monitoring sites for evaluating nutrient load reduction progress in the Mississippi River near the state line.

Annual Mississippi River TP loads vary greatly from year to year at these sites, depending largely on precipitation and river flow. Except for three low-flow years in La Crosse and six low-flow years in Red Wing, TP loads have remained above the 45% reduction final goal in recent decades (Figure 2-8 and Figure 2-9). Phosphorus loads for the most recent three years with monitoring load results (2021–2023) have been close to the final goal amounts; however, 2021–2023 were also lower river flow years.

Our best indicator of progress, flow-normalized loads calculated with WRTDS, shows a decreasing (improving) TP trend at both the La Crosse and Red Wing sites. This decrease is most pronounced at Red Wing during 1992–1998 and 2004–2012. Since the baseline period (1980–1996, non-flow-normalized WRTDS), the WRTDS flow-normalized loads of TP have decreased (improved) by 11% and 32% at La Crosse and Red Wing, respectively.

WRTDS was used to evaluate the long-term trend statistical significance of TP load trends. The assessed timeframes represent the beginning of the baseline period (1980) or the beginning of when monitoring began within the baseline period (i.e., 1992 in La Crosse).

Figure 2-8. TP annual loads (dark blue bars) and flow-normalized loads (green dashed line) at Lock and Dam 7 (La Crosse) showing an 11% reduction since the 1980–1996 baseline.

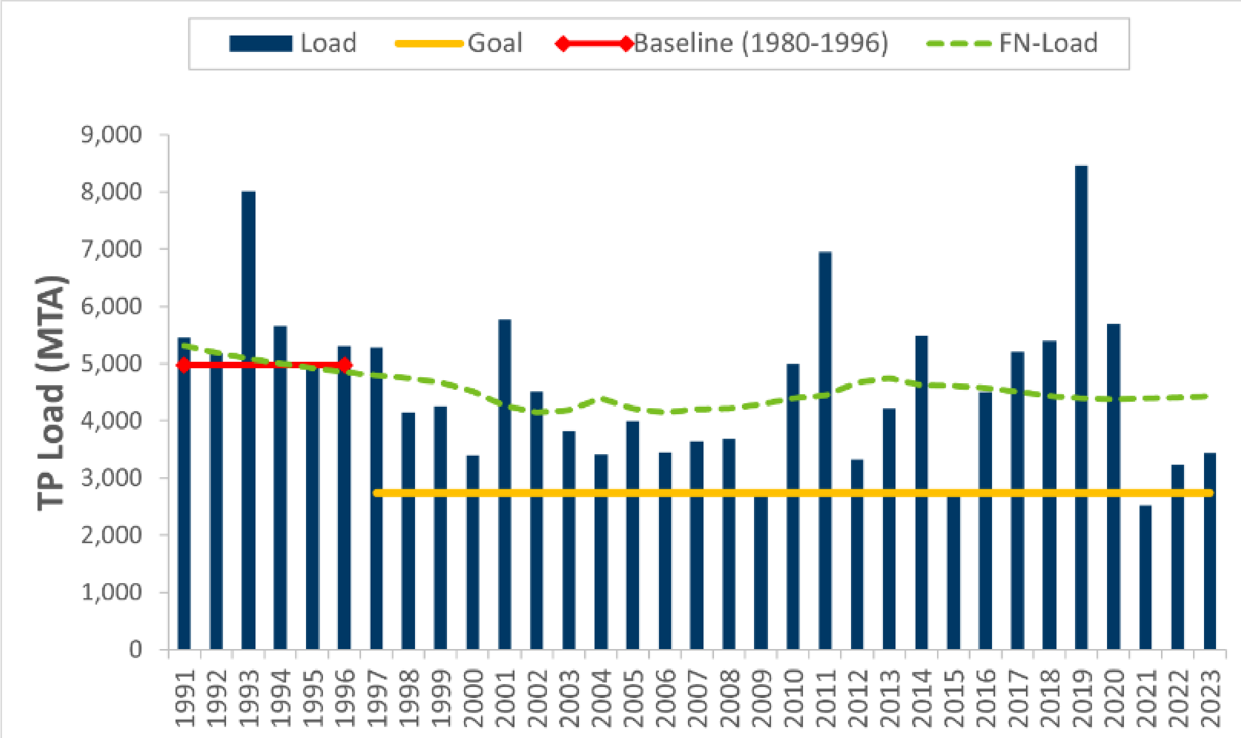
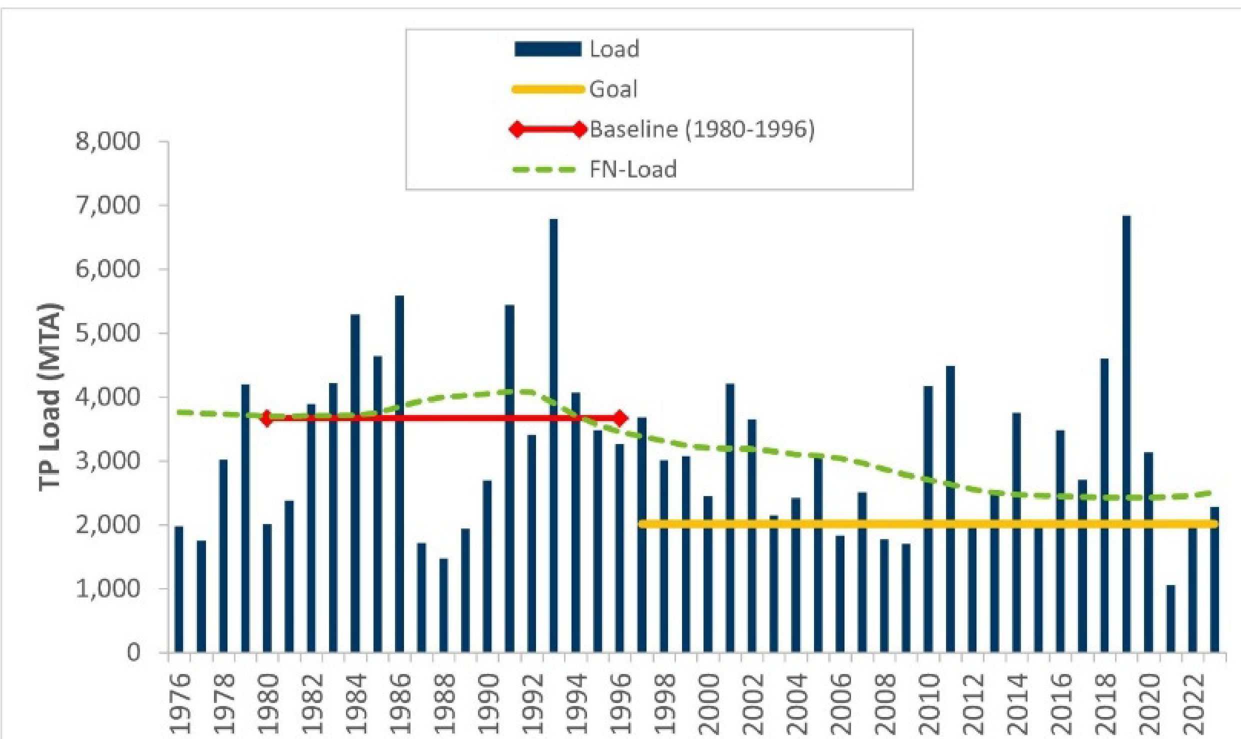


Figure 2-9. TP annual loads (dark blue bars) and flow-normalized loads (green dashed line) at Red Wing (1976–2023), showing a 32% reduction since the 1980–1996 baseline.



TP load reduction trends were evaluated from the earliest date monitored within or following the baseline period through the most recent year assessed (2023). The trends were statistically significant at Red Wing for 1980–2023 (p=0.05). TP load reduction trends were *very likely* according to WRTDS outputs, but not statistically significant, at La Crosse for 1992–2023 (p=0.13). Statistical significance for TP in the Mississippi River is further discussed in Appendix 2-1, Section 2.5.1.1.

QWTREND Model Supports Findings

As a supplemental trend verification at Red Wing, the Met Council analyzed the flow-normalized TP concentration trends using the QWTREND model and found a 47% TP concentration reduction between 1988 and 2023 (see Appendix 2-2), further substantiating the tremendous amount of progress made with phosphorus in the Mississippi River.

The larger magnitude TP load reduction at Red Wing compared to La Crosse (Table 2-4) could be due to several possible factors, including:

- Red Wing is upstream of Lake Pepin and the Mississippi River pools and backwaters, where legacy phosphorus can be stored and released, and other biological phosphorus processing occurs.
- Other tributaries from Wisconsin and Minnesota (e.g., Chippewa, Zumbro, and Trempeleau rivers) add considerable amounts of water and river nutrients between Red Wing and La Crosse, potentially masking some of the reductions observed in Red Wing driven by wastewater and other improvements.
- The monitoring period in La Crosse (began in 1992) does not go back as far as Red Wing (began in 1972), and there is more certainty about the baseline TP loads in Red Wing than in La Crosse.
- Monitoring stations on wide rivers have different challenges in obtaining representative samples, as the river waters do not always mix completely.
- Monitoring stations have different challenges in obtaining representative samples across a wide river where river waters do not always mix completely.
- Laboratory methods for TP analyses for the La Crosse changed (improved) about 20 years ago. Results between the old and new methods were generally comparable, but even slight differences could explain part of the discrepancy.

Table 2-4. Summary of TP flow-normalized load and FWMC changes since baseline (1980–1996) at three Mississippi River sites approaching the Iowa state line.

Site	Load changes (baseline average to 2023 FN load) [a]	FWMC changes (baseline average to 2019–2023 average) [b]
Red Wing (Lock &Dam 3)	-32%	-36%
La Crosse (Lock &Dam 7)	-11%	-23%
Winona [c]	-39%	-42%

Notes:
FN = flow-normalized
A negative sign indicates a decrease (improvement).
See the report narrative regarding statistical significance of trend analysis over different periods of time.
[a] Change from the baseline average load and 2023 WRTDS FN load. Baseline loads represent 1980–1996 baseline load from the 2014 NRS for Red Wing and La Crosse and 1980–1994 average of WRTDS non-FN loads for Winona.
[b] Change from the baseline average FWMC and 2019–2023 average FWMC (WRTDS non-FN). Baseline FWMCs represent averages from 1980–1996 baseline FWMC from the 2014 NRS for Red Wing and La Crosse and 1980–1996 average of WRTDS non-FN FWMCs for Winona. To calculate change, FWMCs were first rounded to the one-thousandth mg/L.
[c] No TP data were available for the Mississippi River at Winona for 1994–2000.

A third Mississippi River site approaching the state line was also evaluated due to the large difference in TP reductions between Red Wing and La Crosse. The Mississippi River at Winona, Minnesota, has a long-term monitoring record beginning in 1982 but has no phosphorus load monitoring results between 1994 and 2000. At Winona, 39% TP load reductions were found when comparing WRTDS flow-normalized loads between 1982–1994 and 2023. This is much closer to the reductions assessed at Red Wing than at La Crosse. However, due to unavailable data from 1980–1982 and 1995–1996, the baseline period for Winona is not identical to the Red Wing baseline of 1980–1996, and the two sites are not directly comparable. TP load reduction trends were *very likely* according to WRTDS outputs, but not statistically significant, at Winona for 1982–2023 ($p=0.17$).


The Mississippi River in southeastern MN

The TP FWMC reductions since baseline at La Crosse and Red Wing were 26% and 36%, respectively (see Table 2-4). At Winona, the FWMC averages decreased by 42% between the 1982–1994 period and the 2019–2023 period. Both the FWMC and WRTDS trend analyses showed that the TP reductions in Winona were closer to the findings at Red Wing than at La Crosse.

While the La Crosse, Red Wing, and Winona sites are important for understanding trends in the Mississippi River, at this time, the Red Wing site (32% improvement) is believed to best represent the effects of Minnesota's phosphorus reduction efforts. Continued monitoring at both sites for years to come is needed to measure the full effects of changes within Minnesota.

Non-normalized load progress indicators

When assessing Mississippi River TP load changes without normalizing for annual river flow variability, the past decade still shows TP reductions. However, higher precipitation and correspondingly higher river flows (especially in 2015–2019) have offset some of the water quality improvements observed with flow-normalized trend methods. The 5-year rolling average TP loads decreased by 6%, 16%, and 31% since the baseline period at La Crosse (Figure 2-10), Red Wing (Figure 2-11), and Winona, respectively (see also Appendix 2-1, Section 2.3.1.1). The percent reduction during low-flow years was higher compared to high-flow years (e.g., Red Wing site; see Appendix 2-1, Table 30). This is not surprising, given that much of the TP reduction has come from WWTFs (see Chapter 4), which were more influential on the total loads during low-flow years when the rural runoff was less.

Summary of Mississippi River TP progress

TP loads in the Mississippi River near the state line have improved (decreased) substantially since the baseline period of 1980–1996. These improvements were evident with both the flow-normalized and non-flow-normalized load assessments (Table 2-5). The monitoring site and analysis method most likely to reflect the outcome of Minnesota's actions during recent decades was the Red Wing WRTDS flow-normalized load assessment, showing a 32% reduction since baseline. This site has the longest continuous monitoring record and reflects fewer lag-time and legacy TP complexities; plus, most of the contributing watersheds are in Minnesota, and the site has data well-suited for the WRTDS flow-normalized load and trend analyses.

Figure 2-10. Mississippi River La Crosse monitoring site 5-year rolling averages of river flow and TP load (not flow-normalized) based on 1991–2023 monitoring.

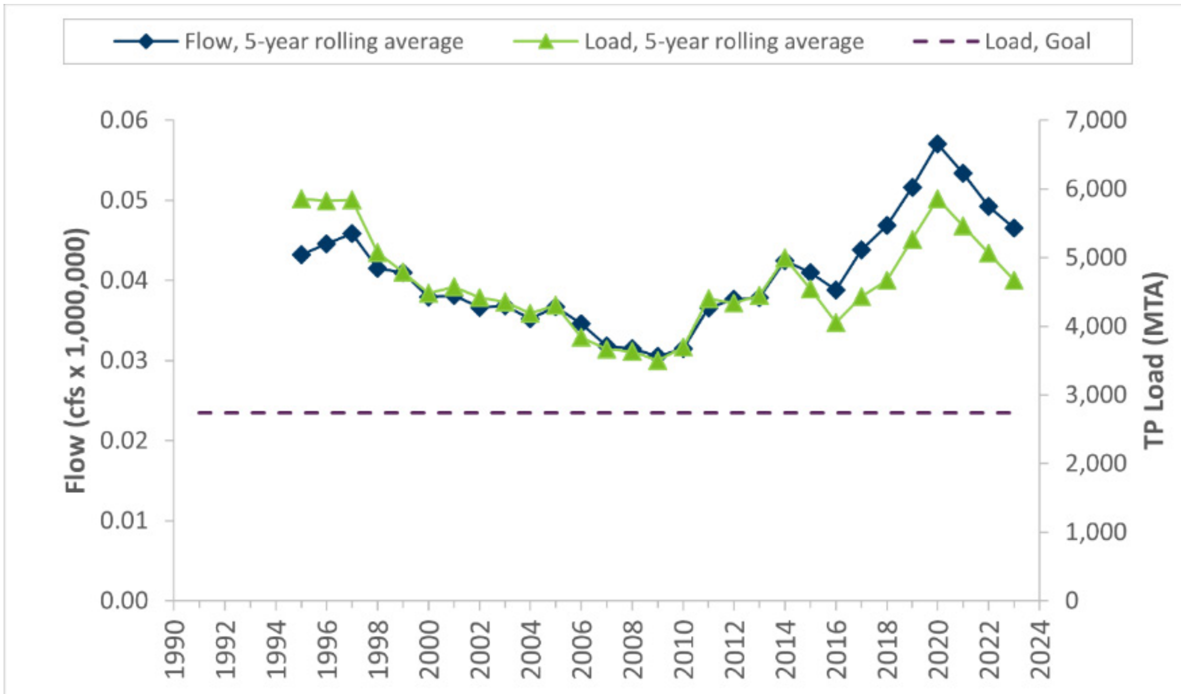


Figure 2-11. Mississippi River Red Wing monitoring site 5-year rolling average river flow and TP load (not flow-normalized), based on 1976–2023 monitoring.

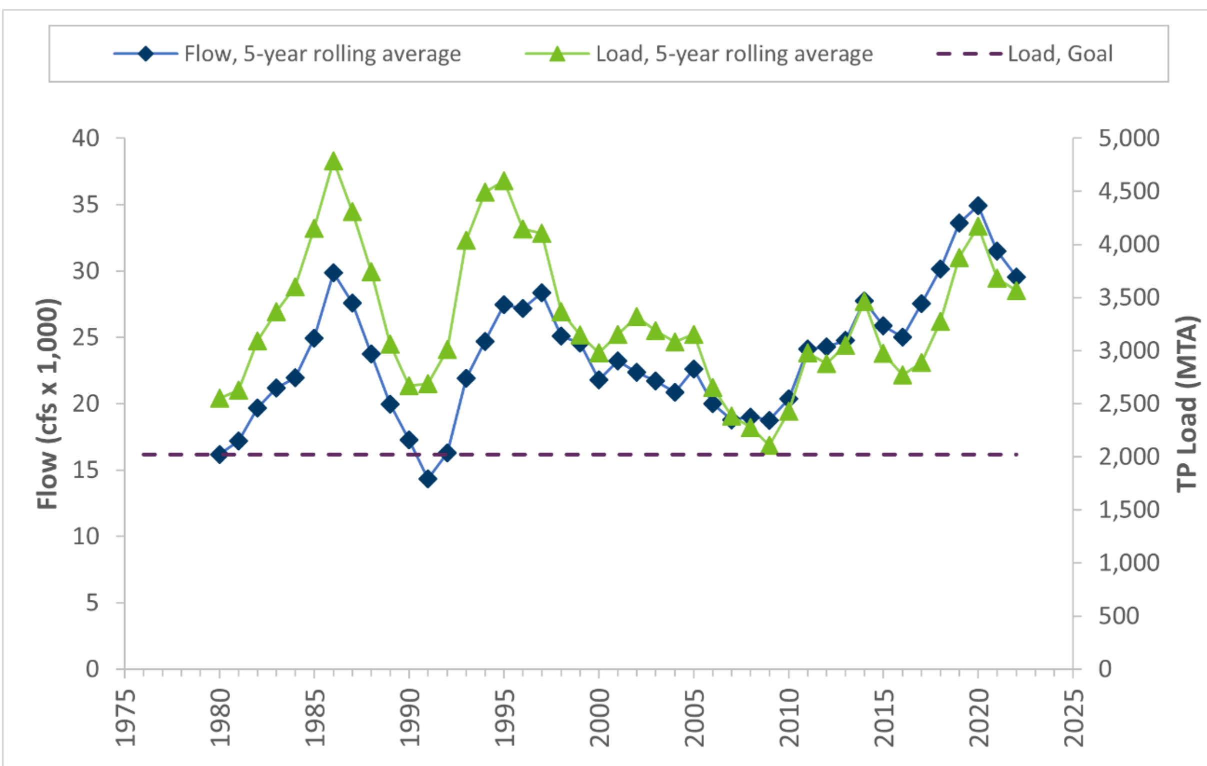


Table 2-5. Summary of TP load change results in Mississippi River approaching the state line.

Monitoring site	FN load changes (baseline average to 2023 FN load) [a]	FWMC change (baseline average to 2019–2023 average) [b]	Non-FN load changes (baseline average to 2019–2023 average) [c]
Red Wing (L&D 3)	-32%	-36%	-16%
La Crosse (L&D 7)	-11%	-23%	-6%
Winona [d]	-39%	-42%	-31%

Notes:
FN = flow-normalized; L&D = lock and dam
A negative value indicates a decrease.
See the report narrative regarding statistical significance of trend analysis over different periods of time.
[a] Change from baseline average load and 2023 WRTDS FN load. Baseline FWMCs represent averages from 1980–1996 baseline FWMC from the 2014 NRS for Red Wing and La Crosse and 1980–1996 average of WRTDS non-FN load FWMCs for Winona.
[b] Change from the baseline average FWMC and 2019–2023 average FWMC (WRTDS non-flow-normalized). Baseline FWMCs represent averages from 1980–1996 baseline FWMC from the 2014 NRS for Red Wing and La Crosse and 1980–1996 average of WRTDS non-flow-normalized FWMCs for Winona. To calculate change, FWMCs are first rounded to the one-thousandth mg/L.
[c] Change from baseline average load (1980–1996 baseline load [NRS 2014] or 1980–1996 average of WRTDS non-FN loads) and 2019–2023 average of WRTDS non-FN loads.
[d] No TP data are available for the Mississippi River at Winona for 1994–2000.

As discussed further in this section, much of the TP reduction realized is from improvements made in wastewater treatment between 2000 and 2014. Since the 2014 NRS, additional TP reductions have been less pronounced, but additional monitoring years are needed to be more certain about recent changes.

Weather-driven effects appear to be offsetting some of the progress, as evidenced by the lower magnitude percent decreases when assessing without using flow-normalized methods (see Table 2-5). The loads are highly influenced by river flows. High precipitation amounts and intensities carry more phosphorus from the land into waters and erode more streambank, bluff, and upland soils that carry attached phosphorus.

Appendix 2-1 provides more information about TP load assessments and results, including the results at several secondary NRS locations within the Mississippi River Basin. Section 2.3.1 in Appendix 2-1 presents baseline and recent flows, FWMCs, and loads (non-flow-normalized) using FLUX32 and WRTDS, while Section 2.5.1 in Appendix 2-1 presents baseline and recent flow-normalized concentrations, flow-normalized loads, and statistical significance using WRTDS. Appendices A and B in Appendix 2-1 include charts of flow, FWMC, loads, and goals, including both flow-normalized and non-flow-normalized loads.

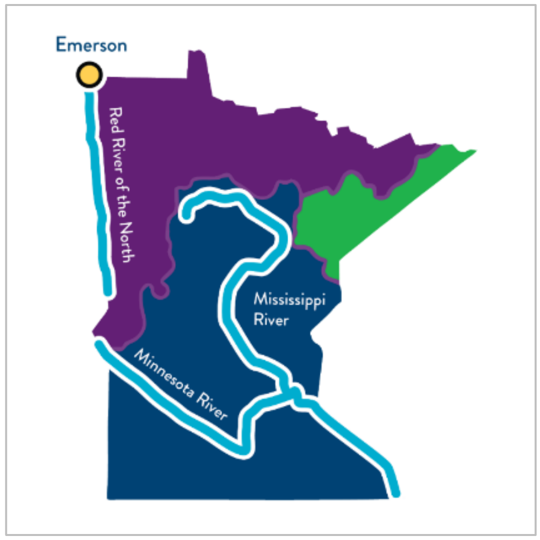
2.4.2 Red River: TP load progress near the state line

The Lake Winnipeg Major Basin includes both the Red River of the North Basin and the Rainy River Basin (see Figure 2-2). The Minnesota portion of the Red River Basin covers about 37,100 square miles in northwestern Minnesota, in all or part of 21 counties, and flows from the Red River into Lake Winnipeg. This basin is characterized by intensive agricultural land uses within the flat topography east of the river, rolling uplands full of trees and lakes in the east-central portion of the basin, and extensive wetlands in the northeast. The Rainy River Basin is home to some of the state's finest forest and water resources. It flows to Lake of the Woods and into the Winnipeg River in Canada, which then winds its way through many water flowages and eventually drains into Lake Winnipeg. Lake of the Woods is impaired due to eutrophication. For that reason, phosphorus reductions upstream of this valuable resource are important for the in-state and international needs.

The Red River at the Emerson, Manitoba monitoring site provides the best long-term load monitoring record, reflecting loads from Minnesota, the Dakotas and a small part of Manitoba since 1994 (Figure 2-12). In-stream monitoring data collected in Emerson by Manitoba Environment and Climate Change were used for the 2025 NRS. Using WRTDS, MPCA performed load calculations and trend analysis on Manitoba's nutrient monitoring information for the 2025 NRS.

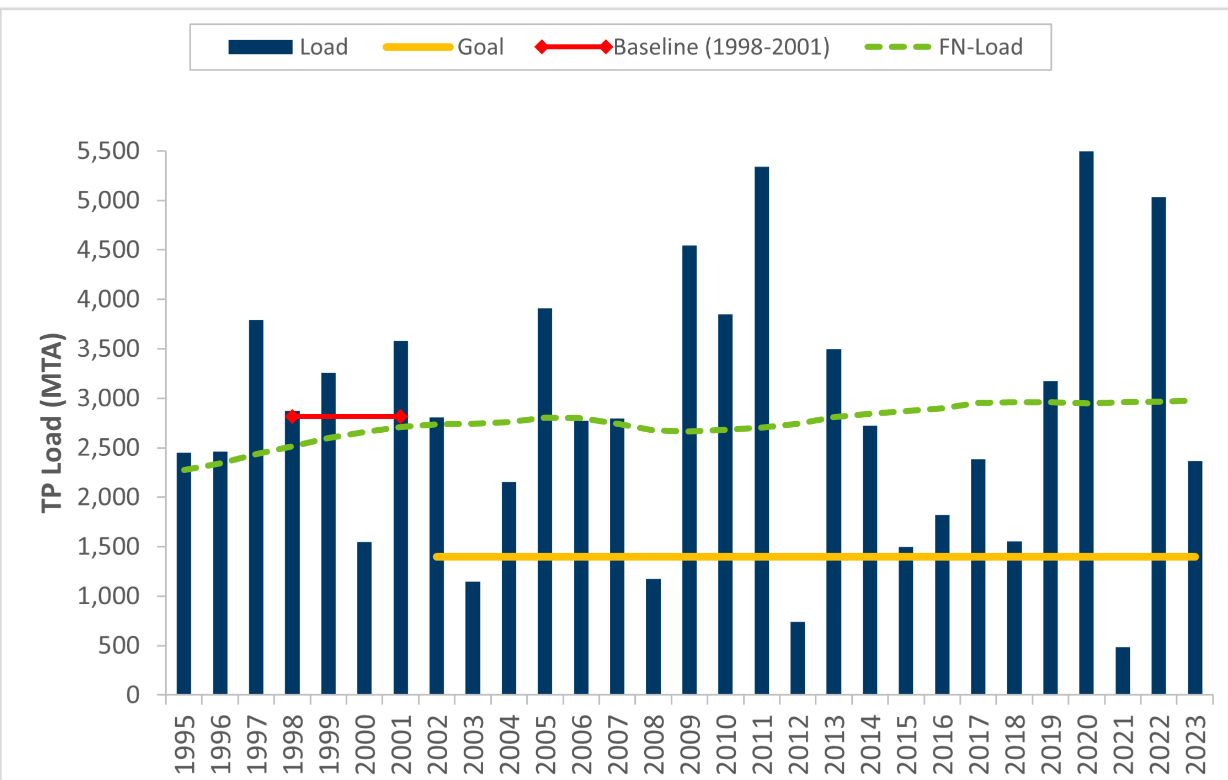
Another important monitoring site discussed in Chapter 2 is the Rainy River at Manitou. This MPCA site is upstream from the eutrophication-impaired Lake of the Woods, with a watershed size that is approximately 90% of the area of the entire drainage into Lake Winnipeg. However, this site has a shorter period of load monitoring history (begun in 2010) compared to the Red River at Emerson. Results at Emerson are emphasized first below, followed by a shorter discussion of the Rainy River Manitou site.

Figure 2-12. Location of the primary Red River monitoring site at Emerson, Manitoba.



Annual nutrient loads in the Red River at Emerson vary greatly from year to year (Figure 2-13) as precipitation and river flow fluctuate. Note that the Red River Basin climate and river flow situations are different than the Mississippi River Basin. Annual TP loads in the Red River were lower than the goal during only four individual years since 1995, all of which were low-flow years (2003, 2008, 2012 and 2021).

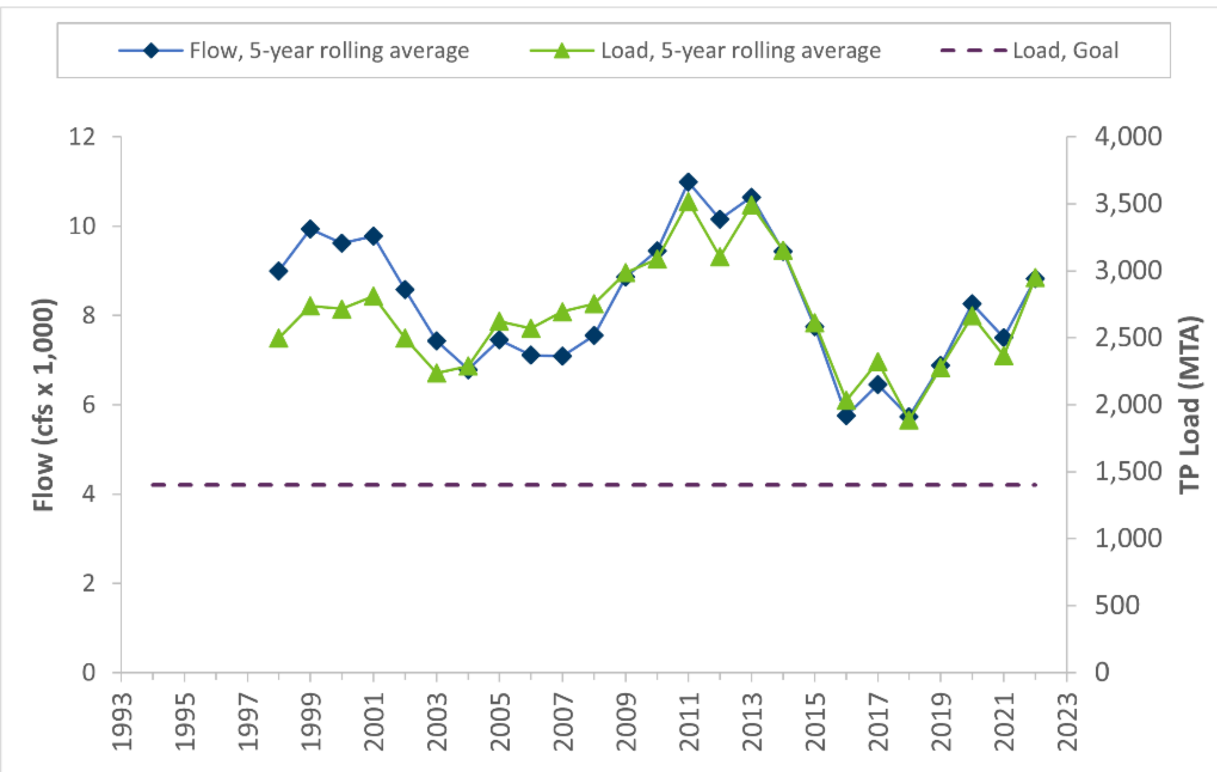
Figure 2-13. TP annual loads (dark blue bars) and flow-normalized load trends (green dashed line) in the Red River at Emerson (border with Canada), 1995–2023.



Our best indicator of progress—the baseline average compared to 2023 flow-normalized loads calculated with WRTDS—showed a 7% TP load increase since the baseline in the Red River at Emerson. No known reasons exist for why the TP would be higher during recent years. Two timeframes were analyzed for statistically significant differences; the first from the beginning of the monitoring record (1994) through 2023, and the second from the end of the baseline period (2001) through 2023. An upward trend of TP flow-normalized loads from the beginning of monitoring in 1994 to 2023 is statistically significant (p=0.025). The trend from the end of baseline (2001) through 2023 is "very likely" according to WRTDS outputs, but not statistically significant (p=0.08). Statistical significance for TP in the Red River is further discussed in Appendix 2-1, Section 2.5.2. Load changes assessed using the simpler FWMC 5-year moving average also show a slight increase of 13% TP since the 1996–2000 baseline period.

When assessing the Red River TP load changes without normalizing for annual river flow variability, the past five years show average TP loads 16% higher than those of the baseline period of 1996–2000 at the Red River at Emerson (Figure 2-14). This 5-year rolling average is how the Manitoba Water Stewardship Division is gauging progress toward the goals for Lake Winnipeg. This change does not correct for the weather and river flow variability that has occurred; rather, it reflects a combination of changes made on the land and the full effects of changing weather and climate.

Figure 2-14. Red River at Emerson monitoring site: 5-year rolling average river flow and TP load (not flow-normalized), representing results for 1995–2023.



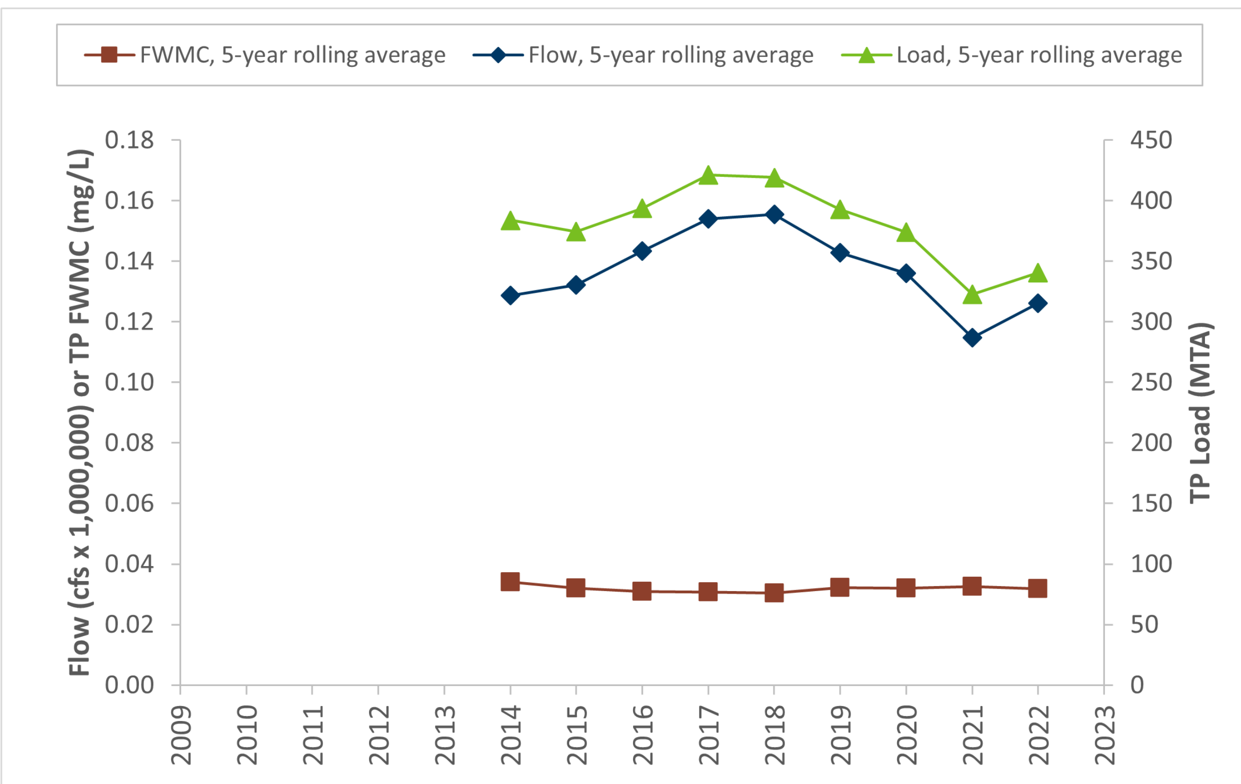
Further upstream from the state line, the Red River monitoring site at the Grand Forks site has been monitored for river nutrient loads since 2007. The 5-year rolling average has shown a TP load that was recently (2018–2022) essentially the same (3% lower) than the initial monitoring results between 2007 and 2011. Average FWMCs are slightly higher (7%) between those same periods (see Appendix 2-1). The loads are highly variable from year to year, and the 5-year rolling average can be influenced by one or two extremely wet or dry years. For example, in two back-to-back years, the loads were the lowest (284 MT in 2021) and the second-highest (3,647 MT in 2022) of the 16-year period. Future analysis with more years of monitoring should include flow-normalized methods to better assess trends without undue influence by extreme years.

Phosphorus load changes in the Rainy River

TP loads in the Rainy River and outlets of Lake of the Woods are much lower nutrient contributors to Lake Winnipeg as compared to the Red River. The primary concern for TP concentrations in the Rainy River is their impact on Lake of the Woods eutrophication. TP concentrations have decreased from a summer (June through September) average of 39.8 µg/L in 2005–2014 to 32.2 µg/L in 2015–2024 (MPCA 2025b). This 19% reduction is close to what is needed to achieve the TMDL goal of 30 µg/L (MPCA 2021).

Intensive monitoring by the MPCA since 2010 in the Rainy River at Manitou has enabled annual nutrient load calculations. The 5-year rolling average loads provide some indication of how the loads are trending. For instance, the 5-year rolling average TP loads were 11% lower when comparing the 2010–2014 period with the 2018–2022 period (Figure 2-15). The 5-year rolling average TP FWMC has decreased by 6% during this same timeframe. Reductions achieved in the Rainy River Basin also have incremental benefits for nutrient transport to Lake Winnipeg through the Winnipeg River that exits Lake of the Woods. Continued long-term monitoring of the Rainy River and Lake of the Woods, along with WRTDS trends analyses, will be needed to determine if the goals for the Lake of the Woods will be met.

Figure 2-15. Rainy River at Manitou monitoring site: 5-year rolling average river flow, FWMC, and TP load (not flow-normalized).



Summary of Red River TP progress

TP loads do not appear to be improving in the Red River Basin. For example, flow-normalized loads at the Emerson site on the Manitoba border were 7% higher in 2023 compared to the 1996–2000 baseline (Table 2-6). Multiple tributaries from Minnesota, North Dakota, and Manitoba add nutrients to the Red River between Grand Forks and Emerson, affecting load trends. Minnesota's TP contribution to the Emerson site represents just over one-third (34%) of the TP flowing down the Red River at Emerson. To evaluate how Minnesota is affecting the Red River loads, trend analyses will be needed for individual tributaries flowing into the Red River. Tributary load trends were not assessed for Minnesota; however, tributary *concentration* trends are reported in Chapter 3. See Appendix 2-1 for additional information on all phosphorus load assessments and results for the Red River Basin.

Table 2-6. Summary of TP load change indicators in the Red River at the state line in Emerson, Manitoba, since the 1996–2000 baseline period and for other benchmark periods for the Rainy River Manitou and Red River Grand Forks sites.

Monitoring site	Load changes comparing 1996–2000 baseline to 2023 [a]	FWMC (baseline to 2019–2023 average) [b]	5-year running average load changes since baseline or initiated load monitoring: non-FN [c]
Red River at Emerson	+7%	+12%	+3% (1996–2000 baseline to 2019–2023)
Red River at Grand Forks	–	–	-3% (comparing 2007–2011 to 2018–2022)
Rainy River at Manitou	–	–	-11% (comparing 2010–2014 with 2018–2022)

Notes:
FN = flow-normalized
See the report narrative regarding statistical significance of trend analysis over different periods of time.
[a] Change from baseline average load (1996–2000 average of WRTDS non-FN loads) and 2023 WRTDS FN load.
[b] Change from baseline average FWMC (1996–2000 average of WRTDS non-FN FWMCs) and 2019–2023 average FWMC (WRTDS non-FN loads).
[c] Change from baseline average load (WRTDS non-FN loads) and recent average load (WRTDS non-FN loads).
Appendix 2-1 provides more information about TP load assessments and results, including the results at several secondary NRS locations within the Lake Winnipeg Basin. Appendix 2-1, Section 2.3.2, presents baseline and recent flows, FWMCs, and loads (non-FN) using FLUX32 and WRTDS, while Appendix 2-1, Section 2.5.2, presents baseline and recent FN concentrations, FN loads, and statistical significance using WRTDS. Appendix C in Appendix 2-1 presents charts of flow, FWMC, loads, and goals, including both FN and non-FN loads, for the Red River and Rainy River.

2.4.3 Lake Superior: TP load progress

The Lake Superior Basin in northeastern Minnesota is over 93% forest, wetlands, and open water. Phosphorus and nitrogen levels in Lake Superior are relatively low, although increasing algal blooms have been reported, as described in Chapter 1. The goal is to maintain these relatively low nutrient levels into the future, making reductions where elevated nutrient levels are generated and vigilantly monitoring nutrient source contributions, river trends, and lake trends. Streambanks with naturally high soil phosphorus levels are eroded in certain watersheds in the basin, such as the Nemadji River, which is a concern for nearshore eutrophication in Lake Superior.

The recent *State of the Great Lakes Technical Report* (EPA and CWA 2022) reported that offshore and nearshore phosphorus concentrations have a status of "good." The definition of that rating is, "The metrics show that the nutrient concentrations are meeting the ecosystem objectives, and they are neither too high nor too low and should be considered in acceptable condition." A trend analysis of phosphorus found that both the 10-year and 1970–2019 offshore concentration trends are "unchanging."

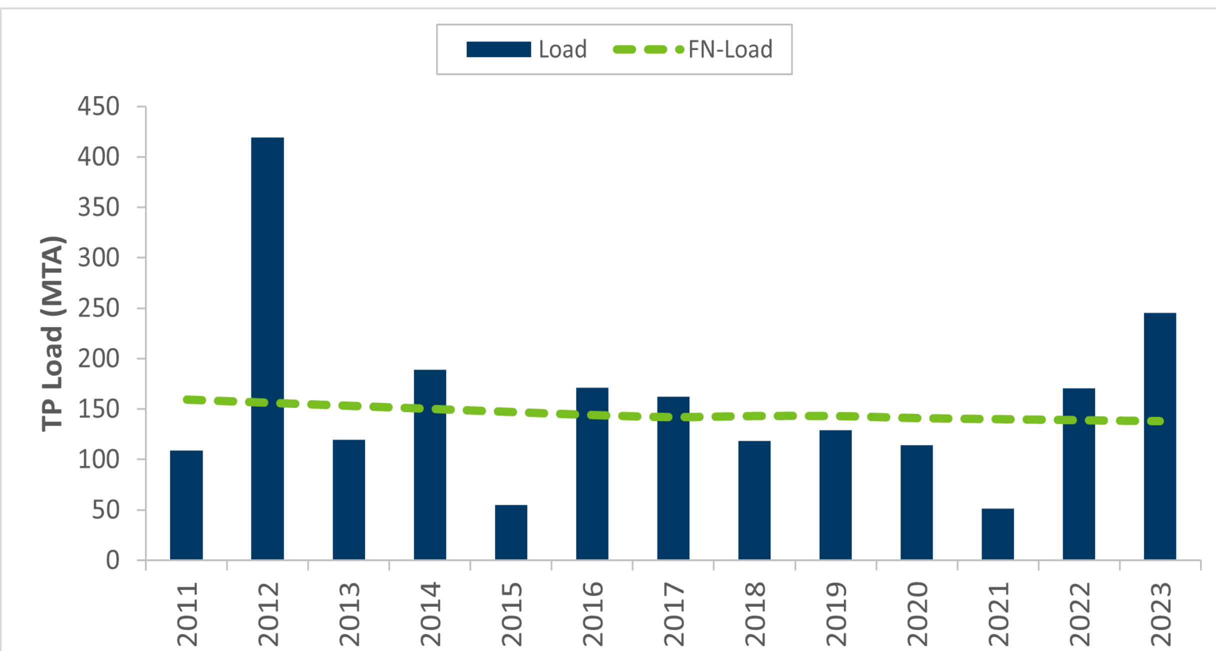
Duluth is the primary urban area within the Lake Superior Basin. The City has constructed numerous green infrastructure projects. Also, several stream channel restorations have recently been completed, which should lead to reduced nutrient export from Duluth's landscape to the lake.

The Nemadji River flows through glacial lake-deposited clay soils, and suspended sediment is high in the river's waters. Phosphorus attached to mineral particles can be exported downstream with the eroded soil. An analysis of MPCA monitoring data showed a very high correlation between total suspended solids (TSS) concentrations and TP concentrations. How much of this phosphorus becomes bioavailable when it reaches Lake Superior remains unknown.

TP load progress indicators

The USGS performed trend analysis and load calculations using WRTDS on the largest Minnesota tributary to Lake Superior, the St. Louis River. Using WRTDS flow-normalized load trends between 2011 and 2023 (Figure 2-16), USGS found the TP load had decreased by a statistically significant 16% at the St. Louis River Scanlon site ($p<0.05$), just upstream from the Duluth (Diebel et al. 2025). During this same timeframe, the 5-year rolling average FWMC decreased by 25% from 0.079 mg/L to 0.059 mg/L, and the non-normalized 5-year rolling average loads decreased from 178 MT/yr to 142 MT/yr, a 20% reduction. Because this monitoring site is upstream of Duluth, it does not represent the changes the City has made to reduce phosphorus in both stormwater and wastewater during recent decades.

Figure 2-16. St. Louis River Scanlon monitoring site annual TP loads (dark blue bars) and the WRTDS flow-normalized load trend (green dashed line), 2011–2023.



Monitoring of the Nemadji River and other Lake Superior tributaries in Minnesota has occurred since around 2009, and loads are calculated each year using the FLUX32 approach (shown on an MPCA website load data viewer). Two years of missing TP data (2012–2013) interfere with the quality of load trend analyses at this time. A consistent, longer monitoring period will improve analyses. Flow-normalized load trend analyses should be conducted in the future for all Lake Superior tributaries after more years of monitoring have been completed to evaluate the success in maintaining or decreasing nutrient loads through Lake Superior tributaries.

Appendix 2-1 provides more information about TP load assessments and results, including the results at two secondary NRS locations within the Lake Superior Basin. Section 2.3.3 in Appendix 2-1 presents baseline and recent flows, FWMCs, and loads (non-flow-normalized) using FLUX32 and WRTDS, while Section 2.5.3 in Appendix 2-1 presents baseline and recent flow-normalized concentrations, flow-normalized loads, and statistical significance using WRTDS. Appendix D in Appendix 2-1 presents charts of flow, FWMC, loads, and goals, including both flow-normalized and non-flow-normalized loads, for sites on the St. Louis River and Nemadji River.

TP loads summary

Using trend analyses with and without normalizing for river flow variability driven by weather/climate, TP loads have been decreasing at key NRS monitoring sites on the Mississippi River Basin (Red Wing, Winona, and La Crosse), the Rainy River Basin (Manitou), and the Lake Superior Basin (St. Louis River at Manitou). One exception to TP load decreases is in the Red River at Emerson, where much of the river's load contribution is from the Dakotas. TP concentrations also show widespread decreases across much of Minnesota, as described in Chapter 3.

2.5 TN load progress near the state lines

Information on water quality monitoring and practice implementation data was evaluated to assess changes in TN load conditions since the baseline periods. Results from each of the three major drainages are discussed separately below, using the approaches and locations previously described.

2.5.1 Mississippi River: TN load progress near the state line

In general, while the Mississippi River TN load results suggest slight levels of improvement, Minnesota has not made the same level of progress with TN loads as TP loads in the Mississippi River Basin.

Flow-normalized load progress indicators

Mississippi River TN annual loads for Lock and Dam 7 (La Crosse; Figure 2-17) and Lock and Dam 3 (Red Wing; Figure 2-18) vary greatly from year to year as precipitation and river flows increase and decrease. Except for two low-flow years (2000 and 2009), the TN loads have remained above the goal at both locations in the Mississippi River. TN loads during the most recent three years have been only slightly above final goal amounts, as influenced by lower river flows during those years.

The NRS's best indicator of progress for TN is flow-normalized loads calculated with WRTDS. These TN flow-normalized loads show that loads in the Mississippi River La Crosse and Red Wing sites were lower in 2023 compared to the baseline period at both sites. The WRTDS flow-normalized loads of TN in 2023 were 4% and 6% lower than the 1980–1996 baseline average load at the La Crosse and Red Wing sites, respectively.

WRTDS was used to evaluate the long-term TN load trend statistical significance from the earliest date monitored within or following the baseline period through 2023. TN load trends were also assessed from the date of the original NRS (2014) through 2023. The decrease in TN load trends was not statistically significant in the Mississippi River at La Crosse since the beginning of monitoring in 1992–2023, but they were "very likely" decreasing from 2014–2023 (p=0.07). TN load changes were not statistically significant at Red Wing for the periods 1980–2023 and 2014–2023. Statistical significance for changes in TN in the Mississippi River is further discussed in Appendix 2-1, Section 2.5.1.2.

Figure 2-17. Mississippi River TN annual loads (dark blue bars) and flow-normalized load trend line (green dashed line) at Lock and Dam 7 (La Crosse), 1991–2023.

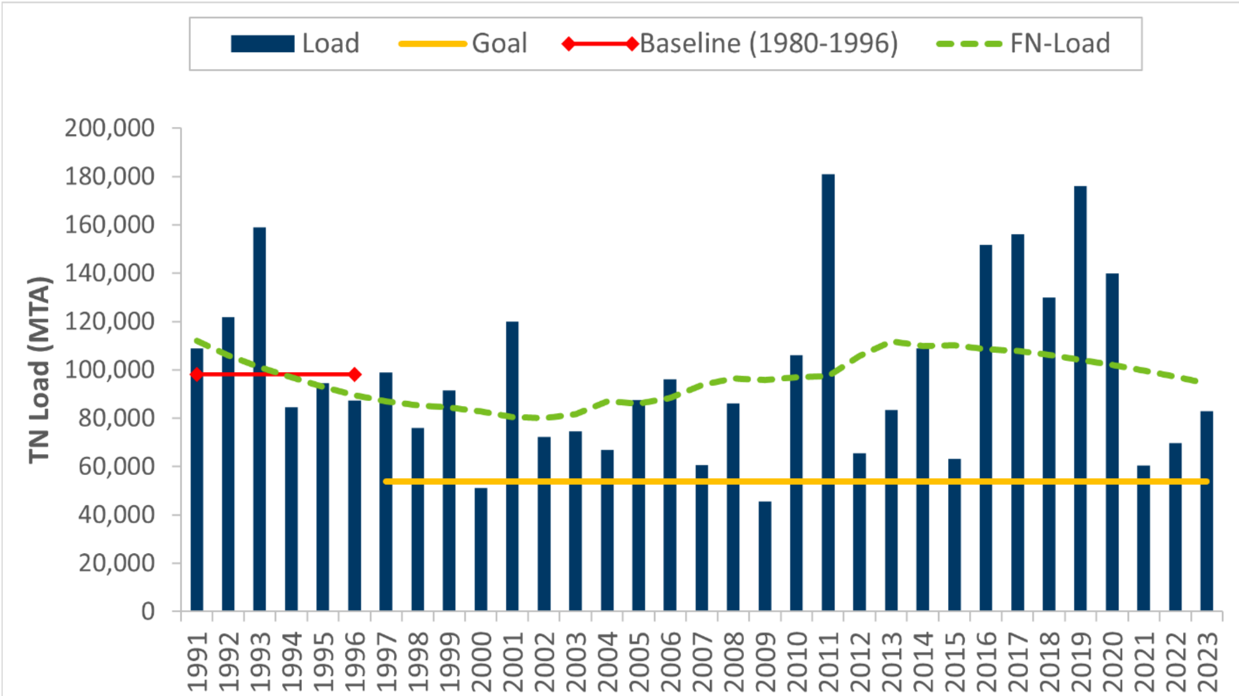
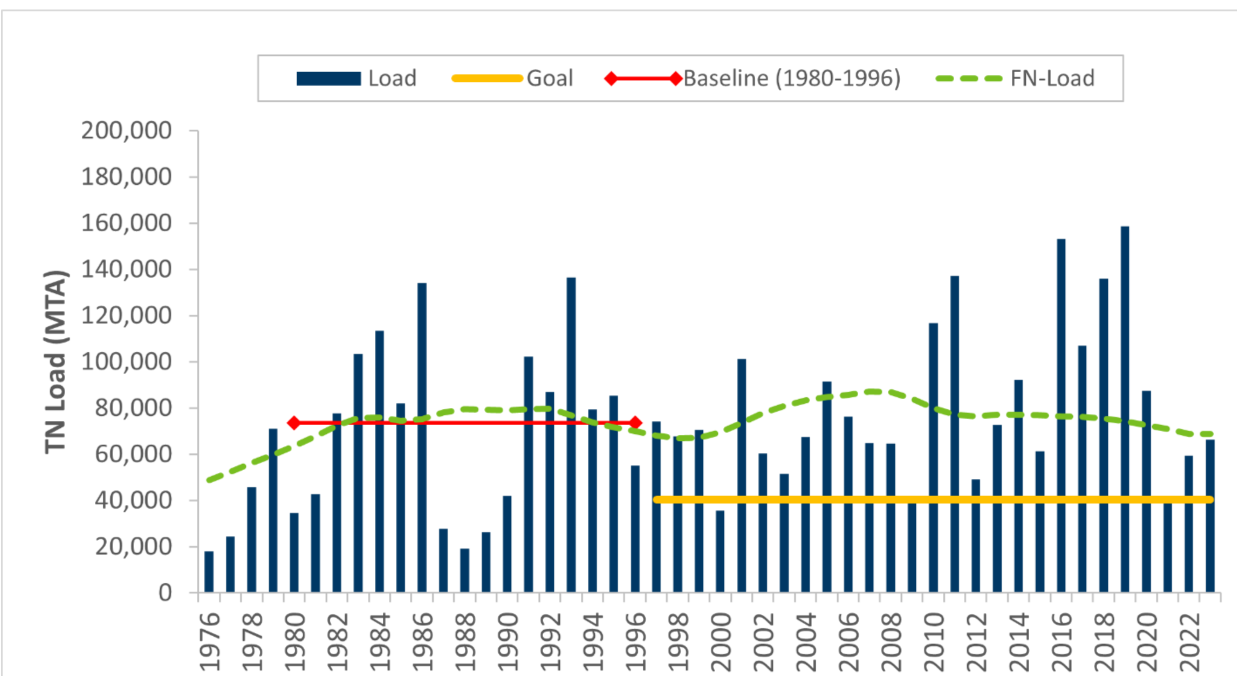


Figure 2-18. Mississippi River TN annual loads (dark blue bars) and flow-normalized load trend line (green dashed line) at Lock and Dam 3 (Red Wing), 1976–2023.



Loads assessed by comparing TN FWMCs between baseline and recent 5-year averages (2019–2023) showed recent TN to be 4% lower at both the La Crosse and Red Wing sites—very similar to the TN load changes noted above.

TN load trends from two secondary sites (Mississippi River at Winona and Minnesota River at Jordan) were also examined to see if they could provide further insight regarding TN load reduction progress in the Mississippi River Basin (Table 2-7). At Winona, a 13% lower TN load was indicated between available baseline period years 1981–1993 and the 2023 WRTDS flow-normalized loads. The missing TN load data from 1994–2008 in Winona does not allow for a direct trend analysis comparison with Red Wing and La Crosse sites. At Winona, the TN FWMC averages are 8% lower recently (2019–2023) compared to the 1981–1993 period average.

Table 2-7. Summary TN flow-normalized load and FWMC change indicators at three Mississippi River sites approaching the Iowa state line and at the Minnesota River at Jordan site.

Site	Long-term WRTDS FN load changes (baseline average to 2023 FN load)	Recent decade WRTDS FN load changes (2014–2023 FN load)	Long-term FWMC baseline average compared to most recent 5-year average
Red Wing (Mississippi R.)	-6%	-10%	-4%
La Crosse (Mississippi R.)	-4%	-14%	-4%
Winona (Mississippi R.)[a]	-13%	-15%	-8%
Jordan (Minnesota R.)	-32%	-35%	-26%

Notes:

FN = flow-normalized

A negative value indicates a decrease.

[a] See the report narrative regarding statistical significance of trend analysis over different periods of time.

[a] Baseline average is based on 13 years of monitoring (instead of 17 years at the other three sites).

Farther upstream, near the confluence of the Minnesota River with the Mississippi River, the Minnesota River at Jordan flow-normalized loads decreased by 32% when comparing 2023 loads to the 1980–1996 baseline average. TN load trends using WRTDS statistical significance evaluation showed the Minnesota River at Jordan decreases to be statistically significant for the 1980–2023 period (p=0.05). The FWMC recent 5-year average was 26% lower than the baseline average (1980–1996) at this site.

At the Minnesota River Jordan site, the most recent decade (2014–2023) showed a 35% TN load reduction (flow-normalized with WRTDS), which was statistically significant (p=0.05). A higher magnitude recent decade reduction was also observed in La Crosse, as previously noted, indicating possible nitrogen reductions since the 2014 timeframe when the NRS was first released.

The above analyses provide some indications of recent TN reduction progress (see Table 2-7), especially since 2014, the year the NRS was finalized. Yet, long-term TN changes since baselines were not statistically significant at La Crosse and Red Wing. The larger TN reductions at Jordan on the Minnesota River are encouraging because it is the largest nitrogen-loading tributary to the Mississippi. Nevertheless, further monitoring and trend analyses are needed to ensure that the trends are not overly influenced by extreme precipitation swings and the 2021–2023 dry period.

Non-normalized load progress indicators

When assessing Mississippi River TN load changes without normalizing for annual river flow variability, the past five years show slightly higher TN loads than the baseline period (Figure 2-19 and Figure 2-20). Higher precipitation and correspondingly higher river flows (especially in 2015–2019) have offset some of the progress, resulting in overall load increases of 2%–12% at primary and secondary sites (Table 2-8).

Figure 2-19. Mississippi River La Crosse site: 5-year rolling averages of river flow and TN load.

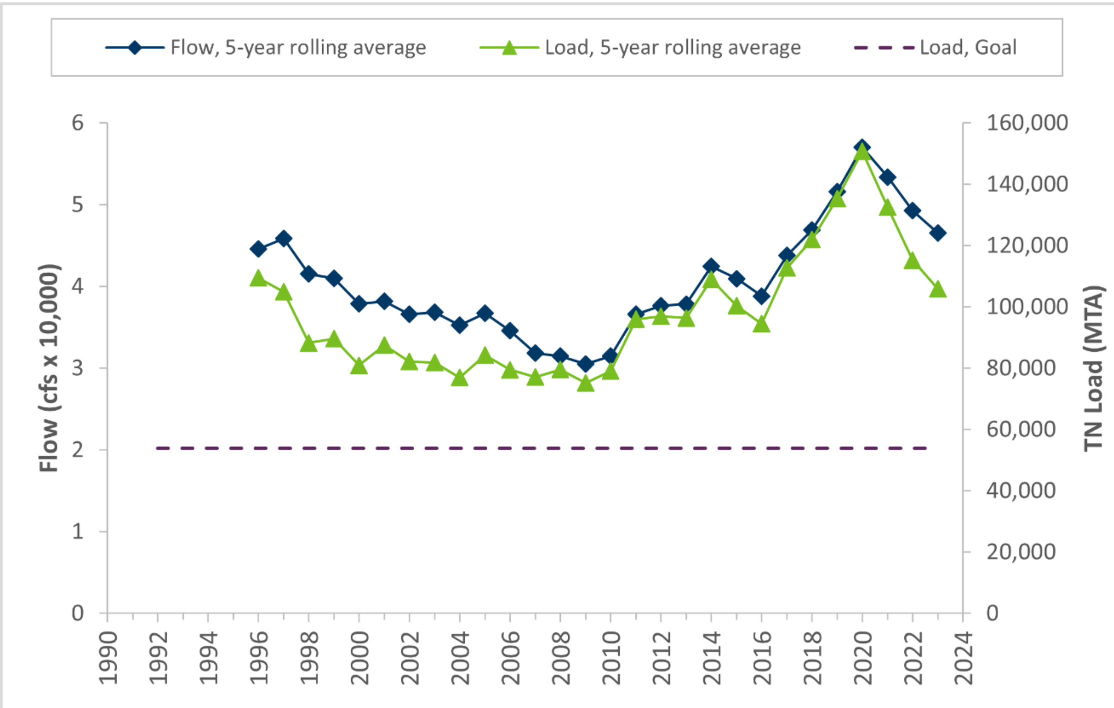


Figure 2-20. Mississippi River Red Wing site: 5-year rolling averages of river flow and TN load.

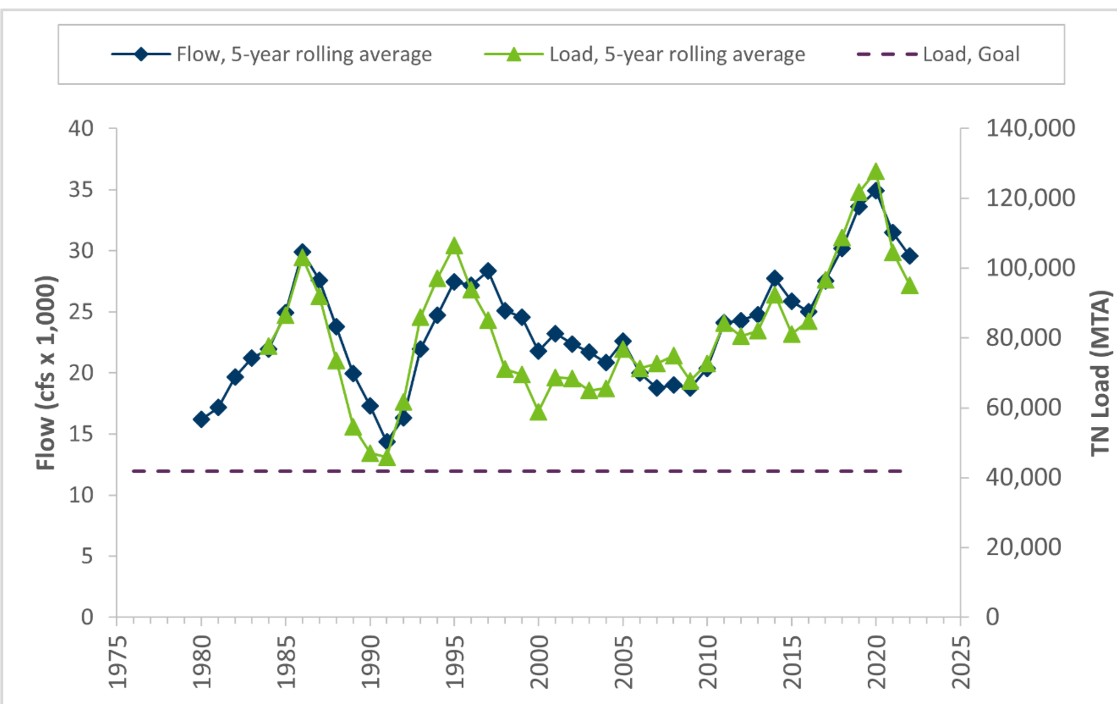


Table 2-8. Summary of TN load change indicators in the Mississippi River approaching the state line and in the Minnesota River at Jordan.

Monitoring site	Load changes (baseline average to 2023)[a]	WRTDS FN load changes 2014–2023	FWMC baseline average compared to most recent 5-year average [b]	Non-FN load changes through 2023 (baseline average to 2019–2023 average)[c]
La Crosse (Mississippi R.)	-4%	-10%	-4%	+8%
Red Wing (Mississippi R.)	-6%	-14%	-4%	+12%
Winona [d] (Mississippi R.)	-13%	-17%	-8%	+4%
Jordan (Minnesota R.)	-32%	-35%	-26%	+2%

Notes:
FN = flow-normalized
Negative numbers indicate decreases and positive numbers indicate increases.
See the report narrative regarding statistical significance of trend analysis over different periods of time.
[a] Change from the baseline average load and 2023 WRTDS FN load. Baseline loads represent 1980–1996 baseline load from the 2014 NRS for Red Wing and La Crosse and 1980–1994 average of WRTDS non-FN loads for Winona.
[b] Change from the baseline average FWMC and 2019–2023 average FWMC (WRTDS non-FN loads). Baseline FWMCs represent averages from the 1980–1996 baseline FWMC from the 2014 NRS for Red Wing and La Crosse, 1981–1994 average of WRTDS non-FN FWMCs for Winona, and 1980–1996 average of WRTD non-FN FWMCs for Jordan. To calculate change, FWMCs are first rounded to the one-thousandth mg/L.
[c] Change from baseline average load to 2019–2023 average of WRTDS non-FN loads. Results in this column do not have adjustments to smooth the interannual river flow variability influences. Baseline loads are represented by 1980–1996 average load from 2014 NRS for Red Wing and La Cross sites, 1981–1994 average of WRTDS non-FN loads at Winona, and 1980–1996 WRTDS non-FN loads at the Jordan site.
[d] No TN data are available for the Mississippi River at Winona for 1994–2008.

In summary, flow-normalized loads of TN in the Mississippi River by the state line are trending down, but the changes have not been statistically significant, with the following exceptions:

- Mississippi River at La Crosse: Decreasing trends for 1992–2023 (p=0.02) and 2014–2023 (p=0.05).
- Minnesota River at Jordan: Decreasing trends for 1980–2023 (p=0.05) and 2014–2023 (p=0.05).

Additional monitoring years are needed to be more certain about whether those improvements will continue.

Appendix 2-1 provides more information about TN load assessments and results, including the results at several secondary NRS locations within the Mississippi River Basin. Section 2.3.1 in Appendix 2-1 presents baseline and recent flows, FWMCs, and loads (non-flow-normalized) using FLUX32 and WRTDS. Section 2.5.1 in Appendix 2-1 presents baseline and recent flow-normalized concentrations, flow-normalized loads, and statistical significance using WRTDS. Appendices A and B in Appendix 2-1 present charts of flow, FWMC, loads, and goals, including both flow-normalized and non-flow-normalized loads.

2.5.2 Red River: TN load progress near the state line

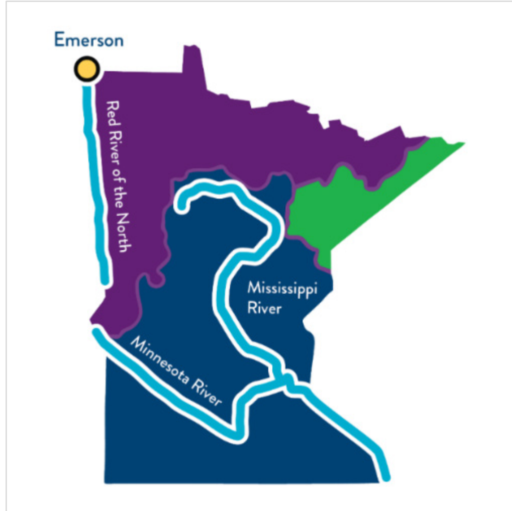
Our best method of analysis to indicate progress on the Red River at Emerson (Figure 2-21), flow-normalized loads calculated with WRTDS, shows a 9% lower TN load in 2023 compared to the baseline average (Figure 2-23). Load changes assessed using the simpler FWMC 5-year moving average show a 24% lower average TN between the 1996–2000 period and the 2019–2023 period.

Without normalizing for river flow variability and looking only at average loads, the recent 5-year period (2018–2022) has averaged 23% lower TN loads since the 1996–2000 baseline period (Figure 2-22).

Nitrogen loads during the six lower-flow years met the targeted load goal, but the other years exceeded final load targets.

An assessment of the TN load trend was completed for the Red River at Emerson from the end of the baseline period (2001) through 2023, and changes were found to be not statistically significant. Statistical significance for TN in the Red River is further discussed in Appendix 2-1, Section 2.5.2.

Figure 2-21. Location of Red River at Emerson monitoring site.



Farther upstream from the state line, TN loads have been calculated since 2007 at the Red River monitoring site at Grand Forks. The 5-year rolling average TN load dropped 3% between the 2007–2011 period and the 2018–2022 period. FWMC 5-year rolling averages are 3% higher during the most recent period. More than half of the nitrogen is coming from North Dakota at both the Grand Forks and Emerson sites, as determined by SPARROW modeling.

Figure 2-22. TN annual loads in the Red River at Emerson (dark blue bars) and WRTDS flow-normalized load trend in 1995–2023 (green dashed line).

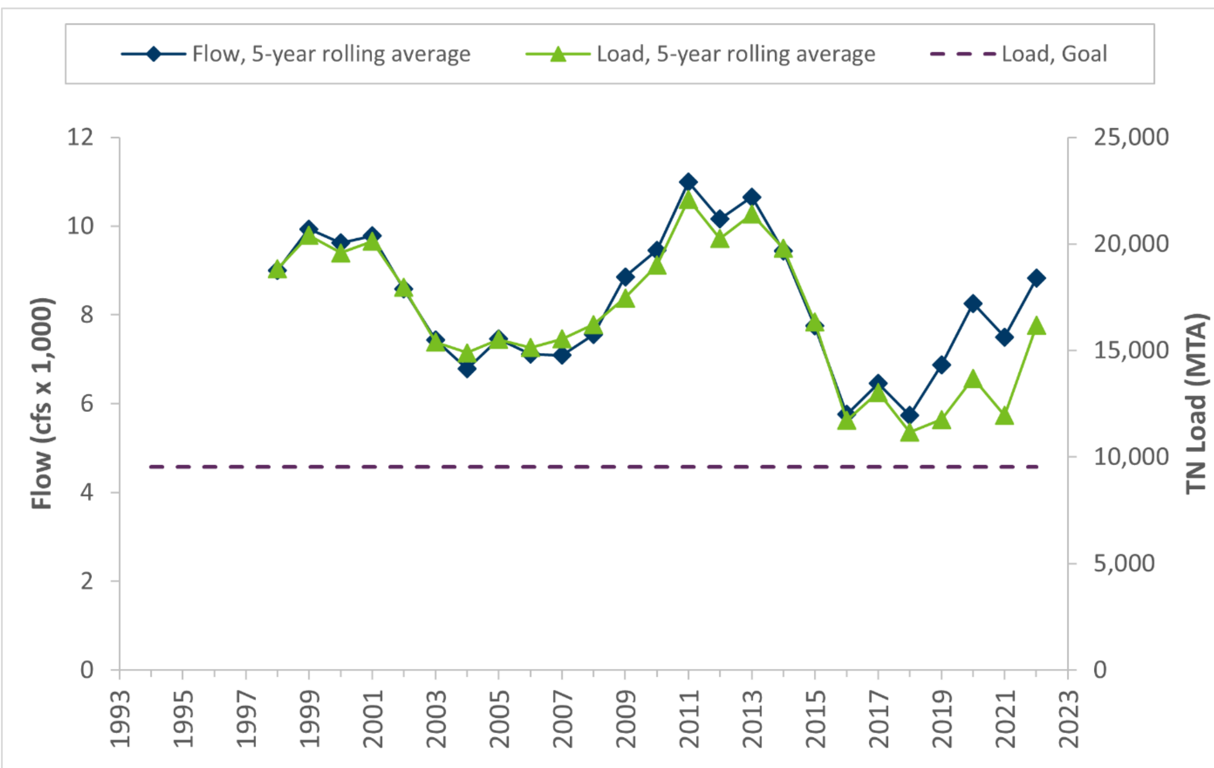
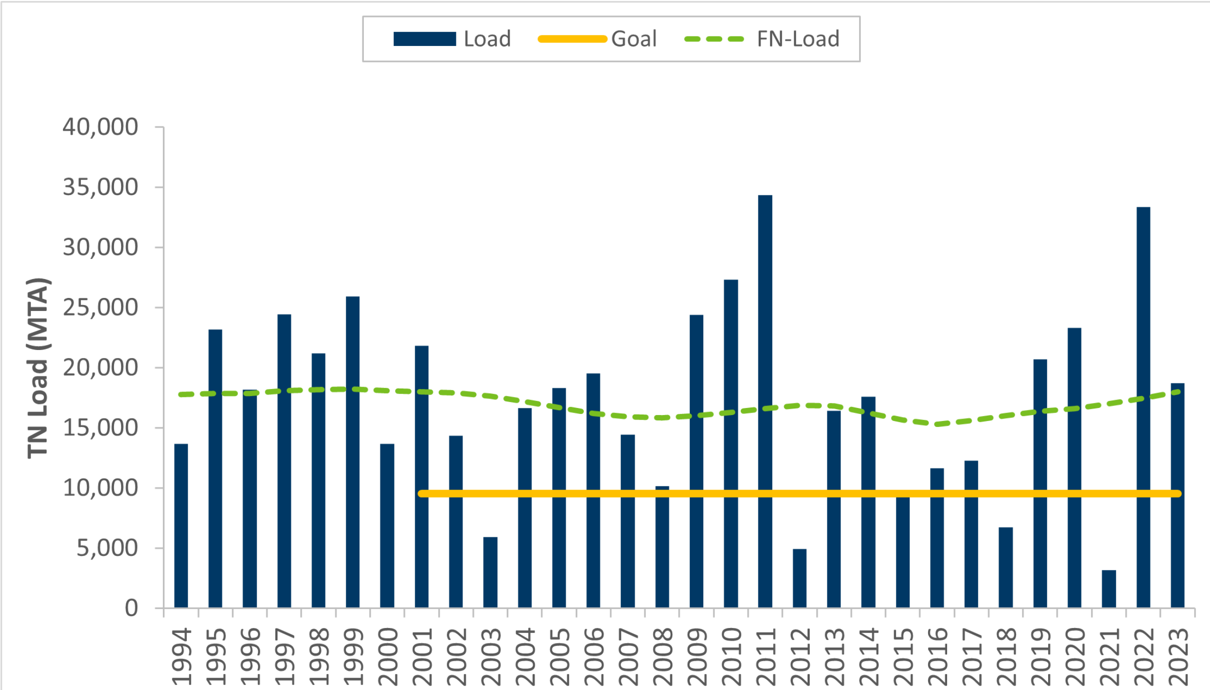


Figure 2-23. Red River at Emerson monitoring site: 5-year rolling averages of river flow and TN load, representing results from 1994–1998 through the period 2019–2023.



In summary, TN loads in the Red River by the border with Canada show indications of improvement (decreases), with a 9% lower flow-normalized load in 2023 compared to the 1996–2000 baseline average, but this improvement is not consistent nor statistically significant. This reduction, along with the 22% reduction in FWMC and the 4% reduction in non-normalized 5-year rolling average loads (Table 2-9), suggests some progress may have been made in the Red River. However, it is uncertain whether different precipitation patterns over time will change the perceived progress. Trend analysis uncertainty will remain until more years of monitoring are completed.

Table 2-9. Summary of TN load change results in Red River at the state line in Emerson, Manitoba, using WRTDS-calculated loads.

Monitoring site	WRTDS FN load changes (baseline to 2023)	WRTDS FN load changes 2014–2023	FWMC 5-year rolling average	Non-FN load change (5-year rolling average)
Red River at Emerson	-9%	+1.6%	-24% (1996–2000 through 2019–2023)	-4% (1996–2000 through 2019–2023)
Red River at Grand Forks	–	–	+3% (2007–2011 to 2017–2022)	-3% (2007–2011 to 2018–2022)

Notes:
FN = flow-normalized
Negative values indicate decreases; positive values indicate increases.

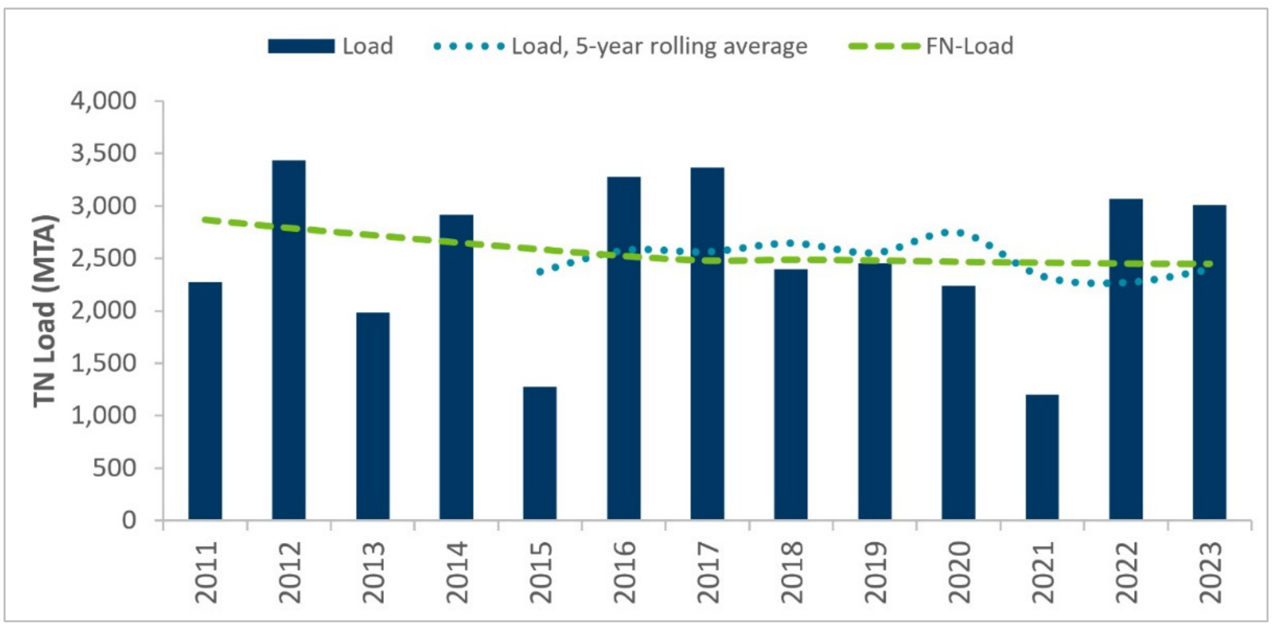
Appendix 2-1 provides more information about TN load assessments and results, including the results at several secondary NRS locations within the Lake Winnipeg Basin. Appendix 2-1 Section 2.3.2 presents baseline and recent flows, FWMCs, and loads (not flow-normalized) using FLUX32 and WRTDS, while Appendix 2-1 Section 2.5.2 presents baseline and recent flow-normalized concentrations, flow-normalized loads, and statistical significance using WRTDS. Appendix 2-1's Appendix C presents charts of flow, FWMC, loads, and goals, including both flow-normalized and non-flow-normalized loads, for the Red River and Rainy River.

2.5.3 Lake Superior: TN load progress

The 2025 NRS trend analysis for the Lake Superior Basin focuses on TN load trends in the St. Louis River at Scanlon, Minnesota (location shown in Figure 2-2). The St. Louis River is the largest Minnesota tributary to Lake Superior. As more years of river monitoring occur in tributaries to Lake Superior, further trend evaluations will help inform whether TN loads coming into Lake Superior from Minnesota are increasing or decreasing.

USGS performed trend analysis and load calculations using WRTDS on the St. Louis River at Scanlon (Diebel et al. 2025). A 14% TN load decrease was observed using WRTDS flow-normalized loads between 2011 and 2023 (Figure 2-24), and while the reasons for this trend are uncertain, this change is statistically significant. During this same timeframe, the 5-year rolling average FWMC changed from 1.12 mg/L to 1.02 mg/L (9% decrease), and the non-normalized 5-year rolling average loads remained about the same (1% increase). This monitoring site is upstream of the city of Duluth, which contributes additional nitrogen loads to the river.

Figure 2-24. St. Louis River Scanlon monitoring site. Annual TN loads (dark blue bars), WRTDS TN flow-normalized load trends (green dashed line), and the 5-year rolling average annual TN loads (blue dotted line), 2011–2023.



Appendix 2-1 provides more information about TN load assessments and results, including the results at two secondary NRS locations within the Lake Superior Basin. Appendix 2-1 Section 2.3.3 presents baseline and recent flows, FWMCs, and loads (non-flow-normalized) using FLUX32 and WRTDS, while Appendix 2-1 Section 2.5.3 presents baseline and recent flow-normalized concentrations, flow-normalized loads, and statistical significance using WRTDS. Appendix 2-1's Appendix D presents charts of flow, FWMC, loads, and goals, including both flow-normalized and non-flow-normalized loads, for sites on the St. Louis River and Nemadji River.

2.6 Estimated load reductions from added practices

In addition to assessing progress through river nutrient load monitoring results, the 2025 NRS uses certain urban and rural practice adoption levels as another indicator of progress toward goals. The 2025 NRS includes an assessment of practice adoption since 2004 via state, federal, and certain local government programs and the estimated effects these practices have on nutrient load reduction to rivers. Estimates of annual nutrient load reduction were developed by modeling the effects of practices on nutrient reduction through 2023. The available information on agricultural and wastewater treatment practice adoption is not a comprehensive evaluation of practices; rather, it provides partial information about two of the biggest nutrient sources across Minnesota. It is only a “partial” assessment for reasons outlined later in this section.

Assessing practice adoption levels can be a supplemental way to assess the potential for water quality change. For example, practice adoption can be used for purposes such as: (1) indicating strategy progress by comparing actual adoption levels to NRS BMP adoption planning scenarios, (2) indicating potential river nutrient load change expectations before the long-term river monitoring trends are observed or available, and (3) helping to understand possible reasons for observed river monitoring results and trends.

The modeled estimates from practice adoption can be compared to the changes detected from river load monitoring. However, differences are expected between the two approaches because both the river monitoring approach and the practice effects modeling approach have inherent limitations and complexities. River load monitoring is complicated by lag time delays, legacy nutrients, and challenges with obtaining representative water samples and calculating annual loads based on laboratory results from those samples. Modeling the effects of new practice adoption has limitations due to uncertainty about the future persistence and longevity of newly adopted practices, external influences on nutrient loads, and imperfect models and underlying research for estimating the effects of those practices. Nonetheless, considering both the river monitoring and practice adoption indicators provides a clearer picture of progress than using either approach alone.

Practice adoption from the time of adoption of the 2014 NRS through 2018–2019 was discussed in detail in the NRS 2020 5-year progress report. The 2025 NRS builds on those previous efforts with updated new practice adoption information and improved models for estimating the effects of practices. The following discussion is divided into two major categories: (1) agricultural practices and (2) wastewater practices. Other categories of practices are not discussed in this section but are included in chapters 4–7 and the 2020 progress report.

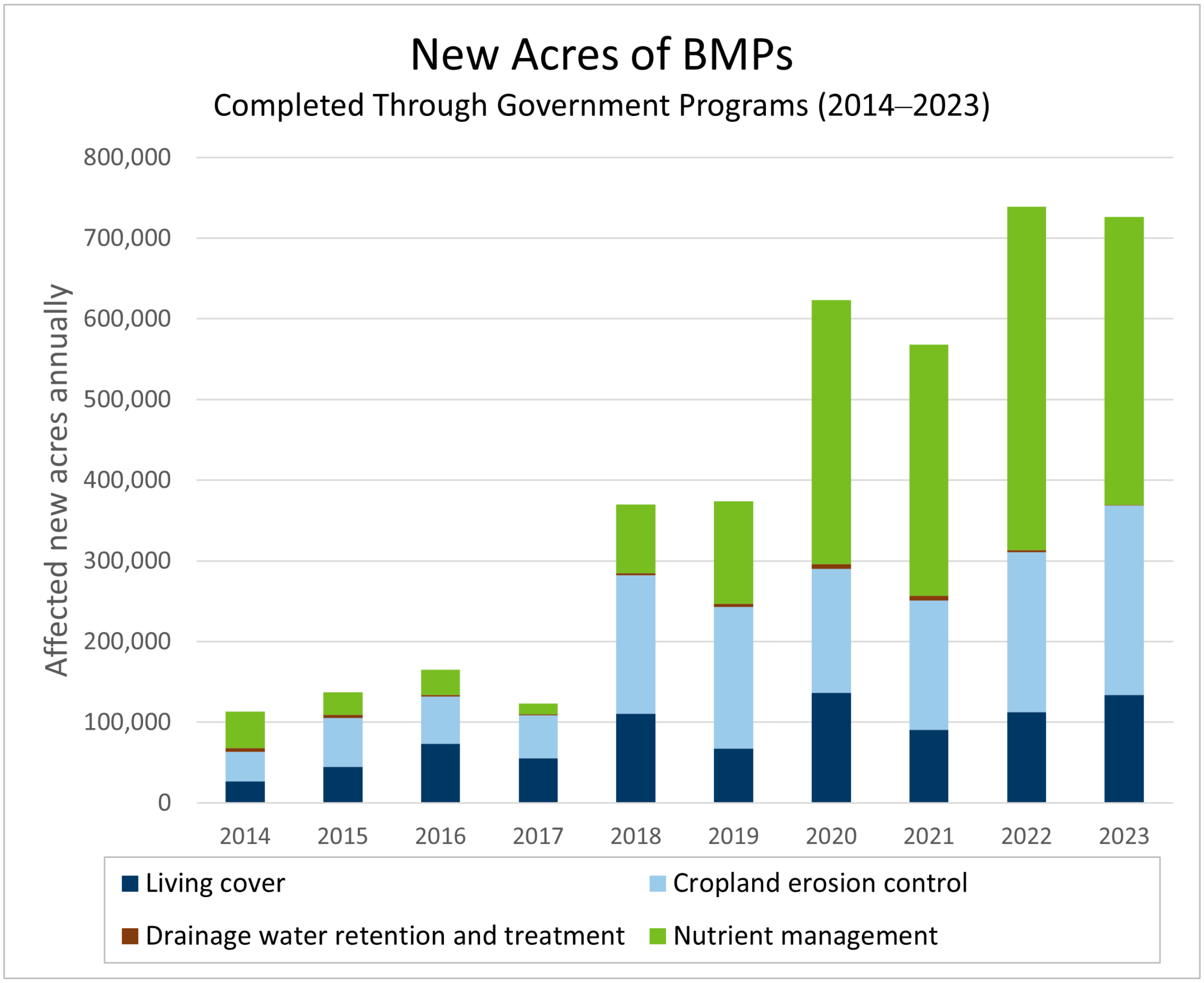

A vegetated buffer protects a stream from runoff

2.6.1 Effects of added agricultural practices

New agricultural BMPs (practices) adopted through government programs have been increasing in recent years as more state and federal money for practices has become available (Figure 2-25). The MPCA’s NRS tracking system for new agricultural BMPs adopted through government programs (state, federal, and local) was used to evaluate agricultural BMP adoption since 2004. These BMPs are tracked on MPCA’s New Acres of BMPs tracking tool, as described in Chapter 7. More details about the tracked practices and their effectiveness in addressing excess nitrogen and phosphorus can be found in Chapter 5 and appendices 5-1 and 5-2.

To simplify the representation of newly added practices, the practices were grouped into the four major categories shown in Figure 2-25: living cover, drainage water retention and treatment, cropland erosion control, and nutrient management. The "drainage water retention and treatment" category of tracked practices has limited new adoption compared to the other practices and is, therefore, barely visible.

Figure 2-25. Annual new additional BMP-treated acres adopted via government programs since the 2014 NRS (2014–2023). Each year should be viewed as an individual year of newly added acres treated by BMPs (data are not cumulative).



Practices such as saturated buffers, treatment wetlands, controlled drainage (drainage water management), bioreactors, and drainage water storage ponds have had limited adoption with government programs, with a total of less than 35,000 acres treated by these practices since 2014, and relatively little adoption of those particular practices is expected outside of the government programs.

The NRS tracking system does not represent or track all adopted practices. For example, a common practice in flood-prone landscapes not included yet in the NRS tracking system, especially important in the Red River Valley, is water impoundment used for flood control, wildlife habitat, and nutrient reduction. Also, large acreages of nutrient management and cropland erosion control (i.e., reduced tillage) occur outside the tracked government programs.

To estimate the load reductions to waters at the state line from specific BMPs adopted through state, federal, and local government programs, the MPCA's BMP Effects Estimator Tool (BEET) was applied to the affected cropland acreages. This tool applies typical nutrient reduction efficiencies determined by field research to the modeled nutrient loads delivered to rivers through three different flow pathways (groundwater baseflow, tile drainage, and surface runoff represented in the HSPF Scenario Application Manager model). The modeled river loads are highly calibrated to monitor results from a large network of Minnesota water quality monitoring locations. Load reduction estimates can be calculated with BEET for different delivery points, including the state-line delivery point.

Based on findings from the most recently updated BEET, the modeled load reductions from agricultural BMPs adopted between 2004 and 2023, if remaining under adoption, could be expected to result in a 5% and 4% nitrogen reduction and 8% and 7% phosphorus reduction in the Mississippi and Lake Winnipeg basins, respectively, at the state lines (Table 2-10). Lake Superior has relatively small amounts of cropland; therefore, the adopted agricultural BMPs resulted in a much lower nutrient reduction (0.5 MT of TN and 0.05 MT of TP).

Table 2-10. Modeled estimates of annual nutrient (TN and TP) load reduction effects to rivers from all agricultural practices newly added through tracked government programs.

Major drainage basin	Nutrient	Estimated load change by cropland BMPs for 2004–2023 (MT/yr at state line)	Baseline loads from MN watersheds (MT/yr at state line)	Progress from cropland BMPs for 2004–2023 (as % of total load delivered to state lines from MN watersheds)
Mississippi River	Phosphorus	364	4,627	8%
	Nitrogen	4,684	91,069	5%
Lake Winnipeg [a]	Phosphorus	87	988	7%
	Nitrogen	364	8,222	4%

Notes:
The load reductions represent the general magnitude of load reductions that would have occurred if all added practices remained in effect on the lands after adoption.
[a] Includes the Red and Rainy River basins

Understanding the external influences on water nutrient trends provides important context for comprehensively and objectively evaluating the overall progress toward NRS milestones and goals. As BMPs (including additional living cover) were adopted through multiple government programs during the past decades, other influential changes have occurred on our lands and in cities. Some of these changes would be expected to increase nutrient loads in rivers, and others would be expected to decrease them.

Changes with external influences on nutrient loads were described in the NRS 5-year progress report in 2020 and in Chapter 1 of the 2025 NRS. Re-evaluating external influences and then modeling the combination of all factors affecting loads was beyond the scope of this 2025 NRS update. In the future, NRS analyses of expected load changes should also consider adding the following information:

- Potential additional nutrient improvements
  - Private adoption of practices outside of government programs
  - Adoption of government programs and nongovernment-assisted practices before 2004, which was the year BWSR implemented the eLINK grant reporting system
  - Other practices not tracked in the existing tracking system (i.e., water storage impoundments, urban stormwater BMPs, septic system improvements)

- Potential offsets (subtractions) to the improvements
  - Discontinued or poorly maintained BMPs
  - BMPs that have exceeded their life expectancy
  - Land use changes, including increased row crops, more impervious lands, and changes to cropland drainage intensity
  - Increasing precipitation extremes and other climate effects

The above influences will somewhat offset one another. However, without a complicated new modeling effort, uncertainties remain about the net effect of all additional reductions and the offsets to those reductions that are not currently modeled through BEET.

2.6.2 Effects of urban wastewater practices with agricultural practices

In this section, the estimated effects of urban wastewater practices are added to the above-estimated effects of agricultural practices and then compared to monitoring results.

The nutrient load changes from wastewater discharges are tracked on the MPCA's Reducing Nutrients in Waters website and are described in detail within Chapter 4. The improvements made with wastewater phosphorus sources have greatly influenced the observed river phosphorus loads, particularly in the Mississippi River, where a 19% TP load reduction in the river has occurred from wastewater improvements alone since the baseline period (Table 2-11).

Table 2-11. Current (2021–2023 average) wastewater effluent phosphorus loads and reduction goals delivered to the state borders in the Mississippi River and Lake Winnipeg drainage basins (2004–2023).

Basin	2021–2023 wastewater TP load (MT/yr)	Wastewater TP load reduction amount since 2001–2003 (MT/yr)	TP change achieved as % of wastewater sources only	TP change as a % of river TP baseline loads at state line
Mississippi River	281	888	-76%	-19%
Lake Winnipeg	37	38	-52%	-4%

Although tremendous progress has been made with TP reductions from wastewater in recent years, only a few facilities in Minnesota have been working to reduce TN. Chapter 4 describes plans for wastewater nitrogen treatment in Minnesota over the next couple of decades.

By combining (1) the estimated load reductions from new cropland BMP adoption through government programs and (2) the known reductions observed from wastewater discharge monitoring, the sum of the combined reductions since 2004 in the Mississippi River Basin is 5% for TN and 27% for TP (Table 2-12).

Table 2-12. Percent load change by agriculture BMPs (government-assisted) and the wastewater sector combined.

Major basin	Total phosphorus	Total nitrogen
Mississippi River	-27%	-5%
Lake Winnipeg	-13%	-5%

Notes:
The load reductions in this table represent estimated load reductions in the rivers at the state border.
Data are a summary of combined recent progress by the wastewater and agricultural sectors.

The TN reduction estimates from these two categories of practices are very similar to the 4% and 6% reductions (not statistically significant) calculated in the Mississippi River at La Crosse and Red Wing based on river monitoring and flow-normalized WRTDS analysis.

The 27% TP reduction estimate from new practices is between the 11% and 32% TP reductions observed in the Mississippi River at La Crosse and Red Wing, respectively (flow-normalized trends). Precise alignment between the river monitoring results and the modeled effect from practice changes is not expected due to differences in lag times, legacy nutrients in waters, uncounted practices, external changes affecting loads, and more. However, the similarities in the general magnitude of change provide evidence suggesting that some progress has been made with nitrogen loads in the Mississippi River.

In the Lake Winnipeg basin, the combined river load reductions from tracked new agricultural BMPs and wastewater practices are estimated to be 5% for TN and 13% for TP (see Table 2-12). Water quality monitoring and trend analysis using flow-normalized WRTDS in the Red River at Emerson had an estimated 13% increase in TP (see Table 2-6) and an 8% reduction in TN since the baseline period (see Table 2-10). The phosphorus monitoring does not align very closely with the expected 13% reduction in phosphorus based on modeling the effects of new practices. One reason for this difference may be the effect of North Dakota tributary TP loads on the river monitoring site; in addition, no tracking or modeling of the expected effects of practices in North Dakota is conducted. Another reason could be related to the influences of the harder-to-control phosphorus contributions from streambank erosion.

Trend analysis work is complicated, and no single monitoring site or analysis method can be solely relied on; multiple indicators tell a more complete story. While the above analysis has a wide range of uncertainty, especially with the agricultural practices, it nonetheless provides an additional indicator of the general magnitude of load reductions to be expected, apart from the influences of weather and other external factors. Progress can be observed through both the river monitoring for loads and estimates based on the addition of new practices. The results from the river monitoring and practice effects modeling methods align reasonably well, especially given uncertainties such as lag times, legacy nutrients, missing practices from the assessment, and the other complicating factors previously described. Both methods indicate that much more work is needed for nitrogen and phosphorus, especially nitrogen. The magnitude of remaining load reduction needs is described in Section 2.7, and the amount of work needed in rural and urban areas to achieve these load reductions is described in chapters 4 and 5.

2.7 Remaining load reductions needed to meet state-line goals

Based on previously described indicators of progress, the remaining flow-normalized loads expressed as a percent of baseline loads were calculated for each primary downstream monitoring site (Table 2-13). These percent changes were applied to the entire drainage basins to estimate the remaining load reductions needed, as described below. The remaining load amounts were then applied to the estimated fraction coming from Minnesota's watersheds alone; this allows an estimation of the annual average load reduction needed in Minnesota so that final nutrient reduction goals can be achieved for Minnesota's share of the loads.

This analysis represents a snapshot in time. Each new year of data and each new use of WRTDS or other statistical models will alter these numbers and the perception of how much progress remains. Additionally, this river monitoring-based information does not represent the full extent of change on the land, due to lag times between nutrients entering the soil and then traveling to rivers. Periodic re-assessment of NRS progress indicators (see Chapter 7) and remaining reduction needs will be necessary.

Table 2-13. Average river loads at primary monitoring sites: baselines, recent loads, goals, remaining reductions in MT, and the remaining reductions as a % of baseline.

River and location(s)	Pollutant	Baseline load	2023 FN load WRTDS [a]	Load upon reaching final goal	Added reduction needed between 2023 and 2040 (FN)	Percent of baseline still needing reduction
Mississippi River (La Crosse L&D 7)	Phosphorus	4,976 [b]	4,432	2,737	1,695	34%
	Nitrogen	97,996 [b]	94,349	53,898	40,451	41%
Mississippi River (Red Wing L&D 3)	Phosphorus	3,664 [c]	2,505	2,015	490	13%
	Nitrogen	73,447 [c]	68,807	40,396	28,411	39%
Red River (Emerson, Manitoba)	Phosphorus	2,787 [d]	2,977	1,400	1,577	57%
	Nitrogen	20,067 [d]	18,007	9,525	8,482	42%
Lake Superior	Phosphorus	245 [e]	NA	245	NA	NA
	Nitrogen	4,670 [e]	NA	4,670	NA	NA

Notes:

FN = flow-normalized; L&D = lock and dam; NA = not applicable

[a] The 2023 loads were determined by evaluating the endpoint of the WRTDS trends line, which ended in 2023. The loads during this end year integrate data throughout the period of evaluation, with increased influence of the previous 7 years of data. Therefore, 2023 does not represent a single year but rather the endpoint of the flow-normalized trend lines.

[b] As reported in the 2014 NRS.

[c] 1980–1996 average loads over baseline period using the WRTDS non-normalized loads.

[d] 1996–2000 average loads over approximate baseline period using the WRTDS non-FN loads (run on 11/13/2024). The IRRWB does not emphasize a specific baseline but focuses on loads needed to reach the final goal (1,400 and 9,525 MT/yr).

[e] Lake Superior nutrient loads from Minnesota tributaries were unknown in 1979. "Baseline loads" in the 2014 NRS were calculated from SPARROW model loads. More monitoring in recent years enabled Minnesota to more accurately model loads in tributaries to Lake Superior using the HSPF model. "Loads upon reaching final goal" based on recent aggregated watershed HSPF model loads (10-year averages of the most recent model for each modeled watershed). HSPF model loads are further described in Appendix 2-1.

2.7.1 Phosphorus

Phosphorus in the Mississippi River Basin

The best indicator of phosphorus load changes from Minnesota actions is the WRTDS flow-normalized assessment at Red Wing. The Red Wing site captures over 95% of loads from Minnesota, has the longest load monitoring history (1976–2023), and is upstream of confounding legacy phosphorus sources between Red Wing and La Crosse. Of the original 45% TP reduction goal in the Mississippi River, TP is estimated to have been reduced by 32% at Red Wing, with 13% of the baseline load reductions still needed. The 32% TP load reduction at Red Wing is also reasonably close to the 36% FWMC reduction estimate at Red Wing, the 39% load reduction estimate at Winona, and the combined practice adoption reduction estimate of 27%.

The 32% reduction at Red Wing was applied to the overall baseline loads from Minnesota tributaries of the entire Mississippi River drainage basin to calculate a 602 MT/yr estimate of TP load reductions still needed (Table 2-14). Note that the 602 MT load reduction amount still needed is different from the Red Wing and La Crosse reductions needed for several reasons, including that the 602 MT/yr further reduction excludes Wisconsin tributaries and includes the Minnesota watersheds of the Cedar River, Des Moines River, and other rivers that reach the Mississippi River downstream of La Crosse.

Table 2-14. Summary of TP load change results and remaining reduction needs to achieve goals in the Mississippi River and Red River basins at the state lines.

Monitoring site	Baseline load at state line (all MN tributaries combined) MT/yr	Best estimate of current load (MN parts only) MT/yr	Load upon reaching final goal (all MN tributaries combined) MT/yr	Best estimate of load change since baseline (% of baseline)	Best estimate of remaining load reduction needed (% of baseline)	Load reduction still needed (all MN tributaries combined) MT/yr
Mississippi River Basin (all MN contributing areas)	4,627 [a]	3,146 [b]	2,544 [a]	-32%	13%	602
Lake Winnipeg drainage (Red River Basin only)	950 [c]	1,015 [d]	477 [e]	Load increased 7%	57%	538

Notes:

[a] From the 2014 NRS, Table 3-7

[b] Subtracting 32% of the baseline 4,267 MT/yr

[c] Updated from 2014 NRS: Minnesota contribution (34.1%) of the 1996–2000 average load (2,787 MT/yr)

[d] Based on MN contribution of 2023 WRTDS flow-normalized load (about 7% increase from baseline)

[e] Updated from 2014 NRS: Minnesota contribution (34.1%) of the updated goals (2,700 MT/yr) set by Manitoba for Red River at the international border in Emerson.

Phosphorus in the Red River Basin

To determine the remaining load reduction amounts needed in the Red River Basin, the current load of 2,977 MT is multiplied by Minnesota's estimated share (34.1% of Red River Emerson loads) to obtain the 1,015 MT current load coming from Minnesota. Minnesota's share of the intended final load goal is 477 MT/yr, meaning that Minnesota will need to reduce an additional 538 MT/yr of its current TP load of 1,015 MT/year in the Red River Basin (see Table 2-14, along with achieving the TP reduction goals for Lake of the Woods.

2.7.2 Nitrogen

Nitrogen in the Mississippi River Basin

Of the original 45% TN reduction goal in the Mississippi River, our best indicators suggest a 6% reduction (with 39% of baseline reduction still needed). This is based on the WRTDS flow-normalized analysis at Red Wing and is very similar to the WRTDS flow-normalized analysis at La Crosse (-4%) and the FWMC reductions at both Red Wing and La Crosse (-4%). While the 13% reduction in Winona using WRTDS flow-normalized analysis is more than the other sites, the monitoring period is not as long or consistent as that of Red Wing. The -6% TN load change estimate is also very similar to the reduction estimated from practice adoption since 2004 (-5%).

The 6% reduction was applied to the overall baseline loads from Minnesota tributaries of the entire Mississippi River drainage basin to calculate a 35,517 MT/yr estimate of TN load reductions still needed at the state line from all watersheds in Minnesota that contribute to the Mississippi River (Table 2-15).

Table 2-15. Summary of TN load change results and remaining reduction needs to achieve goals in the Mississippi River and Red River basins at the state lines.

Monitoring site	Baseline load at state line (all MN tributaries combined) MT/yr	Best estimate of current load (MN parts only) MT/yr	Load upon reaching final goal (all MN tributaries combined) MT/yr	Best estimate of load change since baseline (% of baseline)	Best estimate of remaining load reduction needed (% of baseline)	Load reduction still needed (all MN tributaries combined) MT/yr
Mississippi River Basin (all MN contributing areas)	91,069 [a]	85,605 [b]	50,088 [a]	-6%	39%	35,517
Lake Winnipeg drainage (Red River Basin only)	8,007 [c]	7,286 [d]	3,800 [e]	-9%	42%	3,486

Notes:

[a] From the 2014 NRS, Table 3-7

[b] Subtracting 6% of the baseline 4,267 MT/yr

[c] Updated from 2014 NRS: Minnesota contribution (39.9%) of the 1996–2000 average load of 20,067 MT/yr

[d] Based on Minnesota's contribution (39.9%) of 2023 WRTDS flow-normalized load (18,007 MT/yr; about 10% decrease from baseline)

[e] Updated from 2014 NRS: Minnesota contribution (39.9%) of the updated goals (9,525 MT/yr) set by Manitoba for Red River at the international border in Emerson.

Nitrogen in the Red River Basin

To determine the remaining TN load reduction amounts needed in the Red River Basin, the current load of 20,067 MT is multiplied by Minnesota's estimated share of Red River loads (39.9%) to obtain the 7,184 MT current load from Minnesota. The difference between the current and goal amount for Minnesota is 3,486 MT/yr, which is the amount Minnesota will need to reduce on average in the Red River Basin (see Table 2-15). The right columns of Table 2-14 and Table 2-15 provide the load reduction amounts that Minnesota aims for when developing scenarios of how to potentially achieve the goals (as discussed in Chapter 5).

2.8 Priority sources and watersheds for state-line goals

2.8.1 Priority nutrient sources in major river basins

The sources of nutrients to Minnesota waters were estimated in each of the three major drainage basins for the 2014 NRS. The estimates were derived from various data sources and models, as further described in Chapter 3 of the 2014 NRS. The fraction of loads coming from each source varies among basins and watersheds, and large-scale source assessment results should not be applied to local watersheds. Individual watershed source assessments are included in WRAPS (described further in Chapter 6). The sources also vary with the season and with dry and wet weather patterns. Therefore, nutrient source assessments should be used as a general guide to prioritize sources and not be perceived as a precise representation of the percentage coming from each source.

While some land and land management changes have occurred since the original 2014 NRS source assessments, these changes are expected to have limited influence on the conclusions about the primary nutrient sources. For the 2025 NRS, an alternative type of modeling approach was used to cross-check the sources previously determined for the 2014 NRS. Because each source assessment approach categorizes the sources differently and uses different methods, the results cannot be directly compared to each nutrient source in the original source assessment; instead, they are used to generally compare priority source categories.

2014 NRS source assessment

The nutrient source contributions are different for phosphorus and nitrogen and also differ within each major basin, as represented in the 2014 NRS source assessment (Table 2-16).

Table 2-16. Minnesota phosphorus and nitrogen sources by major basin, average conditions from the 2014 NRS.[a]

Nutrient source	Mississippi River phosphorus	Mississippi River nitrogen	Lake Superior phosphorus	Lake Superior nitrogen	Lake Winnipeg phosphorus	Lake Winnipeg nitrogen
Cropland runoff	35%	5%	6%	2%	42%	11%
Atmospheric [b]	8%	6%	7%	10%	18%	21%
NPDES-permitted wastewater discharges [c]	18%	9%	24%	31%	11%	6%
Streambank erosion	17%	--	15%	--	6%	--
Urban runoff and leaching	7%	1%	10%	1%	2%	0%
Nonagricultural rural runoff [d]	4%	--	32%	--	15%	--
Individual sewage treatment systems	5%	2%	3%	4%	3%	2%
Agricultural tile drainage	3%	43%	0%	5%	0%	7%
Feedlot runoff	2%	0%	0.1%	0%	0.3%	0%
Roadway deicing	1%	--	2%	--	2%	--
Cropland groundwater [e]	--	31%	--	9%	--	35%
Forest runoff	--	4%	--	38%	--	19%

Notes:

Scale: Low — High

[a] From Table 3-2 in the 2014 NRS. Source estimates include more recent MPCA updated wastewater (2011 conditions) and atmospheric deposition sources (2007). Source percentages do not represent what is delivered to the major basin outlets but what is delivered to local waters.

[b] Atmospheric deposition is to lakes and rivers (atmospheric deposition to wetlands is not reflected in this table).

[c] Nutrient loads in the Lake Superior Major Basin are lower than the other major basins in the state; therefore, wastewater is a larger portion of the overall sources. Western Lake Superior Sanitary District (Duluth area) accounts for more than 50% of the wastewater phosphorus load in the major basin.

[d] Includes natural land cover types (forests, grasslands, and shrublands) and developed land uses that are outside the boundaries of incorporated urban areas.

[e] Refers to nitrogen leaching into groundwater from cropland land uses.

Phosphorus sources in the 2014 NRS

The primary sources of phosphorus to Minnesota surface waters described in the 2014 NRS include:

- Cropland and pasture runoff
- Atmosphere (including redeposited sediment from wind erosion)
- National Pollutant Discharge Elimination System (NPDES) permitted wastewater discharges
- Streambank erosion
- Urban runoff
- Nonagricultural rural runoff
- Individual sewage treatment systems
- Agricultural tile drainage
- Feedlots
- Roadway deicing chemicals

Internal loading to lakes from historical phosphorus accumulations in waters can also contribute to current water quality. However, this source assessment only considered new additions of nutrients into rivers.

The largest phosphorus sources varied among the three major water drainage areas:

- Mississippi River Basin – Cropland runoff, wastewater, streambank erosion
- Lake Winnipeg Basin – Cropland runoff, nonagricultural rural runoff, atmospheric deposition
- Lake Superior Basin – Nonagricultural rural runoff, wastewater, streambank erosion

Nitrogen sources in the 2014 NRS

The primary sources of nitrogen to Minnesota surface waters described in the 2014 NRS include:

- Agricultural cropland via tile drainage
- Agricultural cropland via groundwater (nitrogen leached to groundwater beneath cropland, which later reaches surface waters through groundwater flow)
- Agricultural cropland via runoff over the soil surface
- NPDES-permitted wastewater discharges
- Atmospheric deposition into lakes, rivers, and streams
- Forest runoff
- Individual sewage treatment systems
- Urban runoff and leaching
- Feedlot runoff (manure spreading to cropland is part of the cropland/agricultural categories)


Incorporating liquid manure directly into the soil


Nitrogen on cropland can leach to groundwater

The largest nitrogen sources varied among the three major water drainage areas:

- Mississippi River Basin – Cropland (tile drainage, leaching to groundwater and surface runoff), wastewater, atmospheric deposition
- Lake Winnipeg Basin – Cropland (tile drainage, leaching to groundwater and surface runoff), atmospheric deposition, forest runoff
- Lake Superior Basin – Wastewater, forest runoff, atmospheric deposition

Certain nutrient sources (i.e., forests, nonagricultural rural runoff) contribute very low concentrations of nutrients, but the large acreages of those land uses in Minnesota sometimes add up to contribute to the overall nutrient load entering downstream waters.

New 2024 modeled nutrient source estimates from existing models

To support the 2025 NRS, nutrient model results that became available after 2014 were used for comparison with the 2014 NRS source load contribution assessment in Table 2-16 above. The purpose of examining sources with a different type of modeling approach was to identify any major differences that might warrant further investigation in the future. There are advantages and disadvantages to each approach. While the two approaches cannot be directly compared due to different ways of classifying and lumping sources, some general comparisons can be made.

Local watershed nutrient load model results from HSPF within HUC-8 watersheds were used to conduct the 2024 source assessment analysis. The HSPF modeling information was supplemented with other available data sources, which included more recently monitored permitted wastewater discharge data from MPCA. The SPARROW model results were used in seven watersheds without HSPF model results. Complete methods and results are described in Appendix 2-3.

This additional nutrient source assessment confirmed agriculture as the largest contributor to nutrient loading in the Mississippi River and Lake Winnipeg major basins (Table 2-17), whereas forest/wetland was found as the largest contributor in the Lake Superior Major Basin. Permitted wastewater was the second largest contributor of TN (18%) in the Lake Superior Major Basin. In the Lake Winnipeg and Lake Superior major basins, atmospheric deposition and developed lands (urban, roads) contribute much smaller TP and TN loads than agricultural lands and forest/wetlands, respectively.


Wind erosion transports sediment across a field

The 2024 source assessment is not necessarily a more accurate depiction of sources in recent years compared to the 2014 NRS source assessment, except that the wastewater phosphorus updates more accurately reflect recent contributions in the 2024 assessment.

Table 2-17. Simulated average annual loads by source category and major basin from the 2024 source assessment.

Source category	Mississippi River TP	Mississippi River TN	Lake Superior TP	Lake Superior TN	Lake Winnipeg TP	Lake Winnipeg TN
Agriculture [a]	72%	79%	4%	3%	63%	48%
Atmospheric deposition	2%	3%	2%	2%	4%	7%
Developed [a]	7%	4%	4%	4%	6%	5%
Forest/wetland [a]	5%	4%	62%	69%	20%	30%
NPDES-permitted wastewater discharge [b]	6%	8%	10%	18%	3%	5%
Various [a]	9%	3%	18%	4%	4%	8%

Notes:
Average annual loads (lbs/yr) are from the HSPF or SPARROW model, except when noted otherwise. Percentages are rounded to the nearest integer and do not sum exactly to 100% due to rounding with the individual source categories.
[a] Refer to Appendix A of Appendix 2-3 for the sources included in the aggregated source categories.
[b] MPCA estimated point source loads, originally reported by HUC-8. Refer to Appendix 2-3 for a discussion of how MPCA estimated point source loads and how those loads were summarized by major basin.

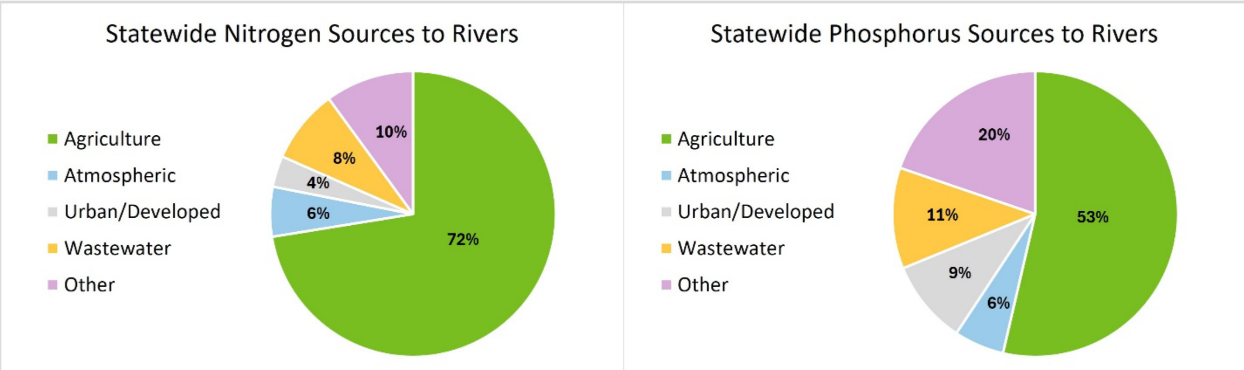
Statewide nutrient sources

By averaging the 2014 and 2024 assessment results and grouping them into similar broad source categories, a general depiction of statewide source contributions and priority sources can be viewed. These sources should be considered approximate because the results are affected by differences between modeling approaches, timeframes examined, and weather/hydrologic conditions. Additionally, these statewide sources vary tremendously from one area to another, and source contributions must be considered for each area of interest individually. Source assessment results for each of the three major river basins are described below.

Across the entire state, agriculture contributes an estimated 72% of the nitrogen load to rivers, wastewater contributes the second highest amount at 8%, and the rest of the sources contribute the other 20% (Figure 2-26, based on the average of the 2014 NRS approach and the new 2024 modeling approach). As previously noted, the vast majority of nutrients flow into the Mississippi River drainage; therefore, sources in that basin have the most influence on statewide sources.

Agriculture contributes about 53% of the phosphorus load (Figure 2-26). Another 20% comes from the combination of streambank erosion, nonagricultural rural runoff, and forest. Municipal and industrial wastewater combined with urban stormwater contribute an estimated 21%, and the remaining 6% is estimated to be from atmospheric deposition directly into waters.

Figure 2-26. Estimated statewide sources of nitrogen and phosphorus to Minnesota rivers, based on the average of two different source assessments.



Notes: “Other” represents streambank erosion, nonagricultural rural runoff, and forest. Percentages are rounded to the nearest percent.

Tremendous progress has been made with phosphorus reductions to waters across the state, as discussed above and additionally supported by the lake and river phosphorus concentration reductions reported in Chapter 3. The wastewater phosphorus source percentages were lower in all three major drainage basins in the 2024 assessment than in the assessment prepared for the 2014 NRS. This is partly due to real decreases in wastewater TP loads from continued treatment improvements to wastewater phosphorus. The higher agricultural phosphorus percent contributions in the 2024 assessment are partly due to the decrease in wastewater phosphorus contributions and lower estimated contributions from atmospheric deposition.

During dry conditions, NPDES-permitted wastewater discharges become a more dominant source of phosphorus. Under wet conditions, streambank erosion becomes a much more significant source of phosphorus in the state. Phosphorus bound to streambank, bluff, and other near-channel sediments may be a more important phosphorus source than previously understood, as discussed in Chapter 5.

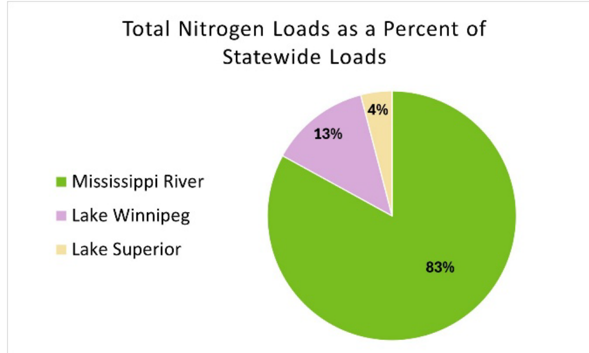
Because so much work has already been done to reduce phosphorus throughout the decades, it will be challenging to further the progress and complete the needed reductions. Not all existing TP sources can be equally reduced from this point onward. Nonetheless, understanding the relative contributions of TP from various sources is important as Minnesota aims to reduce TP loads further.

In subsequent sections, source assessment results are described for each of the three major drainage basins in Minnesota.

Nitrogen sources by basin

Of the three major river drainage basins, the Mississippi River Basin generates 83% of TN delivered to rivers across the state (Figure 2-27). Therefore, from a statewide perspective, the TN sources are dominated by sources in the Mississippi River Basin. Lake Superior represents a relatively small fraction of statewide TN source loads (4%) due to both a smaller geographic area and low nitrogen amounts leaving each acre of land on average. Lake Superior and Lake Winnipeg combined have only a 17% influence on statewide loads, but the differences in sources within those basins are important for understanding nutrient load reduction strategies for each.

Figure 2-27. TN loads delivered to waters in each of the three major NRS drainage basins, showing percent of statewide loads delivered to rivers.



Mississippi River Basin nitrogen sources

The relative amounts of TN coming from major source categories are generally similar in the Mississippi River Basin between the 2014 NRS and the more recent modeled source assessment (Table 2-18). The 2025 NRS uses an average of the two modeling results for the Mississippi River Basin as the best representation of general source categories. The largest contribution of nitrogen is from agricultural sources (79%), followed by municipal and industrial permitted wastewater (8.5%).

Table 2-18. Mississippi River drainage area (Minnesota portion only) nitrogen source assessment grouped into broad categories to allow comparison between the 2014 NRS and the new 2024 source assessment.

Nutrient source category	2014 NRS	New analysis [a]	Average
Agriculture	79% [b]	79%	**79%**
Atmospheric deposition	6%	3%	**4%**
Urban/developed	3% [c]	4%	**3.5%**
NPDES-permitted wastewater discharge	9% [d]	8%	**8.5%**
Other	4%	7%	**5%**

Notes:

Scale: Low — High

Due to rounding and the aggregation of nutrient sources in this table, several columns sum to 99% or 101%.

[a] Refer to Appendix A of Appendix 2-3 for the sources included in the aggregated source categories.

[b] *Agriculture*: cropland runoff, agricultural tile drainage, feedlot runoff, and cropland groundwater

[c] *Urban/developed*: urban, individual sewage treatment systems, and roadway deicing

[d] *Other*: streambank erosion, nonagricultural rural runoff, and forest

The more specific breakout of nitrogen sources in the 2014 NRS can still be used to evaluate the relative contributions of source subcategories. For example, TN loads from the agricultural category were subdivided in the 2014 NRS (see Table 2-16) into agricultural tile drainage (43%), cropland runoff (5%), cropland groundwater (31%), and feedlot runoff at livestock holding facilities (< 1%). All four subcategories are combined into one agricultural category in the following three tables.

Lake Superior Basin nitrogen sources

The Lake Superior nitrogen loads from Minnesota only represent 4% of the nitrogen source loads from all three of Minnesota's major drainage basins. The two biggest sources in the new 2024 analysis remain the same as described in the 2014 NRS. However, the percentages of nitrogen sources coming from agriculture, atmospheric deposition, and wastewater are lower than the previous analysis, and the "other" source category is higher (Table 2-19). The differences are likely due to improved data (i.e., wastewater monitoring data), along with differences in the way the source assessments handle the more natural sources in atmospheric deposition, forests, and streambank erosion.

Table 2-19. Lake Superior drainage area (Minnesota portion only) TN source assessment grouped into broad categories to allow comparison between the 2014 NRS and the new 2024 source assessment.

Nutrient source category	2014 NRS	New analysis [a]	Average
Agriculture	16% [b]	3%	**9.5%**
Atmospheric deposition	10%	2%	**6.0%**
Urban/developed	5% [c]	5%	**5.0%**
NPDES-permitted wastewater discharge	31%	12%	**21.5%**
Other	38% [d]	78%	**58%**

Notes:

Scale: Low — High

Due to rounding and the aggregation of nutrient sources in this table, several columns sum to 99% or 101%.

[a] Refer to Appendix A of Appendix 2-3 for the sources included in the aggregated source categories.

[b] *Agriculture*: cropland runoff, agricultural tile drainage, feedlot runoff, and cropland groundwater

[c] *Urban/developed*: urban, individual sewage treatment systems, and roadway deicing

[d] *Other*: streambank erosion, nonagricultural rural runoff, and forest

Lake Winnipeg Basin nitrogen sources

The Lake Winnipeg Basin includes the Rainy River Basin (largely forested) and the Red River Basin (largely agricultural). Source assessments based on a combination of modeling and monitoring showed generally similar nitrogen source percentages between the 2014 NRS and the new (2024) source assessment approach (Table 2-20). However, the 2024 approach showed less atmospheric deposition of nitrogen contributions and more nitrogen from the "other" category, which includes streambank erosion, nonagricultural rural runoff, and forested lands. Yet the overall differences in results from the two approaches do not change the priority sources for this drainage basin. The 2025 NRS uses an average of the two modeling results as the best representation of source percentages. Sources were also assessed for just the Red River Basin part of the Lake Winnipeg drainage area. Cropland TN sources were more dominant (72%) when isolating the sources in the Red River Basin from loads in the heavily forested Rainy River Basin (Appendix 2-3, Table 19).

Table 2-20. Lake Winnipeg drainage area (Minnesota portion only) TN source assessment grouped into broad categories to allow comparison between the 2014 NRS and the new 2024 source assessment.

Nutrient source category	2014 NRS	New analysis [a]	Average
Agriculture	53% [b]	48%	**50.5%**
Atmospheric deposition	21%	7%	**14%**
Urban/developed	2% [c]	5%	**3.5%**
NPDES-permitted wastewater discharge	6%	2%	**4%**
Other	19% [d]	38%	**28.5%**

Notes:

Scale: Low — High

Due to rounding and the aggregation of nutrient sources in this table, several columns sum to 99% or 101%.

[a] Refer to Appendix A of Appendix 2-3 for the sources included in the aggregated source categories.

[b] *Agriculture*: cropland runoff, agricultural tile drainage, feedlot runoff, and cropland groundwater

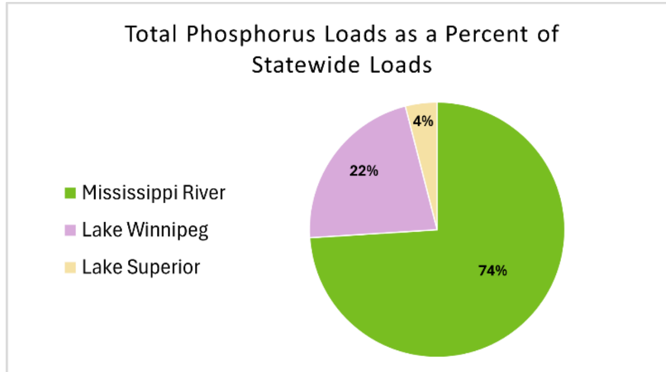
[c] *Urban/developed*: urban, individual sewage treatment systems, and roadway deicing

[d] *Other*: streambank erosion, nonagricultural rural runoff, and forest

Phosphorus sources by basin

Of the three major river drainage basins, the Mississippi River Basin contains 74% of TP delivered to rivers across the state (Figure 2-28). Therefore, from a statewide perspective, the TP sources are dominated by sources in the Mississippi River Basin. Lake Superior represents a relatively small fraction of statewide TP source loads (4%) due to a smaller geographic area and the presence of fewer anthropogenic sources. Lake Superior and Lake Winnipeg contributed a combined 26% of statewide loads, but the differences in sources within those basins are important for understanding nutrient load reduction strategies for these basins.

Figure 2-28. TP loads delivered to waters in each of the three major NRS drainage basins, showing the percent of statewide loads delivered to rivers.



Mississippi River Basin phosphorus sources

In the Mississippi River Basin, the two highest phosphorus source categories in both the 2014 and 2024 assessments remain agricultural runoff and the “other” category. However, the 2024 analysis suggests that agricultural runoff is a larger source than shown in the 2014 analysis, and the percentages of all other sources are lower (Table 2-21). For TP, the largest agricultural pathway is overland cropland runoff (see Table 2-16), which is different from the subsurface pathways for TN. The 2025 NRS uses an average of the two modeling results for the Mississippi River Basin to best represent TP sources. These sources should be considered general approximations of the sources of nutrient deliveries to the river.

Table 2-21. Mississippi River drainage area (Minnesota portion only) phosphorus source assessment grouped into broad categories to combine results from the 2014 NRS and the new 2024 source assessment.

Nutrient source category	2014 NRS	New analysis [a]	Average
Agriculture	40% [b]	72%	**56%**
Atmospheric deposition	8%	2%	**5%**
Urban/developed	13% [c]	7%	**10%**
NPDES-permitted wastewater discharge	18%	6%	**12%**
Other	21% [d]	14%	**17%**

Notes:

Scale: Low — High

Due to rounding and the aggregation of nutrient sources in this table, several columns sum to 99% or 101%.

[a] Refer to Appendix A of Appendix 2-3 for the sources included in the aggregated source categories.

[b] *Agriculture*: cropland runoff, agricultural tile drainage, feedlot runoff, and cropland groundwater

[c] *Urban/developed*: urban, individual sewage treatment systems, and roadway deicing

[d] *Other*: streambank erosion, nonagricultural rural runoff, and forest

Lake Superior Basin phosphorus sources

The Lake Superior Basin phosphorus loads only represent 4% of the TP source loads in Minnesota (Table 2-22). From a statewide source analysis perspective, this basin does not contribute much to the total TP amount leaving the state. Yet, as explained in Chapter 1, phosphorus is key in managing water quality in Lake Superior, particularly in nearshore areas; therefore, identifying the phosphorus sources in this basin is important. The three biggest sources in the 2024 analysis remain the same as described in the 2014 NRS—other, wastewater, and developed land runoff—but the percentage from each source differs between the two assessments.

Table 2-22. Lake Superior drainage area (Minnesota portion only) TP source assessment grouped into broad source categories from the 2014 NRS and the new 2024 source assessment.

Nutrient source category	2014 NRS	New analysis [a]	Average
Agriculture	6% [b]	4%	**5%**
Atmospheric deposition	7%	2%	**4.5%**
Urban/developed	15% [c]	4%	**8.5%**
NPDES-permitted wastewater discharge	24%	7%	**15.5%**
Other	47% [d]	83%	**65%**

Notes:

Scale: Low — High

Due to rounding and the aggregation of nutrient sources in this table, several columns sum to 99% or 101%.

[a] Refer to Appendix A of Appendix 2-3 for the sources included in the aggregated source categories.

[b] *Agriculture*: cropland runoff, agricultural tile drainage, feedlot runoff, and cropland groundwater

[c] *Urban/developed*: urban, individual sewage treatment systems, and roadway deicing

[d] *Other*: streambank erosion, nonagricultural rural runoff, and forest

The "other" source category is substantially higher in the 2024 assessment, whereas all other sources are lower. The "other" category includes streambank erosion, nonagricultural rural runoff, and forested land runoff. The differences between the two source assessments are likely due to real changes that have occurred (i.e., wastewater and stormwater improvements) along with differences in how the source assessments reflect the more natural sources in atmospheric deposition, forests, and streambank erosion.

Lake Winnipeg Basin phosphorus sources

The Lake Winnipeg Basin includes the Rainy River Basin (largely forested) and the Red River Basin (largely agricultural). The Lake Winnipeg Basin phosphorus source percentages show a higher agricultural contribution in the new 2024 analysis compared to the 2014 NRS; in contrast, the percentages for atmospheric deposition, wastewater, and developed land runoff are all lower in the new assessment (Table 2-23). However, the overall differences in results from the two approaches do not change the priority sources for this drainage basin, and the 2025 NRS uses an average of the two modeling results to represent source category percentages. In addition to agricultural runoff, important TP sources in this basin include streambank erosion and atmospheric deposition.

Table 2-23. Lake Winnipeg drainage area (Minnesota portion only) TP source assessment grouped into broad categories, showing differences between the 2014 NRS and the new 2024 source assessment.

Nutrient source category	2014 NRS	New analysis [a]	Average
Agriculture	42% [b]	64%	**53%**
Atmospheric deposition	18%	4%	**11%**
Urban/developed	7% [c]	6%	**6.5%**
NPDES-permitted wastewater discharge	11%	2%	**6.5%**
Other	21% [d]	24%	**22.5%**

Notes:

Scale: Low — High

Due to rounding and the aggregation of nutrient sources in this table, several columns sum to 99% or 101%.

[a] Refer to Appendix A of Appendix 2-3 for the sources included in the aggregated source categories.

[b] *Agriculture*: cropland runoff, agricultural tile drainage, feedlot runoff, and cropland groundwater

[c] *Urban/developed*: urban, individual sewage treatment systems, and roadway deicing

[d] *Other*: streambank erosion, nonagricultural rural runoff, and forest

When isolating sources in just the Red River Basin portion of the Lake Winnipeg Basin, the 2024 assessment shows cropland as 78% of the phosphorus load and developed land runoff as the second-highest source, with 5% of the load (Appendix 2-3, Table 20).

Priority sources

Priority sources are determined on the major basin scale, recognizing that different sources may be more or less important at the local scale. Priority sources at the HUC-8 scale or smaller are determined through watershed planning efforts. For example, individual sewage treatment systems are not identified as a significant source of nutrients at the major basin scale but can contribute to local lake eutrophication, potentially resulting in specific water body impairments.

Based on a consideration of both the 2014 and 2024 source assessment results at the major river drainage basin scale, certain sources rise to the top of the priority list (Table 2-24). Cropland-associated sources are a priority in the Mississippi River and Lake Winnipeg basins. Conversely, in the more forested Lake Superior Basin, combined sources such as streambank erosion, nonagricultural runoff, and forested lands contribute a higher fraction of the nutrient loads to waters.

Some priority sources cannot be reliably reduced by local- or regional-scale implementation activities, such as atmospheric deposition and loads from forested areas. However, managing for local wind erosion can reduce some atmospheric deposition of phosphorus, and improving forest management and logging road design and maintenance could help reduce nutrient export from forested regions.

Table 2-24. Priority sources at the major river basin scale, with the highest priority sources in bold.

Major basin	Priority phosphorus sources	Priority nitrogen sources
Mississippi River	**Cropland runoff**, wastewater point sources, and streambank erosion	**Cropland leaching loss to tile drainage** and groundwater, wastewater point sources
Lake Superior	**Nonagricultural rural runoff**, wastewater point sources, and streambank erosion	**Nonagricultural rural runoff**, wastewater point sources
Lake Winnipeg	**Cropland runoff**, nonagricultural rural runoff	**Cropland**, other rural runoff and atmospheric sources

2.8.2 Priority watersheds for downstream goals

Accomplishing nutrient reduction goals effectively and efficiently requires an understanding of (1) the priority geographic areas within the state where nutrient reductions are most needed, (2) the priority nutrient sources, and (3) the key programs needed for delivering those reductions. Ultimately, the NRS should provide the information necessary to align the priority major watersheds and the priority programs that help program staff at the local, state, and federal levels better target key resources.

Priority watersheds for in-state nutrient concentration concerns do not directly align with priority watersheds for addressing load reductions for waters downstream of Minnesota. This section discusses priority watersheds for *downstream* goals. See Chapter 3 for a discussion on priority watersheds to address *local needs*, including nitrate in drinking water, phosphorus-caused eutrophication of lakes and rivers, and the potential effects of nitrate on aquatic life health.

Priority watersheds for nutrient reduction to waters downstream of Minnesota were identified using average annual TP and TN yields (average nutrient amount per acre of land in the watershed) delivered to state boundaries (Table 2-25). For each HUC-8 watershed, the annual yields derived from HSPF modeling were averaged with the annual yield from SPARROW modeling. The HSPF-derived, SPARROW-derived, and two-model average yields are presented in Appendix 2-1 (see Table 58). The SPARROW model was also used to estimate nutrient losses and attenuation between the HUC-8 watershed outlets and the state border.

Table 2-25. Annual loads and yields (Minnesota only) for TN and TP delivered to state boundaries in each of the major river basins and drainage areas.

Major basin [a]	Basin	Area in Minnesota (ac)	TP delivered load (MT annually)	TN delivered load (MT annually)	TP delivered yield (lbs/ac/yr)	TN delivered yield (lbs/ac/yr)
LS	**Lake Superior** *Total*	**3,804,324**	**245**	**4,670**	**0.14**	**2.6**
LW	Rainy River	6,876,154	228	4,275	0.07	1.4
LW	Red River	10,481,948	1,084	8,674	0.23	1.8
LW	***Total***	**17,358,103**	**1,312**	**12,950**	**0.17**	**1.6**
MR	Upper Mississippi River	11,493,793	1,396	12,115	0.27	2.3
MR	Minnesota River	9,399,895	1,192	43,989	0.28	10.3
MR	St. Croix River	1,627,054	121	1,623	0.16	2.2
MR	Lower Mississippi River	3,233,412	1,178	22,552	0.80	15.4
MR	Missouri River	1,135,264	156	4,977	0.30	9.7
MR	Cedar River	649,823	143	7,657	0.48	26.0
MR	Des Moines River	969,848	87	1,255	0.20	2.9
MR	***Total***	**28,509,089**	**4,183**	**93,467**	**0.32**	**7.2**

Notes:

ac = acres; lbs/ac/yr = pounds per acre per year.

Numbers are rounded: areas to the nearest acre, loads to the nearest MT annually, and yields to the one-hundredth lb/ac/yr for TP and one-tenth lb/ac/yr for TN. Areas, loads, and yields are for Minnesota only (i.e., excludes out-of-state areas and loads).

[a] Major basins: LS = Lake Superior; LW = Lake Winnipeg; MR = Mississippi River. The total for each major basin is in bold.

Major watersheds (i.e., HUC-8s) with higher nutrient loading per acre are considered to have higher priority over lower-yielding major watersheds. To identify priority watersheds and develop priority watershed maps, the average annual TP and TN yields delivered to state boundaries were grouped into categories: *protection*, *medium* priority, and *high* priority; for TN, a *very high* priority category was also included. These categories used the same yield thresholds across the entire state (Figure 2-29).

If priority watersheds were determined separately for each of the three major drainage basins, the priority watersheds would be different, especially in the Lake Winnipeg and Lake Superior drainage basins. Because nutrient yields are generally lower in the Lake Winnipeg and Lake Superior drainages in northern Minnesota compared to other parts of the state, watershed priorities in these northern regions are commonly categorized as *protection* or *medium priority* in this statewide analysis. More details about how the yields to state lines used in Figure 2-30 were calculated are provided in Appendix 2-1.

Two important datasets used to develop the priority watersheds map include the HSPF-modeled watershed TN and TP yields (as mapped in Figure 2-30). Due to modeling gaps with some watersheds and variability amongst the HUC-8 watershed HSPF model development details, the priority watershed analysis included averaging both SPARROW model and HSPF nutrient yield results.

For the Mississippi Twin Cities watershed, wastewater is the primary source of phosphorus load to the river. However, the SPARROW model does not include reductions from wastewater sources implemented from 2014 to 2024 and may be overestimating the phosphorus load from this source.

Figure 2-29. Priority HUC-8 watersheds determined using average annual TP and TN yields (Minnesota only) delivered to state boundaries.

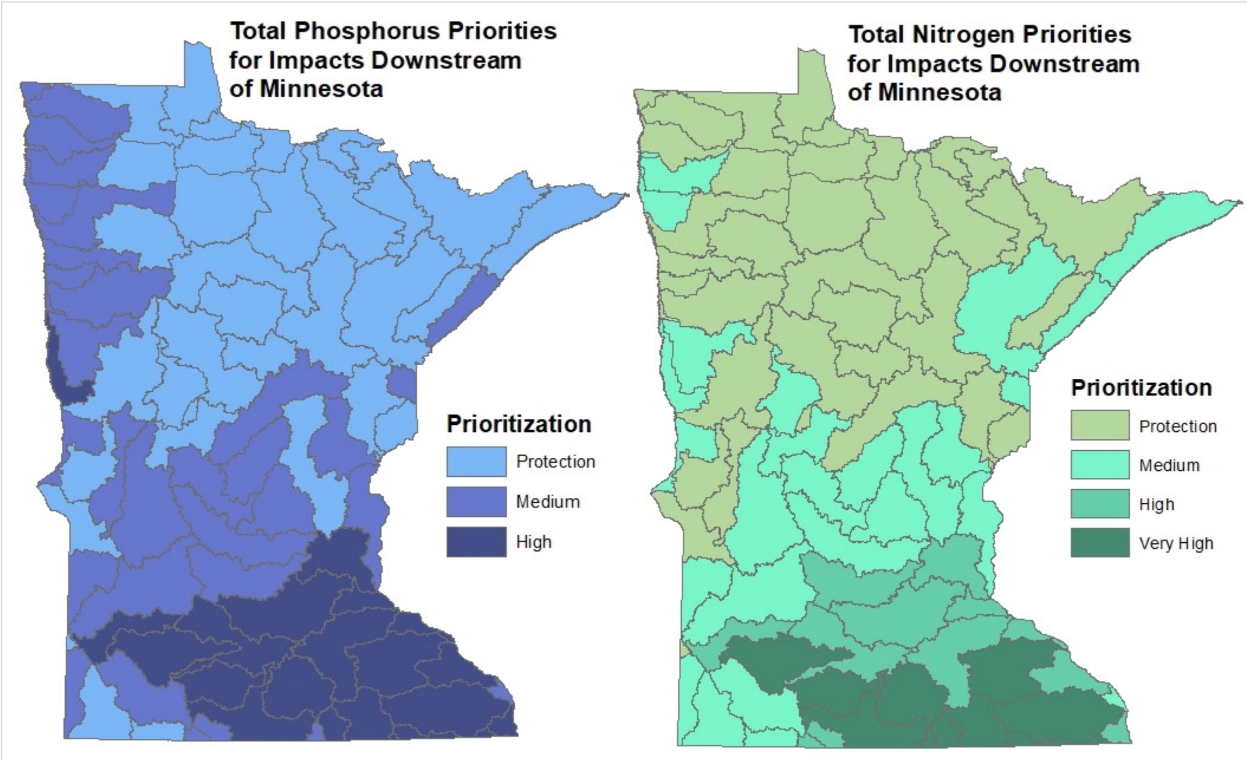
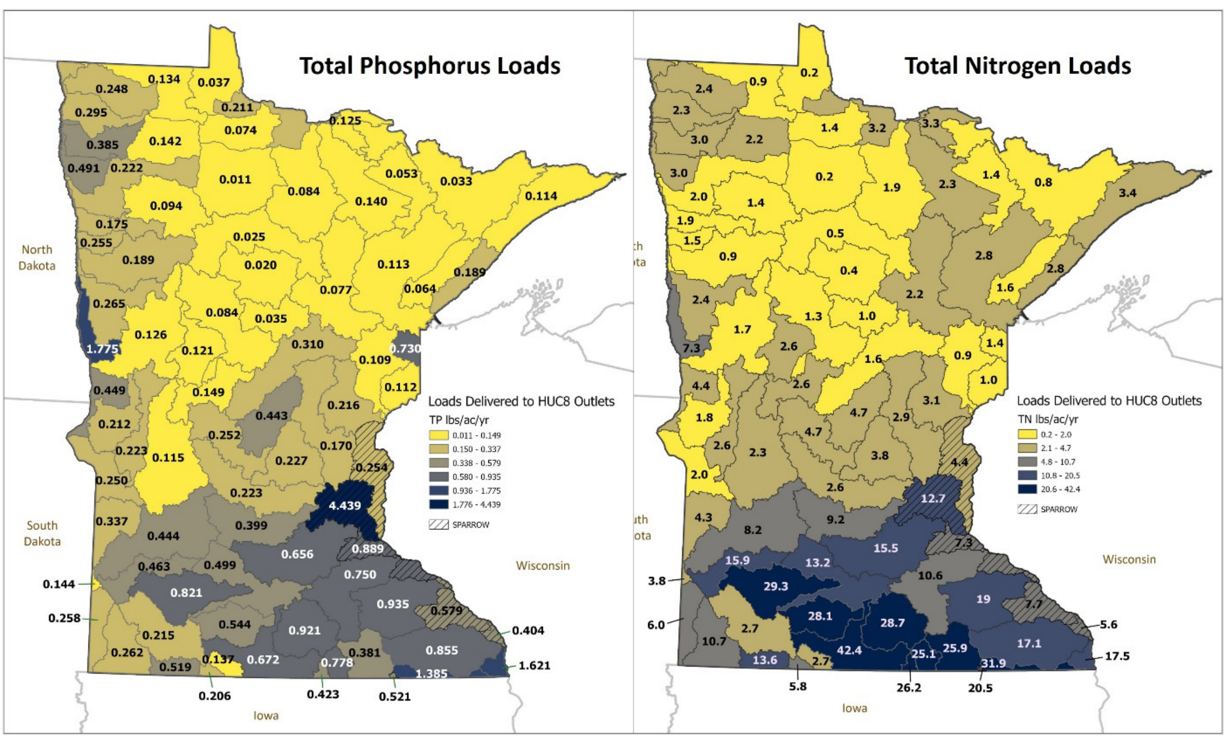


Figure 2-30. TP and TN yields delivered to subbasin outlets, derived from HSPF model results (except for cross-hatched watersheds, which are from SPARROW).



The results shown in Figure 2-29 indicate a similar pattern of priority watersheds across the state as in the 2014 NRS. Additionally, the 2025 NRS includes priority 10-digit hydrologic unit code (HUC-10) watersheds for various in-state nutrient concerns (see Chapter 3). The in-state needs show that priority watersheds are also in the north-central part of the state, especially for lake phosphorus and groundwater nitrate. Determining the highest priority watersheds for nutrient reduction should consider both priorities for addressing in-state nutrient reduction needs and downstream needs. It is important to recognize that although prioritization is a beneficial management tool for directing limited resources, significant reduction targets to meet the goals of the NRS cannot be achieved solely through implementation in a limited number of high-priority major watersheds.

2.9 Watershed outlet load reductions needed to achieve state-line goals

To achieve downstream nutrient load reductions at the state lines, Minnesota's 2014 NRS showed the nutrient load reduction amount needed from each HUC-8 major watershed to cumulatively achieve milestone goals for the Mississippi River, Red River, and Lake Superior.

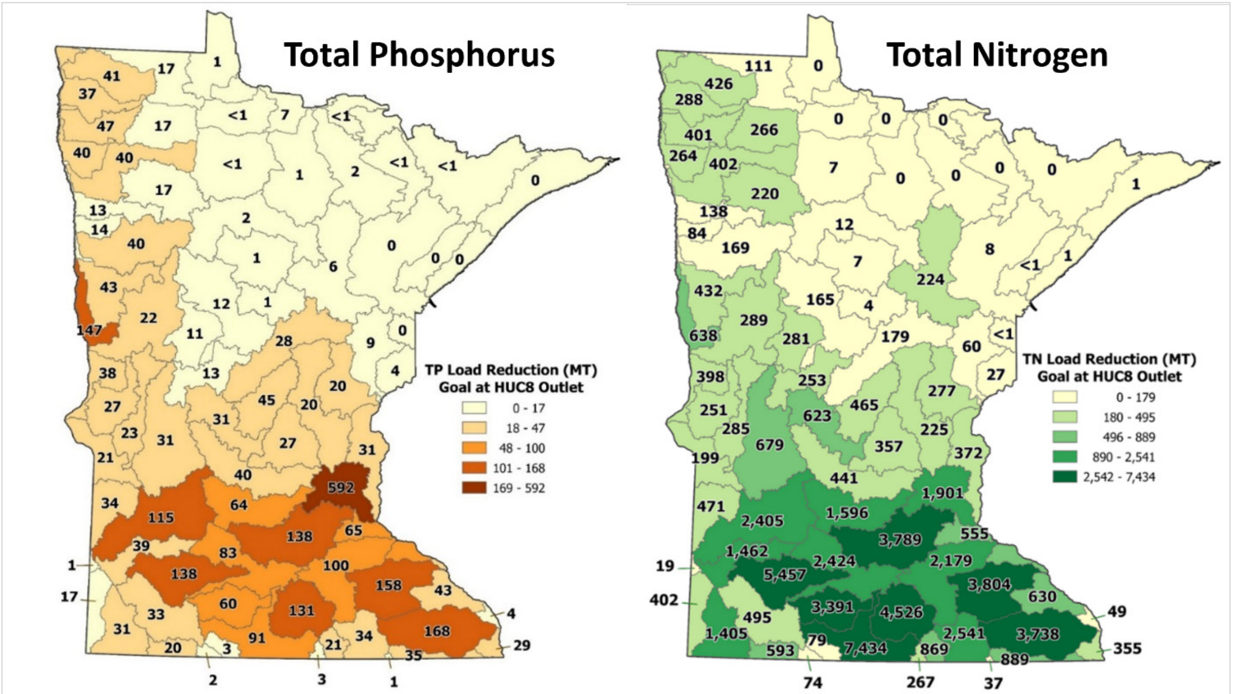
If each watershed reduces a certain fraction of its reducible or anthropogenic nutrient loads, downstream nutrient goals can be met. The 2014 NRS provided some guidance on the general magnitude of load reductions needed from each HUC-8 watershed to achieve milestone targets for downstream waters. Since the 2014 NRS, Minnesota has improved monitoring and modeling information, enabling the state to develop improved estimates of nutrient load-reduction planning targets for each HUC-8 watershed outlet. These updated watershed load reduction targets are established with the assumption that measurable load reductions are unlikely to occur on well-managed forests and grasslands. The watershed nutrient reduction planning targets focus on anthropogenic nutrient load reductions needed to meet final goals at the state lines.

The HUC-8 watershed outlet load reduction targets to meet state-line final goals are provided for both TN and TP (Figure 2-31), with tabular results in Appendix 2-4 and detailed methods and results in Appendix 2-5. The load reduction planning targets are intended to provide watershed planners with information on what each watershed can do to achieve long-term final-goal nutrient load reductions for downstream waters.

The load reduction planning goals are one consideration, among many, that will inform long-term land cover and BMP implementation needs (rural and urban) when WRAPS and associated comprehensive local watershed plans (e.g., 1W1P) are updated. The watershed planning goals should be viewed as approximate, recognizing that localized modeling and monitoring supporting these goals will improve and be updated over time.

While these targets provide a common method of understanding watershed load reduction targets across the state to collectively achieve downstream goals, they are not intended to supersede local priorities, strategies, and plans. Instead, downstream considerations should be recognized, along with local priorities, when local watersheds re-examine their priorities and needs for long-term BMP adoption.

Figure 2-31. Approximate annual HUC-8 watershed TP and TN load reductions (MT/yr) at the watershed outlet needed to meet the final load goals at state lines.



It should be noted that the modeled loads described above in the major river basins are not the same as the monitored loads previously outlined in this chapter. This is due to several differences:

- The timeframes between the monitoring results and modeled results are different, and the modeled timeframes vary from watershed to watershed.
- The modeled loads include loads only from Minnesota watersheds, whereas the major river monitoring sites do not include all Minnesota watersheds (some watersheds flow out of the state in a location that bypasses the major river monitoring sites) and are also confounded with loads originating from other states.
- The models are calibrated with local river and stream monitoring information, whereas major river monitoring sites only reflect single downstream sites influenced by multiple tributaries.

The planning goals were developed using the most recent decade of HSPF-modeled information for each watershed, except for a small number of watersheds without HSPF modeling, where SPARROW loads were used. The beginning and ending dates for the most recent modeled decade vary by watershed, with an average end date of 2015. Therefore, the "recent" modeled loads more closely represent load conditions during the timeframe of the 2014 NRS than the 2025 NRS. These targets should be periodically updated over time but will always lag behind actual river nutrient monitoring results and associated watershed modeling.

In the future, the planning goals described in this section and associated appendices should be placed on the NRS Dashboard so that watershed planners can easily access the information. The next section describes this and other recommendations for future action related to Chapter 2. Chapter 6 describes the more complete integration of NRS components into Minnesota's Water Management Framework efforts.

2.10 Recommendations for future actions

The following recommendations, subject to funding availability, pertain to river load-related content presented in Chapter 2:

- Continue load monitoring at NRS primary and secondary sites to evaluate annual river nutrient load trends through 2040 and beyond to ensure the river load goals are achieved and sustained over the long term.
- Provide updated trend results at least every three years for primary and secondary sites. A 2028 load trend evaluation can be used to evaluate the 2025 milestone goals established in the 2014 NRS. Make results available at NRS partners' workshops, the NRS dashboard, and other reporting mechanisms outlined in Chapter 7.
- Increase the use of load evaluation models, such as WRTDS, to evaluate flow-normalized load trends for MPCA load monitoring sites across Minnesota.
- Continue NRS partnerships with MPCA, Met Council, USGS, and Manitoba so that limited resources can be maximized when evaluating water quality throughout Minnesota.
- Conduct a new nutrient source assessment in 2030 to account for changes in source contributions from various sources, improvements in modeling approaches, and better data tracking.
- Work to achieve the remaining nutrient load reductions needed to meet goals at the state lines, as reported in Table 2-14 and Table 2-15, by reducing TP by 602 MT and TN by 35,517 MT in all Minnesota tributaries to the Mississippi River.
- Achieve TP and TN reductions from all combined Red River Basin tributaries in Minnesota by 538 MT/year and 3,486 MT/yr, respectively. Ensure that nutrient loads to Lake Superior from Minnesota tributaries do not increase over time, and work with local entities to develop ways to further decrease any nutrient loading to the lake.
- Aim to adopt the practices necessary for achieving the above reduction goals by 2040 and include monitoring to verify achievement within a timeframe that accounts for inherent lag times. Adjust both the needed reduction amounts and the timeframes as changes occur, such as with trend results and/or when national and international goals and associated timeframes change due to new science, sustained climate change, or other major changes.
- Provide guidance and nutrient reduction planning targets to local watershed staff, along with assistance and tools to determine how targets for downstream waters can potentially be achieved within their watersheds.

2.11 NRS support documents

- Appendix 2-1: Assessment of major river basin loads and reductions needed to meet goals. Minnesota NRS support developed with MPCA by Tetra Tech and labeled as the Objective 1 report.
- Appendix 2-2: Major river nutrient concentration trends over time at select Met Council sites.
- Appendix 2-3: Assessment of nutrient source contributions to major river basin loads
- Appendix 2-4: Watershed load reduction needs to achieve state-line goals.
- Appendix 2-5: Methods for watershed load reduction needs to achieve state-line goals.

Chapter 3

In-State Nutrient Reduction Needs and Priorities

Key Messages

Chapter 3 presents a state-level perspective on local nutrient reduction needs for lakes, rivers, and groundwater, and it compares these needs with the nutrient-reduction goals for waters downstream of Minnesota.

In-State Phosphorus

- **Phosphorus in general**. Lake and river phosphorus concentrations are generally improving; however, more work remains to restore and protect Minnesota's lakes and rivers from phosphorus additions.
- **Lake phosphorus trends**. Lake phosphorus concentrations have detectable trends in 119 (46%) of the 260 assessed lakes (54% had no trend detected). Within the group of 119 lakes with detectable trends, 87 lakes (73%) showed decreasing (improving) phosphorus concentrations, and 32 lakes (27%) showed increasing (worsening) concentrations.
- **Lake impairments**. High phosphorus concentrations cause eutrophication impairments in 686 Minnesota lakes. To meet water quality standards (WQS), phosphorus in these lakes would need to be reduced by an average of 42%. Also, many unimpaired lakes experience increased algae production when phosphorus levels increase.
- **River phosphorus trends**. River phosphorus concentrations have generally decreased or remained stable throughout Minnesota at 61 MPCA river monitoring sites during recent decades. Between 2008 and 2022, phosphorus concentrations decreased at 19 sites (31%), increased at three sites (5%), and showed no detectable trend at the remaining 39 sites (64%).
- **Mississippi River phosphorus trends**. Mississippi River phosphorus concentrations have decreased by over 40% since the 1980s, largely due to actions to reduce both point source and nonpoint source phosphorus.
- **River impairments**. River eutrophication standards were exceeded in 11% of assessed rivers in Minnesota, with an additional 48% having high phosphorus concentrations but no confirmed eutrophication standard exceedances. As with lake impairments, the phosphorus concentrations in impaired rivers would need to be reduced by an average of 42% before standards could be met.
- **Priority watersheds for in-state phosphorus needs**. Priority watershed maps for phosphorus reduction show different priority areas for lake eutrophication and river eutrophication. Priority watersheds for lake eutrophication are found in the southern, central, and some northern parts of Minnesota. Priority watersheds for river eutrophication are more concentrated in southern Minnesota.
- **Mississippi River Basin in-state and downstream phosphorus reductions**. Minnesota's share of Mississippi River phosphorus reduction goals for the Gulf could only be achieved if Minnesota meets its in-state goals for local and regional lake eutrophication, in-state river eutrophication,

and sediment and phosphorus reductions in southeastern Minnesota tributaries to the Mississippi River.

- **Red River in-state and downstream phosphorus reductions**. In the Red River and Lake Winnipeg Basin, achieving both river eutrophication and lake eutrophication standards will only reduce phosphorus by a small fraction of the total load reduction needed. Few waters in this region are impaired by eutrophication, although many rivers and streams have high phosphorus concentrations. Local and state strategies that go beyond addressing local watershed eutrophication goals will be needed to reduce Minnesota's share of the phosphorus entering Lake Winnipeg in Manitoba.

In-State Nitrogen

- **Nitrate in general**. Nitrate is the most dominant form of the TN constituents in waters most impacted by human activities. High nitrate concentrations are a concern for drinking water and stream aquatic life in Minnesota, and the high TN loads leaving the state are a concern for downstream neighbors. The progress indicators for nitrate concentrations show a greater mix of results than phosphorus. Increasing trends are more common, although some decreases are also evident. Rivers having no trend detected are the most common.
- **Well water nitrate exceedances**. Well water nitrate concentrations exceed the 10 mg/L drinking water health risk limit in certain parts of the state. In geologically vulnerable areas, the MDA initially found that 9.1% of 32,217 sampled private domestic wells exceeded the health risk limit. In a resampling effort of wells without concerns about well construction or nearby nonfertilizer sources, 4.7% of 28,932 wells exceeded the limit (over 95% of wells did not exceed the health risk limit). Three areas of Minnesota are identified as having a higher fraction of wells with elevated nitrate: the southeastern karst region, the southwestern corner, and central Minnesota.
- **Well water nitrate trends**. In the more vulnerable parts of aquifers across agricultural and urban parts of the state, nitrate concentrations have been decreasing (improving) in 24% of ambient monitoring and domestic wells while increasing (worsening) in 3% of those wells (between 2007 and 2023). However, most of those wells (73%) show no trend during recent years. Further monitoring is necessary to gain a better understanding of groundwater nitrate trends over time.
- **Cold-water stream nitrate impairments**. Cold-water streams (i.e., trout streams) are interconnected to groundwater, and the 10 mg/L nitrate drinking water standard is commonly exceeded where high-nitrate-level groundwater flows into these streams, such as in southeastern Minnesota. Thirty-two stream reaches, mostly in southeastern Minnesota, exceed the nitrate standard for cold-water streams.
- **Stream nitrate and aquatic life**. Stream nitrate concentrations in southern Minnesota are frequently high enough to potentially harm aquatic life.
- **River nitrate trends**. Between 2008 and 2022, river nitrate concentrations showed no trend at the majority (86.5%) of the 52 MPCA-monitored sites across the state. Where trends were detected, nitrate concentrations increased at five sites (10%) and decreased at two sites (4%).
- **Priority watersheds for in-state nitrate reduction needs**. High-priority watersheds for reducing drinking water nitrate and river/stream nitrate do not overlap much except in the southeastern and southwestern portions of the state, which have both high river/stream and groundwater nitrate levels.
- **Addressing in-state and downstream needs together**. Minnesota's highest-priority strategies should focus on actions addressing both local water concerns and downstream needs.
- **Mississippi River Basin in-state and downstream nitrogen reductions**. Some progress will be made toward Mississippi River nitrogen reduction goals if efforts focus on improving high nitrate levels in drinking water. Protecting local drinking water and stream aquatic life from high nitrate

levels could, in combination, bring Minnesota close to achieving its commitment to reduce the nitrogen levels in the Mississippi River heading toward the Gulf.

- **Red River in-state and downstream nitrogen reductions**. In the Red River Basin, which drains into Canada's Lake Winnipeg, reducing nitrate levels to meet local drinking water and aquatic life goals will be insufficient to achieve the needed reductions for Lake Winnipeg. In this region, nitrate concentrations are generally lower in both groundwater and rivers/streams as compared to the Mississippi River Basin.

3.1 Introduction

The Minnesota NRS is written to address nutrient concerns in Minnesota waters and also downstream of Minnesota. This chapter provides a state-level view of local nutrient reduction needs for lakes, rivers, streams, and groundwater in Minnesota. It also compares these needs with the goals for waters downstream of Minnesota. Subsequent chapters address solutions to the needs identified in Chapter 3.

Most in-state standards and goals pertain to nitrate and TP *concentrations*, whereas the goals for waters downstream of Minnesota are typically based on TN and TP annual *loads* (see Section 2.1.1 for more details). The concentration refers to the amount of a pollutant present in a specific volume of water, typically measured in mg/L or µg/L. Load refers to the total amount of a pollutant transported by water over a specified period, often expressed on an annual basis as tons per year. The goals for in-state waters are based on meeting state WQS and improving and protecting water resources that are not impaired but are sensitive to nutrient additions. A water body is impaired if it fails to meet one or more WQS. The specific in-state load reductions needed to meet standards in each water body are determined by existing and future TMDLs and through watershed planning activities that focus nutrient reduction activities at the major watershed level (i.e., HUC-8).

Water quality standards in Minnesota

WQS, included in Minn. R. chs. 7050 and 7052, are used to accomplish the following:

1. Protect beneficial uses, such as healthy fish, invertebrates (bugs), and plant communities, swimming and other water recreation, drinking water, and human consumption of fish.
2. Evaluate the water monitoring data used to assess the quality of the state's water resources.
3. Identify the waters that are polluted, impaired, or in need of additional protection.
4. Set effluent limits and treatment requirements for NPDES discharge permits and cleanup activities.
5. Enable the development of TMDLs for restoring impaired waters that do not attain their designated uses.

The federal Clean Water Act (CWA) requires states to designate beneficial uses for all waters and develop WQS to protect each use. These WQS include:

- **Beneficial uses.** The identification of how people, aquatic communities, and wildlife use state waters.
- **Numeric standards.** The allowable concentrations of specific pollutants in a water body, established to protect the beneficial uses.
- **Narrative standards.** Statements of unacceptable conditions in and on the water.
- **Nondegradation.** Extra protection for high-quality or unique waters and existing uses.

Explicit in the CWA is the presumption that a water body should attain healthy aquatic life and recreation uses unless proven to be unattainable. Minnesota's rules provide a framework that broadly protects aquatic life, recreation, and the following additional uses: drinking water (domestic consumption), industry, agriculture, navigation, and aesthetic enjoyment.


Paddling downstream

Reducing phosphorus is important for attaining in-state lake and river eutrophication standards. Eutrophication occurs when a water body becomes overly enriched with nutrients, leading to excessive growth of algae and plankton and often resulting in decreased water oxygen levels. The MPCA uses numeric eutrophication criteria for lakes and rivers to protect recreation and aquatic life uses, respectively.

Nitrate-nitrogen (often abbreviated as "nitrate-N" or simply "nitrate") reduction is important for meeting drinking water standards and for protecting the health of aquatic life/organisms in local waters.

This chapter describes water quality issues and priority areas as related to:

- Lake eutrophication standards and associated phosphorus concentrations
- River eutrophication standards and associated phosphorus concentrations
- Drinking water nitrate concentration standards for cold-water streams and wells
- River and stream aquatic life toxicity potential from elevated nitrate concentrations

Because water quality concerns and standards differ for phosphorus and nitrate, the sections below address each nutrient individually.

3.2 In-state water phosphorus concentrations

Minnesota's standards for allowable TP concentrations are specified by water body type, designated use, and ecoregion. The MPCA adopted lake criteria in 2008; in 2015, the MPCA adopted numeric criteria for rivers. For information about the state's Lake Eutrophication Criteria and River Eutrophication Criteria, see Minn. R. ch. 7050.0222 and Heiskary et al. (2013). Rivers and lakes must exceed both the causative parameter (i.e., TP) and one or more response variables to be considered impaired, including (1) rivers: chlorophyll-a (chl-*a*) concentration, dissolved oxygen flux, 5-day biochemical oxygen demand, or pH; and (2) lakes: Secchi depth or chl-*a* concentration. For more information, see the MPCA's Phosphorus in Wastewater website.

3.2.1 Lake phosphorus

Conditions: Lake phosphorus and eutrophication

As of 2024, 686 lakes (including bays of lakes) and reservoirs are on Minnesota's Impaired Waters List due to eutrophication. These listings are based on monitoring for nutrients conducted between 2002 and 2022 on approximately 3,500 out of Minnesota's 12,000 lake basins greater than 10 acres (Strom et al. 2024). The WQS that are used to determine impairments vary by ecoregion (Figure 3-1 and Table 3-1).

While most of the drainage areas for lakes are quite small, some reservoirs, flowages, and regional lakes, such as Lake Pepin, have very large watersheds. These regional lakes have watersheds that receive water from about 67% of Minnesota's land area (Figure 3-2; blue-shaded watershed areas). The spatial, seasonal, and annual distributions of phosphorus loadings within these watersheds vary. Individual or watershed TMDLs in Minnesota identify where phosphorus reductions are needed, sometimes at very large scales, within a watershed. The regional lakes need phosphorus reductions ranging between 11% and 33% (Table 3-2). These levels of reduction are similar to or exceed the phosphorus load reductions needed for the state-line goals discussed in Chapter 2 (in the geographic areas where they apply). Therefore, achieving our Minnesota in-state regional lake goals in those watersheds will sufficiently address the reductions needed for the Mississippi River leaving the state.

Figure 3-1. Minnesota's ecoregions.

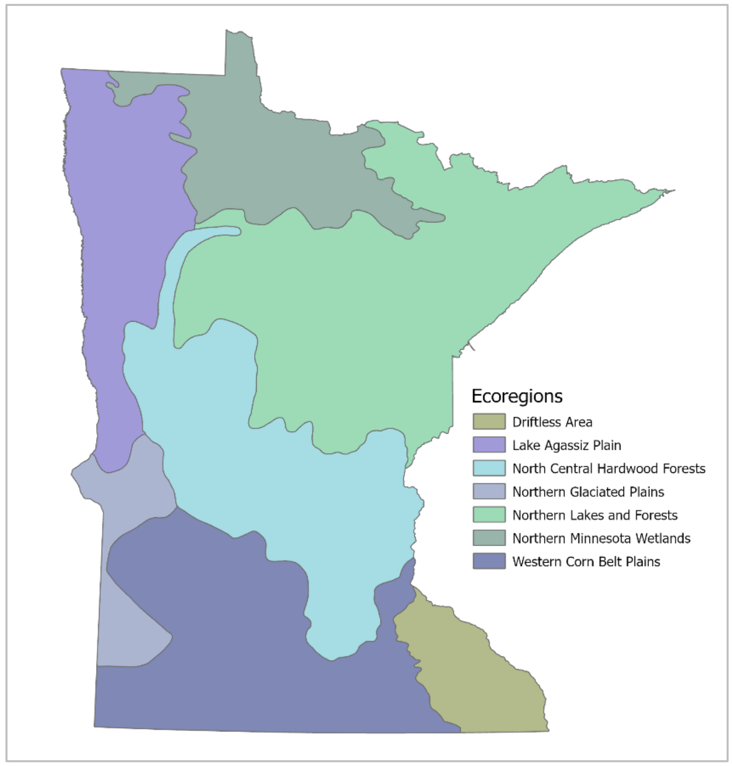


Table 3-1. Minnesota's lake eutrophication standards vary by ecoregion.[a]

Ecoregion (classification)	Phosphorus (µg/L)	Chl-*a* (µg/L)	Secchi (meters)
NLF: Lake trout lakes	≤12	≤3	≥4.8
NLF: Stream trout lakes	≤20	≤6	≥2.5
NLF: Deep and shallow lakes	≤30	≤9	≥2.0
CHF: Stream trout lakes	≤20	≤6	≥2.5
CHF: Deep lakes	≤40	≤14	≥1.4
CHF: Shallow lakes	≤60	≤20	≥1.0
WCP & NGP: Deep lakes	≤65	≤22	≥0.9
WCP & NGP: Shallow lakes	≤90	≤30	≥0.7

Notes:

CHF = Central Hardwood Forest; NGP = Northern Glaciated Plains; NLF = Northern Lakes and Forest; WCP = Western Cornbelt Plains.

[a] A lake must exceed the cause variable (phosphorus) and one of the response variables chl-*a* or transparency (Secchi) to be considered impaired. Additional site-specific criteria for several water bodies expand the TP criteria range to 105 µg/L and the chl-*a* criteria range to 48 µg/L.

Figure 3-2. Contributing watersheds of eutrophication-impaired regional lakes and reservoirs.

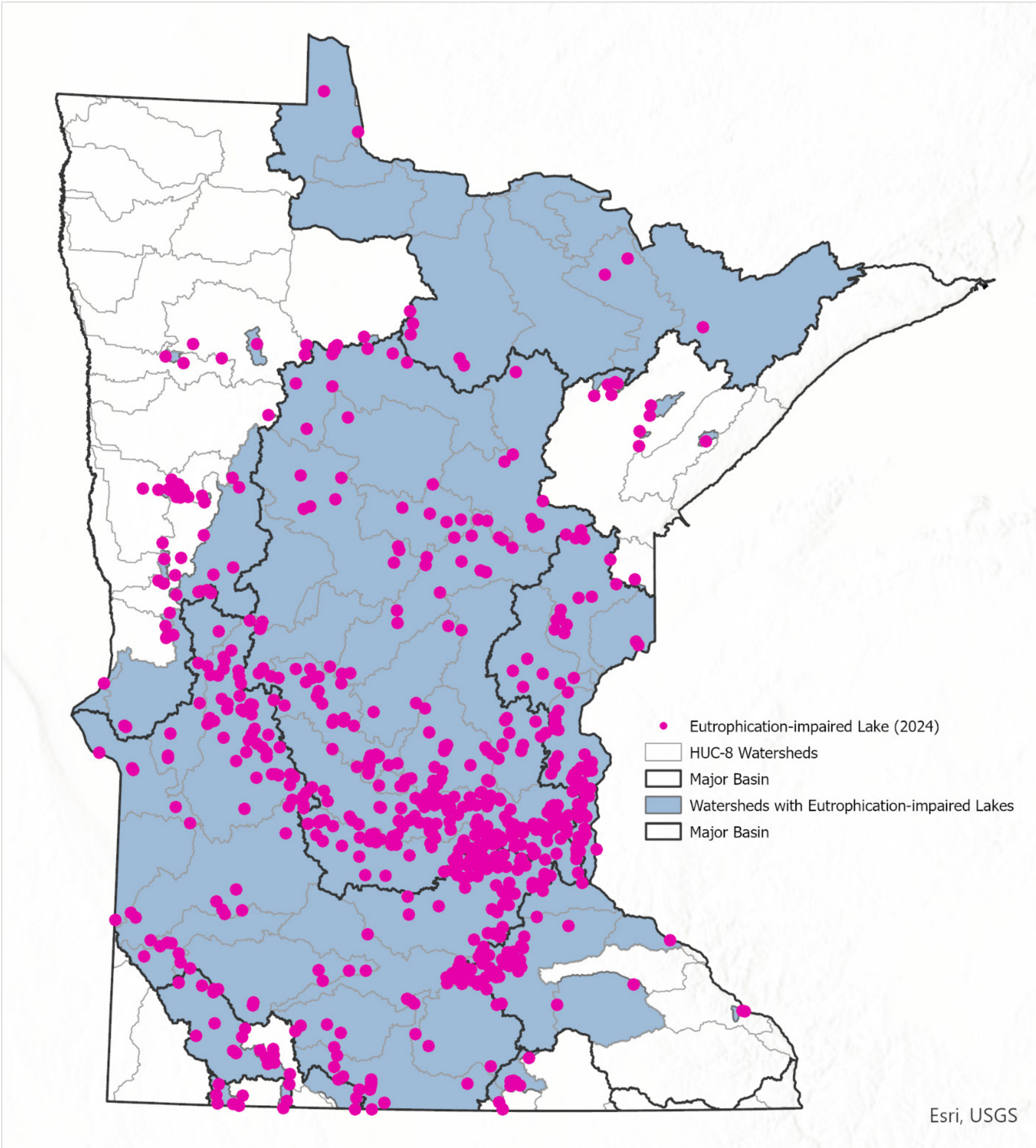


Table 3-2. Approximate phosphorus reduction needed in eutrophication-impaired lakes with large watersheds.

Lake	Location	Watershed size (mi^2)	Phosphorus reduction needed	Notes
Lake Pepin	Minnesota-Wisconsin border	48,634	33%	The Lake Pepin watershed contains hundreds of impaired lakes, including the 7,674 mi^2 Lake St. Croix and the 1,116 mi^2 Lake Byllesby watersheds, which need phosphorus reductions of 4% and 50%, respectively. Phosphorus reductions are needed in contributing watersheds, including the Minnesota River (50%), St. Croix River (20%), Upper Mississippi River (20%), and Cannon River (50%).
Lake of the Woods	Canada-Minnesota border	26,930	11%	
Lake Zumbro	Minnesota	845	21%	
South Heron Lake	Minnesota	467	37%	
Talcot Lake	Minnesota	519	Unknown	Recent data are insufficient for calculating the current phosphorus reduction needed for Talcot Lake.

Source: MPCA 2025b.
Note:
mi^2 = square miles

An analysis of 523 regional nutrient-impaired lakes indicated that an overall average reduction of 42% is needed to meet lake eutrophication standards, with a minimum of 3% and a maximum of 72% (Table 3-3). Addressing the relatively large average phosphorus reductions needed for impaired local lakes will go a long way toward addressing the needs for regional lakes in Minnesota and the needs downstream of Minnesota. However, not all parts of Minnesota have impaired lakes to address (i.e., northwestern and southeastern Minnesota), which will impact phosphorus reductions in those areas.

Table 3-3. The phosphorus reductions needed to meet applicable standards for nutrient-impaired lakes with sufficient data (reductions needed from 2015–2024 average conditions).

River basin	Minimum	Average	Maximum	Count (# of lakes in dataset)
Cedar	18%	36%	60%	6
Des Moines	34%	42%	62%	11
Lower Mississippi	34%	52%	72%	26
Superior	6%	34%	52%	6
Minnesota	38%	45%	66%	119
Missouri	50%	63%	62%	7
Red River	50%	40%	59%	26
Rainy River	3%	26%	65%	8
St. Croix	25%	32%	60%	58
Upper Mississippi	31%	43%	65%	256
Statewide	–	**42%**	–	**523**

Source: MPCA 2025b.

Lake phosphorus trends

The MPCA analyzes lake water clarity trends and phosphorus concentrations. While lake phosphorus conditions often drive water clarity, other factors can also influence clarity. Both water clarity and TP concentrations show similar improvements (32% and 33%, respectively).

Clarity

In 2024, the MPCA lake transparency website showed 4,896 lakes statewide with some water clarity monitoring data; of these, 1,702 met the minimum data requirements for temporal trends analysis (at least 8 years of data and 50 observations in the EQuIS database, which has data for some lakes as far back as 1971).

To be considered an *improving* or *degrading* water clarity trend, a lake must exhibit a Secchi disk water clarity change greater than 6 inches per decade using the Seasonal Kendall Test and a p-value of <=0.05. A lake demonstrating either an improvement or reduction in water clarity that is equal to or less than six inches per decade is classified as having *no change* in water clarity trend. A lake that meets the minimum data requirements but has a nonsignificant statistical result (i.e., the p-value is greater than 0.05) is considered to have *no trend* detected.

Of the 1,702 lakes assessed for clarity trends, data show:

- 32% are improving (increasing clarity)
- 59% show no change or no trend detected
- 9% are worsening (decreasing clarity)

These results are very close to those reported by Vitense and Hansen (2023), who found lake clarity improved in 34.5% of 909 Minnesota lakes assessed, with 6.5% worsening and 59% showing no trend.

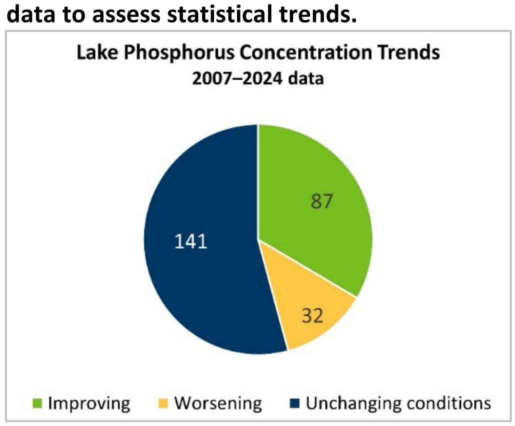
The lake clarity trends noted above are a way to gauge progress with an easy-to-measure approach on numerous lakes without conducting more expensive monitoring of phosphorus and chl-*a*. Determining the causes for the improved clarity requires additional study, and those causes can vary from one lake to another. While it is encouraging that more lakes have improved clarity than worse clarity, this analysis did not study all possible drivers of lake clarity, including invasive species such as the zebra mussel. Approximately 36% of the lakes with improving water clarity also have zebra mussel populations.

Phosphorus

A more direct indicator of progress with lake phosphorus is through the monitoring of lake TP concentrations. The MPCA recently examined lake TP concentration trends in 260 lakes with sufficient data. These lakes have data spanning at least 10 years during the 2007–2024 timeframe, and they have datasets containing at least five samples. Of the 260 lakes assessed for TP trends, data show (Figure 3-3):

- 34% (87 lakes) are improving (TP concentrations are decreasing).
- 12% (32 lakes) are worsening (TP concentrations are increasing).
- 54% (141 lakes) have not changed.

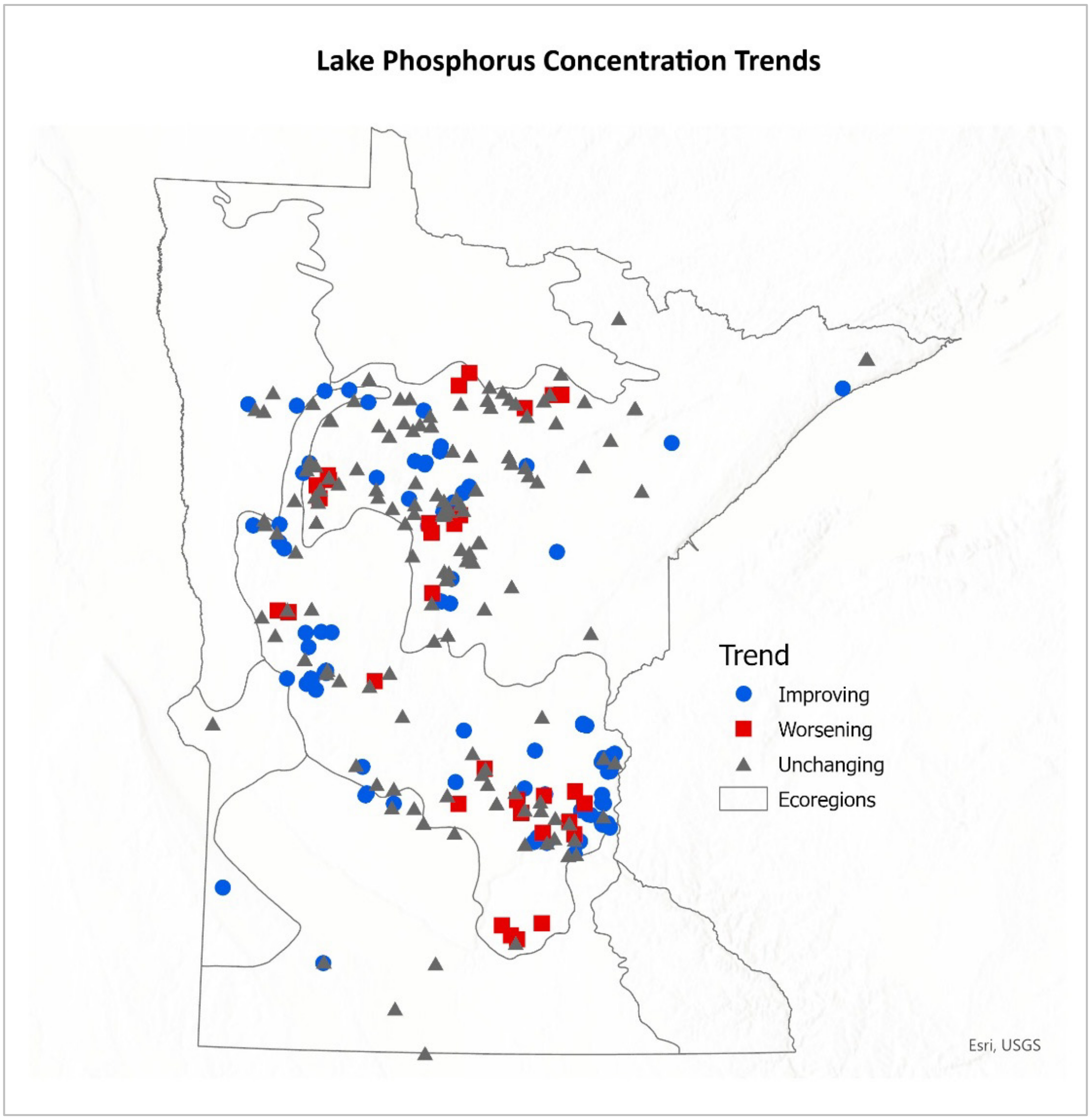
Figure 3-3. TP concentration trends in 260 Minnesota lakes with sufficient monitoring data to assess statistical trends.



Statistical significance for trends was based on a p-value of less than 0.10. The results suggest that TP concentrations to date most commonly remain unchanged or are decreasing (TP levels are improving) in lakes. The spatial distribution of increasing and decreasing trends does not show any readily discernible patterns, with increasing and decreasing levels found in all regions with lakes (Figure 3-4).

The impacts of TP limitation requirements in NPDES dischargers' permits may not yet be fully realized in many downstream waters because the TP limit requirements began fairly recently (in 2008 for lakes and 2015 for rivers). Stream phosphorus concentration trends often respond more quickly, as described in Section 3.2.2.

Figure 3-4. Lake phosphorus concentration trends throughout Minnesota.



Priority watersheds: Lake phosphorus

Local watershed planning teams establish local water priorities within each HUC-8 watershed through a local watershed planning process (see Chapter 6). Each watershed partnership determines the priority issues and water bodies based on science and local values.

The 2025 NRS evaluates watershed priorities (on HUC-10 basis) across the state to better understand differences in large-scale geographic priorities. These priorities vary with the nutrient considered (phosphorus or nitrate-N) and the environmental concern (i.e., lake eutrophication, river eutrophication, drinking water, or aquatic life health). The 2025 NRS priority HUC-10 watershed assessments for lake phosphorus and eutrophication used data representing: (1) lake eutrophication impairments and (2) lake phosphorus reductions with a high benefit-to-cost ratio.

During 2022, the MPCA determined that 693 Minnesota lakes were impaired by eutrophication due to excess phosphorus levels. The sizes of the impaired lakes vary tremendously. Larger eutrophic lakes have more potential to impede beneficial uses for more people as compared to smaller lakes, if all else is equal. Therefore, this assessment of priority watersheds for lake impairments is not based on the number of lakes impaired in a watershed, but rather on the total impaired lake acreage within the watershed. Results show that watersheds with the highest acreage of impaired lakes are mostly in the central part of the state (Figure 3-5) (MPCA 2022b).

Several priority watersheds for lake impairments also exist in southern and northern Minnesota. For information on specific watershed identifiers for high-priority watersheds, see Appendix 3-1.

Minnesota values restoring impaired lakes and protecting water quality in unimpaired sensitive lakes. For the 2025 NRS, the DNR and MPCA also identified priority watersheds for reducing and preventing lake phosphorus additions using the DNR's lake benefit-to-cost ratio assessment (LBCA). That assessment evaluates how much lakes would benefit from work in the watershed to reduce phosphorus inputs, as compared to the general cost of accomplishing phosphorus reductions (Radomski and Carlson 2018). Priority LBCA lakes are high-quality, high-value lakes that likely provide the greatest return on investment. LBCA scores were determined by DNR for each lake and then summed for each HUC-10 watershed. Watersheds were ranked and mapped based on the LBCA sums (Figure 3-6).

Impairment status is not factored into the LBCA; however, some nutrient-impaired lakes also have a high LBCA. The LBCA score calculations factor in the following variables:

- Lake surface area.
- Phosphorus-loading sensitivity (which considers the lake water TP concentration and how much water clarity would be reduced with additional phosphorus loading).
- The proportion of the lake's immediate catchment in disturbed land cover.

Many of the highest-priority LBCA watersheds are found in north-central Minnesota. In this lake-dense part of the state, fewer impaired lakes are found compared to southern Minnesota. Many of these high-quality lakes are very sensitive to phosphorus additions. Relatively small amounts of phosphorus added to many north-central region lakes can lead to a disproportionately high increase in algae growth, which can be exacerbated by rising water temperatures. Reducing phosphorus in these lakes can lead to noticeable water quality improvements. Comparatively, impaired lakes in southern Minnesota are generally subject to such high phosphorus loading that the same levels of phosphorus concentration changes will yield less change to the lakes' beneficial use support.

A merged map showing the highest-ranking category of the LBCA-based priorities with the impaired lake acreage priority watersheds suggests that most regions of Minnesota need phosphorus reduction to either restore impaired lakes or protect and improve unimpaired lakes (Figure 3-7). However, fewer lake-phosphorus priority watersheds were mapped in northwest and southeastern Minnesota due mainly to fewer lakes in those regions. Northeastern Minnesota is known for numerous pristine lakes, but it also has relatively little disturbed land that can provide opportunities for phosphorus loss reduction improvements.

Figure 3-5. Priority watersheds based on acreage of lakes impaired by eutrophication stemming largely from excess phosphorus.

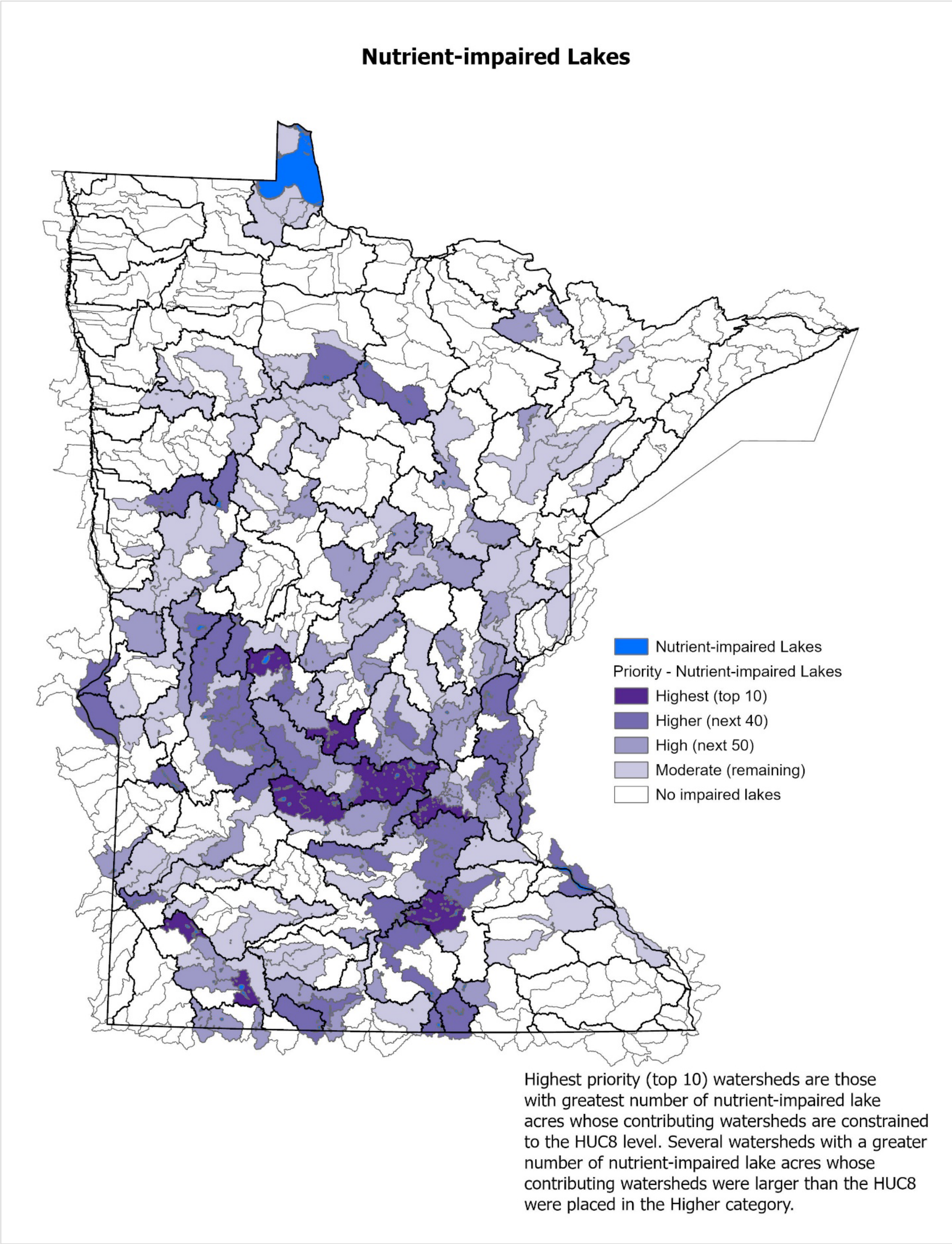
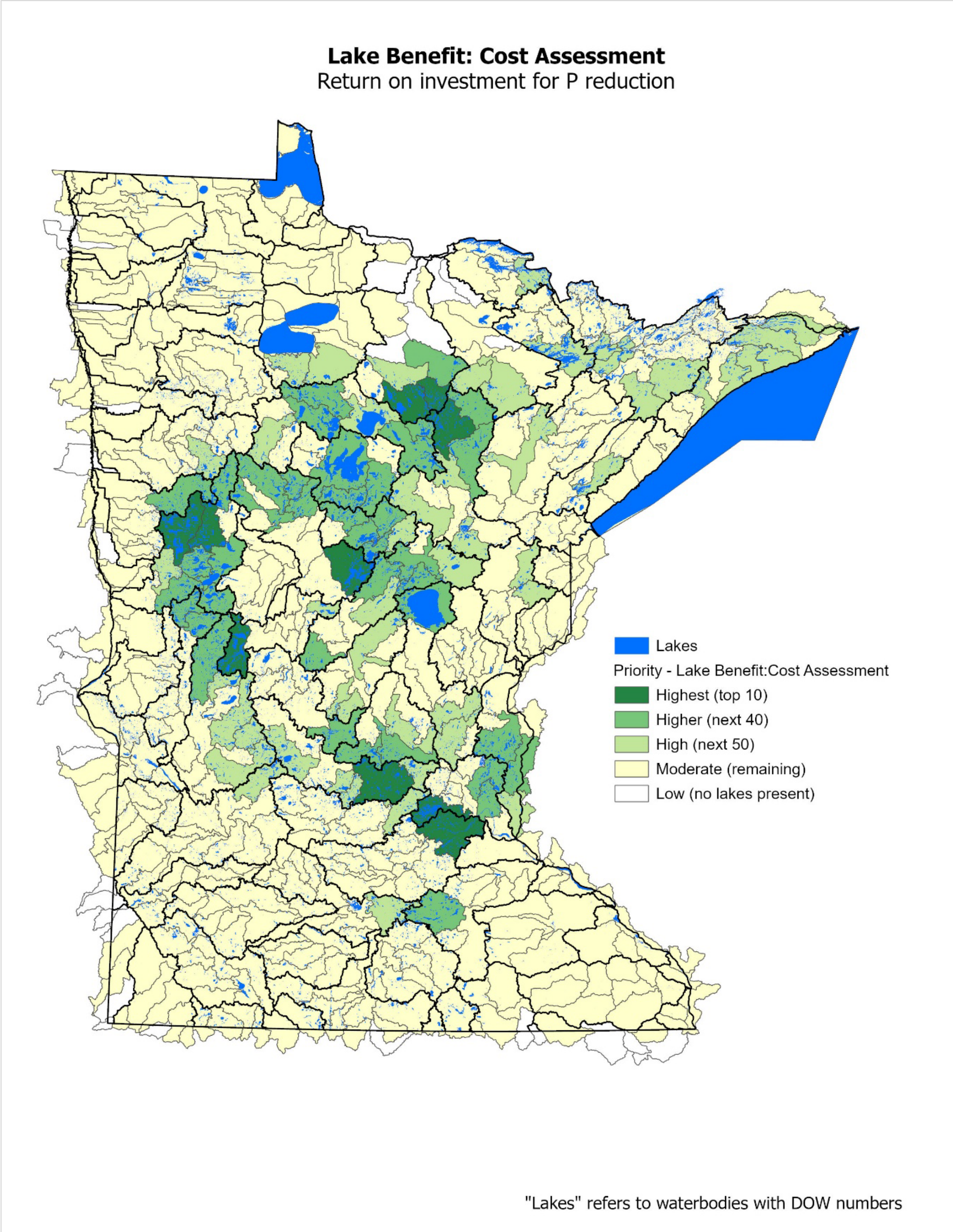
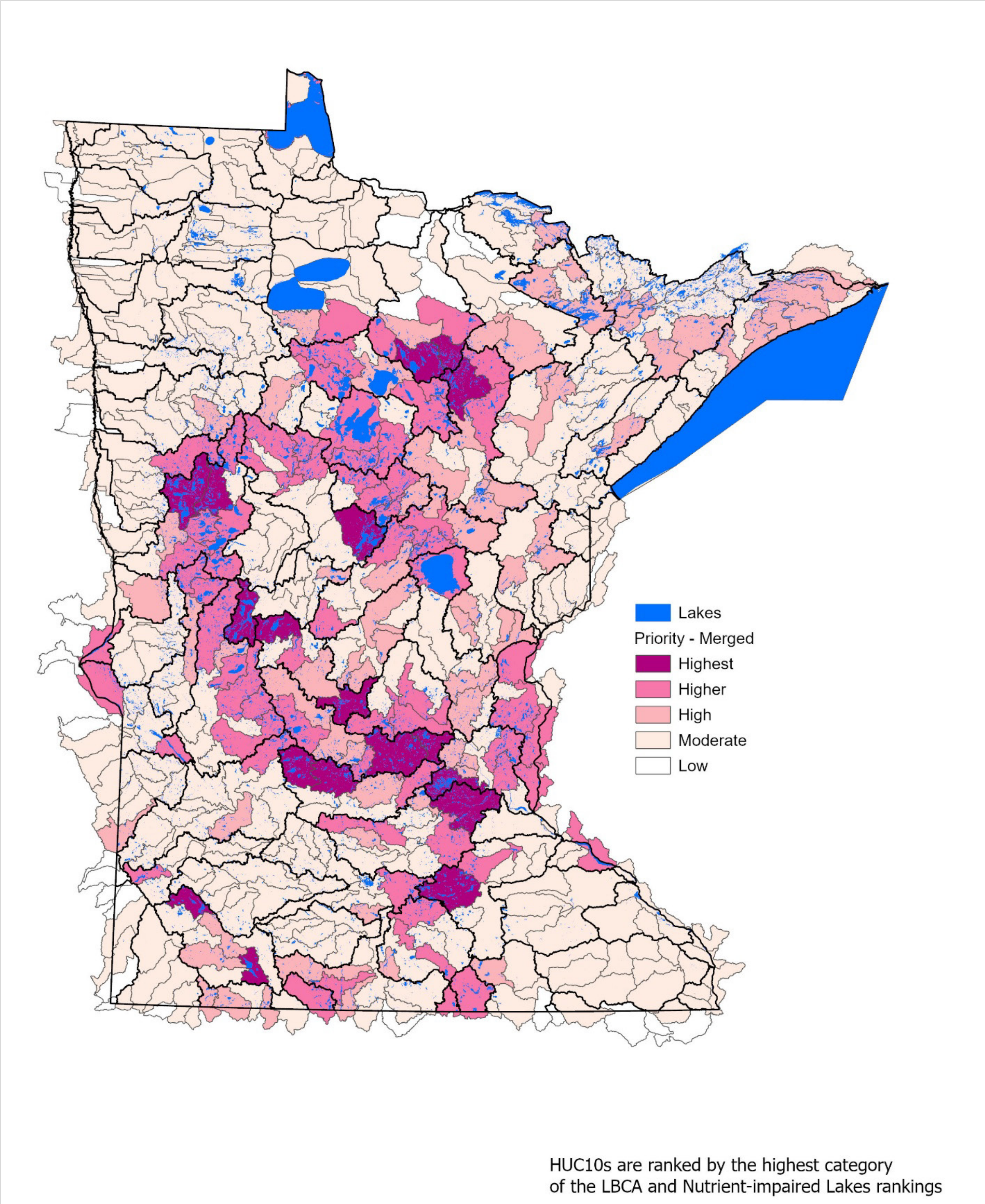


Figure 3-6. Priority watersheds based on an LBCA assessment of anticipated benefits to lakes from phosphorus reductions.



Source: Data based on Radomski and Carlson (2018).

Figure 3-7. Watershed priorities for reducing the phosphorus entering lakes, created from merging priority watersheds for impaired lake acreages and the LBCA scores.



Source: Data based on Radomski and Carlson (2018).

3.2.2 River phosphorus

Conditions – river phosphorus and eutrophication

Minnesota's river eutrophication standards combine criteria in which both a TP concentration threshold and a biological response threshold need to be exceeded before the river is designated as impaired. More specifically, both TP and any one response variable (5-day biochemical oxygen demand, chl-*a* [sestonic], and diel dissolved oxygen flux) must exceed thresholds to be considered as exceeding eutrophication criteria (Table 3-4 and Table 3-5). River/stream nutrient TMDLs are calculated for the TP component of the WQS (e.g., pounds [lbs]/day of phosphorus); they are not calculated for the response variables of chl-*a* (sestonic), diel dissolved oxygen flux, 5-day biochemical oxygen demand, or pH.

Table 3-4. River eutrophication standards by river nutrient region for Minnesota.

Region	Causal variable (nutrient)	Response variable #1	Response variable #2	Response variable #3
	Phosphorus (µg/L)	Chlorophyll-a (µg/L)	Dissolved oxygen flux (mg/L)	5-day biochemical oxygen demand (mg/L)
North	≤50	≤7	≤3.0	≤1.5
Central	≤100	≤18	≤3.5	≤2.0
South	≤150	≤35	≤4.5	≤3.0

Table 3-5. Site-specific criteria for mainstem rivers, Mississippi River pools, and Lake Pepin.[a]

River/pool	Site	Data source	Phosphorus (µg/L)	Chlorophyll-a (µg/L)
Mississippi River at Anoka [b]	UM-872	Met Council	100	18
Lake St. Croix [c]	SC-0.3	Met Council	40	14
Minnesota River at Jordan [b]	MI-39	Met Council	150	35
Pool 1 [d]	UM-847	Met Council	100	35
Pool 2 [e]	UM-815	Met Council	125	35
Pool 3 [e]	UM-796	Met Council	100	35
Pepin (Pool 4)[f]	Four fixed sites	LTRMP	100	28
Pools 5–8 [g]	Near-dam	LTRMP	100	35

Notes:

LTRMP = Long-Term River Monitoring Program

[a] Concentrations expressed as summer averages. Assumes aquatic recreational and aquatic life uses are maintained if phosphorus and chl-*a* are at or below criteria levels.

[b] Based on river eutrophication criteria. Based on modeling UM-872 and MI-3.5, criteria will meet Pepin requirements.

[c] Based on Minnesota lake eutrophication criteria. Based on modeling St. Croix outlet (SC-0.3), would meet Pepin requirements.

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

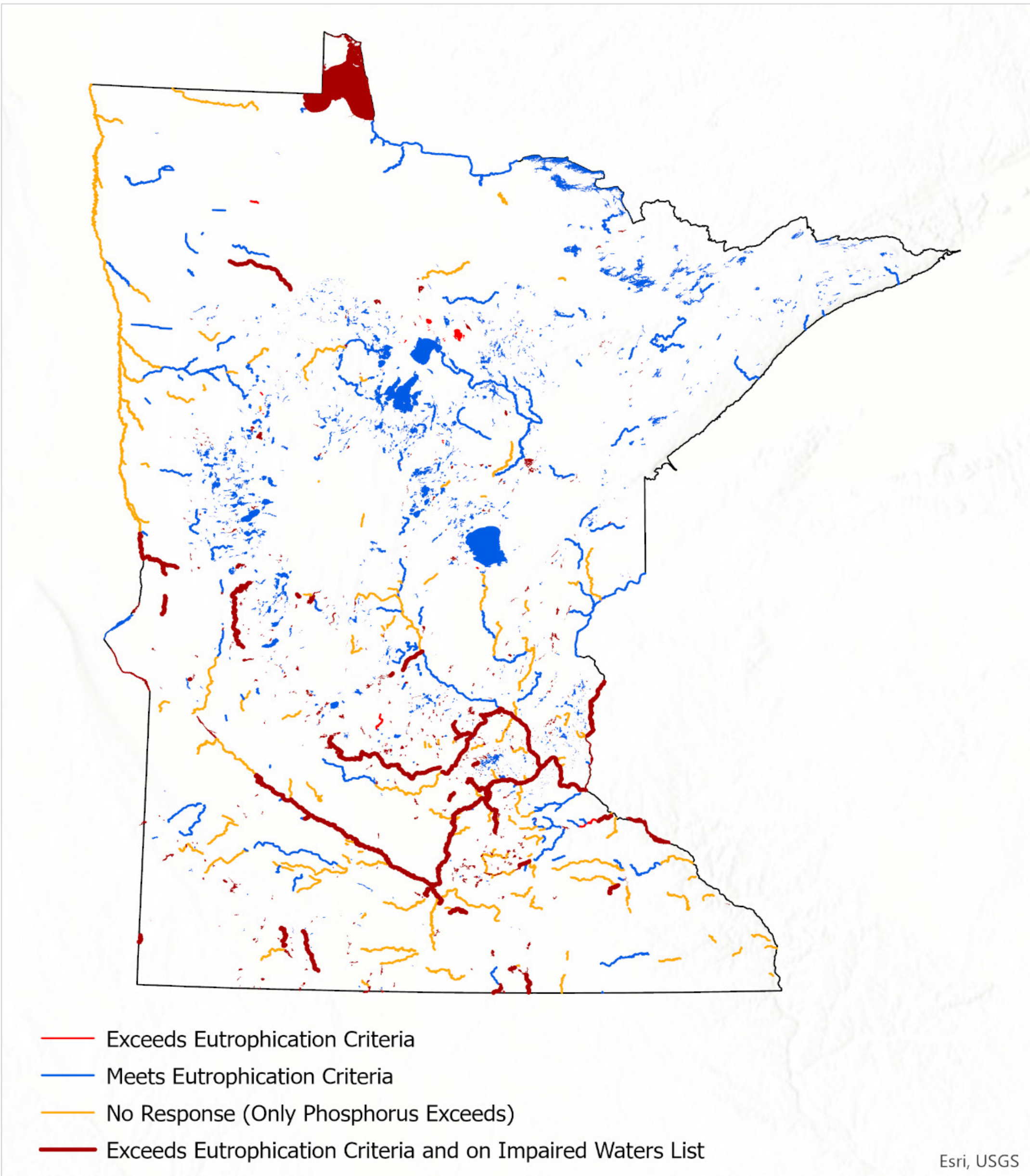
[e] Minimize frequency of severe blooms and meet Pepin requirements.

[f] Phosphorus consistent with the Wisconsin standard. Lake Pepin criteria assessed based on mean from four monitoring sites.

[g] Minimize frequency of severe blooms; upstream phosphorus requirements benefit lower pools. The Wisconsin standard of 100 µg/L could apply to Pools 5–8.

The phosphorus reductions needed to meet the river eutrophication standards are highly variable. In 2024, approximately 41% of streams and rivers in the state are meeting both the TP and the response variable criteria; therefore, they are not impaired or threatened to be impaired (Figure 3-8). About 11% of rivers with sufficient data exceed the criteria of both the causal variable (e.g., TP) and at least one response variable of the river eutrophication standards. These watersheds will need to reduce TP loads to meet standards. The remaining 48% of rivers with sufficient data exceed their phosphorus variable criteria, but they do not exceed any response variable criteria.

Figure 3-8. Minnesota rivers and lakes exceeding and meeting eutrophication criteria.



Note: Waters that exceed their applicable eutrophication criteria are red. Rivers that exceed their applicable phosphorus criteria, but do not exceed their applicable response criteria (e.g., chl-*a* concentration), are yellow. Rivers that meet their applicable eutrophication criteria are blue. Waters that exceed eutrophication criteria, and are currently listed as impaired in the 2024 assessment, are shown as bold dark red.

Some of the unimpaired river reaches with high phosphorus levels are contributing to downstream eutrophication impairments. For example, the Minnesota River Basin has 57 reaches that are not locally impaired based on river eutrophication standards but need reductions to meet eutrophication standards throughout much of the Minnesota River and farther downstream in Lake Pepin, which is impaired based on site-specific lake eutrophication criteria.


The backwaters of Lake Pepin

Other river reaches, such as several of those in the Red River of the North Basin, have elevated phosphorus, but they do not exceed river eutrophication standards because they meet their applicable response variable criteria. Nevertheless, those rivers contribute to eutrophication in downstream Lake Winnipeg.

On average across Minnesota, a 42% phosphorus load reduction from recent conditions is needed to bring eutrophication-impaired rivers into compliance with standards (Table 3-6).

Table 3-6. Preliminary analysis of all available phosphorus and chl-*a* data (2015–2024) in river and stream reaches in Minnesota compared to river eutrophication standards.

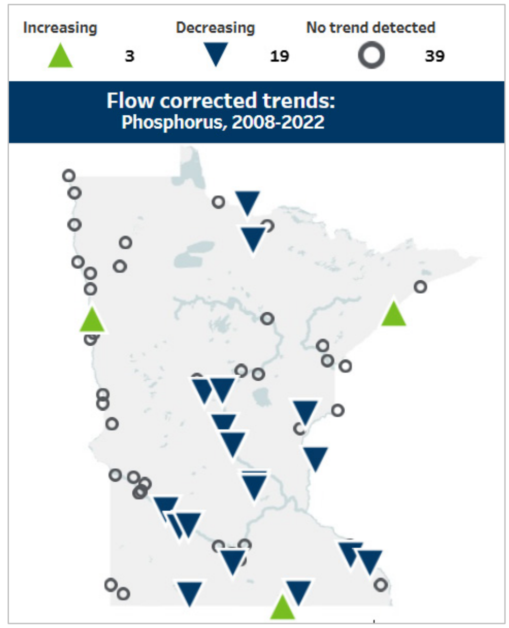
Basin	High P & chl-*a* levels: # of reaches	P reduction needed for reaches with high P & chl-*a* (%)	High P levels: # of reaches	P reduction needed for reaches with high P levels (%)	# of reaches meeting standards	P reduction needed for reaches meeting standards	Total # of reaches
Cedar	2	37%	3 [a]	41%	2	NA	7
Des Moines	2	23%	2 [a]	40%	--	--	4
Lower Mississippi	3	46%	24 [a]	38%	21	NA	48
Minnesota	21	40%	43 [b]	35% [b]	19	NA	83
Missouri River	1	82%	-- [a]	--	--	--	1
Rainy River	--	--	3 [b]	19% [b]	15	NA	18
Red River	5	58%	25 [a]	47%	31	NA	61
St. Croix	1	7%	5 [b]	46% [b]	9	NA	15
Superior	--	--	--	--	9	NA	9
Upper Mississippi	15	42%	29 [b]	47% [b]	40	NA	84
Total	**50**	**42%**	**134**	**39%**	**146**	**NA**	**330**

Notes:
This chart is only for streams with sufficient phosphorus and chl-*a* data (minimum 12 observations each).
Percent phosphorus reduction is the average reduction needed to meet the phosphorus variable of river eutrophication standards.
= number; NA = not applicable (standards are met in those reaches); P = phosphorus
[a] Downstream resources might be beyond state boundaries.
[b] Stream reaches with elevated phosphorus will only need reductions if a downstream water exceeds a standard for a response variable.

River phosphorus concentration trends

Phosphorus concentrations have been decreasing at many river sites throughout the state. Between 2008 and 2022, phosphorus concentrations at 61 river sites monitored by the MPCA decreased (improved) at 19 sites (31%) and increased at three sites (5%), with 39 sites (64%) showing no trend (Figure 3-9 and the MPCA long-term stream trends in Minnesota website). Even when not corrected for flow variability, over four times as many sites showed improvements as declines in phosphorus concentrations. When lengthening the timeframe (2003–2022), the number of river monitoring sites available for trend analysis is reduced to 35, and the results show even more improvements, with zero sites increasing, 23 (66%) decreasing, and 12 (34%) showing no trend.

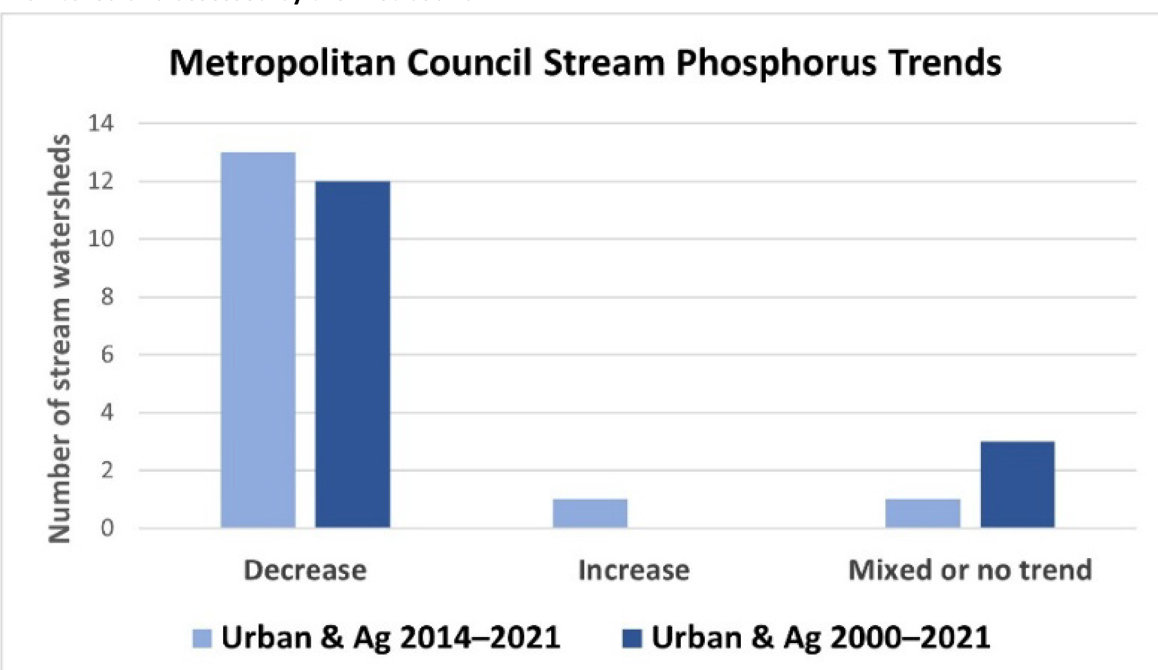
Figure 3-9. TP concentration trends at 61 MPCA-monitored river sites, 2008 to 2022.



Note: Trends are corrected for flow variability.

The MPCA's assessed trends noted above are consistent with the phosphorus improvements observed in the Twin Cities region through the Met Council's long-term stream monitoring trends analyses (Met Council 2023). The Met Council found phosphorus concentration improvements in both urban- and agriculture-dominated HUC-10 and 12-digit hydrologic unit code (HUC-12) stream watersheds (Figure 3-10).

Figure 3-10. Phosphorus concentration trends in the Twin Cities metro region's stream watersheds monitored and assessed by the Met Council.



Note: Results extracted from the Met Council's Stream and River Tributary Monitoring website.

Between 2014 and 2021, phosphorus concentrations decreased (improved) in 13 out of 15 assessed watersheds. One watershed showed an increase, and one showed no trend. The results are similar when assessing trends over two decades (2000–2021), as 12 watersheds showed decreases, three showed no trend, and none showed an increase. The Met Council continues to monitor these streams and is expected to periodically update their statistical trend results using the most recent years available.

The Met Council has also assessed TP concentrations in the major rivers in the Twin Cities area, going back to the late 1970s. A statistical pollutant concentration trend model (Quality of Water Trend [QWTREND]) reported statistically significant decreasing (improving) trend results at the three major river sites assessed for the 2025 NRS (Table 3-7) (Met Council 2024). This analysis, included in more detail in Appendix 2-2, is generally consistent with the MPCA finding of widespread phosphorus concentration decreases (improvements). Chapter 2 described some of the reasons for this improvement, including implementing conservation practices on the land and achieving large reductions in wastewater phosphorus discharges. Other sectors have achieved reductions as well, including urban stormwater, septic systems, and feedlots.

Table 3-7. Statistical trends ($p < 0.1$) for TP concentration changes since the late 1970s.

River monitoring site (trend years)	Change in concentration
Minnesota River at Jordan (1979–2023)	-35.4%
Mississippi River at Anoka (1976–2018)	-35.3%
Mississippi River at Red Wing (1988–2023)	-47.0%

Source: Met Council 2024.

River phosphorus and eutrophication priority watersheds

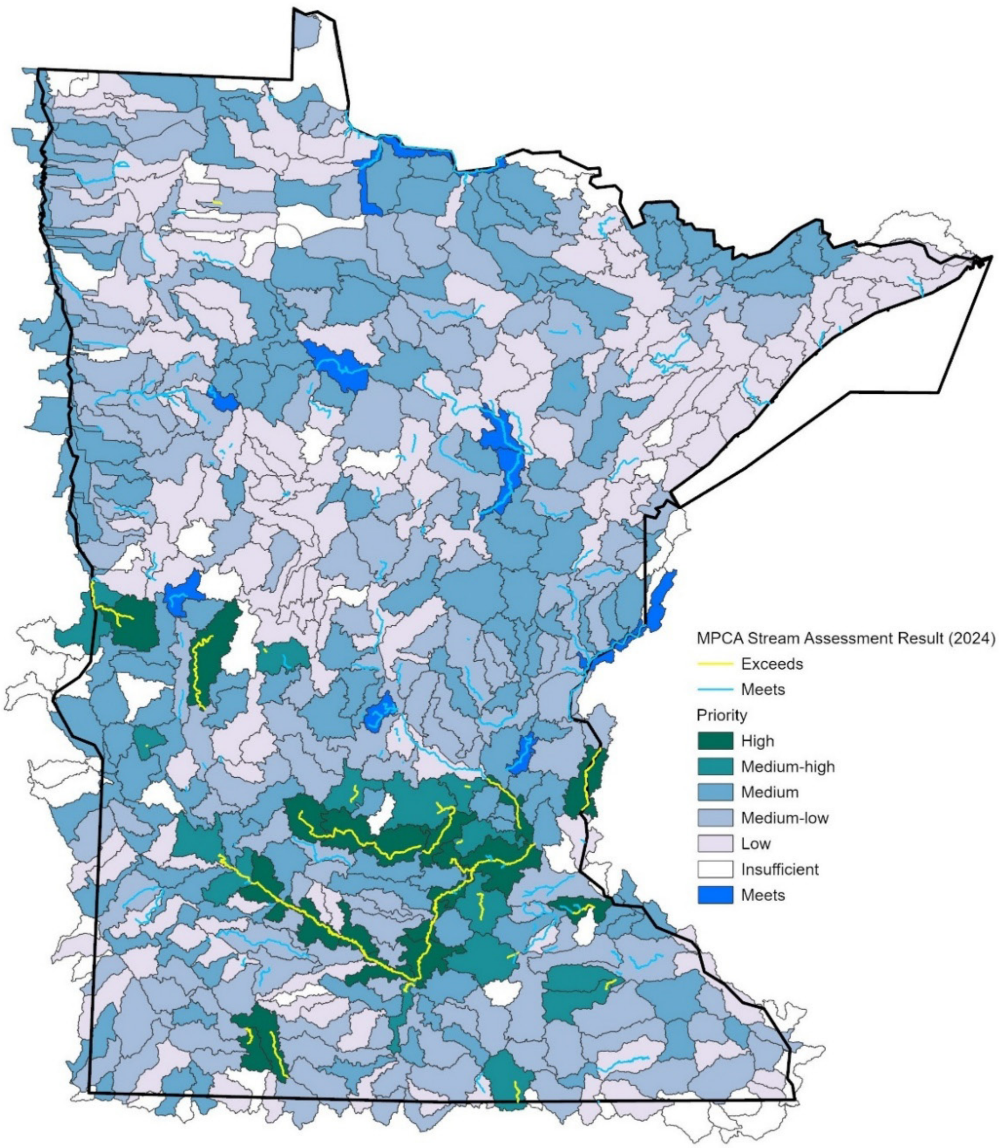
The NRS shows watershed priorities (at a HUC-10 scale) across the state to illustrate the differences in large-scale geographic priorities and how these priorities vary with the nutrient considered and the environmental concerns identified. As previously noted, local water priorities within each HUC-8 watershed are established by the local watershed planning team through comprehensive local water planning processes (see Chapter 6). Each watershed planning team uses its own methods for selecting these local priorities.

The NRS used river and stream eutrophication impairment data and phosphorus concentration data when determining the priority HUC-10 watershed assessments for eutrophication. The highest-priority watersheds for river and stream eutrophication were those with a relatively high fraction of assessed river miles with impairments (Figure 3-11; see the high and medium-high categories).

The NRS also considered watersheds a priority for local phosphorus reductions when phosphorus levels are high, but no observed response variables were triggered due to inadequate monitoring or because the response variable results were lower than the criteria (Figure 3-11; see the medium and medium-low categories). More investigation of eutrophication issues in high-priority watersheds is warranted before drawing conclusions about the severity of river eutrophication in a given watershed.

Priority watersheds for river and stream eutrophication are largely found in south-central Minnesota (see Figure 3-8). Northwestern Minnesota has many watersheds with high river and stream phosphorus concentrations (i.e., above the criteria for impairment) but little data showing eutrophication response variable exceedances. In some of these watersheds, more monitoring of response variables is needed before the MPCA can determine the impairment status. Some of these high-phosphorus rivers and streams in northwestern Minnesota have elevated levels of suspended sediment that prevent sunlight penetration, thereby limiting algae growth. These rivers and streams do not exceed the response variables, but they are still shaded to indicate a potential for phosphorus-related concerns. The light gray and dark gray shaded watersheds in Figure 3-11 are not currently considered impaired, but they often flow into other rivers that become impaired downstream. Therefore, they are also a priority for local phosphorus reductions.

Figure 3-11. Priority HUC-10 watersheds for phosphorus reductions to reduce river and stream eutrophication potential.



Notes: Green- and teal-shaded watersheds have higher fractions of stream miles impaired by phosphorus (with eutrophication response variable also triggered). Gray-shaded watersheds have fewer verified impaired rivers and streams but still show high enough phosphorus to be a potential cause of eutrophication either locally or downstream. Priority categories are *High*: Over 25% of monitored river miles impaired (n=20); *Medium-high*: 1%–25% impaired (n=15); *Medium*: <1% impaired, high phosphorus in >75% of stream miles (n=143); *Medium-low*: <1% impaired, high phosphorus in 25%–75% of stream miles (n=151); *Low*: <1% impaired and <25% of stream miles with high phosphorus (n=138); *Meets – protection needed*: >75% of the streams meet the standard (n=10); *Insufficient:* less than 10 miles of streams monitored (n=56). For specific watershed identifiers for high-priority watersheds, see Appendix 3-1.

3.2.3 Addressing in-state and downstream phosphorus reduction needs together

Large phosphorus reductions have been achieved in Minnesota; however, further reductions are still needed in many areas to meet in-state eutrophication standards. Achieving these phosphorus reductions for local waters will have cascading benefits for larger downstream in-state rivers and lakes and for national and international waters. This section describes the intersections of phosphorus goals downstream of Minnesota, as described in Chapter 2, and the phosphorus reduction needs for lakes, streams, and rivers within the state, as described in the above sections of Chapter 3.

The following questions are often asked pertaining to nutrient reduction goal attainment: "If each HUC-8 watershed works to meet nutrient-related standards for waters within the watershed, will that be enough to meet downstream goals? In what areas will it be enough to solely focus on local lake and stream phosphorus reductions, and in what areas will more work be needed within the watersheds to also meet the needs downstream of Minnesota?"

An analysis conducted for the 2014 NRS estimated that, for the 433 nutrient-impaired lakes with sufficient monitoring data, an overall average reduction of 45% (from 2002–2011 concentrations) would be needed to meet eutrophication standards for lakes. A more recent MPCA analysis of 523 nutrient-impaired lakes indicated an overall average reduction of 42% (ranging from 3% to 72%) would be needed to meet lake eutrophication standards. The actions taken to reduce phosphorus in these lakes will also benefit downstream waters. However, the size of the cumulative watersheds draining to these lakes is relatively small compared to the total land area that affects phosphorus loss to downstream waters.

Kayaking on the LeSueur River in southern Minnesota

The actions taken to restore local lakes will provide a relatively small fraction of the phosphorus reductions needed to reduce the downstream eutrophication of regional lakes, the Gulf, and Lake Winnipeg. In particular, the Red River Basin has fewer lakes and, thus, fewer impaired lakes as compared to the Mississippi River Basin. Therefore, addressing impaired local lakes in the Red River Basin will yield minimal phosphorus load reductions compared to what is needed for Lake Winnipeg. Similarly, the karst region of southeastern Minnesota has few lakes, and addressing lake impairments in this part of the state will have a minimal effect on Mississippi River phosphorus levels flowing out of the state towards the Gulf.

The phosphorus reductions needed to meet river eutrophication standards and regional downstream lakes, such as Lake St. Croix and Lake Pepin, align closely with the load reduction amounts needed to achieve Minnesota's commitment for the Gulf. Lake Pepin, a flowage (or riverine) lake on the Mississippi River, needs phosphorus loads reduced by approximately 29% to meet lake standards (Appendix 2-4). In comparison, Minnesota needs an approximate 29% reduction for the state's Gulf commitment, based on a 5-year rolling average in the Mississippi River at Red Wing. The remaining needed reduction for the Gulf is only 13% when adjustments are made to account for river flow variability (see Chapter 2).

A recent MPCA analysis using updated monitoring information showed that Minnesota rivers can meet eutrophication standards if phosphorus is reduced by an average of 42%. Meeting in-state river eutrophication standards will align with achieving Minnesota's share of phosphorus reductions needed to protect the Gulf. The Mississippi River phosphorus reduction goals for the Gulf will be achieved if Minnesota focuses on meeting the goals for:

1. Local lakes that are impaired or vulnerable to eutrophication.
2. In-state rivers that are impaired by eutrophication.
3. Regional lakes that are impaired by eutrophication, including Lake Pepin.
4. Watershed soil and phosphorus loss reduction in southeastern Minnesota watersheds that enter the Mississippi River downstream of Lake Pepin, such as the Zumbro and Root River watersheds.


Diving into a Minnesota lake

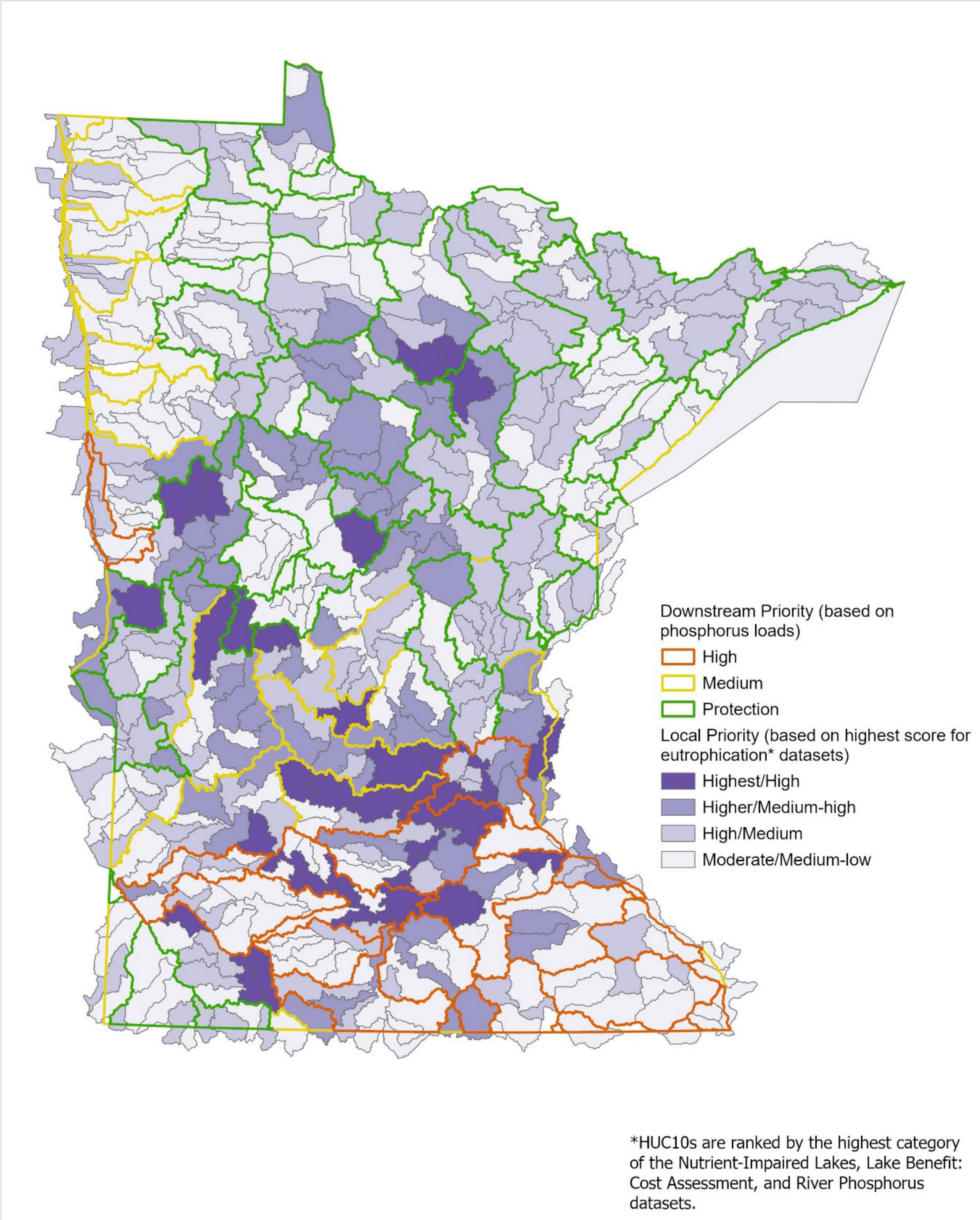
For the Lake Winnipeg Basin, achieving both river eutrophication and lake eutrophication standards will reduce phosphorus by a small fraction of the total load reductions needed for Lake Winnipeg. Therefore, local and state strategies will be needed beyond those addressing local watershed eutrophication goals. Sediment reduction in this basin will be important for meeting total suspended sediment standards. Because phosphorus readily binds to soil particles from upstream tributaries and can be released as dissolved phosphorus farther downstream, sediment reduction will also be important for reducing phosphorus loads in the Red River. Further study is needed to determine how much of the phosphorus and sediment in the Red River Valley originates from streambank erosion and near-channel sources, and whether achieving sediment standards by controlling those sources will result in attainment of phosphorus reduction goals for Minnesota's phosphorus contribution to the Red River and, ultimately, Lake Winnipeg.

The selection of priority watersheds for phosphorus reduction should consider in-state lake and river eutrophication levels as well as the watersheds prioritized for meeting downstream needs (see Chapter 2). Appendix 3-1 includes the priority mapping classifications for each HUC-10 watershed in the state, including priority scoring for both in-state and downstream needs.

Priority watersheds for combined phosphorus needs

When overlaying the highest ranking in-state HUC-10 watershed phosphorus priority category with the priority HUC-8 categories for contributing to TP loads downstream of Minnesota (as included in Chapter 2), a few watersheds in south-central Minnesota have both the highest category HUC-10 watersheds for in-state needs and the highest category for downstream needs (Lower Minnesota and Middle Minnesota watersheds) (Figure 3-12). More commonly, watersheds with the highest results for either in-state or downstream state reduction needs do not overlap. Therefore, it is important for watershed planners to consider both the downstream and in-state priorities when setting local priorities for work in their watershed.

Figure 3-12. Highest-category phosphorus priority HUC-10 watersheds, along with the HUC-8 priority watersheds contributing TP loads downstream of Minnesota.



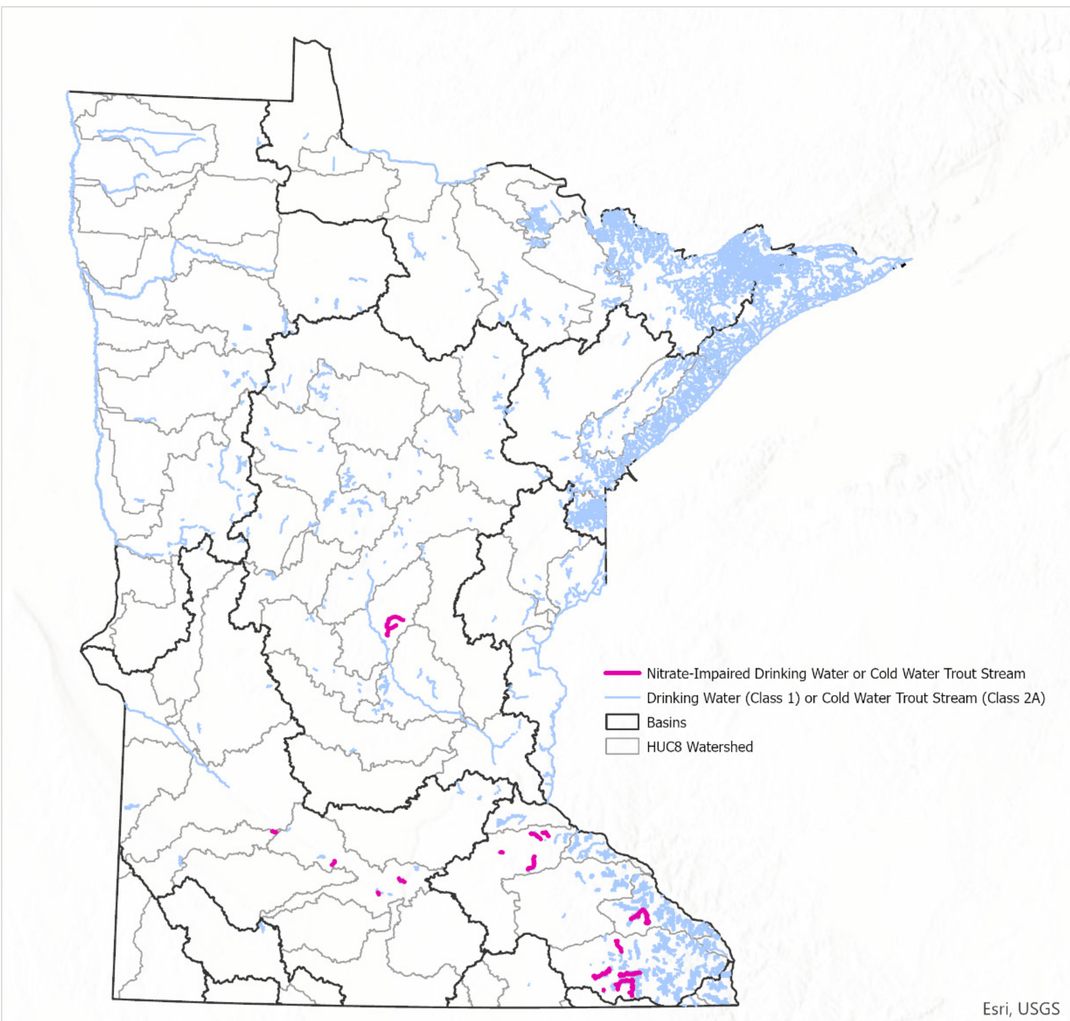
3.3 In-state nitrate concentrations

3.3.1 Drinking water nitrate

Conditions: Cold-water stream nitrate

The 10 mg/L drinking water standard applies to Minnesota's cold-water streams (trout streams). Because the nitrate in cold-water trout streams comes mostly from groundwater baseflow, when the stream exceeds the 10 mg/L standard, the associated groundwater aquifers are also most likely to exceed the 10 mg/L standard for drinking water. Nitrate is listed as a cause of impairment for Class 1 drinking water streams if two or more exceedances of the acute nitrate standard (10 mg/L) occur in a 3-year period. The overall stream miles covered by the existing standard are a relatively small portion of the total stream miles in Minnesota and are most applicable in southeastern and northeastern Minnesota (Figure 3-13).

Figure 3-13. River and stream reaches protected as drinking water sources (blue) and impaired waters (red) exceeding the nitrate-N standard for cold-water streams.



Note: Much of the state is neither blue nor red, indicating that relatively few stream reaches across the state have nitrate standards applicable to cold-water streams.

The 2024 Impaired Waters List noted that 32 cold-water streams in Minnesota are not meeting the 10 mg/L nitrate WQS established to protect potential drinking water supplies. Most (78%) of these were in southeastern Minnesota. Reducing nitrate in groundwater is important in these areas because (1) numerous wells have nitrate levels above the drinking water standard, and (2) reducing nitrate levels in groundwater is part of the NRS effort to meet goals at the state boundary. However, because these nitrate-impaired watersheds are of limited geographic extent compared to the entire Mississippi River Basin, the nitrate reduction measures implemented to meet these standards will have a limited effect on achieving the nitrogen load reduction goals for the Mississippi River.

Surface water—primarily the Mississippi River—provides drinking water for almost a quarter (23%) of Minnesotans, including the people of Minneapolis and St. Paul, Minnesota's two largest cities, and some of the surrounding suburbs. Nitrate levels in the Mississippi River near the direct or indirect intakes for the Twin Cities are far below the drinking water standard; thus, reductions are not currently needed to protect human health (MDH 2024). However, protecting surface waters from nitrate remains important to ensure safe drinking water supplies in the future.

Conditions: Groundwater nitrate

More than 75% of Minnesota's population relies on groundwater for its drinking water, including many areas where aquifers exceed the nitrate drinking water standard of 10 mg/L. Groundwater is most susceptible to nitrate pollution where there is a combination of vulnerable geology and nitrogen sources. Groundwater vulnerability is highest when the soils are sandy or not very thick above bedrock. Such soils are found throughout Minnesota, particularly in southeastern and north-central Minnesota (Figure 3-14) and in many of the state's river valleys. The DNR has advanced the understanding of groundwater sensitivity in recent decades, as found at the agency's groundwater pollution sensitivity website.

In addition to affecting drinking water wells, groundwater baseflow with high nitrate that flows into rivers contributes substantial amounts of nitrogen to Minnesota's rivers and streams, affecting local and downstream surface water quality. These groundwater nitrate contributions vary with land use, geology, groundwater flow pathways, and the transport time between the groundwater recharge area and re-emergence into rivers. Some groundwater nitrate is lost to the atmosphere through denitrification before it enters a stream.

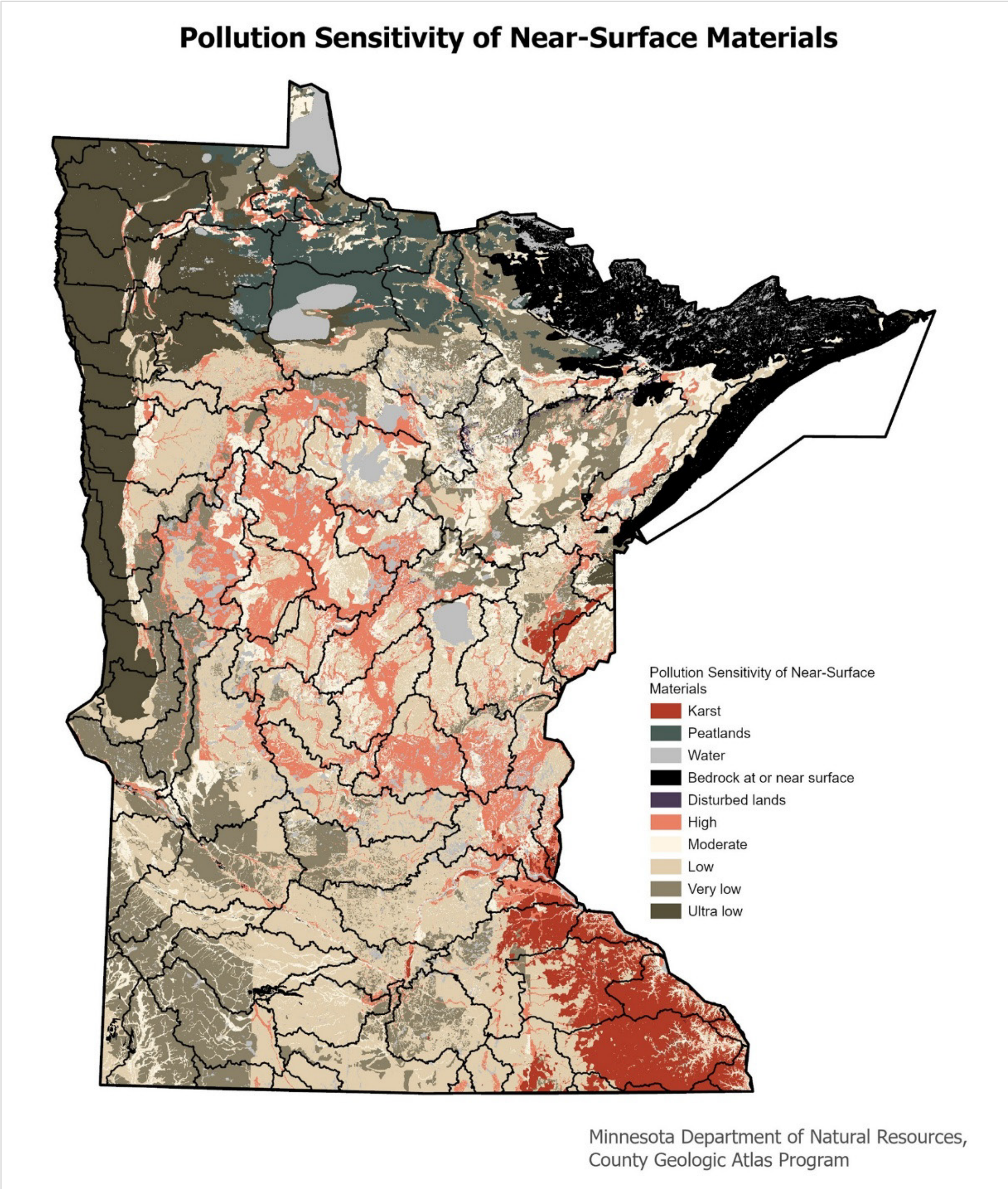
Wells drilled into an aquifer can indicate nitrate concentrations at a discrete point and depth within the groundwater system. Well water nitrate concentrations often vary greatly within short distances, both horizontally and vertically; therefore, data from multiple wells are typically needed to characterize groundwater nitrate concentrations and trends in a given area.

State agencies have collected well water nitrate concentration information through several different programs, including:

- MDA Township Testing Program
- MPCA and MDA ambient monitoring programs
- MDH datasets for newly drilled wells (WELLS), source water investigative sampling (WCHEM), and compliance data for public water supplies (Minnesota Drinking Water Information System, or MNDWIS)
- DNR County Geologic Atlas development program

Each of these programs provides a different view of well water nitrate concentrations. Collectively, they show the nature and extent of nitrate contamination in drinking water wells.

Figure 3-14. Groundwater pollution sensitivity based on near-surface geologic materials.



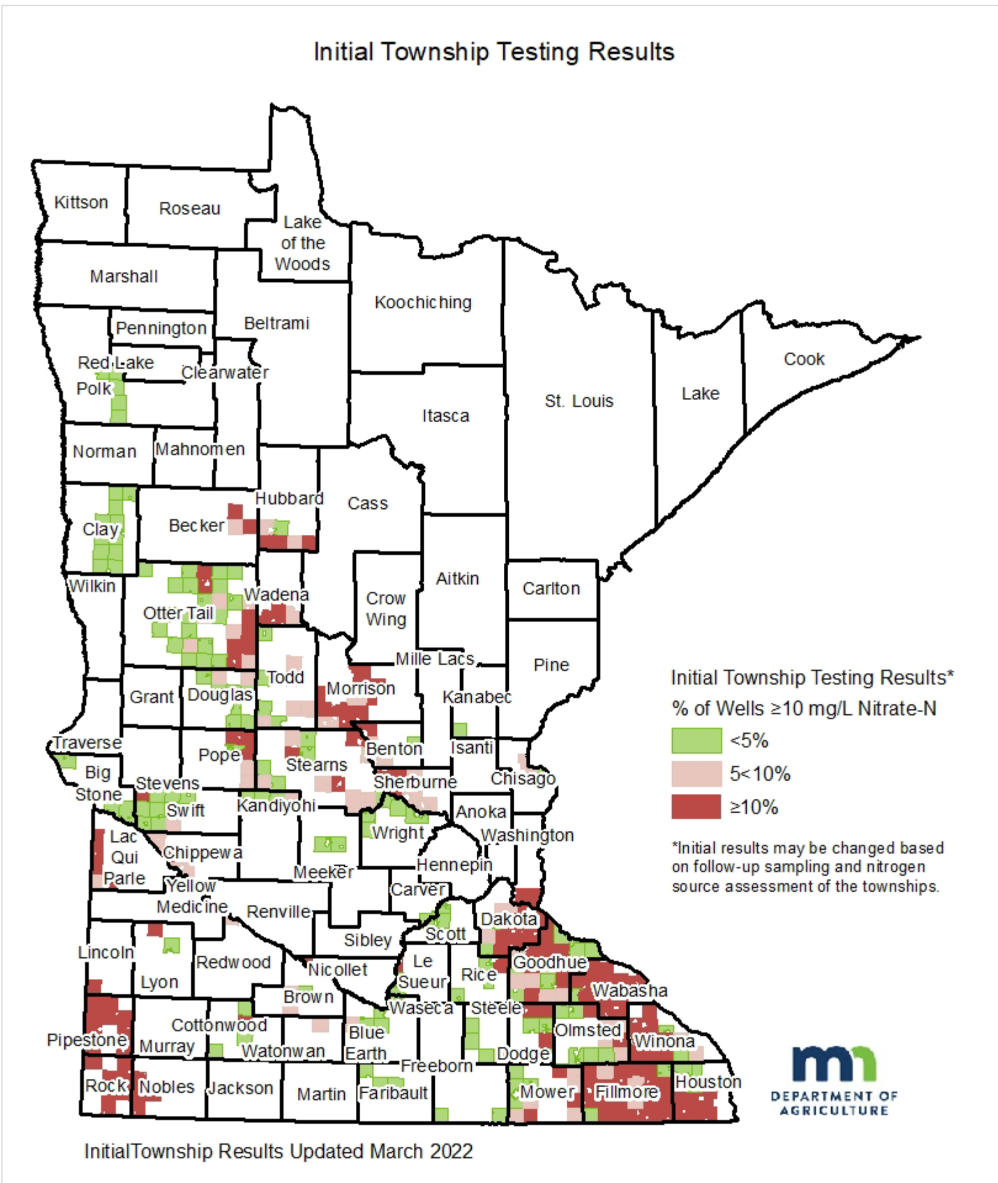
MDA Township Testing Program

The MDA conducted a well-testing program in townships that had (1) a significant portion (typically 30% or more) of land areas vulnerable to groundwater and (2) a significant portion (typically 20% or more) of land areas in row crop production. All wells were initially tested between 2013 and 2019, regardless of well construction or nitrogen source. Those results showed that 9.1% of the 32,217 private wells exceeded the health risk limit for nitrate-N. Another 14% had 3–10 mg/L nitrate-N, with a total of 23.1% of tested wells exceeding 3 mg/L. Of the 344 townships tested, 143 (44%) had at least 10% of sampled wells above 10 mg/L (Figure 3-15).

If nitrate was detected in the initial sample, the homeowner was offered a follow-up nitrate test, pesticide test, and well site assessment. A process was then initiated to remove wells from the dataset that had construction concerns or insufficient construction information or were located near potential nonfertilizer sources of nitrate (e.g., septic systems, manure storage areas). Final results were determined after two rounds of sampling between 2014 and 2020.

In the final dataset, 4.7% of the 28,932 sampled wells exceeded 10 mg/L nitrate-N, and another 10.6% had levels of 3–10 mg/L. Therefore, a total of 15.3% of sampled wells exceeded 3 mg/L. The lower percentages of high-nitrate wells in final testing compared to initial testing indicate that many of the initially sampled high-nitrate wells had questionable well construction or nearby nonfertilizer nitrogen sources. The results also indicate that many wells in geologically vulnerable agricultural areas have high nitrate levels, even with good well construction and no obvious interferences from nearby nonfertilizer sources. For more details, see the MDA's Township Testing Program website.

Figure 3-15. MDA initial township testing results for wells in geologically vulnerable agricultural townships in Minnesota.



MPCA and MDA ambient groundwater monitoring

The MPCA and MDA each maintain their own ambient groundwater-monitoring networks, which, when combined, cover a variety of conditions across the state. The MPCA's ambient groundwater monitoring primarily targets aquifers in urban parts of the state, and most of the MDA's monitoring is performed in agricultural areas. One value of the ambient monitoring programs is the ability to assess groundwater nitrate trends over time (discussed below).

Using the results from the ambient monitoring programs, the MPCA periodically publishes a report on conditions in Minnesota groundwater. The most recent report, *The Condition of Minnesota's Groundwater Quality 2018 – 2023*, was published in April 2025 (MPCA 2025c). The NRS focuses only on well monitoring results from the upper aquifers, which are generally more vulnerable to nitrate contamination.

MDH well water nitrate data

Health concerns associated with nitrate in drinking water are described on MDH's Nitrate in Well Water website. The MDH manages three sets of well water nitrate data: (1) WELLS, from samples taken as required for newly drilled wells; (2) WCHEM (soon to be in EQuIS), source water investigative sampling of private and public wells to determine groundwater vulnerability; and (3) MNDWIS, compliance data for public water supplies. The combined results of these three datasets, along with other data, help in assessing priority watersheds for drinking water nitrate, as discussed later in this chapter.

DNR's Watershed Health Assessment Framework accessed these datasets in 2024 to assess nitrate levels from 186,621 wells. Based on the highest result obtained from each well, 4% exceeded 3 mg/L, and less than 1% exceeded 10 mg/L. Locations of high-nitrate wells from these data can be used to help identify the geographic areas with a potential for high-nitrate wells; however, due to the nature of the wells sampled (i.e., largely newly drilled wells), the results should not be used to estimate the fraction of wells in Minnesota above the drinking water standard.

Community water systems

All community water systems test for nitrate to ensure that levels meet the EPA drinking water standard, also known as the maximum contaminant level (MCL). The MCL for drinking water nitrate-N is 10 mg/L. Community public water systems with elevated nitrate levels (above 3 mg/L) tend to be in the state's southwestern, southeastern, central, and north-central areas. In 2024, MDH reported that 95% of 879 community water systems had low average nitrate levels (0–3 mg/L). Three water systems received a violation for serving water that exceeded the 10 mg/L MCL and are working towards a long-term solution (installing treatment or finding an alternate water source). The source water for seven other community water systems included at least one well with nitrate levels exceeding 10 mg/L during 2024. Water blending and/or treatment enabled these communities to provide finished water with nitrate levels below the 10 mg/L MCL.

Groundwater testing along Lake Superior

Other nitrate data

Additional nitrate data exists. For example, other well water nitrate data have been collected through the following efforts.

- The DNR has sampled wells for its county groundwater atlas mapping program.
- The MDA has established volunteer well monitoring networks.
- Groundwater springs are sampled by MPCA, MDA, and others.
- Many counties and some watershed districts have their own well sampling programs.
- Universities and the USGS also collect nitrate data for special studies of limited duration.

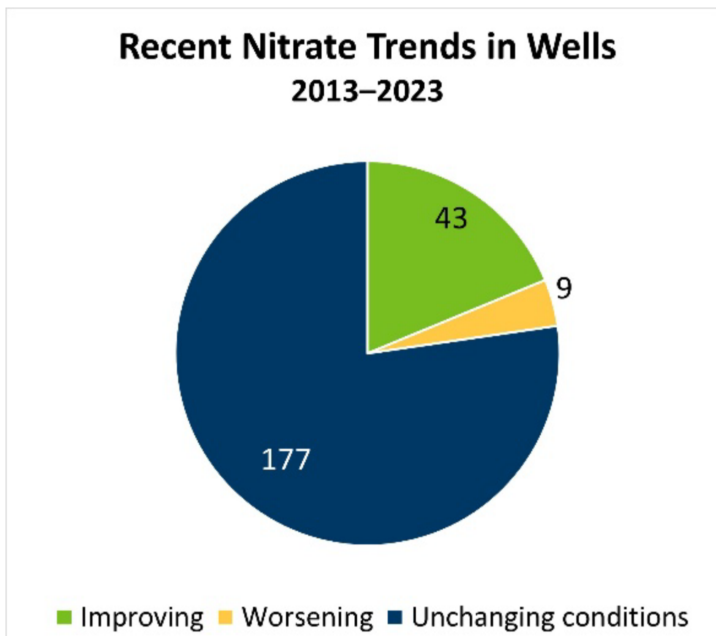
This NRS does not provide a comprehensive assessment of all existing nitrate data; rather, it uses the largest datasets in terms of geographic scale and number of wells sampled to show the parts of the state with the greatest concern (see Figure 3-19, Figure 3-20, and Figure 3-21 in the next section).

Trends: Groundwater nitrate concentration

Trend results from the MDA and MPCA ambient monitoring programs are summarized below. Due to data limitations, the groundwater trend summaries do not provide definitive conclusions about groundwater nitrate trends in any given region. Instead, they provide information about the general nature of groundwater nitrate trends across Minnesota. Longer periods of monitoring and a higher density of sampled wells are needed to assess trends more accurately across any given region of the state.

Two time periods were assessed: (1) short-term trends from wells sampled between 2013 and 2023 and (2) mid-range trends from wells between 2007 and 2023. The MPCA assessed trends using the Mann-Kendall test ($p < 0.05$) on wells with five or more samples taken during the applicable timeframes, most with annual sampling.

Figure 3-16. Nitrate concentration short-term trends in 229 upper aquifer wells (domestic and monitoring wells) sampled at least five times during 2013–2023 across Minnesota.

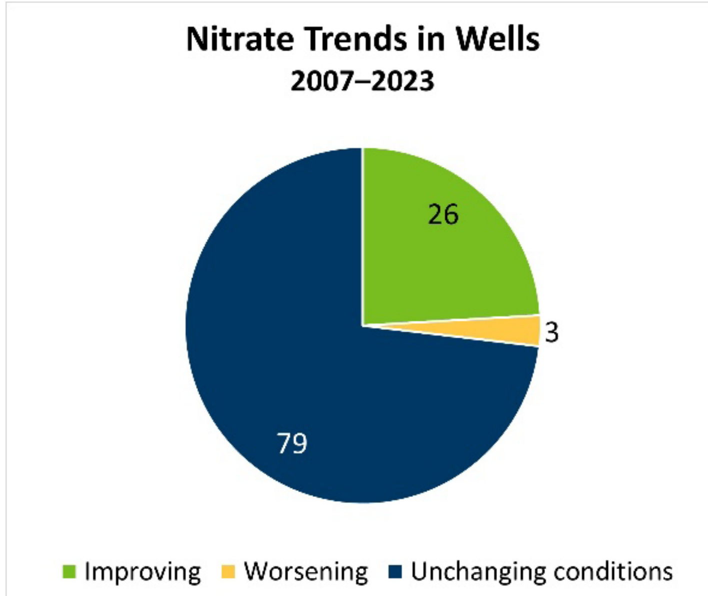


Short-term trend results for 229 wells in urban and agricultural upper aquifers (i.e., the more vulnerable wells and those more likely to reflect activities during recent decades) mostly showed no significant trend detected between 2013 and 2023; however, more wells were found to be trending down (improving) than trending up (worsening) overall (Figure 3-16).

The 2013–2023 trend results were similar between the urban and agricultural upper-aquifer area wells. The sites with significant upward or downward trends were scattered throughout the state and generally did not appear to be located within any specific region or land use setting.

The MPCA-assessed trend results for ambient program wells sampled between 2007 and 2023 show similar results as the more recent decade trends (Figure 3-17 and Figure 3-18). The trend results for 108 wells developed in upper aquifers showed 3 (3%) increasing, 26 (24%) decreasing, and 79 (73%) with no trend. Trends in agricultural and urban land use settings were generally similar.

Figure 3-17. Nitrate concentration trends in 108 upper-aquifer wells sampled over 17 years (2007–2023); data from MPCA and MDA ambient monitoring program wells.



Relatively few upper aquifer wells in southeastern Minnesota are sampled through the ambient monitoring program described above, largely because the area is extensively monitored through other programs. In a separate monitoring program reported by Kuehner et al. (2025), 1,097 wells in southeastern Minnesota were assessed for trends between 2000 and 2021. Four percent had decreasing trends, 13% had increasing nitrate trends, and the remainder had either no trend or no detected nitrate. In the southeastern Minnesota study, wells impacted by more recent management on the land (younger groundwater less than 20 years old with elevated nitrate levels) were more likely to have either no trend or a decreasing trend. Wells with increasing trends were generally drawing older groundwater that entered the ground more than 20 years ago.

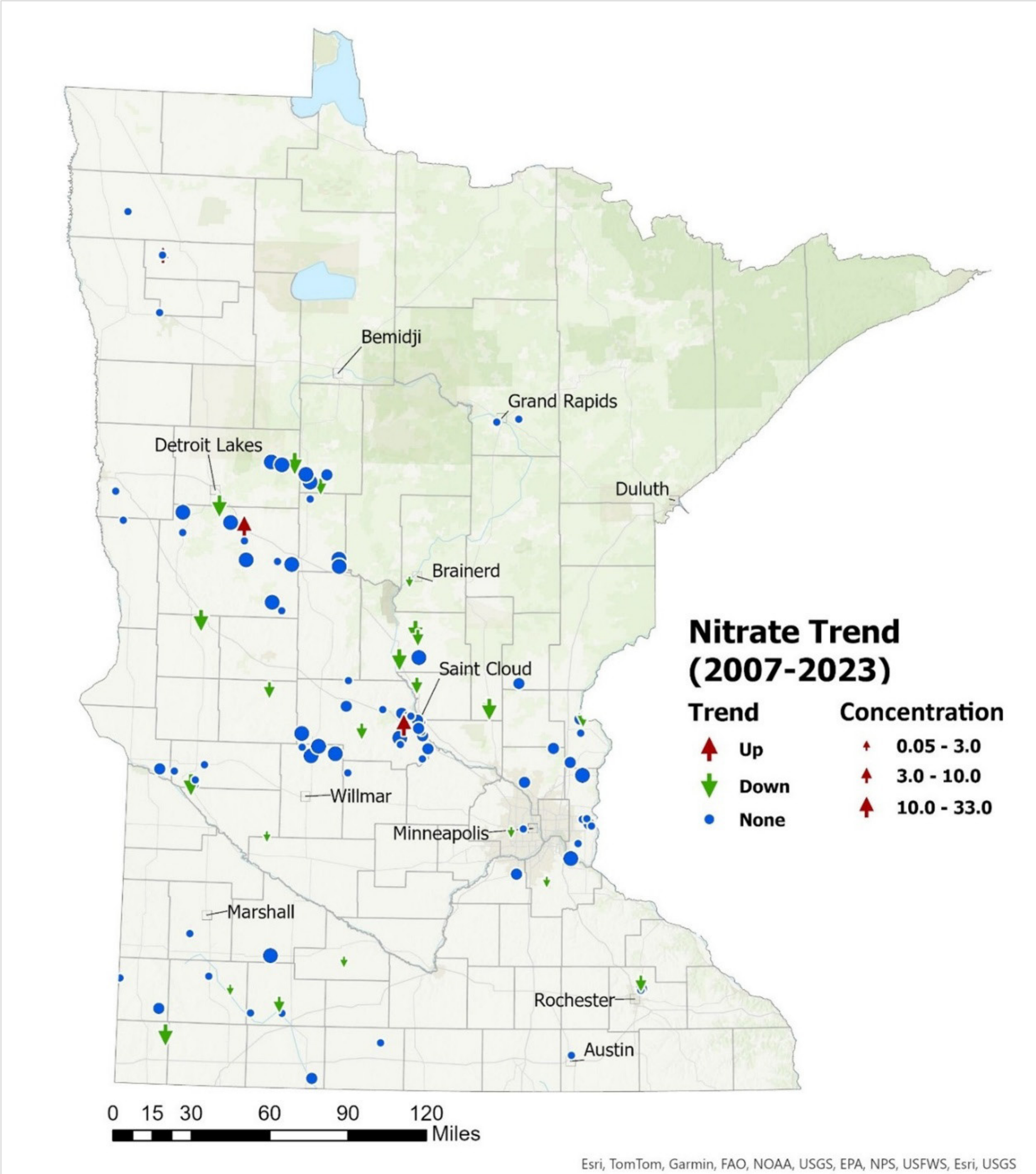
It is important to note that an increasing trend is not the same as high risk. Small nitrate additions to low nitrate waters can result in increasing trends without creating health concerns. Also, a decreasing trend does not necessarily indicate that the water quality is good. Nitrate decreases occurring in highly polluted wells may still require large nitrate reductions before the water is safe to drink.

Another consideration when evaluating trends is the lag times. The residence time of well water varies by geologic setting and well depth. Many private domestic wells, public wells, and groundwater-fed streams sampled today reflect the nitrate that entered the ground several decades ago. Well water conditions are influenced by the land use and management practices during the timeframe when the nitrate leached through the soil; therefore, the trends observed over the past decade may actually represent the effects of land management practices from years ago. For example, in southeastern Minnesota, many nitrate-impacted wells and springs have water that first entered the ground 10–40 years ago (Kuehner et al. 2025). Nitrate concentrations in certain springs, streams, and wells can continue increasing until equilibrium is reached with historical and modern land use practices.

Precipitation patterns can also affect trends. For example, the dilution of nitrate concentrations from above-normal precipitation can influence the trend results as stable or declining.

For the above reasons, the 2025 NRS emphasizes the need to continue long-term water monitoring and assess any practice changes in Minnesota's cities and cropped lands and to use that information to predict future outcomes (similar to the analyses included in Chapter 2).

Figure 3-18. Well water monitoring results (trend direction and relative concentrations) in 108 ambient upper aquifer wells sampled between 2007 and 2023.



Priority watersheds for well water nitrate concentrations

Across Minnesota, priority watersheds for aquatic life protection due to high nitrates (see Section 3.3.2) differ from the priority areas for well water protection. The priority watersheds differ because aquatic life can be affected by nitrates from tile-drainage systems and wastewater discharges, which bypass the groundwater or well-water pathway and enter surface waters more directly. A notable exception is the karst region of southeast Minnesota, where high nitrate concentrations can affect both drinking water use and aquatic life use because the chronic nitrate condition in the trout streams is directly associated with high nitrate levels in the local groundwater aquifers.

Mapping groundwater nitrate at a small scale more accurately shows the locations of locally high-nitrate well water because groundwater nitrate can vary substantially over short distances. However, for the well water nitrate priority watershed mapping, the HUC-10 watershed mapping scale was chosen so it could be more easily compared with watershed-scale priority maps for other nutrient-related concerns.

Two primary datasets were used to assess priority areas: (1) well sampling results generated from MDA's township testing program as provided by watershed, with results from the most recent round of testing, and (2) MDH's well water nitrate data systems. A third dataset was evaluated but not used for the NRS priority watershed maps due to its limited geographic extent.

Priority watersheds based on MDA township testing results

The MDA township well-testing program for nitrate was previously summarized, with results shown at the township scale. Here, the most recent results from wells sampled as part of the MDA township testing program were mapped at a HUC-10 watershed scale (Figure 3-19), including each watershed that had a minimum of 20 wells sampled. A nitrate concentration threshold of 5 mg/L was used; at this concentration, there is a higher potential for levels to increase to above 10 mg/L. Also, this concentration is similar to the 5.4 mg/L used by MDA as a threshold for increasing action in Level 1 drinking water supply management areas. Forty-one watersheds had more than 25% of wells sampled through the MDA township testing program, with nitrate exceeding 5 mg/L. Another 69 watersheds had 10% to 25% of recently sampled wells exceeding 5 mg/L.

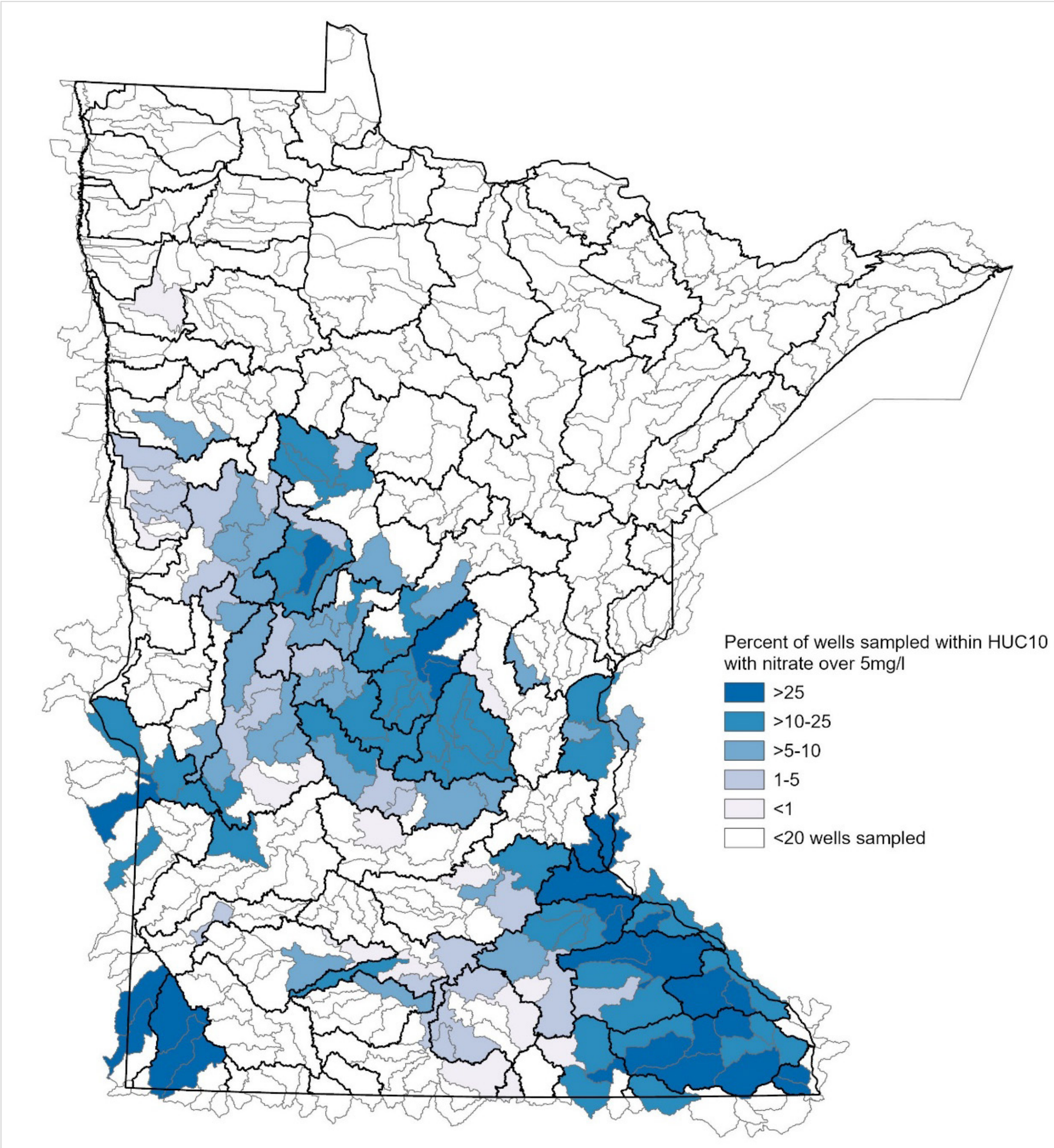
Three areas of the state stand out with a relatively high fraction of wells containing elevated nitrate levels: the southeastern karst region, the southwestern corner, and the central portion of Minnesota. Many parts of the state were not assessed through the MDA township testing program because they have a low geologic vulnerability and/or a relatively low fraction (< 20%) of agricultural cropland.

Priority watersheds based on MDH nitrate databases

The purposes of the well sampling programs and the data collection also significantly influence the results within the datasets. The largest fraction of the MDH well water nitrate sampling is WELLS data, which are generally biased toward lower nitrate concentrations because the dataset was developed largely from newly constructed wells. Well drillers typically know the depth required to drill new wells to obtain acceptable levels of nitrate in a given area. When deeper aquifers are accessible, they will usually drill deeper to meet state or local standards for drinking water quality (i.e., < 10 mg/L nitrate-N).

While the WELLS dataset does not represent a random sampling of groundwater nitrate conditions, it was included in this analysis because it has the broadest geographic coverage across the state of any nitrate dataset and is useful for identifying potential areas of high nitrate. In the MDH datasets, most HUC-10 watersheds across Minnesota (86%) have at least 20 wells with nitrate results.

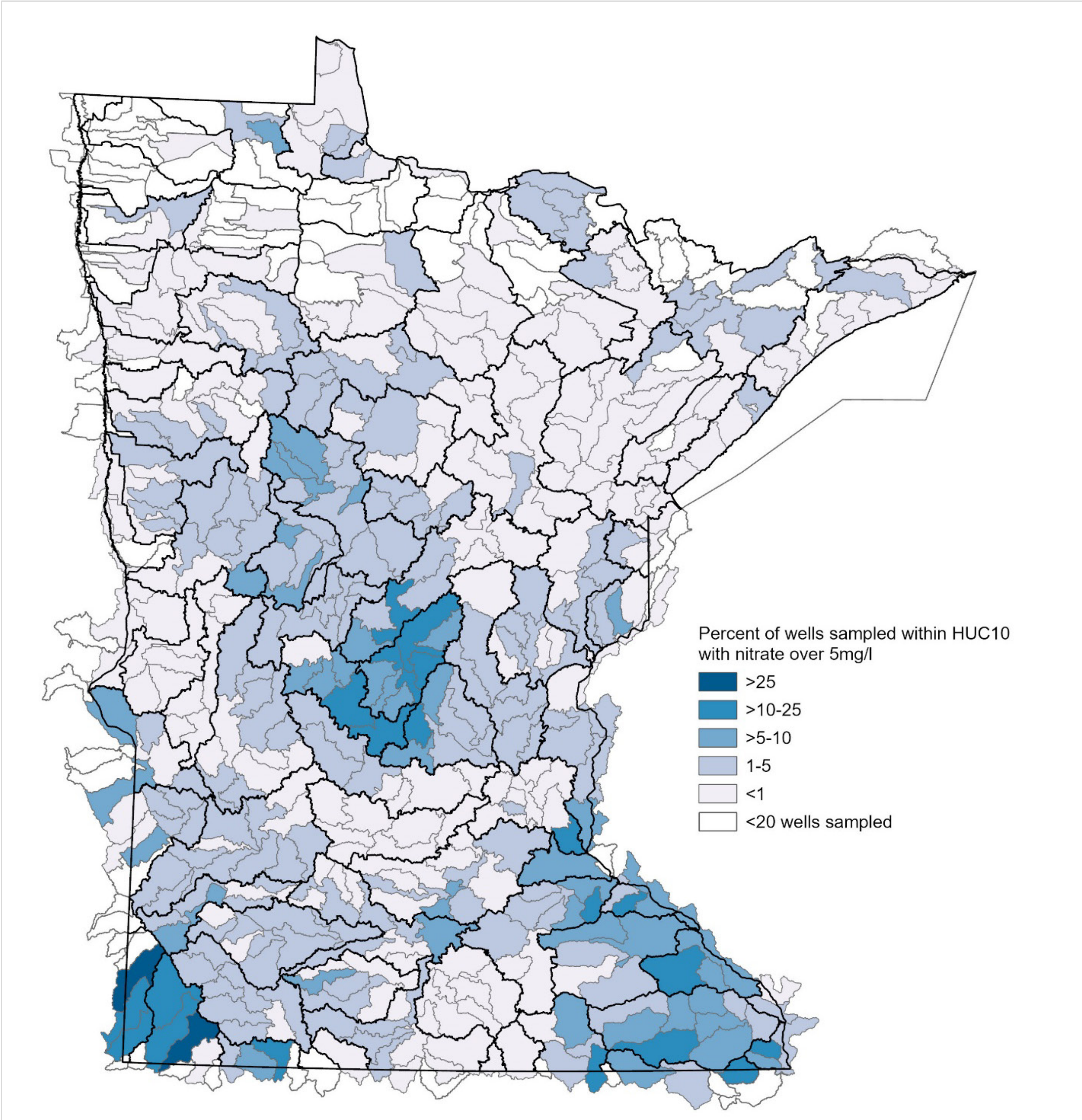
Figure 3-19. Priority watersheds for groundwater nitrate based on the fraction of high-nitrate wells sampled through MDA's Township Testing Program.



Notes: Analysis used the most recent well monitoring result for each well in watersheds where 20 or more wells were sampled between 2014 and 2020. Specific watershed identifiers for high-priority watersheds are provided in Appendix 3-1.

Like the MDA Township Testing Program, MDH nitrate data shows three parts of Minnesota with the most elevated nitrate concentrations in wells: central Minnesota, southeastern Minnesota, and the southwestern corner (Figure 3-20). While the spatial patterns are similar between the two datasets, the fraction of wells above 5 mg/L is considerably lower in the MDH datasets due to the nature of the types of wells and the reasons for sampling those wells.

Figure 3-20. Priority watersheds based on the fraction of high-nitrate wells tracked in MDH datasets.



Notes: Nitrate concentration ranges are represented by the highest nitrate concentration recorded for each well, including only where 20 or more wells were sampled within the HUC-10 watershed. Specific watershed identifiers for high-priority watersheds are provided in Appendix 3-1.

The MDA dataset was created by sampling existing wells in geologically vulnerable agricultural townships. In contrast, the MDH dataset mostly includes the results from newly drilled wells across the entire state. When considered together, both datasets provide nearly complete coverage of the state and generally show the areas of Minnesota with higher and lower probabilities of observing high nitrate levels in wells. In any specific watershed, further monitoring may be needed to verify the results.

Ambient groundwater monitoring dataset not used for prioritization

A third well water sampling dataset was assessed for potential use in mapping priority watersheds for well water nitrate. The EQuIS database includes all ambient monitoring data from MPCA and MDA, along with wells sampled as part of DNR's Groundwater Atlas development program. This dataset represents results from a combination of domestic wells and monitoring wells located away from domestic residences. This dataset includes over 3,400 sampled wells, with 23% of those wells having recent nitrate concentrations exceeding 5 mg/L.

Far fewer HUC-10 watersheds from this dataset met the minimum of 20 sampled wells, as compared to either the MDA Township testing or WELLS datasets. Watersheds in this dataset with more than 20 well water nitrate samples were generally a subset of the same watersheds mapped with MDA and/or MDH datasets. For these reasons, this third dataset was not used to identify priority watersheds across the state. A few watersheds from this dataset showed a notably higher potential of having high nitrate levels than the other two datasets, emphasizing the need to monitor further before drawing conclusions about the degree to which wells are impacted by nitrate in these watersheds.

Combined map of groundwater nitrate priority areas

Mapping the highest category between the MDH database and MDA township testing datasets provides a means of viewing the combined results across the state (Figure 3-21). The combined map shows the same general patterns as expected based on those previously shown in Figure 3-19 and Figure 3-20. Priority watersheds are evident in the central part of the state, where both cropland and sandy soils are found. The geologically vulnerable karst region in southeastern Minnesota, as well as the geologically vulnerable areas of southwestern Minnesota, are also clear priority areas.

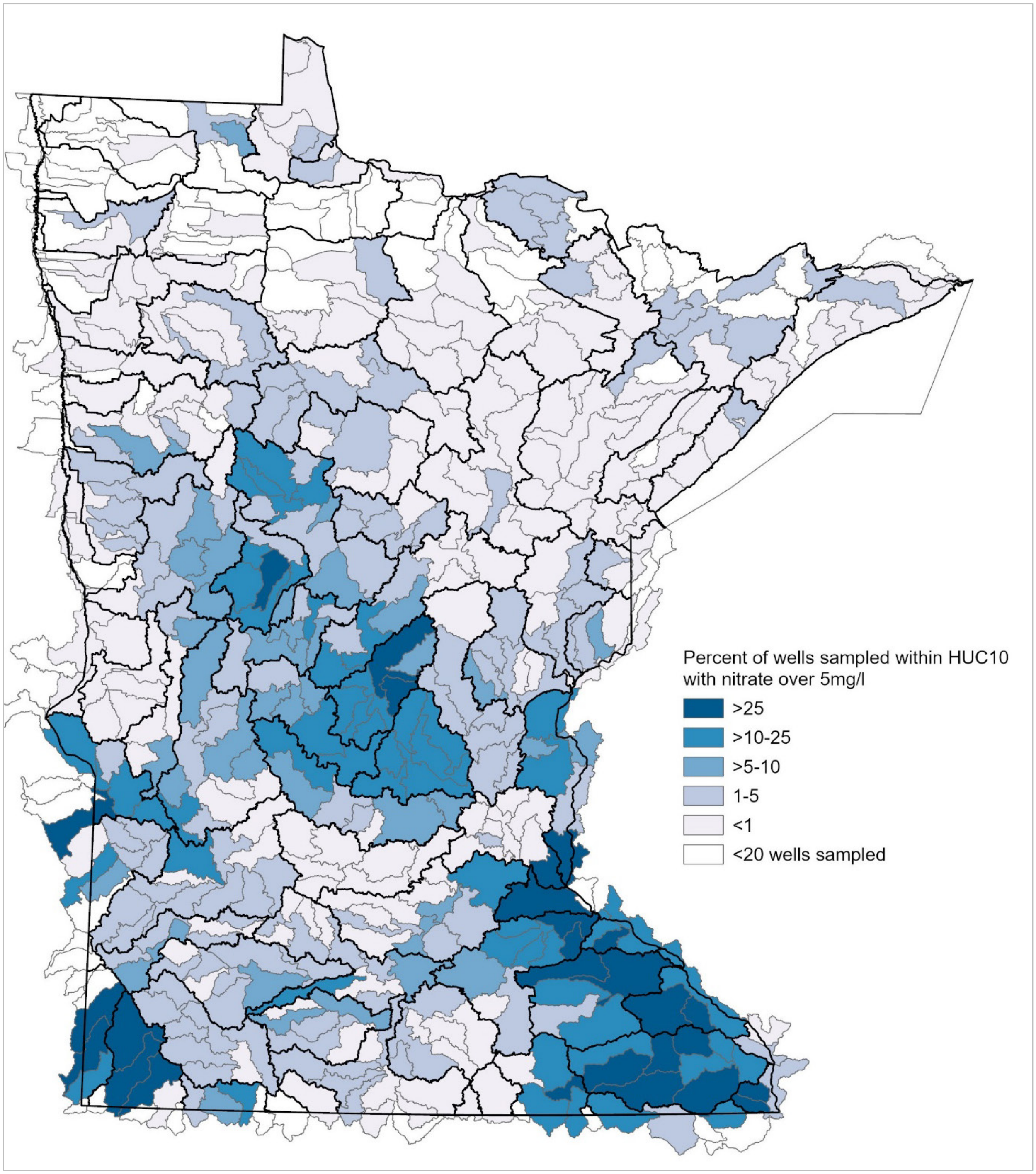
Prioritization efforts to reduce nitrate leaching should consider both surface water and groundwater nitrate reduction needs. The southeastern Minnesota region has high nitrate levels in streams and well water. In this karst geology part of the state, surface water and groundwater are highly interconnected. The southwestern corner of Minnesota also has high-nitrate priority watersheds for both streams and well water.

South-central Minnesota shows large differences between well water nitrate (see Figure 3-20) and the stream water nitrate discussed in Section 3.3.2. This region has many tile-drained soils, which are largely fine-textured (clayey glacial till) with slow water percolation. In this region, nitrate leaches quite slowly below the root zone toward groundwater and is often lost to the atmosphere through denitrification before the groundwater reaches local wells. As a result, south-central Minnesota has high-nitrate streams caused largely by agricultural tile drainage, but it has comparatively few groundwater wells with high nitrate levels.

Working farm in Carver County, MN

The central and north-central portions of Minnesota have many high-nitrate wells but comparatively lower stream nitrate concentrations. In this area, farmed sandy soils are common. The underlying sand aquifers have locally high nitrate levels below nitrate sources, such as fertilized cropland. However, with increasing distance from the nitrate sources, the nitrate concentrations typically decrease through a combination of denitrification in the aquifer and dilution from areas with land uses that produce less nitrate (i.e., forests).

Figure 3-21. Priority watersheds for groundwater nitrate based on the highest category rankings from MDH and the MDA Township Testing Program.



Note: Specific watershed identifiers for high-priority watersheds are provided in Appendix 3-1.

3.3.2 River nitrate concentrations

Concerns with nitrate and aquatic life health

Nitrate is both a naturally occurring compound and an important nutrient in the life cycle of plants in natural and cultivated settings. However, when present at concentrations well above natural or background levels, it can also be toxic to aquatic organisms in Minnesota's surface waters (MPCA 2022a).

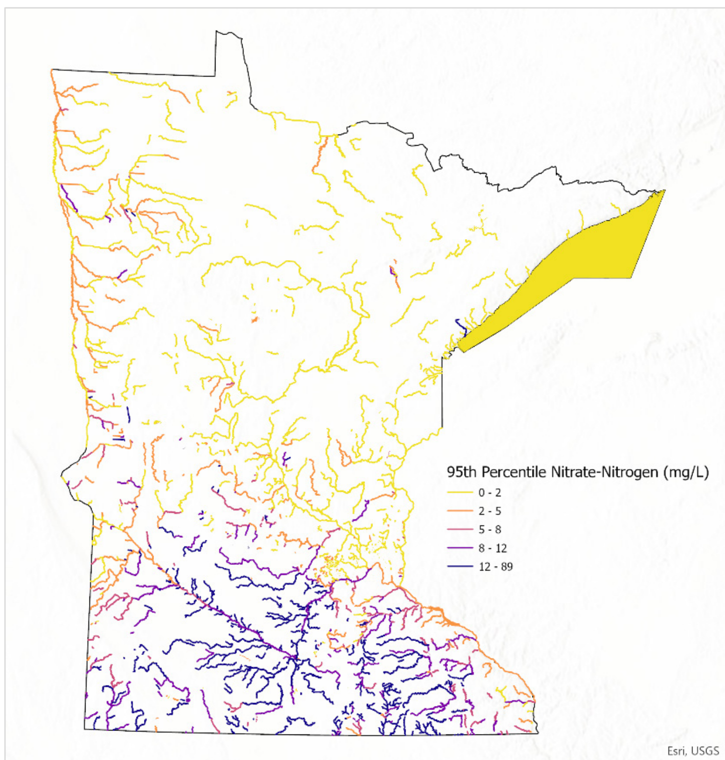
The nitrate standard development process is independent of the 2025 NRS, and analyses conducted for the NRS are not directly related to establishing numeric nitrate standards. However, recognition of these developing standards by the NRS is important because of the large fraction of southern Minnesota rivers and streams that could be affected. Addressing nitrate concentrations in local streams will affect both local and downstream waters.

The MPCA began to develop draft nitrate standards in 2011 but paused the effort after determining that additional research was needed. In October 2022, the MPCA added more recent research results to a draft technical support document for aquatic life toxicity related to nitrate in surface waters (see *Aquatic Life Water Quality Standards Draft Technical Support Document for Nitrate*). The document proposes draft numeric standards based on peer-reviewed literature for nitrate to protect aquatic life in the state's lakes and streams designated as Class 2 waters. This use classification sets specific rules for protecting cold-water uses (Class 2A) and cool/warm water uses (Class 2B).

The MPCA developed the draft WQS for nitrate to protect river and stream beneficial uses based on the best available scientific information. The draft acute value (maximum standard) calculated was 60 mg/L nitrate-N for a 1-day duration concentration for all Class 2 waters. This high concentration is rarely exceeded in Minnesota waters.

However, the MPCA's mapping of the 95th-percentile nitrate concentrations across the state shows that the draft chronic values are commonly exceeded in streams and rivers throughout much of southern Minnesota (Figure 3-22). The draft chronic values are 8.26 mg/L (rounded to 8 mg/L) nitrate-N for cool/warm waters (Class 2B) standards and 5 mg/L nitrate-N for cold waters (Class 2A), based on a 4-day duration exceedance.

Figure 3-22. High-end (95th percentile) nitrate-N concentrations in streams sampled at least 10 times during recent years by MPCA.



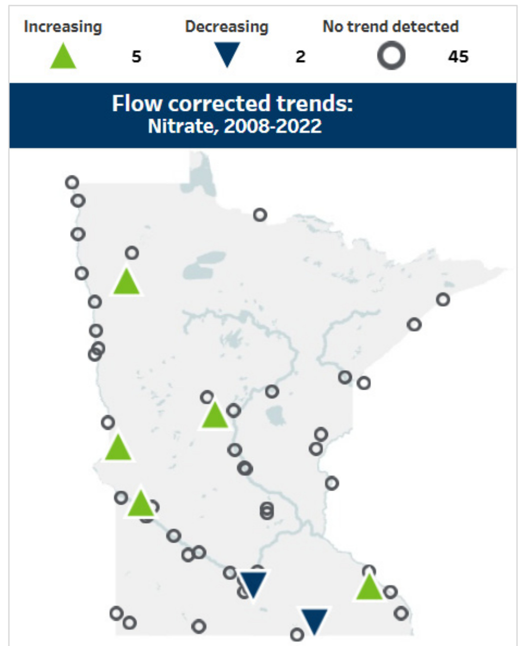
Trends in river nitrate concentrations

In Chapter 2, the NRS discusses trends in TN loads at key large-river sites around the state. In Chapter 3, the analyses focus on nitrate concentrations in medium-sized and large rivers across Minnesota.

Nitrate concentration, as opposed to the TN load, is the parameter that most directly pertains to nitrogen-related standards and draft standards in Minnesota's waters.

While phosphorus concentrations have been decreasing at many river sites throughout the state, nitrate concentrations have varied more depending on the dataset, region of the state, watershed size, time period, and other factors. Between 2008 and 2022, nitrate concentrations at 52 medium- and large-scale rivers monitored by the MPCA decreased (improved) at two sites (4%) and increased at five sites (10%), while the overwhelming majority, 45 sites (86%), had no trend detected (Figure 3-23; also see the long-term stream trends in Minnesota website). When not correcting for flow variability, the number of sites with increasing concentrations changes from five to nine sites, indicating the effects of weather and climate variability on nitrate concentrations. By increasing the trend analysis timeframe to 2003–2023, monitoring sites in the Minnesota River Basin show more decreases, while other parts of the state exhibit a mix of increases and no trend detected.

Figure 3-23. Nitrate concentration trends at 52 MPCA-monitored river sites (2008–2022).



Note: Trends are corrected for flow variability.

In the Twin Cities region, the Met Council evaluated nitrate trends in streams dominated by both urban and agricultural land uses (Met Council 2023). Stream watersheds (HUC-10 and HUC-12) in the Twin Cities Metropolitan region show mixed trends in nitrate concentrations, which vary by the assessed timeframe and land use.

Urban watershed nitrate concentration long-term trends (2000–2021), assessed by the Met Council, show decreases (improvement) in four watersheds, an increase in one watershed, and three with no trend or mixed trends. Nitrate concentrations in urban watersheds remain low, with FWMCs typically less than 1 mg/L.

Nitrate concentrations in agriculturally dominant watersheds, as monitored and assessed by the Met Council, are higher compared to those in urban watersheds. When combining urban and agricultural watersheds, seven streams showed a decreasing trend, two showed an increasing trend, and five had no trend or showed a mix of increases and decreases over time.

The Met Council has also assessed major river nitrate concentrations in the metropolitan area using monitoring data collected since the late 1970s. Using QWTREND, a flow-normalized statistical pollutant concentration trend model, the Met Council found different nitrate (nitrite+nitrate) trends at three monitoring sites (Table 3-8).

As shown in Table 3-8, the Met Council found no statistically significant trend for nitrate concentration at the three major river sites over the past decade. Examining the long-term trends, flow-normalized nitrate concentrations have decreased in the Minnesota River since the 1970s, whereas nitrate concentrations in the Mississippi River have increased. Differences in lag times in these river systems may be affecting these differences. The Minnesota River nitrate sources are much more influenced by cropland tile drainage, which has a relatively quick travel time to the rivers. The Mississippi River nitrate levels are influenced by groundwater nitrate, which has a slow travel time to surface waters. Other possible reasons for trend differences include unequal changes in management and land use, as well as different natural capacities for denitrification.

Table 3-8. Statistical trends ($p < 0.1$) for flow-normalized nitrate concentrations since the late 1970s.

River monitoring site (trend years)	Average nitrate concentration at start of sampling period (mg/L)	Average nitrate concentration in 2023 (mg/L)	Change in nitrate concentration
Minnesota River at Jordan (1979–2023)	3.16	2.22	29.7% decrease
Mississippi River at Anoka (1976–2023)	0.52	0.86	67.0% increase
Mississippi River at Red Wing (1981–2023)	1.59	1.98	24.3% increase

Source: Met Council 2024 and Hong Wang, Met Council, personal communication, January 8, 2026

It should also be noted that the Mississippi River in Anoka also has much lower nitrate concentrations than the Minnesota River and the Mississippi River at Red Wing, even though a 67% increase has been observed. A given change in nitrate concentration in Anoka will have a larger percentage change than if that same nitrate concentration change had occurred at the other two sites.

Also, it is important to note that nitrate trends do not equal trends in TN. For example, TN concentrations at Red Wing showed a nonsignificant 2.1% decrease between 1981 and 2023, whereas nitrate concentrations had increased by 24.3%. In addition to nitrate, TN contains organic nitrogen and ammonium. The fraction of TN that is nitrate varies greatly across the state.

Load reduction goals for state lines are based on TN, whereas local in-state goals are based on nitrate concentrations. Nitrate concentrations affect local concern for drinking water or the aquatic life in rivers and streams. However, because rivers carry nitrate and the other forms of nitrogen, such as organic nitrogen, to downstream waters, these other forms of nitrogen can be converted to nitrate during the long transport process to waters like the Gulf and Lake Winnipeg.

More details and results associated with the Met Council's nitrate concentration trend analyses are included in Appendix 2-2.

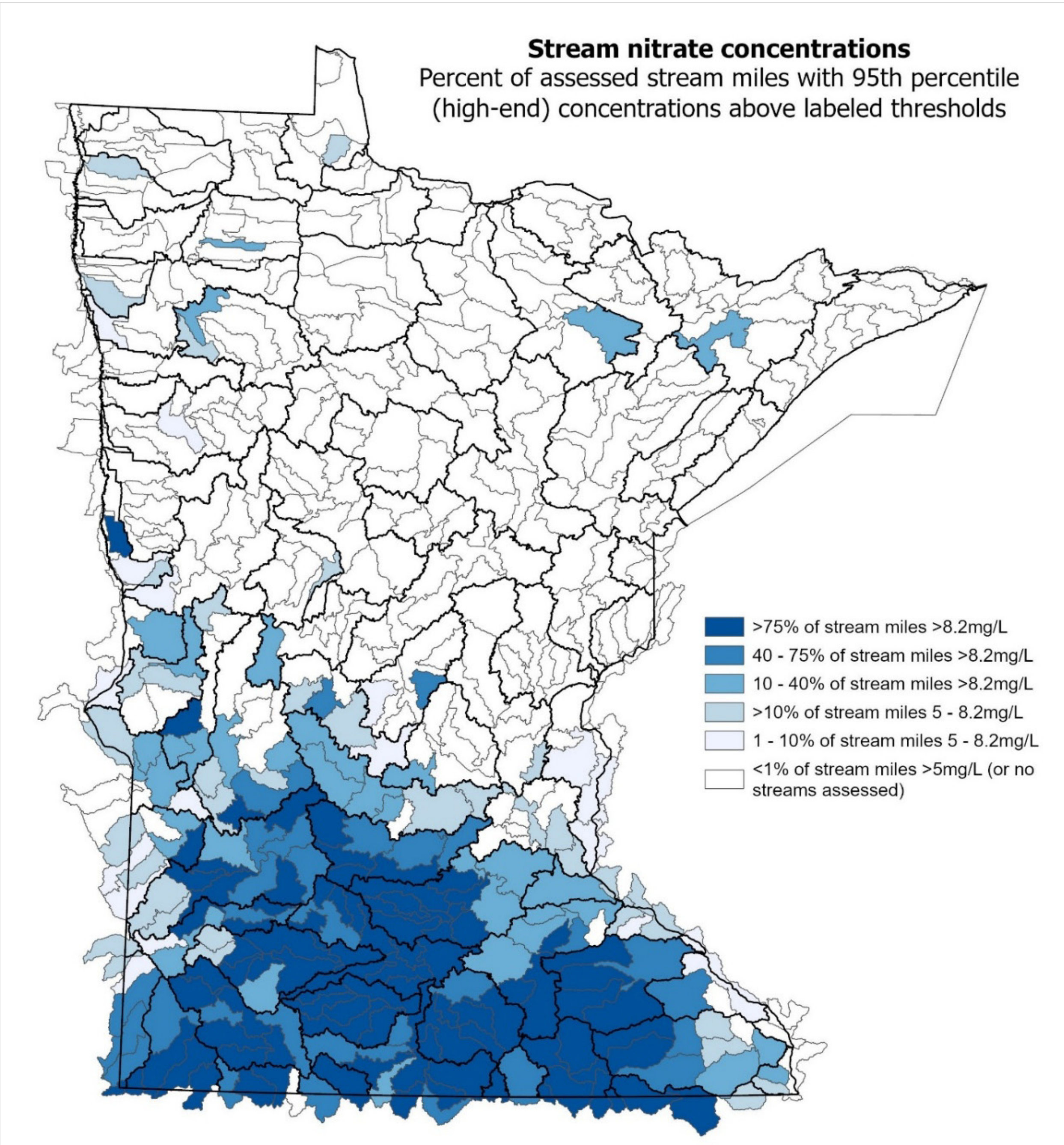
Priority watersheds for river nitrate and aquatic life

The local watershed planning team establishes local water priorities within each HUC-8 watershed through comprehensive local water planning processes (see Chapter 6). Each watershed planning team uses its own methods for selecting these local priorities. In the context of the NRS, priority HUC-10 watersheds were assessed for (1) river and stream nitrate concentrations for aquatic life toxicity potential and (2) well water nitrate concentrations and drinking water (previously discussed).

Over 75% of assessed stream and river miles in most southern Minnesota watersheds have high nitrate concentrations (i.e., more than 8 mg/L), enough to potentially harm aquatic organisms (see Figure 3-22). Correspondingly, as shown in Figure 3-24, watersheds that frequently exceed this threshold are predominantly watersheds where cultivated row crop agriculture is the primary land use and are a high priority for nitrate reduction. Watersheds with a mix of cultivated agricultural land and urban or forested land cover have lower nitrate aquatic life impacts, while much of northern Minnesota has very low nitrate stream concentrations.

Southern Minnesota includes a large fraction of land with (1) cropland tile drainage with direct, faster-flowing pathways to surface waters or (2) a shallow depth to fractured bedrock and a high geologic vulnerability. Other parts of the state without fractured bedrock and with less tile drainage have slower-flowing subsurface pathways to surface waters. This additional water travel time often permits natural nitrate treatment through denitrification (i.e., the conversion of nitrate to nitrogen gas) between the nitrate source and the receiving stream. Most streams in northern Minnesota have less than 1% of stream miles exceeding 5 mg/L (see Figure 3-19). This part of the state has fewer nitrate source areas, less tile drainage, and/or slow groundwater flow. However, note that the nitrate concentrations in some north-central Minnesota rivers and streams have shown increasing trends in recent decades. The highest-priority watersheds for nitrogen reduction include those where overlapping priorities exist for drinking water, aquatic life toxicity, and the loads delivered to waters downstream of Minnesota.

Figure 3-24. Priority watersheds for potential aquatic life toxicity concerns based on nitrate concentrations that exceed thresholds (95th percentile) in monitored stream miles.



3.3.3 Addressing local and downstream nitrogen reduction needs together

Large nitrate reductions will be needed to meet in-state drinking water standards and improve the health of aquatic organisms. Achieving these nitrate reductions for local waters will provide cascading benefits for larger downstream rivers as well as national and international waters beyond Minnesota. But by how much? If each HUC-8 watershed implementation team works to meet nutrient-related standards for waters within their drainage area, will that be enough to collectively meet the needs of downstream waters? In what areas will it be enough to focus on local nitrate reductions, and in what areas will more work be needed within the watersheds to meet downstream needs as well?

Mississippi River Basin

For the Mississippi River, nitrate reduction goals will not be met if efforts focus only on improving high-nitrate drinking water. Reductions, in addition to those for groundwater nitrate, will especially be needed in tile-drained areas. Heavily tile-drained watersheds typically have low nitrate in groundwater/ well water, but they contribute the most nitrogen to the Mississippi River nitrogen loads. However, addressing both local drinking water and local river/stream aquatic life protection from high nitrate levels could, in combination and based on best available estimates, would enable Minnesota to achieve its commitment for the Mississippi River nitrogen levels headed toward the Gulf.

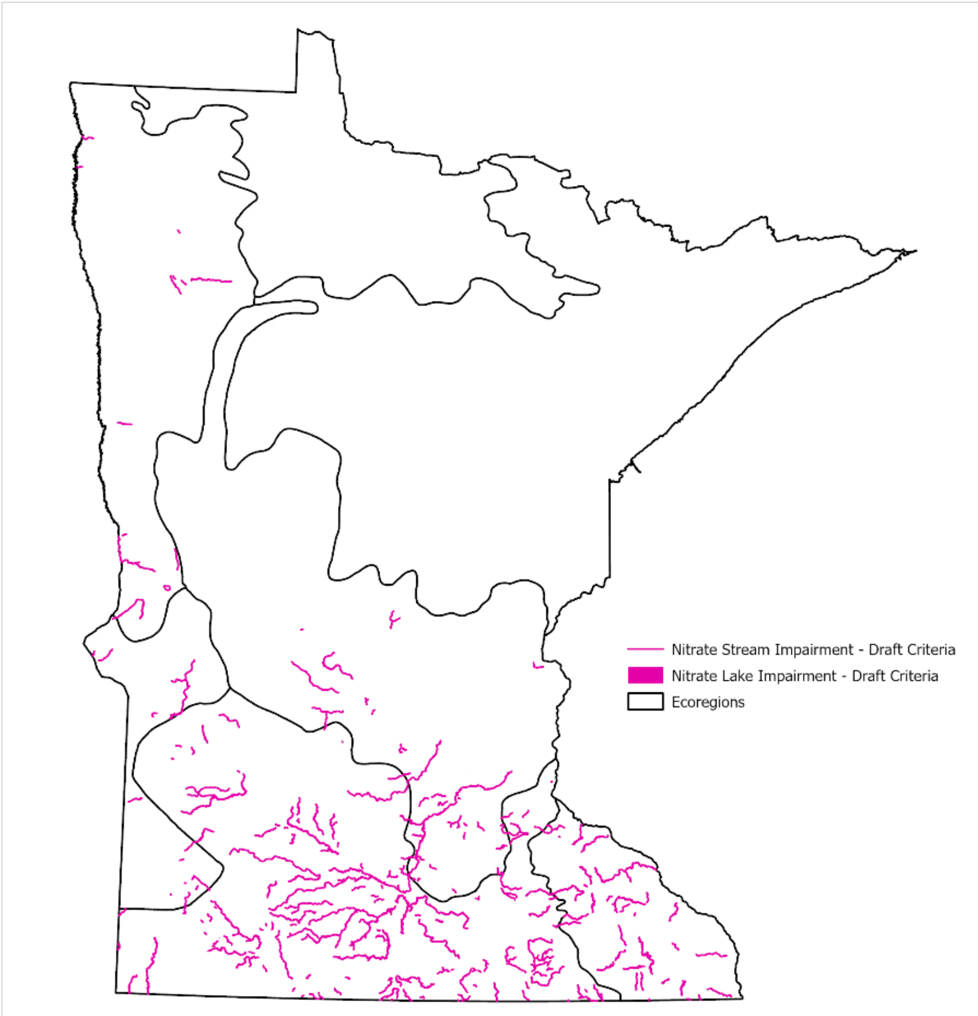
For nitrate, addressing drinking water problems in groundwater and surface water (i.e., where the MCL or standards are exceeded) will result in incremental reductions in Mississippi River nitrate at the state line. Based on the MDA Township Testing Program data, the average nitrate concentration in high-nitrate wells (those exceeding 10 mg/L) is approximately 16 mg/L. A reduction of at least 38% would be necessary to lower this current average to meet the 10 mg/L health risk limit.

In these high-nitrate groundwater areas, the magnitude of such a reduction would align reasonably well with the Mississippi River nitrogen reduction needs. Because groundwater contributes less than one-third of the nitrogen load to the Mississippi River, however, substantial reductions would be needed in other geographic areas—beyond the areas with high groundwater nitrate levels—to achieve the final goal for Mississippi River nitrogen (e.g., tile-drained cropland and urban areas). Also, because groundwater often flows slowly to surface waters, reducing nitrate concentrations in groundwater might take decades to translate into lower nitrate levels reaching rivers and streams (as previously described).

Protecting aquatic life from chronic nitrate toxicity may be another potential local driver for substantially reducing nitrate levels entering surface waters. For example, the peak nitrate level in streams with a high-nitrate average (those with more than 5 mg/L) is 10.4 mg/L, with many streams much higher than the average. Statewide, the average reduction needed among all waters over 8 mg/L is 32%.

The needed reductions vary widely (0%–80%) for a given water. The needed nitrate reductions vary spatially as well. For instance, Figure 3-25 shows a clear majority of waters with nitrate concentrations greater than 8 mg/L occurring in the southern portion of Minnesota. The magnitude of a 32% nitrate reduction aligns reasonably well with the needs in the Mississippi River; however, a full analysis of the effect of achieving 8 mg/L of nitrate in nonsalmonid waters on downstream load reductions has not yet been conducted.

Figure 3-25. Streams and lakes in Minnesota exceeding 8 mg/L nitrate.



Red River Basin

Red River Valley, MN

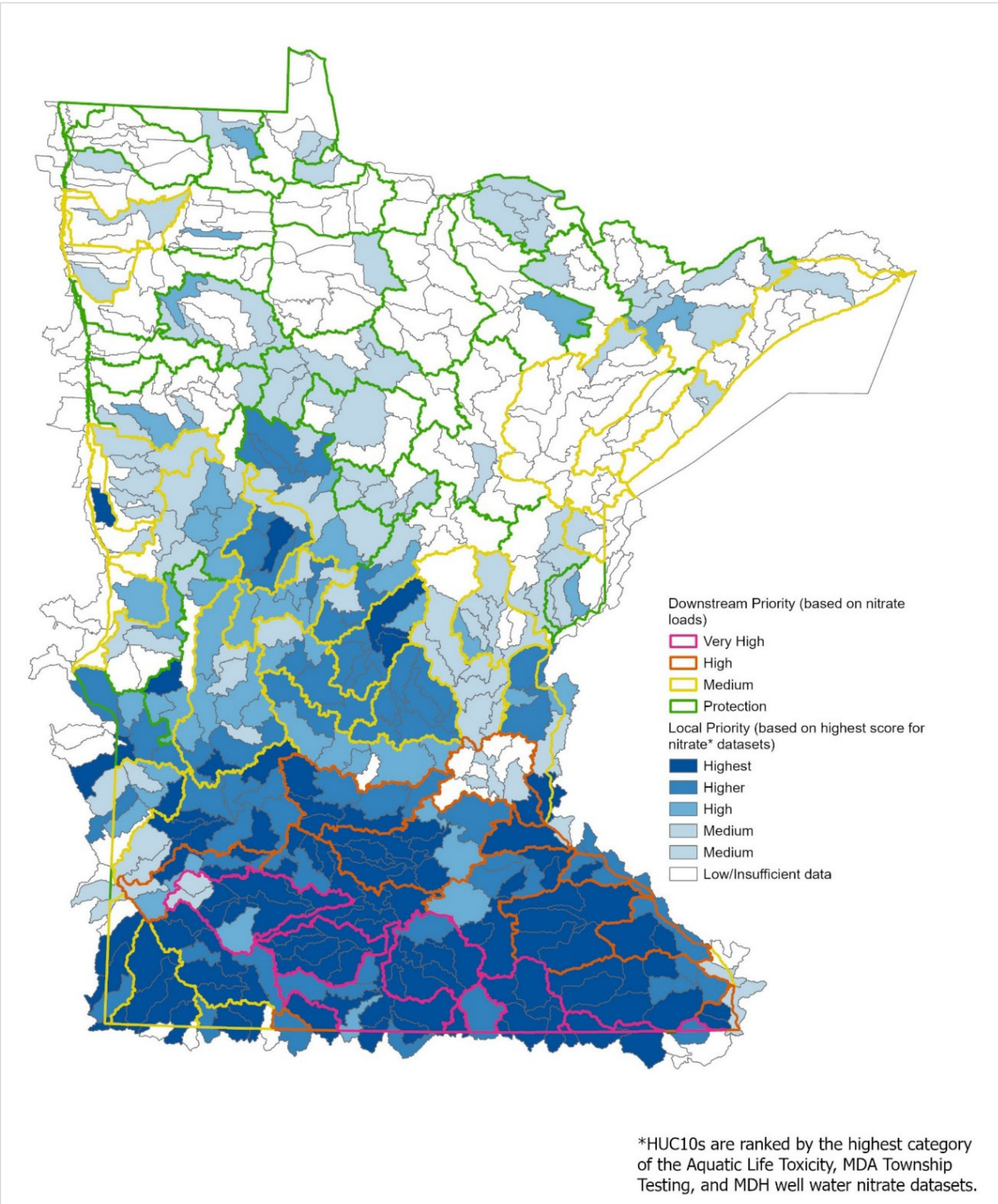
In the Red River Basin, which drains into Lake Winnipeg, the local drivers for drinking water and aquatic health nitrate reductions are largely absent and thus will not be sufficient to affect the TN load reduction needs for commitments to Lake Winnipeg. In this region, the nitrate concentrations are generally lower in both groundwater and streams than in large parts of the Mississippi River Basin.

The local needs for nitrate reduction differ in the Red River Basin compared to the Mississippi River Basin. The Red River Basin has relatively few streams and wells above nitrate drinking water standards or above the proposed draft aquatic life toxicity standard when compared to the Mississippi River Basin; therefore, meeting all standards for local waters in this region of the state is not expected to substantially reduce the TN loads reaching the Red River and Lake Winnipeg. The nearly 50% TN load reduction needed in the Red River Basin will require considerable additional nitrogen reductions after addressing local nitrogen priority concerns.

Priority watersheds for combined nitrogen needs

When overlaying the highest ranking in-state HUC-10 watershed nitrate priority category with the priority HUC-8 categories for contributing TN loads downstream of Minnesota (as included in Chapter 2), much of the state is at least a high priority for addressing nitrogen in water (Figure 3-26). Southern Minnesota has the highest priority rankings for both in-state and downstream needs. Central Minnesota loads have less impact downstream of Minnesota, but it has a number of local watersheds in the second-highest category for in-state needs due mostly to well-water nitrate concerns.

Figure 3-26. Highest-category nitrate priority HUC-10 watersheds, along with the priority watersheds contributing TN loads downstream of Minnesota.



Conclusion

Minnesota’s highest-priority strategies should focus on where local actions will address both local water concerns and downstream needs, including addressing high-nitrate groundwater and protecting aquatic life from harm in local rivers and streams. Addressing drinking water alone will not be enough to achieve the goals for waters downstream of Minnesota. But, by addressing high-nitrate-related toxicity for both drinking water and aquatic life, Minnesota’s commitment to downstream waters at state lines is expected to be largely met in the Mississippi River Basin. Because the same drinking water and aquatic health local drivers for nitrate reductions in the Mississippi River drainage basin will not be sufficient to meet goals in the Red River Basin, further attention to nitrate reduction in the Red River Basin will be important for achieving Minnesota’s commitments to Manitoba for Lake Winnipeg.

3.4 Recommendations for future actions

Based on an analysis of the in-state phosphorus and nitrate reductions and priorities, the NRS recommends the following future efforts:

- Continue the monitoring and trend analyses of lake, river, and groundwater nutrient concentrations and evaluate the progress with nutrient-impaired waters. Consider where additional monitoring sites could be beneficial, such as increasing the number of groundwater monitoring wells.
- Develop an interagency NRS long-term monitoring and assessment plan, coordinating work among state, federal, and metropolitan agencies and organizations to ensure clarity of roles, minimize overlap, prevent data gaps, and align methods.
- Continue documenting progress results determined from ongoing monitoring and discuss updated findings at NRS partner workshops regularly (e.g., annually or biannually).
- Focus on in-state phosphorus reduction needs for local and regional lakes and rivers, which will also address most of the phosphorus reduction needs for the Mississippi River. More phosphorus reduction actions will be needed in the Red River Basin, where, although relatively few nutrient impairments exist within Minnesota, nutrient reduction needs exist downstream of Minnesota.
- Continue addressing local impairment priorities and lake protection priorities using the watershed approach and other programs identified in chapters 4, 5, and 6.
- Communicate NRS priority HUC-10 watershed information to local watershed planners so they can consider this information when updating plans and priorities within their areas of jurisdiction.
- Reduce river and stream nitrate concentrations, especially from cropland sources in southern Minnesota, where nitrate levels are high enough to affect aquatic life and contribute considerably to the river pollutant loads leaving the state.
- Reduce nitrate concentrations in surficial aquifers vulnerable to groundwater nitrate contamination from overlying nitrate sources (particularly row-crops). Aim to concurrently benefit local drinking water resources and reduce nitrate seeping into rivers and streams and, ultimately, reduce Minnesota’s nitrogen loads to states and provinces downstream of Minnesota.
- Track trends and progress toward achieving safe and healthy waters for Minnesotans, as described in Chapter 7. Periodically assess lake and river nutrient concentration trends, well water nitrate concentration trends, and river and stream nitrate concentration trends.

3.5 NRS support documents

- Appendix 3-1: Priority watershed lists for lake phosphorus, river phosphorus, well water nitrate and stream nitrate concentrations for aquatic life protection.

Chapter 4
Urban Nutrient Reduction

Key messages

- Urban nutrient sources—domestic and industrial wastewater effluent and stormwater runoff—contribute to local watershed nutrient loads and those leaving the state. These sources contribute a greater percentage of nutrients to the Lake Superior watershed relative to their presence in the Mississippi River and Lake Winnipeg watersheds, but both sources must be reduced in all watersheds to meet NRS goals in and out of state.
- WWTFs have effectively treated phosphorus across the state, cutting loads by 76% since 2000–2002.
- The 2014 NRS outlined a plan to address nitrogen in wastewater effluent; greater nitrogen monitoring in effluents was established to better understand the nitrogen discharged by the wastewater sector.`
- The MPCA released a Wastewater Nitrogen Reduction Strategy in 2024, which includes phased implementation. Fully implementing it will result in NRS's wastewater sector nitrogen reduction goals being met, but the implementation process will likely be lengthy and costly.
- To reduce nutrients in wastewater effluent in the future, Minnesota should continue to support the successful treatment of phosphorus in wastewater. The state should plan for WWTFs to manage nitrogen by supporting the optimization of and funding for wastewater infrastructure and pursuing opportunities to expand nutrient trading.
- Urban stormwater runoff contributes small amounts of nutrients to most watersheds; however, these nutrients, especially phosphorus, can have large impacts on local water bodies and the nearshore areas of Lake Superior.
- Minnesota has fostered a comprehensive and innovative stormwater program that is well-integrated into its Water Management Framework and the work of municipal governments, state agencies, and research institutions.
- Stormwater management effects are challenging to measure, but the recent removal of dozens of urban lakes from the state's impaired water list, along with good water quality trends in urban streams, show that these efforts are working.
- To continue achieving successful nutrient management in stormwater, Minnesota should maintain its current programs and seek opportunities to build on previous successes.

4.1 Wastewater nutrient reduction

Reducing nutrient loads in wastewater effluent is challenging. Despite this, the wastewater sector has continued to achieve extraordinary reductions in effluent phosphorus since 2000. As of December 2023, 415 municipal and 61 industrial wastewater NPDES and State Disposal System (SDS) permits include TP effluent limits. Statewide effluent TP loads have decreased by 76% from a 2000–2002 average load of 1,838 MT/yr to a 2021–2023 average load of 443 MT/yr. In contrast, only nine municipal and three industrial NPDES/SDS permits include TN or nitrite-plus-nitrate effluent limits. However, the number of municipal and industrial WWTFs monitoring effluent TN concentrations has increased substantially in accordance with the recommendations of Minnesota's 2014 NRS. Effluent TN loads for the 2000–2016 period are mostly derived from estimated effluent TN concentrations. Effluent TN loads for the period from 2017 through the present are mostly derived from monitored effluent concentrations. The uniformity between the pre- and post-2017 TN load estimates suggests that the estimates for the earlier time period were relatively accurate. Statewide effluent TN loads are estimated to have increased by 2% from a 2000–2002 average load of 13,893 MT/yr to a 2021–2023 average load of 14,111 MT/yr, with annual variability attributed mainly to the variability in effluent flow volumes.

4.1.1 Phosphorus in wastewater

Wastewater effluent phosphorus loading changes since 2000

Substantial progress has been made in reducing wastewater effluent phosphorus loads in the Des Moines River, Minnesota River, Mississippi River, Missouri River, Rainy River, and Saint Croix River major basins since the year 2000 (Figure 4-1; Table 4-1). Minor wastewater effluent phosphorus load reductions have been achieved in the Red River Basin, while loads in the Cedar River and Lake Superior basins have remained relatively stable.

Figure 4-1. Wastewater effluent phosphorus loads by basin.

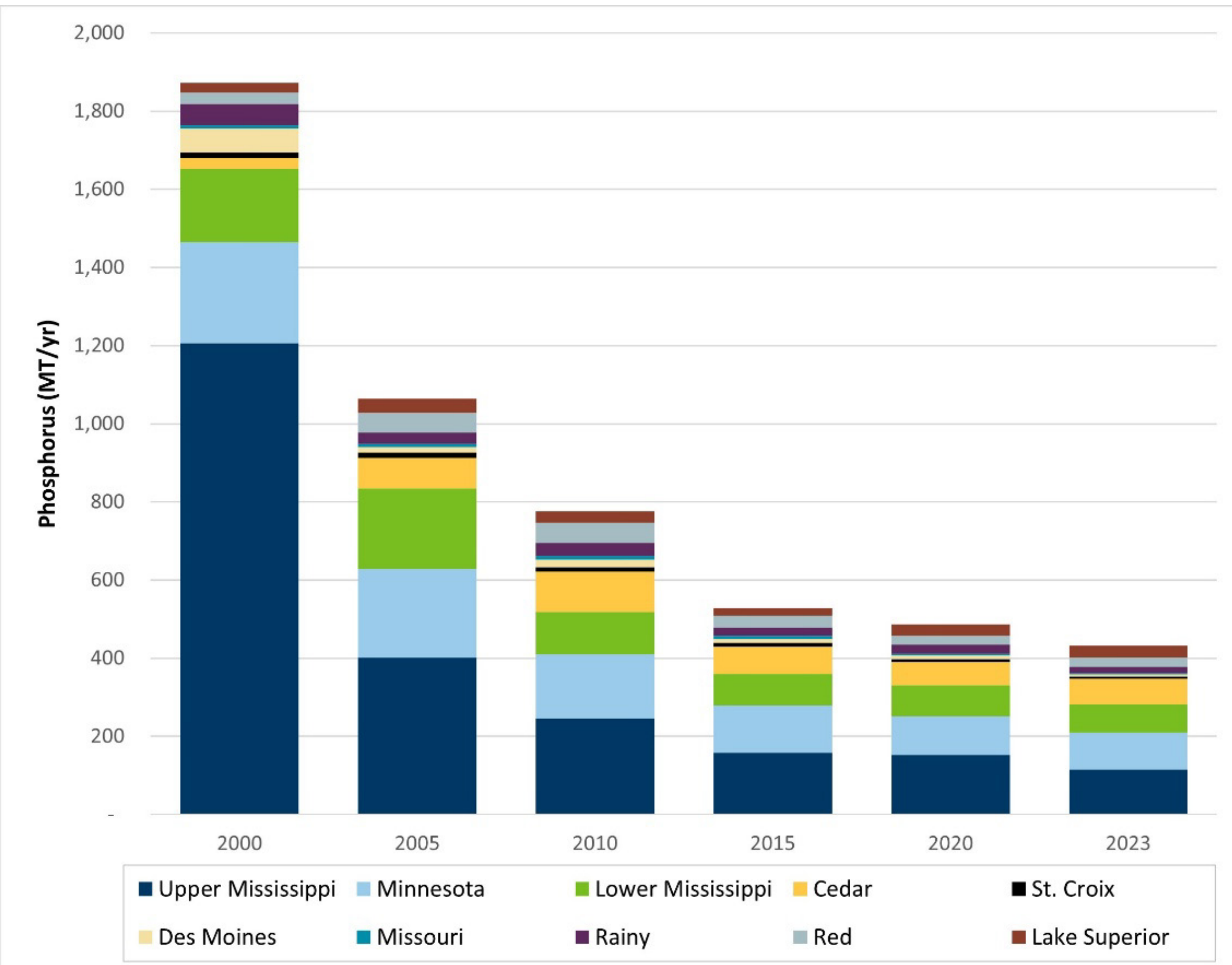


Table 4-1. Wastewater effluent phosphorus loads by basin by year (in MT/yr).

Basin	2000	2005	2010	2015	2020	2023
Mississippi River	1,765	948	661	455	413	362
Lake Winnipeg	84	78	85	52	45	41
Lake Superior	25	37	28	19	29	30
Total	1,874	1,063	774	526	487	433

Addressing phosphorus loads – timeline

Over the past 50 years, Minnesota has implemented policies, rules, and standards to control the amount of phosphorus the wastewater sector discharges to state waters. Effluent phosphorus reductions achieved by Minnesota's wastewater sector have benefitted local and regional lakes and rivers and exceeded Minnesota's 2014 NRS load reduction goals for the sector.

Phosphorus Rule (1970s)

Since the 1970s, Minnesota has established wastewater phosphorus effluent limitations for most facilities discharging to lakes or reservoirs:

> *Where the discharge of effluent is directly to or affects a lake or reservoir, phosphorus removal to one milligram per liter shall be required… In addition, removal of nutrients from all wastes shall be provided to the fullest practicable extent wherever sources of nutrients are considered to be actually or potentially detrimental to the preservation or enhancement of designated water uses.*

This rule, referred to as the "Phosphorus Rule," had historically applied to discharges upstream of lakes or reservoirs. The rule did not affect most of Minnesota's wastewater facilities because they discharge to rivers; by 1999, 85 WWTF permits included phosphorus effluent limits.

Phosphorus Strategy (2000/2008)

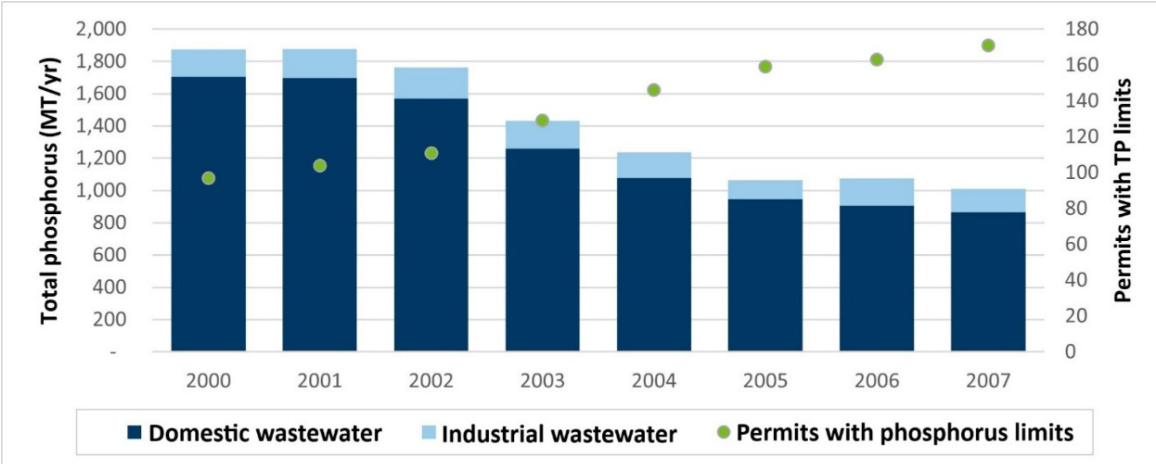
On March 28, 2000, the MPCA's Citizens' Board adopted a strategy for addressing phosphorus in NPDES permits (the Phosphorus Strategy), which established a process for developing 1 mg/L phosphorus limits for new and expanding WWTFs that had the potential to discharge more than 1,800 lbs/yr of phosphorus. It also established requirements for other WWTFs to develop and implement phosphorus management plans. In 2008, the MPCA's Phosphorus Strategy was formally adopted as Minn. R. ch. 7053.0255.

Implementing MPCA's Phosphorus Strategy has resulted in significant wastewater effluent phosphorus load reductions since the year 2000 (Table 4-2; Figure 4-2). The number of wastewater permits containing phosphorus effluent limits increased from 97 in 2000 to 171 in 2007.

Table 4-2. Phosphorus strategy: statewide wastewater effluent phosphorus loading (MT/yr).

Wastewater source	2000	2001	2002	2003	2004	2005	2006	2007
Industrial wastewater	167	176	193	172	159	116	167	146
Domestic wastewater	1,706	1,700	1,572	1,260	1,079	948	908	865
Total	1,873	1,876	1,764	1,432	1,238	1,064	1,074	1,011
Permits with TP limits	97	104	111	129	146	159	163	171

Figure 4-2. Phosphorus strategy: statewide wastewater effluent phosphorus limits and loading.



Substantial effluent phosphorus load reductions resulted from implementing 1 mg/L TP limits for WWTFs that discharged directly to or affected[1] lakes, shallow lakes, or reservoirs and for new or expanding facilities with the potential to discharge more than 817 kilograms (1,800 lbs) of phosphorus each year. From 2000 to 2007, effluent wastewater loads were reduced by 1,131 MT/yr (51.7%).

The MPCA's Phosphorus Strategy remains an important phosphorus control regulation for the wastewater sector. The MPCA enhanced this strategy by adopting eutrophication WQS for lakes and rivers in 2008 and 2015, respectively.

Lake eutrophication water quality standards (2008)

In 2008, in addition to codifying the Phosphorus Strategy, the MPCA adopted new lake eutrophication water quality standards (LES) as modifications of Minn. R. ch. 7050.0222. The LES became the basis for developing phosphorus water quality-based effluent limits (WQBELs) and lake eutrophication TMDLs. Lake protection effluent limits are generally expressed as 12-month moving total or calendar year-to-date total loading limits (in kilograms/yr).

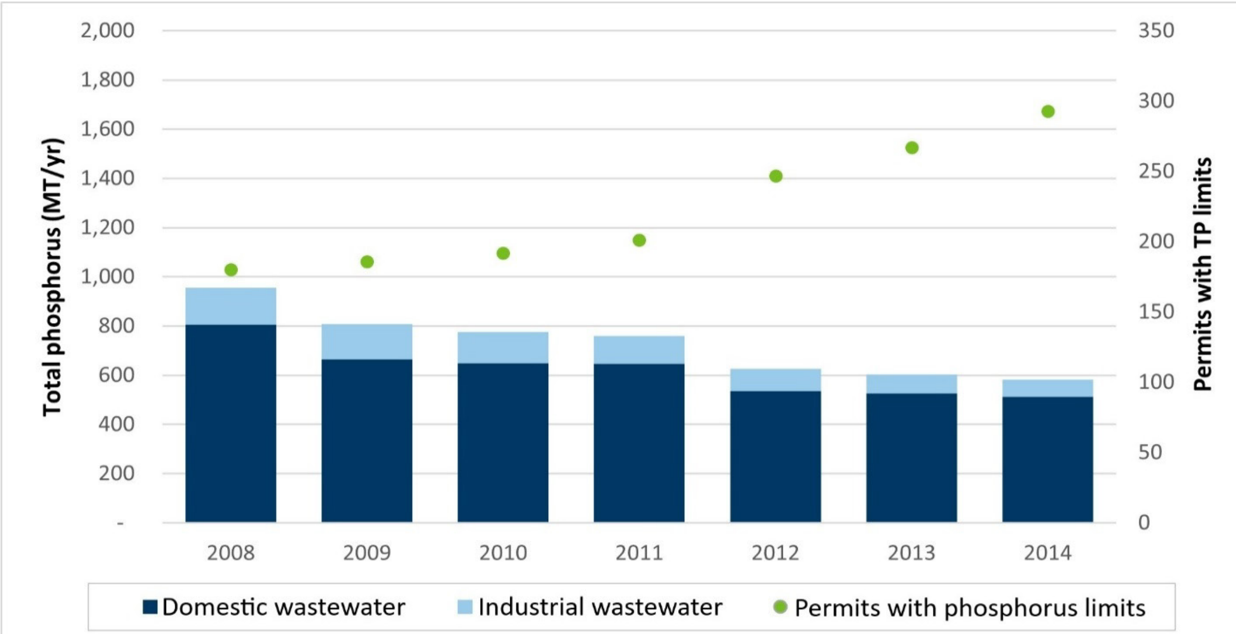
After MPCA adopted the LES, the number of wastewater permits containing phosphorus effluent limits increased from 180 in 2008 to 293 in 2014 (Table 4-3; Figure 4-3). From 2008 to 2014, effluent wastewater loads were reduced by 417 MT/yr (41.7%). The magnitude of the statewide reductions during this period was smaller than that obtained by implementing the Phosphorus Strategy's 1 mg/L effluent limit in the early 2000s; however, the WQBELs developed for protecting lakes, shallow lakes, and reservoirs are more targeted because they were derived from wasteload allocations (WLAs) consistent with the attainment of water body-specific WQS.

[1] "Affects" is defined as a measurable increase in the adverse effects of phosphorus loading from an individual point source discharge as determined by monitoring or modeling, including, but not limited to, an increase in chl-*a* concentrations, a decrease in water transparency, or an increase in the frequency or duration of nuisance algae blooms (Minn. R. ch. 7053.0255, subp. 2.A).

Table 4-3. Lake eutrophication standards: statewide wastewater effluent phosphorus loading (MT/yr).

Wastewater source	2008	2009	2010	2011	2012	2013	2014
Industrial wastewater	151	142	126	112	89	77	69
Domestic wastewater	805	665	649	647	536	526	513
Total	956	807	775	760	626	603	583
Permits with TP limits	180	186	192	201	247	267	293

Figure 4-3. Lake eutrophication standards – statewide wastewater effluent phosphorus limits and loading.



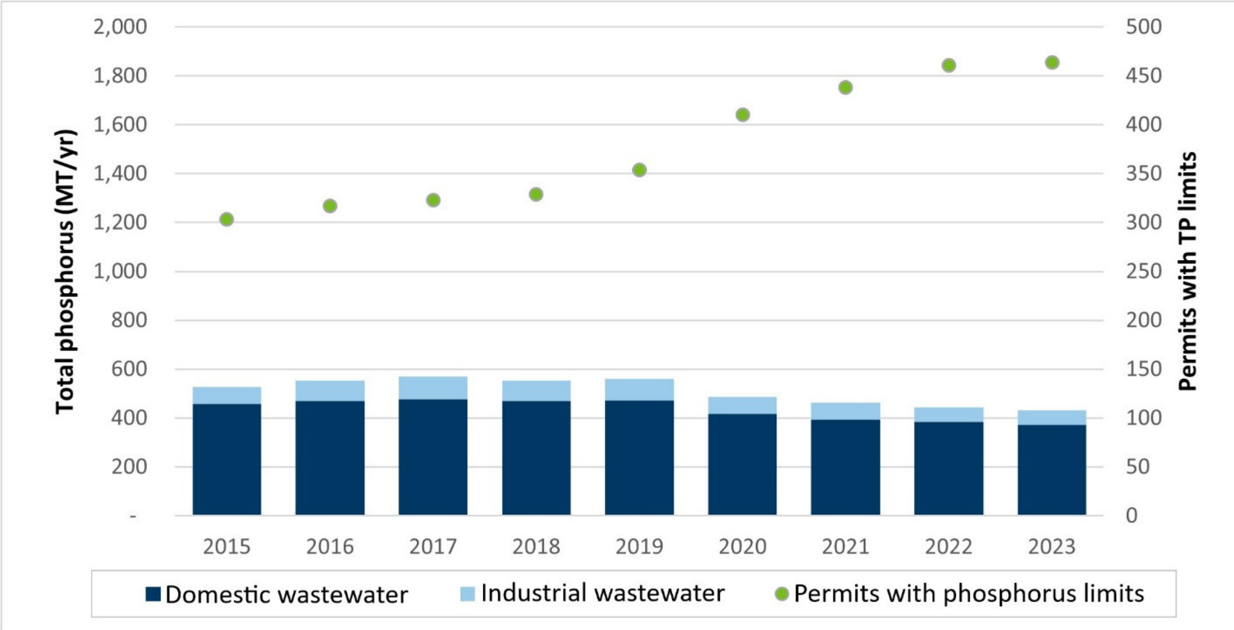
River eutrophication water quality standards (2015)

In 2015, the MPCA adopted new river eutrophication water quality standards (RES) as modifications to Minn. R. ch. 7050.0222. The RES became the basis for developing phosphorus WQBELs and river eutrophication TMDLs. River protection effluent limits are only applicable during the summer months (June–September) and are generally expressed as calendar month average loading limits (in kilograms/day), although they may be expressed as concentration limits (in mg/L), where load-based limits alone are not sufficient to ensure attainment of applicable WQS. After MPCA adopted the RES in 2015, the number of wastewater permits containing phosphorus effluent limits increased from 303 in 2015 to 464 in 2023 (Table 4-4; Figure 4-4). From 2015 to 2023, wastewater effluent loads were reduced by 96 MT/yr (18.2%).

Table 4-4. River eutrophication standards: statewide wastewater effluent phosphorus loading (MT/yr).

Wastewater source	2015	2016	2017	2018	2019	2020	2021	2022	2023
Industrial wastewater	70	84	92	84	87	69	70	57	59
Domestic wastewater	458	470	477	469	473	418	393	386	374
Total	528	553	569	553	560	486	463	443	432
Permits with TP limits	303	317	323	329	354	410	438	461	464

Figure 4-4. River eutrophication standards – statewide wastewater effluent phosphorus limits and loading.



Analyzing phosphorus load reductions over time

Overall, Minnesota's wastewater sector has achieved impressive reductions in wastewater effluent phosphorus loads. As MPCA adopted and implemented the Phosphorus Strategy in 2000, initial large-scale reductions were achieved due to the number and volume of WWTF discharges addressed. These reductions in average effluent concentrations from 4–6 mg/L to less than 1 mg/L, multiplied by the significant effluent flow volumes discharged by large facilities, resulted in substantial overall phosphorus load reductions.

The more recent adoption and implementation of LES in 2008 and RES in 2014 have further refined and targeted phosphorus load reductions. WQBELs developed in accordance with the 2008 LES resulted in the calibration of existing 1 mg/L limits for many large and mid-sized WWTFs. Annual loading limits are calculated from facility design flows, effluent concentration assumptions that vary depending on facility type and size, and the availability of any pre-existing phosphorus limits (Table 4-5). Many more mid-sized and small facilities were also assigned LES WQBELs.

Table 4-5. Annual phosphorus limit concentration assumptions.

Facility category	Design flow	Concentration assumptions
Met Council WWTFs	314–1.6 mgd	0.28–0.8 mg/L
Major municipal WWTFs	≥ 1 mgd	0.8 mg/L
Minor municipal: mechanical WWTFs	0.2–0.99 mgd	1.0 mg/L
Minor municipal: mechanical WWTFs	≤ 0.2 mgd	3.5 mg/L
Minor municipal: stabilization pond WWTFs	All design flows	2.0 mg/L
Industrial: high concentration	All design flows	1.0 mg/L
Industrial: low concentration	All design flows	Existing load + 15%
All facilities with pre-existing concentration limits	All design flows	Existing concentration limit

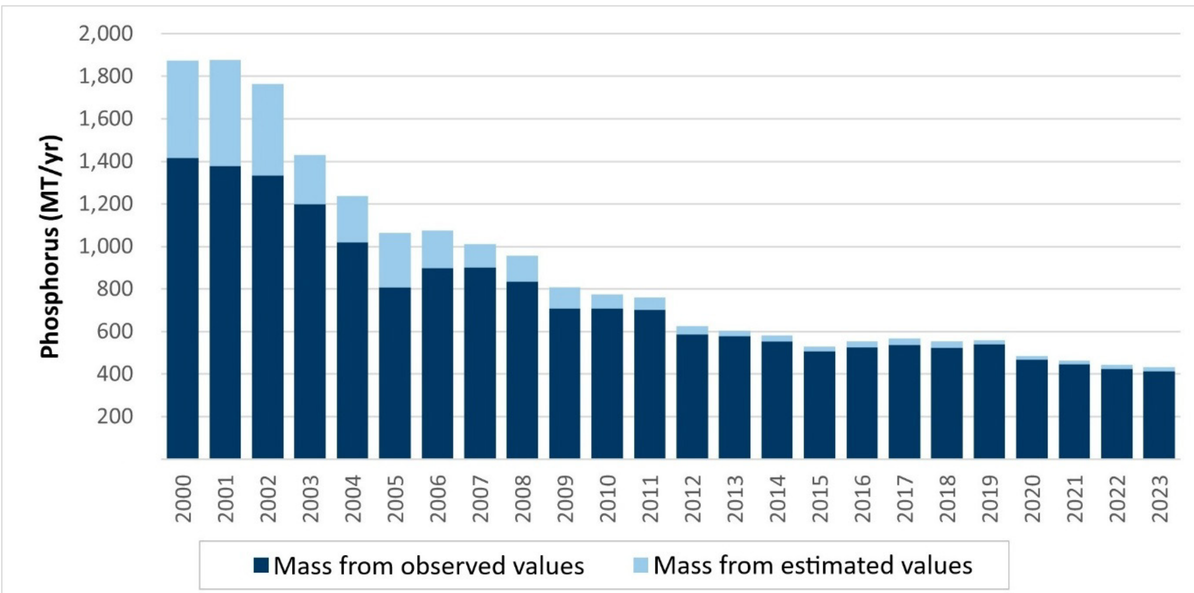
Notes:
mgd = million gallons per day; mg/L = milligrams per liter

Although the magnitude of statewide phosphorus reductions attributed to the implementation of LES WQBELs is not as extensive as that attributed to the implementation of the Phosphorus Strategy, the resulting reductions are important for attainment of WQS. Table 4-5 summarizes the WLA concentration assumptions developed for Lake Pepin and other large watershed TMDLs that are representative of typical LES-based WQBELs.

WQBELs developed in accordance with the 2015 RES resulted in a further adjustment of phosphorus effluent limits for facilities whose discharges cause or have reasonable potential to cause or contribute to exceedances of RES. The RES WQBELs only apply from June through September.

The accuracy of wastewater effluent phosphorus load estimates has increased since 2000 due to the increased availability of monitoring data reported by WWTFs. This has reduced the use of assumed effluent concentration values based on WWTF type (Figure 4-5).

Figure 4-5. Confidence measure for effluent phosphorus data by year.[a]



Note:

[a] Mass estimates derived from effluent concentration assumptions (light blue) have less certainty than the mass based on observed monitoring results (dark blue).

Most effluent phosphorus loads are discharged by domestic WWTFs (Figure 4-6), but the percentage of industrial phosphorus loading has increased in proportion to the phosphorus reductions achieved by municipal WWTFs. Between 2000–2002 and 2021–2023, the proportion of phosphorus loading discharged by industrial wastewater discharges increased from 10% to 14% of the total, while domestic wastewater contributions dropped from 90% to 86% of the total.

Industries and municipalities have both made substantial progress in reducing effluent phosphorus loads, achieving a 76% reduction in loads since MPCA adopted the Phosphorus Strategy in 2000. As shown in Table 4-6, effluent TP loads dropped from an average yearly load of 1,838 MT in 2000–2002 to 446 MT in 2021–2023. The estimated 1,392 MT/yr reduction in statewide wastewater effluent phosphorus loading represents the amount of phosphorus discharged by WWTFs, not the phosphorus load delivered to the state line. Reduction percentages were calculated from 3-year loading averages to account for the annual flow variability.

Figure 4-6. Comparison of annual industrial and municipal wastewater effluent phosphorus loads.

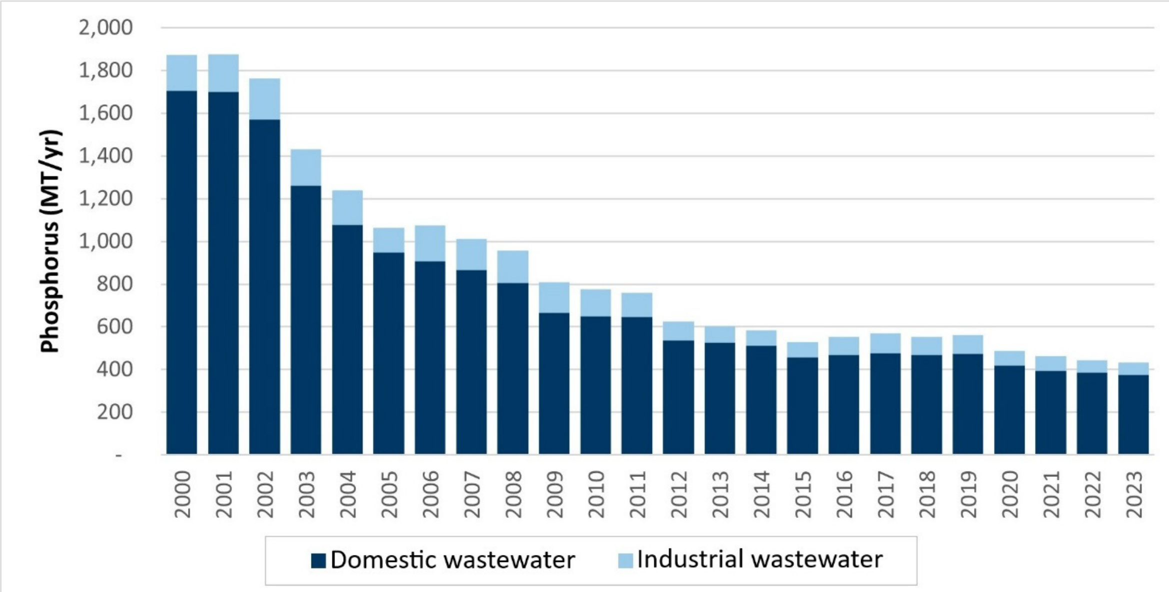


Table 4-6. Statewide wastewater effluent phosphorus percent reduction estimates.

Wastewater source	Average 2000–2002 (MT/yr)	Average 2021–2023 (MT/yr)	Percent reduction (%)
Industrial wastewater	179	62	65%
Domestic wastewater	1,659	384	77%
Total	1,838	446	76%

Controlling phosphorus – next steps

Effluent phosphorus reductions achieved by the wastewater sector in Minnesota to address state eutrophication impacts have exceeded the 2014 NRS's load reduction goals. Table 4-7 shows baseline wastewater effluent phosphorus loads delivered to the state's borders based on attenuation coefficients calculated from the SPARROW water quality model. Table 4-8 shows the 2021–2023 average annual effluent phosphorus load reductions achieved, along with the percent load reductions achieved from the 2001–2003 baseline loads delivered to the state borders.

Table 4-7. Baseline wastewater effluent TP loads and reduction goals delivered to the state borders.

Basin	Baseline 2001–2003 TP load (MT/yr)	NRS percent reduction goal from baseline (%)	NRS load goal (MT/yr)	Reduction needed (MT/yr)
Mississippi River	1,169	45%	526	643
Red River	42	50%	21	21
Rainy River	43	10%	39	4
Lake Superior	41	NA	No net increase	NA

Table 4-8. Current effluent phosphorus loads and reduction goals delivered to the state borders.

Basin	2021–2023 TP load (MT/yr)	TP load reduction achieved from baseline (MT/yr)	TP percent reduction achieved (%)
Mississippi River	281	888	76%
Red River	20	22	52%
Rainy River	22	21	49%
Lake Superior	28	13	32%

Minnesota's Phosphorus Strategy, LES, and RES will continue to address phosphorus reductions in the wastewater sector in the future. Further reductions of approximately 85 MT/yr in the Mississippi River watershed and 6 MT/yr in the Red River watershed are expected based on current flows and the attainment of final permit effluent limits. However, future effluent phosphorus loads are likely to increase statewide in the coming decades due to increased population and commercial and industrial activity that will result in increased WWTF flows. Although difficult to quantify, it is also possible that effluent phosphorus concentrations may increase somewhat due to future efforts to optimize WWTF operations for nitrogen removal.

4.1.2 Nitrogen in wastewater

Wastewater nitrogen load changes since 2000

Effluent nitrogen loads were largely estimated from effluent flows and typical pollutant concentration assumptions until 2014, when additional nitrogen monitoring requirements began to be included in permits as they were issued. Based on more reliable monitoring data since 2016, statewide loads are estimated to have decreased by 3%, from a 2016–2018 average of 14,534 MT/yr to a 2021–2023 average of 14,111 MT/yr. The changes in wastewater effluent nitrogen loads reported here are likely to reflect both an increase in data reliability and actual changes in the effluent loads.

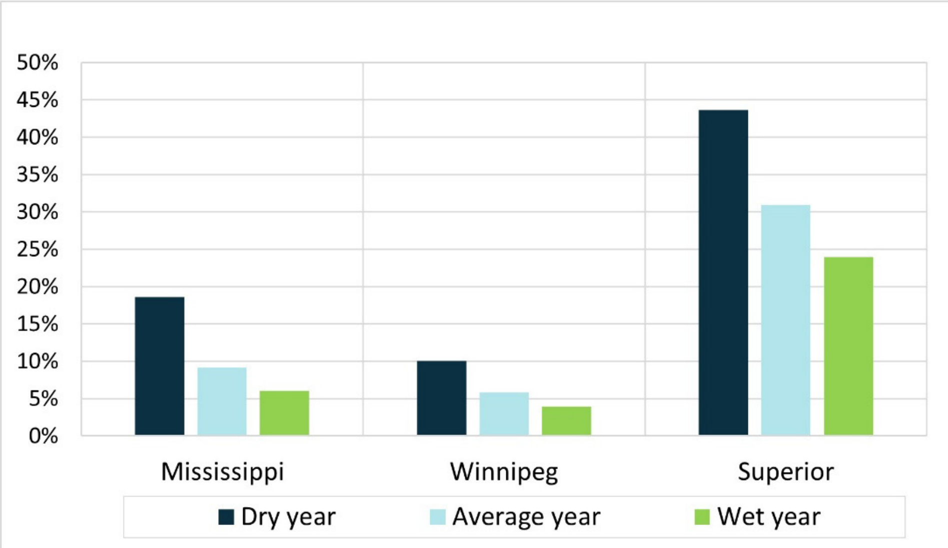
Comparing 2016–2018 to 2021–2023 average effluent TN loads by basin (Minnesota portions), Mississippi River Basin loads have decreased by 4%, from 13,207 MT/yr to 12,662 MT/yr; Lake Winnipeg Basin loads have increased by 10%, from 467 MT/yr to 513 MT/yr; and Lake Superior Basin loads have increased by 29%, from 860 MT/yr to 936 MT/yr (Table 4-9).

The overall proportion of nitrogen contributions from point sources (municipal and industrial WWTFs) and nonpoint sources (agriculture, septic, etc.) varies with weather conditions statewide (Figure 4-7). These differences are also seen on the individual basin scales (Table 4-10).

Table 4-9. Wastewater effluent nitrogen loads by basin by year (MT/yr).

Basin	2016	2017	2018	2019	2020	2021	2022	2023
Mississippi River	12,745	13,263	13,612	13,703	13,257	12,265	12,659	13,059
Red River	228	224	226	302	254	263	306	304
Rainy River	156	235	330	290	197	126	303	238
Lake Superior	814	915	852	802	797	849	1,063	897
Total	13,943	14,637	15,020	15,097	14,505	13,503	14,331	14,498

Figure 4-7. Wastewater effluent TN contribution estimates by hydrologic year.



Source: MPCA 2013.
Note: The updated source assessment described in Chapter 2 shows slightly lower TN source percentages from wastewater in the Mississippi and Lake Winnipeg basins, and substantially lower percentages from wastewater in the Lake Superior Basin.

Table 4-10. Wastewater effluent TN contribution estimates by hydrologic year.

Hydrologic condition	Basin	Point sources (% contribution)
Dry year	Mississippi River	19%
	Lake Winnipeg	10%
	Lake Superior	44%
Average year	Mississippi River	9%
	Lake Winnipeg	6%
	Lake Superior	31%
Wet year	Mississippi River	6%
	Lake Winnipeg	4%
	Lake Superior	24%

Note: The updated source assessment described in Chapter 2 shows slightly lower TN source percentages from wastewater in the Mississippi and Lake Winnipeg basins, and substantially lower percentages from wastewater in the Lake Superior Basin.

Addressing wastewater nitrogen loads – timeline

The 2014 NRS emphasized the importance of reducing nitrogen pollution from all sectors, including point sources (e.g., WWTFs) and nonpoint sources. The following rules and strategies have guided Minnesota's nutrient-reduction efforts.

Minnesota Nutrient Reduction Strategy (2014)

Minnesota's 2014 NRS set nitrogen reduction goals for the Mississippi River, Lake Winnipeg, and statewide drinking water supplies. Lake Superior has a no-load-increase goal. Relatively few WWTF monitoring data results were available for nitrogen when Minnesota's 2014 NRS was developed. Therefore, the NRS recommended implementing a series of sequential steps to build the knowledge base and generate the data necessary to support informed decisions and investments for nitrogen control, as reflected in Step 1 of the 2014 NRS five-step plan below:

- **Step 1: Conduct influent and effluent nitrogen monitoring at WWTFs.** Increase the nitrogen series monitoring frequencies for all dischargers, including industrial facilities, starting with permits issued in 2014. (Status note: this step has been ongoing since 2014.)
- **Step 2: Require nitrogen management plans (NMPs) for WWTFs.** Require all major facilities and those facilities with discharges above certain effluent concentrations to develop NMPs; this requirement does not include industries such as power generation, which have limited potential to discharge new nitrogen to surface waters. (Status note: this step has been ongoing since 2024; see the *Minnesota Wastewater Nitrogen Reduction and Implementation Strategy*.)
- **Step 3: Add nitrogen effluent limits as necessary.** Once the state adopts nitrate standards for the protection of aquatic life, MPCA should begin incorporating WQBELs based on these new standards, as necessary. (Status note: nitrate standards have not yet been adopted.)
- **Step 4: Add nitrogen removal capacity with facility upgrades.** Establish a technology-based threshold to achieve nitrogen reductions based on facility type and size. Encourage early adoption of nitrogen removal for major WWTFs planning to upgrade. (Status note: the early reduction incentive step has been ongoing since 2016; see Minn. Stat. §115.426. Guidance for incorporating denitrification technologies for new, expanding, and significantly upgraded facilities has been in effect since 2024.)
- **Step 5: Implement point-source-to-nonpoint-source trading.** Pollutant trading is an example of a market-based strategy because it is driven by finding the lowest cost treatment approach. When Minnesota is working in concert with other states to reduce downstream impairments, the viability of an interstate nitrogen trading network should be considered. (Status note: Pollutant trading has been developing in Minnesota since 1997. Future effluent limits are expected to generate demand for nonpoint source-derived nitrogen credits.)

Most NPDES/SDS permits issued since 2014 have included additional nitrogen series monitoring requirements. Historically, select municipal and industrial NPDES/SDS permits included monitoring requirements for ammonia, total Kjeldahl nitrogen and, to a lesser degree, nitrite plus nitrate or nitrate. Very few permits included monitoring requirements for nitrite and TN.

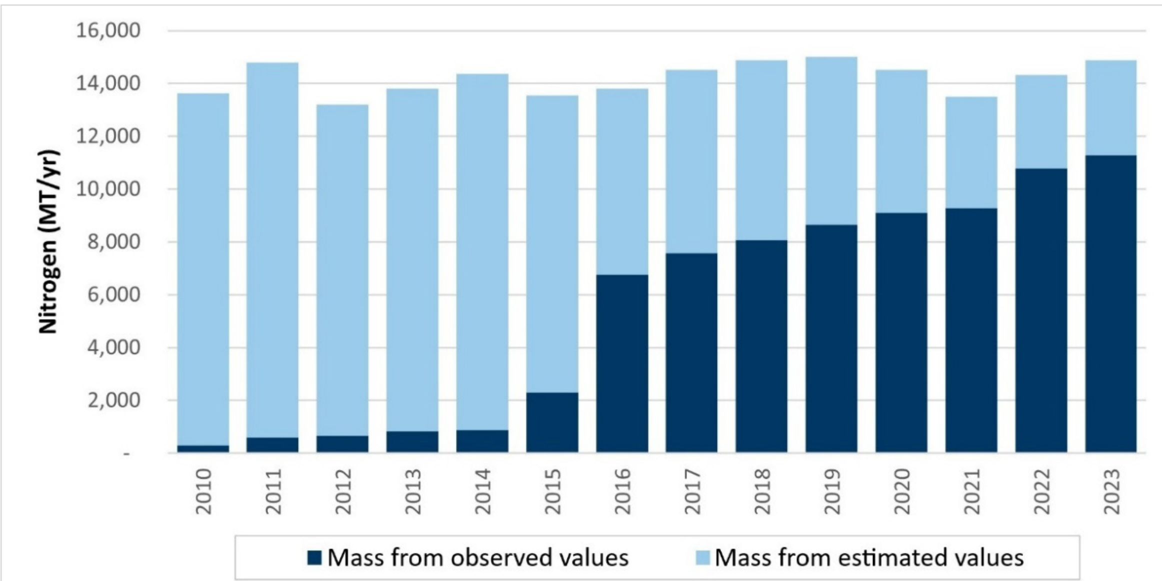
The MPCA began including additional but infrequent nitrogen series monitoring requirements in municipal wastewater permits beginning in 2010. Beginning in 2014, more robust nitrogen series monitoring requirements were included in most municipal and industrial NPDES/SDS permits. Table 4-11 shows the increase in the number of wastewater permits that included nitrogen monitoring requirements since 2000.

The increase in available wastewater effluent nitrogen data allows for a more accurate analysis of the wastewater sector's nitrogen footprint than was possible with the smaller amount of data available for developing the 2014 NRS. In 2010, only 2% of the wastewater effluent TN load was estimated from monitoring data. By 2016, 49% of the wastewater effluent nitrogen load was calculated from effluent monitoring data; in 2023, 76% of the load was calculated from effluent monitoring data (Figure 4-8). The remaining fraction of the load was calculated from effluent flows and estimated TN concentrations, or the typical pollutant concentrations for various categories of wastewater discharges. The more recent effluent nitrogen load data (after 2016) are considered more reliable, based on the decreasing percentages of wastewater effluent loads derived from estimated effluent concentrations over time.

Table 4-11. Wastewater permits with nitrogen series monitoring requirements.

Nitrogen type	2000	2005	2010	2015	2020	2023
Nitrogen, Kjeldahl, total	126	158	264	518	806	873
Nitrite plus nitrate, total (as N)	93	77	178	500	800	867
Nitrogen, total (as N)	6	20	67	153	518	683
Nitrogen, ammonia, total (as N)	180	237	322	455	461	459
Nitrogen, nitrate, total (as N)	63	112	113	40	24	20
Nitrogen, nitrite, total (as N)	3	6	4	1	2	1

Figure 4-8. Statewide wastewater effluent TN loads derived from monitored and estimated effluent concentrations.



All municipal and a few industrial WWTFs are assigned to classes A through D based on factors such as operational complexity, restrictiveness of effluent limits, and influent wastewater variability characteristics. Most industrial permits authorize wastewater discharges that do not require biological wastewater treatment and are not assigned a facility classification.

Effluent TN data exhibit considerable variability. Municipal WWTFs can be divided into two broad types: continuous discharge (i.e., mechanical) facilities and controlled discharge (i.e., stabilization pond) facilities. Mechanical facilities, represented in classes A, B, and C, have relatively consistent mean and median values of approximately 20 mg/L across classes; however, they also have a high degree of variability between facilities. Stabilization ponds, represented in Class D, have relatively low effluent TN concentrations, around 4 mg/L, and a lower variability. High-concentration industrial facilities comprise a small group (n = 6) of dischargers, mostly in the food processing sector. Low-concentration industrial facilities represent a large group (n = 161) of dischargers across various industrial sectors. The 2018–2022 effluent TN data reported by Minnesota WWTFs are summarized in Table 4-12.

Table 4-12. 2018–2022 TN wastewater effluent concentrations by facility classification (mg/L).

Data type	Class A n = 82	Class B n = 93	Class C n = 63	Class D n = 298	High-concentration industrial n = 6	Low-concentration industrial n = 114
Mean	19.8	19	20.5	4.4	44	2.3
Median	19	17.2	18	3.6	35.6	1.5
Maximum	54	53	73	14	160	8.1
Minimum	1.6	0.5	0.1	0	1.3	0
Standard deviation	10.5	10.5	14.8	3.1	33	1.9

It is notable that in 2023, 39 (16%) continuous-discharge municipal WWTFs (12 Class A, 17 Class B, and 10 Class C) already discharge median effluent TN concentrations of 10 mg/L or less. Conversely, 53 (10%) municipal facilities (16 Class A, 13 Class B, 21 Class C, and 2 Class D) and four (3%) industrial facilities discharged median TN concentrations of 30 mg/L or greater.

As of December 31, 2023, nine municipal and three industrial NPDES/SDS permits for surface water discharges in Minnesota included TN or nitrite-plus-nitrate effluent limits, although the limits for two of the industrial facilities are very high-concentration, technology-based effluent limits (125 mg/L and 164 mg/L). Seven of the 10 mg/L TN limits for municipal WWTFs are for facilities with discharges that may affect drinking water wells because they release treated wastewater to losing stream reaches (i.e., where stream water infiltrates into the soil or bedrock and underlying groundwater). One limit is for a facility with whole effluent toxicity attributed to excess nitrate concentrations. Another is for a new WWTF that voluntarily accepted a TN limit under the terms of Minnesota's Incentive for Voluntary Municipal or Industrial Investment in Nutrient Treatment Technology, a state statute that came into effect in 2016 to promote the design and construction of biological nutrient removal WWTFs.

Analyzing wastewater nitrogen load reductions over time

The NRS's nitrogen load reduction goals for Minnesota's wastewater sector have not yet been achieved. Table 4-13 shows the 2010–2012 baseline wastewater effluent nitrogen loads delivered to the state's borders based on attenuation coefficients calculated from the SPARROW water quality model. The 2010–2012 period was selected as the NRS baseline for TN reduction from the wastewater sector at a time when effluent nitrogen loads were largely estimated from effluent flows and typical pollutant concentrations.

Table 4-13. Baseline effluent nitrogen loads and reduction goals delivered to the state borders.

Basin	Baseline 2010–2012 TN load (MT/yr)	NRS percent reduction goal from baseline (%)	NRS load goal (MT/yr)	Reduction needed from 2010–2012 (MT/yr)
Mississippi River	8,721	45%	3,924	4,796
Red River	258	50%	129	129
Rainy River	167	TBD	TBD	TBD
Lake Superior	1,645	TBD	TBD	TBD

Note:
TBD = to be determined

Recent wastewater effluent load estimates, calculated from more reliable effluent monitoring data, suggest that the 2010–2012 baselines are sufficiently accurate, so they continue to serve as NRS load reduction baselines for the wastewater sector. Comparing 2010–2012 to 2021–2023 average effluent data, TN loads have increased by 4% in the Mississippi River Basin and by 5% in the Lake Winnipeg Basin. Effluent TN loads in the Lake Superior Basin are estimated to have decreased by 29%, but the apparent reductions are largely attributable to an improved understanding of the effluent TN concentration discharged by several large WWTFs in the basin.

Controlling wastewater nitrogen – next steps

Implementing the Wastewater Nitrogen Reduction and Implementation Strategy (2024)

On April 1, 2024, the MPCA published a *Wastewater Nitrogen Reduction and Implementation Strategy* (hereafter "Wastewater Nitrogen Strategy"), which details approaches to address steps 2 through 5 of the 2014 NRS's wastewater nitrogen reduction recommendations. The 2024 Wastewater Nitrogen Strategy was developed outside of the NRS revisions, through a separate MPCA process that included stakeholder engagement. It is designed to outline a process that helps ensure the wastewater sector achieves the necessary nitrogen reductions to protect and restore Minnesota's and downstream water bodies while meeting Minnesota's NRS goals. To accomplish these goals, the Wastewater Nitrogen Strategy relies on the following:

- Denitrification design requirements for new, expanded, and significantly upgraded WWTFs.
- NMPs and water quality trading.
- WQBELs derived from nitrate WQS that the MPCA intends to adopt as a modification of Minn. R. ch. 7050.0222.
- 10 mg/L TN State Discharge Restriction (SDR) effluent limits that the MPCA intends to adopt as modifications of Minn. R. ch. 7053.

The MPCA proposes to implement this Wastewater Nitrogen Strategy in the following three phases over multiple 5-year NPDES/SDS permit cycles.

Phase 1 of the Wastewater Nitrogen Strategy

Phase 1 commenced during the first permit cycle, which began on April 1, 2024. It includes the following elements, without specific timelines.

- The MPCA will implement guidance for new, expanding, and significantly upgraded WWTFs.
  - For discharges that will cause or have a reasonable potential to cause or contribute to (1) exceedances of the nitrate drinking water standard in downstream water bodies used as drinking water sources or (2) nitrate levels causing biological stress to aquatic organisms. Note: MPCA will develop nitrogen effluent limits to ensure that downstream uses are protected. Effluent limits will be included in the WWTF's NPDES/SDS permit, and construction of all necessary treatment units will be required to achieve effluent denitrification to levels sufficient to protect downstream uses.
  - For all other discharges, project proposers will be required to submit facility plans that include design considerations for denitrification to levels sufficient to protect downstream uses and to achieve the future projected nitrogen limit.
- The MPCA will begin the administrative process to adopt nitrate aquatic life toxicity WQS and a 10 mg/L 12-month moving average or calendar year average TN SDR for major municipal WWTFs, high-concentration minor municipal WWTFs, and industrial discharges. Rulemaking processes for the adoption of the nitrate WQS and the TN SDR may occur simultaneously or sequentially.
  - The SDR will include an optimization incentive: facilities that optimize operations to achieve 15 mg/L TN effluent concentrations as a 12-month moving average or calendar year average during Phase 1 will have the 10 mg/L SDR limit deferred to the permit's second permit cycle following SDR adoption (i.e., Phase 3). Permittees will be made aware of this SDR optimization opportunity during Phase 1.

- All reissued permits for high-concentration municipal and industrial dischargers will include requirements to develop and implement NMPs.
- For all NPDES/SDS permitted facilities discharging upstream of a known Index of Biological Integrity-impaired water with nitrate as a stressor, the reissued permit will include requirements to develop and implement enhanced NMPs.
- The MPCA will continue to develop WQBELs for discharges that cause or have a reasonable potential to cause or contribute to impairments based on existing nitrogen standards.
- Nitrogen WQBELs will be developed for NPDES/SDS permitted discharges that have a reasonable potential to cause or contribute to a nitrate-impaired Class 1 water.

Phase 2 of the Wastewater Nitrogen Strategy

Phase 2 begins during the first permit cycle following the adoption of nitrate aquatic life toxicity WQS and/or the adoption of a 10 mg/L SDR. If nitrate WQS and TN SDR rules are adopted separately, implementation of WQBELs and SDRs will begin upon adoption of each relevant regulation. Phase 2 includes the following elements.

- All Phase 1 implementation steps will remain in effect except as modified by the implementation of Phase 2.
- Low-concentration municipal and industrial dischargers will develop and implement NMPs if their effluent concentrations exceed the established concentration thresholds (see the “Assigning SDRs” section below).
- Nitrogen effluent limits will be established.
  - Nitrogen WQBELs will be developed for NPDES/SDS permits found to have reasonable potential in accordance with the adopted nitrate aquatic life toxicity WQS.
  - 10 mg/L TN 12-month moving average or calendar year average SDR limits will be included in NPDES/SDS permits in accordance with the criteria of the adopted SDR.
  - An optimization incentive will be included: 10 mg/L TN effluent limits will be deferred to Phase 3 for facilities that have successfully optimized operation to achieve a 15 mg/L TN 12-month moving average or calendar year average concentration during Phase 1 of this strategy.

Phase 3 of the Wastewater Nitrogen Strategy

Phase 3 begins during the second permit cycle following the adoption of nitrate aquatic life toxicity WQS and a 10 mg/L SDR. Phase 3 includes the following elements.

- All Phase 1 and 2 implementation steps will remain in effect except as modified by the implementation of Phase 3.
- 10 mg/L TN SDR 12-month moving average or calendar year average effluent limits will be included in NPDES/SDS permits for major municipal WWTFs, high-concentration minor municipal WWTFs, and industrial dischargers that had successfully optimized operations per the incentive offered in Phase 2.

The rulemaking procedures for adopting nitrate WQS and TN SDRs as described in Phase 1 above may take a number of years to finalize. New, expanded, and upgraded municipal and industrial WWTFs require significant investments of public and private funds and are typically designed for a 20-year service life. To maximize future benefits from impending investments in WWTF design and construction, and to expedite the ability of newly constructed, expanded, and upgraded WWTFs to attain future nitrogen effluent limits, the MPCA intends to ensure that WWTF designs prepared before the adoption of aquatic life toxicity nitrate WQS and TN SDRs consider the treatment units and hydraulic capacity necessary to achieve effluent denitrification. Additionally, nitrogen discharged from the proposed facilities will be evaluated; effluent limits will be developed if needed to protect an existing drinking water source or where biological stress to aquatic organisms exists because of high nitrate levels.

Adopting nitrogen management plans

NMPs help WWTF operators and managers understand the inputs of nitrogen to their facilities and the capabilities of their facilities to address those nitrogen inputs. NMPs help to evaluate pollution prevention and WWTF optimization and treatment options that can reduce the amount of nitrogen discharged to Minnesota waters. Reducing nitrogen inputs and outputs can reduce WWTF operating costs.

Enhanced NMPs include plans to achieve effluent nitrogen reductions to levels sufficient to protect sensitive downstream waters and aquatic life. They are required for all wastewater dischargers upstream of known Index of Biological Integrity impairments for which nitrate has been identified as a stressor.

NMPs may also serve as preliminary water quality trading planning documents. It is anticipated that WWTF optimization for nitrogen removal may be supplemented with point-to-nonpoint trading projects to achieve facility effluent nitrogen reduction goals.

The MPCA's *Nitrogen Management Plan Guidance* describes a suggested NMP development outline, summarized below.

1. Data review. Summarize the last five years of available influent and effluent flow and nitrogen series monitoring data.
2. Facility performance determination (benchmarking). A facility's influent and effluent nitrogen levels can be compared to those from other facilities using the MPCA's wastewater nitrogen data summary tool.
3. Develop a process control monitoring plan. The goal of process control monitoring for nitrogen removal is to obtain the data needed to evaluate and understand the facility's nitrogen removal process. These data are necessary for making informed operational changes related to TN removal.
4. Develop goals. The NMP goals may be based on facility priorities or driven by permit requirements or Minnesota's Wastewater Nitrogen Strategy.
5. Develop the facility's nitrogen management implementation plan. Provide a detailed sequence of implementation steps designed to achieve the NMP's chosen goals.

An evaluation of nitrogen removal at WWTFs in cold-weather climates (see "Implementing wastewater nitrogen reduction technologies and management plans" below) was completed in 2025 and is intended to inform the development of nitrogen management and facility optimization plans. The MPCA has also developed a Nitrogen DMR [discharge monitoring report] lookup tool to help facility operators develop their NMPs.

Adopting water quality-based effluent limits

The MPCA's 2022 *Aquatic Life Water Quality Standards Draft Technical Support Document for Nitrate* defines the chronic and acute values that will serve as a basis for developing the WQS (i.e., criteria) (Table 4-14). After adopting the nitrate WQS, MPCA should develop nitrogen WQBELs for wastewater discharges that cause or have a reasonable potential to cause or contribute to water body excursions above the applicable standards. However, while WQBELs based on the draft nitrate standards would meet goals to protect aquatic life locally in streams and rivers, future reductions expected from the attainment of WQBELs alone will be insufficient to achieve the wastewater effluent reductions necessary to meet the Minnesota NRS's goals for the Mississippi River and Red River basins. After fully attaining the WQBELs, an additional 2,208 MT/yr TN reduction (28%) would be needed in the Mississippi River Basin, and an additional 118.6 MT/yr TN reduction (45%) would be needed in the Red River Basin to meet statewide NRS goals (Table 4-15). Wastewater TN load goals for the Lake Superior and Rainy River basins had not yet been established during the development of the Wastewater Nitrogen Strategy.

Table 4-14. Proposed nitrate criteria for the protection of aquatic life.

	Acute (Class 2 waters)	Chronic (Class 2A waters)	Chronic (Class 2B waters)
Criteria value	60 mg/L [a]	5 mg/L [b]	8 mg/L [b]

Notes:
[a] 1-day duration
[b] 4-day duration

Table 4-15. Annual wastewater effluent TN loads and load reductions expected from nitrate WQBELs delivered to the state borders.

Basin	Annual end-of-pipe wastewater TN load (MT/yr)	Annual wastewater TN load delivered to the state border (MT/yr)	Estimated annual TN load reduction from WQBELs (MT/yr)	Estimated TN percent reduction at the state border (%)	NRS percent reduction goal from baseline (%)
Mississippi River	13,656	10,163	2,365	23%	45%
Red River	307	294	28.4	10%	~50%
Lake Superior	785	785	94.3	12%	No increase
Rainy River	191	179	0.12	01%	TBD

Additional load reductions described in the SDR section below will be necessary to achieve the NRS TN reduction goals for the wastewater sector.

The need for additional TN load reductions beyond those attainable by implementing WQBELs is because most water column and biological nitrate impairments are associated with smaller streams, while many of Minnesota's larger WWTFs discharge to larger rivers. Therefore, most major municipal WWTFs are not expected to be subject to future nitrogen WQBELs. In the Mississippi River Basin, the facilities expected to be subject to nitrogen WQBELs discharge accounted for approximately 29% of the sector's TN load. In the Red River Basin, the facilities that are expected to be subject to nitrogen WQBELs discharge approximately 9% of the wastewater sector's TN load. Implementing the WQBELs and SDR effluent limits is expected to result in new nitrogen effluent limits for 178 NPDES/SDS wastewater permits (Table 4-16).

Table 4-16. Predicted numbers of facilities with effluent limits from the wastewater nitrogen reduction strategy implementation.

Basin	WQBELs			SDR [a]			Total
	Domestic major	Domestic minor	Industrial	Domestic major	Domestic minor	Industrial	
Mississippi River	33	88	5	29	2	1	158
Red River	1	2	0	3	1	0	7
Rainy River	0	0	0	2	0	0	2
Lake Superior	2	5	0	3	0	1	11
Total	**36**	**95**	**5**	**37**	**3**	**2**	**178**

Note:
[a] SDR only applied for permits that are not subject to WQBELs.

Assigning state discharge restrictions

To meet the NRS's wastewater effluent TN load reduction goals as described in the previous section, MPCA is also proposing to modify Minn. R. ch. 7053 to assign 10 mg/L TN SDR effluent limits for major municipal WWTFs and other high-concentration dischargers. For the purposes of the Wastewater Nitrogen Strategy, the threshold for distinguishing between high- and low-concentration discharges is the facility classification mean TN concentration plus one standard deviation and rounded to the nearest integer (Table 4-17). The two exceptions are high-concentration industrial facilities, which are assigned the same concentration threshold as Class A and Class B facilities, and low-concentration facilities, which are adjusted up to the draft nitrate criterion for cold-water streams.

Table 4-17. High-concentration versus low-concentration discharges for WWTF classifications.

Threshold	Class A	Class B	Class C	Class D	High-concentration industrial	Low-concentration industrial
High/low-discharge TN concentration threshold	30 mg/L	30 mg/L	35 mg/L	8 mg/L	30 mg/L	5 mg/L

The Wastewater Nitrogen Strategy specifies 12-month moving average TN limits; however, calendar year-to-date limits may be developed for controlled discharge WWTFs due to the intermittent nature of their discharges. The Wastewater Nitrogen Strategy calls for implementing the 10 mg/L TN effluent limits following the adoption of SDR regulations.

Meeting Nutrient Reduction Strategy goals

The estimated TN load reductions based on the Wastewater Nitrogen Strategy are expected to achieve Minnesota's NRS wastewater goals at the state's borders for the Mississippi River Basin and the Red River Basin. The load reductions are estimated based on current effluent flows and effluent TN limits consistent with the proposed nitrate WQS and TN SDR (Table 4-18).

Table 4-18. Wastewater nitrogen reduction strategy estimated wastewater effluent load reductions.

Major basin	2010–2012 NRS wastewater baseline TN load at state line (MT/yr)	NRS reduction goal (%)	NRS wastewater TN load goal at state line (MT/yr)	2021–2023 wastewater TN load at state line (MT/yr)	Projected state-line wastewater TN loads resulting from strategy implementation (MT/yr)	Reduction from 2021–2013 to meet NRS TN load goal (%)
Mississippi River Basin	8,721	45%	4,797	10,163	4,069	53%
Red River Basin	326	50%	163	294	127	61%
Lake Superior Basin	1,212	TBD	TBD	785	664	TBD
Rainy River Basin	218	TBD	TBD	179	137	TBD

Identifying priority areas and facilities for wastewater nitrogen

Wastewater effluent nitrogen reduction priorities are for facilities that cause or have a reasonable potential to cause or contribute excess nitrate to:

- Exceedances of drinking water standards in Class 1 waters protected as drinking water sources.
- Biological impairment linked to excess nitrate.
- Exceedances of the proposed aquatic life nitrate WQS.

Seven surface water discharge municipal WWTF permits currently include 10 mg/L TN limits for the protection of drinking water sources. All are located in southeast Minnesota's karst region and discharge to losing streams or cold-water streams that are protected as potential drinking water sources. In addition, 103 municipal and three industrial WWTF permits for subsurface discharge include 10 mg/L limits for nitrite plus nitrate or TN.

Implementing wastewater nitrogen reduction technologies and management plans

The MPCA contracted with Tetra Tech to study the success of wastewater denitrification in cold climates in support of this NRS. The full report can be found in appendices 4-1 and 4-2, and the spreadsheets used for cost calculation may be requested from MPCA. The study's objectives are described below.

Objective 1: Determine where wastewater nitrogen reduction has been achieved in cold climates. The first objective focused on gathering and summarizing a wide range of information sources relevant to nitrogen reduction in WWTFs. A comprehensive assessment of peer-reviewed literature, reputable websites, and various databases was conducted to ensure a well-rounded understanding of the topic. Tetra Tech compiled and reviewed approximately 100 studies of WWTFs in the United States, Canada, Scandinavia, Finland, Poland, the United Kingdom, and other locations and prepared an annotated bibliography. The information gleaned from this activity served as a foundation for the rest of the study and helped to identify potential case studies. The report summarizes the findings of the literature review concerning various key factors, including:

- Key factors for nitrogen removal
- Key factors for phosphorus removal
- Considerations for combined nitrogen and phosphorus removal
- Wet-weather flows
- Cold climate denitrification

Objective 2: Investigate and document how the facilities identified in Objective 1 achieved success and how much change in effluent nitrogen levels occurred. The second objective involved identifying and conducting a more detailed investigation of various facilities that have successfully implemented nitrogen reduction strategies. To gather information for these case studies, a multifaceted approach was adopted. This included reaching out to facility operators via emails and phone calls and reviewing information online. Facility-specific case studies were developed for 28 facilities in 10 U.S. states and two Canadian provinces (Table 4-19; Figure 4-9).

Table 4-19. Facility-specific case studies.

Location	Number of case studies
British Columbia	1
Colorado	1
Iowa	1
Illinois	1
Massachusetts	1
Minnesota	11
Montana	7
New York	1
Pennsylvania	1
Saskatchewan	1
Vermont	1
Wisconsin	1

Figure 4-9. Facility-specific case study locations.

The report summarizes key findings from the case studies and includes a detailed analysis of capital and operations and maintenance costs. The estimated annual cost per pound of TN removed ranged from approximately $3 to $23, excluding facilities that reported no costs or cost savings. For WWTFs with design flows less than 5 million gallons per day, the average cost ranged from approximately $3 to $19 per pound, while those with design flows greater than 5 million gallons per day had average costs ranging from $5 to $23 per pound. Both the average and median costs per pound of TN removed were approximately $9.


Quiet time on a Minnesota lake.

Objective 3: Connect the methods that achieved success from Objective 2 to Minnesota's existing wastewater treatment situation; develop written recommendations for improving Minnesota's wastewater NMP template.

Tetra Tech provided recommendations for improving Minnesota's wastewater NMP template in a technical memorandum titled, Review of MPCA Nitrogen Management Plan Guidance. The memorandum emphasizes that WWTF staff developing NMPs would benefit from the identification of various selection factors when evaluating their own plants for retrofits and upgrades to remove nitrogen:

- **Footprint**. Space available for additional tanks.
- **Buildings**. Buildings needed for cold-weather operations.
- **Construction in an existing aeration basin**. Modifications needed for retrofitting biological nutrient removal processes in existing tanks.
- **Piping and pumping**. Additional return lines, feed lines and pumping capacity required for biological nutrient removal.
- **Secondary-process recycle streams**. Treatment considerations for high-concentration return flows.
- **Additional carbon source**. Determine whether adequate carbon sources are available for biological nutrient removal.
- **Additional electricity**. Increased electricity usage is expected if additional pumping is needed due to increased hydraulic head, additional reactor volume, or new or increased return rates.
- **Chemicals**. It can be a significant cost driver if additional carbon sources are required. Other chemicals that might need to be added include caustic soda or lime for alkalinity control and metal salts, such as alum or ferric chloride, for phosphorus removal.
- **Additional sludge**. Additional sludge generation is typically associated with chemical addition. All additional sludges will typically incur additional disposal costs.

4.1.3 Resources for reducing nutrients in wastewater

Minnesota works to connect the wastewater sector with financial and technical resources to control nutrient loadings. Some of these resources also support efforts to reduce nutrients in urban stormwater runoff, which is discussed further in Chapter 4.2, below.

Funding resources

Owatonna WWTF, southeastern Minnesota.

Minnesota has a long-standing approach to financial assistance through grants, loans, and bonding appropriations that help municipalities address municipal point source wastewater and stormwater projects. This approach includes low-interest loans with supplementary grants based on energy efficiency/renewable energy, affordability, and or pollutant-based aspects of a construction project. The Minnesota Public Facilities Authority and MPCA actively solicit project proposals annually to add to the Clean Water Project Priority List; then, they coordinate with other state and federal financial assistance programs to provide the best funding mix available to help municipalities maintain aging collection and treatment facilities and meet additional permit requirements. Wastewater projects that are eligible for funding include system improvements and efforts to rehabilitate, expand, or replace wastewater treatment or collection facilities. Other Project Priority List-eligible projects include excess nutrient-related projects in areas served by existing wastewater treatment systems, as well as stormwater projects that address existing water quality issues and provide permanent treatment systems. Example financial assistance programs include:

- **Clean Water Revolving Fund.** Also referred to as the State Revolving Fund (SRF), this program is the backbone of the funding approach based on low-interest loans at 20- to 30-year terms. These loans provide significant interest savings of 15% to 20%, resulting in the lowest available interest rate. The Minnesota Legislature has established the Clean Water Revolving Fund under Minn. Stat. § 446A.07 to receive federal capitalization grants and state matching funds.
- **Green Project Reserve.** This program offers 25% principal forgiveness (i.e., a grant) of up to $1 million for projects involving energy efficiency, renewable energy, or stormwater green infrastructure, which can be used to reduce the final loan amount.
- **Water Infrastructure Fund**. The Minn. Stat. § 446A.072 established the Water Infrastructure Fund program to provide grants to help cities build projects to replace aging and obsolete water systems that would otherwise be unaffordable. Without this assistance, municipal water systems in small and disadvantaged communities would be at increased risk of major system failure. The Public Facilities Authority awards Water Infrastructure Fund grants in conjunction with loans from its Clean Water Revolving Fund and Drinking Water Revolving Fund programs and project funding from the USDA's Rural Development grant and loan program.
- **Point Source Implementation Grant Program**. Minn. Stat. § 446A.073 established the Point Source Implementation Grant program to provide grants to help cities upgrade WWTFs to improve water quality by reducing the discharge of specific pollutants. These grants cover 80% of eligible project costs, up to a maximum of $7 million.

The federal, state, and local investments in wastewater nutrient reduction projects since the publication of the NRS are shown in Table 4-20.

Table 4-20. Nutrient-related WWTF project funding.

Fiscal year	Clean water funds and bond grants [a]	SRF loans and supplemental grants [b]	Other funding sources [c]	Total
2014	$12,926,188	$16,555,370	$2,359,718	**$31,841,276**
2015	$12,849,596	$7,392,057	$4,327,569	**$24,569,221**
2016	$22,195,204	$15,527,385	$16,873,042	**$54,595,631**
2017	$24,092,169	$20,023,463	$1,232,123	**$45,347,755**
2018	$31,419,527	$45,029,134	$10,839,948	**$87,288,609**
2019	$31,041,691	$42,208,228	$7,454,189	**$80,704,108**
2020	$27,484,928	$18,349,203	$982,432	**$46,816,563**
2021	$15,791,214	$3,242,782	$1,899,547	**$20,933,543**
2022	$2,274,942	$0	$454,989	**$2,729,931**
2023	$40,865,912	$95,940,083	$95,563,018	**$232,369,013**
Total	**$220,941,370**	**$264,267,705**	**$141,986,574**	**$627,195,649**

Notes:

[a] Clean water funds and bond grants include Point Source Implementation Grant Clean Water Fund awards and the Small Community Wastewater Grants and Loan programs.

[b] SRF loans and water infrastructure fund awards include SRF loans, USDA Rural Development grants and loans, and Minnesota Department of Employment and Economic Development Small Cities Development Program grants.

[c] Other funding sources include city funds, other local funding sources, state special appropriations and other project-specific funding sources.

Training and technical assistance resources

Minnesota offers programs to ensure WWTF operators and managers receive the technical assistance they need to plan and implement municipal point source wastewater and stormwater projects:

- **Wastewater operator training and certification.** MPCA administers Minnesota's wastewater and collection system operator certification program, administers certification exams, and provides various wastewater workshops and conferences that offer training credit hours required for certification renewal. Specific certification requirements, course offerings, and examination schedules are available at the MPCA's wastewater training and certification website.
- **Wastewater technical assistance.** With funding from the Infrastructure Investment and Jobs Act, MPCA staff are partnering with the Midwest Technical Assistance Program, Minnesota Rural Water, and the Minnesota Technical Assistance Program (MnTap; see box on the next page) staff to provide technical assistance to small, rural, and Tribal WWTFs. The program will provide outreach and technical assistance to small, rural, or Tribal WWTFs, focusing on permitting support, financial assistance guidance, pollutant identification and reduction plans, technical evaluation of facility operations, optimization, climate resiliency, and energy efficiency solutions. It will also help them build additional technical, managerial, and financial capacity.

  During an initial 2-year period, MPCA staff will focus on outreach and assistance with 10 to 20 small, rural, or Tribal WWTFs. The program will track the number of participating communities, the number of WWTFs that received assistance in developing pollutant identification and reduction plans, and the number of WWTFs that received training to improve their technical, managerial, and financial capacity. Program staff will also document WWTFs that received technical evaluations, including treatment facility operation and/or optimization assistance, energy efficiency or renewable energy options identification or training, climate resiliency planning support, and assistance with emerging contaminant monitoring or training on pollution identification and reduction plans.

Minnesota Technical Assistance Program

MnTAP is a grant-funded technical assistance and outreach program based at UMN. MnTAP staff provide no-cost, nonregulatory, confidential technical assistance to industrial manufacturing facilities in Minnesota. For the past 40 years, MnTAP has helped improve public health and the environment by preventing pollution at its source, optimizing the use of resources, and reducing energy use and costs.

MnTAP provides services through three main pathways: general technical assistance, special projects, and the MnTAP intern program. Many of MnTAP's services are provided through general technical assistance, where MnTAP staff answer questions via phone or email and perform site visits to identify opportunities such as wastewater loading reductions, water conservation, pollution prevention, and energy efficiency. MnTAP also applies for grant-funded projects, which enable them to provide targeted outreach to organizations working on specific topics, such as biological nutrient removal and energy efficiency at WWTFs. Finally, each summer, MnTAP scopes projects for engineering and science student interns to spend three months identifying and implementing resource conservation and/or energy efficiency solutions at industrial and municipal facilities.

In 2022, an MnTAP project helped the Whitewater River Regional Wastewater Treatment Plant achieve biological nutrient treatment within their oxidation ditch treatment process. After receiving a new nitrogen permit limit of 10 mg/L, the facility needed help reducing its nitrogen load. Using various models to explore the best operational changes to reduce nitrogen, the team began cycling aeration in the oxidation ditches of the plant and successfully reduced the nitrogen load to 3.9 mg/L, resulting in a decrease of 73,200 lbs/yr of nitrogen from the WWTF.

Nutrient trading

Offsite point or nonpoint source phosphorus or nitrogen reduction projects can offset a portion of a permit's load reduction goals. The MPCA's Water Quality Trading website and *Water Quality Trading Guidance* provide information about trading options. Trading can be particularly important for new and expanding facilities in TMDL watersheds where no additional WLAs are available or upstream of impaired waters before the development of TMDLs. Trading can also be a strategy to meet a permit's load reduction targets. For example, a wastewater facility with a 10 mg/L TN effluent limit may be able to cost-effectively optimize facility operations to achieve a 13 mg/L 12-month moving total effluent concentration. The remaining 3 mg/L reduction requirement could be satisfied by implementing nonpoint source BMPs that will reduce TN loads upstream of the target water body by an amount equivalent to the remaining reduction amount.

The development of new WWTF nitrogen effluent limits may result in renewed interest in water quality trading in the foreseeable future. The MPCA has created a new Water Quality Trading Coordinator position and expects increased interest in trading projects in the coming years.

4.1.4 Roadmap for achieving wastewater nutrient reductions

Remaining challenges

Wastewater treatment in Minnesota has made significant progress in reducing phosphorus and has begun to implement nitrogen reduction plans. However, there are opportunities to continue making reductions in the years ahead. Existing barriers to achieving nutrient reduction in wastewater include:

- **High costs.** Minnesota wastewater utility managers have expressed support for developing the nitrate WQS and the effluent limitations necessary for protecting local water resources. However, they have expressed concerns about the significant capital costs and ongoing operations and maintenance expenditures that will be necessary to attain nitrogen effluent limits. The American

Society of Civil Engineers' *2021 Report Card for America's Infrastructure* indicated that the capital investment gap between what is needed for wastewater management replacement in the United States and the available funding was $81 billion (ASCE 2022). In Minnesota, the Met Council has estimated that treating TN to a 10 mg/L standard at its nine water resource recovery facilities would require a $1.6 billion capital investment. The cost of upgrading an existing WWTF to remove nitrogen from wastewater is highly dependent on whether the treatment plant is sized to nitrify (convert ammonia to nitrate) year-round. The existing facilities that are designed to nitrify year-round would require a 20% to 30% expansion in their secondary treatment. Other facilities would require a larger expansion. For example, the Metro Water Resource Recovery Facility, which does not nitrify year-round, would require a 70% increase in aeration tank volume and a 40% increase in final clarifiers.

A Changing Perspective

The Met Council and other facilities across Minnesota have transitioned from using the term "wastewater treatment plants" to "water resource recovery facilities." This change acknowledges that the facilities do much more than just treat and dispose of wastewater. They also produce clean water, recover materials for secondary uses (including nutrients), use renewable energy, and provide research and innovation opportunities. Resource recovery provides multiple benefits beyond pollution control, allowing significant infrastructure investments to better support Minnesota's future.

- **Emerging contaminants are a concern.** As more is discovered about per- and polyfluoroalkyl substances (PFAS), microplastics, and other novel substances released into aquatic systems by human activity, wastewater treatment will be required to evolve to address these materials. It is unknown whether these treatments will interfere with nitrogen and phosphorus treatments, but they will certainly add to the complexity and cost of wastewater treatment.
- **Urban populations are increasing.** As noted in Chapter 1, Minnesota's urban areas are experiencing growth, which in turn increases the volume of wastewater treated by municipal plants. WWTFs that are operating near their design capacity will have difficulty optimizing operations for nitrogen removal.

Measures for achieving wastewater nutrient reduction

Phosphorus reduction in wastewater in Minnesota has largely been successful in protecting and restoring Minnesota lakes and rivers, which will continue through the application of WQS in permits.

The nitrogen reduction plan outlined in the 2014 NRS served as a framework for the MPCA in developing the detailed Wastewater Nitrogen Reduction Strategy. Significant efforts are still needed to reduce nitrogen in Minnesota's wastewater sector and achieve the state's nitrogen reduction goals. The following actions are recommended by the Urban Wastewater work group involved in the NRS revision process.

1. **Optimization.** Using NMPs and optimizing existing wastewater infrastructure for nitrogen removal represent potential low-cost nitrogen reduction opportunities for the wastewater sector and should be emphasized as a key step in nitrogen reduction.
2. **Time, flexibility, and prioritization.** Every WWTF is unique, and allowing facilities time to implement and test optimization and NMPs through a stepwise approach to nitrogen reduction will be important for success. State agencies should provide additional support to facilities that cause or have a reasonable potential to cause or contribute excess nitrate to waters where there are:
   - Exceedances of drinking water standards in Class 1 waters that are protected as drinking water sources.

- Biological impairment linked to excess nitrate.
- Exceedances of the proposed aquatic life nitrate WQS.

3. **Water quality trading.** Water quality trading frameworks and initiatives should be further developed to help offset the cost of wastewater nutrient reductions and provide financial incentives for implementing nonpoint source BMPs for nitrogen reduction. Trading may also support the development of urban-rural partnerships to advance the comprehensive, regional water quality planning and projects needed to meet NRS goals both in and out of state.
4. **Technological advancements.** The state should support technological innovation for treating nutrients in conjunction with emerging contaminants. Successful technologies and approaches to reduce wastewater nitrogen should be shared with other HTF states.
5. **Research.** Minnesota should support research on nutrient recovery from wastewater for reuse at Minnesota's research institutions that will help generate new solutions for wastewater nutrient management. Minnesota should partner with other HTF states to research this topic to maximize the use of limited research funds and promote regional solutions for a common challenge.
6. **Advocating for projects.** State agencies and local governments should voice support for funding wastewater projects through state and federal sources.
7. **Education.** The state can support local government by developing education and outreach materials for rate payers/municipal governments, including information on the importance of wastewater nitrogen reduction for national and international water restoration. For example, demonstrating the value of wastewater nitrogen reduction in Lake Superior, where wastewater is a larger source of nitrogen, could broaden appreciation for wastewater nitrogen reduction in other watersheds.

4.2 Urban stormwater nutrient reduction

The 2014 NRS assessments identified stormwater as contributing 7% of the phosphorus load to the Mississippi River, 10% of the phosphorus load to Lake Superior, and 2% of the phosphorus load to Lake Winnipeg. However, urban stormwater contributed only 1% of the nitrogen load in both the Mississippi River and Lake Superior, while contributing an insignificant amount of nitrogen to Lake Winnipeg. Based on recent modeling results aggregated across the state, the nutrient contributions from stormwater remain relatively low, but they are estimated as slightly higher compared to results reported in the 2014 NRS based on a different model approach (Appendix 2-2 and Chapter 2.8). Urban stormwater is a much more significant nutrient source to lakes and streams in local watersheds that are urban-dominated or otherwise have few anthropogenic nutrient sources.

The 2014 strategy recommended maintaining the stormwater permit program (Section 4.2.2), providing technical assistance to communities seeking to implement effective stormwater management, and establishing a unified stormwater research program for the state (Section 4.2.4) for managing urban nutrients.

These programmatic goals have been met over the past 10 years since the original strategy was developed, and additional changes have also taken place within Minnesota's stormwater management programs. The WRAPS process has been completed for all major watersheds in Minnesota, documenting the impacts that urban stormwater has on local waters as well as those within Minnesota's largest watersheds. Components of urban stormwater management have also been included in the CWMPs prepared through the 1W1P program, and TMDL reports, other local watershed plans, and Minnesota's stormwater permitting structure have also contributed to achieving nutrient management.

4.2.1 State-level stormwater regulatory programs

The MPCA stormwater program regulates the discharge of stormwater and snow melt runoff from municipal separate storm sewer systems (MS4s), construction activities, and industrial facilities, mainly through the administration of NPDES and SDS permits (see MPCA's stormwater permits website).

Phosphorus Lawn Fertilizer Law

In 2002, Minnesota became the first state to regulate the use of phosphorus fertilizer on lawns and turf. Implementation of the law began in the seven-county Twin Cities Metro Area and expanded outward. As part of the Fertilizer, Soil Amendment, and Plant Amendment Law, the ban prohibits the use of phosphorus on lawns and turf unless a soil or plant tissue test shows a need for phosphorus, a new lawn is being established, the fertilizer is applied to a golf course by trained staff, or the phosphorus is used on a farm growing sod for sale. A 2007 analysis of the law's effectiveness found that the amount of phosphorus contained in lawn fertilizers had decreased from 292 tons in 2003 to 151 tons in 2006.

MS4 General Permit

The first MS4 General Permit was issued in 2006. MS4 permit regulation is based on proximity to an urbanized area, population size triggers, or when discharging to special water bodies. There are 247 permitted MS4s in Minnesota. Permittees include cities, townships, colleges, hospitals, correctional facilities, watershed districts, counties, and the Minnesota Department of Transportation (MnDOT). The most recent MS4 General Permit became effective on November 15, 2020, and it continues to require that all permitted MS4 operators or owners create a stormwater pollution prevention program with six components:

1. Public education and outreach that includes teaching citizens about better stormwater management.
2. Public participation, which involves including citizens in solving stormwater pollution problems.
3. A local program to detect and eliminate illicit discharges to the storm sewer system (like chemical dumping and wastewater connections).
4. Construction site runoff controls.
5. Post-construction runoff controls.
6. Pollution prevention and municipal "good housekeeping" measures, like covering salt piles and sweeping streets.

Additionally, there are specific requirements for discharges to impaired waters with an approved TMDL and an applicable WLA, which applies to most, but not all, permitted MS4s.

Construction Stormwater General Permit

Minnesota's latest Construction Stormwater (CSW) General Permit was reissued and became effective on August 1, 2023. The CSW permit applies to new developments and redevelopments that disturb more than one acre of soil or to smaller sites if the activity is part of a larger development. From a nutrient reduction perspective, the CSW permit addresses construction activities, including erosion control, and post-construction water quality requirements. The CSW permit continues to include volume control requirements for post-construction water quality treatment. The permit states that one inch of stormwater runoff from new impervious areas will be retained on-site via infiltration, harvesting, and reuse, unless prohibited. This one-inch standard was designed to mitigate any increases in phosphorus due to development to the extent practicable. The modeling was based on a theoretical 10-acre site with varying amounts of impervious surface on B and C soils. The results showed that the range of phosphorus removal was between 72% and 97% compared to a site with no permanent stormwater treatment. From January 1, 2014, through December 31, 2023, approximately 225,000 acres were permitted via the CSW. Using conservative estimates, the standards in place in the permit have prevented 452,800 lbs of phosphorus from entering Minnesota's surface waters.

Industrial Stormwater – Multi-Sector General Permit

Minnesota's Multi-Sector Industrial Stormwater General Permit was last reissued on April 5, 2020. This permit addresses stormwater being generated on industrial properties and requires a series of benchmark and effluent monitoring activities for various pollutants, depending on the type of industrial activity. Effluent limitations are required for certain categories of industrial activity (e.g., sector C1 Phosphate Subcategory of Agricultural Chemicals includes a phosphorus effluent limit for stormwater discharges). Typically, most industrial activities do not have effluent limits but are required to mitigate for pollutants that exceed the monitored benchmark values through BMP implementation.

For measured nutrients, the current permit captures TP, TN as ammonia, and nitrite + nitrate. Sector C (Chemical and Allied Products) and Sector U (Food and Kindred Products) are the two industrial sectors with phosphorus monitoring requirements. Sector G (Active Metal Mining), Sector I (Oil and Gas Extraction Refining), Sector K (Hazardous Waste Treatment, Storage, and Disposal), Sector L (Landfills and Land Application Sites), Sector S (Air Transportation), and Sector U (Food and Kindred Products) are the six industrial sectors with nitrogen monitoring requirements.

Monitoring data are submitted to the MPCA as a benchmark value monitoring report or an effluent limit report. Effluent limit monitoring submittals are required annually under the current permit and will be required twice per year under the 2025 industrial stormwater permit. Benchmark value monitoring submittals are required once per calendar quarter. Once the permitted facility collects four consecutive benchmark value samples, the average value of the samples is taken and compared to the permit-specific benchmark value monitoring limit. A facility that meets its benchmark value monitoring limit is no longer required to conduct quarterly sampling unless the MPCA lists a newly impaired water within a mile of the facility that receives its discharge. Quarterly benchmark monitoring will restart if a new impairment listing occurs where the new impairment is the same as (or a surrogate to) the facility's benchmark monitoring requirement. Effluent limit sampling is conducted annually (soon to be biannually) throughout the life of the permit.

Since 2014, 210 facilities have submitted benchmark or effluent monitoring data to the MPCA. Of the 80 that are required to report whether they are meeting or exceeding the 1 mg/L benchmark for phosphorus, about half report always meeting it. Over half of the 201 facilities required to measure for the benchmark value of 2.8 mg/L for nitrogen also reported always meeting it.

Total maximum daily loads

TMDLs are a mechanism for pollution control created by the federal CWA and are developed by states for waters that are listed as impaired. In Minnesota, TMDLs are closely coordinated with the WRAPS process, and impaired waters are organized into TMDL reports. In the TMDL process, all sources of pollutants are identified, and a needed reduction is determined for each pollutant source so that WQS can be met in that body of water.

Thanks in large part to the watershed approach and funding from the CWLLA as of 2024, Minnesota has developed TMDLs for almost 2,000 impairments (not including mercury impairments) on hundreds of different lakes and rivers; of those, approximately 676 address nutrient impairments. Once a TMDL study is completed and approved by the EPA, any WLAs assigned to an MS4 permittee by that TMDL must be addressed by the permittee in future NPDES/SDS permits.

Depending on the pollutant, the MS4 General Permit either requires permittees to implement specific permit items or to develop compliance schedules for EPA-approved TMDL WLAs not already being met at the time of permit application. A compliance schedule includes BMPs that will be implemented over the permit term, a timeline for their implementation, and a long-term strategy for continuing progress towards achieving assigned WLAs. For WLAs being met at the time of permit application, the same level of treatment must be maintained in the future. Regardless of WLA attainment, all permitted MS4s are still required to reduce pollutant loadings to the maximum extent practicable.

As of the most recently issued 2020 MS4 General Permit, 231 of the 247 MS4 permittees had WLAs assigned to them in 469 EPA-approved TMDLs. The annual reporting of any pollutant-reducing BMPs associated with those WLAs has been delayed until MPCA's new reporting e-service is developed. Once the service is operational and MS4 permittees catch up on their reporting, a more comprehensive picture of BMP implementation will be available based on the most recent permit requirements. Annual TMDL BMP reporting from the previous permit only included 78 permittees and 43 TMDLs completed before August 2013. But, even with the limited number of permittees and TMDLs being reported on, MS4s reported implementing over 4,000 BMPs through 2020. Almost 2,500 of those were structural and removed 5,200 lbs of phosphorus. This does not provide a complete picture of phosphorus reductions, as some MS4s reported a percentage reduction instead of the number of pounds reduced.

An example of how Minnesota's permitting, TMDL process, and Watershed Framework are coordinated to address nutrient reductions can be seen in the South Metro Mississippi TSS TMDL and the Lake Pepin Eutrophication TMDLs that affect most of the regulated MS4s in the state. The South Metro Mississippi TMDL was EPA-approved before the 2020 MS4 General Permit; therefore, 105 permitted MS4s had to evaluate whether they were meeting the loading rate target (154 lbs/acre/yr of TSS or less) set in the TMDL. Of these, 45 permittees concluded that they were not meeting the loading rate or needed to conduct further analyses. The permittees that are not meeting the loading rate are implementing BMPs over the course of the current permit to reduce their sediment load, which will also help reduce phosphorus loads. Making WLA determinations via the MS4 permit is an iterative process; therefore, permittees re-evaluate their progress toward meeting TMDL goals with each reissued MS4 permit.

The Lake Pepin TMDL was approved on May 19, 2021, and affects 200 MS4s as well as wastewater facilities (see Section 4.1). During the next MS4 General Permit term (estimated to begin in 2026), those MS4s will be required to implement BMPs that will reduce their phosphorus load to 0.35 lbs/acre/yr if it is estimated they exceed that export rate. The TP export coefficients for MS4s' "existing" conditions presented in the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (Barr Engineering Company 2004) were estimated to be approximately 0.5 lbs/acre/yr (see Appendix J of the Detailed Assessment, Table 10 for average of loading rates for an average year for the Upper Mississippi River, Minnesota River, and Lower Mississippi River basins, and areas from Table 6). A 30% reduction that is consistent with the reduction called for in the Minnesota River dissolved oxygen TMDL for MS4 areas results in 0.35 lbs/acre/yr. The extent of reduction needed to achieve 0.35 lbs/acre/yr will vary by MS4.

Tributary monitoring conducted by Met Council Environmental Services shows that many MS4 areas are likely already meeting 0.35 lbs/acre/yr as a 10-year average (Met Council 2014). Modeling by 30 MS4s, as part of their evaluation of nondegradation, showed that median loading rates were slightly below 0.35 lbs/acre/yr after implementing BMPs. The overall basin reductions needed to meet WQS in Lake Pepin range from 20% to 50%.

4.2.2 Local-level stormwater programs

Water planning for Minnesota's urban areas has been happening statewide for more than 40 years, carried out by watershed districts, watershed management organizations, counties, SWCDs, and municipalities. In the seven-county Twin Cities Metro Area, the 1982 Metropolitan Surface Water Management Act required entities to prepare and implement watershed management plans (Minn. Stat. 103B.231), resulting in a total of 32 plans (see Chapter 6 for greater detail). In the 1990s, municipal local water plans were required, and county groundwater plans were optional in the Twin Cities Metro Area. Starting with a law passed in 2012, Minnesota local governments and their partners were allowed to voluntarily develop and implement watershed-scale management plans, with the goal of having CWMPs for the entire state by 2025. Most of these local water plans address urban stormwater management and include actions to improve water quality in urban lakes and streams.

Much of this local work is carried out by diverse public and private partnerships that work to minimize and reduce nutrient pollution through urban stormwater management. These entities collaborate on many efforts, including policy development, research, education, training, and practice implementation. It is impossible to adequately describe these many organizations and their important work in this document, but examples of some of the larger organizations include:

- Minnesota Cities Stormwater Coalition
- Minnesota Erosion Control Association
- Watershed districts and watershed management organizations that operate independently and collectively through Minnesota Watersheds
- Minnesota Association of SWCDs
- Regional Stormwater Protection Team in the Lake Superior/Duluth Region
- Met Council Environmental Services
- The Association of Minnesota Counties

4.2.3 State-level stormwater planning guidance

Minnesota works to connect the stormwater sector with the necessary resources to support planning and implementation efforts aimed at reducing nutrients in urban stormwater runoff.

Minnesota Stormwater Manual

MPCA first developed the *Minnesota Stormwater Manual* in 2011 as a "single-source guide" for stormwater managers. It contains detailed information related to stormwater management in Minnesota and describes various structural and nonstructural BMPs that can be used to address pollutant load reductions from urban runoff. The manual is widely used by stormwater practitioners across the state and country and is regularly updated by the MPCA and stakeholders.

Some of the major updates over the last 10 years include extensive guidance on Minimal Impact Design Standards (MIDS) and the MIDS calculator, a stormwater and rainwater harvest and use/reuse section, fact sheets for pollution prevention, updated swales information, an MS4 Toolkit, and TMDL guidance. In addition to general content updates and additions, the manual is updated every time a stormwater permit is reissued to reflect any new requirements. A fairly comprehensive history of updates to the manual can be found here: What's New - Minnesota Stormwater Manual. A variety of content is prioritized for development or improvement in the manual over the next two years, including:

- **MS4 permit implementation guidance.** Develop an off-the-shelf package for each Minimum Control Measure that an MS4 permittee can adopt and use to meet the corresponding permit requirements. Update relevant fact sheets for specific topic areas (e.g., snow storage/ management, use of splash pads) as appropriate.

- **Guidance for managing stormwater systems at the treatment train level.** Use existing information to develop guidance for designing stormwater management systems that incorporate multiple practices to address specific water quality issues, such as phosphorus, flooding, bacteria, etc. Historically, guidance for stormwater had focused on individual BMPs, rather than practices used in combination.
- **Stormwater ponds.** Incorporate new information from stormwater research, funded by the Minnesota Stormwater Research Council, about stormwater pond design, construction, maintenance, assessment, and performance into the *Minnesota Stormwater Manual* as appropriate.
- **Green infrastructure.** Add additional guidance to the *Minnesota Stormwater Manual* on using green stormwater infrastructure as a comprehensive management strategy to meet post-development water quality and volume management goals (e.g., green infrastructure guide booklet). Continue working on improving vegetation selection and access, such as enhancing the Blue Thumb plant selection tool to include functionality specific to stormwater management.
- **Chloride site design tool/guidance.** Develop tools and guidance for managing deicing activity at sites other than roads (e.g., commercial properties, institutions, businesses). Develop guidance for reducing the use of deicing chemicals through site design strategies (i.e., low-salt design).
- **Street sweeping.** Update the guidelines for managing street sweeping waste based on characterizations of contaminants found in swept material. Develop street sweeping-related credits for TMDLs for sediment, TSS, nitrogen, and bacteria based on need and additional characterizations of sweeper waste. Develop more tools for identifying best sweeping practices (e.g., aerial photography, geographic information system [GIS]).
- **Iron-enhanced sand filters and engineered media.** Incorporate information on the design, construction, and maintenance of iron-enhanced sand filters from the UMN research into the *Minnesota Stormwater Manual* as appropriate. Continue updating information on engineered media and soil used in stormwater applications (e.g., the use of spent lime, biochar, water treatment residual) as appropriate.
- **Pretreatment tool enhancement and pretreatment.** Convene a group of technical experts to identify mechanisms for more effectively communicating information on pretreatment to stormwater practitioners and then implementing those mechanisms. Update the existing pretreatment selection tool to include an up-to-date list of technologies.
- **Permeable pavement.** Use the latest information from the literature and research to update information on the design, construction, and operation and maintenance of permeable pavement. Incorporate new information on different types of permeable surfaces into the *Minnesota Stormwater Manual*. Develop case studies of permeable pavement applications.
- **Harvest/reuse.** Use the latest information from the literature and research to update information on the design, construction, and operation and maintenance of harvest and reuse systems. Develop case studies of harvest and reuse applications. Update and enhance the existing database of harvest and reuse applications in Minnesota.
- **Emerging BMPs.** Build information into the *Minnesota Stormwater Manual* on emerging BMPs and technologies for managing stormwater. The information will be developed from existing literature and recent research. Generally, this information will not be at the design level because the technologies will typically not be adequately tested; however, the information may include summaries and links to case studies.
- **Contaminants of emerging concern in stormwater**. Build a page in the *Minnesota Stormwater Manual* on contaminants of emerging concern, such as those for phosphorus and solids.

- **Social aspects of pollution prevention.** Add new and updated information on residential and commercial pollution prevention practices to the *Minnesota Stormwater Manual*. Examples include providing guidance to practitioners on developing residential- or community-based programs (e.g., leaf collection, rain barrel programs), developing ordinances (e.g., related to tree preservation or reducing imperviousness), incorporating tools into the manual (e.g., fact sheets, checklists), and highlighting case studies.

Minimal Impact Design Standards information

MIDS was established in response to legislation passed in 2009 directing the MPCA to "develop performance standards, design standards, or other tools to enable and promote the implementation of low-impact development and other stormwater management techniques…an approach to stormwater management that mimics a site's natural hydrology as the landscape is developed. Using the low-impact development approach, stormwater is managed on-site, and the rate and volume of predevelopment stormwater reaching receiving waters are unchanged. The calculation of predevelopment hydrology is based on native soil and vegetation" (Minn. Stat. § 115.03). MIDS contains four main elements to meet these needs:

1. Stormwater volume performance goals for new development, redevelopment, and linear projects.
2. New credit calculations that standardize the use of a range of structural stormwater techniques.
3. Design specifications for a variety of green infrastructure BMPs.
4. An ordinance guidance package to help developers and communities implement MIDS.

Many watershed districts, watershed management organizations, and communities across Minnesota have adopted MIDS performance goals in their stormwater rules or ordinances. As of 2020, 50 MS4 permittees reported adopting MIDS performance standards.

Watershed Restoration and Protection Strategies process

WRAPS are described in detail in Chapter 6 and include stormwater recommendations when stormwater management was identified as a significant water quality issue for that watershed. For instance, the *Mississippi River – St. Cloud WRAPS Report Update 2024* documents both sources of urban stormwater—MS4 permitted municipalities, industrial stormwater permitted facilities and increased urban runoff in rapidly developing areas—and strategies to reduce their impacts. It also highlights success stories in the watershed, including the delisting of Lake George for excess nutrients in 2022 due to the work of the City of St. Cloud and partners over the previous 10 years.

One Watershed, One Plan program

The 1W1P program is discussed in more detail in Chapter 6. However, the CWMPs generated through this program provide a platform through which urban stormwater management goals can be addressed. For example, the *St. Louis Watershed Comprehensive Watershed Management Plan*, adopted in 2023, identifies measurable stormwater programmatic goals in both the St. Louis River South and Duluth Urban Area and the Lake Superior Streams portions of the planning area, noting that urban stormwater management can control nutrient pollution and contribute other local benefits such as flood control and fish passage. While it is too early to determine the impact of the plan on local water quality and its contributions to phosphorus loading of Lake Superior, future evaluations of watershed plans can provide insight into progress made in statewide nutrient reductions.

4.2.4 Research programs

The 2014 NRS suggested that a unified group compile and compare stormwater research in the state to help advance nutrient reduction. In 2016, a group of stormwater professionals, practitioners, managers, engineers, researchers, and others established the Minnesota Stormwater Research Council (the Council) to address this need.

MINNESOTA STORMWATER RESEARCH COUNCIL

Collecting water samples

The UMN's Water Resources Center administers the Council, which facilitates research on urban stormwater management and transfers that knowledge to professionals who can use it to prevent, minimize, and mitigate the impacts of runoff, including those from excessive nutrients. The goals of the Council include:

- Facilitate the completion of needed applied research that enables more-informed decisions about using, managing, and protecting water resources in urbanized areas.
- Periodically assess the status of research, identify consensus research priorities, and communicate these to Minnesota's public and private research agencies and organizations.
- Promote coordination of research goals, objectives, and funding among the research agencies and organizations.
- Advise on technology transfer efforts to disseminate research results and train professionals with information discovered through research.

Financial support for the Council is provided by member cities, watershed districts and organizations, and private businesses. Additional support is provided through the Clean Water Fund from Minnesota's CWLLA; the UMN Water Resources Center; Minnesota Sea Grant; the College of Food, Agriculture, and Natural Resource Sciences; and the National Institutes for Water Resources funded through the USGS.

Eight major areas of research priorities were established in 2018. These address several concerns, including reducing and preventing nutrients in urban stormwater runoff and creating knowledge to improve the efficiency and effectiveness of practices to capture, treat, and remove nutrients and other contaminants. Learn more about the research projects by visiting the individual project web pages.

The program also emphasizes the importance of transferring the knowledge discovered through research to those professionals, practitioners, and policymakers who can benefit from it. The program accomplishes this through several efforts:

- The Minnesota Stormwater Seminar Series, which shares the latest research occurring in Minnesota and nationally.
- The Clean Sweep Extension program, which builds on research led by the university and MPCA.
- Training programs, such as the Inspection and Maintenance of Stormwater Practices.

In addition to the Council, the interdisciplinary Water Resources Center brings together research professionals and efforts from across the university system to accomplish research from the multiple departments (Bioproducts and Biosystems Engineering; Civil Engineering; Forest Resources; and Ecology, Evolution, and Behavior) and units such as the St. Anthony Falls Laboratory and the Natural Resources Research Institute.

The Local Road Research Board and the Center for Transportation Studies also provide mechanisms to conduct research and demonstration projects, particularly focused on highway and other impervious surface design, installation, and management to reduce runoff and pollutants. The MnDOT is also a key partner and leader in many of these efforts.

4.2.5 State education, outreach, and training programs

Stormwater extension education, outreach, communication, and training programs provide opportunities to enhance the knowledge and skills of practitioners, professionals, policy leaders, and citizens, enabling their roles in the reduction of nutrient pollution. State-level programs are reported here, as there are too many local and regional programs to document in this space.

Minnesota Pollution Control Agency programs

The MPCA provides webinars and trainings and utilizes the *Minnesota Stormwater Manual* as a primary platform to provide technical guidance to stormwater permittees and practitioners. Examples of these specific efforts include a series of webinars conducted during the reissuance of the 2020 MS4 General Permit, an MS4 101 webinar series following the permit's issuance, and various MIDS Calculator and Simple Estimator training sessions.

University of Minnesota programs

In addition to the work of the Minnesota Stormwater Research Council described above, the UMN and its varied centers (e.g., Water Resources Center), departments and units (Minnesota Extension and Minnesota Sea Grant) lead and collaborate on many programs and efforts meant to bring stormwater science and knowledge to practitioners, professionals, and policy leaders. They continue to provide resources such as conferences (the Minnesota Water Resources Conference), newsletters (*Minnegram*, *Confluence*, and the Minnesota Sea Grant Program), and training opportunities.

The erosion and stormwater certification program led by the university's Department of Bioproducts and Biosystems Engineering provides comprehensive CSW training for project managers, contractors, inspectors, and designers in the construction industry. This program was created in partnership with the MnDOT and MPCA to provide certification to MnDOT employees and contractors.

The *Stormwater Updates* newsletter, produced by the St. Anthony Falls Lab, is a regular publication that provides research and scientific information on stormwater management, assessment, monitoring, and maintenance that helps lead to the reduction or prevention of nutrients in urban stormwater runoff. The lab also provides professional training on watershed and urban water management models, such as the Storm Water Management Model used by many throughout Minnesota in their planning and implementation efforts to reduce impacts to water resources.

UMN–Duluth and its affiliated Natural Resources Research Institute also maintain a stormwater management and water remediation research program. Current projects range from research on biofiltration medium to a collaboration with the MnDOT to reuse regional waste in soils used for stormwater treatment.

4.2.6 Funding support for stormwater nutrient reduction

State funding

A growing number of resources are available to the stormwater sector that either didn't exist or weren't easily accessible 10 years ago. The Minnesota SRF funds both stormwater and wastewater projects with low-interest Clean Water Revolving Fund loans. The funds for the SRF are derived from a combination of money from the EPA and a required 20% match from the state. In contrast, the Clean Water Fund supports stormwater projects with Point Source Implementation Grants. The money for the Clean Water Fund comes from the revenue of a sales tax imposed by the CWLLA, which Minnesota residents voted to establish in 2008, and is appropriated through the legislature. Grants through the Point Source Implementation Grant program may fund up to 80% of project costs, with a maximum of $7 million.

Eligible projects must meet the following requirements from Minn. R. ch. 7077.0115:

- The project addresses water quality needs (ponds for water quality may also include associated flood control benefits).
- The project consists of permanent stormwater treatment structures.
- The project is based on accepted engineering practices that result in water quality benefits.
- A determination of acceptability will be based on a reasonable assurance of providing water quality benefits.
- The applicant must be a local government, such as a city, county, township, sanitary district, watershed district, or other governmental subdivision.

The MPCA has recently established climate resilience grant programs primarily intended to address water quantity rather than water quality. However, some overlap exists between water quality projects and projects targeting localized flooding. The MPCA will use approximately $70 million over Fiscal Year (FY) 2024–2025 for a new grant program to prepare Minnesota's aging stormwater infrastructure for climate change. Tribal nations, cities, counties, and other local governments can apply for funding to upgrade their stormwater systems with climate-smart improvements that will protect properties and prevent or reduce localized flooding. Examples of projects eligible for funding through this program include building stormwater retention ponds, improving stormwater drainage systems by increasing stormwater pipe capacity, and using rain gardens and similar practices to reduce flow volume.

The MPCA's Planning Grants for Stormwater, Wastewater, and Community Resilience are also periodically available. The grants are intended to assess risk, identify options, and develop plans for resiliency of stormwater systems, wastewater systems, and the overall community.

The MDH administers a Source Water Protection grant program that supports public water suppliers in their efforts to address contamination risks upstream of their drinking water intakes (surface water and groundwater). Successful past implementation projects commonly include stormwater treatment and management strategies that benefit the public water supplier and address nutrient TMDLs present in the upstream watersheds.

Local flooding near the city of Kasota in La Sueur County, MN.

Board of Water and Soil Resources-administered funding

The BWSR offers Competitive Clean Water Fund Grants. Since 2007, this competitive Clean Water Fund grant has invested in on-the-ground projects to protect or restore water quality in lakes, rivers, and streams or protect groundwater or drinking water quality. For FY 2025, $6.3 million was available to local governments statewide for water quality improvement projects, including urban stormwater management practices.

Since 2017, the Clean Water Fund-supported Watershed-Based Implementation Funding program has provided noncompetitive funding biennially to local government partnerships. This program supports projects to implement activities listed in the CWMPs developed through the BWSR's 1W1P program and the seven-county Twin Cities Metro Area's groundwater plans or watershed management plans. For FY 2024–2025, $76.5 million was available statewide for projects to protect and/or restore surface water, groundwater, and drinking water in both rural and urban areas. Of that amount, $9 million was allocated for activities in the seven-county Twin Cities Metro Area, and many of those projects are stormwater-related.

Local funding

Cities, watershed districts and organizations, and other local units of government provide substantial funding to conduct urban stormwater planning and to design, implement, and monitor practices that reduce stormwater runoff volume, nutrients, and other pollutants. Many watershed districts have taxing authority, and many cities have adopted stormwater utility fees. Both efforts provide significant financial resources for reducing urban nutrient pollutants. Since the Clean Water Fund was established in 2008, many of these communities have leveraged state dollars with local funds, resulting in a greater pool of resources to expand and effectively implement projects to reduce urban nutrient pollution. Several of these projects are described below to illustrate how a combination of state, federal, local, and private funding has been used to develop urban stormwater solutions that reduce nutrient loading to water resources.

- **City of Coleraine**. A series of new rain gardens and sediment traps were installed as part of a plan to protect the recreational and community value of Trout Lake in Coleraine, Minnesota. The new stormwater management measures were designed to keep 15 tons of sediment and 43 lbs of phosphorus out of the lake each year, directly helping reduce algal blooms and keep the lake clean for all to enjoy. Clean Water Funds were paired with those from a private foundation, the lake association, and in-kind labor from the city to plan, design, and install the project. Local fourth-grade elementary school students helped plant the rain gardens.
- **City of Bemidji**. Lake Irving in the city of Bemidji, an MS4-permitted community, was impaired by nutrients, and the 2018 TMDL determined that a 36% reduction in phosphorus loading was needed to meet the WQS. Installing a treatment wetland with an iron-enhanced sand filter and adding meanders and native plantings to a drainage ditch were designed to reduce annual loading by 233 lbs of phosphorus, reduce algal blooms, and protect the lake and the downstream waters of Lake Bemidji and the Mississippi River for drinking water, recreation, and wildlife habitat. The project was supported by Clean Water Funds, the city's stormwater utility funds, and some funding from Enbridge, which maintains a pipeline near the project.
- **City of Saint Paul**. A collaborative effort was undertaken by Saint Paul, the Capitol Region Watershed District, and others to use innovative stormwater management techniques in the redevelopment of a 122-acre site where Ford Motor Company operated an assembly plant from 1925 to 2011. MPCA awarded a $7 million Point Source Implementation Grant, and the Capitol Region Watershed District provided over $1.7 million to support the redevelopment project. The

project treats 64 million gallons of runoff annually, preventing an estimated 28 tons of TSS and 147 lbs of phosphorus from entering the Mississippi River each year.

4.2.7 Trends, opportunities, and challenges

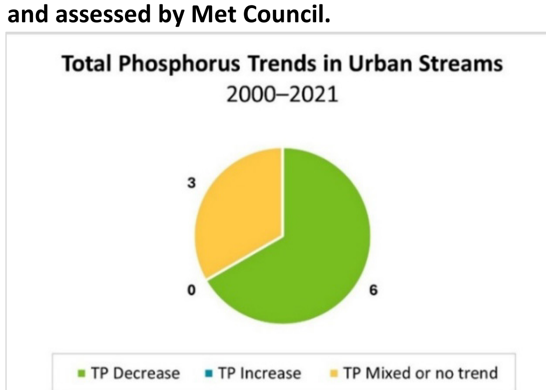
This section focuses on water quality trends in urban-dominated watersheds, as assessed by the Met Council, whereas Chapter 3 presents both urban and agriculturally dominated watershed trend results. Met Council's long-term stream monitoring trend results within the Twin Cities Metro Area show phosphorus concentration improvements in both urban and agriculturally dominated stream watersheds (Table 4-21; Figure 4-10).

Table 4-21. Urban-dominated stream watersheds monitored by the Met Council for nutrient concentration trends.[a]

Watershed	Recent phosphorus 2014–2021	Long-term phosphorus 2000–2021	Recent nitrate 2014–2021	Long-term nitrate 2000–2021	Land use percentage urban/ag
Basset Creek	Increased	Decreased	Increased	Decreased	64/0
Bluff Creek	Decreased	Decreased	Increased	Decreased	35/21
Battle Creek	Decreased	Decreased	Increased	Decreased	63/<1
Browns Creek	Decreased	Mixed	Increased	Mixed	32/12
Credit River	No trend	No trend	Decrease	Mixed	33/14
Fish Creek	Decreased	Mixed	Increased	Decreased/mix	59/1
Eagle Creek	Decreased	Decreased	Nondetects	Nondetects	42/9
Nine Mile Creek	Decreased	Decreased	Decreased	No trend	64/0
Riley Creek	Decreased	Decreased	Mixed	Increased	37/4

Notes:
ag = agriculture
[a] Results extracted from Met Council (2025) data.

Figure 4-10. Phosphorus concentration trends in urban-dominated stream watersheds monitored and assessed by Met Council.



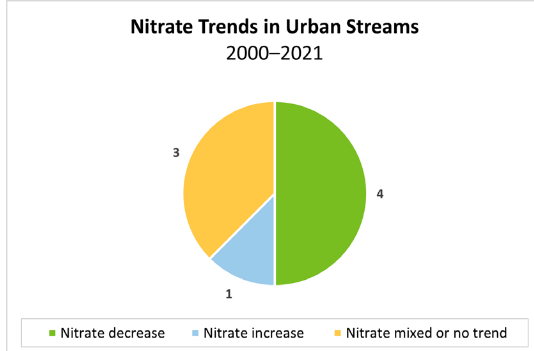
Source: Met Council 2025.

Between 2014 and 2021, phosphorus concentrations decreased (improved) in seven out of nine urban-dominated watersheds. One urban-dominated watershed showed an increase, while one showed no detectable trends. The results are generally similar when assessing trends over two decades (2000–2021). Six out of nine watersheds showed decreases, and three showed no trend. These trends suggest that stormwater phosphorus reduction efforts are having a positive impact in the Twin Cities Metro Area's waters.

Urban watershed nitrate concentrations are quite low, with FWMCs less than 1 mg/L. Nitrate trend directions show a mix of results (Figure 4-11; also see Table 4-21). Long-term trends (2000–2021) show decreases (improvement) in four watersheds, an increase in one watershed, and three with no trend or mixed trends. However, when analyzed over a shorter timescale (2014–2021), the trends shift to more increasing trends (five increases, two decreases, and one mixed trend). Nitrate concentrations remain low in urban watersheds, but the recent small increases in five urban watersheds suggest that stream monitoring and pollution prevention should continue in urban streams to maintain progress.

While equivalent analysis of urban lake nutrient trends was not conducted, the Spring 2024 issue of *LakeLine*, the publication of the North American Lake Management Society, included an article evaluating 20 years of lake nutrient impairment removals from the CWA Section 303(d) list, or the Impaired Waters list, in Minnesota. The authors, who are staff of the MPCA, documented the progress in water quality in the 64 lakes delisted over that time, noting that “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” (Strom et al. 2024). Many of the delistings occurred in the Twin Cities Metro Area and are attributed to the restoration and watershed management activities described in this chapter and elsewhere in the NRS, although no “silver bullet” or “quick fixes” existed for any of these lakes.

Figure 4-11. Nitrate concentration trends in urban-dominated stream watersheds monitored and assessed by the Met Council.



Source: Met Council 2025.

Remaining challenges

Stormwater experts in the work group preparing this chapter concluded that both the reported data and anecdotal documentation included in this chapter demonstrate that Minnesota’s efforts towards urban stormwater nutrient reduction are yielding results and should be continued. However, challenges remain:

- **Data variability and incomplete monitoring**. As mentioned previously, the state-level complement of stormwater data, both in terms of BMP locations as well as stormwater monitoring, is rather incomplete. Possible solutions were demonstrated by a research project recently completed by the Water Resources Center (Leveraging Minnesota's Stormwater Data for Improved Modeling and Management), which assembled the last 20 years of available data from multiple local municipalities in an attempt to better characterize Minnesota stormwater. The project highlights that the large amount of variability in the data makes drawing specific conclusions a challenge. The data repository suggested that shared and compatible data among the various entities working in stormwater may prove helpful in identifying factors that could assist in targeted BMP placement and implementation; however, common methods and data management techniques would need to be adopted across the state for greater progress.
- **Unregulated stormwater**. While Minnesota’s regulatory stormwater program continues to evolve with each permit issuance, hundreds of unregulated communities across the state have conveyance systems that contribute nutrients to local or downstream waters. Without a regulatory framework in place, it can be challenging for these communities to access or leverage available resources to improve their systems. The resources needed can range from buy-in from local leaders and residents to finances and staff capacity (both in terms of knowledge and time).
- **Increasing precipitation amounts**. As mentioned in Chapter 1, more intense storms and other changes in precipitation patterns (e.g., the proportion of precipitation received as rain versus snow) have increased in Minnesota during the 21st century. These bigger storms can overwhelm existing stormwater infrastructure, leading to flooding and damage to other types of infrastructure, including roads, bridges, and buildings. More urban stormwater management and planning are required to handle the increasing amounts of water. Research on new techniques to enhance the efficiency and efficacy of stormwater management is also necessary.
- **Funding gap**. The American Society of Civil Engineers’ 2021 Report Card for America’s Infrastructure identified the annual federal funding for stormwater as approximately $250 million,

leaving a gap of over $8 billion for supporting the maintenance of existing structures (ASCE 2022). This estimate does not account for the funding required for new or upgraded stormwater infrastructure. While Minnesota has Clean Water Funds available at this time to support millions of dollars of stormwater work each year, the fund is scheduled to expire in 2034. Local funds, including stormwater utility fees and watershed district funds, will be strained to meet all the needs related to urban stormwater management.

- **Need for more public engagement**. One continuing challenge in stormwater treatment is the public's lack of understanding about what stormwater runoff is and why it matters. Building awareness and knowledge remains a challenge, as does motivating behavior changes that could prevent or reduce nutrient pollution. Efforts to build awareness and lead communication, education, and training programs need to evolve and innovate to reach a broader audience.
- **Emerging contaminants of concern**. Emerging contaminants such as PFAS, microplastics, and heavy metals may present challenges in monitoring and management practices that could strain efforts to reduce nutrients. Diversified approaches to address nutrients, other pollutants, water volumes, and flow rates need to be expanded.

Measures for achieving stormwater nutrient reduction

1. A platform for sharing project and monitoring data should be established outside of regulatory agencies to allow for communities to benefit from the lessons learned. The database established at the UMN may provide a useful starting point.
1. A standard set of methods and data collection could be developed. For example, the Minnesota Stormwater Research Council could provide a list of recommendations for stormwater methodology and data collection techniques.
2. Greater collaboration between upstream and downstream communities should be supported by state agencies to maximize stormwater planning, reduction, retention, and treatment actions.
3. Research on new techniques to increase the efficiency and efficacy of stormwater work should be supported through state funding mechanisms, such as the Clean Water Fund and the Environment and Natural Resources Trust Fund.
4. The *Minnesota Stormwater Manual* should be regularly updated to provide guidance on managing increased water volumes.
5. Clean Water Funds and SRF dollars should continue to be made available for implementing stormwater projects. Access to funding for nonpermitted sources could be improved by more frequently incorporating stormwater recommendations into comprehensive water management plans.
6. Continue education and outreach efforts (an established minimum control measure for regulated MS4s). Expanding partnerships and shared materials can expand the impact while lessening the burden for some smaller/unregulated communities. The Duluth area's Regional Stormwater Protection Team and the Central Minnesota Water Education Alliance are excellent examples of collaboration.

4.3 NRS support documents

- Appendix 4-1: Denitrification in Cold Climates – Final Report.
- Appendix 4-2: Denitrification in Cold Climates – Cost Spreadsheets.

Chapter 5
Addressing Rural Nutrient Sources

Key Messages

Chapter 5 describes how rural nutrient loss reduction is being addressed and enhanced to meet Minnesota's water quality goals. This chapter emphasizes practices, alone and in combination (e.g., BMPs and CLC), that can be used to reduce nutrient losses and achieve other benefits through Minnesota's strong existing foundation of programs. This chapter's key messages focus on the following nutrient source categories: cropland, feedlots, septic systems, forested areas, and the erosion of streambanks and channels.

Needed cropland practices

- **Many helpful practices are available**. Minnesota has research-based information on the effectiveness of most nutrient-loss reduction practices on cropland. Extensive literature reviews through 2024 were used to update expected nitrogen and phosphorus loss reductions from specific practices (BMPs, including CLC practices). The reviews identified:
  - 22 specific practices that reduce leaching of nitrate through the soil into water by 4% to 94%.
  - 20 practices that can reduce phosphorus lost in runoff from 5% to more than 75%.

  No single practice will work on every acre. However, most cropland acreage is suitable for at least one or more practices that would help prevent nitrogen and/or phosphorus loss to waters.
- **Multiple benefits from practices will be needed**. The multiple benefits provided by most nutrient-reducing practices can help justify the cost and effort and provide motivation to add and manage the practices. Besides water quality, these benefits can include reducing nitrous oxide emissions, reducing sediment in waters, improving soil health and carbon storage, increasing the resilience of croplands to precipitation extremes, sustaining long-term agricultural productivity, increasing or stabilizing farm profitability, reducing flooding, and adding habitat for wildlife and pollinators. Water quality benefits include making drinking water safer, reducing algae growth, and protecting aquatic life to improve fisheries and recreation use in lakes, rivers, and oceans.
- **Certain practices result in more benefits**. Effective nutrient-reducing practices that also offer other benefits include:
  - Conservation crop rotation (e.g., adding small grains or perennials into rotations)
  - Using perennial crops on working lands (including rotational grazing)
  - Cover crops
  - Strip-till (and other reduced tillage methods)
  - In-field nutrient management (fertilizer and manure precision/efficiency)
  - Drainage water recycling (storing and irrigating drainage waters)
  - Wetland construction and restoration

  Each of these practices is emphasized in the NRS, although some practices need more research and development before they can be broadly implemented.

- **Practice costs vary greatly**. The estimated costs of treating land for nutrient reduction and other multiple benefits are typically $14–$63 per acre but can range from "negative costs" (a cost savings for many fertilizer and tillage practices) to costs of more than $250 per acre.
- **Farmers have made good progress, which needs to be maintained and increased.** Since 2014, over 4 million acres of land have been treated by new practices adopted through government programs alone (roughly 18% of cropland). These additional practices follow decades of conservation work and improved fertilizer efficiencies.
- **In-field nutrient management is an essential component of the solution.** Implementing in-field fertilizer and manure practices across millions of acres yields significant collective water quality benefits. Continued work to improve precision nitrogen and phosphorus management on every acre is a critical component for achieving NRS goals, when combined with other types of practices. Many of the most scalable nitrogen management practices align with the *4R framework*, which refers to applying the right rate, at the right time, using the right source, and placing nutrients in the right location. Practices such as reducing applications based on the maximum return to nitrogen (MRTN) value, using split applications, and applying nitrification inhibitors are the foundation of nutrient stewardship and are adaptable across diverse cropping systems and farm sizes. These strategies are supported by research and can be implemented through voluntary programs, technical assistance, and decision-support tools. Continued work to improve precision nitrogen and phosphorus management on every acre remains central to achieving NRS goals.
- **Millions of acres of change can achieve goals**. To achieve the Mississippi River nutrient reduction goals and most in-state goals, Minnesota will need large-scale adoption of CLC practices, drainage water treatment, and other practices. One scenario indicated that nearly 17 million acres of additional cropland practices would be needed. Often, combining practices can further reduce nutrient loss from the same field.
- **The costs to reach final goals add up**. The estimated annual cost for farmers implementing and maintaining the needed practice additions to achieve final goals is $700–$850 million per year for the combined Mississippi River and Red River basins, not including the costs of administering government assistance programs. The 2025 NRS recommends that, from 2025 to 2030, emphasis be placed on increasing the adoption of lower-cost and profitable practices (e.g., strip-till, fertilizer efficiencies, harvestable and marketable CLC on marginal croplands) while continuing to develop crop rotations and harvestable/marketable CLC with lower inputs and adequate yield, markets for these crops, and the supporting long-term infrastructure.
- **The human dimension needs to be understood**. The NRS is science-based. This science includes social science and the human dimension of conservation adoption and behavior change. Money alone cannot solve the water nutrient issues. Achieving a high level of practice adoption requires working with people. Understanding and removing barriers to adoption and engaging farmers and the agricultural community will help Minnesota move toward progress.

Cropland program development

- **Use successful programs.** Minnesota has achieved nutrient reduction through many excellent programs and approaches over the past 15 years. These programs should continue and evolve to be most effective in the future. Private sector involvement has been crucial and will be increasingly important.
- **Increase practice adoption**. Proven approaches to scaling up practice adoption share common characteristics, including building trusted relationships, increasing the local capacity to assist farmers and meet them where they are, establishing flexibility to accommodate diverse farm situations, using consistent messaging, maintaining strong local leadership, growing peer networks, and offering financial incentives.

- **Two scales of work are needed**. The NRS has a two-pronged strategy for further reducing rural nutrients: (1) reduce nutrients in local priority lakes, streams, and aquifers, and (2) take steps for landscape-level changes statewide to reduce nitrogen by about 40% in surface and groundwater while also reducing downstream phosphorus.
- **The Minnesota Water Management Framework is foundational for program delivery**. The Minnesota Water Management Framework (as discussed in Chapter 6) should continue to serve as the foundation for program delivery to improve priority local waters. With further support, the framework can also be used to deliver programs that address the broader landscape-level changes needed to meet downstream goals.
- **Support is needed to reduce nutrient losses to local priority waters**. To finish the work of improving specific local priority waters, the following will be important:
  - Increasing local conservation workforces and training
  - Fostering new partnerships with the private sector
  - Securing long-term state funding
  - Leveraging federal programs
- **Landscape-level changes require several areas of program modification**. Achieving the large-scale changes needed to meet NRS goals will require the following adjustments to existing programs:
  - Streamlining practice delivery and programs
  - Adding more streamlined practice installation opportunities
  - Increasing private sector involvement
  - Showcasing and replicating successful ongoing local efforts
  - Expanding soil health and water storage grant opportunities
  - Increasing the conservation workforce capacity
  - Improving the tools and information needed for practice adoption planning
  - Including focused outreach to absentee landowners
- **Expand the Minnesota Agriculture Water Quality Certification (MAWQCP)**. Continuing and expanding the MAWQCP will aid progress with both local water improvement efforts and landscape-level changes. A nitrogen endorsement certification should be added to the five existing MAWQCP special endorsements.
- **A CLC campaign is needed**. Nitrogen water quality goals cannot be achieved without transformative changes in crop system rotations and more months of living cover each year. Infrastructure and market development support are needed for perennials, pasture, small grains, and harvested/marketable cover crops. For example, the momentum building for improved market access for oats in Minnesota could be a practical underpinning for a CLC campaign to move the state toward achieving the first additional million acres of living cover adoption (in addition to current levels). A work group should be organized to plan and implement the campaign, including specific steps of a phased strategy to further develop the market and promote CLC practices.
- **Research and demonstration remain critical**. Enough research has been completed in the past to enable Minnesota to move forward in promoting and implementing proven practices. However, to reach the landscape levels of change previously described, more research, demonstration projects, and pilot programs are needed to support existing and emerging cropping systems, technologies, and practices. The research should include confirming and quantifying the multiple benefits provided by nutrient-reducing practices in colder climates.
- **Cropland summary**. The NRS shows a path forward to achieving in-state and downstream nutrient goals. This path requires changes to agricultural and food systems. Without implementing most of the Chapter 5 strategies, there is little chance of achieving the TN load and nitrate concentration

goals outlined in chapters 2 and 3. The successful implementation of the recommendations will require adequate funding and commitments from local, state, federal, and private sector organizations. The structure of the current agricultural system, including lender requirements, market dynamics, financing mechanisms, and federal policy, can influence the pace at which new practices are adopted.

Feedlots

- **MPCA's Feedlot Program**. Since the 2014 NRS, the MPCA's feedlot program has continued work on minimizing the risk to waters from the land application of manure and animal holding and manure storage areas. The biggest policy change since 2014 has been modifications to the land application of manure requirements in NPDES and SDS permits for large feedlots, including concentrated animal feeding operations and other 1000+ animal unit feedlots with operating permits. Permit requirements were modified to reduce pollutants, particularly nitrate, from manure applications. Additional requirements were specified for manure management plans (MMPs), transferred manure, field inspections, early fall manure applications, winter manure applications, and spreading in vulnerable groundwater areas. In 2025, the MPCA began a process to revise the overarching animal feedlot rule (Minn. R. ch. 7020), which is expected to take several years to complete.

Septic systems

- **Minnesota's Subsurface Sewage Treatment Systems (SSTS) Program**. The implementation of Minnesota's SSTS program will continue to serve as the primary strategy for reducing nutrient loads from septic systems. The number of septic systems considered as imminent public health threats has continued to decrease (down to 4% in 2023). Older septic systems continue to be replaced at a rate of about 5,000 to 7,000 per year. Reducing the number of septic systems that inadequately protect groundwater remains a priority of the SSTS program.

Forests

- **Minimize forest nutrient losses by preservation, restoration, and BMPs**. Forestland preservation, peatland restoration, and harvesting timber with care for water quality are all important to minimize nutrient losses to waters in forested areas. Comprehensive local watershed planning, supported by WRAPS Updates and 1W1P, should continue and promote solutions for these activities.
- **Expand programs**. Existing state programs should be expanded to preserve forests (e.g., Sustainable Forest Incentive Act) and monitor and promote forest harvesting BMPs, such as through the Minnesota Forest Resources Council.

Erosion of streambanks

- **Data on phosphorus vary**. Most peer-reviewed studies of streambank contributions to water phosphorus levels have examined individual streams or small watersheds and found that 6% to 93% of total stream phosphorus loads originate from streambank erosion, with variations that depend on watershed characteristics, soils, and hydrology. Studies of large rivers and watersheds have shown that 17% to 31% of phosphorus originates from stream channel sources.
- **More practices are needed**. To achieve the in-state and downstream goals for phosphorus, adding practices to reduce streambank and gully erosion will be needed. Practices include:
  - Off-channel water storage
  - Reconnecting floodplains
  - Bank stabilization or protection
  - Riparian buffers

  - Two-stage ditches
  - Near-channel gully or ravine stabilization
  - Grade control structures
  - Stream channel restorations
- **Emphasize practice combinations**. While stream channel restoration is a systemic approach that generally has the greatest potential for reducing nutrients and sediment from bank erosion, a multifaceted strategy that incorporates combinations of the above practices, including floodplain reconnection and floodplain wetlands, is most effective.
- **Focus on local and statewide strategies**. Efforts to decrease streambank erosion should be implemented through Minnesota's Water Management Framework, along with water storage grants provided by the BWSR. Because the sediment reduction goals around the state are closely linked to reducing streambank and gully erosion, both local sediment TMDLs and large-scale sediment reduction strategies are important drivers in reducing this source of phosphorus.

5.1 Cropland practices to achieve nutrient loss reduction goals

5.1.1 Overview of the best practices for broad-scale adoption

In agricultural sectors, NRS goals are often called nutrient "loss" reduction goals to emphasize that the goal is to keep the nutrients on the cropland and in the soil rather than lose them into surface water and groundwater. Often, scientists point out that there is no "silver bullet" practice—no single cropland practice—that can solve nutrient reduction issues. To reach Minnesota's nutrient reduction goals, various practices will need to be implemented. Some practices can be applied more broadly across larger geographic areas, and others are better suited for addressing specific local nutrient reduction needs. The practices best suited for NRS large-scale adoption include those with a combination of the following characteristics:

- **Effectiveness**. The practice achieves nitrogen and/or phosphorus load reduction efficiencies across multiple landforms and soils, climates, and/or land management systems.
- **The potential to affect large acreages**. The practice is well-suited to treat many acres of land.
- **A favorable cost-benefit ratio**. A practice is feasible when the cost to adopt, manage, and maintain it is balanced by the water quality improvements made, the nutrient reductions achieved, and the co-benefits provided (agronomic, climatic, wildlife, soil health, water storage, etc.).
- **Manageability.** The practice is practical and does not add substantially to risk and uncertainty within the land management systems.

Additional considerations should include farm economics, the affordability of practices, and which practices farmers are most likely to adopt within the intended timeframe.

In the 2014 NRS, the practices considered to best meet the combination of the above characteristics included:

- **Fertilizer use efficiencies** gained by adjusting the rate, placement, timing, form and precision of added nutrients to cropland.
- **Drainage water management and treatment**, especially treatment wetlands and controlled drainage.
- **Field erosion control** designed to reduce phosphorus, especially through reduced tillage.

- **Increasing and targeting living cover**, especially cover crops added on early harvested crops, but also by adding vegetative buffers, cover crops on traditional corn/soybeans, and perennial crops on marginal lands.

For the 2025 NRS, these best practices were reconsidered based on updated science and an assessment of their effectiveness, their potential to affect large acreages, and the multiple benefits they provide. The 2025 recommended practices generally align with the 2014 NRS but have some differences and more specific justifications for selecting those practices. Recommended 2025 NRS practices include:

- **In-field nutrient management**. Increase the use of optimal nutrient rates and the timing of application, and expand the research to improve the precision of applications based on soil type, weather, and other variables.
- **CLC**. Add multiple types of cover crops, relay crops, and companion crops into existing row crop systems. Diversify the rotations with more perennial crops and small grains. In some cases, perennials can replace annual crops and then be harvested for food, fuel, and forage or otherwise converted to pasture. These practices are often referred to as "continuous living cover or CLC" practices due to the increased duration of living vegetation throughout the year. The NRS emphasizes the use of harvestable and marketable CLC, in particular.
- **Drainage water management and treatment**. Construct local and regional treatment wetlands, in-field controlled and shallow drainage, and edge-of-field treatment with saturated buffers and denitrification bioreactors. Develop the practice of drainage water recycling.
- **Reducing tillage and field runoff**. Reduce intense tillage; instead, use strip till and other reduced tillage options. Incorporate prairie strips and increase contour strip-cropping.

It is important to note that no single practice will work on every acre. But, with the scale of adoption needed to meet the 2025 NRS goals, most cropland acres will need something added to help reduce nutrient losses. Not all practices will be effective on every farm, and specific practices must be tailored to fit within the systems used by the farmer. For example, drainage water management and treatment practices are not suited to systems without tile drainage. Likewise, prairie strips may have a minimal impact on water quality in areas with a flatter topography. Furthermore, there might be environmental trade-offs associated with certain practices that should be acknowledged and anticipated. There is a future need to better identify which agricultural BMPs—under certain circumstances—can be a nutrient source due to natural conditions (e.g., freeze/thaw release of dissolved phosphorus) and long-term maintenance challenges. The above practices are further discussed in sections 5.1.2 to 5.1.5. A combination of practices adopted on a large scale will be needed, as described in Section 5.1.6. Much more information can be found in the accompanying science assessments (see Appendix 5-1 [Christianson and Rosen 2025] and Appendix 5-2 [Souza and Rosen 2025]).

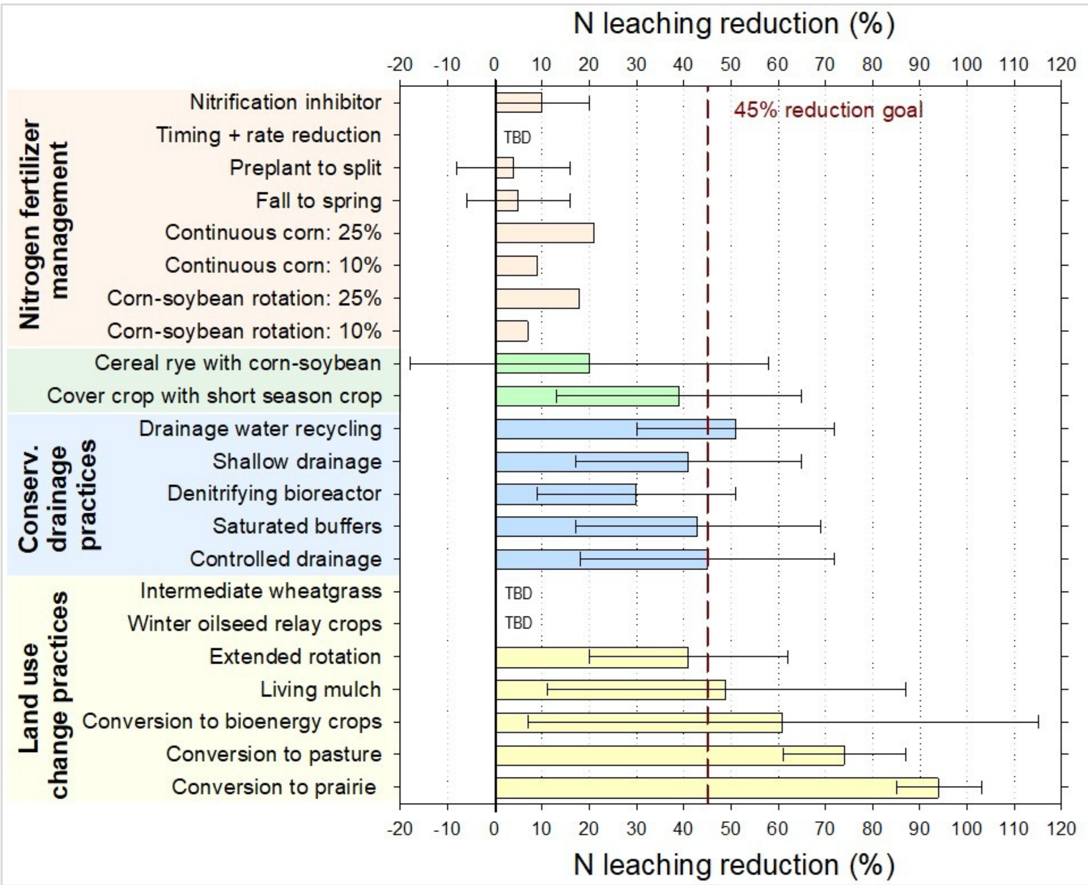
5.1.2 Nutrient reduction efficiencies of specific practices

The 2025 NRS development process reevaluated nutrient reduction efficiencies based on the current research relevant to Minnesota conditions. Updated efficiencies are useful for prioritizing practices, describing how practice performance varies, improving models and tools used to estimate nutrient load reductions in Minnesota, and communicating expected results of practice implementation to farmers and local watershed staff.

UMN conducted two literature reviews. The first, from Christianson and Rosen (2025), primarily reviewed nitrogen fertilizer management, cover crops, land use changes, and in-field/edge-of-field conservation drainage practices (Appendix 5-1). The comprehensive report included water quality information from 270 of 710 reviewed studies. Most of the studied practice efficiencies exhibited a wide range of variability, which was influenced by site, soil, weather, crop management, and other factors.

The mean nitrogen reduction percentage and standard deviation are shown in Figure 5-1 and Table 5-1. In-field nitrogen management practices had average reductions of 4% to 21%, depending on the practice. CLC efficiency showed average reductions of 17% to 94%, while drainage water management and treatment practices achieved average reductions of 30% to 51%.

Figure 5-1. Visual representation of recommended nitrogen reduction efficiencies for leachate or tile drainage.



Source: Christianson and Rosen 2025.

Notes:

TBD = to be determined. The bar represents the mean; the whiskers show plus and minus one standard deviation (SD). The method used to develop practice efficiency values for the nitrogen rate reduction did not facilitate the development of associated SDs. The literature does not have a consistent nomenclature for the practice category names, and the broad categories used in Figure 5-1 differ from those in Table 5-1.

The research review provided a strong foundation for understanding nitrogen removal practice efficiencies, drawing from a broad and well-vetted body of scientific literature. While most of the studies reviewed originate from outside Minnesota, they offer valuable insights and a credible starting point for decision-making. At the same time, the geographic focus of the available research highlights a clear opportunity to enhance the relevance of practice efficiencies by investing in more locally generated data. Building on efforts from Discovery Farms, UMN research, extension programs, and local expertise will help refine the understanding of how practices perform in Minnesota's soils, climate, and cropping systems. Importantly, this gap should not delay progress; rather, it reinforces the need to act while continuing to strengthen the research infrastructure.

Table 5-1. Summary of recommended nitrate reduction efficiencies for loss to surface water, standard deviation as an indicator of variability, and number of site years used to determine efficiencies.

Practice	Nitrate reduction %	Standard deviation	Number of site years
(1) In-field nitrogen management			
Corn-soybean rotation: 10% fertilizer rate reduction to achieve maximum return to nitrogen, or MRTN [a]	7%	NA	151
Corn-soybean rotation: 25% fertilizer rate reduction to achieve MRTN	18%	NA	151
Continuous corn: 10% fertilizer rate reduction to achieve MRTN	9%	NA	101
Continuous corn: 25% fertilizer rate reduction to achieve MRTN	21%	NA	101
100% fall to 100% spring pre-plant	5%	+/-11%	15
100% spring preplant to split application	4%	+/-12%	21
Timing modification toward spring and side-dress, plus a rate reduction	TBD		
Nitrification inhibitor	10%	+/-10%	15
(2) Continuous living cover increase			
Extended rotation (including perennial)	41%	+/-21%	17
In rotation: alfalfa	63% [b]	+/-41%	32
In rotation: small grains – oats	60% [b]	+/-12%	11
Kura clover living cover	49%	+/-49%	17
Winter oilseed relay crops	TBD	NA	
Intermediate wheatgrass (Kernza®)	TBD	NA	
Cover crop: cereal rye in corn-soybean rotation	20%	+/-38%	60
Cover crop: cereal rye in continuous corn	17%	+/-33%	19
Cover crop: oat cover crop in corn-soybean rotation	TBD	NA	
Cover crops following short-season crops in a cold climate (not undersown)	39%	+/-26%	24
Conversion to prairie	94%	+/-9%	32
Conversion to pasture	74%	+/-13%	17
Conversion to bioenergy crops	61%	+/-54%	23
(3) Drainage water management and treatment			
Controlled drainage	45%	+/-27%	38
Saturated buffers	43%	+/-26%	42
Denitrifying bioreactors	30%	+/-21%	57
Shallow drainage	41%	+/-24%	20
Drainage water recycling	51%; limited data	+/-21%	26
Constructed treatment wetlands	42% [c]	+/-6%	109 wetland site years

Source: Christianson and Rosen 2025.
Notes:
NA = not applicable; TBD = to be determined
[a] MRTN is described further in the NRS 5-year Progress Report
[b] The reduction is for the year when the field is in this crop, compared to a control with corn, and does not represent reductions over the entire rotation. For alfalfa, nitrate leaching may increase following corn, and the transition out of alfalfa must be managed to reduce the risk of increased subsequent nitrate loss.
[c] Supplementary to the work of Christianson and Rosen (2025) as added by Souza and Rosen (2025).

The review of practices for nitrogen concluded that practices would work on every acre, but to meet in-state and downstream nitrate and TN reduction goals, most acres of cropland would need at least one practice. Many different practices are needed to make significant headway toward water quality goals in Minnesota. The nitrogen reduction effects of floodplain reconnection practices were not reported by Christianson and Rosen (2025); however, Mazer (2023) assessed and reported the results provided in three other studies, which showed that floodplain reconnection practices yielded a 64% nitrate reduction (Gordon et al. 2020), an 80% dissolved inorganic nitrogen reduction (Dee 2019); and a 32% TN reduction (Dee 2019).

The second literature review, by Souza and Rosen (2025), evaluated phosphorus loss reductions from in-field phosphorus management, tillage practices, and cover crops. This report included water quality information from an additional 21 of 52 studies reviewed (Appendix 5-2). Souza and Rosen (2024) did not report on the phosphorus reduction effects of floodplain reconnection practices, but they are reported as 26.5% in Gordon et al. (2020) and summarized by Mazer (2023). The work of Souza and Rosen (2025) is ongoing, and additional reviews of phosphorus-reducing practices will be provided in support documents in 2026.

Phosphorus practices are reported in Table 5-2 from Souza and Rosen (2025). Two other sources of phosphorus practice efficiencies are also included in Table 5-2 to temporarily fill the gaps of ongoing work by Souza and Rosen and provide an additional reference point of the typical expected reduction efficiencies. More details about nitrogen and phosphorus practice efficiencies can be found in appendices 5-1 and 5-2, respectively.

In general, rainfall simulation studies were excluded from the NRS analysis by Souza and Rosen (2025). A supplemental analysis was conducted to examine how phosphorus reduction efficiencies differ between studies using simulated rainfall and those using natural rainfall. This distinction is important because simulated rainfall studies often dominate the NRS reports of surrounding states because they are a common and faster method to test BMPs. However, these studies typically capture only initial runoff events after practice implementation, which can overestimate reductions, especially for practices that temporarily stabilize surface-applied phosphorus. For example, no-till systems showed an average TP reduction of 88% after the first simulated event, but only 5% under natural rainfall conditions. Similarly, ridge-till and subsurface phosphorus application showed 54% and 71% TP reduction, respectively, under simulated rainfall, compared to 47% and 40% under natural rainfall. These discrepancies highlight the importance of context when interpreting efficiency estimates. For the current NRS phosphorus practice efficiencies, reductions based on natural rainfall are prioritized for consistency and long-term applicability, though simulator-based results may still offer useful mechanistic insight and may be reported alongside natural rainfall values where differences are substantial (e.g., for no-till). Additional discussion of this analysis and supporting data is provided as a supplementary rainfall simulation section in Souza and Rosen (2025).

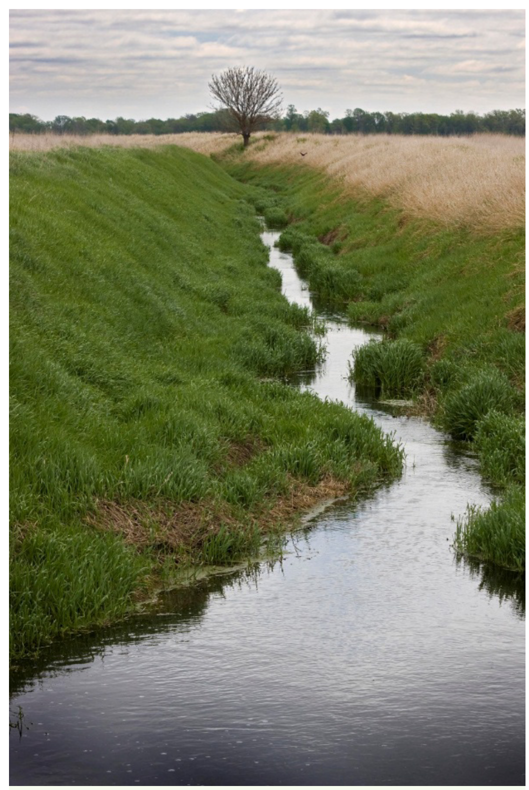

A drainage ditch in an agricultural area.

Table 5-2. Summary of average phosphorus reduction efficiencies.

Practice	UMN 2025 TP reduction % average [a]	TP reduction efficiencies used in HSPF-SAM as defaults [b]	Iowa State University TP reduction % average [c]
(1) In-field phosphorus management			
Nutrient management: improved rates/timing		10%	
Nutrient management: precision/variable rate		15%	
Manure/fertilizer incorporation (no surface spreading)		35%	35% incorp < 1 week
Phosphorus subsurface banding	42.0%		25%
Drawdown soil phosphorus	25.5%		17%
Switch from fall to spring applications	18.4%		
(2) Continuous living cover increase			
Conservation crop rotation		30%	
Conversion row crops to prairie		84%	75%
Conversion row crops to pasture		59%	59%
Conversion to bioenergy crops			34%
Cover crops	21.5%	29%	18% winter rye & wheat; 30% seed mixes
(3) Reducing tillage and field runoff			
Conservation tillage	47%	33%	33%
No-till		68%	90%
Water and sediment control basin		85%	85%
Terrace		75%	77%
Grassed waterway		45%	
Buffers at field edge		67%	65%
Contour buffer strips		62%	
Contour strip cropping		44%	
Alternative tile intakes		66%	57%

Notes:

[a] Souza and Rosen 2025

[b] RESPEC 2024; HPSF-SAM = HSPF-Scenario Application Manager

[c] Iowa State University 2023 (draft)

It should be noted that regional differences in BMP effectiveness can occur due to variations in climate and soil conditions across the state. However, often there are not enough studies in specific regions to differentiate the average nutrient reduction efficiencies by region. The Red River Basin, in particular, has a colder and drier climate than the rest of Minnesota, along with vast areas of flat soils. Practice effectiveness reviews that are specific to this region were completed or updated about four years prior to the 2025 NRS and can be found at the Red River Watershed Management Board's Flood Damage Reduction Work Group website and at the Red River Basin Commission's Beneficial Management Practices website. Relevant papers from these analyses were also included in the reviews by Christianson and Rosen (2025) and Souza and Rosen (2025). Additionally, in 2024, the Red River Basin Flood Damage Reduction Work Group began leading a 5-year study to look at the long-term natural resource benefits of large-scale impoundment projects, which will help inform how these projects can be improved in the future to reduce nutrient loss.

5.1.3 Multiple benefits from practices

Nitrogen reduction efficiency is one of several considerations when selecting practices at the local or large river basin scales. Another important consideration is the potential for achieving multiple benefits from individual practices. Many of the practices identified in the NRS will result in multiple other benefits in addition to the expected improvements for drinking water from wells, lake and river eutrophication, aquatic life affecting fisheries and recreation, and hypoxia. Additional benefits include:

- Long-term agricultural sustainability and profitability
- Soil health improvement
- Resilience to precipitation extremes and soil erosion
- Greenhouse gas mitigation
- Sediment reduction in rivers and downstream lakes
- Wildlife habitat and pollinator increases
- Other ecosystem benefits

The cost and effort required to implement more nutrient-related practices can often be justified by considering the multiple benefits of such practices. Motivation to add or change practices can increase when people understand the full range of benefits expected when various practices are adopted. Additionally, aiming for multiple benefits helps maximize limited finances at the personal and government levels. Therefore, NRS practices, while primarily focused on reducing nutrients in water, are amplified when also addressing other needs on the farms and within the state. Several information sources were examined to estimate the potential for multiple benefits from nutrient-reducing practices, including:


A wetland improves water quality and provides habitat

- USDA's NRCS Conservation Practice Physical Effects and previously published NRCS Climate Smart Mitigation activities
- Upper Mississippi River Basin Association's multi-benefit conservation practice workshops
- Iowa's *Whole Farm Conservation Best Practices Manual*
- Minnesota Office for Soil Health practice reviews and State Soil Health Action Framework
- USDA's Carbon Management Evaluation Tool planner for estimating carbon sequestration and greenhouse gas mitigation benefits from conservation practices
- Minnesota's Climate Action Framework documents
- NRCS's *Common Wildlife Conservation Practices*
- Minnesota's Water Storage Planning and Decision Support Framework
- Midwest Cover Crop Council

Co-benefits from practices

The potential for co-benefits from various practices, in addition to nutrient reduction, is summarized in Table 5-3 and discussed below. These co-benefits were determined by the best professional judgment of Chapter 5 authors after reviewing the previously noted and linked reports.

Table 5-3. The type of potential benefits and general degree of anticipated benefits a provided by conservation practices for water, nutrients, water quality, climate, water storage, soil health, habitat, and agriculture.

Practices to reduce rural nutrient losses to waters and the associated NRCS/BWSR practice code number(s) for each	Water quality: Nitrogen	Water quality: Phosphorus	Water quality: Sediment	Climate: Resiliency to climate extremes	Climate: Greenhouse gas emission	Climate: Carbon storage	Water storage: Reduce high flows, flooding, & bank	Soil health & productivity	Wildlife habitat	Agriculture: Production/profit
Edge-of-field practices for tile water treatment										
Denitrifying bioreactor (#605 [747 interim])	H	L	L	L	L	L	L	L	L	L
Drainage water management (controlled drainage) (#554)	H	L	L	M	L	L	L	M	L	M
Drainage water recycling (stored water used for irrigation) (#447)	H	L	M	H	M	L	H	M	M	H
Wetland construction on tiled lands (#s 656, 657, 658)	H	M	M	M	L	L	H	L	H	L
Saturated buffer (#604)	H	L	L	M	L	L	L	L	M	L
Two stage ditch (#582)	H	M	M	M	L	L	H	L	M	L
Field erosion controls and tillage										
Improving open tile intakes & side inlets (#s 170M, 171M, 172M, 606, 410)	L	H	M	M	L	L	L	M	L	L
Water and sediment control basin (#638) & grade stabilization structure (#410)	L	M	H	H	L	L	H	L	L	L
Grassed waterway in areas with concentrated flow (#412)	L	M	H	H	L	L	H	H	L	L
Contour buffer strips or prairie strips (#332)	M	H	H	H	M	M	L	H	H	L
Residue and tillage management: no-till/strip-till (#s 329, 329A)	L	H	H	H	H	H	H	H	L	M
Residue and tillage management: reduced till (#s345, 346, 329B)	L	H	H	M	M	M	H	H	L	M
Living cover duration increase, in-field										
Conservation crop rotation (2+ years conservation crops in rotation) (#328)	H	M	H	H	H	H	H	H	H	L
Contour buffer strips or prairie strips (#332)	M	H	H	H	M	M	L	H	H	L
Conversion of row crops to perennial crops for food, energy, pasture, + (#s 327, 327M, 342, 612)	H	H	H	H	H	H	H	H	H	L
Conversion of cultivated lands to strategically placed perennials (#s 327, 327M, 342, 612)	M	M	M	H	H	H	M	H	H	L
Cover crop (including relay crops, companion crops, +) (#340)	H	H	H	H	M	M	H	H	M	L
Cover crop following early harvest crops (#340)	H	H	H	H	M	M	H	H	M	L
In-field nutrient management										
Manure/fertilizer injection or immediate incorporation (#590)	M	H	L	L	M	L	L	H	L	M
Nutrient rates for optimal economic returns (#590)	H	H	L	L	M	L	L	H	L	H
Precision nutrient management with variable rates (#590+)	M	H	L	M	M	L	L	H	L	M
Improved timing: fall-to-spring or spring preplant-to-spring split (#590)	H	M	L	M	M	L	L	H	L	M
Nitrogen fertilizer type: nitrification and urease inhibitors (#590+)	H	M	L	M	M	L	L	H	L	M

Practices to reduce rural nutrient losses to waters and the associated NRCS/BWSR practice code number(s) for each	Water quality: Nitrogen	Water quality: Phosphorus	Water quality: Sediment	Climate: Resiliency to climate extremes	Climate: Greenhouse gas emission	Climate: Carbon storage	Water storage: Reduce high flows, flooding, & bank	Soil health & productivity	Wildlife habitat	Agriculture: Production/profit
Livestock and grazing management										
Manure storage facility construction to also capture feedlot runoff (#s 313, 784)	L	M	L	M	L	L	L	L	L	L
Grazing to exclude or control livestock access to waters (#472)	L	M	L	M	L	L	M	L	L	L
Grazing and pasture management improvement, such as rotational grazing (#s 101, 528)	L	M	H	M	L	L	M	H	L	M
Feed type changes and additions	L	M	L	L	M	L	L	L	L	M
Additions to manure to acidify or stabilize	M	L	L	L	M	L	L	L	L	L
Hydrologic and other types of restoration										
Floodplain reconnection	H	M	L	M	L	L	H	L	H	L
Peatland preservation and restoration	L	L	L	L	H	H	L	L	L	L
Streambank & near-channel stabilization/restoration/ protection (#s 582, 584, 580, 410, 000)	L	M	L	M	L	L	M	L	H	L
Large-scale impoundments and flood damage reduction control structures	H [b]	H	H	H	L	M	H	L	H	L
Restored oxbow	M	L	M	M	L	L	M	L	H	L
Windbreak establishment (#s 650, 380)	L	M	H	M	H	M	L	M	H	L
Adding and preserving trees, including silvopasture & multistory cropping (#s 612, 147M)	M	M	M	M	H	H	M	H	H	L

Notes:

[a] The degree of benefit generated is indicated by letters and shading as determined by best professional judgment of Chapter 5 authors after reviewing the previously noted and linked reports:

- H (dark shading) = High: Indicates an important practice for achieving the specific benefit.
- M (light shading) = Medium: Indicates a potentially helpful practice for achieving the specific benefit (but is limited).
- L (no shading/white) = Low: Indicates a lower potential for achieving the specific benefit.

[b] Nitrogen benefits may vary depending on hydrologic retention time and biological activity affecting denitrification processes.

Practices with high potential for multiple benefits

As noted in the table above, various practices provide potential benefits beyond nutrient reduction. Eight practices listed in Table 5-3 stand out as offering particularly high potential for co-benefits:

- Conservation crop rotation
- Increased use of perennial crops in rotations and working lands
- Cover crops
- Strip-till, no-till, and other reduced tillage
- Contour buffer strips or prairie strips
- Drainage water recycling
- Wetland construction
- In-field nutrient management

Each of these practices is emphasized in the NRS, although several of them require further research and development before they can be broadly implemented. These eight key practices fall within the following four practice groupings that share characteristics that increase the potential for co-benefits: (1) fertilizer and manure management and efficiencies, (2) CLC increases, (3) drainage water management and treatment, and (4) field erosion control and water runoff conservation practice.

Fertilizer and manure management and efficiencies

Increasing nitrogen fertilizer and manure efficiencies reduces nitrate leaching into groundwater and tile drainage waters, reduces nitrous oxide emissions (a potent greenhouse gas), and often lowers production costs.

CLC increases

Adding more CLC or otherwise increasing the duration of living cover in crop rotations has potential benefits for:

- **Water quality**. Reduces nitrate leaching, TP runoff, and sediment loss
- **Resilience to weather extremes**. Protects soil from high soil erosion events (from both wind erosion and runoff erosion)
- **Soil health**. Improves soil health and associated long-term agricultural production sustainability
- **Climate**. Offers potential benefits in some situations by storing soil carbon and reducing greenhouse gas emissions, including nitrous oxide and carbon dioxide.
- **Habitat**. Increases wildlife and pollinator habitat
- **Water quantity**. Incrementally reduces runoff and increases soil water holding capacity, thereby reducing high river flows that can lead to streambank erosion and flooding.

Changing the landscape to include longer durations of living cover on the soil has the most co-benefits, but this is also the most challenging practice to adopt on a large scale because it requires system changes related to infrastructure, government subsidies, and markets. Efforts are underway by groups like UMN's Forever Green to advance all aspects of alternative crops to increase harvestable CLC, including market development. Also, farmer-led efforts, such as Green Acres Milling and the "Oat Mafia," are expanding the adoption of oats in rotation in Minnesota. These farmer-led groups represent the producers of nearly 6,000 acres of oats and have helped with new market accessibility. These efforts, which include education and collaboration on agronomics, machinery, and marketing, are essential for successful cropping system changes.

Unintended consequences and environmental tradeoffs sometimes associated with pesticide use, dissolved phosphorus losses, and conflicting goals with other beneficial practices (e.g., liquid manure injection) should be recognized and managed with all types of CLC. NRS strategies for large-scale additions of CLC are described in Section 5.4.

Drainage water management and treatment

Agricultural drainage is prevalent throughout Minnesota's landscape and provides agronomic benefits for increased crop production, improved trafficability in fields, and reduced sheet and rill erosion (see Appendix 5-1, Chapter 6, Conservation Drainage Practices). Drainage water management practices have been developed and studied over the last few decades to determine their effectiveness in managing hydrology, mitigating nutrient loss, and reducing impacts on crop production. Despite the high capital costs, annual operation and maintenance costs, and limited agronomic benefits associated with many edge-of-field or in-field drainage water practices, there is a high degree of certainty surrounding their water quality benefits (Christianson and Rosen 2025). Some new practices, such as drainage water recycling, offer agronomic benefit potential by providing irrigation water access during critical crop growth times of the year. Drainage water recycling and controlled drainage can reduce the volume of water leaving a field, thereby improving downstream water quality. More studies are needed to determine the long-term economic and hydrologic ramifications of drainage water recycling.

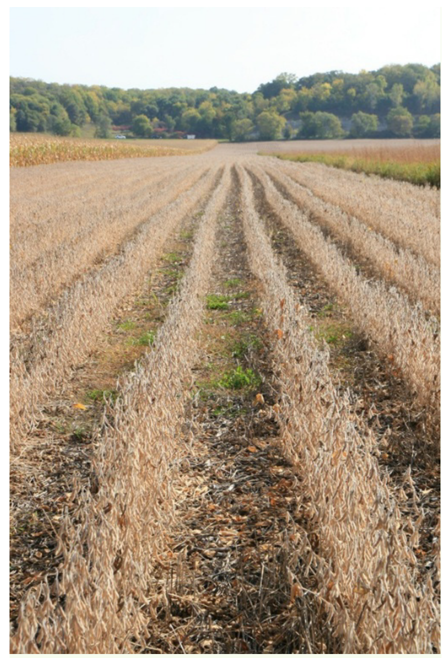
Another set of drainage water management and treatment practices with multiple benefits includes installing ponds, wetlands, and impoundments to treat drainage water and surface runoff. These practices can increase wildlife and also store water for incremental reduction of peak river flow, although the hydrologic implications at local and regional scales require more study. Modeling results of the effects of water storage on reducing high river flows at three HUC-8 watershed outlets in the Minnesota River Basin indicated a wide range of hydrologic benefits from six types of practices. High flows at the watershed outlets were reduced by less than 2% with restored historic wetlands and by 7% to 12% with farm ponds representing drainage water recycling (Tetra Tech 2024). Off-channel large impoundments had the largest hydrologic benefit of the six practices. Such impoundments have been widely constructed in the Red River Basin, where flooding problems have motivated their use. These are most feasible when constructed in unfarmed areas or marginal croplands.

Field erosion control and water runoff conservation practices

The field erosion control practices with the most benefits are reduced tillage techniques, including strip-till, no-till, and other practices that leave more crop residue on the soil surface. Reduced tillage will have benefits for reducing sediment and TP loss, improving soil resilience to precipitation extremes, improving soil health, and potentially mitigating greenhouse gas emissions.

Agricultural soils can also benefit from other soil and water conservation practices, such as grassed waterways, water and sediment control basins, prairie strips, and contour strip-cropping. These practices can be particularly beneficial in slowing down water from precipitation extremes on sloping soils.

Establishing and renovating cropland windbreaks provides benefits for soil health and wildlife and helps reduce phosphorus and sediment losses to the atmosphere and its subsequent deposition into ditches and waters. More research is needed to quantify the water quality benefits. The 2025 NRS does not quantify the benefits of cropland windbreaks.



Leaving crop residue prevents erosion

5.1.4 Potential for adding practices to the land

When selecting the NRS practices to emphasize for large-scale practice additions to cropland landscapes, it is important to consider the upper limits of acres that can be added. The potential for scaling up adoption is different for each practice. For some practices, data uncertainties and limited data only allow for rough approximations of potential additional treated acres, and the existing infrastructure and economics largely govern what is practically grown. The NRS evaluates the potential for adding practices to the land based on the following:

- **Suitability of lands**. This includes the total area of land that can theoretically be treated with the specific practice based on factors such as land use, vegetative cover, slopes, drainage characteristics, fertilization, the distance from waters, and geology. Estimates of land suitability acreages for each practice can often be derived from GIS analyses. These estimates were provided for priority practices in the 2014 NRS (see Table 5-13 in the 2014 NRS).

- **Mutually exclusive practices**. Many practices cannot be used in combination with other practices on the same lands; therefore, these must be subtracted from the upper limits of land acres suitable for the practice. Estimates of lands affected by mutually exclusive practices can be approximated with GIS analyses, with some uncertainty.
- **Practicality and feasibilit**y. The upper limit of practical adoption is often well below the theoretically suitable land acreages, depending on the short- and long-term costs, additional management needs, risk to the farmer, assistance needs, the capacity of professional assistance, land ownership/control, and other practical considerations. This upper limit can vary locally and regionally and can also depend on the adoption timeframe under consideration and the rate of technology advancements that can reduce cost, risk, and labor.
- **Practices already in use**. Certain soil and water conservation practices have been promoted and adopted for decades, while others have had little historical adoption. Some of the historically adopted practices have not continued or have not been maintained. Those practices that are currently in use and maintained are not available for additional new adoption; therefore, they should also be subtracted from the suitable land acreages to arrive at the maximum practical additional adoption acreages. The existing use of some practices is fairly well understood, but the adoption of other practices is less so. Since 2014, over 4 million acres of land have been affected by new practices adopted through government programs alone. Estimates of the nutrient load reduction effects of all government program practices adopted since 2004 are described in Section 2.6.1.

The *maximum practical additional adoption acreage* is the total treated land area likely available for receiving a practice after accounting for the above considerations. A study of the maximum practical additional adoption acreages is underway (at the time of this writing) and will be available for future refinements of NRS-related strategy documents and tools (RESPEC consulting working with MPCA and MDA). For the 2025 NRS, existing information from the NRS 5-Year Progress Report (2020) and other tracking systems of practices, as described in Chapter 7, was reviewed to provide a general understanding of new practice adoption potential and the reasonable upper limits to adoption.

Each individual practice will have different considerations and results concerning the maximum practical additional adoption acreage. An example practice to consider is a saturated buffer designed for treating nutrients flowing out of tile drainage lines. Because this is a relatively new conservation practice, first conceptualized around 2015, its adoption is still in its infancy. Lands deemed suitable for saturated buffers were estimated to be 750,000 acres in Minnesota (Chandrasoma et al. 2019). For example, a 100% adoption of saturated buffers, given current design criteria, would result in 750,000 acres being treated. As of 2023, roughly 240 acres in Minnesota were being treated with saturated buffers implemented through government programs, including USDA programs (e.g., Environmental Quality Incentives Program [EQIP]) and state programs (e.g., MAWQCP, projects reported to eLINK) (MPCA 2024).

With saturated buffers, even after subtracting the progress to date, the remaining acres will be close to the 750,000 suitable acres. However, other practices could be used on these same suitable acres instead of saturated buffers, including denitrifying bioreactors, drainage water recycling, controlled drainage, or treatment wetlands/ponds. The maximum practical number of acres for an individual practice needs to consider the totality of suitable lands for combining such practices. It is unreasonable to assume that 750,000 acres will be available for saturated buffers alone. Other practical constraints may further reduce the anticipated adoption of this practice, including limits of design and construction assistance and a lack of benefits to farming.

Due to the dynamics of each conservation practice and the potential interaction between them, it is important to evaluate the maximum practical additional adoption acreages of various conservation efforts individually. This concept of conflicting or supportive conservation is intuitive and has been referred to in literature as "stackability" (Christianson et al. 2018).

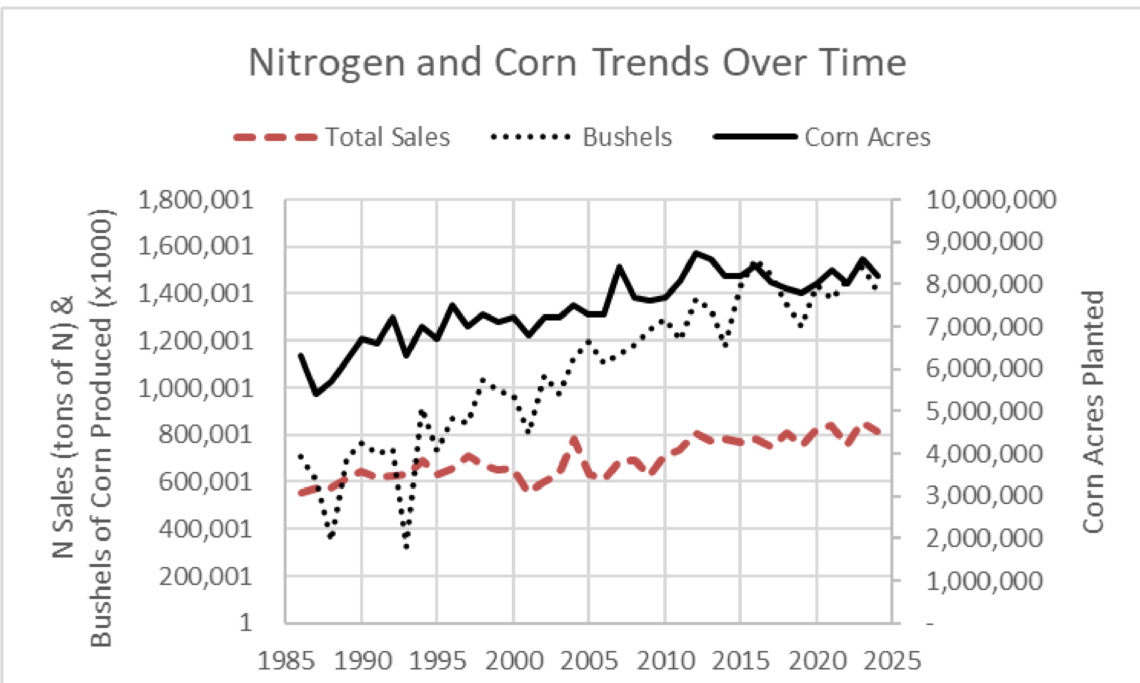
Adoption potential for improving in-field nutrient management

While the amount of nitrate leaching reduced per acre of adoption is typically a lower percentage compared to other types of practices, fertilizer management and efficiency improvements can be applied to numerous acres across the state and, therefore, have a relatively large cumulative water nitrate benefit.

In-field nutrient management practices for both nitrogen and phosphorus are particularly difficult to track and know, with certainty, the potential opportunities for improvement. Adding to the challenge, the practices evolve as new research about specific practices and combinations of practices becomes available. For example, nitrogen use recommendations have changed in recent years as new crop hybrids were developed that respond differently to reduced or increased fertilizer application rates. The UMN fertilizer rate recommendations for corn are frequently re-evaluated and revised based on new research data from field-plot trials.

Methods to develop historic fertilizer use trends have utilized fertilizer sales and crop production when evaluating nitrogen (Cao et al. 2017). The MDA tracks fertilizer sales and has been tracking nitrogen use since the late 1980s (Figure 5-2).

Figure 5-2. Trends in nitrogen sales, corn grain acreage, and corn grain production since 1986, from MDA.



Note: Data compiled from fertilizer sales, and production information from the USDA NASS (USDA 2024b).

Farmer surveys of fertilizer use

Large-scale estimates of nutrient use can provide insights into opportunities for improvement. One way to do this is by extrapolating information from farmers' fertilizer use survey results. MDA and others have estimated nitrogen application of synthetic fertilizer and manure sources based on surveys conducted at various spatial scales and times (Bierman et al. 2011; MDA 2014, 2016, 2017, 2019, 2023).

These studies have generally shown that corn fertilizer rates have gradually come into closer alignment with the UMN-recommended rates.

The [NRS 5-Year Progress Report] described several nutrient management indicator metrics, including the above-referenced farmer surveys conducted by the National Agricultural Statistics Service (NASS) in partnership with MDA. Over the past few years, UMN has updated its [fertilizer rate recommendations] based on field research, and MDA has updated its survey results on nitrogen fertilizer use for corn, a crop that accounts for 74% of fertilizer additions in Minnesota, according to MDA's average since 2010.

The most recent survey (MDA 2023) of fertilizer use on corn following soybeans (on 16,446 fields) for the 2019 crop year found an average application rate of 155 lbs of nitrogen, which is similar to the UMN's current (2025) recommended MRTN of 150 lbs (0.10 fertilizer cost-to-crop value ratio). About 27% of corn-soybean rotation fields exceeded 170 lbs/acre (10 lbs/acre above the upper bounds of UMN recommendations for a 0.10 ratio), indicating some potential to reduce rates on certain fields. The average TN applied on corn following soybeans when manure was used, as all or part of the nutrient source, was 161 lbs/acre, slightly more than the 150 lbs average when only commercial fertilizer was used. The potential room for improvement to meet UMN rates on corn following corn was less than on corn following soybeans, with 10% of fields exceeding the upper bounds of current recommended rates (200 lbs/acre at 0.10 ratio).

Based on the surveys, farmers have generally been applying efficient nitrogen rates, and the gap between reported rates and the UMN-recommended rates has narrowed over time. Yet, it appears that some room for improvement exists on about 27% of the corn following soybean fields and about 10% of the corn following corn fields, according to survey results from the 2019 cropping year. The annual and monthly weather conditions greatly affect the needed rates of application, which can vary from farm to farm and from year to year.

The greater potential for reducing nitrate leaching is to better match the nitrogen application rate and timing with crop nitrogen use, which can be achieved by investing in research and technological advancements that enable improved application timing, forms, and amounts to more closely match how and when crops extract nitrogen from the soil. Climate extremes are making it increasingly challenging to precisely manage nitrogen application rates and timing to minimize nitrate leaching losses.

Minnesota cropland nutrient balance assessment

Another way of evaluating opportunities for improving nutrient management is to examine nitrogen and phosphorus balances. A nutrient balance analysis was conducted for the 2025 NRS using the best statewide information sources available (Porter and Conowall 2025b; draft in Appendix 5-3). At the time of final publication of the NRS, this draft report is being updated and finalized and will be included with the other NRS supporting documentation later in 2026. The assessment used information from fertilizer sales, field-specific 6-year crop rotations, livestock and poultry numbers and distribution, UMN nitrogen fertilizer recommendations, estimated crop phosphorus removal rates, and more. Total additions from fertilizer and crop-available manure nutrients were compared to needed rates for nitrogen (per UMN recommendations) and crop phosphorus removal (literature-based). This type of analysis can help determine areas of potential imbalances, where the overapplication of nutrients may be occurring; however, results are not definitive, and site-specific investigation is needed to further validate this initial analysis of potential surpluses.

Results of this in-depth statewide nutrient balance assessment suggest that nitrogen additions, from the combination of nitrogen fertilizer and manure crop-available nitrogen, onto Minnesota cropland exceed the UMN-recommended rates by an estimated statewide average of 18%. The range of surplus, or excess, was 15%–21% above the UMN-recommended rates and varied with the method used to determine available manure nitrogen. The nitrogen balance results are almost identical when estimating nitrogen fertilizer use from farmer survey results (MDA 2023) or from fertilizer sales data provided by MDA, with the fertilizer sales method resulting in an imbalance of less than 2% difference compared to the fertilizer use survey results. This suggests that the fertilizer use survey information from MDA (2019) provides a reasonably accurate large-scale representation of actual use.

Watershed nitrogen balance results vary spatially. Mapping the balance across HUC-8 watersheds shows many watersheds, especially in northern Minnesota, with either no surplus or within 10% of crop needs, which means that, on average, the applied available nitrogen matches crop needs well (Figure 5-3 and Figure 5-4). Southern Minnesota has many watersheds with a nitrogen surplus potential of 20–30 lbs per cropland acre, on average, across the watersheds (see Figure 5-3). When viewing this as an average surplus per watershed acre instead of per cropland acre, the surplus in southern Minnesota is lower (10–20 lbs per watershed acre). Methods and more results are described in detail in Appendix 5-3. In general, the nutrient balance-based results corroborate reasonably well with the survey-based findings.

For phosphorus, the statewide additions of manure and fertilizer phosphorus closely match the expected crop removal of phosphorus throughout most of Minnesota, although crop phosphorus removal estimates are approximate, and specific removal rates by crops are not consistently reported in the literature (Porter and Conowall 2025b; draft in Appendix 5-3). The balance between crop nutrient additions and crop nutrient removal varies from one watershed to another (Figure 5-5). The highest potential surpluses that could build soil phosphorus levels on croplands are found in central Minnesota, where some watersheds appear to have an excess of 15–30+ lbs of phosphorus per cropland acre per year. Central Minnesota has relatively high manure phosphorus sources from poultry and dairy, which contribute to this surplus. While the transporting of poultry manure away from barns was generally accounted for in this analysis, long-distance transporting of poultry manure was not determined and, where it occurs, would reduce the surplus in central Minnesota as depicted in Figure 5-5.

This assessment (Appendix 5-3) identified several limitations using current data sets and methodologies in this report, as well as future work that is needed to enhance and build on this effort. Limitations relate to the accuracy of the feedlot database and the assumptions made on animal counts, manure recoverability, and nutrient losses; spatial variability of transport of manure specifically from poultry operations; spatial distribution of commercial fertilizer and conversion of county data to a watershed scales; difficulty in connecting local and regional survey data to statewide estimates; and challenges with phosphorus (P_2O_5) removal rate assumptions and access to phosphorus soil test data statewide. To address these limitations, NRS partners will work with UMN staff to build on this assessment to conduct additional validation of the manure application assumptions, compare results of this assessment with other nutrient and water quality data, and develop decision-support tools based on these data.

In summary, for nitrogen fertilizer and manure additions, results from both the nutrient balance assessment and farmer surveys indicate a limited ability to reduce large-scale fertilizer rates by an amount expected to substantially decrease nitrate losses to waters. However, fine-tuning nitrogen rates may still be feasible on about 10% of corn-following-corn acres and about 27% of corn-following-soybean acres, based on survey results. These levels are generally consistent with the 18% nitrogen surplus estimates based on statewide nutrient balances derived from fertilizer sales, manure production, and field-specific cropping information reported in Porter and Conowall (2025b).

Additional unquantified nitrogen efficiencies may also be gained by other improvements with fertilizer and manure timing, forms, and placement. More research on how to improve in-field nutrient management will be helpful in the future, along with changes to add a longer duration of living cover on cropped landscapes.

Figure 5-3. Estimated comparison of plant-available nitrogen additions (fertilizer and manure) to crop nitrogen needs in pounds per cropland acre based on UMN recommendations.

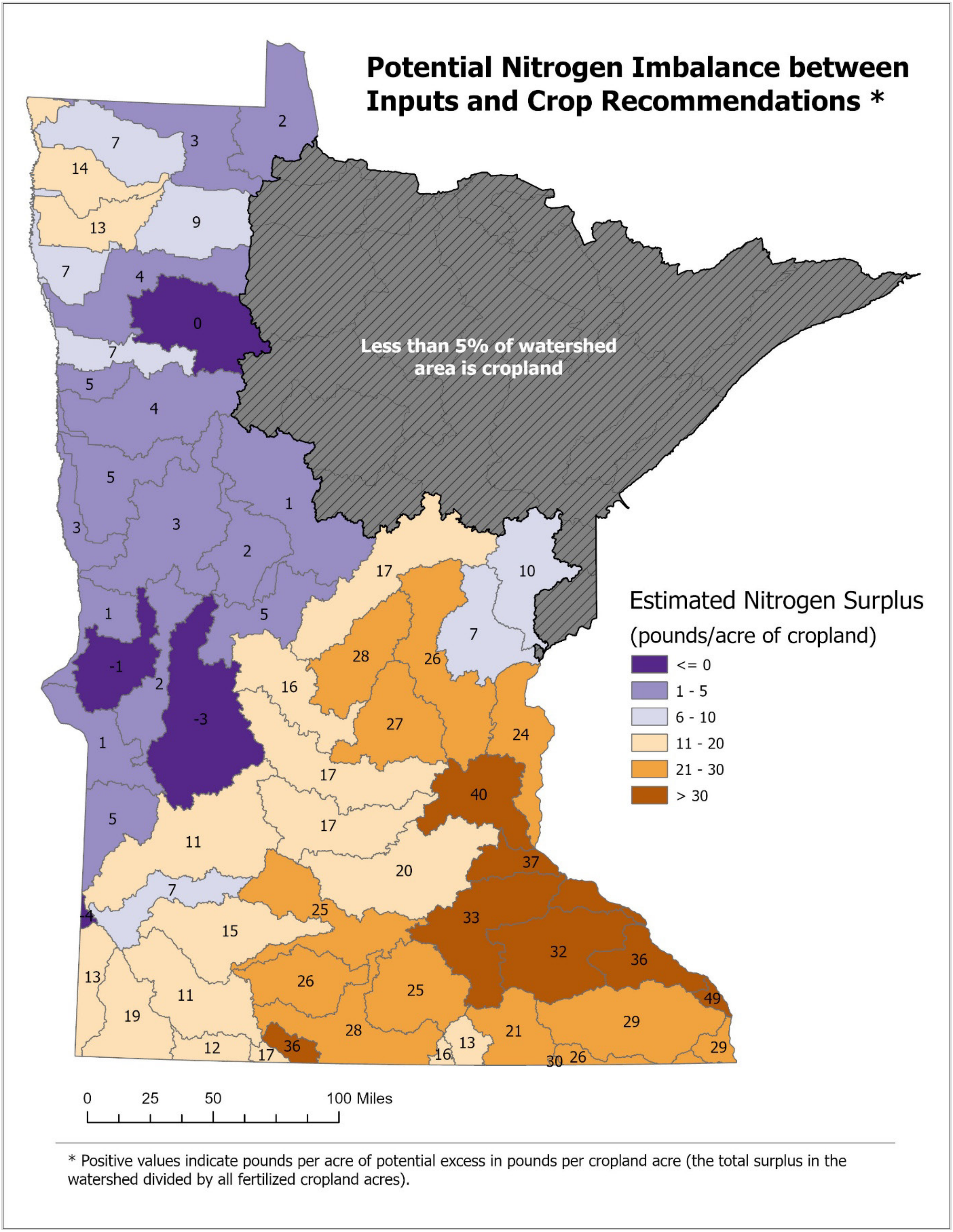


Figure 5-4. Estimated comparison of plant-available nitrogen additions (fertilizer and manure) to crop nitrogen needs in pounds per watershed acre based on UMN recommendations.

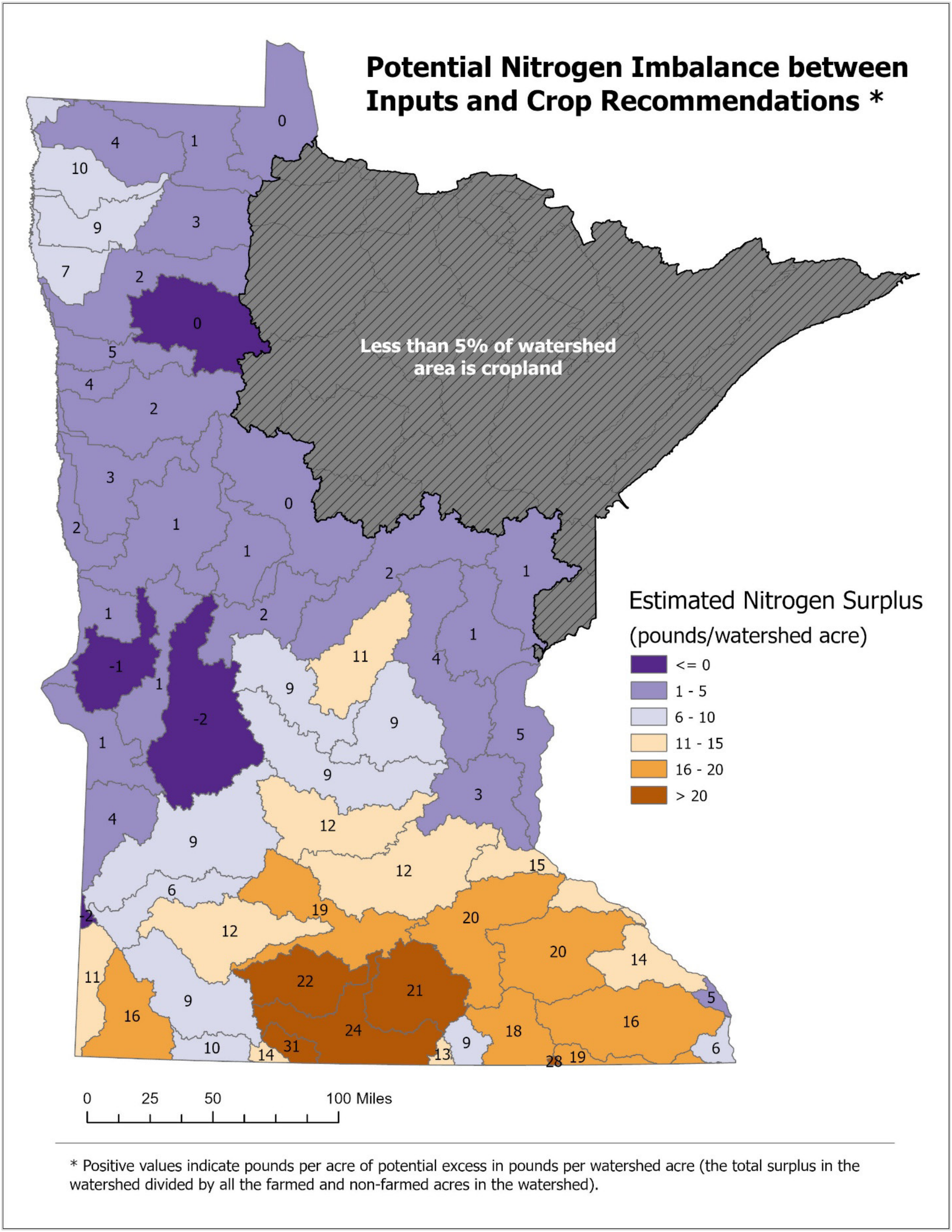
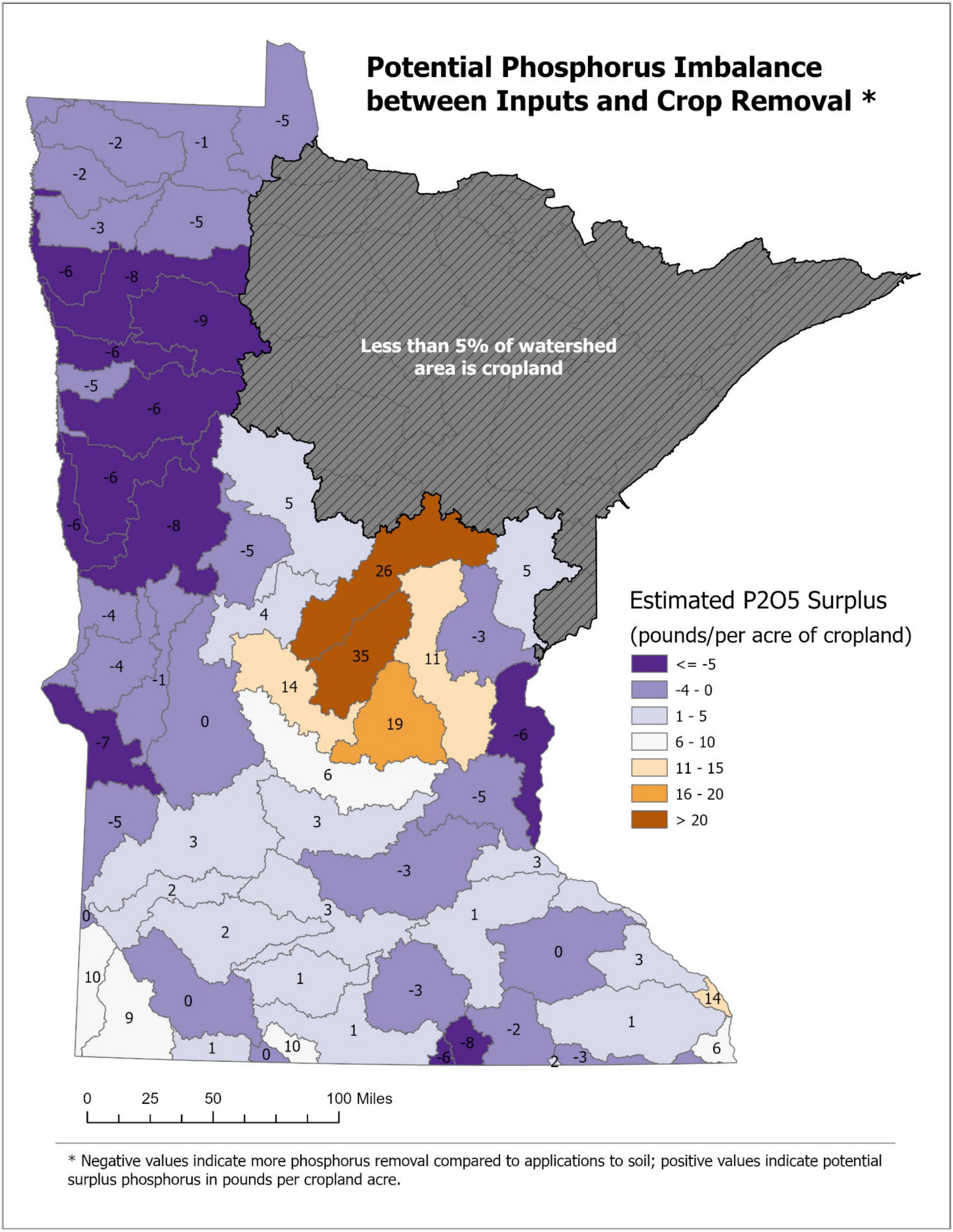


Figure 5-5. Estimated comparison of phosphorus additions (fertilizer and manure) to crop phosphorus removal, measured here as P2O5.



For phosphorus, the potential for soil phosphorus build-up across watersheds appears to be highest in central Minnesota watersheds, although soil phosphorus levels can build up on any farm where the application of manure or fertilizer exceeds the amount of soil phosphorus used by crops.

Potential to increase continuous living cover

Minnesota is still in the early stages of adding CLC to cultivated lands, although adoption has been increasing. These practices have been more commonly added to short-season crops (i.e., harvested earlier than corn/soybeans) around the state, which include wheat, sugar beets, corn for silage, early harvested potatoes, canning crops, etc. The U.S. Census of Agriculture reports that cover crops were planted on a total of 760,423 acres in Minnesota in 2022. This is much higher than the 408,147 acres planted in 2012, but still only represents a small fraction of the nearly 17 million acres of corn, soybeans, and wheat grown in the state. It is important to note that U.S. Census data captures what farmers are planting and not the acres where cover crops are established successfully. This is distinctly different than satellite-derived data sources (e.g., remote sensing efforts by BWSR and UMN, efforts by the Conservation Technology Information Center), which "see" successfully growing cover crops; this is a more direct measure of impact on water quality. In the future, remote sensing tools will likely be prevalent and used to capture the full impact of cover crops and tillage activities.

Potentially, cover crop use could be increased on most cropland in Minnesota. However, the practicality of such widespread adoption will depend on our ability to meet various challenges, such as: (1) ensuring fall rainfall amounts are sufficient to germinate cover crop seeds, (2) obtaining equipment to inject manure through cover crops, (3) assessing spring termination timing to prevent interference with corn and soybean crops, (4) ensuring cover crop seed availability, (5) finding markets for harvested cover crops, (6) managing cover crops to sustain or increase corn and soybean yields, and (7) facing colder climate and shorter seasons when establishing cover crops in areas such as the Red River Valley. Progress has been made to address these challenges during the past decade, but more work remains. Many farmers have found ways to overcome these challenges, and farmer-to-farmer peer networks to share learning experiences will be important as Minnesota scales up the use of cover crops.


Inter-seeded cover crop (*Source*: USDA, L. Betts)

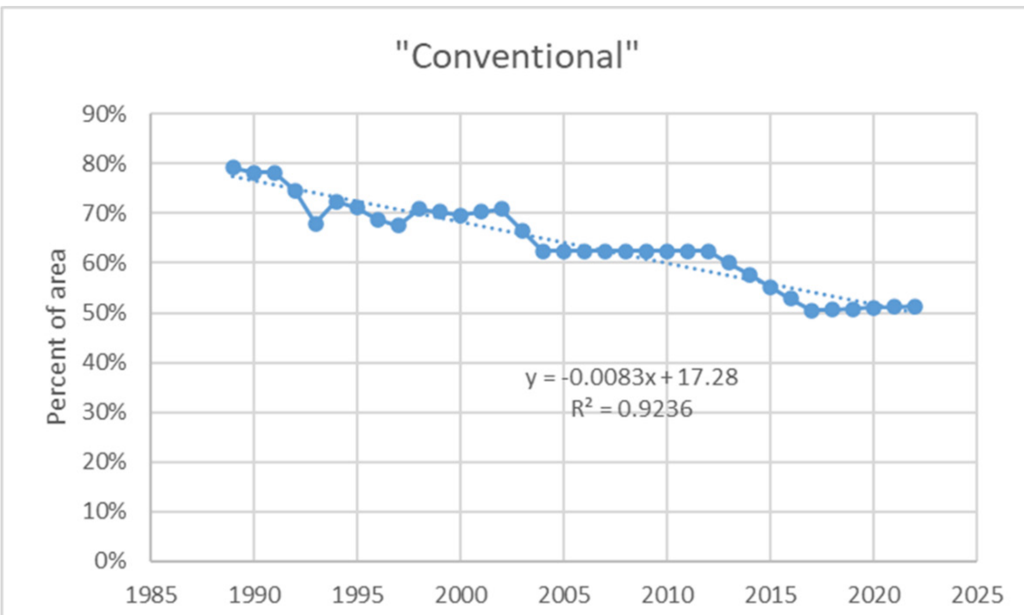
Perennial crops, such as alfalfa, clover, and Kernza®, provide even more protection from the loss of nutrients to waters compared to cover crops planted in row-crop systems. However, challenges with crop markets, economics, infrastructure, and perhaps government policies have interfered with making transformational changes to perennial crops on large acreages. According to the NASS, planted acres of all hay/haylage/alfalfa decreased by about 700,000 acres between 2014 and 2024. While it is theoretically possible to convert many annual crops to perennial crops and pastures, the practicality of this type of transformation is limited by markets and economics. Conservation crop rotations that add perennials and small grains into row-crop rotations can also increase the extent and duration of living cover across the state. This practice is often more economically favorable than complete conversion to perennials; however, markets and supporting infrastructure are also needed to help expand these crops.

Tracking the current levels of cover crops, conservation crop rotations (e.g., perennial crops added into row crop rotations), and perennials on vulnerable lands is discussed in Chapter 7. The estimated suitable lands and maximum practical additional adoption acreages for living cover practices are being updated in 2025. Upon completion, this information will be added to BEET as described in Chapter 7.

Potential to add more reduced tillage

Reduced tillage practices have been increasing across Minnesota for decades, along with other soil and water conservation practices to prevent runoff. When considering the trend in conventional tillage, there is a strong downward trend to about 50% adoption (Figure 5-6), indicating that reducing tillage has been successful. However, that also means other lands could potentially benefit by further reducing tillage intensity. *Note*: Some lands currently under reduced tillage could further reduce the tillage intensity and maintain even higher levels of crop residue on the ground surface. The decrease in conventional tillage and increase in reduced tillage is likely due to innovations with conservation tillage implementation and an economic benefit by reducing the number of passes over a field, also made possible with herbicide-resistant varieties of crops being grown. There are also visible and perceived benefits, like reduced surface erosion from water and wind and improved soil health. Strip-till is one type of reduced tillage that shows great potential for further replacing conventional tillage or other reduced tillage methods. The estimated suitable lands and maximum practical additional adoption acreages for reduced tillage and erosion control practices are being updated in 2025; upon completion, this information will be added to the BEET tracking tools described in Chapter 7.

Figure 5-6. Trend in conventional tillage (intense tillage).



Note: Data from a compiled USGS dataset (Dataset 573) and the USDA Census of Agriculture. Data were interpolated between known data points to have a continuous annual record.

Potential to add drainage water management and treatment practices

Nearly 35% of harvested cropland in Minnesota has tile drains, according to the 2022 U.S. Census of Agriculture (Ghane 2024). Most drained cropland does not have drainage water management and treatment practices (e.g., controlled drainage, saturated buffers, bioreactors, constructed wetlands) because these practices are relatively new, are still being researched, and typically do not have direct benefits to cropland soils or farm profitability. Typically, government cost-share and technical assistance are used for most types of these practices, and government program records show a relatively low adoption of this set of practices. Government tracking since 2014 indicates that less than 35,000 acres have been affected by drainage water management practices, representing less than 1% of all drained cropland (this does not generally include where lift pumps function as controlled drainage).

The addition of these practices is limited to relatively flat soils. Most of these practices require some degree of design and engineering assistance. Therefore, the number of new practices is limited, in part, by the design/engineering capacity and construction worker capacity, even when money is available for implementation. With adequate assistance, however, these types of practices could potentially treat millions of cropland acres in Minnesota.

The estimated suitable lands and maximum practical additional adoption acreages for the various drainage water management and treatment practices are being updated in 2025 and, upon completion, will be added to the BEET tracking tools described in Chapter 7.

5.1.5 Practice costs

Costs of practices used for nutrient loss reduction vary tremendously and can be viewed in multiple ways, including: (a) the cost per acre of treated land, (b) the cost per pound of a pollutant prevented from reaching waters, or (c) the cost compared to the combined multiple benefits of the practice. All three types of cost analyses can provide helpful information for making decisions about practice adoption.

The NRS focuses largely on the cost per acre of treated land to best fit with information used in models and tools for estimating the effects of nutrient reduction. The cost per pound of nutrient reduced, while helpful, only provides partial information for prioritizing practices. Generally, it is preferable to compare the combination of financial cost, added burdens, and potential risk of the practices with the combination of nutrient reduction and the practices' other multiple benefits to producers and society.

Costs evaluated for the NRS include ongoing operation and maintenance cost estimates over the life of the practice and the opportunity costs related to changing crops and crop yields. The NRS costs do not include the additional costs from the government, such as cost share, technical assistance, and the administration of programs.

The NRS views costs as the annualized net cost of the practice (upfront establishment and operational costs) if it were paid in constant annual payments for the design lifetime of the practice. These annualized values are referred to as lifecycle costs and are presented in Table 5-4.

Practice costs depend on many site-specific factors. For a large-scale assessment, such as the NRS, representative or typical values are used. Cost estimates depend greatly on the economic and technical assumptions used in the analysis, including how much land is treated by each practice, on average. The results shown herein are approximate, and these costs will vary significantly at the local and farm scales. Cost estimates for many of the practices will also vary over time, depending on the cost of fertilizer, cost of labor, cost of materials, installation costs, commodity prices, and much more.

The practice cost estimates shown in Table 5-4 are provided as approximations to enable calculating the general magnitude of costs to achieve nutrient reduction goals associated with the Mississippi River Basin scenarios described in Section 5.1.6. These estimates of annualized costs per treated acre were obtained from the Watershed Nitrogen and Phosphorus Reduction Planning Tool, known as NP-BMP, developed by Lazarus et al. (2024). The estimated costs per acre of treated land mostly fall between $14 and $63 per acre but range from negative costs (cost savings) to more than $250 per acre for lands changed to set-aside grassed lands. Cost savings are more common when improving fertilizer efficiencies and reducing tillage.

Table 5-4. Example life-cycle annualized net practice costs to landowner per acre of land treated by the practice; includes opportunity costs as determined with NP-BMP tool.[a]

Practice	Lifecycle cost [a] ($/treated ac/yr)	TN [b] reduced at state line – Miss. R. Basin (avg lbs/ac)	TP [b] reduced at state line – Miss. R. Basin (avg lbs/ac)	Costs from other sources ($/ treated ac/yr)
Drainage water management & treatment				
Denitrifying bioreactor	$21	1.9	0.23	
Drainage water management (controlled drainage)	$14	3.8	0.02	
Drainage water recycling (stored water back onto cropland)	NA	6.0	NA	
Saturated buffer	$37	4.0	NA	$29 [c]
Wetland construction	$62	6.0	0.18	
Fertilizer management and efficiencies				
Fertilizer efficiency practices	Cost savings	1.2–2.6	0.05	
Continuous living cover increases				
Conversion of row crops to perennial crops for food, fuel, forage and other working lands	$63 Kernza®	7.8	0.21	
Conversion of cultivated lands to strategically placed set-aside grasses	$252	9.0	0.29	$175/ac/yr continuous CRP payments in MN [d]
Conservation crop rotation (at least 2 yrs perennial crops added into rotation)	$32 if Kernza® grown 3/6 yrs in rotation	4.0	0.10	
Cover crop (into corn/soybean)	$45–$65	2.7	0.11	$50–$60 [e] $70 [c]
Cover crop following short season crops	$34	2.9	0.15	
Erosion and overland runoff controls				
Residue and tillage management, no-till/strip-till		1.4	0.23	Cost savings [f]
Residue and tillage management, reduced-till	Cost savings	0.6	0.23	
Improving open tile intakes	$1.2	0.8	0.23	
Water and sediment control basin	NA	2.6	0.31	
Grassed waterway	NA	0.8	0.17	
Contour buffer strips or prairie strips	NA	NA	NA	$30 [c]

Notes:
avg lbs/ac = average pounds per acre; CRP = Conservation Reserve Program; NA = not available; yr = year; yrs = years
Costs are based on prices in January 2024 and are expected to change with changing markets, fertilizer prices, grain prices, labor costs, materials costs, design life, and other site-specific factors.
[a] Determined by NP-BMP tool (Lazarus et al. 2024); does not include any government program costs.
[b] TN and TP reduced at state line derived from BEET (MPCA 2025a)
[c] Bravard et al. 2022
[d] Lauer 2025
[e] Van Nurden et al. 2023
[f] UMN Extension 2022

Nutrient reductions at the Iowa state line, as averaged over the entire Mississippi River Basin in Minnesota, were determined with the BEET tool (MPCA 2025a) and added to Table 5-4 to enable comparisons with typical nutrient reduction benefits for downstream waters. The amount reduced in local watersheds will often exceed twice the average reductions at the state line due to nutrient attenuation between local watershed outlets and state-line outlets. Nutrient reduction estimates at local scales should be modeled for the watershed being evaluated using BEET or another model.

The costs-per-acre data from the NP-BMP tool were compared to the nitrogen-reducing benefits at the Iowa state line. This assessment showed that most nitrogen-reducing practices cost $2–$8 per pound of nitrogen reduced at HUC-8 watershed outlets in the Mississippi River Basin and $4–$12 per pound of nitrogen reduced at the state line when applying the BEET tool. However, some CLC practices exceed $20 per pound of nitrogen reduced at the state line. The average cost is $11 per pound of nitrogen reduced at the state line. Costs are much higher per pound of phosphorus reduced. Costs are generally higher in the Red River Basin per pound of nutrient reduced because the water nutrient levels are lower compared to southern Minnesota (due to different soils, climate, etc.).

While the costs of many individual practices can be high, whole farm profitability analyses comparing the 1,600+ farms certified through the MAWQCP showed that certified farms with intensified environmental practices had twice the profitability, on average, compared to noncertified farms (MDA 2025). These MAWQC-certified farms have added more than 7,700 conservation practices to protect water quality.

Cost estimates of agricultural practices should be updated periodically to reflect changing economic conditions, improved technologies, and potential improvements in implementation delivery efficiencies. Additionally, the tools for estimating the economics of various BMPs and CLC practices are also expected to change and improve.

A comprehensive cost-benefit analysis of all costs versus benefits to the public and landowners was not within the scope of the 2025 NRS. This type of analysis should be considered in the future to account for monetary and nonmonetary impacts on the public as compared to the total cost of solutions.

5.1.6 Practice adoption example scenarios to achieve river nutrient reduction goals

The magnitude of new practice adoption needed to ultimately achieve the final nutrient load goals is better understood by considering the modeled combinations of practices and the anticipated load reductions from those practices. There is no single correct combination of practices that would achieve the goals.


Mississippi River in southeast Minnesota

The NRS work group on BMP science considered different combinations of practices and selected the example scenarios highlighted below. Although the work group aimed for practical and effective practice combinations that offered multiple benefits and a high potential to add new adoption acreages, the magnitude of reductions needed to meet goals required more acres of practices than could be practically installed. To achieve the nitrogen goals, the scenarios include a dramatically higher level of adoption compared to historic rates of adoption, and the feasibility of such high levels of adoption is unlikely. Section 5.3 outlines important steps to succeed in scaling up practice adoption in Minnesota.

Mississippi River Basin scenarios

Estimated nitrogen and phosphorus average annual load reductions needed in the Mississippi River at the state border with Iowa are 39% and 13% of original baselines for the two nutrients, respectively (as discussed in Chapter 2). These percentages are equivalent to a TN reduction of 35,517 MT/yr and a TP reduction of 602 MT/yr, needed from all nutrient sources at the state line from all Minnesota watersheds that ultimately flow into the Mississippi River. The source assessment results presented in Chapter 2 indicate that 79% of TN and 58% of TP (the average of the two source assessments) originate from cropland in the Mississippi River Basin. Applying those percentages to the total river nutrient load reductions needed, the amount of TN reduction from *cropland sources* would be estimated at 28,058 MT/yr (61.9 million lbs TN), and 349 MT/yr for TP (770,000 lbs TP). These amounts represent estimates based on the most up-to-date monitoring and trend analysis results (see Chapter 2) of the remaining amount to be reduced from cropland sources (above and beyond what has been achieved to date).

For phosphorus in the Mississippi River Basin, the urban wastewater sector has already reduced considerably more than its 45% goal since the baseline period, with little room for further improvement. However, additional practices on cropland are still needed to meet final goals. The same practices needed for nitrogen reduction in the Mississippi River Basin are expected to sufficiently reduce the 349 MT/yr of the cropland sector's remaining phosphorus reduction needs in that basin.

Using the estimated nutrient reduction at the state line per acre of adoption from BEET, hypothetical combinations of practices that would be expected to achieve the goals were developed, as represented in Table 5-5 and Table 5-6 (MPCA 2025a).

Table 5-5. Mississippi River cropland practice additions, Scenario A. This hypothetical scenario reduces cropland TP by the amount needed to meet the goal at the state line and to partially meet the remaining cropland TN reduction needs of 62 million lbs/yr at the state line.

Practice	Treated acres future scenario	TN reduction (lbs/yr)	TP reduction (lbs/yr)
Tile water management and treatment	1.4 million	6.7 million	85,000
Continuous living cover increased	5.6 million	24 million	769,000
Tillage with more crop residue	1.5 million	1.3 million	225,000
Overland runoff controls	1.2 million	1.3 million	213,000
Fertilizer and manure management	2.3 million	3.6 million	93,000
Total	**11.9 million**	**36.9 million**	**1,385,000**

Table 5-6. Mississippi River cropland practice additions, Scenario B. This hypothetical "all-in" scenario meets the cropland TN reduction goal of 62 million lbs/yr and the TP reduction goal of 770,000 lbs/yr at the state line.

Practice	Treated acres future scenario [a]	TN reduction (lbs/yr)	TP reduction (lbs/yr)
Tile water management and treatment	3.0 million	13.8 million	206,000
Continuous living cover increased	7.8 million	33.4 million	1,083,000
Tillage with more crop residue	2.0 million	2.0 million	340,000
Overland runoff controls	1.2 million	1.3 million	213,000
Fertilizer and manure management	2.8 million	4.4 million	117,000
Subtotal	**16.8 million**	**55.0 million**	**1,959,000**
Channel water treatment, restored oxbows, livestock/ grazing, floodplain reconnection	TBD	7 million [a]	TBD
Total nutrient reduction estimate (annual)		**62 million**	**> 2 million**

Notes:

TBD = to be determined

[a] Treatment amount needed to achieve 62 million lbs/yr total. These practices are not part of the model used for this analysis.

The scenario in Table 5-5 represents a very ambitious long-term scenario but falls short of the nitrogen reduction goal. In the scenario represented in Table 5-6, further increases were made to acreages of tile drainage water treatment, CLC, and fertilizer and manure management to show a combination of practices that would, in theory, achieve the necessary nitrogen and phosphorus reduction amounts at the state line. All scenarios assume that pre-existing practices remain in place and that any sustained changes in climate do not worsen nutrient losses.

The BEET model used for this analysis is continually updated and improved as new river monitoring data, models, and field research become available. As such, the scenarios below represent a snapshot in time, illustrating the magnitude of practice adoption needed to achieve goals based on current best estimates. Note that not all updated BMP efficiencies reported in Section 5.1.1 are included in the version of the model used for the scenarios below. These updates will be made to the model later in 2025, and the scenarios will be subsequently reassessed.

The specific practices and treated acres of new adoption used in Table 5-6 include the more specific practice acreages shown in Table 5-7. If these practices are placed in high-priority areas for water quality, this level of adoption would be expected to concurrently achieve much of the agricultural sector's nutrient reduction needed to meet the in-state water quality goals described in Chapter 3.

Recognizing that different scenarios can achieve similar outcomes and different modeling approaches with different sets of practices, the NRS also includes a scenario for the Mississippi River Basin below, using the NP-BMP tool (Lazarus et al. 2024) and slightly different adoption scales and practice type priorities. The hypothetical scenario shown in Figure 5-7 is projected to reduce TN by 68,772,000 lbs/yr and TP by an estimated 1,480,000 lbs at watershed outlets, which would appear to meet the goals. However, after adjusting for expected transformations between the watershed outlet and the state line using coefficients derived from the SPARROW model, this scenario would fall short of achieving the final TN load reduction goal at the state line.

Both the results from BEET and NP-BMP show that millions of acres of land (i.e., 16–18 million acres) need treatment to meet the nutrient reduction goals in the Mississippi River Basin alone, with about half the practices being acres with CLC practices. Each acre of cultivated fields would need at least one new practice added to achieve the final goals.

The 7.8 million acres of Mississippi River Basin CLC practices in Table 5-6 and the 7.3 million acres of new CLC practices in Figure 5-7 represent a dramatic transformation of agricultural systems in Minnesota. This magnitude of change was also reported in the *Putting Down Roots* study (Ecotone Analytics et al. 2023), which showed a Minnesota statewide scenario with about 10 million new acres of CLC by 2050. In the study, the two leading CLC crop categories were expected to be: (1) winter annual oilseeds with over 5 million additional acres by 2050 and (2) perennial forage and pasture with about 1.7 million additional acres by 2050. The *Putting Down Roots* analysis projected a 23% reduction of nitrogen in waters from the combined CLC practices.

A total of 78 million lbs of TN reduction per year could be achieved for the Mississippi River Basin at the Iowa state line if the nutrient reductions that were achieved by the practices outlined in Table 5-6 and Table 5-7 were combined with the additional reductions realized from urban wastewater treatment, streambank and floodplain practices, and stormwater and other miscellaneous practices. In addition to achieving the Mississippi River nitrogen load goals, this hypothetical scenario would also be expected to meet the Mississippi River phosphorus load goals, most in-state nitrate concentration goals, and most in-state phosphorus concentration goals.

Table 5-7. Specific practice acreages in the scenario in Table 5-6 to achieve nutrient reduction goals in the Mississippi River Basin.

Practice	New treated acres
Field-edge treatment of tile water	
Denitrifying bioreactor	200,000
Drainage water management (controlled drainage)	800,000
Drainage water recycling	400,000
Saturated buffer	800,000
Wetland for treatment	800,000
Overland runoff controls	
Improving open tile intakes	300,000
Water and sediment control basin	300,000
Grassed waterway	300,000
Contour buffer strips or prairie strips	300,000
Conversion to long-term perennials	
Conversion of row crops to perennial crops for food, fuel, or forage	1,400,000
Conversion of cultivated lands to strategically placed set-aside perennials	400,000
Adding living cover to crop rotations	
Conservation crop rotation (2+ yrs perennial crops added into rotation)	1,800,000
Cover crop with corn and soybeans	3,000,000
Cover crop following short-season crops	1,200,000
Tillage changes	
Residue and tillage management, strip-till or no-till	1,000,000
Residue and tillage management, other reduced-till	1,000,000
In-field fertilizer and manure management	
Manure/fertilizer injection or immediate incorporation	300,000
Nutrient management for optimal economic returns (e.g., 10%–25% lower rate)	1,600,000
Precision nutrient management with variable rates	600,000
Improved timing: fall-to-spring, or spring preplant-to-spring split	150,000
Nitrification and urease inhibitors	150,000
Livestock and grazing management	
Manure storage facility construction to also capture feedlot runoff	10,000
Grazing management to fence and control access to water	20,000
Grazing and pasture management (types of grasses, manage heavy-use areas, rotational grazing, etc.)	400,000
Total new acres treated	**16,800,000**

Figure 5-7. Image of the NP-BMP tool-derived Mississippi River Basin scenario for achieving 68,772,000 lbs/yr of nitrogen reduction and 1,480,000 lbs/yr of phosphorus reduction at local watershed scales.

Watershed: Mississippi Basin overall — 14.171 million acres in watershed or state

HUC10 Subwatershed: All — 70

	% existing	% suitable	% adoption	% treated	% treated, combined	acres treated (000), combined
Variable rate N split-applied on corn that is currently all applied in fall or spring	NA	33.47%	30%	10.04%	9.21%	1,305.04
U of MN rate with inhibitor/stabilizer on fall applied corn	2.38%	11.09%	30%	3.60%	3.33%	471.37
U of MN N rate on corn without changing timing, form, or methods	NA	47.41%	20%	9.48%	8.21%	1,163.49
U of MN soil test-based P2O5 rate on six major crops	NA	89.01%	20%	17.80%	17.80%	2,522.77
Apply P as banded spring preplant/starter on fall-applied corn & wheat	23.17%	9.07%	50%	4.54%	4.54%	642.98
Use reduced tillage on corn, soy & small gr >2% slopes	30.87%	29.41%	50%	14.70%	14.70%	2,145.48
Treatment wetlands on tiled land	NA	10.93%	20%	2.19%	2.19%	309.64
Tile line bioreactors	NA	6.98%	5%	0.35%	0.35%	49.42
Controlled drainage	NA	6.97%	20%	1.39%	1.39%	197.61
Saturated buffers	NA	6.97%	5%	0.35%	0.35%	49.40
Alternative tile intakes	2.51%	7.54%	80%	6.03%	6.03%	2,137.75
Riparian buffers on public ditches & streams	NA	0.80%	0%	0.00%	0.00%	0.00
Corn grain & soybean acres w/cereal rye cover crop	2.65%	81.90%	50%	42.27%	38.70%	5,484.48
Short season crops planted to a rye cover crop	2.65%	4.53%	80%	3.59%	5.57%	789.88
Switchgrass on marginal corn & soy land >2% slope	NA	8.89%	50%	2.94%	2.94%	416.27
Kernza on all corn & soy land	NA	86.64%	5%	4.23%	4.22%	597.62
Inject or incorp manure	NA	5.69%	50%	2.85%	2.85%	403.20

Cost to achieve basin cropland scenarios

A grassed waterway slows and filters runoff

The estimated annualized net cost to achieve and maintain most practices in Table 5-7 is estimated at over $564 million per year, as long as the practices remain in place. This total cost per year does not include costs to improve livestock and grazing management, streambank restoration, reducing erosion along rivers and streams, and reconnecting floodplains. With these additional practices, the total amount can be roughly estimated as $600–$700 million per year. No subtractions were made for potential cost savings stemming from fertilizer efficiency and reduced tillage practices. The costs for the Red River Basin scenario described below would add another $110–$150 million per year, which would bring the statewide total to likely be in the $700–$850 million per year range.

In comparison, work from Feyereisen et al. (2022) noted costs as high as $1.2 billion per year for Iowa. In Illinois, Christianson (2020) reported an annual equalized cost of nearly $800 million to fully meet nitrogen and phosphorus reduction goals, after subtracting farmers' estimated cost savings. Minnesota's costs to achieve the goals, while very high, appear to be consistent with the general order of magnitude projected in those other states.

The above-noted cost estimates for agricultural practice implementation will decrease over time if technologies improve and implementation delivery becomes more streamlined and efficient. Widespread adoption could also further reduce costs due to economies of scale.

The NRS BMP-Science Team considered the needed magnitudes of adoption (as shown in Table 5-6 and Table 5-7) to be very challenging, at best, to achieve by 2040. Important steps to work toward the large-magnitude adoption levels are described in sections 5.2 and 5.3.

Red River Basin scenarios

Scenarios for achieving nutrient reduction goals in the Red River Basin differ from those in the Mississippi River Basin for several reasons. The Red River has lower nutrient loads per acre of land compared to the Mississippi River; therefore, a new practice in the Red River Basin will not decrease loads as much as the same practice in the Mississippi River Basin. Colder weather, a longer winter, different soils and hydrogeology, and different cropping systems also affect the combination of practices needed to achieve goals. Also, less progress has been made with phosphorus reduction in the Red River Basin compared to the Mississippi River Basin.

As of 2023, the estimated average annual load reduction needed from all sources in the Red River at the state border with Manitoba is 42% and 57% of the original baselines for the nitrogen and phosphorus, respectively (as discussed in Chapter 2). These percentages of nutrient reduction are equivalent to a TN reduction of 3,486 MT/yr and a TP reduction of 538 MT/yr needed from all nutrient sources at the state line from all Minnesota watersheds that ultimately reach the Red River at the Canadian border. The source assessment results presented in Chapter 2 indicate that 50.5% of TN loads and 53% of TP loads come from cropland in this region of the state. After applying those percentages to the total load reductions needed, the amount of needed nutrient load reductions from cropland sources is estimated to be 1,760 MT/yr TN (3,880,000 lbs) and 285 MT/yr for TP (628,000 lbs) in the Minnesota portions of the Red River Basin.

Using nutrient reduction estimated averages at the state line per acre of adoption from BEET (MPCA 2025a), hypothetical combinations of practices expected to achieve the TN goals and partial achievement of TP goals were developed, as represented in Table 5-8. The scenario in Table 5-8 represents a highly ambitious long-term scenario. The scenario feasibility concerns previously noted for the Mississippi River Basin scenarios also apply to the Red River Basin analysis. The Red River Basin scenario would be expected to meet the needed TN reduction but would fall short of meeting the TP reduction goal. Red River Basin TP reduction scenarios should be developed in the future for the Red River Valley, following all updates of phosphorus reduction efficiencies and associated models. Additionally, each watershed planning team can use existing tools to develop watershed-specific scenarios for reducing their nutrient loads to the Red River.

Table 5-8. Red River cropland practice additions to fully reduce TN to the final goal and reduce TP to just over half the final goal amounts for the cropland sector.

Practice	Treated acres future scenario	TN reduction (lbs/yr)	TP reduction (lbs/yr)
Tile water management and treatment	475,000	574,000	15,250
Continuous living cover	1,850,000	2,360,000	198,000
Tillage with more crop residue	375,000	98,750	50,000
Overland runoff controls	300,000	95,250	42,750
Fertilizer and manure management	675,000	291,250	24,250
Livestock and grazing management	165,000	83,600	17,200
Channel water treatment, impoundments & floodplain	TBD	TBD	TBD
Total	**3,840,000+**	**3,502,000+**	**347,450+**

5.2 Recent approaches to increase cropland practice adoption

5.2.1 Government and private sector nutrient management programs since 2014

MDA met with agricultural stakeholders, internal staff, conservation program staff, and state agencies to create an inventory of agricultural conservation implementation programs that stakeholders view as having successfully increased the adoption of practices on cropland in Minnesota. Additionally, these groups discussed new ideas that could effectively increase the rate of adoption of agricultural conservation practices.

The process was iterative and included the separation of regulatory and voluntary programs. Further, the list of programs was not intended to be exhaustive but rather to highlight recent efforts that have resonated with the involved stakeholders. The resulting list of existing programs served as a platform to identify commonalities and overall trends in program development and implementation. In addition to identifying and evaluating existing programs, ideas for new programs were compiled and discussed.

Some of the most frequently discussed programs are detailed below, representing a range of program approaches and lessons learned. A larger inventory of programs is presented at the end of Section 5.2.1 and in Appendix 5-4.

Descriptions of select existing programs

Minnesota Agricultural Water Quality Certification Program

MAWQCP, initiated by the MDA in 2014, is a voluntary statewide program designed to recognize and reward farmers for implementing conservation practices that protect water quality. This program provides farmers with a whole-farm risk assessment framework to implement practices tailored to their specific operations, accounting for risks to water quality. It also offers payment and certification that demonstrates their commitment to environmental stewardship. While the certification process can be time-consuming, the program has shown high scalability and is growing in popularity and environmental impact. The program benefits from having MDA as a champion and a strong peer network that promotes the program through trusted sources. This combination of flexibility and recognition appears to resonate with farmers, encouraging participation in the program.

Lessons Learned: The MAWQCP has demonstrated that farmers are more likely to adopt conservation practices when they are given the flexibility to choose from a suite of options that address their specific challenges. The program's success may also be partially attributed to farmer recognition and the indications that participating farmers have a higher average net income. The program's ability to adapt and grow, along with its focus on rewarding farmers' efforts, are key elements that other programs could implement. Additionally, the program has learned that the whole-farm risk assessment process and the 10-year obligation to maintain practice changes can deter some people from participating due to a greater commitment level than other, less-comprehensive farm interventions.

Soil Health Financial Assistance Program Grants

The Soil Health Financial Assistance Program Grants, another statewide initiative from MDA, was launched in 2023. This voluntary program provides financial assistance to farmers, helping them overcome the financial barriers to purchasing new equipment that promotes soil health practices. The program specifically targets tillage and nutrient management, areas where there is a high level of farmer interest. The program has a demonstrated high demand that significantly outpaced the available resources, indicating its potential for immediate impact if expanded. This program is considered to have high innovation and scalability, although it requires significant farmer buy-in and education to be fully successful. The program leverages a public-private partnership model and focuses on encouraging practices that farmers are already interested in, which likely helps with program implementation.

Lessons Learned: A key lesson from the Soil Health Financial Assistance Program is that direct financial assistance for large capital expenses like equipment can significantly increase the adoption of soil health practices. The program has observed strong interest among Minnesota farmers in adopting soil health practices, including tillage and cover crops.

Minnesota Nitrogen Smart Program

The Nitrogen Smart program, developed by UMN Extension and supported by the Minnesota Corn Growers Association, provides education to help farmers make informed, economically sound, and environmentally responsible nitrogen management decisions. Through in-person and online courses, the program offers practical, research-based guidance on nitrogen sources, timing, placement, and rates, which helps producers align practices with the 4R principles of nutrient stewardship.

Nitrogen Smart emphasizes understanding how nitrogen behaves in soil and water, enabling participants to optimize fertilizer use efficiency while reducing nitrogen losses to the environment. The program's flexible, locally delivered approach has reached thousands of producers statewide, contributing to improved farm profitability and measurable progress toward Minnesota's nutrient reduction goals.

Lessons Learned: The Nitrogen Smart program demonstrates that targeted, research-based education can effectively accelerate the adoption of improved nutrient management. Its success highlights the importance of farmer-centered learning, practical delivery methods, and trusted partnerships in achieving voluntary conservation outcomes at scale.

BWSR Soil Health Staffing Grants

The BWSR Soil Health Staffing Grants, started by the BWSR in 2024, is a voluntary statewide program that invests in local organizations to implement soil health practices. This program provides funding to SWCDs to increase their staff capacity, including the ability to hire agronomists. The program emphasizes that increased staffing leads to more outreach, technical assistance, and the implementation of conservation practices, all of which are deemed critical to conservation adoption. This program is considered groundbreaking for its investment in local capacity, and it also has high equity and scalability.

Lessons Learned: This program underscores the importance of investing in local capacity through staffing grants to support conservation efforts. Increased staff capacity allows for more outreach and technical assistance to farmers, which is vital for the adoption of conservation practices.

MDA AgBMP Loan Program

The Minnesota Agricultural Best Management Practices (AgBMP) Loan Program, administered by the MDA since 1995, is a voluntary, market-based program that provides low-interest financing to farmers, rural landowners, and agricultural businesses. The program helps fund a wide range of conservation and water quality improvements—including nutrient and manure management systems, erosion control practices, and water storage projects.

Delivered through local governments and private lenders, the AgBMP Loan Program enables participants to implement practices that protect surface and groundwater quality while maintaining farm profitability. Since its inception, the program has financed more than $300 million in projects statewide, demonstrating the value of flexible, locally driven conservation financing.

Lessons Learned: The AgBMP Loan Program illustrates how long-term, low-interest financing can accelerate conservation adoption. Its success underscores the importance of local delivery, broad eligibility, and financial flexibility in achieving voluntary conservation at scale.

Olmsted County Soil Health Program

The Olmsted County Soil Health program is a locally focused, voluntary program initiated by the Olmsted County SWCD in 2022. This program connects groundwater protection and soil health and offers a "you choose" approach to encouraging the increase of small grains, perennial crops, and cover crops. The program provides producers with the flexibility to select only those practices that meet their specific needs. With these flexibilities and simple ways to report progress, the program had successfully enrolled over 50 producers by 2024, resulting in more than 6,500 acres of cover crops. This program leverages local knowledge (created with strong input from local farmers), and it works to build trust and relationships to promote soil health. The program demonstrates that strong local leadership and community engagement can be highly effective in promoting conservation practices. Although its geographic scope is limited, the lessons learned from this program could be adopted by other efforts.

Lessons Learned: The success of this program highlights the importance of local focus and flexibility in promoting conservation practices. The program's "you choose" approach, along with high payment rates, enables farmers to select practices that fit their specific needs, is highly effective, and can increase participation. Strong local leadership and community engagement are also critical components of success.

Root River Field to Stream Partnership

The Root River Field to Stream Partnership in southeastern Minnesota has successfully advanced conservation by prioritizing trust-building and direct engagement with farmers. Instead of relying solely on data-driven strategies, the program has focused on one-on-one field walkovers, where farmers receive personalized conservation recommendations tailored to their land. This relationship-centered approach has fostered widespread voluntary participation, with farmers responding positively to simplified conservation planning and hands-on guidance, leading to meaningful on-the-ground changes.

Lessons Learned: This program has shown that building trust through personal, one-on-one engagement proved essential, as farmers responded positively when approached individually rather than through broad outreach efforts. The field walkover process was a key driver of success, allowing conservation specialists to meet landowners where they are, discuss site-specific challenges, and present practical solutions in an approachable way. By focusing on targeted conservation efforts, the program ensured that farmers could address high-risk resource concerns effectively, leading to meaningful, lasting improvements in land stewardship.

Inventory of existing programs

Ultimately, progress in conservation adoption is made collectively, whether through an established program, a pilot program, or individual efforts. These collective efforts provide momentum that cannot be fully quantified. For all programs inventoried, a multidimensional matrix was developed using a set of consistent parameters to identify and present the top programs.

The most notable program parameters evaluated were elements that led to the program's success, including geographic scope, scalability, innovation, and target audience. MDA determined the characterization of these programs and assessment of different parameters through discussions with partners and contributions from the NRS subteam working on scaling up BMP adoption.

Programs were grouped by geographic scale into four categories: (1) statewide programs (Table 5-9), (2) regional programs (Table 5-10), (3) watershed-scale programs (Table 5-11), and (4) national programs (Table 5-12). The goal is to use this information to identify opportunities for strategically scaling up the adoption of conservation practices.

Table 5-9. Existing state-level programs to accelerate agricultural conservation practice adoption.

Where initiated	Program	Funding	Scalability	Innovation	Target audience	Elements leading to success
	4R Certification Program in Minnesota	Private	High	High	Farmers, agricultural retailers	Public-private partnership, peer network
	BWSR Soil Health Staffing Grants	Public	High	High	SWCDs	Public-private partnership, peer network
	Clean Water Fund Implementation Grants	Public	High	Medium	Local governments, SWCDs (then to landowners)	Public-private partnership, flexibility
	Climate Smart Farms Project	Public	High	High	Farmers	Public-private partnership, peer network
	Forever Green	Public	High	High	Farmers, researchers	Public-private partnership, peer network
	MDA's Nutrient Management Initiative	Public	High	Medium	Farmers	Public-private partnership, peer network
	MDA AgBMP Loan Program	Public	High	Medium	Rural landowners	Public-private partnership
	Soil Health Financial Assistance Program Grants	Public	High	High	Farmers	Public-private partnership, flexibility
	Watershed Based Implementation Funding	Public	High	Medium	Local governments, SWCDs (then to landowners)	Public-private partnership, flexibility
	MAWQCP	Public	High	Medium	Farmers	Champion, peer network
	We Are Water MN	Public	High	High	General public	Public-private partnership, peer network
	Nitrogen Smart Programs	Public	High	High	Farmers	Public-private partnership, peer network
	MN Corn Innovation Grants	Private	Medium	High	Farmers, researchers	Champion, flexibility
Illinois	Fall Cover for Spring Savings	Hybrid	High	High	Farmers	Public-private partnership, flexibility
Iowa	Cover Crop Business Accelerator	Hybrid	Medium	High	Farmers	Public-private partnership, peer network
	The Conservation Infrastructure Initiative	Private	High	Medium	Landowners, SWCDs	Public-private partnership, flexibility

Table 5-10. Existing regional and watershed programs to accelerate agricultural conservation practice adoption.

Where initiated	Program	Funding	Scalability	Innovation	Target audience	Elements leading to success
Minnesota	Farmers Protecting Bridgewater Streams (Rice Creek)	Private	Low	Medium	Farmers, landowners	Peer network, flexibility
	International Water Institute Stewardship Program	Hybrid	Medium	High	Farmers, landowners	Public-private partnership, peer network
	Irrigation RCPP	Public	High	Medium	Farmers	Public-private partnership, flexibility
	Red River Basin initiative	Public	High	Medium	Landowners, local organizations	Public-private partnership, peer network
	Root River Field to Stream Partnership	Public	Medium	Medium	Landowners, local organizations	Public-private partnership, peer network
Minnesota, Iowa	Oatly	Private	High	High	Consumers, farmers	Champion, public-private partnership
Minnesota, Iowa, Nebraska, Missouri, South Dakota	Practical Farmers of Iowa – Cover Crops	Private	Medium	High	Farmers	Public-private partnership, peer network
Midwest states	Cover Crop Cost Share Program – Iowa and Nebraska; Full Supply Chain Collaboration – Nebraska	Private	Medium	High	Farmers	Public-private partnership, peer network
Multiple	Soil and Water Outcomes Fund	Private	High	High	Farmers	Public-private partnership, flexibility
Iowa	4R certification plus (4R nutrient management plus soil health & conservation)	Private	High	High	Farmers, agricultural retailers	Public-private partnership, peer network
	Cedar River Source Water Partnership RCPP	Public	Medium	Medium	Landowners, local organizations	Public-private partnership, peer network
	Iowa batch and build	Public	High	High	Farmers, landowners	Public-private partnership, peer network
	N Rate Risk Protection Program	Private	Medium	High	Farmers	Public-private partnership, flexibility
	Sustainable Soy Cover Crop Program	Hybrid	Medium	High	Farmers	Public-private partnership, peer network

Table 5-11. Existing county- and local-scale programs to accelerate agricultural conservation practice adoption.

Where initiated	Program	Funding	Scalability	Innovation	Target audience	Elements leading to success
Minnesota	Cooperatives for Climate	Private	Low	High	Farmer-led Cooperatives	Peer network, flexibility
	Olmsted County Soil Health	Public	Medium	Medium	Farmers	Champion, peer network
	Stearns County Cover Crop Program	Public	Medium	Medium	Farmers	Public-private partnership, peer network
	Wilkin County Soil Health Demonstration	Hybrid	Medium	High	Farmers	Champion, peer network
Multiple	Conservation Agronomist (example)	Private	Medium	Medium	Farmers	Champion, flexibility

Table 5-12. Existing national programs to accelerate agricultural conservation practice adoption.

Where initiated	Program	Funding	Scalability	Innovation	Target audience	Elements leading to success
National	Saving Tomorrow's Agricultural Resources (STAR) Program	Hybrid	High	High	Farmers	Public-private partnership, flexibility
	Truterra tillage and cover crop	Private	High	High	Farmers	Public-private partnership, peer network

5.3 Characteristics of successful programs

Characteristics of successful programs and approaches to scaling up agricultural practice adoption are summarized from programs and findings highlighted in Section 5.2 and from recent social science research and surveys. A few years ago, Nelson et al. (2017) clearly laid out the components of programs that have successfully controlled nonpoint source pollution, which include:

- Apply systems thinking
- Are locally relevant
- Engage local community members
- Build strong relationships and enduring partnerships
- Stay focused, learn, and adapt

"We Are Water MN" builds networks and programs to protect water

Many of these themes are found in the programs previously discussed, although the importance of each is likely dynamic. Nelson et al. (2017) also noted the need for individual behavior modification through changes in social norms and expectations.

5.3.1 Successful approaches from recent Minnesota and upper Midwest programs

A central characteristic common to all successful programs noted in Section 5.2 is the establishment of trusting relationships. These types of relationships grow from long-term partnership development, which include delivering technical assistance and empowering farmers to adopt BMPs appropriate to their system through education. The Nitrogen Smart education partnership program with private sector involvement has reached numerous farmers and farm advisors over the past decade. Success in building and sustaining trust and achieving desired outcomes often included the following elements:

- Flexibility is critical, enabling programs to accommodate diverse farm situations.
- Targeted outreach using trusted sources is more effective when approaching farmers.
- Long-term support and a consistent message are needed for lasting behavior and social norm changes.
- Strong local leadership and peer networks play a crucial role in program success.
- Financial incentives were also found to help reduce barriers to adoption.

The Root River Field to Stream Partnership in southeastern Minnesota has achieved remarkable success in accelerating targeted conservation practices using a batch-and-build style approach for streamlined practice installation. Several years of multiscale water quality monitoring revealed that high-risk runoff areas were contributing a disproportionate amount of sediment, nutrient, and pesticide loss. After several years of planning and relationship-building, the partnership hired a retired SWCD conservation specialist to help coordinate and conduct field walkovers.

Within two years, 100% of the 47 farmers in the small watersheds participated in the voluntary walkovers, spanning over 10,000 crop acres. After the walkovers, producers received a simple one-page report along with an individual action plan and out-of-pocket cost quotes. Conservation planning maps derived from the Agricultural Conservation Planning Framework were key in helping target and prioritize projects. After an additional three years, 70% of the farmers added other targeted practices. About 30% of the farmers addressed all their resource needs, going beyond what was requested, including 27% who installed practices without cost-share assistance. The initial $50,000 investment in the field specialist produced over $1.8 million in conservation cost-share assistance. The keys to success for this program included a dedicated technician who provided high-quality customer service and experienced leadership.

This type of successful one-on-one interaction with farmers was also seen in a watershed described by Osmond et al. (2015), where a dedicated conservation professional was hired to work with farmers. In that study, relationships were with fewer than 65 farmers. Until this step was taken, adoption of nutrient management practices was low. Pradhananga and Davenport (2017) also reported the importance of one-on-one positive relationships between farmers and technical assistance staff, which was more important for adoption and continued enrollment than other factors (e.g., the amount of financial assistance).

Further, flexibility should be built into all aspects of program delivery, including the practice types being suggested/used/acceptable and the spending/contract options. This message was found in the literature and was provided by multiple stakeholders and program delivery professionals. The sentiment is that all farms are different, so a rigid approach will only work in a few cases. Additionally, participants' financial situations can change at any moment, so having long lead times or an onerous process is not conducive to streamlined conservation implementation.

MAWQCP is an example of where this type of flexibility has been built in. Flexibility is achieved through the ability to implement practices customized to each farm after a full farm evaluation. Participation in this program continues to grow, with over a million acres enrolled as of 2024.

The 1W1P program is an overarching effort that provides a management structure with watershed-specific priorities and locally led targeting and implementation. Participation in the program opens up eligibility for additional noncompetitive implementation funding. These plans work closely with local governments, such as SWCDs, watershed districts, counties, and joint powers boards, to identify projects and the people ready and willing to implement conservation on the landscape. In some instances, funding will deliver streamlined practice implementation, where many conservation practices have been identified and will be installed in rapid succession. With this example, the conservation delivery mechanism is being changed to better align with local goals in a targeted approach. Also, flexibility is built in through local priorities (rather than mandated ones) and allows local organizations to pivot between potential projects.

Another promising approach is the strategic coordination of conservation practices across multiple farms and fields, often referred to as a “Batch-and-Build” model. Piloted in Iowa, this approach has demonstrated success in accelerating voluntary conservation by grouping practices geographically, implementing them in a single construction window, and shifting common pinch points—such as up-front capital costs—away from farmers and landowners. While Minnesota’s delivery systems differ, similar concepts are already in use through SWCD-led efforts, Watershed-Based Implementation Funding, and other grant programs. These efforts often involve bundling practices within a watershed and delivering them in a coordinated manner to improve efficiency and reduce burdens on participants. The NRS encourages further exploration and adaptation of this model to fit Minnesota’s context, particularly where efficiencies in design, contracting, and construction can be realized.

Finally, the momentum of our current agricultural system (including federal crop insurance, lender rules, existing markets, financing, and policy) may limit the profitable incorporation of conservation activities without some sort of incentive. For example, markets have been developed for major crops like corn, soybeans, sugar beets, and potatoes. Other products, such as intermediate wheatgrass (Kernza®), have limited marketability because consumable products have not yet created enough demand for the crop. Deviation from the current system is often perceived as risky for individual producers; therefore, support is needed for the adoption of conservation practices. There is no immediate solution for this, though market development for alternative crops is being actively pursued in Minnesota, and other technical and financial support is being considered.

5.3.2 Socioeconomic and human dimension research

To accelerate the adoption of BMPs, addressing the socio-economic and human dimension factors that influence farmers’ decision-making is crucial. These factors have been examined in social science literature over the years and continue to be critical elements in understanding conservation adoption.

Understanding farmer decision-making is essential because adopting conservation practices is not solely a technical or economic decision—it is shaped by a complex interplay of individual motivations, operational realities, and broader policy and social environments. Decisions are often made under uncertainty and influenced by values, trust in information sources, and perceived social pressures. Acknowledging this complexity enables more targeted and effective strategies that meet farmers where they are.

As outlined in the 2020 NRS 5-year Progress Report and in recent research by Roth (2022) and Prokopy et al. (2019), several key factors influence adoption, including:

- **Farm characteristics.** Farm size, type, presence of livestock, and land ownership structure all influence the feasibility, practicality, and profitability of BMP adoption. For instance, farmers who rent land may be less likely to invest in long-term practices, such as cover crops or buffers, as they may not see a return on those investments.
- **Personal characteristics.** A farmer’s age, education, risk tolerance, and conservation values shape their openness to change and experimentation. Younger or more environmentally motivated

producers may be more willing to try new practices, especially if they align with personal goals or long-term farm stewardship objectives.

- **Perceived practice characteristics.** Perceptions of a practice's cost, complexity, or benefits (e.g., improving soil health or yield) heavily influence decisions. If a practice is seen as high-risk or low-reward, its adoption is less likely—even if the actual outcomes are more favorable.
- **Social factors.** Farmers are often influenced by their peers and community norms. Seeing neighboring farms successfully adopt a BMP or hearing positive experiences from trusted peers can increase the likelihood of trying it themselves.
- **Structural factors.** Policy frameworks, financial incentives, and market forces all impact adoption. Complicated application processes, burdensome reporting requirements, and limited BMP options can become substantial barriers, even when farmers are motivated to implement practices.

Recent literature demonstrates the importance of local conservation staff and their relationships with producers in influencing the adoption of conservation practices (Cutforth et al. 2001; Pradhananga and Davenport 2022; Lee et al. 2018; Kalcic et al. 2014; Prokopy et al. 2019; Morris and Arbuckle 2021). A recent study showed that farmers who have met with local conservation professionals at least once are more likely to use soil health practices and believe in their benefits for soil, water, and wildlife (Roth et al. 2025). Local conservation staff, however, often lack training on how to best support producers and promote adoption. For more information on the status of the social science surrounding agricultural conservation adoption, see a review of the social/human dimension factors affecting the adoption of new practices available from Roth (2022). Additionally, the MDA provided a summary of some of the most influential literature in Appendix 5-4.

Work is continuing to explore the above themes to help quantify decision-making in the state. In 2024, a statewide survey was sent to 8,000 randomly selected producers across Minnesota to better understand producer decision-making related to the adoption of soil health practices (specifically cover crops), very low tillage (no-till and strip-till), and diversified rotations. The purpose of the survey was to better understand the motivations for using soil health practices, the barriers to adoption, and the intentions related to future adoption and practice use. Over 1,000 producers responded to the survey, which provided a baseline understanding of current practice adoption perspectives, experiences, and behaviors in the state.

Results show that landowners have a strong sense of responsibility to protect water resources and ensure they are not contributing to water resource problems. While most respondents (83%) believe that soil health practices can significantly reduce soil erosion and have a positive impact on water quality (85%), nearly 75% of respondents still use conventional tillage on some or all of the land they farm. Only half the respondents are using diversified rotations, and even fewer are using cover crops (43%) or no-till (39%) on at least some of their farmed land. In fact, a quarter of respondents believe soil health practices can have a negative impact on yield.

While 64% of respondents believe they have the knowledge and skills necessary to use soil health practices, key barriers to adoption included not enough cost-share (52%), pressure to make profit margins (52%), tedious paperwork and requirements (49%), and lack of appropriate equipment (35%). Most agreed they would be more likely to adopt conservation and soil health practices if they had evidence that it would improve their bottom line (72%) and not reduce crop yield (65%). Additionally, protecting land productivity, increasing profitability, and increasing yield were identified as the top three factors influencing soil management decisions for producers.

Given current producer perspectives and attitudes, support and programming aimed at reducing perceived risks to yield and profitability of practices is recommended. Producers want to see successful examples of the practices, talk to other farmers who use the practices, and have more flexible incentive programs. Full survey results can be found at the Soil Management Farmer Survey website and from Roth et al. (2025).

Social factors, such as peer influence and social norms, play a significant role in farmers' decisions about living cover strategies. Farmers often trust information from their peers more than from other sources. Roth et al. (2025) found, based on the large Minnesota survey of farmers related to soil health practices, that what producers most want in peer networks is more farmer participation, more demonstration events/hands-on workshops, and more informal farmer-to-farmer conversations. Roth et al. (2025) reported that the number one benefit reported by those who have participated in peer groups is learning from other farmers. Other important benefits were the opportunity to observe practices, the open communication about practice risks, and the availability of social support when trying new practices.

Recommendations for reducing human dimension barriers

While state agencies can address many barriers to the adoption of conservation practices, broader economic, social, and environmental trends also play a significant role. A review of social science research and lessons from successful programs highlights several strategies that can help the 2025 NRS better support adoption by addressing the human dimensions of change:

- **Build trust and foster relationships.** The adoption of conservation practices is deeply influenced by trust, both between producers and conservation professionals and among peers within farming communities. State agencies can support trust-building by funding farmer-led groups, reducing administrative friction, and facilitating peer learning and local leadership. These efforts help create a culture of conservation where information flows through trusted relationships, and producers are empowered to lead adoption efforts (Kalcic et al. 2014; Arbuckle and Roesch-McNally 2015; Atwell et al. 2009; Baumgart-Getz et al. 2012; Bressler et al. 2021; Che et al. 2022).
- **Adopt a systems thinking approach.** BMP adoption doesn't happen in isolation—it's shaped by an interconnected web of ecological, economic, and social factors. State agencies can strengthen program impact by designing conservation strategies that reflect this complexity and support multiple on-farm and watershed-level goals. Taking a systems approach helps ensure that programs are aligned across sectors, responsive to local conditions, and capable of delivering co-benefits such as resilience, profitability, and environmental outcomes without adding unnecessary rigidity (Roesch-McNally et al. 2018).
- **Streamline program access and delivery.** Even well-designed programs can fail if producers can't easily access them. State agencies can increase participation by simplifying application and reporting requirements, minimizing administrative burdens, and improving coordination across programs. Exploring options for consolidating offerings or aligning eligibility criteria can reduce confusion and make it easier for producers to engage (Atwell et al. 2009). Over 60% of farmers surveyed reported that the perceived ease of the enrollment process was moderately to strongly influential in their decision to enroll in a program (Roth et al. 2025).
- **Enhance knowledge and information access.** Navigating the conservation landscape can be overwhelming for producers, especially when information is fragmented or overly technical. State agencies can help by providing clear, streamlined information about BMPs, program eligibility, and funding opportunities that are tailored to local conditions and farm realities. Developing user-friendly tools and centralized online platforms, along with targeted, strategic outreach, can improve understanding and support more confident decision-making (Zimnicki et al. 2020).
- **Provide targeted technical assistance.** Offer tailored technical assistance to farmers to help them implement BMPs effectively, addressing specific needs and challenges (Tucker and Napier 2002).

In a recent survey, only one-third of farmers agreed that sufficient technical support is available for soil health management practices.

- **Increase conservation staff capacity.** To meet the growing demand for technical assistance and program delivery, state agencies should invest in staffing, training, and long-term support for local conservation professionals. In some areas, existing capacity is estimated to be too low to meet producer needs (e.g., Houston Engineering Inc. [2023]).

Although state agencies have limited control over larger trends, such as market forces, weather variability, and technology shifts, they play a crucial role in shaping how conservation is implemented on the ground. Long-term progress will require coordinated, locally grounded efforts that build trust, strengthen institutional capacity, and reflect producers' realities. Investing in these strategies now will be essential to scaling conservation in ways that are both effective and enduring.

5.4 Roadmap to further increase cropland practice adoption

Though agricultural conservation practice implementation has accelerated since 2014 through many new and existing programs, the pace of adoption will need to increase further to meet statewide water quality goals by 2040. Enhancing existing programs and developing new initiatives will be needed to broadly scale up adoption and shift from incremental progress to the type of transformative progress needed to achieve goals. Based on experiences from existing successful programs and social science research, along with the information discussed in Section 5.1, the 2025 NRS identifies a strategic framework (roadmap) to build on past progress and strengthen critical areas needed for achieving final goals. Two types of efforts are needed:

- **Increase focus on local priority waters.** Multiple smaller-scale, targeted watershed efforts are needed to address local lake and stream phosphorus reduction priorities, drinking water nitrate reductions in Drinking Water Supply Management Areas, and other local priority areas for nitrate.
- **Emphasize landscape-level changes.** Broad-scale adoption on vast acreages is also needed to reduce nitrogen by about 40% in surface and groundwater to meet goals for downstream waters, local aquatic life health, and groundwater nitrate. The needed reduction in phosphorus will be achieved largely through practices that achieve nitrogen reduction.

The efforts to address local priority waters within watersheds will have some benefit for downstream waters, but landscape-scale change is also needed to reach nutrient goals in downstream rivers within Minnesota and those leaving the state.

The two major categories of remaining work are outlined below, including recommended ways to move Minnesota toward achieving its goals. More emphasis is placed on landscape-level changes in the following sections of Chapter 5, as Minnesota has already focused much of its work locally through the Water Management Framework, as described in detail in Chapter 6.

5.4.1 Cropland management for local priority waters

To address nutrients in local priority lakes and drinking water sources, a multifaceted approach is needed that combines traditional and innovative practices and strategies. The 2025 NRS recommends building on the successes of the Minnesota Water Management Framework and other existing programs while addressing emerging challenges. Each watershed and region has unique challenges and goals related to nutrient transport from cropland to lakes, streams, rivers, and groundwater. Minnesota's local Water Management Framework is well-positioned to continue addressing local challenges and priorities related to rural nonpoint sources of nutrients. However, continued and strengthened support for watershed efforts will be needed due to the large number of local priority waters and the magnitude of nutrient reduction needed in those waters (see Chapter 3).

The 2025 NRS recommends that the Minnesota Water Management Framework and associated comprehensive watershed planning efforts be strengthened, as follows, to further provide technical assistance to implement targeted conservation practices:

- **Continue to support and promote MAWQCP.** This program evaluates the entire farm operation, looking for opportunities to incorporate conservation. This program should continue to be a primary initiative for accelerating the adoption of conservation practices to protect local waters.
- **Develop tailored regional approaches.** Develop region-specific strategies to address unique challenges and opportunities, such as reduced tillage in southeastern Minnesota, phosphorus mitigation in northwestern Minnesota, and tile drainage treatment in southcentral Minnesota. Consistent messaging across a given region can help lead to solutions that are common throughout the region.
- **Strengthen the local conservation workforce.** Provide training and support to conservation professionals in both public and private sectors to enhance their capacity to deliver effective technical assistance. This includes addressing concerns with staff turnover; limitations related to local job approval authority; technical service providers; and bottlenecks for design, approval, and implementation of certain engineering practices.
- **Partner with the private sector.** Private sector involvement is critical for achieving nutrient goals for local priority waters and for downstream waters. Several public-private partnership projects were started within the past decade. Successful partnerships should be continued and also serve as models for watersheds without such partnerships (see *Public-Private Partnerships for Protecting Minnesota's Water* for more details).
- **Continue use of Clean Water Funds.** Clean Water Funds have strongly supported Minnesota's Water Management Framework for addressing nutrients, and continued funding will enable the continuation and strengthening of the framework. Specific areas of funding may need to shift over time to address emerging issues, new technologies, and evolving programs.
- **Leverage federal programs.** Federal programs, such as RCPP, EQIP, the Conservation Reserve Program, the Conservation Reserve Enhancement Program (CREP), and Section 319, are critical for in-state successes of prioritized waters within Minnesota. Maintaining and strengthening partnerships with these programs will be important for continued successes in watersheds.

The types of support noted above are also important for landscape-level changes. More specific recommendations for increasing these support efforts are provided in the next section.

5.4.2 Cropland management for landscape-level changes

As previously noted, landscape-scale changes are needed to reach nutrient goals in downstream rivers within Minnesota and in rivers leaving the state, especially for nitrogen-related goals. Landscape-level changes are also needed in the Red River Valley, where fewer nutrient-related water impairments exist locally but where large nutrient reductions are needed for Minnesota's role in restoring Lake Winnipeg.

Each of the steps noted in Section 5.4.1 to strengthen the Minnesota Water Management Framework will also benefit landscape-level change efforts. However, to achieve the magnitude of practice changes outlined earlier in this chapter, additional support for broad-scale adoption will be needed. For example, 8–10 million acres of cover crops, relay crops, perennial crops, and new crop rotations will require systems changes that are beyond the scope of local efforts addressing small-scale priority lake, stream, and well-water improvements. Similarly, achieving 3 million acres of drained lands treated by edge-of-field practices (e.g., wetlands, saturated buffers, controlled drainage, bioreactors, drainage water recycling) will require substantial investment and support of new and efficient ways of adding BMPs to the landscape. Water storage practices such as landscape-level soil health improvements, floodplain reconnections, wetlands, ponds, and impoundments will also be important at the broader landscape levels. Information on large-scale impoundments is available in the RRWMB's report, *Involvement in Agricultural Land Protection in the Red River Basin in Minnesota*, which describes examples of these projects to store water and reduce peak flows in northwest Minnesota. The strategy to achieve nitrogen-related goals also includes millions of acres of in-field nutrient management refinements that will, in part, rely on developing technologies to reach further precision with applications of fertilizer and manure.

Discussions with stakeholders were held with the intent of identifying and promoting potentially transformative programs to address the challenge of accelerating conservation adoption, with a focus on the previously described social, economic, and structural factors that influence farmers' decision-making.

Many of the 2025 NRS-generated ideas are not a departure from existing programs; instead, they aim to build on the successes/lessons learned by emphasizing the importance of relationships, flexibility, and targeted outreach. This section outlines the program development, support, and implementation needed to move Minnesota toward achieving landscape-level change. The NRS recommends expanding, replicating, streamlining, and advancing focused programs (public, private, and nonprofit), while also providing broad-scale support to drive existing programs to the next level. Successfully implementing the recommendations is contingent upon adequate funding. It should be noted that even with these steps taken, other factors could affect complete success, including climate, the federal Farm Bill, national and worldwide food and energy markets, and other external influences.

The NRS recommends that Minnesota invest in developing the following to achieve the landscape levels of change needed in tandem with smaller-scale local efforts:

- Strengthen Minnesota's Water Management Framework
- Conduct a statewide CLC campaign, emphasizing harvestable/marketable CLC crops
- Support and expand existing successful agricultural practice improvement programs
- Expand research related to cropland nutrients

Specific recommendations to move forward with each of these strategies are provided below. Full implementation of these initiatives will depend on future funding levels. Without most of these strategies being implemented, little hope remains of achieving the TN load and nitrate concentration goals outlined in chapters 2 and 3.

Strengthen Minnesota's Water Management Framework

New initiatives needed to support landscape-level change through Minnesota's Water Management Framework include:

- Increasing workforce capacity
- Streamlining practice delivery, reporting, and funding systems
- Making streamlined practice installation programs easy to initiate and fund
- Supporting and strengthening private sector involvement and public-private partnerships
- Showcasing and replicating existing successful elements of local/regional programs
- Expanding soil health grant opportunities and other funding
- Approaching absentee landowners with conservation and soil health strategies/incentives

Increasing workforce capacity

A significant barrier to conservation adoption at landscape-level scales is the limited capacity of organizations to provide technical assistance and effective outreach to farmers. All four types of practices to achieve goals (living cover, drainage water treatment, water storage, and precision fertilizer application) require shared expertise and experiences through both the public and private sectors. Minnesota needs to continue building a skilled workforce to support conservation efforts by:

- Supporting conservation workers through training and compensation to increase retention.
- Incentivizing universities and agencies to encourage people to enter the conservation field.
- Providing training for agronomists and engineers on traditional and emerging conservation practices; then, incentivizing agronomists to provide conservation outreach and assistance.
- Investing in staff to achieve job approval authority through technical training and the ability to certify practices per NRCS practice standards.
- Supporting the creation of public-private conservation agronomist positions.
- Incentivizing farmers to lead groups in implementing new conservation practices.

Relationships and trust are central pillars of successful conservation programs. Creating public-private conservation agronomist positions, for example, could help build trust with farmers by providing them with locally relevant and reliable sources of information. These positions could also provide the consistent messaging and long-term support necessary for lasting behavioral and social norm changes. Further, leveraging existing private sector networks that farmers already trust could be an efficient way to reach farmers with conservation information.

These workforce development and capacity-building efforts shift the focus away from solely investing in practices and instead recognize the need to invest in the people who are essential to conservation adoption. This has been acknowledged and is being carried out by some existing programs (e.g., BWSR Soil Health Staffing Grants). This emphasis on people and program support aligns with the broader need for the private sector to expand its capacity for environmental services and integrate conservation delivery into its revenue model, whether as a core function or a complementary business strategy.

Streamlining practice delivery, reporting, and funding systems

When attempting to adopt conservation practices, farmers often face challenges such as navigating complex programs, finding programs that do not meet their needs or are not flexible enough to accommodate farm-specific circumstances or opportunities, needing to invest the time required to implement new practices, and facing the fear of financial risks. Reducing red tape, simplifying processes, and increasing flexibility in conservation programs are becoming increasingly important as the need to scale up adoption becomes a higher priority. It may be beneficial for state and federal agencies, as well as partners in the private and nonprofit sectors, to collaborate on a strategy for streamlining processes. Streamlining should be accomplished through:

- **Reducing administrative burdens**. Simplify application processes and reduce paperwork to minimize the time and effort required for farmers to participate in programs.
- **Consolidating programs.** Explore opportunities to consolidate multiple programs into fewer programs or a single, streamlined program to reduce confusion and increase efficiency.
- **Linking programs to achieve multiple benefits.** Seek ways to accomplish multiple environmental objectives with the same practices by leveraging additional state and federal funding sources.

Additional ideas to address streamlining were identified by the NRS work group focused on scaling up adoption. A few of the most promising were developing an app to interface with multiple conservation programs, compensating farmers for the burden and risks associated with newer practices, and implementing programs that streamline the installation of conservation practices.

Making streamlined practice installation programs easy to initiate and fund

A batch-and-build approach, like the one in Iowa, can reduce program complexity by packaging multiple conservation practices into a single project; this approach is recommended for further development in Minnesota. The typical existing conservation delivery generally relies on a farmer or landowner to be proactive, proceeding according to the farmer/owner steps outlined below:

1. Hears about a practice/program
2. Feels it applies to them or addresses a problem they think they have
3. Reaches out to program provider (or does more research on a program)
4. Applies to do a specific practice under a program and waits to hear if they are accepted
5. If accepted, signs a contract with the funding organization
6. Practice is planned/designed by a third-party
7. Practice is paid for upfront
8. Practice is installed by the farmer or a third party
9. Practice is certified
10. Reimbursement is made
11. Operation and maintenance activities are conducted

In contrast, the typical steps for a batch-and-build type of program are:

1. Complete state/regional prioritization of pollutants/problems
2. Identify targeted areas to address that pollutant (this may happen with a third party, state agency, or within a watershed plan)
3. Directly approach those farmers/owners where areas were identified. Approach using a trusted source like a crop adviser, SWCD, extension specialist, etc.
4. Do a field walk-over to discuss the problem (if applicable)
5. Provide options to solve the problem and let the farmer/owner choose from a list of options
6. Use a pre-identified and established funding source for practices to avoid requiring an out-of-pocket payment from the farmer/owner (especially where benefits are external to the farm)
7. Pay the farmer/owner an incentive (this may be optional, depending on the ask)
8. Conduct ongoing operation and maintenance activities

Batch-and-build programs in Iowa began with installing practices such as saturated buffers and bioreactors, but this approach could also be used for other types of practices, including cover crops and constructed wetlands. The concepts used in Iowa’s batch-and-build program have been used in certain Minnesota programs. For example, SWCDs often batch projects under Watershed-Based Implementation Funding or competitive grant programs. In these cases, they may have identified project needs (maybe a running list) and implemented them based on the funding received. For NRS implementation, streamlining practice installation should be incorporated into the 1W1P efforts based on local and statewide priorities as these plans are updated.

Another consideration for a streamlined installation program is how to simplify the ongoing maintenance of practices once built. For example, bioreactors need periodic replacement of woodchips or other carbon media, and saturated buffers and controlled drainage may need stoplog management at certain times of the year. These programs should have a corresponding batch maintenance program that includes funding to alleviate the maintenance burden or make it easier for the farmer to regularly maintain and repair the practices, ensuring they continue to perform as designed.

Supporting and strengthening private sector involvement and public-private partnerships

The agricultural industry, working in collaboration with other experts and organizations, can bring innovation, solutions, and motivation to farmers and landowners with consistent and persistent messaging. Private industry has played a significant role through programs such as MAWQCP, and its involvement is critical for other programs assisting farmers. The NRS partners working on implementing agricultural practices should include representatives from the private and nonprofit sectors of the agricultural industry.

The food processing and marketing industry is also a critical partner for landscape-level change, as it can help create products and build consumer demand for food developed through regenerative agricultural practices. MBOLD®, a Minnesota-based initiative of the Greater Minneapolis-St. Paul (MSP) Partnership, brings together leaders in food and agriculture to drive innovation and sustainability in the industry. The Minnesota Jurisdictional Initiative is a coalition focused on strengthening coordination across Minnesota's agricultural landscape, aiming to enhance soil health, water quality, farm profitability, climate resilience, and rural vitality. Engaging with these and other groups will help align efforts, leverage existing expertise, and create pathways for scaling regenerative practices across the food supply chain.

At the watershed scale, staff in each watershed within agricultural regions of the state should work to develop partnership projects with the private sector and collaborate on solutions to the nutrient loss that ends up in waters. Staff working on NRS implementation should make examples of successful partnerships readily available to others.

Showcasing and replicating existing successful elements of local/regional programs

Successful local and regional programs and their key elements were described in Section 5.2. Agencies implementing the NRS should broadly communicate the existing successful adoption models through the NRS dashboard and by working with BWSR staff. Watershed planners and others should consider how they can tailor a program in their own areas to achieve the broad implementation of soil health practices and other NRS practices.

Expanding soil health grant opportunities and other funding

Minnesota should expand and enhance MDA's Soil Health Assistance Grant program to incentivize soil health practices and reduce nutrient loss. Research, development, and training support from the Minnesota Office for Soil Health is critical for a sustained soil health improvement effort in Minnesota. Water Storage Grants and the AgBMP Loan Program have also proven helpful in funding practices that help reduce nutrients, and continued funding is recommended. The effects of soil health practices on farm economies need further study to identify sustainable practices and management systems that will, over time, pay for themselves.

Approaching absentee landowners with conservation and soil health strategies/incentives

Landowners who do not reside near the land they are renting are more difficult to reach and pose unique challenges for local conservation staff. Engaging with these landowners is necessary to promote investment in long-term conservation practices, such as soil health. Minnesota partners will develop an outreach plan and associated tools to reach remote landowners and renters with information, opportunities, and incentives for investing in practices that protect soil and reduce nutrient losses to waters.

Conduct a statewide CLC campaign

To improve soil health, reduce nitrogen inputs and leaching, and reduce wind and water erosion to mitigate nutrient loss, Minnesota will need to increase practices aimed at harvestable/marketable CLC on croplands. A CLC campaign should be launched to achieve the first million new acres of CLC, also recognizing that many more millions of acres will ultimately be needed to achieve the NRS goals and other multipurpose benefits of these practices. The NRS recommends that a CLC campaign work group be formed to develop a specific timeframe for the goal, outline the campaign process, identify the next steps for developing cover crops and their markets, and establish a phased strategy for promoting and implementing various CLC practices. The CLC campaign and work group should include participation from both high-level leadership and technical staff from agricultural organizations, academia, government agencies, and private industry. While the initial goal will be to add a million acres of new CLC, the work group should also establish approaches and systems that will lead to long-term living cover additions on millions of acres. The work group should make recommendations to various audiences, including the Minnesota governor's office, the Minnesota Legislature, the Clean Water Council, and others.

The campaign efforts should also support the development of new markets for CLC crops, infrastructure, and new crop genetics. The UMN Forever Green Initiative is working on this and has been making progress with 15 crops that can provide an increase in the extent and duration of living cover on the landscape (Figure 5-8). Forever Green is based in UMN's College of Food, Agricultural, and Natural Resource Sciences and was formed as a consortium of crop research and development projects. Each Forever Green crop is supported by a multidisciplinary team that typically includes expertise in areas of genomics, plant breeding, agronomics, environmental sciences, food and end-use science, sociology, economics, and commercialization.

New living cover crop varieties recently developed by the Forever Green teams include:

- The world's first Kernza® variety, MN-Clearwater (2019–2020)
- The next Kernza® variety, MN-Itasca, which is slated for release in 2025
- A winter barley variety, MN-Equinox (2022)
- A hardier hairy vetch variety, Vinter (2022)
- Hazelnut lines (4–5), being prepared for commercial release
- Early maturing winter camelina line optioned to a commercial partner
- A hybrid rye
- Pennycress, domesticated and commercialized in Illinois and Indiana, paving the way for commercialization in Minnesota in the coming years

Forever Green crops have been used by a wide range of private companies, from food startups and small bakeries to large Minnesota food companies. To better support farmers, Forever Green has developed and runs the Environmental and Economic Clusters of Opportunity Program, which is funded by the CWLLA Clean Water Fund through the MDA. This program provides financial and technical assistance to farmers who adopt four CLC crops: Kernza®, winter camelina, hybrid winter rye, and winter barley, with an extra incentive for use on acres in Drinking Water Supply Management Areas.

Figure 5-8. Forever Green Initiative portfolio of CLC crop types.

Forever Green and MBOLD recently released a jointly produced report, *Reflections on the 2023–2024 Piloting of Winter Camelina: Lessons and Implications for Further Scaling*. The report summarizes the lessons learned from the 2,000-acre commercial winter camelina pilot in the Upper Midwest in 2023–2024. It includes critical reflections on field-scale production of winter camelina, highlighting agronomic considerations, weather challenges, observations for continued breeding of the crop, and potential pathways for further scaling and commercial uptake

A potentially promising recent development with sustainable aviation fuels (SAF) could also provide markets for certain CLC crops. Camelina and other crops can produce jet fuels to be used in today's aircraft engines. MNSAFHUB is part of the Greater MSP Partnership and involves Bank of America, Delta Air Lines, Ecolab, Xcel Energy, Minnesota, the Metropolitan Airports Commission, and UMN. This partnership aims to develop both supply and demand for over 100 million gallons of jet fuel annually. If SAF feedstocks are developed from crops with low nutrient input needs or high nutrient efficiencies, this potential new market can help to make nutrient reduction progress in our waters.

Financial obstacles to CLC

It is important to recognize the substantial financial investment required to implement large-scale conservation programs. Estimates suggest that annual funding of $500 million to $1 billion may be necessary for each of the Midwest states (Minnesota, Iowa, and Illinois) to achieve nutrient reduction goals (Feyereisen et al. 2022). Much of the anticipated cost is due to the expenses associated with CLC practices, including reduced profit from changing crop types and the costs of planting and terminating cover crops. Financial incentives can help farmers manage risk when deviating from the current system. While federal, state, and local funding sources exist, it will be challenging to align funding with the practices identified in the NRS and also to transition from grants and cost-sharing to market-driven forces for long-term viability.

To support long-term adoption of CLC and diversified crop rotations, the CLC campaign should emphasize pathways that help farmers manage financial and production risks. Existing federal programs, such as crop insurance and the Commodity Title of the Farm Bill, can play a role in this effort, particularly when paired with purchase contracts or targeted support for crops like wheat, oats, and barley that are underrepresented in current rotations. Leveraging and adapting these tools to better align with CLC systems can help reduce barriers to entry and create more stable economic conditions for farmers transitioning to new practices.

The CLC campaign work group should consider the financial challenges associated with changing to CLC practices and the following economic incentives and market-based approaches:

- Develop more markets for ecosystem services like clean air, clean water, and carbon sequestration.
- Provide tax incentives for putting marginal lands into pasture or perennial crops.
- Offer grain premiums for implementing carbon-sequestering practices.
- Compensate farmers according to the burden of adopting practices.
- Provide financial incentives for implementing cover crops and reduced tillage.
- Advance and expand MDA's Developing Markets for CLC Crops grant program.
- Explore market-based incentives, such as carbon markets and premium payments for sustainable agricultural products. Reward low-carbon fuels and the use of winter oilseeds in the renewable fuels market space.
- Further expand the channels of communication with agribusinesses to better understand and align their sustainability programs and priorities with state-level living cover and soil health priorities.
- Consider alternative payment mechanisms for agricultural retailers, such as payments based on environmental outcomes or the adoption of specific practices.
- Offer incentives to landowners who can use CLC practices and measure the average nitrate concentrations leaving their tile line systems to ensure they remain at less than 8 mg/L.

Financial incentives alone are insufficient to drive widespread adoption, but they can reduce major barriers when coupled with other supportive approaches. Economic strategies need to move beyond traditional incentive programs to incorporate broader changes to the marketplace. Strategic investments on the public side are needed to support the development of market demand for CLC-related agricultural products.

Other considerations

The work group and campaign should include participation by multiple agencies and sectors, including the private sector. The efforts should be specific, actionable, and focused on scaling harvestable CLC crops that will stimulate economic growth and achieve the desired environmental outcomes.

The CLC campaign work group should also consider how to scale up the integration of crop and livestock systems. For example, how can late fall/early spring grazing of cover crops in annual row-crop fields best be implemented? The MDA's Cropland Grazing Exchange, an example of a program geared towards this integration, matches livestock farmers with crop farmers who have forage (crop residues, cover crops, etc.) to harvest.

The work group should also strongly consider social factors, as described in Section 5.3.2. For example, programs like the Root River Field to Stream Partnership have yielded remarkable success using peer networks and farmer champions. The work group should consider ideas raised by stakeholders that would help foster strong relationships among farmers and landowners to facilitate knowledge sharing and peer-to-peer learning:

- Establish a referral program where landowners are paid to encourage their neighbors to adopt conservation practices.
- Create a neighbor-to-neighbor (or farmer-to-farmer) learning network.
- Support farmer champions and peer networks who can share their experiences and knowledge.
- Highlight the benefits of conservation to the general public through "show-and-tell" opportunities, describing how conservation is beneficial not only to the farmer or landowner, but to their neighbors and the surrounding community. This approach leverages the power of social networks to create a culture of conservation.

Expand research related to cropland nutrients

Enough research has been completed to enable Minnesota to move forward in promoting and implementing many practices. And yet, to reach the landscape levels of change previously described, considerably more Minnesota-specific research will be needed, along with demonstration projects and pilot programs for emerging technologies and practices to fill critical knowledge gaps. Additional research is needed on the following topics:

- **Drainage water recycling.** This promising practice, which involves storing excess water during rainy seasons for irrigation use during drier periods, has shown great promise at one research site in Minnesota and other sites in Iowa and elsewhere. More information is needed about the best designs, siting locations, economics, and hydrologic management.
- **Find improved ways to manage cropland nutrient additions.** To address weather extremes and increase nutrient efficiencies in those situations, more research is needed to fine-tune in-field nutrient management using precision technologies. Minnesota's diverse soils and climate conditions necessitate site-specific approaches for estimating crop nitrogen needs and the best rates and methods of application that can be adjusted to accommodate springtime weather.
- **Market-based CLC practices.** Research is needed on living cover practices and cropping systems to provide sustainable food, fiber, and energy sources. Minnesota should build on the past decade of research and continue to find new cropping systems for soil health, profitability, water quality protection, and other environmental benefits. Economic research is also needed to ensure CLC development and progress that can be sustained.
- **Constructed wetlands.** Relatively little research has been performed in Minnesota on how to best site, design, and construct wetlands to treat nitrate in tile drainage water. More research is needed on how to practically implement this practice across Minnesota to reduce nutrients in water while also providing wildlife benefits.
- **Practice efficiencies for nutrient reduction**. Numerous conservation practices provide in-field and edge-of-field environmental benefits. Christianson and Rosen (2025) and Souza and Rosen (2025) highlight many of the water quality benefits, although both reports note gaps in research on some of the listed practices. For example, Christianson and Rosen (2025) highlight large research gaps in tile drainage and associated conservation practices in Minnesota. Developing or enhancing drainage research facilities would be a critical step in reducing uncertainty and advancing more effective conservation strategies.
- **Stacked practices and field-level outcomes.** Future research should quantify the nutrient reductions from stacked practices (i.e., more than one practice treating the same water) on the same acres to better reflect real-world conditions.

- **Biological Nitrification Inhibitors (BNI).** Investigate the role and potential of biological nitrification inhibitors to further enhance in-field nutrient management, facilitate nitrogen uptake, and reduce input quantity and cost.

Support and expand successful agricultural practice improvement programs

MAWQCP has proven that it can scale-up efforts to cover over one million acres. The NRS recommends:

- Continuing and expanding the program so that MAWQCP can ultimately affect several million acres of Minnesota farmland, including farmland rented by others.
- Add a nitrogen endorsement to the five other MAWQCP endorsements to further promote and incentivize the types of practices that can reduce nitrate leaching to less than 8–10 mg/L. Endorsement criteria could consider a modeled approach for evaluating nitrate leaching to groundwater and a monitoring approach for tile line self-monitoring by farmers (reducing nitrate to less than 8–10 mg/L).
- Replicate and expand other successful regional soil health programs and private industry-led programs. Several additional county and regional soil health programs have been very successful in Minnesota and other upper Midwest states, as described in Section 5.3.1. These programs should be showcased, brought to other parts of the state, made flexible for farmers, streamlined, and financially supported.
- Statewide soil health initiatives and the related Minnesota Office for Soil Health program need to continue and be expanded.
- Private sector leadership and support are critical for achieving NRS goals. The NRS encourages continued work by the private sector to promote nitrogen BMPs through private-sector programs such as the Minnesota 4R Nutrient Stewardship Certification program and Minnesota's recently initiated parallel approach to the Iowa Nutrient Research and Education Council.

5.4.3 Funding of Chapter 5 roadmap actions

The NRS shows the practices and program development needs for achieving local and large-scale nutrient reduction to waters from rural areas across Minnesota. The NRS is written to identify the technical and programmatic needs to achieve goals, but it was not intended to show all specific funding sources and mechanisms. Annual costs are expected to exceed $1 billion per year for all implemented and maintained practices. The NRS recommends starting with lower-cost practices and programs, while rapidly improving technologies and efficiencies to offset the costs of more expensive practices and programs. The NRS recommends conducting an economic analysis to inform the development of a strategy for funding the needed practice changes and additions. Recommended parts of the analysis include:

- Building from information in chapters 4 and 5, assess the total costs to landowners, city residents, and government agencies to implement the practices identified in chapters 4 and 5.
- Estimating the economic benefits to society of the adoption of the practices in chapters 4 and 5, including benefits to local and downstream water quality and the additional multiple benefits to society expected from these practices apart from nutrient reduction in waters. Compare the societal benefits to the cost of implementation.
- Identifying funding options for adding the NRS practices to the landscape, including pros, cons, and unintended consequences/risks associated with the options. Make recommendations on the best ways to pay for the practices.

The NRS organizations should evaluate the above analyses and develop a strategy for ongoing funding. While Minnesota currently has partial funding for certain NRS implementation measures, much more funding will be needed both before and after the 2034 end date of the CWLLA Clean Water Fund monies.

5.5 Reducing other rural nutrient sources to waters

The following noncropland rural sources also contribute to nutrients in rivers, streams, lakes, and groundwater:

- **Feedlots** can contribute nutrients from livestock and manure-holding areas and from the application of manure and poultry litter to the land. Land application to cropland was largely addressed in previous parts of Chapter 5, but the discussion is expanded in Section 5.5.1 to include updates to current permitting and regulatory requirements through Minnesota's feedlot rules (Minn. R. ch. 7020).
- **Septic systems** can add nitrate to groundwater and nutrients to surface waters; these are discussed in Section 5.5.2.
- **Forested lands** contribute relatively few nutrients to waters and need to be preserved and harvested using practices to protect water quality. Forest practices and programs and the restoration of historically drained peatlands are described in Section 5.5.3.
- **Erosion** of streambanks and other bluffs, ravines, and gulleys can add large amounts of phosphorus and some nitrogen to streams, rivers, and downstream water bodies. Practices to reduce this source of nutrients are described in Section 5.5.4.

5.5.1 Feedlots

Minnesota has about 17,000 livestock feedlots registered under the state's feedlot rule. They range in size from small farms to large-scale commercial livestock operations. Many organizations and programs work with livestock producers to ensure that Minnesota continues to support a healthy livestock industry and natural environment. Feedlot rules have been in effect in Minnesota since the early 1970s. A major revision of the feedlot rule (Minn. R. ch. 7020) went into effect in October 2000 and was followed by a minor update in 2014.

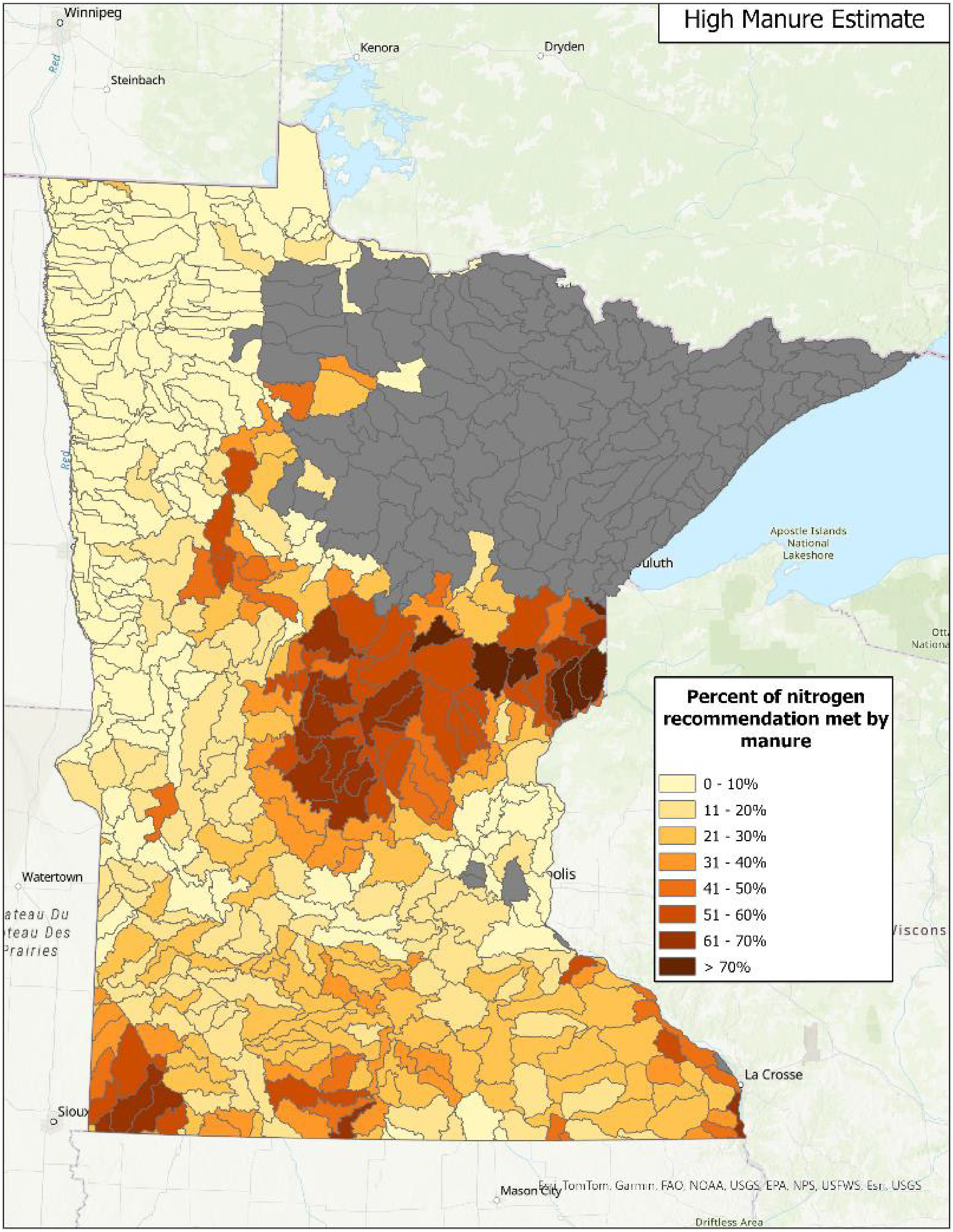
The MPCA regulates the collection, transportation, storage, processing, and disposal of animal manure and other waste from livestock operations, which pertains to the land application of manure. The MPCA Feedlot Program implements rules governing these activities and provides assistance to counties and the livestock industry (see MPCA's Feedlot website for requirements). The two primary objectives of the rules relating to protecting water from pollution from feedlots are:

- Ensuring that manure from a feedlot or manure storage area does not run into water.
- Ensuring that valuable nutrient-rich manure is applied to cropland at a rate, time, and method that prevents nutrients and other possible contaminants from entering streams, lakes, and groundwater.

Runoff from feedlot sites and manure-fertilized cropland can be a localized source of nutrients to waters. Statewide, however, runoff from feedlot sites (not including manure application on cropland) represents less than 1% of nitrogen and less than 2% of phosphorus based on the 2014 NRS source assessments (see Chapter 2).

A recent study indicated that manure contributes about 19% of the statewide crop fertilizer nitrogen need, with a likely range of 15% to 22%, depending on the data sources used (Porter and Conowall 2025b). However, in many central Minnesota watersheds and some southern Minnesota watersheds, manure can potentially supply over half the crops' nitrogen needs (Figure 5-9).

Figure 5-9. The fraction of crop nitrogen needs that could potentially be supplied by manure from feedlots in the general vicinity.



Source: Porter and Conowall 2025b.

The NRS generally includes manure with cropland sources of nitrogen because manure is part of the nitrogen pool used by crops, including soil mineralization, fertilizer, legumes, precipitation, and other sources. Once nitrogen is in the cropland soil, differentiating the individual impacts on water quality from each of these different sources is very difficult.

Depending largely on how the manure is managed, land-applying manure to cropland can create a pathway for nutrients to reach waters. Additionally, manure presents different management challenges compared to inorganic commercial fertilizers. For example, determining how much organic nitrogen in manure will be available for crop uptake is more difficult compared to inorganic commercial fertilizer. Nutrient availability to crops is highly dependent on the type and size of animal, the climatic conditions, the type of bedding used for livestock, manure storage methods, application method, and other practices. Therefore, the MPCA feedlot program focuses on the land application of manure practices, including checking the required records for the land application of manure, conducting nutrient management training for program staff and commercial animal waste technicians, and providing free nutrient management planning and record-keeping tools.

MMPs are required when feedlot owners need to apply for a feedlot permit, or when a feedlot facility has 300 or more animal units and does not use a licensed commercial applicator to spread manure. MMPs help ensure that application rates do not exceed the crop's nutrient needs and that setbacks from waters and sensitive features are observed.

Since the 2014 NRS, the MPCA's feedlot program has continued working to minimize the risk to waters from the land application of manure. The biggest changes since 2014 have been modifications made to the requirements for land application of manure in the NPDES and SDS permits for the largest feedlots, including concentrated animal feeding operations and other feedlots that have more than 1,000 animal units and hold operating permits. Changes were made to these requirements in the 2021-issued NPDES permit, and further requirements were added to permits going into effect in 2025–2026.

The MPCA's General Feedlot SDS Permit lasts for 10 years, and its General Feedlot NPDES Permit lasts for five years. The new SDS and NPDES general permits go into effect in 2025 and 2026, respectively. Feedlots operating with the new SDS and NDES general permit coverage need to meet the following requirements:

- **MMP development**. All applicants for these permits will use the new online Nutrient Management Tool to develop their MMP, and they will submit the MMP electronically to the MPCA as part of the online permit application process. The Nutrient Management Tool incorporates a GIS-based mapping program that clearly represents water features and required setbacks.
- **Transferred manure**. Manure recipients must also comply with the land application requirements outlined in the permits. Existing state feedlot rules require that recipients of transferred manure follow the MMP of the facility where manure was generated. All manure generated at NPDES- and SDS-permitted sites must be land-applied in accordance with the permit requirements designed to provide more protection to surface water and groundwater resources. Certain manure transfer prohibitions were also added to the new permits to prevent manure and associated nutrient losses during the winter months. Record-keeping requirements for the transferred ownership of manure were also increased.
- **Inspections of manure application sites**. Inspections must occur at downgradient field edges, tile intakes, water features, and any other potential point of discharge from the fields. These inspections must take place at least once each day that manure is applied to the field, at the end of manure application to the field, and within 24 hours of 0.5-inch or greater rainfall that occurs within 14 days of the end of application (unless the manure is injected or incorporated).

- **Manure application required practices**. Certain practices are required wherever manure from a permitted facility is applied, including when the manure ownership is transferred. Required practices vary with the date that the manure is applied:
  - *Manure application during June, July, August, and September.* One of the following BMPs is required: (a) application to a growing perennial or row crop or (b) cover crop planted prior to or within 14 days of application.
  - *Manure application from October 1–14.* Within vulnerable groundwater areas, follow the BMPs for June–September. For application from October 1–14 outside of vulnerable groundwater areas, one of the following BMPs is required: (a) follow the BMPs for June–September, (b) ensure soil temperature has reached 50°F for two consecutive days, (c) use a nitrapyrin-based nitrification inhibitor, or (d) split application of no more than one-half of the nitrogen needs.
  - *October 15–31* (beginning in 2027). Within vulnerable groundwater areas, one of the following BMPs is required: (a) follow the BMPs for June–September, (b) ensure soil temperature has reached 50°F for two consecutive days and a perennial crop is grown two out of five years, (c) ensure soil temperature has reached 50°F for two consecutive days and a nitrapyrin-based nitrification inhibitor is used with all liquid manure and, for solid manure, a split application of no more than one-half of the nitrogen needs.
  - *November manure applications* (beginning in 2027). Within vulnerable groundwater areas, one of the following BMPs is required for liquid manure application: (a) follow the BMPs for June–September, (b) grow a perennial at least two out of five years, or (c) use a nitrapyrin-based nitrification inhibitor.
  - *Winter (December–February).* All application of manure to frozen or snow-covered fields, including when manure ownership is transferred, is prohibited for liquid manure during December, January, and February and is prohibited for solid manure application unless all the following apply: (a) the field is approved in an MMP, (b) manure is not applied in vulnerable groundwater areas, (c) includes a 300-foot setback to waters/tile intakes, (d) some runoff storage is in tillage furrows, (e) the soil slope is 6% or less (and 2% or less in February), and (f) under a 50% chance of 0.25-inch or more rainfall within 24 hours of application (24 hours increases to 5 days for application in February), and, if 2 inches or more of snow, the temperature must be below 40°F for 24 hours after application (24 hours increases to 5 days for application in February).
  - *March.* Liquid and solid manure application is prohibited to frozen or snow-covered fields.
  - *Nonwinter conditions.* If winter conditions do not exist at the time of application during the months of December through March, land application is allowed, provided the manure is injected or incorporated within 24 hours.

Other requirements for all-sized feedlot facilities and associated land application of manure remain in effect and are specified on MPCA's feedlot construction, operation, and technical requirements website. The recent permit changes are expected to further reduce nitrate losses to water.

Additionally, the MPCA's feedlot program opened the animal feedlot rule for rulemaking on March 24, 2025, and asked for comments and questions through July 22, 2025. One of the purposes of opening the rule is to improve the practices for land application of manure that can address nitrate and bacteria in waters. Other reasons include improving technical standards to avoid fish kills and updating outdated language, practices, and data services. During the multiyear rulemaking process, the agency intends to engage with affected and interested parties through several informal (not required by law) opportunities, and ultimately with a public notice of the draft rule and Statement of Need and Reasonableness, as required by the state Administrative Procedures Act.

5.5.2 Septic systems

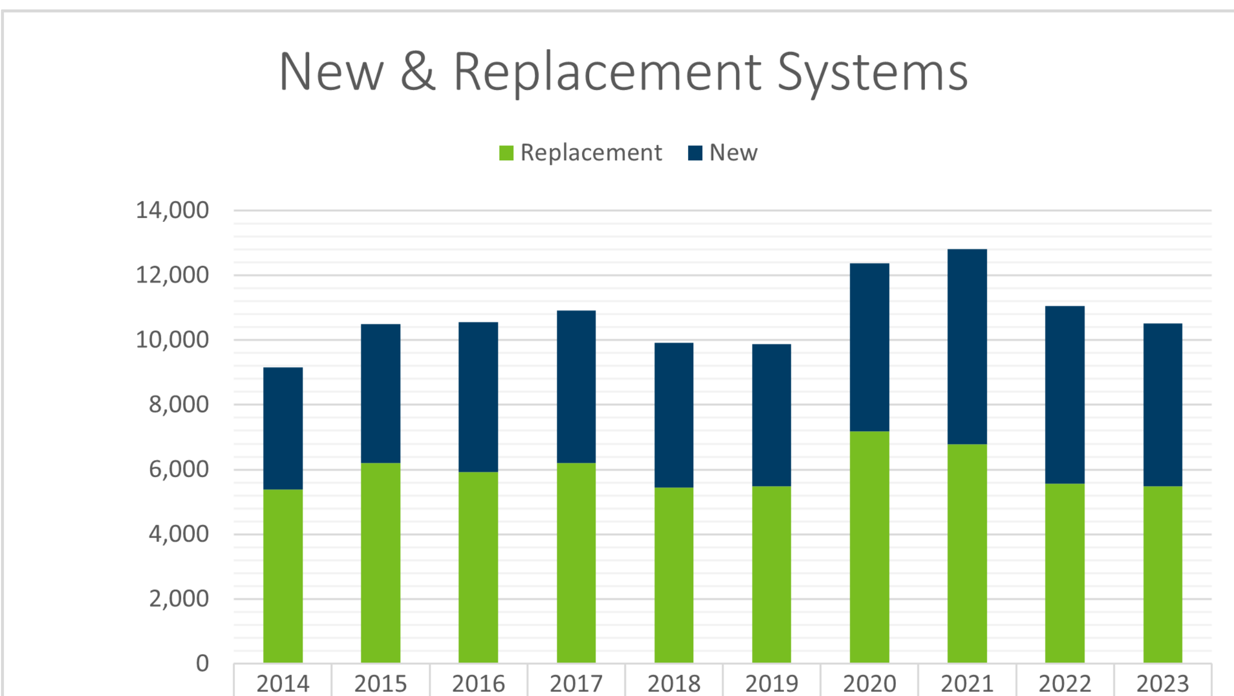
Septic systems are a small nutrient contributor statewide, but they can create local groundwater and surface water problems when improperly sited, constructed, and maintained. The 2014 NRS called for continued progress with Minnesota's regulatory program for septic systems. Implementation of Minnesota's SSTS program serves as the primary strategy in the 2014 NRS to reduce nutrient loads from septic systems. Progress since 2014 is determined using information from SSTS inspections and compliance rates.

Between 2014 and 2023, over 147,768 inspections of septic systems occurred. The number of septic systems considered to be imminent public health threats has dropped to less than 5%, thus meeting the NRS strategy target. It is estimated that, in 2023, 14% of total systems failed to fully protect groundwater. The SSTS program will continue implementation to further protect groundwater and surface waters.

Of the reported 649,493 existing systems in Minnesota, 12,800–15,900 systems (2.2%–2.8%) were evaluated for compliance each year from 2014 to 2023. Inspections are typically triggered at the point of sale for the property. Currently, 147 local government units (77%) have point-of-sale inspection requirements included in their local SSTS ordinance. This includes 60 (70%) county SSTS programs.

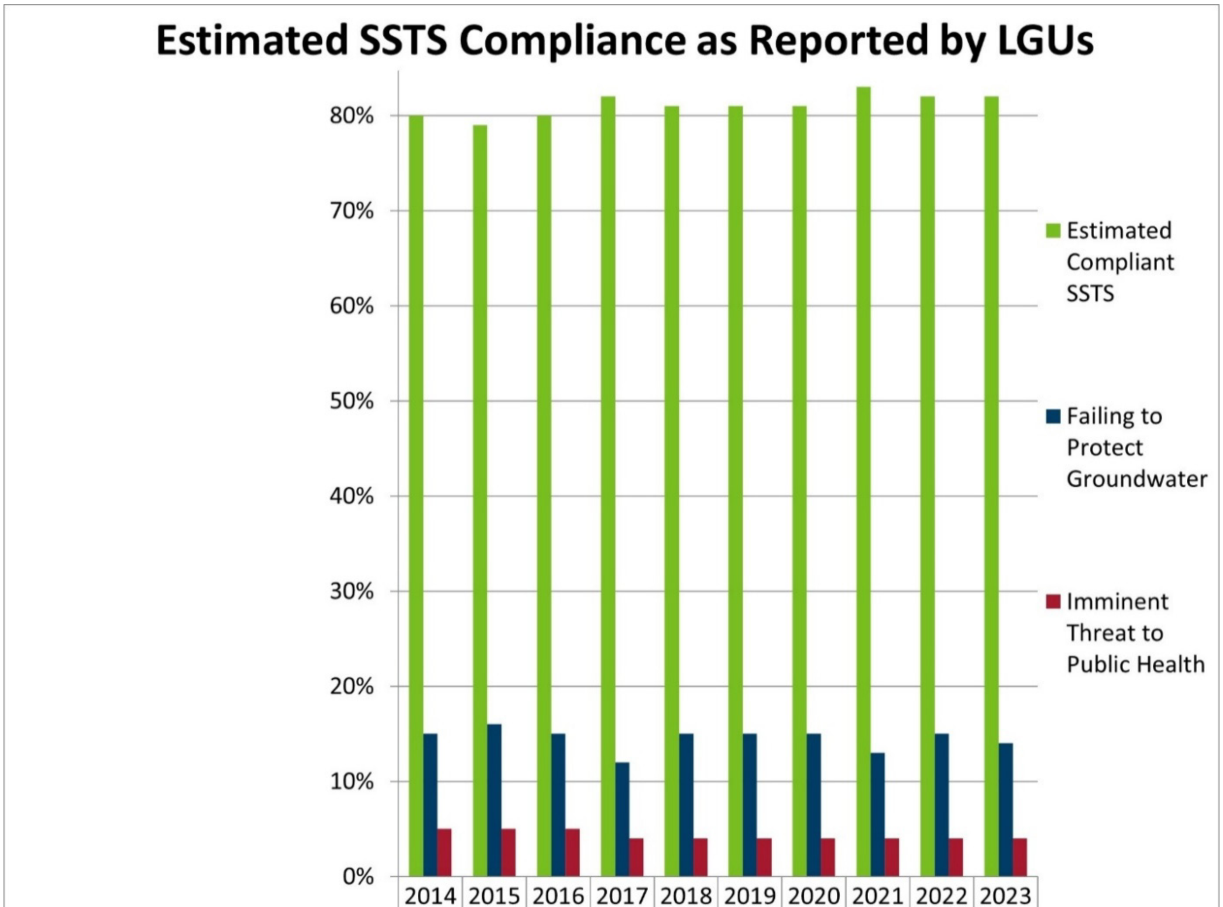
Since 2014, local government units have issued over 59,665 SSTS construction permits for replacement SSTS or for systems that replace an existing sewage system that was identified as noncompliant for either failing to protect groundwater or an imminent threat to public health and safety through an inspection (Figure 5-10). While inspection rates have remained fairly steady since 2014, the number of compliant systems has increased, and the number and fraction of septic systems that fail to protect groundwater or are otherwise considered an imminent threat to public health and safety have dropped (Figure 5-11). The number of estimated compliant systems has increased from 424,000 systems in 2014 to roughly 534,600 systems in 2023.

Figure 5-10. New and replacement SSTSs over time (2014–2023) as summarized by MPCA.



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
New	3,767	4,288	4,639	4,709	4,483	4,377	5,185	6,026	5,483	5,029
Replacement	5,393	6,205	5,917	6,197	5,436	5,492	7,183	6,786	5,568	5,488

Figure 5-11. Estimated SSTS compliance (2014–2023) by local government units and summarized by MPCA.



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Estimated Compliant SSTS	80%	79%	80%	82%	81%	81%	81%	83%	82%	82%
Failing to Protect Groundwater	15%	16%	15%	12%	15%	15%	15%	13%	15%	14%
Imminent Threat to Public Health	5%	5%	5%	4%	4%	4%	4%	4%	4%	4%

5.5.3 Forests

Healthy, well-managed forestlands are important for protecting water quality. To maintain the benefits of forested and peatland areas, the NRS focuses on three ways to reduce potential nutrient impacts for these areas: (1) timber harvesting, (2) forest preservation and restoration, and (3) restoring historically drained peatlands.

Timber harvesting

In northern Minnesota, one of the primary ongoing landscape disturbances that could contribute nutrients to surface waters is timber harvesting. This industry is particularly active in the major watersheds of the Upper Mississippi River Basin, Rainy River Basin, and Lake Superior Basin, but it also affects other areas.

Nutrient export from harvested forests is a much less-studied phenomenon than nutrient export from agricultural activities and, in general, is a lower contributor of nutrients to waters on a per-acre basis as compared to other agricultural and urban land uses (Shah et al. 2022). Nutrient export from harvested acres is also a more temporary issue on any given tract of land, as most harvested acres, both private and government-owned, are allowed to regenerate into forest again.

Most studies on forest management practices (i.e., harvest) have focused on sediment export or changes in hydrology from harvested areas. These relate to nutrient export, especially regarding phosphorus, which binds to soil particles and is often exported along with sediment. These eroded soils may originate from the harvested area itself, from the temporary roads created to haul away the cut timber, and potentially from increased stream bank erosion due to higher peak flows in streams caused by increased precipitation runoff after the mature trees are removed.

The science of understanding the impacts of forest management continues to evolve. A study in Minnesota examined the effects of harvesting on nitrate and phosphorus availability in riparian buffer soils adjacent to upland clearcuts (Kastendick et al. 2012). They found that post-clearcut soils have increased inorganic nitrogen levels, and soils do appear to export inorganic nitrogen into adjacent forested stream buffers. However, the width of their study buffers (45 meters) appeared to be sufficient to capture most of this exported nitrate, particularly during the growing season. A recent literature review noted that sediment transfer to streams is the most prevalent water quality issue associated with forest harvesting (Shah et al. 2022). Phosphorus is commonly attached to the sediment. Leaving vegetation buffers can reduce the amount of sediment, nitrate, and phosphorus moving off harvested areas.

In Minnesota, BMPs have been developed by the Minnesota Forest Resources Council to protect water resources (MFRC 2012). For harvests occurring on state lands (e.g., within state forests), these site-level BMPs/guidelines (e.g., leaving uncut buffers along streams) are required. On other lands (county or private forests), these BMPs are encouraged but voluntary, and logger/landowner education is important for BMP implementation.

Forestland along Lake Superior

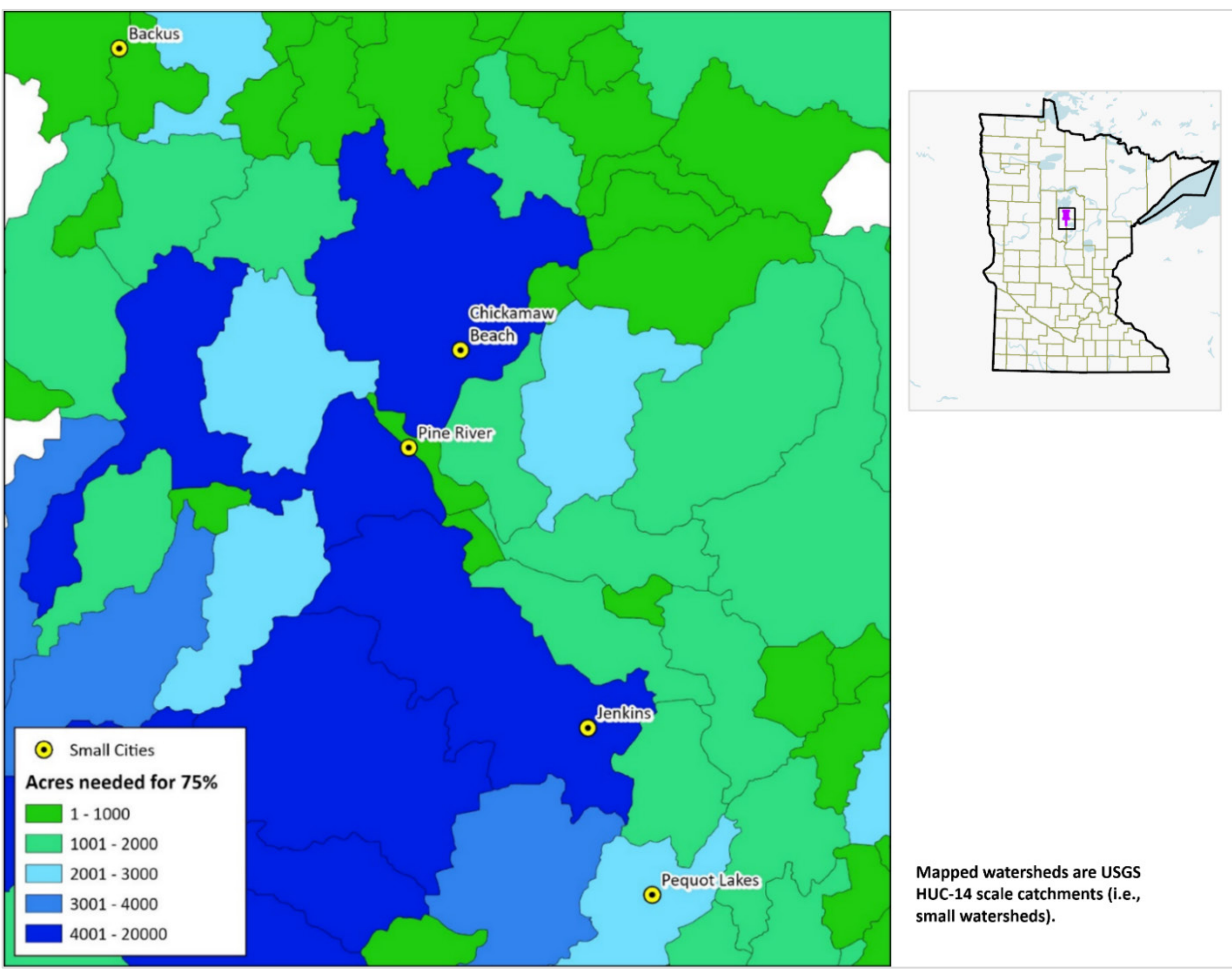
In 2000, the Minnesota Forest Resources Council instituted a forest harvest BMP monitoring program, assessing practices on state, county, and private lands; the council modified it in 2014 to provide results by HUC-8 watersheds. Individual HUC-8-scale watersheds are analyzed on a rotating basis, and the first statewide watershed-based assessment was completed in 2018. A second round is planned for completion in 2025. DNR published a report on the findings of compliance and/or adoption by HUC-8 watershed in 2021. Yearly reports are available on the Minnesota Forest Resources Council website. Results are used to determine the educational target audiences and training needs for harvesters. In late 2025, the Minnesota Forest Resources Council released *Voluntary Site-Level Forest Management Guidelines*, a revised version of the 2012 guidelines.

Trends in forest harvest and forested acre coverage are of interest for helping determine how forest management could affect nutrient movement to water resources. Recent harvesting trends in Minnesota indicate increasing harvest on private lands relative to public lands, although most harvest still comes from public lands (Bowe et al. 2025). A slight increase also occurred in state-harvested lands, suggesting county-owned and/or federally owned lands are being harvested less (Bowe et al. 2025). Consequently, educating private landowners on the use of forest-harvesting BMPs is increasingly important.

Forest preservation and restoration

Forest lands provide definite water quality benefits to Minnesota's inland lakes. A DNR study on watershed forest cover and lake water quality health found that lakes are well-protected from water quality degradation if 75% of the lake watershed (lakeshed) is forested (Cross and Jacobson 2013). Some WRAPS documents have listed working toward achieving 75% lakeshed forest cover in the protection strategies; the implementation of additional forest lands or protecting existing forest lands is especially important for lakes with cisco (*Coregonus artedi*) populations (MCCS 2025). The primary focus is on limiting phosphorus input to lakes to minimize algae growth and protect the dissolved oxygen needed by aquatic life (Fang et al. 2010). The DNR has produced a GIS layer (HUC-14 scale) that serves as a protection tool to assist water resource managers by showing the forested acres needed for each watershed catchment to achieve a 75% forest cover across Minnesota. An example of this mapping tool for one small part of central Minnesota is shown in Figure 5-12.

Figure 5-12. A DNR GIS map showing the forested acres needed to reach a goal of 75% forest coverage for lake health benefits for the area between Pequot Lakes and Backus in north-central Minnesota.



A substantial amount of forest land in Minnesota is privately owned and, therefore, plays an important role in preserving water quality. The Sustainable Forest Incentive Act was developed to help achieve the goal of maintaining forested lands. The state pays the landowner per acre enrolled in the program to incentivize keeping forest lands undeveloped, with various options of enrollment period duration available. Nonstate forest protection programs exist but are not documented here.

Peatland management

Northern Minnesota has vast areas of peatlands formed by decaying plant material under saturated conditions, creating deep layers of organic soils. In these peatlands, often classified as bogs, fens, or wooded swamps, the water table lies just inches below the ground surface. Northern Minnesota has, fortunately, retained the great majority of its original natural wetlands. However, in the early 1900s, peatlands were commonly trenched in major efforts to drain them for farming. These ditches generally did not create farmable land, but they did, and still do, function to drain some of the water from the peatlands. Downstream effects from historically drained peatlands include greater peak flows in downstream channels, which lead to altered hydrology, streambank erosion, stream habitat loss, and the export of phosphorus, dissolved organic carbon, and methylmercury.

Peatland restoration by blocking or filling ditches to restore the original hydrology can lead to multiple benefits, including improved water quality and water storage, as well as carbon sequestration, improved plant ecology, and expanded wildlife habitat. Peatland initiatives are described by BWSR at Peatlands – A Restorable, Carbon-Rich Resource and by DNR at For the sake of peat: Peatland Resilience Initiative in Minnesota.

Forestland summary

Preserving forestland, restoring peatland, and harvesting timber with care for water quality are all important for minimizing nutrient losses to waters in forested areas. Comprehensive local watershed planning through WRAPS Updates and 1W1P should continue and increase attention to these practices. State programs, such as the Sustainable Forest Incentive Act and the Minnesota Forest Resources Council BMP monitoring program, should continue and expand to protect more forestland.

5.5.4 Erosion of streambanks and gully systems

A substantial body of research has established that streambank erosion can be a significant source of nutrients. Most studies found in the literature have examined individual streams or small watersheds, finding that phosphorus loads from streambank erosion ranged widely, from 6% to 93% of total stream phosphorus loads (details and references provided in DNR [2025b], Appendix 5-5). Erosion from streambanks, bluffs, ravines, and gullies was also identified in Chapter 2 as a substantial source of phosphorus to rivers and streams, estimated to be at least 17% of phosphorus loads in the Mississippi River Basin. A study in Iowa estimated the statewide contribution of stream channel sources to the TP riverine export at 31% (Schilling et al. 2022), and a study in the Le Sueur River in Minnesota found a total of 23% of phosphorus derived from a combination of streambanks, bluffs, and ravines (Baker 2018).

Recognizing the importance of this phosphorus source to local and downstream waters, the 2025 NRS includes an expanded discussion on this topic. The full report by DNR can be found in its entirety in Appendix 5-5, with a summary included below.

Background

Stream processes drive the release, storage, and processing of nutrients. Their relationships to water quality, watershed hydrology, and ecology are complex.

One of the main characteristics of a stable stream channel is its lateral connectivity to the floodplain. Floodplains are relatively flat areas adjacent to the stream channel that are formed through erosional and depositional processes. In a stable stream system, lateral connectivity means that any floods greater than the effective discharge of a stream channel will access the floodplain. Floodplains serve multiple functions for stream stability, nitrogen and phosphorus cycling, hydrology and hydraulics, and ecology. During floods, continuous, high-capacity floodplains allow high flows to spread out across the stream's valley, reducing the erosive force of the flows on the channel bed and banks.

Incised channels are the predominant form of unstable channels in Minnesota. These are streams that have cut into their beds and no longer reach the floodplain at effective discharge flows. As the degree of incision (i.e., the bank-height ratio) increases, the relative velocities and shear stresses on the channel during flood events increase, resulting in higher streambank erosion and less removal of nitrogen and phosphorus in the water.

Many factors can lead to channel instability. Altered hydrology (changes to the natural magnitude, duration, or frequency of hydrological events) is one of the main drivers of instability in Minnesota streams. Altered hydrology results from several activities, including draining wetlands and land areas, adding impervious surfaces in urban areas, and denuding forests or grasslands of vegetation. Another primary cause of channel instability is the direct alteration of channel form through physically ditching and/or realigning streams, building dams, adding road crossings, or allowing cattle in streams.


Streambank erosion in the Red River Basin

When a stream channel becomes destabilized in response to a disturbance, a channel evolution process is often initiated. Channel evolution is a series of sequential changes in the width-to-depth ratio and floodplain connectivity, resulting in increased erosion and deposition rates as the stream moves towards developing a new stable form, typically at a new elevation.

A primary consequence of channel instability that affects the ecological health of the system, as well as receiving waters, is the increased rate of bed and bank erosion, resulting in higher sediment and nutrient export. Changes that occur when a channel becomes destabilized will continue until a new equilibrium is reached. Hence, implementation actions that don't address restoring a stable channel form will have a limited ability to achieve major reductions in sediment and, therefore, nutrient export.

Strategies to reduce in-channel sources

Many methods and strategies are used to address excess nutrients derived from in-channel sources, such as streambank and gully erosion. As with any approach, there are tradeoffs to consider for each strategy. The eight ways nutrient losses from streambank and gully erosion can potentially be reduced are:

- **Off-channel water storage**. Collect water on the landscape using practices such as in-field drainage management, water and sediment control basins, cover crops, off-channel impoundments, and constructed wetlands.

- **On-channel water storage**. Directly place a structure to hold back water on a stream or river, using practices such as small and large impoundments and dams, undersized culverts, and ditch plugs. (Note: this practice can have unintended consequences and has limited situations where it should be used.)
- **Bank stabilization or protection**. Prevent erosion of streambanks using methods such as rip rap, toe wood sod mats, revetments, re-sloping of banks, vegetated reinforced soil slopes, and other similar strategies.
- **Buffers**. Use perennial vegetation—particularly deep-rooted native plants, shrubs, and trees—to maintain long-term channel stability by preserving streambank structure and reducing near-bank shear stress. Minnesota's Buffer Law requires perennial vegetative buffers of up to 50 feet wide along lakes, rivers, and streams and buffers of 16.5 feet along ditches.
- **Two-stage ditch**. Create a small floodplain bench in an existing or new ditch by either pulling back and re-sloping the bank or physically removing the excess sediment, with the intended purposes of slowing flows, depositing sediment, re-establishing nutrient uptake, and stabilizing side slopes.
- **Near-channel gully or ravine stabilization**. Reduce erosion in the channel by creating a pond, wetland, or water and sediment control basin at the top of the forming gully to retain runoff and allow it to be slowly released. Water drop structures and grade control structures are also commonly used as part of ravine stabilization.
- **Grade-control structures**. These natural or man-made structures regulate the elevation and slope of the streambed, often aiming to reconnect the channel to its abandoned floodplain. They are typically placed in the shallowest point on the stream profile and help dissipate stream energy by regulating flow and creating pools upstream to slow velocities.
- **Stream channel restoration**. Physically restore a stable form to the channel and floodplain within the current constraints of the landscape to achieve the erosion and deposition rates, nutrient processing, hydrology, and biological functions that are similar to those in unaltered systems.

All BMPs, no matter their benefits or limitations, require effective targeting, prioritization, project-level scaling, and proper design and construction. A project will fail to meet its intended goals if it is not targeted or is poorly constructed. Understanding the underlying processes that drive channel instability can provide insight into which method to employ and where to place it.

Challenges, limitations, and tradeoffs exist with all the above practices. While channel restoration is a systemic approach that has the greatest potential for reducing nutrients and sediment from bank erosion, a multifaceted strategy is most effective for addressing all watershed sources of nutrients. Combining approaches can be effective when the strategies work together. For example, water storage projects that process nutrients and help to stabilize the hydrology of a watershed will have the most impact when paired with efforts that restore stream channels to a stable form that is connected to the floodplain.

All BMPs can have feasibility constraints related to scalability. Cost-benefit analyses are useful for project planning at the watershed scale. Costs should include planning, permitting, design, construction, nutrient removal potential and/or prevention, ongoing nutrient processing, and long-term maintenance. Consideration should also be given to auxiliary benefits, such as habitat and connectivity enhancement.

Roadmap to future steps for reducing streambank erosion

To achieve the final in-state and downstream goals for phosphorus, adding various practices to reduce streambank and gully erosion will be needed. Some of this work can be facilitated through Minnesota's Water Management Framework, along with water storage grants provided through BWSR.

Because the sediment reduction goals around the state are so closely linked to reducing streambank and gully erosion, both local sediment TMDLs and large-scale sediment reduction strategies will be important drivers in reducing this source of phosphorus around the state. Locating stream restoration projects near facilities like confined animal operations may also be a technique to help stack practices to address multiple nutrient needs at once.

5.6 NRS support documents

- Appendix 5-1: Cropland Practices Science Assessment for Minnesota's Nutrient Reduction Strategy: Part 1 Nitrogen.
- Appendix 5-2: Cropland Practices Science Assessment for Minnesota's Nutrient Reduction Strategy: Part 2 Phosphorus.
- Appendix 5-3: Agricultural Nutrient Balance in Minnesota Watersheds: A Spatial Framework for Estimating the Contribution of Nitrogen and Phosphorus from Livestock Manure and Commercial Fertilizer.
- Appendix 5-4: Conservation Practice Adoption Trends and Programs.
- Appendix 5-5: Nutrient Reduction Strategies for Stream and Gully Systems.

Chapter 6
Watershed Framework for Addressing Nutrients

Key Messages

- Minnesota developed the Minnesota Water Management Framework at the major watershed (HUC-8) scale, which includes monitoring and assessment of waters, strategies to address both the restoration and protection of water quality, detailed plans for actions to address these concerns, and funding to implement these actions. These items are complete or in development for all the state's major watersheds.
- Minnesota works with statewide and regional programs that provide financial and technical support to implement practices addressing larger-scale nutrient issues that complement efforts of the Minnesota Watershed Management Framework.
- The NRS is a foundational document that will continue to support the Minnesota Water Management Framework through statewide-level nutrient monitoring, goal setting, and tracking of implementation efforts.
- Continual updates are needed to the program guidance for WRAPS, GRAPS, and watershed plans to better characterize how to address downstream nutrient impacts in large river systems.
- Synergies between multiple tiers of watershed work and programs at different scales can create opportunities to meet multiple goals with similar actions.
- Local implementers and their state, federal, and other partners will need to collaborate regionally to successfully deploy larger-scale strategies that address nutrients broadly and significantly reduce nutrient loss. Local practitioners need to be more informed about nutrient impacts, receive training and help with watershed tools and models, and increase staff capacity to make progress on NRS goals and watershed monitoring, analysis, planning, and implementation.
- Based on the findings, the recommended actions include investing in data for adaptive management and tracking, integrating nutrient reduction strategies across various scales, scaling up the adoption of practices to achieve nutrient reduction, and keeping the NRS in front of practitioners and programs.

6.1 Introduction

This chapter outlines Minnesota's watershed-based approach to addressing the impacts of nutrients on water quality. Minnesota agencies, along with partners from the public, private, and nonprofit sectors, have invested significantly in the watershed approach, adapting their efforts over time based on new data, programs, policies, and practices.

This chapter provides a road map to water management in Minnesota, enabling NRS partners to align their nutrient management strategies and actions with NRS goals. It focuses on:

- Improving the existing efforts to ensure they align with the NRS's goals and aims.

- Determining the capacity and resources needed to support watershed management contributions to nutrient reduction goals at multiple scales.
- Identifying the short- and long-term steps needed to meet NRS goals.

6.2 Watershed-scale efforts affecting nutrients

Many statewide and regional programs provide financial and technical support to help reduce nonpoint source pollution. The approaches and programs described in this section, such as the Minnesota Water Management Framework and local watershed planning efforts, can help guide planning and implementation efforts to address larger-scale nutrient issues.

6.2.1 Minnesota's watershed approach

Since 2006, Minnesota has been transitioning many of its core water management functions to be carried out statewide on a major watershed (HUC-8) scale. The Clean Water Legacy Act (CWLA; Minn. Stat. 114D, 2006) is the policy legislation that describes the watershed approach. The passage of the CWLLA (Minnesota Constitution, Article XI, Sec. 15, 2008) catalyzed the transition to the watershed approach, providing funding to accelerate and broaden the scope and depth of monitoring, strategy development, planning, and implementation.

A brief history of Minnesota's water management

Due to scarce funding, surface and groundwater monitoring before 2006 was primarily accomplished through ephemeral monitoring networks in response to specific needs or requests. Dedicated monitoring networks—such as those established by the Met Council and watershed management organizations in the Twin Cities metropolitan ("metro") areas and watershed districts outside the metro—were not established statewide.

The 1955 Minnesota Watershed Act allowed for the creation of watershed districts and required each district to create a watershed management plan. However, because watershed districts are only established via citizen petition, much of Minnesota did not have watershed planning or monitoring.

County-based local water planning began in the 1980s, but the staff lacked the comprehensive water quality datasets needed to inform planning prioritization. Implementation efforts were generally a series of "one-off" projects driven by landowner requests for help rather than a watershed view of natural resource priorities and needs.

Also in the 1980s, metro watershed management organizations were established and began managing water on a watershed scale.

In the 1990s and early 2000s, the state developed basin plans for Minnesota's major basins (i.e., four-digit hydrologic unit code [HUC-4]). The MPCA was responsible for gathering data and feedback from stakeholders to inform these high-level plans, which were used primarily to coordinate efforts within regional areas of Minnesota. Also, during this same period, MPCA began publishing the CWA Section 303(d) impaired waters list and completed a few early TMDL reports. Additionally, the Environmental Quality Board, which coordinates across many state agencies on environmental issues, was required to develop a 10-year water plan for the entire state of Minnesota, starting with the first plan published in 1991. The most recent plan was published in 2020.

In 2002, a report from the Office of the Legislative Auditor found that Minnesota was making insufficient progress in fulfilling its responsibilities under the CWA, specifically in developing TMDLs. The implications came to the forefront when a 2005 lawsuit threatened to halt development in a rapidly expanding community because the lack of a TMDL meant the MPCA could not issue a permit to expand a wastewater treatment plant. These events brought together a broad partnership of environmental nongovernmental organizations (NGOs), developers, state and local agencies, and others who advocated for the CWLA and the CWLLA in the mid-2000s.

The CWLA was passed in 2006 and established the watershed framework for the state to conduct systematic monitoring, assessment, and strategy development. Soon after, the Local Government Water Roundtable—with members representing the Association of Minnesota Counties, Minnesota Watersheds (formerly Minnesota Association of Watershed Districts), and the Minnesota Association of SWCDs—recommended a transition to local planning on a watershed basis and noncompetitive funding to support implementing these watershed plans.

The Minnesota Water Management Framework

Minnesota's state water agencies—the Met Council, BWSR, MDA, MDH, DNR, MPCA, and MN Public Facilities Authority—developed the *Minnesota Water Management Framework* over the last two decades to clarify roles and enhance coordination. The framework defines five categories of work included in an adaptive management approach. By collaborating and coordinating with each other and with other partners, the agencies aim to improve the effectiveness and efficiency of water management while empowering local action for clean and sustainable water statewide. As illustrated in Figure 6-1, the Minnesota Water Management Framework includes five main steps:

1. **Monitoring, assessment, and characterization:** State and local agencies monitor and assess the condition of surface water, groundwater, and other resources.
2. **Problem investigation and applied research:** Agencies create information products to support research and planning.
3. **Restoration and protection strategy development:** State and local agencies develop WRAPS and GRAPS.
4. **Comprehensive watershed management planning:** Local partners commit to action based on WRAPS and GRAPS through the 1W1P program.
5. **Implementation:** With state support, local partners address sources of point and nonpoint source pollution.

Figure 6-1. Illustration of the Minnesota Water Management Framework five-step process.

Working at the watershed scale

A key element of the CWLA was the emphasis on the major watershed (HUC-8) scale (Figure 6-2). This scale enables a meaningful (yet admittedly still high-level) examination of watershed data and priorities that would have been too cumbersome at the major basin scale (i.e., HUC-4). This scale also allows the MPCA to develop a manageable number (~80) of watershed reports and achieve statewide coverage for data collection and planning (a smaller scale would require thousands of reports and plans to cover the state). The MPCA selected this scale to develop a predictable statewide schedule for surface water monitoring and WRAPS (and WRAPS Updates). Subsequently, this scale was adopted by other agencies to help organize data, strategies, planning, and implementation partnerships for other statewide efforts, including GRAPS and 1W1P.

Figure 6-2. Major basins (HUC-4) and major watersheds (HUC-8).

Although HUC-8 is the best scale for planning, it is not the ideal scale for implementing BMPs. Most nonpoint sources of pollution and management occur at a 16-digit hydrologic unit code (HUC-16) or smaller scale, which equates to the size of an agricultural field or a small urban neighborhood. This scale enables agencies to use hydrologic pathways and processes (e.g., variable source areas [Brooks et al. 2013]) to explain the dynamics of pollutant transport, which allows modeling tools, such as the Agriculture Conservation Planning Framework (ACPF) and the Prioritize, Target, Measure Application (PTMApp), to help focus BMP placement.

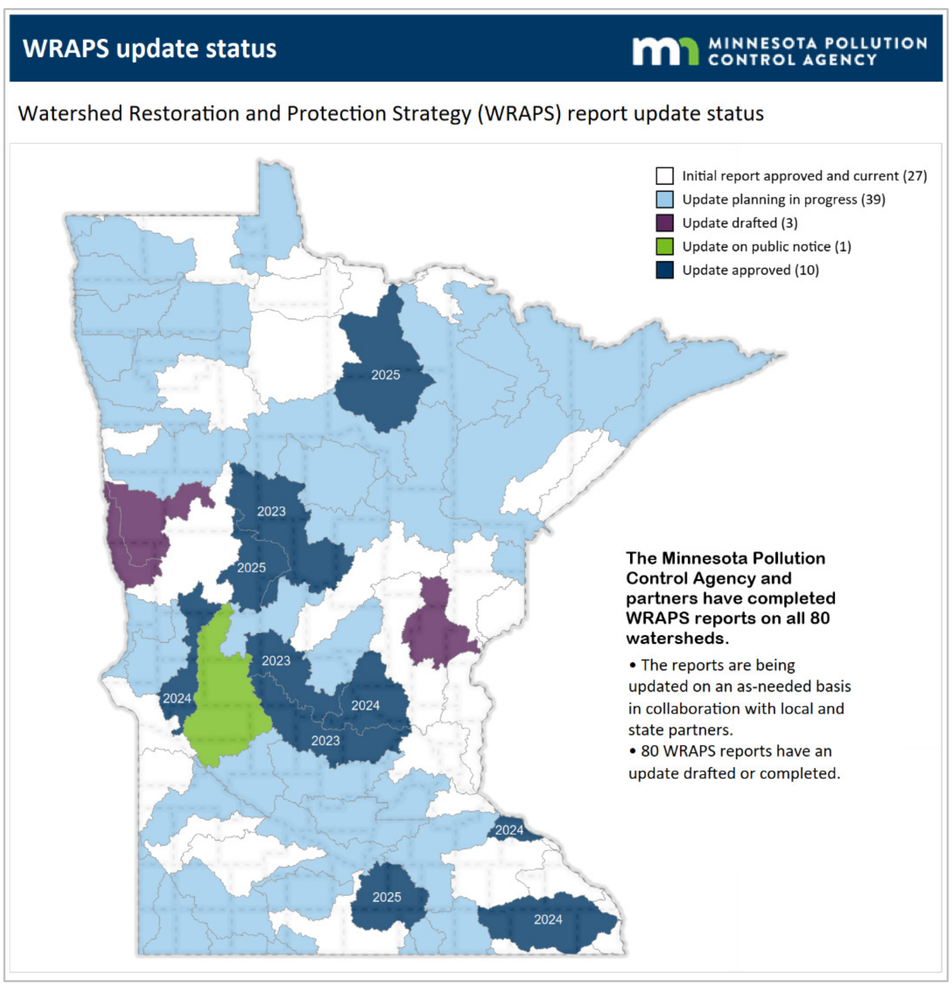
6.2.2 Minnesota's Water Strategies and Planning

Minnesota agencies and partners synthesize and "package" information from data collection and analysis, assessments, models, tools, and research results to develop strategy reports at the major watershed scale for surface water (WRAPS and WRAPS Updates) and groundwater (GRAPS). These reports are intended to help local partnerships set goals and develop planning strategies.

Watershed restoration and protection strategies

The CWLA requires that the MPCA develop WRAPS across the state; the MPCA completed WRAPS reports between 2013 and 2023 for all 80 of the state's watersheds. WRAPS reports summarize water quality data, stressor identification results, TMDLs, and goals for protecting and restoring watersheds. The MPCA finalized nine WRAPS Updates from 2023 to 2025, with plans to update the remaining WRAPS documents in the next 10 years (Figure 6-3).

Figure 6-3. Interactive status map of WRAPS.

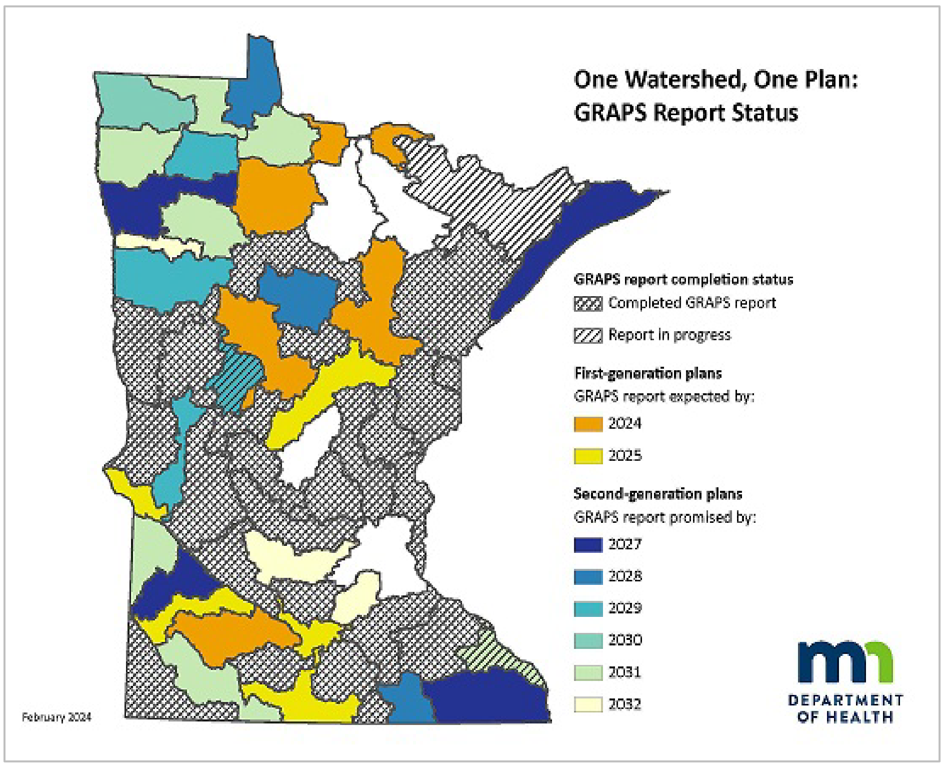


The purpose of updating the existing WRAPS is to compare, contrast, and summarize water quality conditions from the previous 10 years with current information, perform more detailed investigations of particular water bodies or areas of a given watershed as desired locally, and then update the strategies necessary to restore and/or protect surface water quality in the watershed. MPCA's guidance for WRAPS Updates includes prompts for WRAPS Updates to strengthen linkages to the nutrient reduction goals and strategies contained in the NRS.

Groundwater restoration and protection strategies

The MDH compiles GRAPS reports, which summarize available state groundwater and drinking water information. These reports identify groundwater and drinking water issues and recommend implementation strategies to address them. They are geographically organized according to planning boundaries defined by the 1W1P program (Figure 6-4).

Figure 6-4. Status map of the GRAPS development process.

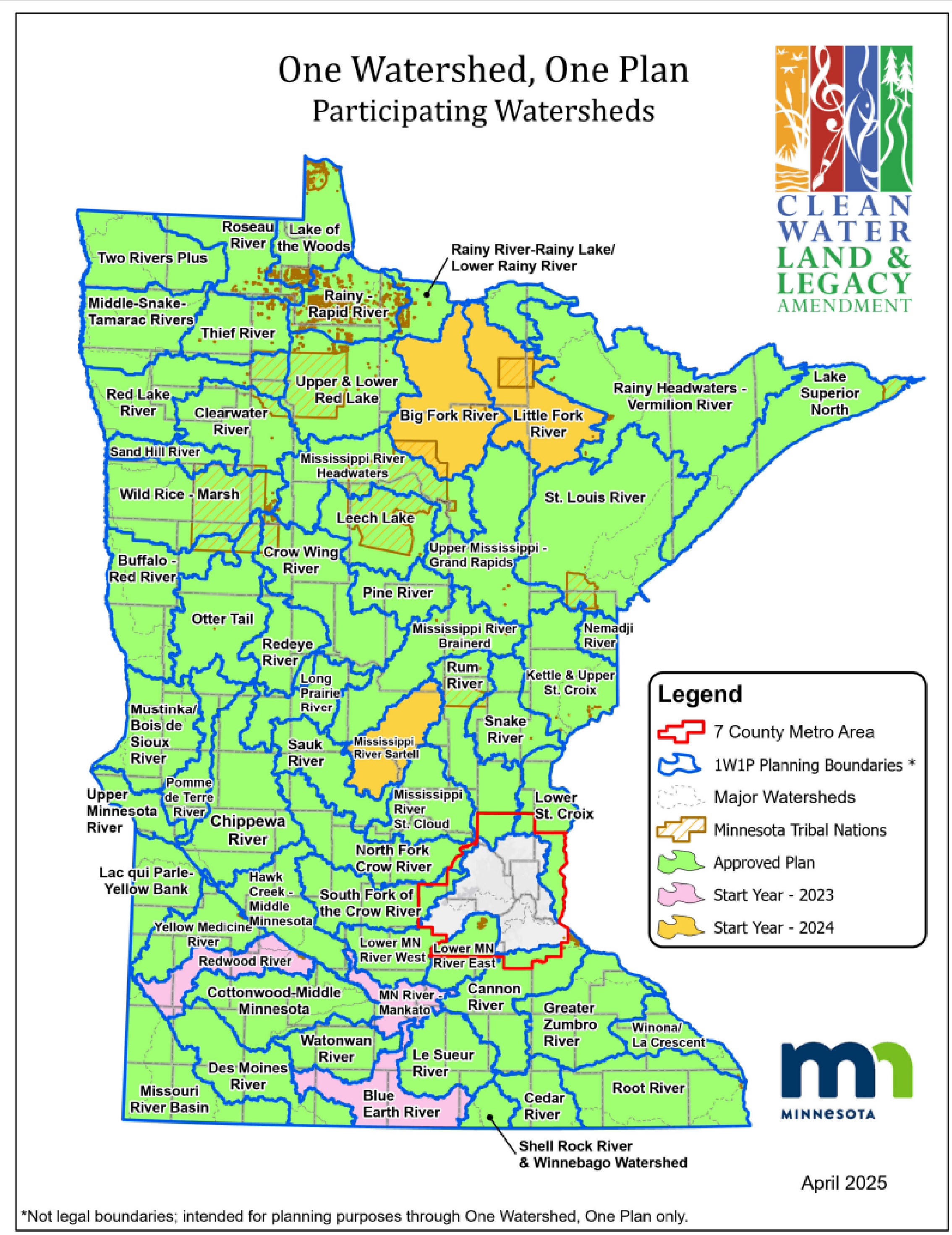


One Watershed, One Plan – comprehensive watershed management planning

Local partners commit to action through the Minnesota BWSR's 1W1P program, which connects local values and priorities with state data and other information. The 1W1P program supports government partnerships in developing prioritized, targeted, and measurable implementation plans. The key principles are to conduct planning at approximately the major watershed scale and align local plans with state strategies. This type of watershed management structure, with high-level goals and local priorities and targeting, has been identified as an efficient delivery mechanism to encourage adoption (Power et al. 2022; Rao and Power 2019).

Plans created through the 1W1P program are referred to as CWMPs and are described in Minn. Stat. 103B.801. The statute lists specific items that each plan must address, including "surface water and ground water quality protection, restoration, and improvement, including prevention of erosion and soil transport into surface water systems." The 1W1P program goals and purpose help establish a planning framework that guides efforts toward meeting NRS goals and milestones. As of December 2025, CWMPs exist for 54 of 60 planning boundaries (Figure 6-5). The boundaries are based on HUC-8 watersheds with some variations, such as incorporating partial watersheds near the state line and lumping or splitting watersheds to reduce the overall number of plans for some local governments. These plans help guide the use of dollars from various funding sources, including Clean Water Funds awarded via competitive and formula-based processes.

Figure 6-5. Status of participating 1W1P watersheds and approved plans.



Transitioning from county-based to watershed-based planning and implementation has required local governments and other partners to invest in building and maintaining new relationships, which encourages important upstream/downstream discussions about overall watershed priorities based on the best available science.

The strong scientific foundation built in the previous framework steps enables partnerships, with input from the community, to create plans that prioritize specific issues and locations, set measurable goals, and target actions based on what's known about the watershed. These comprehensive natural resource plans address a range of local issues, including surface water and groundwater resources.

Metro watershed management and groundwater planning

Since 1987, watershed management organizations within the Twin Cities Metro Area have been developing watershed management and county groundwater plans. The seven-county Twin Cities Metro Area includes 14 watershed districts and 19 watershed management organizations. Each must develop a watershed management plan to protect water resources in accordance with Minn. Stat. 103B.231. Metro municipalities are also required to develop and implement local water management plans. BWSR developed the requirements for metro watershed management plans, outlined in Minnesota Administrative Rule 8410, and is also responsible for approving these locally adopted plans. Additionally, counties within the seven-county Twin Cities Metro Area may develop groundwater plans in accordance with Minn. Stat. 103B.255.

6.2.3 State programs addressing nutrients

The State of Minnesota has supported several programs through the General Fund and the CWLLA that address nutrients directly and indirectly at various scales. Many of these state agency programs, described below, work directly with local watershed partners to implement actions that help reduce nutrient impacts on both surface water and groundwater sources through grants, incentives, certification programs, and loans.

Minnesota Department of Agriculture

Root River Field to Stream Partnership

The Root River Field to Stream Partnership is a long-term, multiple-scale study in southeast Minnesota with the objective of better understanding the relationship between agriculture and water quality. Led by the MDA, the partnership has been active since 2010. The study partners combine rigorous data collection, strong personal relationship-building, and real-world conservation action. This project focuses on three distinct subwatersheds with different landscape features, soils, farming systems, and nutrient loss pathways. It uses edge-of-field and in-stream monitoring to characterize water quality in three study areas within the Root River watershed. Through outreach activities and one-on-one meetings, the results are discussed with farmers, landowners, fertilizer dealers, water managers, and community leaders to promote an advanced level of conservation planning and delivery. The Root River Field to Stream Partnership seeks to determine whether changes being made on the land are reflected in the water quality benefits. To achieve this, the partners conduct intensive surface and groundwater monitoring at multiple scales to assess nutrient and sediment levels and combine this data with information on agricultural conservation practice implementation.

Soil Health Financial Assistance Program

The MDA Soil Health Financial Assistance grant program provides cost-share for purchasing and retrofitting the expensive soil health equipment required when adopting soil health practices.

Agricultural BMP Loan Program

The AgBMP Loan Program is a water quality program that provides low-interest loans to farmers, rural landowners, and agricultural supply businesses. The purpose is to encourage operators to use agricultural BMPs to prevent or reduce runoff from feedlots, farm fields, and other sites with pollution problems identified in comprehensive local water plans. The AgBMP loan program provides loans for projects that reduce existing water quality problems caused by nonpoint source pollution. The program provides needed funding for local implementation of clean water practices at a very low cost. Its structure is unique and not duplicated by other programs or funding sources.

Discovery Farms Program – Minnesota Agricultural Water Resource Center

Discovery Farms Minnesota is a farmer-led initiative to collect field-scale water quality information from various farming systems across Minnesota under real-world conditions. The goal is to provide practical, credible, site-specific information to enable better farm management. The program is designed to collect accurate measurements of sediment, nitrogen, and phosphorus movement across the soil surface and through subsurface drainage tiles, thereby improving the understanding of the relationship between agricultural management and water quality. This effort, which includes several core farms and other demonstration and special research projects in the state, receives support from MDA and UMN Extension.

Minnesota Agricultural Water Quality Certification Program

MAWQCP is a voluntary program in which farmers and agricultural landowners take the lead in implementing conservation practices that protect water quality. Those who implement and maintain approved farm management practices are certified. Certified producers receive:

- **Regulatory certainty for 10 years**. Certified producers are deemed to be in compliance with any new water quality rules or laws that take effect during the certification period.
- **Recognition**. Certified producers may use their status to promote their business as protective of water quality.
- **Priority for technical assistance**. Producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality.

To learn more about specific certified farms and how they are reducing nutrients through management and BMP adoption, visit the MAWQCP story map.

Family Focuses on Nutrient Management

Jerry and Nancy Ackermann were among the first farmers to enroll in MAWQCP in 2016. They farm 1,200 acres in Jackson County, raising corn, soybean, and alfalfa crops. Nutrient management is a key part of their operation, and they employ various practices to optimize the use of nutrients for crop production while minimizing environmental impacts. Over the past 20 years, they have transitioned from conventional tillage to strip-till and no-till practices and incorporated cover crops. Using cover crops has enabled them to reduce their herbicide and fertilizer use while improving soil health. They further reduce their fertilizer application by using variable-rate technology and grid sampling for all acres on a 4-year rotation, ensuring they apply only the needed nutrients. They also have alternative tile intakes that reduce sediment and nutrient loss from the fields and filter strips that prevent nutrient runoff and protect water quality.

Minnesota Board of Water and Soil Resources

Multipurpose Drainage Water Management Program

The competitive Multipurpose Drainage Water Management grant program funds the drainage management practices that target critical pollution source areas to reduce erosion and sedimentation, reduce peak flows and flooding, and improve water quality while protecting drainage system efficiency and reducing drainage system maintenance for priority Chapter 103E drainage systems (established systems with priority sediment and/or water quality concerns). Practices include eligible on-field, on-farm, and on-drainage system practices within the benefited area or the watershed of a priority Chapter 103E drainage system. Eligible practices must help mitigate the impacts of altered hydrology, sedimentation, or nutrient loadings. Practices that may be implemented through this program to help reduce nutrient loss at the watershed level include wetlands restoration, grassed waterways, saturated buffers, and drainage water management structures.

Water Quality and Storage Grant Program

The Minnesota Legislature passed a law in 2021 requiring the BWSR to develop a program that provides financial assistance to local government units to control water rates and/or volumes, thereby protecting infrastructure, improving water quality and the related public benefits, and mitigating climate change impacts. Projects funded by the Water Quality and Storage Program improve conditions in areas with flooding, water quality issues, or climate change vulnerabilities. Water storage practices include retention structures and basins; soil and substrate infiltration; wetland restoration, creation, or enhancement; channel restoration or enhancement; and floodplain restoration or enhancement. This program is offered through BWSR and supported by a combination of state funds and NRCS RCPP grant funds.

Projects and Practices Grant Program

The Clean Water Fund-supported Projects and Practices competitive grant program invests in on-the-ground projects and practices that protect or restore water quality in lakes, rivers, or streams or protect groundwater or drinking water. Examples include stormwater practices, agricultural conservation, livestock waste management, lakeshore and stream bank stabilization, stream restoration, and SSTS upgrades.

Watershed-Based Implementation Funding Program

The Clean Water Fund-supported Watershed-Based Implementation Funding grant program offers an alternative to the traditional project-by-project competitive grant processes often used to fund water quality improvement projects. This funding enables local governments to collaborate on pursuing timely solutions that address a watershed's highest priority needs. The approach depends on CWMPs developed by local partnerships under the 1W1P program or the Metropolitan Surface Water or Groundwater Management Framework (Minn. Stat. 103B.201-255) to ensure that actions are prioritized, targeted, and measurable.

Advancing Soil Health in the Red River Valley

The Watershed-Based Implementation Funding Program has helped accelerate the adoption of practices on the landscape based on priorities developed through CWMPs. The article "Kittson SWCD grows soil health program via incentives, outreach," featured in the BWSR's March 2023 *Snapshot* newsletter, highlights efforts that benefit soil health and reduce soil erosion while also addressing nutrient issues. Producers received technical and financial assistance to implement a suite of practices that included no-till, strip-till, and cover crops.

Soil health grant programs

BWSR offers various soil health programs supported by state funds. Programs support implementing on-the-ground practices (Soil Health Cost Share grant program) and increasing staff capacity (Soil Health Staffing grant program) for soil health assistance through local governments.

Minnesota Pollution Control Agency

Clean Water Partnership loans

The Clean Water Partnership program offers low-interest loans to local units of government for implementing nonpoint source BMPs and other activities that target the restoration and protection of water resources such as lakes, streams, or groundwater aquifers. Funds can be used for nonpoint source pollution BMPs, including wellhead protection, inflow and infiltration (residential laterals), green infrastructure, SSTS upgrades/replacements, and wetland or stream restorations. About $4 million per year is loaned through the program.

6.2.4 Federal watershed programs addressing nutrients in Minnesota

Minnesota has a long history of working with federal partner agencies to provide financial and technical assistance, supporting actions that help meet local and state nutrient reduction goals. Funding has traditionally been made available through the EPA and the USDA NRCS and Farm Service Agency (FSA).

U.S. Environmental Protection Agency

Federal CWA Section 319 Program

The MPCA developed a CWA Section 319 Small Watersheds Focus Program in partnership with local governments to support comprehensive nonpoint source implementation on small-scale watersheds for WRAPS. Participants worked with the MPCA to develop a detailed nine-element plan following the EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*. The watersheds receive four grant awards of four years each—spanning a total of 16 years. Based on the program's principles, these funds are used to implement a series of projects outlined in the nine-element plan, provide a steady funding source, focus implementation efforts, and achieve measurable water quality improvements on a specific water body. These watershed-based plans build upon existing local water plans and state reports, such as the NRS. There were 35 watersheds selected between 2020 and 2023 for nine-element plan development (Figure 6-6). The MPCA passes approximately $2.8 million in Section 319 grants annually to local governments and organizations to implement BMPs and adopt strategies to mitigate nonpoint source pollution.

U.S. Department of Agriculture – Farm Service Agency

Conservation Reserve Enhancement Program

CREP is a part of the Conservation Reserve Program (CRP), the country's largest private-land conservation program. Administered by the FSA, CREP leverages federal and nonfederal funds to target specific state, regional, or nationally significant conservation concerns. In exchange for removing environmentally sensitive land from production and establishing permanent resource-conserving plant species, farmers and ranchers are paid an annual rental rate and receive other federal and nonfederal incentives as specified in each CREP agreement. Participation is voluntary. The contract period is typically 10–15 years for federal contracts and may involve long-term or perpetual easements with funding from the state agency that serves as the state lead partner.

An edge-of-field streambank erodes in the Red River Basin

In Minnesota, three separate CREP initiatives have been implemented since the 1990s. The BWSR is the lead state partner that works with local SWCDs and landowners to secure long-term conservation easements. The most recent CREP program focused on 54 counties in the agricultural zone of Minnesota to promote practices that reduce nutrient impacts on surface water and groundwater (Figure 6-7). The original 2014 NRS was important in identifying practices and prioritizing watersheds for this effort.

Figure 6-6. Minnesota watersheds selected for nine-element watershed plans (2020–2023).

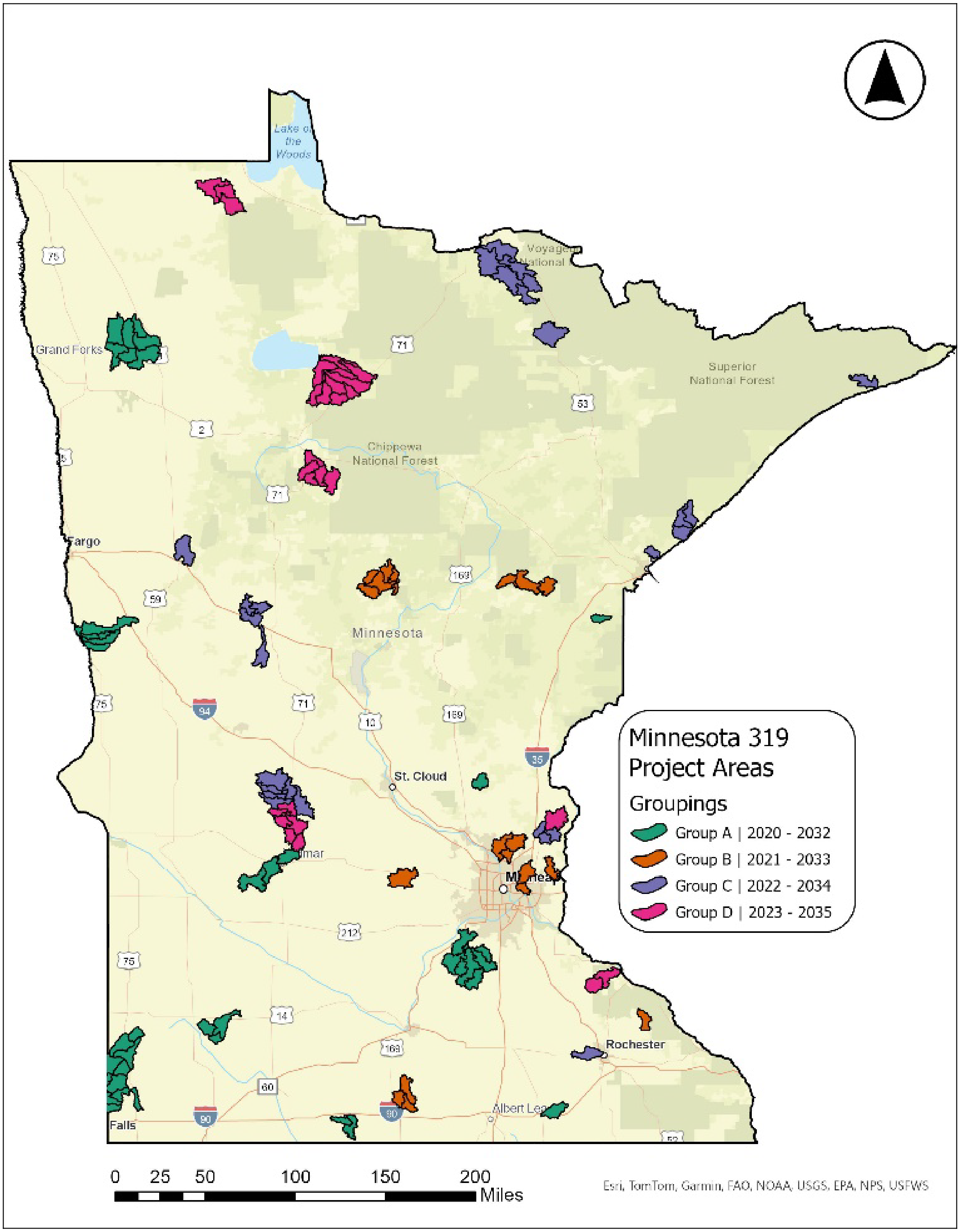
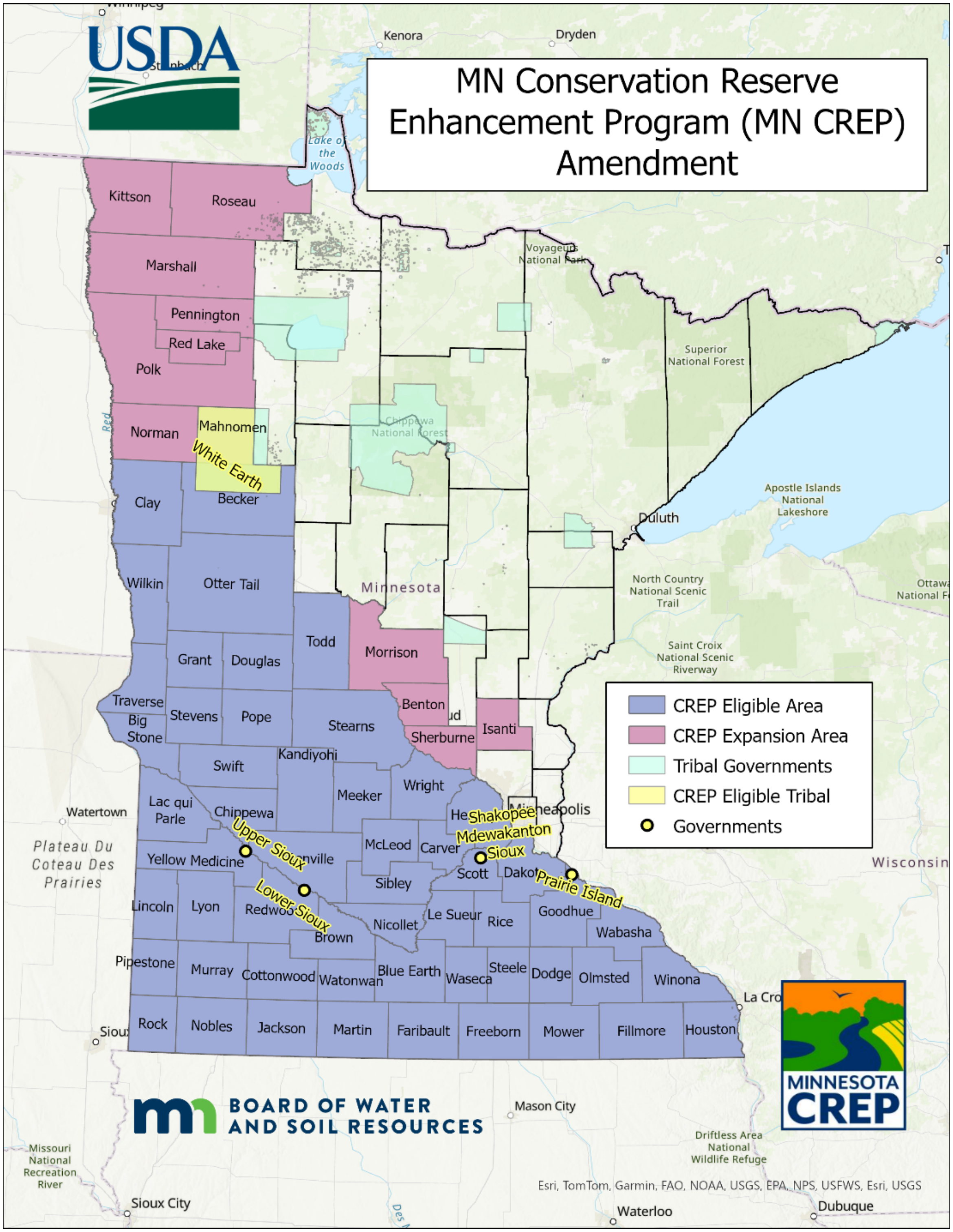


Figure 6-7. Minnesota Conservation Reserve Enhancement Program area.



CREP Linkages to the Minnesota NRS

Minnesota CREP has protected more than 35,000 acres of environmentally sensitive land since enrollment began in 2017. Minnesota CREP is a state-federal collaborative partnership that relies on local government staff and landowners to protect land via conservation easements in 54 southern and western Minnesota counties. The BWSR and the USDA FSA oversee and administer the program.

Landowners simultaneously enroll land in a 15-year federal CRP contract and a permanent state Reinvest in Minnesota Reserve program conservation easement. Landowners receive payments from both programs to restore native vegetation and wetlands on enrolled acres, maximizing the water quality and habitat benefits. The land remains privately owned and controlled.

Local SWCD staff play an essential role in the program. These professionals help guide landowners through the application process and explore the best restoration options for each unique application. So far, SWCDs have submitted more than 650 applications and provided outreach and resources to thousands of landowners.

Previous CREP programs were active in Minnesota in 1998 and 2005. Those programs focused primarily on creating wildlife habitat. The current Minnesota CREP program takes a broader approach, supporting projects such as wetlands restoration, filter strips, wellhead protection, and other conservation practices that improve water quality and enhance habitat.

U.S. Department of Agriculture – Natural Resources Conservation Service

The NRCS has a proud history of supporting Minnesota farmers, ranchers, and forest landowners by providing financial and technical assistance to protect natural resources while meeting their unique conservation needs. Since FY 2014 through the beginning of FY 2025, the NRCS has obligated over $1 billion to almost 19,000 producers across the state, averaging about 1,575 new contracts per year.

National Water Quality Initiative

The National Water Quality Initiative is a federal program designed to accelerate voluntary, on-farm conservation investments and focus water quality monitoring and assessment resources where they can deliver the greatest benefits for clean water.

Mississippi River Basin Healthy Watersheds Initiative

Launched in 2009, the 12-state Mississippi River Basin Healthy Watersheds Initiative uses several Farm Bill programs, including EQIP, to help landowners conserve America's natural resources through voluntary conservation. The initiative uses a small-watershed approach to support the 12 states' nutrient reduction strategies. Watershed partners implement "avoiding, controlling, and trapping" practices to reduce the amount of nutrients flowing from agricultural land into waterways and improve the resiliency of working lands.

Environmental Quality Incentives Program

EQIP provides technical and financial assistance to agricultural producers and forest landowners to address natural resource issues, such as water and air quality, the conservation of ground and surface water, increased soil health, reduced soil erosion and sedimentation, improved or created wildlife habitat, and mitigation against drought and increasing weather volatility. The NRCS works one-on-one with producers to develop a conservation plan outlining conservation practices and activities to help solve on-farm resource issues. Producers implement practices and activities in their conservation plan that can benefit the environment while improving their agricultural operations. EQIP helps producers make conservation work for them. Benefits include reduced contamination from agricultural sources (e.g., animal feeding operations), more efficient use of nutrients, lower input costs, reduced nonpoint source pollution, and improved soil health. These benefits can make the land more resilient to increased weather volatility (e.g., drought, flooding). Other benefits are associated with implementing climate-smart practices that improve carbon sequestration and reduce greenhouse gas emissions while building more resilient landscapes. Financial assistance for practices may be available through EQIP.

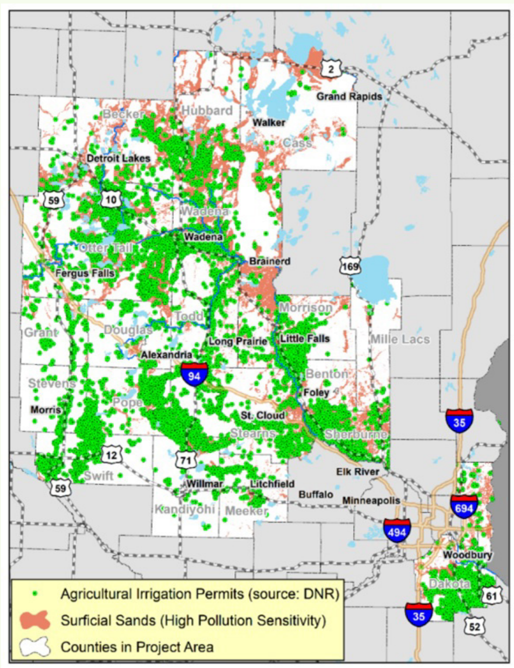
Conservation Stewardship Program

The [Conservation Stewardship Program](https://www.nrcs.usda.gov/programs-initiatives/csp-conservation-stewardship-program) (CSP) is a voluntary conservation program that encourages producers to undertake new conservation activities and improve, maintain, and better manage existing conservation activities. CSP is available on Tribal and private agricultural lands (e.g., cropland, pasture lands, rangeland, farmsteads) and nonindustrial private forest land. CSP is a working lands program that helps landowners build on existing conservation efforts while strengthening the operation. The program provides equitable access to all producers, regardless of operation size, crops produced, or geographic location.

Regional Conservation Partnership Program

The RCPP is a partner-driven approach to conservation that funds solutions to natural resource challenges on agricultural land. Through the RCPP, NRCS co-invests with partners on innovative, workable, and cost-effective conservation approaches that benefit farming, ranching, and forest operations, as well as the local economies and communities in a watershed or other geographic area. The partners develop project applications to address specific natural resource objectives in a proposed area or region. Eligible partnering organizations design, promote, implement, and evaluate the project outcomes. Once projects are selected, NRCS works with partners to set aside a certain pool of funding for an awarded project. Producers, landowners, and partners then enter into producer contracts and supplemental agreements with NRCS to carry out the agreed-on conservation activities. RCPP projects may include any combination of authorized, on-the-ground conservation activities implemented by farmers, ranchers, and forest landowners.

RCPP in Action: Implementing Innovative Irrigation Practices to Protect Groundwater Quality and Quantity in Minnesota



Irrigated lands often have coarse-textured soils where the groundwater is susceptible to nitrate contamination. The groundwater has elevated levels of nitrate in some of these areas. Most of the population in the irrigated areas obtains their drinking water from private or public groundwater wells. Groundwater withdrawals for agricultural irrigation might affect the groundwater-surface water hydrology, such as reduced streamflow.

This 5-year irrigation RCPP project, sponsored by MDA, started in 2022 with $3.5 million available from the USDA to help state and local project partners with implementation. A total of 33 partners are working toward the program goals, which include working directly with irrigators within the project area to implement conservation practices that protect groundwater, building professional capacity among SWCD and NRCS technical staff, expanding irrigation-related education activities, and quantifying the environmental, economic, and social impacts of the implemented practices. For more details, see the Minnesota Agricultural Center of Excellence Irrigation Partnerships to Protect Groundwater website. This project will generate multiple benefits, including protecting groundwater and surface water resources from nitrate contamination.

6.3 Improving watershed approaches for nutrient reduction

6.3.1 Watershed load reductions for downstream goals

To achieve downstream nutrient reduction goals, Minnesota's 2014 NRS called for partners in each HUC-8 watershed to voluntarily do their part to cumulatively achieve the goals for the Mississippi River, Red River, and Lake Superior. If a portion of each watershed's reducible or anthropogenic nutrient loads is removed, downstream nutrient goals can be met, and local waters within each HUC-8 will markedly improve.

The 2014 NRS provided limited guidance on the magnitude of load reductions needed from each HUC-8 watershed to achieve the milestone targets for downstream waters. Since the development of the 2014 NRS, Minnesota has improved monitoring and modeling information, enabling the state to develop improved estimates of nutrient load-reduction planning targets for each HUC-8 watershed outlet. The watershed load reduction planning goals were set equitably so that each HUC-8 within a major river basin would reduce a similar fraction of its reducible/anthropogenic nutrient load. These updated watershed load reduction targets are established with the assumption that load reductions from such lands as well-managed grasslands and forests will not be achieved. The updated watershed load reduction estimates show how to collectively achieve final goals at the state line rather than downstream endpoint milestone goals.

The estimated load reductions needed from each HUC-8 watershed to collectively meet Minnesota's nutrient reduction needs at the state lines are shown in Chapter 2 and Appendix 2-3. In aggregate, achieving each watershed reduction planning goal would enable Minnesota to meet the NRS goals while addressing the many nutrient reduction needs within the HUC-8 watersheds. These voluntary targets should be considered when watershed managers re-evaluate their needs, goals, priorities, and plans, as established in WRAPS products and CWMPs. The planning goals included in this document should be considered approximate because of the inherent uncertainties, complexities, and time lags with watershed modeling and monitoring.

6.3.2 Connecting the NRS, WRAPS, and CWMPs

Minnesota is unique among states because it has a systematic watershed management framework in place to support water resource management. The original NRS was important because it brought the nutrient-related data and scientific research from across the state together into one document, which now serves as a foundational information source that supports the framework. As the initial NRS was formulated in the early 2010s, very few WRAPs and no CWMPs or GRAPS were completed at that time.

The 2014 NRS has benefited the watershed approach in Minnesota in many ways by:

- **Serving as a source of scientific information**. Many WRAPS, WRAPS Updates, and CWMPs have used data and scientific information directly from the NRS and incorporated that data within the document. The NRS brings together monitoring data, watershed-modeled scenarios, nutrient reduction source assessments, and BMP science and economics.
- **Helping in setting goals**. One of the NRS's strengths is setting long-term goals for nutrient reduction, BMP adoption, and future scientific needs. The scenario analysis within the NRS helped provide a framework of the level of change needed to meet nutrient goals at the state line, which provided a vision of how setting goals at smaller watershed scales could be accomplished through the Watershed Management Framework.

- **Providing for watershed tool and model development and support**. The NRS brought together a significant amount of modeling data from the SPARROW and HSPF models to support the scientific underpinnings of the document. Through the NRS effort, advancements have been made to both the HSPF-SAM and the Watershed Pollutant Load Calculator Tool, which also support most WRAPS and WRAPS Updates and over 50% of all current CWMPs. Additionally, the NP-BMP tool (a watershed nitrogen and phosphorus reduction planning tool spreadsheet for surface water) was developed and has been enhanced and updated over time. This tool is used not only for developing economic scenarios for the NRS but also to support numerous other efforts regarding BMP economics in Minnesota.

Understanding the existing connections

To better understand the connections between the NRS, WRAPS Updates, and CWMPs, the state needs to evaluate how nutrients have been addressed in the WRAPS Update and CWMP documents. A preliminary analysis of the connections between WRAPS and the NRS was initiated in 2020, but at the time, only part of the state was covered by completed WRAPS. In 2024, the analysis was expanded to include the complete set of WRAPS for all the state's watersheds and the CWMPs completed as of June 2024. The full result of this analysis is included as Appendix 6-3. A summary of the findings includes:

- **Nutrient sources**. Previously developed WRAPS reports, WRAPS Updates, and CWMPs typically identified and prioritized the sources of nutrients. Throughout much of Minnesota, outside of the seven-county Twin Cities Metro Area, agricultural sources and pathways were the most common sources of impairment and were most frequently prioritized, with crop operations often prioritized over livestock operations. In the WRAPS and WRAPS Update reports, sources were typically quantified using the HSPF model. Sources were not often quantified in CWMPs. Most reports did not discuss source pathways in much detail. Less than one-quarter of WRAPS and WRAPS Update reports discussed sources and source pathways relative to low- or high-flow conditions, and less than 10% of WRAPS and WRAPS Update reports discussed temporal trends with nutrient sources or pathways.
- **Prioritized waters**. The WRAPS and WRAPS Update reports often prioritized specific waters based on various factors, including impairment status, threat to public health, biological significance, financial considerations, and public participation and involvement. The CWMPs typically prioritized issues and resources, which did not always translate to prioritizing a water body for phosphorus and nitrogen sources. The WRAPS and WRAPS Update reports generally did not address or prioritize downstream water bodies, though many WRAPS and WRAPS Update reports acknowledge potential downstream impacts identified in the 2014 NRS. The CWMPs did not address downstream water bodies explicitly, though some plans did base the nutrient goals on the NRS.
- **Water quality trends**. Temporal trends in TP and TN monitoring data were discussed in most WRAPS and WRAPS Update reports and only in a few CWMPs. Several reports focused on other parameters (e.g., TSS). Analyzing trends was challenging because individual WRAPS reports often presented trends with multiple monitoring sites, but the trends were inconsistent across monitoring sites.
- **Nutrient goals**. Most WRAPS and WRAPS Update reports and CWMPs identified nutrient goals, but those goals were inconsistent with the 2014 NRS in more than half of the watersheds. Goals were identified for phosphorus (88% of the reports) and nitrogen (65% of the reports) in most WRAPS reports, but only 48% of phosphorus goals and 25% of nitrogen goals were consistent with the 2014 NRS. Many WRAPS reports identified goals that were designed to address local impairments and were consistent with TMDLs or river eutrophication standards. All the CWMPs identified phosphorus goals, while 90% identified nitrogen goals. Only about a third of the plans

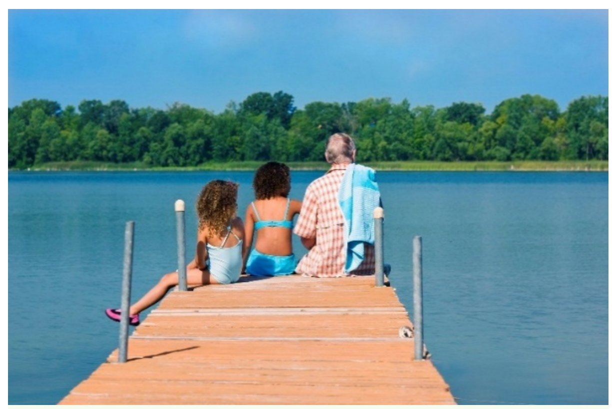
identified goals consistent with the 2014 NRS for both nutrients. Many CWMPs identified goals designed to address local impairments or protect unimpaired waters.

This analysis provides a baseline for MPCA and BWSR to gauge future progress in incorporating nutrient goals and evaluate the consistency of those goals with the NRS. All WRAPS Update Products and CWMPs recommended practices and actions, but not all address nutrients directly. WRAPS Update products and CWMPs, in general, addressed phosphorus more frequently and consistently than nitrogen. Although trends and goals were established in both documents, there is a need to better define and prioritize sources of nutrient pollution in these documents. MPCA and BWSR will work cooperatively to relay the results of this analysis to partners and develop a schedule for future updates.

Improving connections between NRS and local watershed plans

Minnesota has made significant progress in developing science and local plans at the major watershed scale since the original 2014 NRS was published. However, more effort is needed to better connect the NRS with local watershed plans, a process that has begun and will continue in an adaptive approach. BWSR supports partnerships of local and Tribal governments in developing CWMPs that prioritize issues and target actions to address nutrients and other concerns. These plans set locally defined measurable surface water and groundwater quality and quantity goals. Goals address a 10-year timeframe; plans may also articulate a long-term goal or desired future condition. The desired future condition may be derived from goals set in the original NRS, TMDL, WRAPS, or other watershed analyses. Goals are based on factors like available data, projected implementation resources, estimated staff capacity, and landowner willingness to engage in voluntary conservation. The goals apply to a variety of scales, including specific water bodies, subwatersheds, aquifers, planning regions, or watershed-wide.

Understanding the needed nutrient load reduction amounts for downstream waters will help estimate the levels of rural and urban BMP adoption and other actions needed to achieve those reductions. Natural resource managers should consider the NRS nutrient reduction planning targets when reassessing their local watershed goals, priorities, strategies, and plans. Some key considerations are:

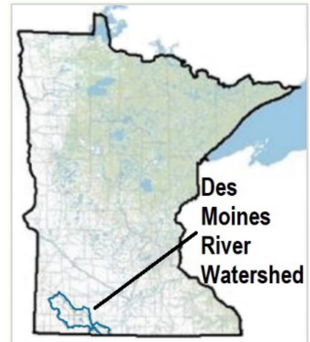

A family relaxes along a Minnesota lake

- How do watershed nutrient load reductions for downstream needs compare with the sum of local load reduction needs to address priority waters within the watershed?
- How can these load goals for downstream waters be used to set planning goals for HUC-8 outlets (milestones and final goals)?
- How do these goals inform the long-term vision for land cover changes in the watershed and the adoption of other BMPs?

Minnesota’s NRS includes basin-wide BMP adoption scenario examples that will meet the state-line nutrient goals. Watershed planners may use the information from the strategy when selecting BMPs that will affect local water quality concerns and downstream nutrient reduction needs. Many watersheds might need more nutrient reduction practices for downstream goals than for local needs; therefore, it will be important for watershed planners to document the difference in the reduction need at various scales. Additionally, because of the wide range of nutrient reduction needed across the state, watershed planners should consider the local short-term and downstream long-term nutrient reduction goals when updating strategies and plans to address nutrients. Assessing and planning for both local and downstream nutrient reduction needs can be challenging, but this information is needed to comprehensively address nutrient-related water quality issues in Minnesota watersheds.

Example: The Des Moines River Watershed – Exploring Connections

Watershed planners in the Des Moines River watershed made direct connections from the nutrient reduction goals in the original NRS to the WRAPS and CWMPs developed for their watersheds. The Des Moines River – Headwaters watershed in southwestern Minnesota covers approximately 1,334 square miles and includes parts of Lyon, Pipestone, Murray, Cottonwood, Nobles, Jackson, and Martin counties. It has five subwatersheds: Lake Shetek, Beaver Creek, Heron Lake, Lime Creek, and the West Fork Des Moines River main stem. The river joins the East Fork Des Moines River in Iowa and eventually enters the Mississippi River at Keokuk, Iowa. The primary land use within this watershed is row crop agriculture, with an extensively drained landscape that has altered the watershed's natural hydrology.



The Des Moines River is a Mississippi River tributary

The Des Moines River watershed contributes nutrients that affect local streams and lakes and the Gulf hypoxic zone. In 2021, the MPCA completed the WRAPS for this watershed, and the Des Moines River Watershed One Partnership subsequently adopted a CWMP in 2023. Both these efforts referenced the NRS as drivers for decision-making related to nutrients in this watershed. Table 6-1 compares the goal statements between the three documents and how they relate to each other.

Table 6-1. Comparison of goals in the NRS, WRAPS, and CWMP for the Des Moines River Watershed.

Document	Nitrogen goals	Phosphorus goals
Minnesota NRS	• Statewide 2040 reduction goal: 45% • High-priority watershed in original NRS • Load reduction goal from MPCA guidance for WRAPS/planning (2022 guidance): 49.8%	• Statewide 2040 reduction goal: 45% • Medium priority in original NRS • Load reduction goal to HUC-8 outlet from MPCA guidance for WRAPS/planning (2022 guidance): 30.8%
Des Moines River Watershed WRAPS (2021)	• Future condition: 30% goal reduction of instream concentrations and loads (2060) • 10-year target: 10% reduction	• Future condition: 45% reduction in lake and stream concentrations and load • 10-year target: 7% for lakes and 15% for streams
Des Moines River Watershed CWMP (2023)	• Future condition: 30% reduction • 10-year goal: 4%	• Future condition: 45% reduction • 10-year goal: 4% reduction

6.3.3 Updating 1W1P and WRAPS nutrient reduction plans and strategies

The BWSR approves CWMPs developed through the 1W1P program for a 10-year period. The program policy requires partnerships to thoroughly assess the plan at least once every 10 years. If the partners incorporate the plan assessment results and meet other procedural requirements, the board may approve a "plan renewal amendment," which results in a new plan expiration date that is 10 years from the date the board approves the amendment. Partnerships may request this type of amendment anytime during the plan's life.

Plan assessments must evaluate plan implementation, assess progress toward goals, add new information, and identify other changes that have occurred since the plan was approved. Program policy requires new WRAPS Update information, if available, to be included in the assessment. BWSR offers guidance and funding for plan assessments.

As of this writing, only a small number of approved CWMPs have had assessments that evaluate the effectiveness of plan implementation completed. Some partners set overly ambitious goals, while others intentionally set goals thought to be realistic before receiving watershed-based funding. Moving forward, the partnerships conducting the assessments should shift their plan goals toward a more realistic picture of what can be accomplished relative to the NRS goals. BWSR and the MPCA will cooperatively develop guidance for CWMPs related to plan renewals and amendments, including how incorporating efforts to address nutrients can help meet the overall goals of the NRS. The guidance will encourage partners developing updated CWMPs to consider all newly available watershed data and analyses, updated BMP efficiency data, the status of watersheds as a priority for nutrient reduction, and whether novel conservation practices and programs will help meet local and downstream nutrient goals.

The MPCA aided in the development of WRAPS for all major watersheds by 2023; these WRAPS are now transitioning into the update stage. MPCA staff coordinate bringing data, analyses, and people together for the WRAPS Update process. In 2024, MPCA modified the WRAPS Update templates and created MPCA staff guidance documents to better connect elements of the NRS within future WRAPS Update documents. WRAPS Updates will continue with the latest information from monitoring and modeling data, new TMDLs, or special studies or assessments over time. MPCA also conducts annual surveys of local project partners engaged in WRAPS Update development on the document's usefulness and associated data in supporting their work. All respondents said the downstream impacts are a focus of their work. Respondents provided suggestions to align NRS priorities with local strategies. Most respondents told MPCA that the WRAPS Update process was useful in setting goals for nutrients and protecting downstream waters.

> "We need to do a better job of aligning our local watershed goals with the state's nutrient reduction strategy. We need state agency assistance in making sure the goals developed in the watershed plans also reflect the statewide goals." – *A local partner*

Specifically, the MPCA will strengthen the connections to downstream water quality targets and trends related to nitrogen and phosphorus in WRAPS Updates. The trends in BMP adoption that MPCA has compiled through the Healthier Watersheds website or through NRS-specific dashboards will also be included in these updates. Including this information will help provide context for nutrient reduction efforts at the watershed scale (e.g., WRAPS Updates) and the statewide and major basin scales.

Benefits of continued nutrient connections to the watershed approach

Minnesota's watershed approach has resulted in the development of critical, foundational data, strategies, plans, and programs that support water quality efforts at local, watershed, and basin scales. The NRS is also foundational in that it brings together the science, vision, and goals to help guide nutrient reduction needs into the future. There is a strong connection between the watershed approach and the NRS that will only continue to strengthen over time. Integrating the statewide NRS with the watershed approach is an effective way to address nutrient contamination. The following lists the intersections and benefits of continuing and building upon this coordinated effort:

- Coordinated goal setting
  - Align statewide nutrient reduction targets with watershed-specific goals.
  - Ensure that watershed-level objectives contribute to overall state targets for nutrient reduction.
- Prioritized watershed targeting

  - Use statewide data to identify watersheds with the highest nutrient loads or the most significant contribution to downstream water quality issues.
  - Focus resources and efforts on these priority watersheds for maximum impact.
- Tailored implementation strategies
  - Develop watershed-specific plans that align with statewide strategies but are customized to local conditions, land use patterns, and nutrient sources.
  - Incorporate local stakeholder input to ensure strategies are feasible and effective for each watershed.
- Consistent monitoring and reporting
  - Implement a unified monitoring system that tracks nutrient levels across watersheds.
  - Use consistent metrics and reporting methods to compare and aggregate data at the state level.
- Adaptive management framework
  - Use watershed-level results to inform and adjust statewide strategies.
  - Allow for flexibility in statewide approaches based on lessons learned from individual watersheds.
- Multiple-agency and cross-boundary collaboration
  - Coordinate efforts between state agencies (e.g., environmental protection, agriculture) and local watershed organizations.
  - Ensure clear roles and responsibilities for implementation and monitoring.
  - For watersheds that cross state lines, coordinate with neighboring state agencies to ensure consistent approaches and shared goals for nutrient reduction.
- Policy and regulatory alignment
  - Develop state policies and regulations that support watershed-based nutrient reduction.
  - Consider watershed-specific regulations where necessary to address unique local challenges.
- Funding mechanisms
  - Align state funding programs with watershed priorities for nutrient reduction.
  - Develop cost-sharing programs that incentivize practices known to be effective in specific watersheds.
- Education and outreach
  - Develop statewide education programs that can be tailored to watershed-specific audiences and nutrient sources.
  - Share success stories and best practices across watersheds to encourage the adoption of effective strategies.
- Integrated planning
  - Incorporate nutrient reduction goals into broader water quality and land use planning efforts at the state and watershed levels.

This integrated approach allows for a cohesive statewide strategy while maintaining the flexibility to address an individual watershed’s unique characteristics and challenges. It combines state-level policy development and funding with local watershed implementation, potentially leading to more effective and sustainable nutrient reduction outcomes. This work will also include existing initiatives while cultivating new ideas and efforts to continue making progress toward nutrient goals.

6.4 Additional resource needs

The State of Minnesota is committed to providing its partners with the tools, guidance, and technical and financial assistance they need to plan and implement nutrient reduction efforts effectively. The resources needed include watershed planning and tracking tools, research and guidance on nutrient-reducing BMPs, model development and support, and staffing capacity and support.

6.4.1 Watershed planning

Enacting a structured watershed management framework and developing the original NRS in Minnesota built the foundation for delivering nutrient-related science to local practitioners working on the ground. This wealth of information is funneled through the state's conservation delivery system to guide the implementation of practices to help meet nutrient reduction goals at multiple scales. There is a need to continue to distill information related to nutrient reduction for practitioners and the public in clear, transparent, and understandable formats. Agency partners are actively seeking stakeholders' feedback and suggestions for improving technical planning support for meeting nutrient goals (Figure 6-8).

Figure 6-8. Elements for delivering conservation in Minnesota.

Tracking progress is essential for informing future planning to address NRS goals and determine if nutrient reduction progress is being made and where shortfalls occur. The MPCA has developed a suite of tracking tools through both the NRS and the Clean Water Accountability Act. The Healthier Watersheds dashboards illustrate where practices to reduce nutrient loss have been documented and show the adoption trends of practices over time. Tools such as these can support informed watershed planning and annual work plan development by local partners and stakeholders. MPCA and agency partners will evaluate these tools annually and continue to innovate and develop tools that support the technical needs of watershed practitioners.

6.4.2 Nutrient reduction practices

To meet long-term NRS goals, the rate of implementation of proven practices (in terms of amount, geographic breadth, and pace) will need to increase, and the emerging practices currently being developed will require further testing to demonstrate their effectiveness. Finally, new practices and methods will need to be developed, as discussed in Chapter 5. This changing landscape of practices, new and improved technologies, and associated support programs will provide opportunities for and put pressure on local practitioners and landowners over the next few decades to effectively implement practices and actions that make a difference in nutrient reduction. As they navigate these changes, conservation and water quality professionals will need enhanced long-term support to achieve the local, major watershed, and broader goals stated in the NRS.

To address these needs within the watershed approach in Minnesota, actions should be taken to promote the following:

- Continue to support and expand the reach of the Technical Training and Certification Program, which is a collaborative effort between BWSR and USDA NRCS.
- Expand BWSR's existing online learning library for professional staff support to include more training on practices and actions for nutrient reduction.
- Provide information on new and emerging practices to water quality professional staff and landowners; ensure it is clearly explained and disseminated widely.
- Foster existing and new producer-led groups to collaboratively solve nutrient reduction issues at various watershed scales.
- Promote the streamlined practice installation concept when using state and federally funded program funds to implement nutrient-reducing BMPs.
- Evaluate the existing regulatory barriers that prevent the implementation of effective and holistic projects to reduce nutrients.
- Bring in researchers and practitioners from other states to inform state staff and local landowners about the latest advances in nutrient reduction strategies.
- Offer state technical support at the local level—working directly with local governments—to implement larger-scale projects to reduce nutrients.
- Encourage the next generation of workers to consider environmental careers to ensure a stable workforce focused on conservation efforts.

6.4.3 Watershed models and tools

Watershed models and practice siting tools are integral to the framework of WRAPS Updates and CWMPs efforts. They also help support strategic actions in the NRS. The use of these relatively new web- and software-based systems and tools is increasing across the state, but more user training is needed to support ongoing planning and implementation efforts. To better understand the dynamics of this issue, the BWSR undertook a needs assessment in summer 2024 and obtained input from local government, university, and state agency staff (see Appendix 6-1). This work included an online user survey of over 80 participants, which was followed by a series of small-group and one-on-one conversations with staff.

The user survey provided direct insight into the familiarity, understanding, use, and training needs for various models and tools that support watershed work in Minnesota. Over 20 different models or tools were presented to survey participants to rate and provide insight into the functionality. The user audience was familiar with Minnesota's WRAPS, WRAPS Update, and CWMP processes in Minnesota, and the results reflected the support needs for the Minnesota Water Management Framework. Of the programs identified, the family of HSPF model software and web-enabled products was the most widely recognized and used by staff. The PTMApp tool was the most-used tool for siting conservation practices and measuring local watershed effects of agricultural BMPs. The BWSR Estimator tools and USDA NRCS Revised Universal Soil Loss Equation, Version 2 calculator are still prevalently used to determine in-field and near-channel soil loss of sediment and phosphorus. The survey indicated a significant need for training on all the models and tools, specifically those used for watershed management work. Users identified that in-depth, in-person training, complemented by online or recorded webinars, would be helpful for staff.

The direct discussions with staff helped illuminate users' specific needs, challenges, and opportunities. In addition to questions on the model and tool needs, feedback related to approaches for nutrient reduction for nitrogen and phosphorus and local capacity needs were also gathered. Table 6-2 summarizes the main themes from these conversations (See Appendix 6-2 for more detail).

Table 6-2. Summary of small-group conversations with local and state agency staff.

Discussion topics	Main themes	Recommendations
Model and tool utilization	• More training/guidance needed (beginner to expert): in-person, virtual, and videos. • Local and state agency staff use some of the tools only once annually, so gaining core competencies in the tools is difficult. • Some models/tools are difficult to use, and results vary between models. • Need guidance and training on which tool to use and when. • Models or tools applied or used vary regionally.	• Responsible agencies will develop training materials and videos, provide training, and continue to survey users on needs. • Develop a "one-stop shop" for resources and training on models and tools.
Opportunities and challenges for nutrient reduction	• Minnesotans are more concerned about local issues than downstream (e.g., the Gulf) issues. • More people are accepting and adopting newer soil health practices, so expand on this. • Need more community-led, grassroots efforts to make headway. • Challenged by the staggering amount of change needed to make progress on nutrients. • Equipment costs to change agricultural systems to reduce nutrients can be prohibitive. • Nitrogen reduction opportunities apply to both groundwater and surface water.	• Develop a plan to connect local landowners more directly to watersheds and larger-scale water quality issues. • Increase public awareness of projects and actions that successfully reduce nutrient impacts on water quality. • Help streamline permitting processes for implementing nutrient reduction practices. • Foster landowner buy-in via trusted networks (SWCD, NRCS, agronomists, etc.) to scale up practice adoption. • Develop benchmarks for nutrient reduction success; develop user-friendly systems to track progress.
Local capacity needs to meet nutrient goals	• Need to establish regional power users or specialists for tools (e.g., HSPF SAM/PTMApp) and practices (e.g., cover crops). • Concerns about hiring new staff when the funding from the legacy amendment isn't guaranteed forever. • Staff change and shift roles, making it difficult to build lasting working relationships. • USDA NRCS and FSA staff capacity in the field varies by county; technical service providers are often unavailable to help.	• Create a mentorship program that connects local watershed organizations to higher education institutions to help develop future watershed practitioners.

The results of this assessment work will inform efforts by state agency partners as they support the use of watershed models and tools to meet the NRS goals and the Minnesota Water Management Framework to measure, track, and identify future nutrient reduction efforts and actions. Led by BWSR, state agencies and partners will cooperatively develop training materials and provide outreach on downstream nutrient reduction needs and connections to local concerns. Also, more information will be provided on the effects of nutrients on water bodies outside of Minnesota's borders, such as Lake Winnipeg, the Lower Mississippi River, and the Gulf.

To support the needs assessment work, an MPCA contractor analyzed which models and tools were used to complete WRAPS and CWMPs (Table 6-3). To conduct the analysis, the contractor performed an extensive search through each report and plan. This analysis indicated a long-term need for support, training, enhancement, and maintenance of watershed models and tools to support nutrient reduction work to achieve goals at all scales. In addition, continuing to develop and support web-enabled, user-friendly applications to help access modeling data is important for local watershed staff. These applications allow the user to quickly develop implementation scenarios and evaluate the effectiveness of a wide range of management practices. See Appendix 6-3 for the detailed analysis of this work.

Table 6-3. Models and tools used in WRAPS and CWMP documents.

Model/tool name	Type	WRAPS reports	CWMP documents
ACPF	BMP siting tool (beta version with BMP load estimation)	16%	33%
BATHTUB	Reservoir eutrophication model	9%	8%
HSPF	Flow and water quality model	85%	70%
HSPF-SAM	BMP siting and load estimation tool	23%	38%
PTMApp	BMP siting and load estimation tool	18%	55%
SWAT	Flow and water quality model	14%	10%
Zonation	Priority area identification model	Not applicable	20%

6.4.4 Staffing support

Staffing capacity to support watershed management efforts addressing nutrient reduction has been a challenge at the local, state, and federal government levels, as well as within the nonprofit and private sectors. Local staff support is needed for SWCDs, watershed districts, watershed management organizations, and counties, which all have specific roles in watershed management and implementation in Minnesota.

The needs are significant and go beyond just staff availability; they also include staff training, retention, and mentoring. In recent years, Minnesota has taken steps to increase the technical capacity of local staff through BWSR's Technical Training and Certification program. This effort, with support from BWSR, the Minnesota Association of SWCDs, and USDA NRCS, ensures that the conservation workforce has the technical skills to recommend, design, install, inspect, and implement practices to meet state water quality goals. Additionally, the state has provided supplemental funding to SWCDs since 2016 to increase local capacity to address water quality and natural resource concerns. This funding was initially granted through BWSR to SWCDs and was sourced from the Clean Water Fund. As of 2023, this funding is a part of a state aid package to SWCDs sourced from the State General Fund.

Conservation Agronomist Positions Support Nutrient Reduction Efforts

In 2021, the Morrison SWCD was the first to hire a Conservation Agronomist position in Minnesota. This unique new position was created to bridge the gap between farmers, fertilizer co-ops, and conservation efforts in their county. Since then, several other SWCDs and nonprofit organizations have begun offering similar positions across the state. The Conservation Agronomist can break down barriers at the grassroots level, helping reduce nutrients at the local level and downstream.

"I can help find ways to accomplish your agricultural goals. There are plenty of management options, and you are in control of which ones to use."

– Kolby Hansen, Morrison SWCD Conservation Agronomist

State, federal, and local partners must work cooperatively with NGOs and private industry to ensure that future staffing, technology, and training capacity is adequate to meet the needs and water quality goals identified through the Minnesota Water Management Framework and the NRS. Also, it is important to collaborate with secondary and post-secondary education institutions in Minnesota to ensure that career pathways for critical technical skills are accessible, thereby developing a future workforce for all sectors. Steps should be taken to assess how to better streamline existing systems and programs to help staff and landowners work together to reduce nutrients through conservation efforts.

North shore of Lake Superior

6.5 Roadmap for integration

The State of Minnesota is committed to integrating the NRS with the Minnesota Water Management Framework, which will require further incorporation of nutrient reduction goals into watershed-based strategies and plans. Because the approaches for addressing nutrients vary across Minnesota, state and local governments and their partners must cooperate to ensure that long-term nitrogen and phosphorus reductions are achieved.

6.5.1 Regional considerations and benefits of addressing nutrients

Through the Minnesota Water Management Framework, the approaches and practices used to address nutrients vary regionally by basin, ecoregion, and climate. The nutrient transport pathways also differ, affecting the strategies needed to address these issues. There are different regional planning structures in place for coordinating watershed work (e.g., Red River Water Management Board, Greater Blue River Basin Alliance, Basin Alliance of Lower Mississippi Minnesota). Also, many practices and actions identified through the WRAPS Updates and CWMPs offer multiple benefits, where nutrients in surface waters may not be a high priority, but the practices implemented to address other surface water and groundwater quality issues will help meet NRS goals. Table 6-4 outlines some high-level considerations for each major HUC-4 basin in Minnesota.

Table 6-4. Nutrient considerations by major basin.

Basins	Regional issues and considerations
Minnesota River	• Most of the highest nutrient loads in Minnesota come from this watershed, so practices with multiple benefits will be critical. • Near-channel erosion in riparian areas is a significant source of sediment and phosphorus; efforts to mitigate this source locally will have downstream benefits. • Nitrogen loads from agricultural drainage and surface runoff are significant, but local goals to reduce nitrogen to downstream waters are lacking.
Des Moines River	• Shallow lake eutrophication issues are very localized; addressing nutrients may not have significant downstream effects.
Lower Mississippi, Upper Iowa, and Cedar rivers	• Karst landscape, direct connections between surface and groundwater resources, and drinking water nitrate issues are driving nutrient reductions. • Lake Pepin and large river eutrophication in-state goals align well with the NRS, but significant reductions are needed to meet both.
Upper Mississippi River	• The presence of coarse-textured soils, groundwater nitrate issues, and public water supplies relying on the Mississippi River for drinking water are regional drivers for reducing nitrates. • Protecting high-quality lakes and riparian areas and restoring impaired waters will have local impacts and provide some downstream benefits.
St. Croix River	• The focus has been on serious local eutrophication impairments and stormwater impacts, as downstream nutrient impacts are relatively small compared to other basins in the state. • Near-channel erosion control and stormwater management practices for local concerns will affect downstream waters.
Missouri River, Big and Little Sioux	• Most local efforts have focused on reducing sediment along the glacial buffalo ridge, reducing phosphorus for local lakes, and reducing nitrate in drinking water supply management areas, all of which will have some effect on downstream waters.
Red River of the North	• Relatively few river or lake eutrophication impairments for phosphorus and very few groundwater impacts for nitrogen exist, but large nutrient reductions are still needed to meet Lake Winnipeg goals. • Sediment reduction goals in critical areas like the glacial beach ridge and along eroded streambanks will work towards phosphorus reduction needs.
Rainy River	• Protection activities will be important for local resources and downstream efforts. Changes to land use without proper management can happen quickly in forested areas, but there is a significant lag time before forested BMPs affect water quality.
Lake Superior	• Nutrient reductions in shallow, nearshore areas will be important to prevent future algal blooms on Lake Superior. • Forestry management, wastewater treatment, and streambank stabilization efforts will help local stream health and minimize impacts to Lake Superior.

6.5.2 Linking the NRS to the Minnesota water management framework

Minnesota has made great strides to include nutrient reduction goals in watershed-based strategies and plans, but continued work will be needed by state and local governments and their partners to ensure that long-term nitrogen and phosphorus reductions outlined in the state's NRS will be met.

To continue making progress, the following actions are needed to guide and implement this effort:

- Invest in data for adaptive management and tracking
  - Provide continued investment in the foundational datasets, nutrient data analyses, data visualization tools, tracking systems and dashboards, and outreach materials that are essential for adaptive management and implementing the NRS.
  - Develop NRS tracking systems and dashboards to account for progress at statewide, regional, major watershed, and local watershed scales (see Chapter 7).
  - Work with local watershed staff to provide input in developing systems that are intuitive and user-friendly for delivering information to practitioners and the public for decision-making support.
- Integrate work across scales
  - Periodically update WRAPS, 1W1P, and GRAPS (and other programs that contribute to the NRS goals) to ensure these products and programs incorporate NRS goals.
  - Better connect the NRS's overarching goals with the GRAPS groundwater and drinking water goals as more GRAPS are developed over time. Identify any gaps in research and data needed to better align these goals.
  - Bring regional partners together to identify and collaborate on expanding common regional strategies and practices needed to meet nutrient goals in the NRS and address shared responsibilities for reducing the impacts of nutrients on Minnesota waters. Regional partnerships, such as the Basin Alliance of the Lower Mississippi in Minnesota (BALMM) and the Flood Damage Reduction Work Group in the Red River Valley, are examples of existing groups that have a long history of working on complex water issues.
- Scale-up adoption of practices that achieve nutrient reduction and other benefits
  - Continue to find ways to increase/promote widespread adoption of critical practices and actions needed across diverse watershed landscapes. While increasing the breadth of adoption, continue to prioritize and target locations that will yield the greatest level of nutrient loss reduction.
  - Engage local watershed staff to assist in implementing nutrient reduction practices to meet NRS goals and garner feedback on what resources are needed to increase the adoption rate.
  - Focus on adopting the most cost-effective BMPs with multiple benefits to help achieve local and statewide nutrient reduction goals and address the root cause of nutrient losses, as well as other broadly desired goals of soil health, landscape resiliency to weather extremes, and habitat (see Chapter 5 for more detail).
- Keep the NRS in front of practitioners and programs
  - Provide continuous and intentional outreach to state and local staff on the NRS content, future updates, and pathways to connecting local water management efforts with NRS goals. Focus training for new staff at the local, state, federal, NGO, and private sector through annual training events and online webinars.

6.6 NRS support documents

- Appendix 6-1: Support of Watershed Nutrient Reduction Planning through Tools and Resources: User Survey (BWSR)
- Appendix 6-2: Watershed Staff Interview Summary (Tetra Tech)
- Appendix 6-3: Assessment of Watershed Work (WRAPS & CWMP) to Address Nutrients (Tetra Tech)

Chapter 7
Progress Tracking

Key Messages

- NRS tracking categories include: (1) **practices and actions** related to on-the-ground efforts, (2) **water quality** in surface water and groundwater, (3) **programs** on the state and regional levels that affect nutrients, and (4) the changes in **people's** level of engagement with NRS efforts.
- Tracking progress for the NRS will be an ongoing, iterative, and adaptive process involving numerous partners over many years.
- Since the original strategy was published in 2014, several new metrics have been added that track agricultural practice adoption, watershed planning, and strategy development.
- Minnesota has developed many new online visualization tools that provide the public with greater access and clarity about the status of NRS metrics and indicators.
- Conservation practices adopted through government programs are tracked annually at watershed scales, and a CLC index will be developed in the future.
- A new tool was recently developed to estimate the effects of agricultural practices on reducing nutrient loads into waters across multiple watershed scales in Minnesota. It provides a simple way to compare expected changes in water with monitored changes in water.
- More data and new tools are needed to fill in the known gaps and ensure better tracking of long-term NRS progress, including a dashboard to simplify the accessibility of NRS tracking information for all users.
- NRS partners will increase outreach and awareness about the NRS and nutrient reduction needs and will provide periodic interpretation of data trends and findings.

7.1 Why track progress?

The Minnesota NRS was designed to adapt over time in response to progress made in achieving nutrient reduction in the state's waterways. While the ultimate success of the implementation of the 2025 NRS would be meeting the nutrient reduction goals for waters leaving the state, as laid out in Chapter 2, and meeting the nutrient reduction needs for local waters, as laid out in Chapter 3, there are complexities that influence water quality tracking. These include lag times between changes on land and when those changes can be detected in the water, legacy nutrients, weather and climate, limitations in water monitoring, and changes in watershed characteristics. To compensate for this aspect of water quality monitoring, other factors that lead to improved **water quality** can be used to track implementation of recommended nutrient reduction strategies. This tracking falls into the categories of **practices and actions**, **programs**, and **people** (Figure 7-1).

Figure 7-1. NRS tracking categories.

This chapter explores how these categories can be tracked, identifies existing tracking systems that can be used for this task, and explains how these data should be organized to optimize their use. It also updates the process that will be used to evaluate and adjust the NRS in the next phase of implementation and provides a timeline for when NRS assessments will be made. Finally, the chapter provides the framework to help determine when, and to what degree, the NRS goals have been successfully executed.

7.1.1 Information needed to track progress

Tracking progress is complex because the NRS process has many layers, ranging from local watershed-level work to the downstream effects of nutrient reduction (Figure 7-2). The support given by the governmental and private sectors in Minnesota provides a foundation for local watershed work and the adoption of practices and actions. These efforts result in improved water quality in Minnesota and downstream beyond state borders. This work provides multiple benefits for the environment and Minnesota communities.

Figure 7-2. NRS process for improving in-state and downstream waters.

7.1.2 Measures, metrics, and indicators to track progress

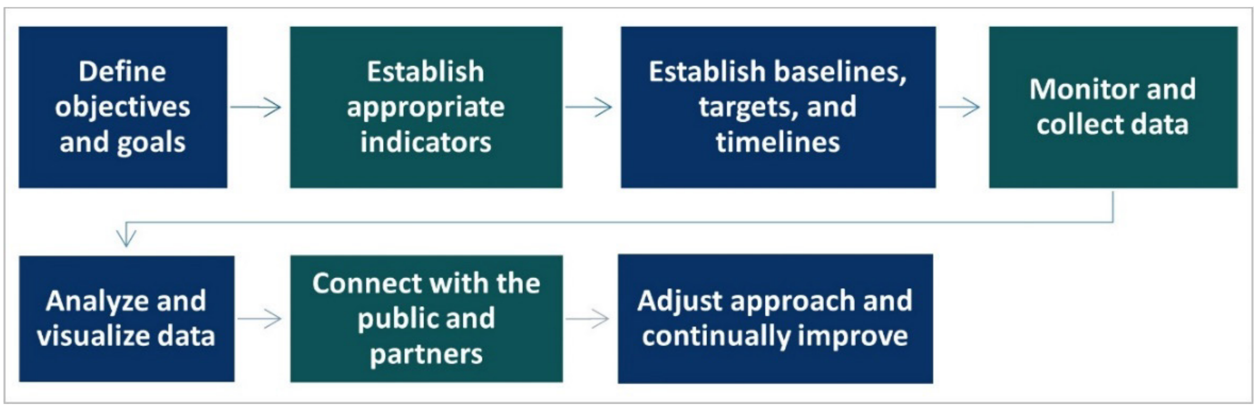
The original NRS was developed in 2014 with the best available scientific information to identify specific, measurable metrics and indicators that have been used to determine whether the identified goals for nutrient reduction and water quality improvements in Minnesota and downstream were being met. Table 7-1 defines the terms used to guide the tracking process over time and provides an example of each term in relation to nitrogen reduction. The 2025 NRS builds on the solid foundation of the original 2014 NRS. It includes more recent data that will be used to update existing datasets and develop new state-of-the-art visualization tools to better convey progress.

The adaptive approach outlined in Figure 7-3 was used when developing the 2014 NRS and the 2025 NRS, and it will be used as the NRS is implemented in the future. During the original development of the NRS, the goals and objectives were defined, and appropriate indicators, targets, and timelines were established. Part of the 2025 revision included using monitoring data to analyze how well the NRS approach is meeting the measures of success, communicating this message to the public, and developing recommendations to improve the next decade of NRS implementation.

Table 7-1. Definition of terms for tracking and measuring progress.

Term	Description	Example
Measure	The basic unit of quantitative raw data.	Individual nitrate sample results for the Mississippi River.
Metric	This unit of measurement uses one or more measures to gauge performance against a standard.	Annual trends in nitrate concentrations and loads in the Mississippi River.
Indicator	This specific, measurable value shows how effectively goals are met. Indicators are often made up of metrics and may include targets or interim goals.	The percent of NRS goals met at the state line for the Mississippi River.
Index	Multiple indicators can be used to create an index to systematically evaluate performance. For the NRS, this will include goals outside the state border.	Local nitrate stressors reduced; fisheries restored; and goals met for local groundwater nitrate, state line nitrogen, and the Gulf hypoxic zone.
Milestone goal	Interim goal(s) for nutrient reduction set at defined intervals of time before the final goal end date.	20% reduction of nitrogen to the Gulf by 2025.
Final goal	Final goal that quantifies a stated reduction value for nutrients at a specific end date.	45% reduction of nitrogen to the Gulf by 2040.

Figure 7-3. Adaptative management approach for NRS tracking.

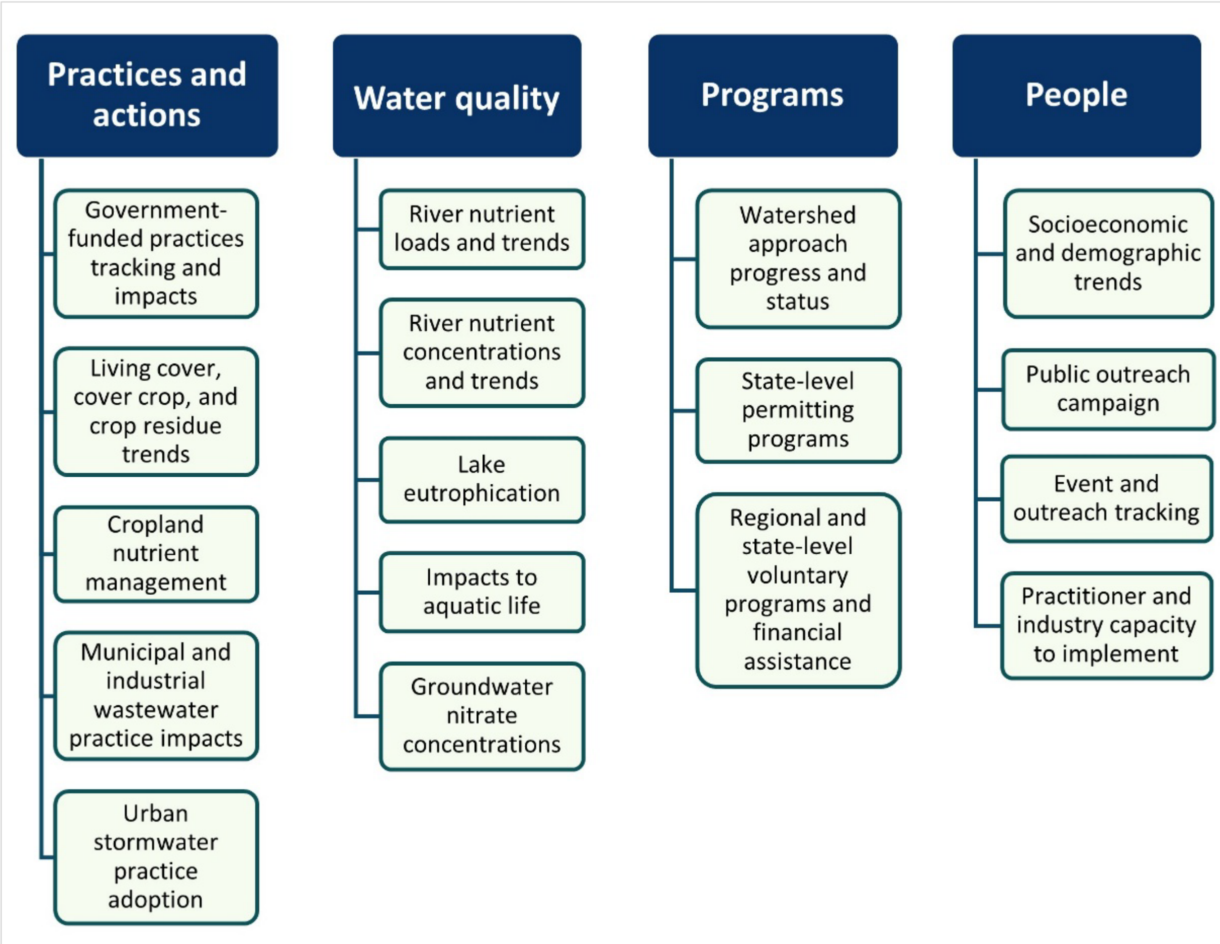


Tracking progress will be an ongoing, living element of the NRS. The results will be evaluated biennially by the NRS Team to determine if additional metrics are needed to identify progress and what strategic changes will be needed to continue the trajectory toward meeting our nutrient reduction goals.

Tracking categories

Minnesota is fortunate to have a tremendous amount of data and existing tracking systems in place, but additional steps will be needed to focus on NRS progress and trends. Part of the progress of the NRS analysis for the 2025 updates included a work group of NRS project partners to assess what has been tracked in the past, what is currently being tracked, what needs to be tracked in the future, and which areas need additional work. The work group identified four major tracking categories to assess progress, as shown in Figure 7-4: (1) practices and actions, (2) water quality, (3) programs, and (4) people.

Figure 7-4. Major tracking categories and subcategories for the NRS.



These main categories, summarized below, are followed by tables providing a high-level overview of the elements within each category that support measuring and tracking. Each table outlines the subcategories within each main category, the metrics and trends being tracked, the supporting data, an example (if available), and future needs. This information will be updated annually by MPCA and posted as part of the NRS implementation efforts.

- The **practices and actions** tracking category captures on-the-ground efforts (Table 7-2). Details include tracking activities funded by government programs or required by permits and land cover trends that influence nutrient losses and reductions. Most of the information in this category is supplied through government programs and data, which continues to improve on an annual basis.
- The **water quality** tracking category encompasses surface and groundwater (Table 7-3). Minnesota has robust programs for monitoring, analyzing, and modeling surface water and groundwater quality. These programs are crucial for tracking long-term success and identifying future needs for reducing nutrients in waters.

Table 7-2. Tracking category #1: practices and actions.

Subcategory	Description	Metrics and trends	Supporting data	Example tracking tool/ database	Future needs
Government-funded practices tracking and impacts	Measure nutrient reduction estimates from federal- and state-funded BMPs implemented in the past	• BMP adoption trends: 2004, 2014, and 2025 to present, by practice • Nutrient load reductions from practices at the watershed and basin scales	• USDA NRCS and FSA program data • BWSR eLINK practice database • MDA AgBMP loan program; Ag certification program database • MPCA CWA Section 319 Program data	Workbook: statewide BMP adoption summary	• Enhance existing tracking systems • Develop a dashboard to better connect practice adoption to NRS goals
Living cover, cover crop, and crop residue trends	Measure living cover across the state; includes perennial living cover, cover crops, pastures, prairie, and forests	• Long-term trends in cover crop adoption • Changes in tillage and crop residue patterns • Changes in crop and forest patterns • Levels of adoption of CLC in agricultural crop systems	• USDA NASS survey data and cropland data layer • Remote sensing analysis • Private and nonprofit sector survey data	USDA NASS surveys	• Develop CLC index • Develop dashboards for remote sensing data
Cropland nutrient management	Measure nutrient management practice trends with commercial fertilizer and manure sources of nutrients	• Spatial changes in commercial/manure nutrient application rates • Changes in adoption of NMPs and precision technologies	• USDA ARS cropland nutrient balance data • MDA nitrogen use survey data • UMN soil test database	MDA fertilizer use and sales data	• Include private sector survey data (e.g., Iowa Nutrient Research and Education Council)
Municipal and industrial wastewater practice impacts	Measure nitrogen and phosphorus discharges; track trends, long-term implementation of wastewater nitrogen strategy	• Adoption of new technologies at WWTFs • Nutrient effluent discharge trends	• MPCA NPDES permit database • Wastewater effluent flow data	Wastewater effluent flow and nutrients	• Develop a system to track long-term wastewater nitrogen strategy progress
Urban stormwater practice adoption	Track the level of adoption needed to meet the urban stormwater sector goals and measure the impacts	• Adoption of innovative stormwater practices and technologies • Percent of urban landscapes treating stormwater runoff	• MPCA MS4 and NPDES permit databases • Metro watershed district permit databases	Future development	• Improve quantification of stormwater BMP implementation • Develop visualization tools to show progress

Table 7-3. Tracking category #2: water quality.

Subcategory	Description	Metrics and trends	Supporting data	Example tracking tool/database	Future needs
River nutrient loads and trends	Measure nutrient loads at the state line for the Mississippi, Red River, and Lake Superior basins	• Nutrient loading trends and progress towards NRS overall goals at the basin scale • Trends in meeting major watershed nutrient reduction goals	• Monitoring data from USGS, Met Council, MPCA Watershed Pollutant Load Monitoring Network, and Province of Manitoba • Watershed modeling analysis from HSPF and SPARROW models	Workbook: Watershed Pollutant Load Monitoring Network water monitoring data	Quantify the impact of past and future practice adoption on watershed loads
River nutrient concentrations and trends	Measure nutrient concentrations in river systems statewide to determine effects on drinking water sources, river eutrophication, and aquatic life	• Tracking nutrient concentrations in river systems statewide to determine effects on drinking water sources, river eutrophication, and aquatic life	• River and stream nutrient monitoring data from MPCA Watershed Pollutant Load Monitoring Network and Met Council monitoring programs	Workbook: Long-term stream trends	Expand and enhance existing online tracking applications
Lake eutrophication	Measure trends in lake eutrophication for impaired and protection lakes in priority watersheds	• Track trends in lake eutrophication for impaired and protection lakes in priority watersheds	• Lake monitoring data from DNR & MPCA • Trend analysis reports and TMDL assessment of individual lakes	Explore Watershed Lakes: Minnesota DNR	Create an interactive visualization application for existing datasets
Impacts to aquatic life	Measure trends in the condition of fish and invertebrate communities inhabiting state rivers and streams	• Track the correlation between BMP implementation, reduced nutrients, and changes in Index of Biological Integrity scores at multiple scales	• MPCA Index of Biological Integrity monitoring data and stressor identification reports.	Workbook: Long-term biological monitoring of rivers and streams	Update and enhance current tracking application
Groundwater nitrate concentrations	Measure trends in groundwater nitrate in private and public wells	• Track long-term trends in groundwater nitrate with a focus on sensitive landscapes (e.g., karst, sand plains) • Track real-time trends with continuous nitrate sensors	• MPCA groundwater condition reports • MDH, MDA, and MPCA well monitoring data • MPCA nitrate sensor network monitoring • MDA effectiveness monitoring data • MDH county well log data	Nitrate in drinking water in Minnesota: MN Public Health Data Access	Expand ambient monitoring networks and the use of continuous nitrate sensors.

- The **programs** tracking category encompasses programs that support watershed management and implementation efforts to reduce nutrients (Table 7-4). Programs will be tracked to ensure that the state is on target to complete WRAPS Updates, GRAPS, and CWMPs. Additionally, key permitted and voluntary programs that directly support larger-scale nutrient reduction efforts will be tracked.
- The **people** category tracks the degree to which the people of Minnesota engage with nutrient reduction efforts (Table 7-5). This element is important, as the human dimension for change influences the actions taken to reduce nutrients, the programs that support those actions, and how people's actions lead to improved surface water and groundwater quality. As the NRS continues to be implemented, partners will work together to strengthen the connection between all elements of this strategy with the people of Minnesota and its downstream partners.

Table 7-4. Tracking category #3: program support.

Subcategory	Description	Metrics and trends	Supporting data	Example tracking tool/ database	Future needs
Watershed approach progress and status	Track impaired waters, WRAPS Updates, and CWMP development to include in nutrient goals derived from the NRS.	• Increase inclusion of NRS goals within WRAPS Updates and CWMPs • Track 10-year CWMP implementation progress against local/downstream nutrient loads • Track GRAPS development progress statewide	• MPCA Healthier Watersheds data (WRAPS Updates, TMDLs) • BWSR CWMP tracking • NRS Appendix 6-3: Assessment of Watershed Work to Address Nutrients	Workbook: Watershed Restoration and Protection Strategy status	• Update CWMP guidance to include approaches to addressing downstream nutrient reductions • Update Appendix 6-3 every five years to include new data
State-level permitting programs	Track the impact of the nitrogen fertilizer management plan (MDA); state buffer law (BWSR); and feedlots, SSTSs, and WWTFs (MPCA) in addressing nutrients.	• Increased adoption of practices and actions through permit processes that directly reduce nutrients to surface water and groundwater resources.	• State agency permitting databases, reports, and summary statistics	Workbook: Wastewater loading by facility	• Develop additional online tracking systems related to permitted programs and nutrient reductions
Regional- and state-level voluntary programs and financial assistance	Analyze the long-term impact of programs such as USDA RCPP, MDA Ag Water Quality Certification, and BWSR watershed-based implementation funding.	• Track trends in practice adoption and water quality improvements where these programs have been implemented	• Federal and state agency practice databases (e.g., MPCA Healthier Watersheds)	Workbook: Statewide BMP adoption summary	• Quantify the proportion of practices funded by these programs • Better track funding, practices adopted, and water quality changes attributed to them

Table 7-5. Tracking category #4: people and the human dimension.

Subcategory	Description	Metrics and trends	Supporting data	Example tracking tool/ database	Future needs
Socio-economic and demographic trends	Track the acceptance of practices, programs, and water quality data across a range of demographic sectors.	• See Table 7-6 in Section 7.5.1	• USDA economic data • Minnesota state demographic data • UMN survey data	Get to know your State | Tableau Public	• Further quantify the social and economic of NRS implementation efforts • Increase survey frequency for various sectors
Public outreach campaign	Track the level of NRS outreach to the public by sector and the impacts on reaching NRS goals.	• Quantify the change in awareness through surveys and focus groups • Track trends in the level of public outreach being provided by NRS partners	• Annual reports to the EPA by MPCA • Agency and UMN survey databases and publications	Future development	• Analyze effects of increased NRS outreach and awareness
Event and outreach tracking	Track the level of participation in interactive, in-person, and experiential learning opportunities related to nutrient impacts.	• Trends in outreach and education events quantified by basin and major watershed • Analysis and research on the effectiveness of outreach platform types	• UMN Extension outreach database; • BWSR eLINK database	Future development	• Work with private sector and NGOs to better account for the scale of outreach • Provide expanded access to outreach events via innovative solutions
Practitioner and industry capacity to implement	Track staff capacity needs for conservation agencies and industry to meet the demand of implementing the NRS.	• Trends in training for staff implementing water quality programs and projects	• BWSR technical training program database • University or NGO surveys on staff capacity	Future development	• Updated local government surveys on staff capacity needs. • Survey of private sector capacity needs

Tracking change for the NRS requires multiple sources of information to frame the whole picture, analyze trends, and determine what additional steps or modifications are needed to meet goals. Long-term water quality monitoring results provide important indications of progress toward goals. Multiple decades of monitoring are needed to best discern trends that are complicated by nutrient transport lag times, legacy nutrients from historical practices, weather and climate variability, and other inherent statistical uncertainties.

The NRS supplements river monitoring tracking with other measures and metrics that can provide short-term evaluation, enabling adjustments and adaptive management along the way. For example, the NRS tracks progress with programs and outreach that can drive practice changes on the land; it also tracks the actual adoption of changes on the land, which will eventually affect water quality monitoring results.

Annual and ongoing long-term tracking

Successful NRS tracking will involve data that are collected, analyzed, and visualized for both short-term (daily, monthly, and annual intervals) and long-term (5- to 10-year intervals) results. Longer-term trends require more thorough analysis and effort to complete. It is appropriate to examine longer intervals to account for annual variability and noise within the datasets. The MPCA, which has been collaborating with NRS partners to analyze and evaluate tracking systems at both short- and long-term temporal scales to determine if existing systems meet NRS needs, has developed a preliminary list of new tracking systems to bring online (see Section 7.6.5). Existing systems will be adapted as necessary to improve methods of tracking, particularly for evaluating the long-term trends. A detailed work plan to accomplish this work with specific recommendations will be developed in 2026; work will commence in mid-2026 and will be ongoing.

7.2 Evaluating adoption of practices and actions

Over the last decade, tremendous progress has been made in collecting, sharing, and displaying data on practice implementation, which is foundational to the ongoing tracking efforts. Prior efforts to track the progress of agricultural and urban practice implementation have produced disconnected data sources collected by many entities with different methods over varying time periods. The complex nature of the data must be considered when evaluating and analyzing the progress that has been made regarding the practices that are impacting nutrient loss reduction.

Implementing the NRS over the last decade has led to the development of improved data collection systems. More advances are needed to ensure practices and actions can be tracked and measured against the scenarios and goals outlined in this strategy, which will help to gauge the long-term progress and success of the NRS. Example groupings of data collected on practices that impact nutrients include, but are not limited to:

- Government financial assistance program databases
- Landowner surveys and statistics
- Spatial and remote sensing analysis
- Regulatory permit databases

7.2.1 Data sources and applications

Minnesota datasets

Minnesota has a robust dataset of government-funded conservation practices, including data from both state and federal agency programs. The BWSR has collected practice information from several grant programs in its eLINK reporting database since 2004, which includes programs not only from BWSR but also from MPCA, MDH, and MDA. This database includes a wide range of practices addressing nonpoint source pollution from agricultural, urban, and forested landscapes. In the last two decades, approximately 50,000 practices have been reported and mapped (Figure 7-5), providing a strong foundation of publicly available practice data. In addition to practices receiving state grant funds, BWSR also collects information on state-held long-term conservation easements (Figure 7-6) that typically include restorations of wetland, prairie land, and forest land.

The MDA's Agricultural Water Quality Certification and AgBMP loan programs provide another robust dataset of agricultural conservation practices. The USDA NRCS also provides Minnesota with program data on practices aggregated at the minor watershed level.

Conservation practice data is aggregated at the minor, major, and basin watershed scales to assess trends and determine the pace of progress made through the adoption of critical nutrient reduction practices. These datasets are important for tracking progress for the NRS and for meeting CWLA reporting requirements.

Figure 7-5. State-funded BMPs reported in the BWSR eLINK database (2004–2025).

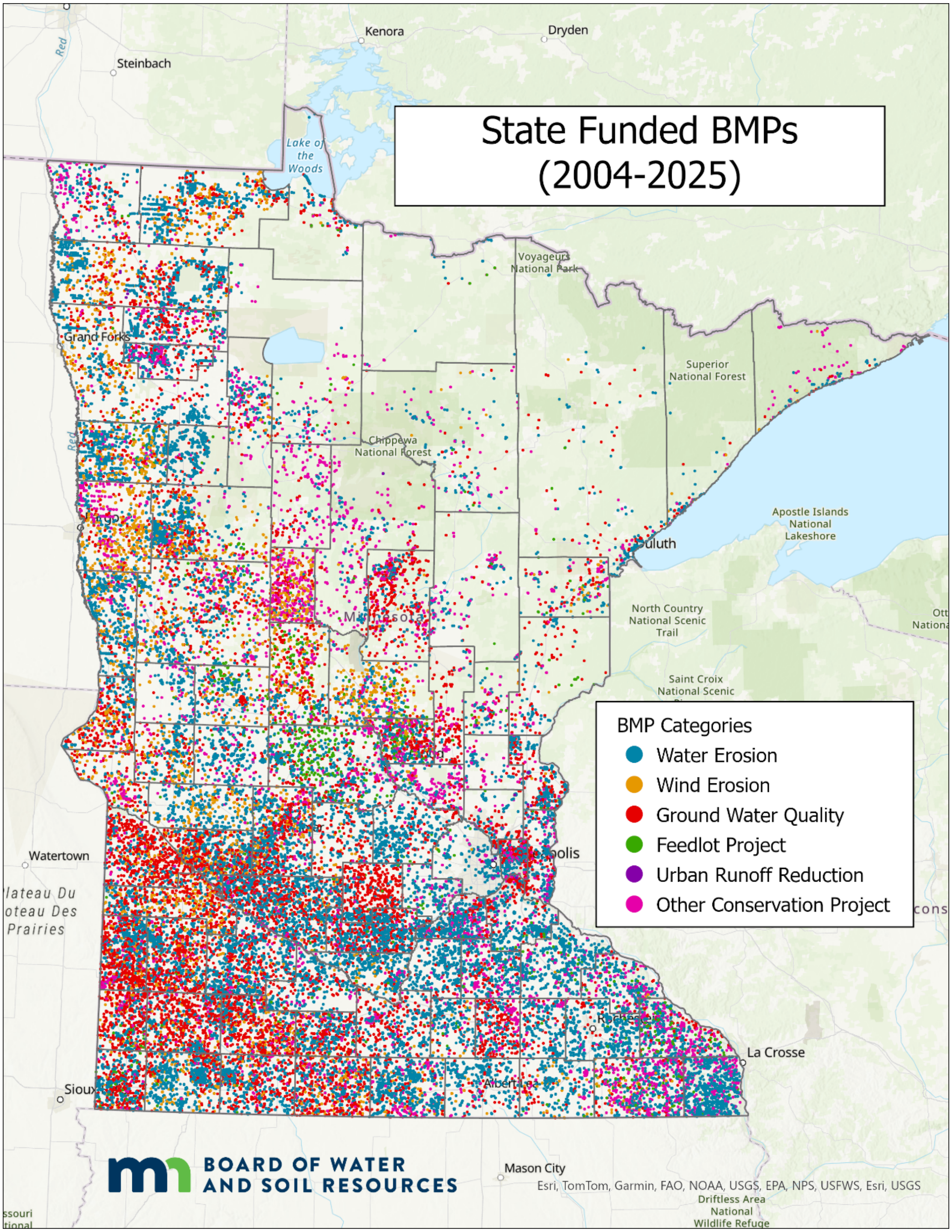
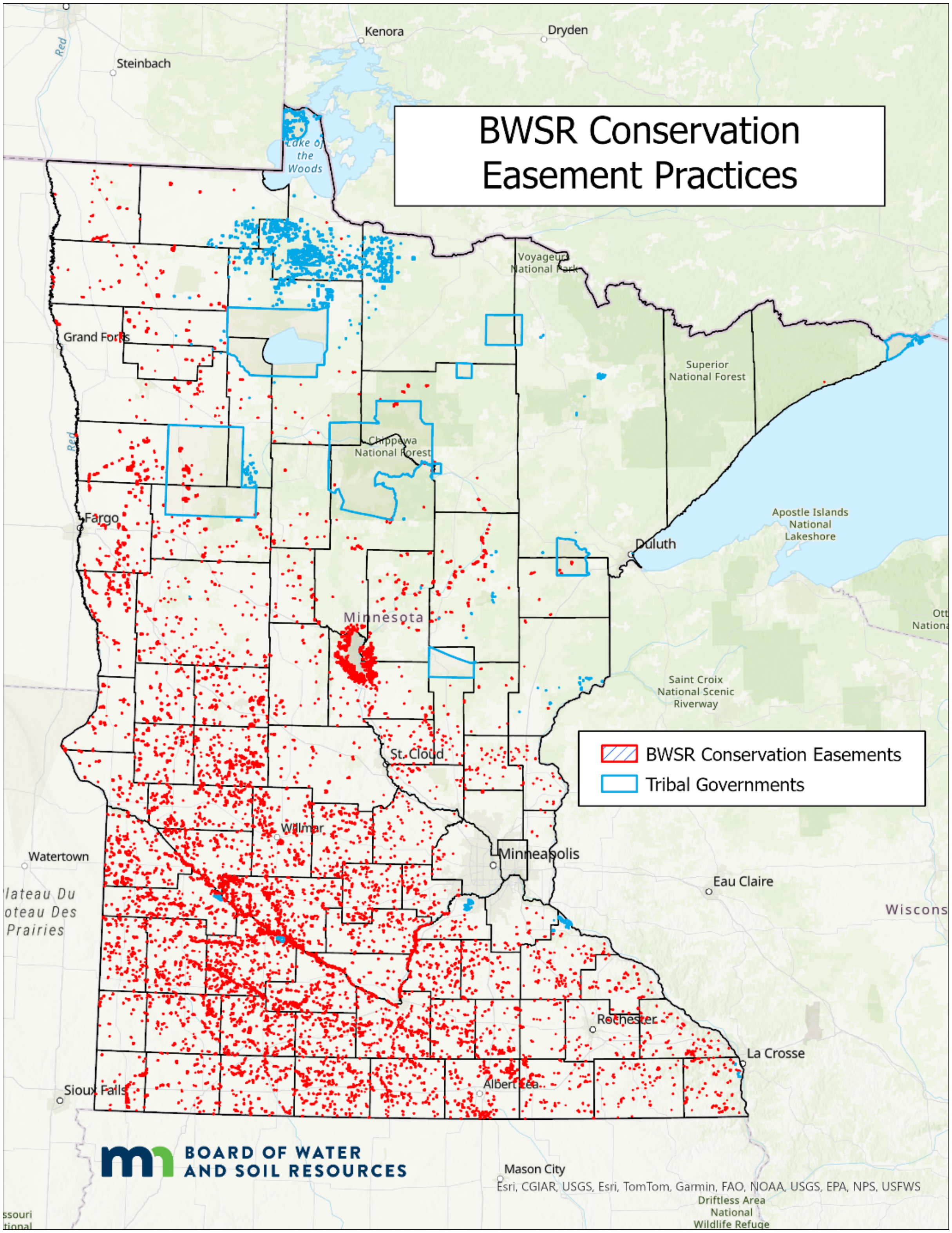
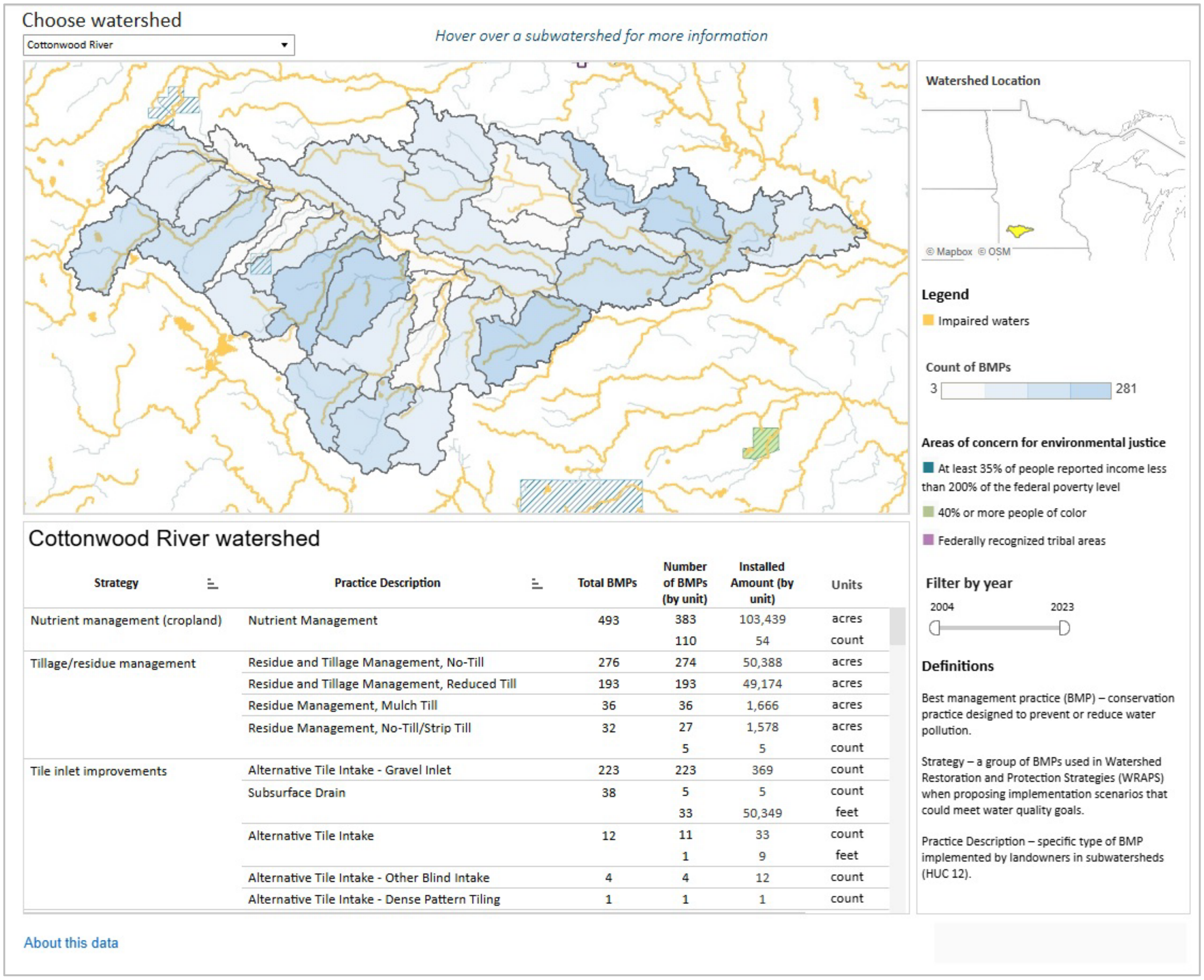


Figure 7-6. BWSR-held conservation easement practices (1986–2025).



The MPCA [Healthier Watersheds website](#) provides information about the number of BMPs implemented by watershed (Figure 7-7) and the spending for implementation projects (Figure 7-8). Project spending can be broken down at the state level and by major watershed and county.

Figure 7-7. MPCA Healthier Watersheds BMP tracking application.



Strategy	Practice Description	Total BMPs	Number of BMPs (by unit)	Installed Amount (by unit)	Units
Nutrient management (cropland)	Nutrient Management	493	383	103,439	acres
			110	54	count
Tillage/residue management	Residue and Tillage Management, No-Till	276	274	50,388	acres
	Residue and Tillage Management, Reduced Till	193	193	49,174	acres
	Residue Management, Mulch Till	36	36	1,666	acres
	Residue Management, No-Till/Strip Till	32	27	1,578	acres
			5	5	count
Tile inlet improvements	Alternative Tile Intake - Gravel Inlet	223	223	369	count
	Subsurface Drain	38	5	5	count
			33	50,349	feet
	Alternative Tile Intake	12	11	33	count
			1	9	feet
	Alternative Tile Intake - Other Blind Intake	4	4	12	count
	Alternative Tile Intake - Dense Pattern Tiling	1	1	1	count

Additionally, MPCA has developed an [NRS BMP Summary application](#) that compares the adoption of practices by basin and includes a summary of all practices by category. It allows the user to break down individual BMP adoption by basin and government program from 2014 to the present (Figure 7-9). This application, as well as the others mentioned in this chapter, will be updated annually to reflect new practice and financial information.

Tracking the conservation practices and actions implemented independently of government programs will be critical to understanding the full picture of improvements and changes happening throughout the state. Improving the methods for capturing information about the private adoption of practices while protecting grower privacy will be necessary to better associate those on-the-ground actions with the nutrient reduction benefits realized downstream. In the future, new initiatives and technologies will need to be deployed to provide the spectrum of data from private adoption to get the truest outlook and trends on practice adoption.

Figure 7-8. MPCA Healthier Watersheds spending for implementing projects in the Cottonwood River Watershed.

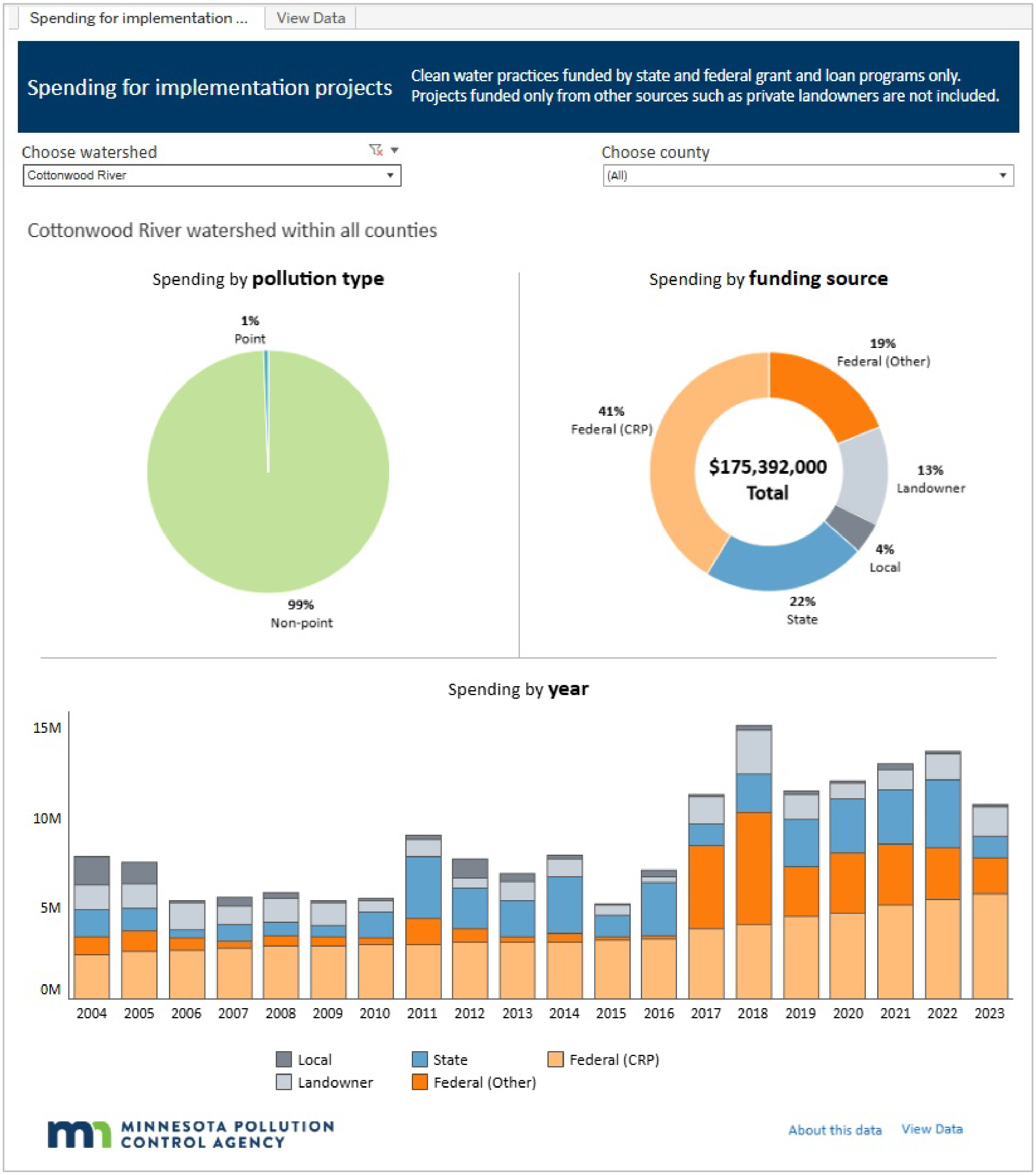
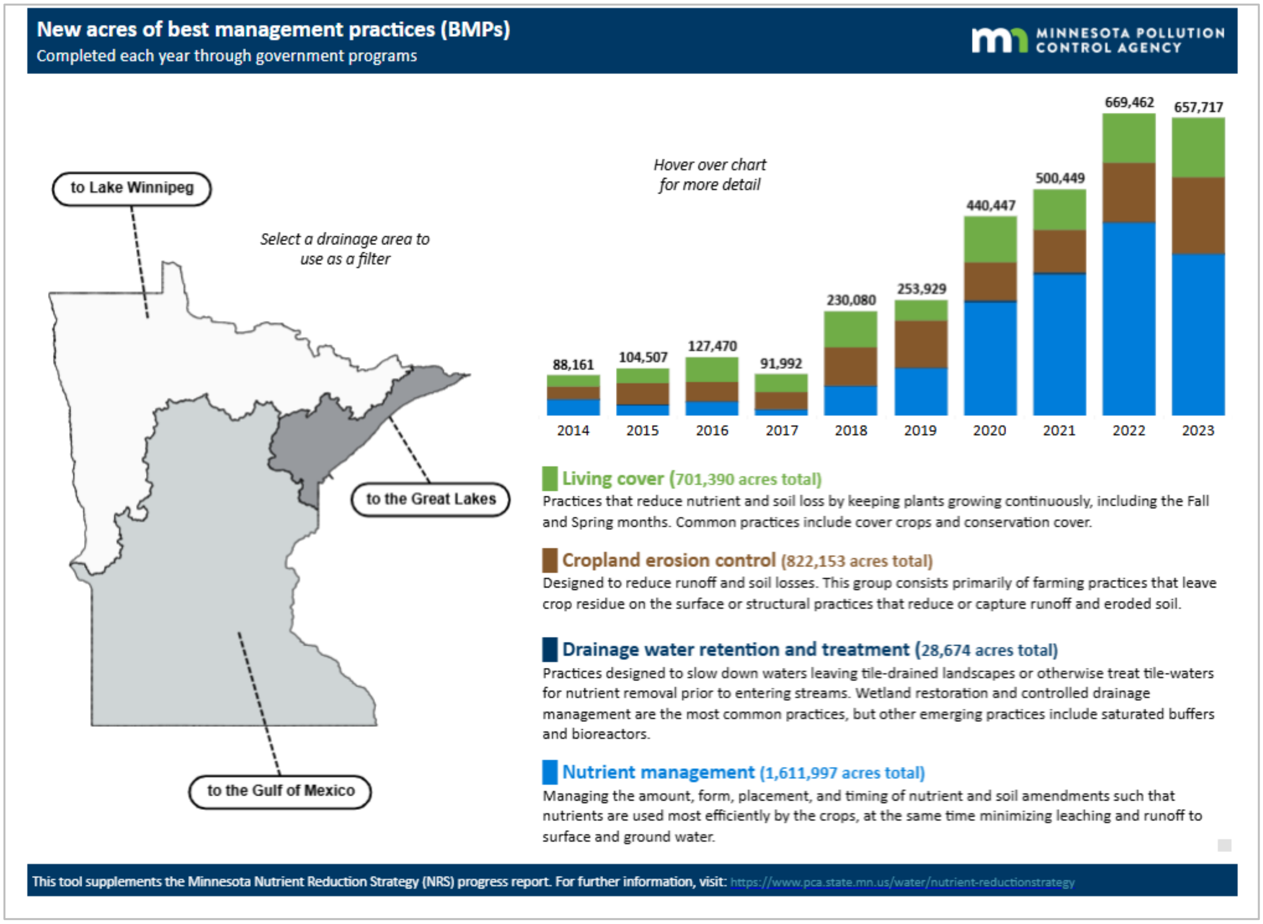


Figure 7-9. MPCA Statewide BMP Adoption Summary Application.



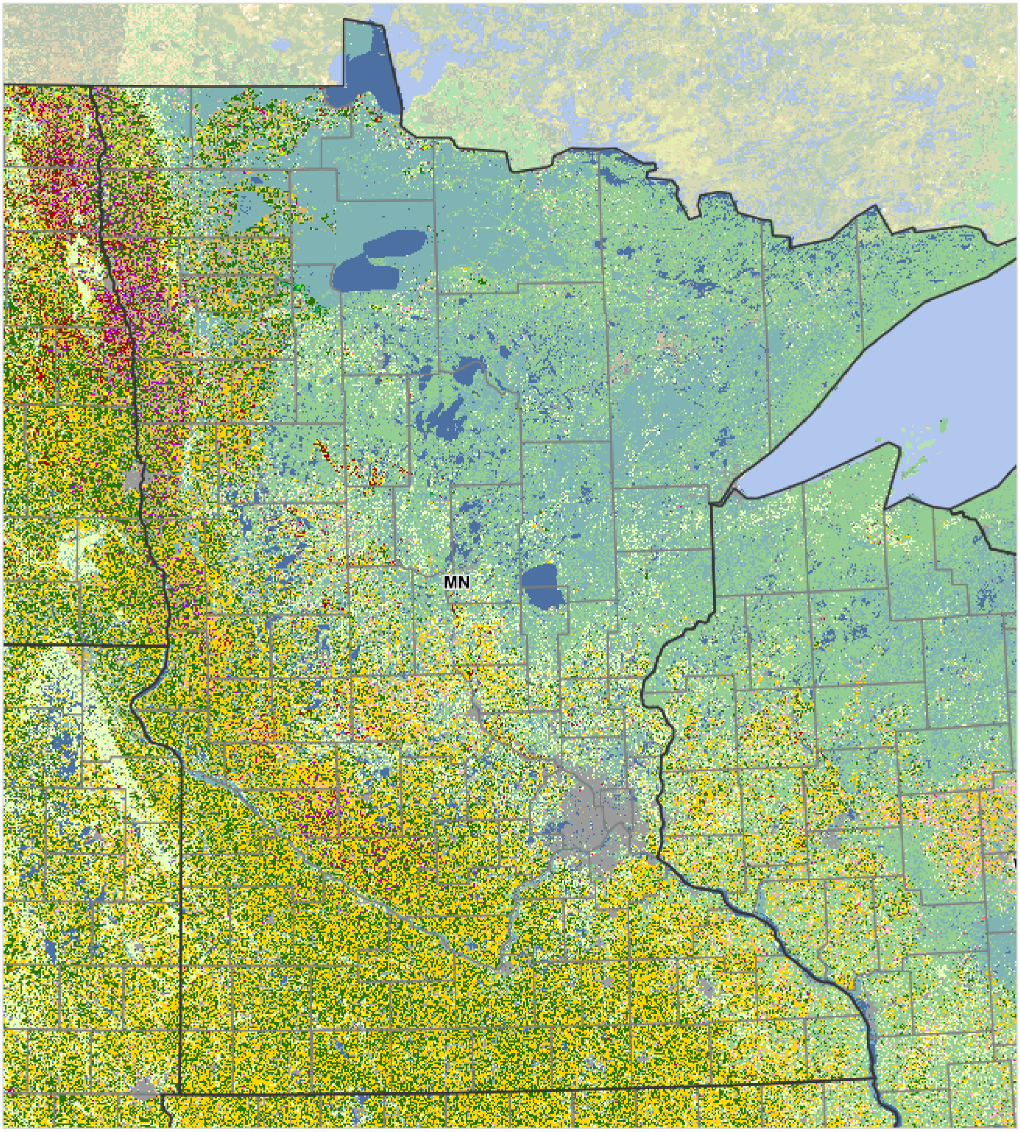
Several efforts described below are underway to capture the private adoption of practices, with a focus on agricultural BMP and continuous land cover adoption. The following projects within Minnesota and other HTF states provide data and analyses that will support NRS tracking now and potentially in the future.

USDA National Agricultural Statistics Service data

The MDA Agricultural Statistics Division partners with the USDA NASS to collect agricultural statistics and survey data that support several efforts, including tracking progress for the Minnesota NRS. One of the long-term surveys, the Census of Agriculture, is completed every five years. A key dataset that drives many efforts is the Cropland Data Layer, which is published annually (Figure 7-10). This layer is a foundational dataset for many watershed modeling programs and is another tracking system that helps inform trends in crops for the NRS.

Further discussion is provided below on possible ways Minnesota could more completely track the adoption of important practices, such as tillage, cover crops, perennials, fertilizer management, and drainage practices. The 2025 NRS did not develop a specific strategy for identifying which approaches will be used in the future, as additional discussions and work are needed to achieve a final plan.

Figure 7-10. USDA NASS cropland data layer for Minnesota.



Tillage trends with long-term USDA and USGS data

Two datasets help show how the adoption of no-till might be assessed. The first is the USGS dataset 573, which is a watershed-based compilation of the historical tillage transect surveys done by the Conservation Technology Information Center. The second is the Census of Agriculture for 2012, 2017, and 2022. When isolating no-till in Minnesota, a historical increase in adoption was identified in the 1990s and early 2000s. Since that point, the number of no-till acres has been relatively stable at around 6% or 7% of tilled acreage while conventional tillage use has trended downward. These data indicate higher levels of adoption of reduced and conservation tillage practices over time. For more detailed information, see Section 5.1.4, "Potential for adding practices to the land."

Remote sensing for crop residue levels and cover crop adoption

Tracking crop residue and cover crops on agricultural cropland is a priority of the 2025 NRS, WRAPS Update products, and CWMPs for reducing nutrient and sediment transport to surface water and groundwater resources. In the late 1990s to early 2010s, the BWSR and Minnesota SWCDs collected in-field tillage transect survey data to estimate the residue cover and tillage methods implemented; however, these data were not collected consistently, and the results were not uniform enough to detect trends. A new methodology was needed to increase the efficiency and accuracy of the data collected related to crop residue and incorporate the cover crop adoption information into the analysis. The UMN and the BWSR worked together to track crop residue, tillage methods, and cover crop adoption using remote sensing analyses. This project was initiated in 2016 and has been supported through the Clean Water Fund since then. Field data are collected in specific agroecoregions to calibrate and validate the remote sensing models. All remote sensing data product outputs are developed at the HUC-12 (minor watershed), HUC-8 (major watershed), county, and agroecoregion scale and do not contain individual farm data. All GIS data is published at the MnGEO Commons, and the analyses are referenced on the BWSR Tillage and Erosion Project and UMN Office for Soil Health websites.

Higher crop residue levels indicate more protection of the soil and use of less intensive tillage systems. Increased crop residue is associated with a reduced risk of soil loss, which in turn will reduce nutrient transport and loss to surface waters. Crop residue levels across Minnesota have gradually increased in recent decades in parts of Minnesota because of several factors, including changes in tillage management systems, changes in crop rotations, and climatic factors. Figure 7-11 shows the average percent crop residue levels across the state since 2017. Higher crop residue levels are found in the southeast and southwest parts of Minnesota, where agricultural fields with higher slopes require additional protection from soil loss, and in central Minnesota's sand plains, where different cropping systems are employed. Lower residue amounts are found in the flatter, poorly drained soils in the Minnesota River and Red River basins.

Cover crops are an important practice for controlling nutrient losses in overland runoff and soil erosion, and from the leaching of nitrogen through the soil profile into agricultural drain tile and groundwater pathways. Cover crop adoption has been increasing since the 2014 NRS was published, but adoption levels remain in the single-digit percentages across the state. Remote sensing analyses can detect cover crop emergence in the fall, but they are not used to detect final spring emergence because of Minnesota's challenging climatic conditions.

Remote sensing analyses underestimate the acres of cover crops planted in the fall in comparison to the USDA NASS surveys because some cover crops do not successfully emerge before the winter, or they emerge at a level that remote sensing cannot detect. Figure 7-12 shows the average acres and percent of cropland with emerged cover crops across the agricultural regions of Minnesota. Overall, most areas of the state have had 1% to 3% of cultivated soils with cover crop emergence; however, areas such as southeast Minnesota, with more beef and dairy cattle operations, and the Red River Valley, with small grains, have shown higher levels of cover crop adoption.

Continuous living cover in agricultural systems

Cropping systems that incorporate CLC are expanding in Minnesota and will be an important strategy to meet NRS goals in the future. CLC includes practices such as perennial crops, cover crops, managed rotational grazing, double-cropping, double-cropping with intercropping, and prairie strips. CLC offers several benefits (Basche and De Longe 2017; Scavo et al. 2022; Huang et al. 2025), including:

- Increased nutrient uptake from deep-rooted systems, which reduces nutrient leaching and improves soil fertility.
- Improved soil health, structure, and infiltration.
- Reduced erosion and transport of sediment-bound nutrients.
- Increased building of organic matter in the soil profile.

Figure 7-11. Average percent crop residue by minor watershed (HUC-12).

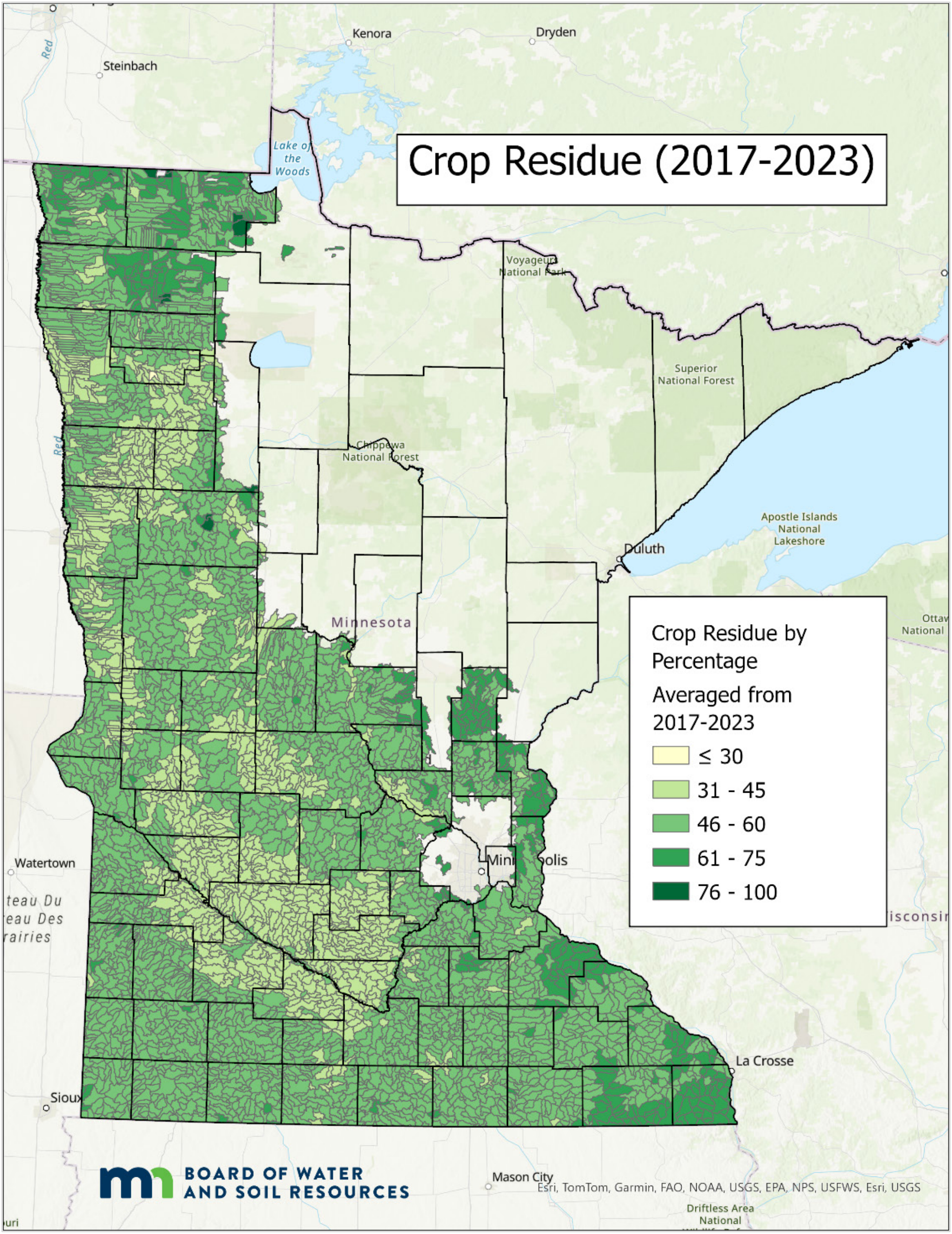
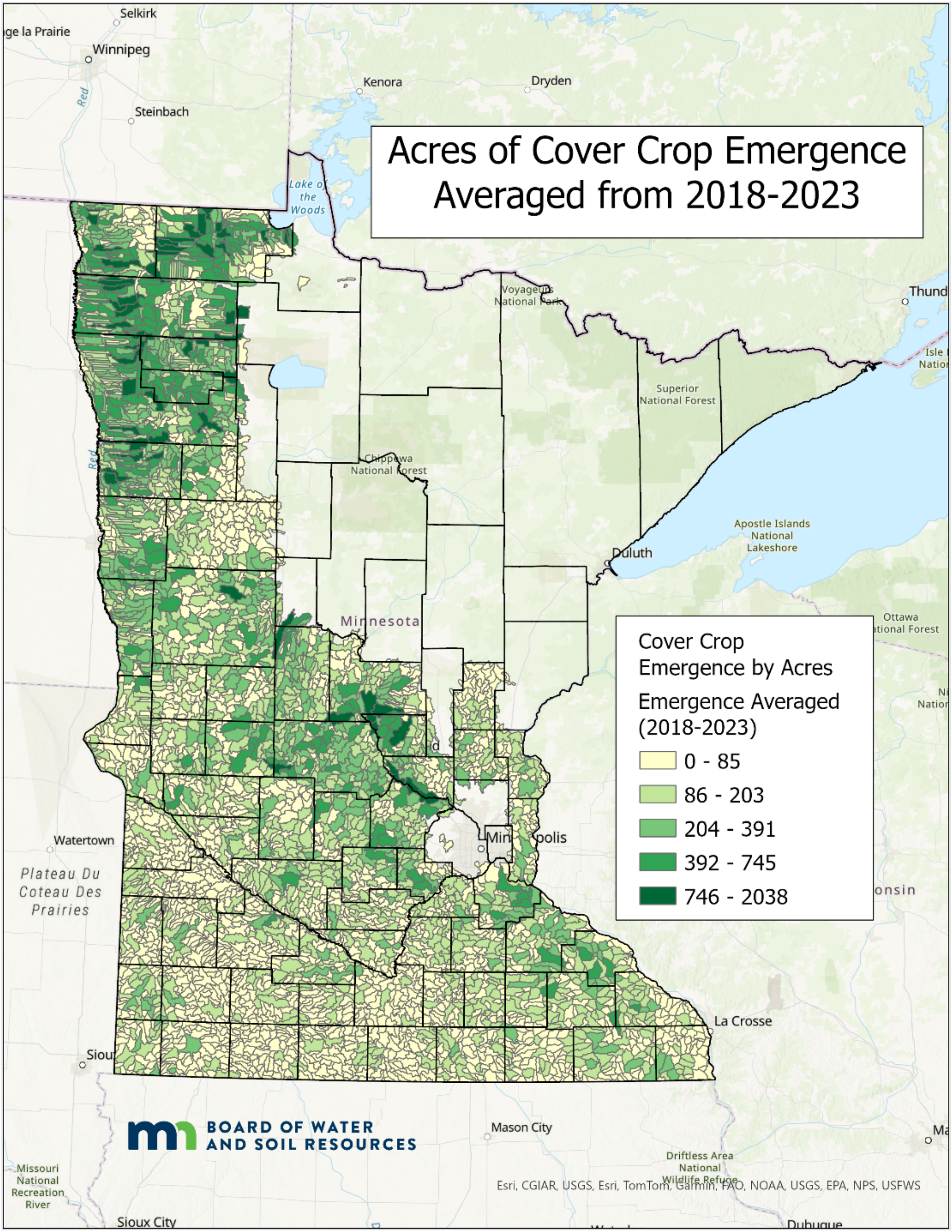


Figure 7-12. Average acres cover crop emergence by minor watershed (HUC-12).



A recent report published by the Friends of the Mississippi River and UMN's Forever Green Partnership, titled *Putting Down Roots*, examined long-term scenarios for increasing the CLC from current (2023) levels to estimated levels for 2035 and 2050. The authors developed a CLC scoring system to evaluate impacts from changes in systems. This report showed that considerable nitrogen, sediment, and greenhouse gas reductions could be realized by including CLC in the current agricultural systems. The report reviewed the latest research to calculate how various CLC crops affect nitrogen impacts.

One future need is to develop an agricultural CLC index to track annual changes in living cover on agricultural lands over time. NRS partners will work with the UMN and other academic institutions to develop methods to track CLC annually in the agricultural portion of Minnesota and track long-term changes on the minor watershed, major watershed, and basin scales. This information will be included in the future NRS dashboard.

Nutrient management tracking

Since 2010, MDA, in partnership with NASS, has conducted extensive farmer surveys to better gauge fertilizer management practices used on Minnesota cropland. This work focuses on collecting data to guide future educational and research programs, gauge the effectiveness of nutrient management programs, and understand trends in fertilizer use efficiency. The MDA's analysis is at the regional and statewide scale and at the farm scale via the use of the Farm Nutrient Management Assessment Program.

Tracking agricultural cropland drainage patterns and trends

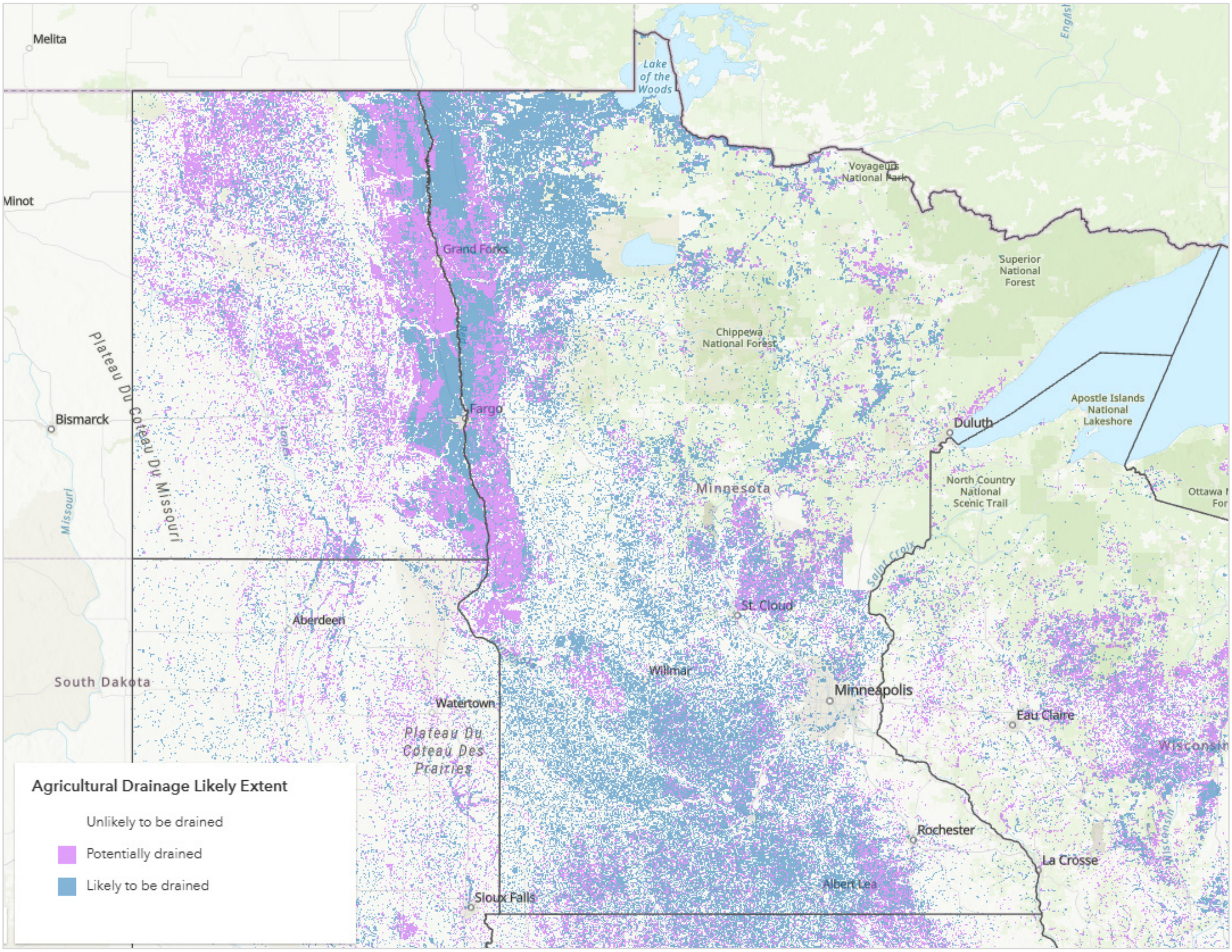
Tracking Minnesota's multijurisdictional public drainage systems and private systems has been a challenge for decades. When watershed districts or counties are the public drainage authority, readily accessible information is available describing public drainage ditches and drainage systems. Information on private systems may not be available to the public. However, limited public data exist regarding agricultural drainage tile within agricultural fields. At a very high level, the U.S. Census of Agriculture has survey data related to farmland with drain tile; these data are updated every five years, with the most recent dataset from 2022.

Modeled data are also available at the national level. Purdue University and other land-grant universities developed the Transforming Drainage website, which includes several resources on agricultural drainage in the Upper Midwest. This research team developed the Likely Extent of Agricultural Drainage tool, which uses publicly available soils and land use data to determine areas likely to have artificially drained agricultural land (Figure 7-13). The user can view the data through the web application or download the data for offline use in a GIS system.

Improving methods of tracking private adoption of agricultural practices

As shown in this chapter, Minnesota has a wealth of information to support the tracking of trends and progress towards goals of practice adoption. The quality and number of data and tracking systems available to visualize and analyze these data have increased since the 2014 NRS document was published. Most of the available practice data is from government-funded programs, landowner surveys, and limited remote-sensing analyses. However, substantial gaps still exist in several areas, including capturing the significant portion of on-the-ground, privately adopted agricultural practices that are not tracked through any reporting system.

Figure 7-13. Extent of likely and potentially drainage agricultural land in Minnesota.



To better track NRS goals, expanded and improved data collection methods on agricultural practices are needed, including those that capture the adoption of:

- Agricultural structural practices (e.g., basins)
- Nutrient and manure management practices
- Small-scale urban stormwater practices (e.g., rain gardens)
- Long-term forestry management practices
- Near-channel streambank and gully protection

Continuous living cover practice

Advances in machine- and deep-learning methods might help better detect the presence of or changes in conservation practice structures or actions that occurred on the land. Iowa State University's BMP Mapping Project is an example of a statewide survey of structural agricultural BMPs in Iowa. This project was very successful but required several years and full-time staff to complete. Reproducing this work in Minnesota would require refining Iowa State University's mapping methods to be Minnesota-specific and including machine-learning methods to automate the process of generating the dataset. MPCA will work with NRS partners in the future to develop a common approach and methodology to better quantify and track these datasets.

7.2.2 Modeling effects of implemented BMPs on nutrient loads

Since the 2014 NRS was published, considerable progress has been made in developing and updating watershed models (e.g., the HSPF/SPARROW models) for most major watersheds and cataloging BMPs funded through government programs. Because of these advancements, the MPCA is working to improve existing tracking tools and develop new ones that combine watershed modeling and conservation practice data into one system.

The MPCA is currently developing the BEET suite of applications that were formally launched in mid-2025; a preview of the first generation of the application can be found in Appendix 7-2. The suite includes the BEET Planner and the BEET Tracker applications. The BEET Planner tool, which is a replacement for the Watershed Pollution Load Estimator Tool, measures the impacts of future conservation practices on nutrient and sediment reductions at multiple scales (e.g., minor and major watershed, major basin) to directly connect with NRS goals. Additionally, the new BEET Tracker application:

- Evaluates the nutrient and sediment reduction impacts of previously implemented practices funded through government programs.
- Allows the user to develop scenarios of past and future levels of practices adopted privately (without government program support).
- Includes estimated reductions from point sources.
- Estimates the overall progress made towards NRS goals.

Over time, MPCA will work with NRS partners to adapt these tools to meet future user needs and expand their functionality. The BEET tools could also be enhanced further to estimate other co-benefits of practices used for nutrient reduction (e.g., greenhouse gas reduction, water storage), which can help planners better understand the more complete benefits expected when investing in various practices.

7.3 Evaluating water quality

Water quality monitoring and modeling efforts in Minnesota are foundational to the support of tracking progress for the NRS. The MPCA will work with state agency partners, the Met Council, and USGS in a comprehensive effort to collect and analyze data and develop predictive models to track long-term trends in nutrient concentrations and loads. Work will focus not only on surface water trends, but also on nutrient trends in soils and nitrate trends in groundwater. Partners will use adaptive management approaches to fill data gaps and improve methods to further hone the ability to track long-term water quality trends at multiple scales.

7.3.1 Nutrient loads leaving Minnesota

TN and TP annual loads in major rivers near state lines will continue to be monitored and assessed for NRS goals. Because annual loads fluctuate widely depending on weather, climate, and river flows, several indicators of progress will continue to be reported as described in Chapter 2 and displayed at MPCA's NRS website. The strongest indicator of progress evaluation will be flow-normalized load trends through the WRTDS model, or other similar approaches used by USGS. Once the NRS Dashboard is built, the MPCA will annually update a web-based display to show the flow-normalized trend results and relate the most recent loads to both the original baseline and the final NRS load goal at the following locations:

- Mississippi River close to the Minnesota/Iowa border at Lock and Dams 7 and 8 (USGS)
- Mississippi River at Winona (MPCA)
- Mississippi River at Red Wing (Met Council)
- Minnesota River at Jordan (Met Council)
- Red River at Emerson (Manitoba and MPCA)
- Rainy River near Lake of the Woods (MPCA)
- St. Louis River at Scanlon (MPCA and USGS) and other Minnesota tributaries to Lake Superior (MPCA)

In addition to showing the flow-normalized loads, the MPCA will display a running average of non-normalized loads and FWMCs; these results will be compared to baselines and goals.

7.3.2 Nutrient concentrations in Minnesota lakes, streams, rivers, and groundwater

In-state nutrient concentrations will continue to be monitored and assessed against nutrient-related standards and protection goals. The results will be updated, consolidated, and displayed at MPCA's NRS website. The following information will be tracked and displayed:

- **Lake phosphorus concentration trends** across the state, including the percentages increasing, decreasing, and having no trend (MPCA).
- **Lake eutrophication impairment** status reports and changes (MPCA).
- **River nitrate and phosphorus concentration trends** across the state, including maps and percentages showing increases, decreases, and having no trend, using flow-normalized and non-normalized statistical trend methods (MPCA analysis of Watershed Pollutant Load Monitoring Network results; Met Council analyses of river and stream trends sites in the Twin Cities area; and MDA's evaluation of heavily tiled watersheds).
- **River progress toward standards**, including the status and progress related to rivers meeting standards associated with nutrient concentrations (MPCA).
- **Well water nitrate concentration trend**, including directions in surficial and vulnerable aquifers across the state (MDA and MPCA ambient groundwater monitoring network).
- **Well water nitrate progress status**, including nitrate levels in comparison with standards (MPCA and MDA ambient monitoring; MDH and MDA private well testing networks; and MDH public well testing information).
- **Successes**, including local nutrient concentration (or load) reductions confirmed through rigorous monitoring and documentation of the changes made that caused the improvements.

7.3.3 Soil nutrient balance – estimating inputs and outputs

The USDA Agricultural Research Service led an effort to better estimate and track a nutrient budget for commercial fertilizer and manure on agricultural lands (Porter and Conowall 2025a). Using GIS methods described in published research, nutrient application estimates were modeled and compared to crop nutrient needs and removal. Nutrient budget findings were summarized at a watershed scale, which will enable watershed planners to use the information to prioritize nutrient-related conservation work and funding. This information will help inform local strategies for watersheds, including where manure and fertilizer additions might occur, where nutrient imbalances could lead to environmental loss through runoff and infiltration, and where potential nutrient reductions could be achieved through soil management. Over time, the degree of nutrient imbalances in the state can be approximated and tracked as another indicator of nutrient reduction progress. Details of the nutrient balance methods and results can be found in Section 5.1.4.

The NRS recommends continuing the efforts to improve and update the nutrient balance findings as data sources and methods improve and as cropping and nutrient addition amounts and patterns change over time. The spatial framework of the Agricultural Research Service modeled analysis provides a platform for integration with other data layers, water quality monitoring, and nutrient models. MPCA will develop a future online visualization tool that will allow conservation practitioners, agronomists, and the public to view the project outputs.

7.4 Evaluating program progress


High Island Creek, a tributary of the Minnesota River

Minnesota agencies currently measure, track, and report the performance and effectiveness of several programs that support NRS efforts. In Chapter 6, the methods of tracking WRAPS Updates, TMDLs, and the federal CWA Section 319 Program at MPCA are outlined, as well as BWSR's tracking of CWMP development through the 1W1P program. MPCA reports on watershed efforts through the Healthy Watersheds website, which is the hub for tracking projects and actions, and also reports on program success (see Section 7.6.1). BWSR tracks the effectiveness of the delivery of their programs through the Performance Review and Assistance Program, which assesses the performance of local units of government responsible for conserving water and related land resources. Federal agencies also have many mechanisms to evaluate the performance of their programs. One notable tracking program is the USDA NRCS Conservation Effects Assessment Program, which examines how federal USDA program funds and the practices implemented using those funds affect water quality.

The state's Clean Water Fund through the CLLWA is a critical source of funding and resources to support efforts like the NRS. State agencies, the Met Council, and UMN biannually publish the Clean Water Fund Performance Report, which provides a snapshot of how Clean Water Fund dollars are being spent and the progress made. The measures are organized into four categories: investment, surface water quality, drinking water protection, and external drivers and social measures. Each measure has detailed status ranking and trend information. This existing, ongoing report will be used in tracking program success related to the NRS.

7.5 Evaluating human dimension changes

Meeting the NRS goals will require landowners in Minnesota to significantly change their current adoption rates for agricultural, urban, and forestry conservation practices. It will also require technological advances, policy changes, and increased public and private financial support. Human adaptation to changes from the current systems and paradigms to a future condition where NRS goals are met will be challenging. Financial constraints and economic factors impacting landowners today and into the future will be limiting factors in achieving NRS goals. The NRS will help facilitate the tracking of demographic and socioeconomic changes over time that affect Minnesotans' ability to address nutrient issues. Outreach and engagement efforts with the public will be tracked, along with the capacity of partners to help implement these efforts. This section will explore concepts for tracking and facilitating needed changes.

7.5.1 Agricultural survey results

The agricultural community is the key audience for making the land use and management decisions that will ultimately affect the pace of change for the NRS. Research and findings on how to best assess the human component of change related to adopting agricultural conservation practices have been lacking. As discussed in Chapter 5, the MPCA contracted with UMN to develop a guide (see Appendix 7-1) to better understand the key indicators and measures for tracking and monitoring the success of the human dimension in conservation actions. This report provides context and support on the critical questions to ask agricultural producers to better understand their perceptions and the factors that drive them to implement conservation efforts to improve water quality. A summary of the report's key indicators and measures is provided in Table 7-6.

Table 7-6. Indicators from UMN's *Guide to Track and Monitor Human Dimensions of Conservation Action.*

Key indicators	Description	Measures
Awareness of a water resource problem and its consequences	Knowledge that a water resource problem exists and has consequences for the well-being of oneself and others.	• Perception of water quality and water protection • Awareness of consequences of water pollution • Awareness of pollutant types and sources
Concern about water resource problems	Individual's concern about water pollution and its consequences for themselves, others, and the natural world.	• Concern about local water resource problems • Concern about the consequences of water pollution
Responsibility to protect water resources	Sense of connection to the problem (e.g., water pollution), its consequences, and a realization that one's actions can help address the problem.	• Personal responsibility to protect water • Collective responsibility to protect water
Personal norms of conservation action	Feelings of moral obligation to take actions to address a problem like water pollution.	• Personal obligation to protect water resources
Social norms of conservation action	Rules and standards that are understood by members of a group and that guide and/or constrain social behavior without the force of laws.	• Social norms of conservation action
Perceived ability and efficacy to take conservation action	Perceptions about the availability of resources (e.g., knowledge, financial resources, equipment) needed to act (e.g., plant cover crops).	• Perceived ability to take conservation action • Perceived self-efficacy to protect water • Perceived collective efficacy to protect water
Perceived benefits and risks of conservation practices	Perceptions about the benefits of conservation practices have a positive effect on adoption decisions, while perceived risks of practices have a negative influence.	• Perceived benefits of conservation practices • Perceived risks of conservation practices
Conservation action	Conservation actions include private-sphere actions (e.g., using/maintaining conservation practices) and public-sphere actions or civic engagement (e.g., participating in a water resource protection initiative, attending a meeting about water resources).	• Current use of conservation practices • Intention to use conservation practices • Current engagement in conservation action • Intention to engage in conservation action • Support for conservation programming/policy

Source: Pradhananga et al. 2023.

To build on the guide, UMN surveyed farmers to collect their perceptions, experiences, and behaviors about the actions related to conservation and soil health practices and what was needed to increase acceptance and adoption of those practices. Sixty percent of respondents (n > 1000) identified as mid to late adopters of new practices stated they would only adopt new practices after others have demonstrated them to be successful. Over 45% of survey respondents had never met with a conservation professional to discuss soil management or sought out technical or financial support for soil health management practices. Many producers (63%) feel they have no control over policies that affect their farm and land, and most agree (55%) that economic factors influence their ability to change soil health practices. However, over 75% of producers agree that making sure their land stays in the family for the next generation is an important factor influencing their soil management decisions. The completed results of this survey were published by the UMN Water Resource Center in September 2025: Soil Management Farmer Survey. A follow-up survey will be conducted (estimated 2028) to measure change in adoption attitudes, experiences, and behaviors over time.


Bluffs along the Mississippi River

The Soil and Water Conservation Society and Iowa State University developed a nationwide conservation practitioner survey that reviewed the opportunities and challenges of implementing more on-the-ground conservation work. This study included polling data from many states, and approximately 15% of the respondents were from Minnesota. The 2024 Conservation Practitioner Poll Summary Report provides a comprehensive look at the experiences of over 300 conservation professionals across six Upper Mississippi River Basin states (Arbuckle et al. 2024). Building on the inaugural 2021 survey, the 2024 poll captures the voices of those on the frontlines of conservation, offering critical insights to inform policies and improve conservation program delivery. Conservation practitioners shared their thoughts about different kinds of support that would help increase the effectiveness of their conservation work. Survey sections centered on human and other resource needs; ways that processes, procedures, and systems might be improved; and professional development needs.

Significant changes in farm size and income have occurred in recent decades, shaping the dynamics of conservation practice adoption. The 2022 Census of Agriculture (USDA 2024) reported 65,531 farms in Minnesota, down from 94,382 in 1982, with the average farm size increasing from 294 to 388 acres over that period. Since the publication of the 2014 NRS, farm income trends in Minnesota have been highly variable, with sharp declines in recent years. In 2024, median net farm income fell to just $21,964—the lowest level this century—driven by declining crop prices and below-trendline yields. Farm profitability has eroded since 2022, leaving many producers with reduced working capital, limited net worth growth, and minimal profitability. These financial realities provide critical context for assessing farmers' capacity to adopt conservation practices. Research from Iowa State University has shown that farms with higher profitability are more likely to adopt conservation practices (Prokopy et al. 2019). Looking forward, farm income trends will continue to be one of the most important factors influencing whether producers can invest in new conservation measures. USDA datasets will be analyzed periodically by the NRS Team to see if any changes in trends are occurring.

7.6 Displaying and communicating strategy progress

A multimedia approach will be used to communicate NRS progress to partners, decision-makers, and the public. The world of technology and communications is rapidly changing, and NRS partners will strive to use the latest methods of creating and distributing content in a user-friendly manner to communicate progress. The section focuses on explaining the existing applications and the actions to be taken to ensure that progress is not only tracked but also shared effectively with interested parties.

7.6.1 Existing tracking tools for showing progress in Minnesota

After completing the 2014 NRS, MPCA and NRS partners identified the need to develop tracking systems that would allow the public to better access nutrient-related data and analyses. MPCA and other agencies began using web-based visualization tools in the late 2010s to present data to the public in an interactive way that was easy to update and maintain. Since the early 2020s, agencies' adoption of web-based tools has accelerated, supporting many water quality efforts, including the NRS. Technological advances and the increased capacity of NRS partner agencies to develop and maintain these web-enabled applications are the main drivers for the shift in how data are accessed and viewed. Some of the tools were showcased in Chapter 6 and earlier in Chapter 7. Only tools with strong foundational data and technical review will be considered and added to the future NRS dashboard. After being placed on the NRS dashboard, the tools and applications should be improved as new and updated data and approaches become available. Table 7-7 provides an overview of the existing tools and other tools under development as of 2025. More details about these tools can be found in Appendix 7-2.

Table 7-7. Summary of existing tracking tools that support NRS efforts.

Name of tracking tool	Description	Responsible partner
Healthier Watersheds – WRAPS Status	Status of WRAPs Updates, the intensive watershed monitoring schedule, and the status of stressor identification reports statewide.	MPCA
Healthier Watersheds – TMDL Status	Status of statewide TMDL development, progress towards addressing impaired waters, TMDL load allocations by impaired water body, and a map of delisted waters in Minnesota.	MPCA
Healthier Watersheds – WWTP Progress	Wastewater pollutant loading and measured reductions by watershed and facility.	MPCA
Wastewater Effluent Flow of Nutrients	Interactive map of wastewater effluent flow of nutrients by watershed and facility.	MPCA
Heathier Watersheds – BMPs Implemented by Watershed	Quantifies the number of BMPs implemented, by watershed, through government-funded programs.	MPCA
BMP Implemented by Basin for the Nutrient Reduction Strategy	The application uses data collected through the Healthier Watersheds effort to show the levels of annual adoption of practices statewide and at the major basin scale.	MPCA
Healthier Watersheds – Spending for Implementation Projects	Quantifies the amount of government funding for BMPs implemented at the statewide, watershed, and county scales.	MPCA
Long-Term Stream Nutrient Trends	Provides long-term trend data on nitrate, phosphorus, and sediment pollutant concentrations across Minnesota.	MPCA
Watershed Pollutant Load Monitoring Network (WPLMN) Viewer	Measures and compares average, annual, and daily pollutant loads from long-term monitoring sites.	MPCA
Watershed Health Assessment Framework (WHAF) Explorer	Provides an index of watershed, stream, and lake health information in the form of reports, charts, and maps. Includes an interactive mapping interface to view geospatial data statewide.	DNR

State and local tracking systems at the major watershed or CWMP level

Throughout the CWMP development process, many local governments have developed their own tracking systems to coordinate the management of plans, grants, and contracts; landowner agreements; project financials; and environmental outcomes. Local elected officials and the public have a keen interest in seeing the impacts of implementing their CWMPs in easy-to-understand visual formats. One challenge facing local governments is the rapid evolution of technology available to display their CWMP implementation progress and how to best tailor the tracking tools to meet their constituents' needs.

7.6.2 Interpreting results from the NRS

The NRS provides a comprehensive framework that integrates multiple lines of evidence and analytical perspectives. This begins with establishing baseline conditions and analyzing key water quality metrics, including TP and TN concentrations and loads at the state line, for the three major basins. The NRS emphasizes the importance of tracking nutrient source contributions, evaluating the implementation progress of BMPs, and conducting economic analyses to assess cost-effectiveness. It incorporates adaptive management principles, social indicators for human change, and progress tracking toward specific reduction targets. The NRS also highlights the significance of using the watershed approach and integrating efforts with other water quality programs during implementation, while also acknowledging the need to consider both short-term and long-term trends, climate variability, and the lag times between implementation and water quality response.

This strong foundation of data and analyses is the key to being able to draw conclusions and interpret results and trends. Several online resources highlighted throughout this document display crucial data, analysis, and trends related to measuring progress. Online video guidance will be developed to show how to use the tools and resources. However, to understand what these resources show, interpretive analysis is often needed by people working more directly on nutrient reduction issues. The MPCA will work with NRS partners to develop online video content providing regular summaries of results with interpretative summaries on what it means for NRS progress.

7.6.3 Communicating progress – intended plans

Because the data on which NRS progress is tracked and the NRS progress itself can be complicated to understand, MPCA will work with NRS partners to update the existing NRS communication plan to provide both a technical and general perspective on the ongoing NRS implementation. A work plan will be developed to coordinate across agencies and ensure communication efforts are being implemented consistently moving forward, and that information is tailored for specific audiences (e.g., rural landowners). Progress will focus closely on the key metrics and measures identified earlier in Chapter 7, significant opportunities or challenges that are bringing change, and resource management changes that have been implemented to better meet NRS goals. The primary communications tool will be the NRS website and dashboard; to ensure the messaging is accessible to most audiences, the communications plan will include a schedule for hosting summary materials on the NRS website.

In addition to the NRS website and dashboard, the nutrient reduction efforts of Minnesota are reported in the following ways:

- **Existing reporting**
  - **Biannual Gulf Hypoxia Report to Congress**: Minnesota, along with its partner HTF states, provides the EPA with a biannual update on NRS progress that is incorporated into an annual report to Congress. This report outlines actions taken by each state to meet the goals in the hypoxia action plans and the goal framework for the Gulf.

- **HTF annual meeting**: The HTF meets annually to share efforts from the states, discuss future actions to be taken, and obtain public input and comments. This venue provides Minnesota with an opportunity to update this group and garner feedback on the processes and actions being implemented.
- **IRRWB report**: Each August, Minnesota shares an annual report with the IRRWB that includes information on the WRAPS Update cycle, TMDLs, NPDES permitting, flood reduction efforts, and 5-year monitoring program reports. Minnesota agency staff working with the board have asked that nutrient-related updates be included in this report in the future.
- **Lakewide Action and Management Plans for the Great Lakes**: Each summer, Minnesota submits information to the EPA about the status of the Minnesota regions of Lake Superior to be included with data from Canada in an annual report.

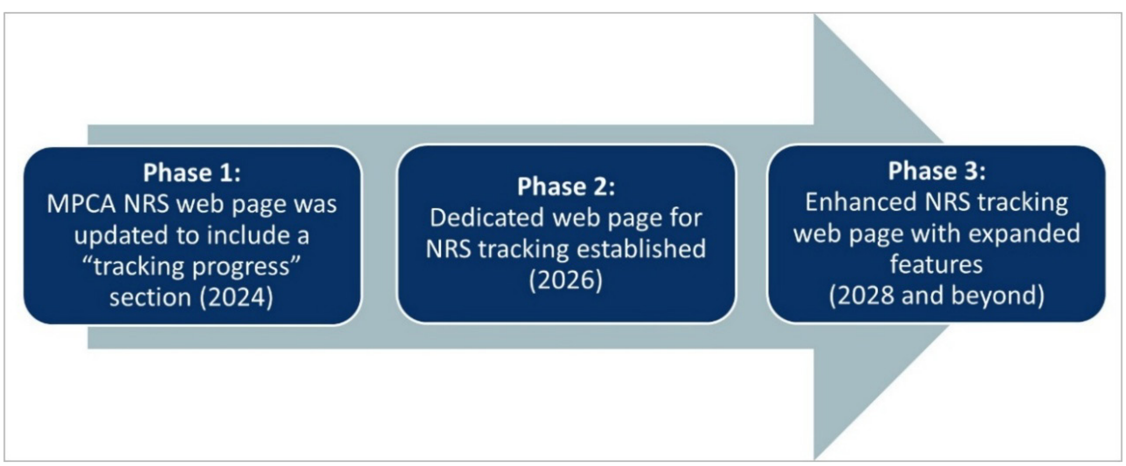
- **New reporting**
  - **Proposed biannual report on program success**: NRS partners should work collaboratively to develop and publish a biannual report on the status of nutrient reduction efforts, actions taken during this period, and progress towards goals. This report will include trends regarding key metrics and indicators for change that have been outlined in the NRS (see Section 7.2), organized by major basin (the Lake Winnipeg/Red River, Lake Superior, and Mississippi River basins). This biannual report will be shared with elected officials, state agency leadership, and the Clean Water Council. This report will be made available to the public on the dedicated NRS website.
  - **Proposed annual partner meeting on nutrients**: An annual meeting should be instituted to provide a forum for partners to provide input on NRS progress, share information related to nutrients and related research, present training on new NRS tools and guidance, and provide feedback on future actions to be undertaken.

7.6.4 Tracking website development and dashboard design

Since the inception of the 2014 NRS, significant progress has been made in visualizing NRS-related datasets and tracking progress in public-facing, web-based environments. MPCA will work with NRS partners to update existing applications, develop new applications, and enhance the public's web experience over the next few years.

Figure 7-14 outlines the development timeline for tracking progress on the web. In 2024, for Phase 1 of this work, MPCA reconfigured and updated the existing NRS web page and created a section on tracking progress, which included the suite of existing visualization tools that support the NRS. Phase 2 is

Figure 7-14. NRS tracking website timeline.

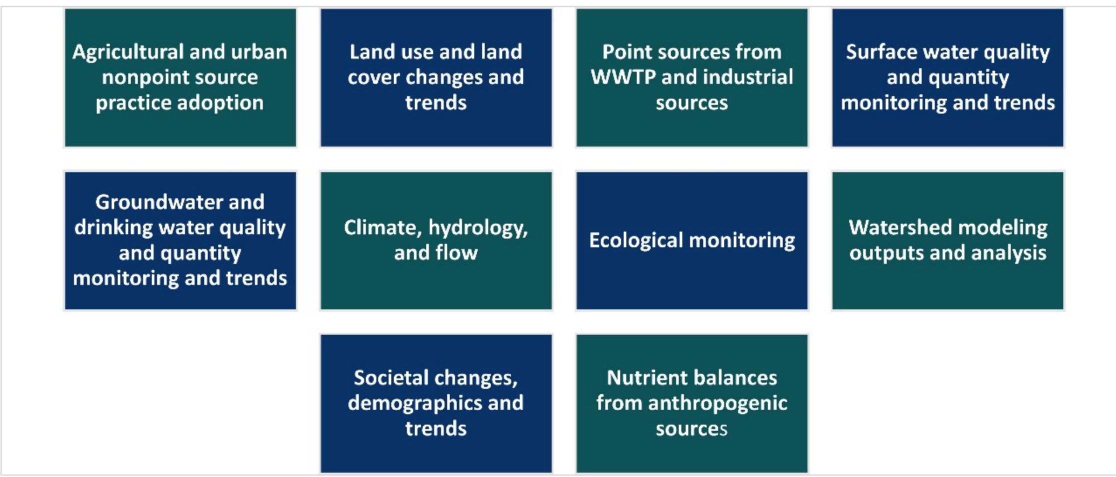


establishing a dedicated NRS progress-tracking web page that will include links to data visualization tools, interactive maps, fact sheets, and video content. This phase will use existing tools and datasets and include a limited number of new visualization tools; the expected rollout is in 2026. Phase 3 will enhance the work completed in Phase 2 and will include new data, tools, and embedded interactive applications for public use. Phase 3 will also explore the concepts of developing accessible and easy-to-use, web-enabled dashboards that provide critical information to the public.

Additionally, the MPCA will work with interested partners through focus group efforts in 2026 to get feedback on the scope and direction of Phase 3 to ensure future development meets the public's needs.

In developing tracking systems and dashboards, understanding the critical data needs is an important step in creating a web experience that is comprehensive and informative. Figure 7-15 illustrates some of the critical components that will be considered for development by NRS partners. For the NRS tracking system, these components will be a part of a suite of media content, including interactive dashboards.

Figure 7-15. Critical components of the NRS tracking website.



For Phase 3 of the web-based tracking system development, enhanced dashboard designs will be developed and implemented to improve the user experience. MPCA will work with NRS partners, private consultants, and the MPCA's in-house staff in communications, web design, data analysis, and information technology to develop a framework that includes more advanced dashboard elements on the NRS tracking web page. Minnesota will consult with other states that have developed or are currently developing dashboards and tracking systems for their NRS, such as Iowa's comprehensive dashboard and Arkansas's interactive story map.

7.6.5 Concepts for future tracking and visualization tool development

To fully support the NRS progress tracking over the long term and develop an integrated dashboard approach to displaying data, MPCA and its agency partners will need to develop new applications to support and complement the existing online visualization tools outlined in this chapter. Table 7-8 summarizes a list of potential tools that can support NRS progress tracking. NRS partners will help advise the prioritization and development of future tool concepts. The MPCA will provide periodic updates to NRS partners and the public on the status of developing and deploying progress tracking tools. MPCA will prioritize enhancing existing tools in the short term and focus on developing new tools based on feedback from NRS partners, availability of funding and staff resources, and how well the new tools will complement the NRS dashboard.

Table 7-8. List of potential future NRS tracking and visualization tools.

Topic or tool	Description	Data source
State line nutrient load interactive map	Develop an interactive map to accompany the *Watershed nutrient loads to accomplish Minnesota's NRS Goals* document.	USGS, MPCA
Minnesota NRS priority watershed interactive map	Develop an interactive map to display the watershed priority maps from Chapter 3 of the 2025 NRS.	MPCA, DNR
SPARROW Model Visualization Tool	The USGS is planning to update the SPARROW national nutrient watershed model web application to include more recent modeling. This new national data could be incorporated into a Minnesota-specific web application.	USGS, MPCA
BMP economics online tool	Display the economic data and analysis from the "N and P BMP Tool" spreadsheet developed by the UMN Applied Economics Department into an online application.	UMN, MPCA, MDA
BMP map viewer for BWSR eLINK BMP database	Develop an online interactive map to display conservation practices from the BWSR eLINK database.	BWSR
Urban stormwater BMP adoption	Develop an application to display data, statistics, maps, and trends of urban stormwater BMP adoption in the Twin Cities Metro Area and other larger urban areas in Minnesota.	MPCA, BWSR, Met Council, local governments
Soil health, conservation cover, and CLC interactive map	Develop an interactive map to display information regarding crop residue and cover crops (see Figure 7-11 and Figure 7-12). Develop a tracking application to display data, statistics, and trends related to soil health and CLC.	BWSR, UMN, MPCA, NGOs
Tracking outreach events and long-term trends	Develop an application that displays data, statistics, and trends of major outreach events and activities related to nutrient reduction and efficiency in Minnesota.	All state and federal agencies, UMN


Mississippi River in southeastern Minnesota

7.6.6 Tracking systems at the regional and national level

Federal government partners (EPA, USDA, NOAA, USGS) and NGOs in the United States have created several interactive maps and tracking systems for Gulf hypoxia-related data. These systems are continually evolving to provide context and background, data, and analyses related to nutrient issues nationwide for scientists, decision-makers, and the public.

The EPA Northern Gulf of America Hypoxic Zone website includes an interactive application that displays the changes in the size and extent of the hypoxic zone on an annual basis. Figure 7-16 is an example of a map that can be viewed and downloaded from the site, and Figure 7-17 graphically shows the size of the hypoxic zone over time.

Figure 7-16. Gulf hypoxic zone dissolved oxygen levels in 2024.

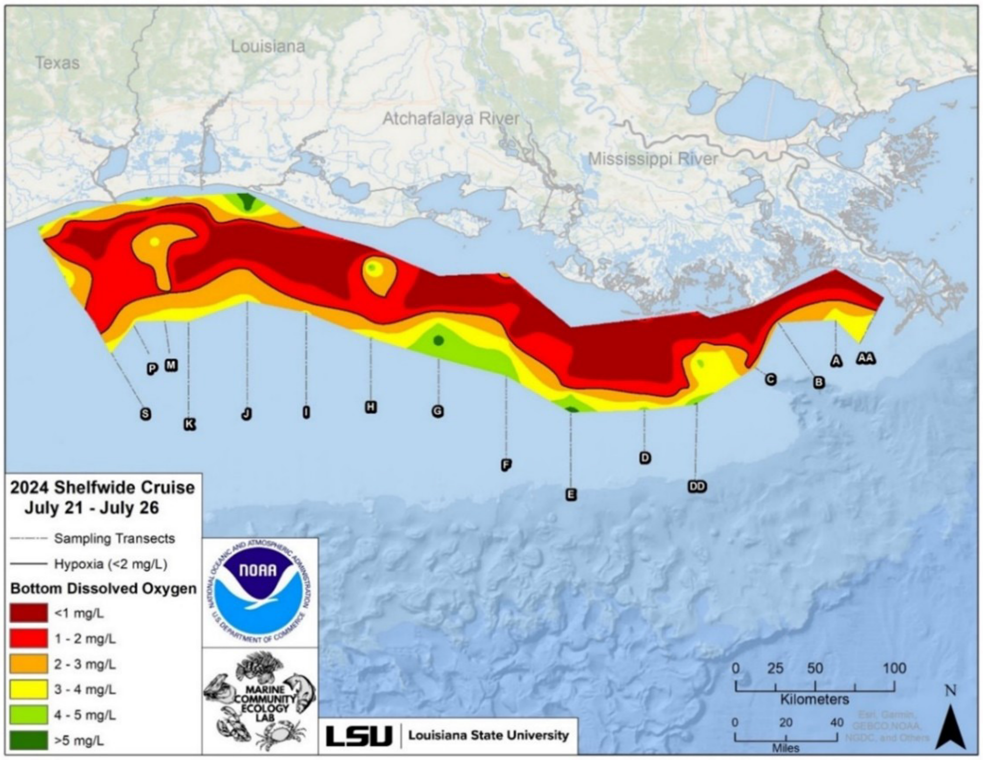
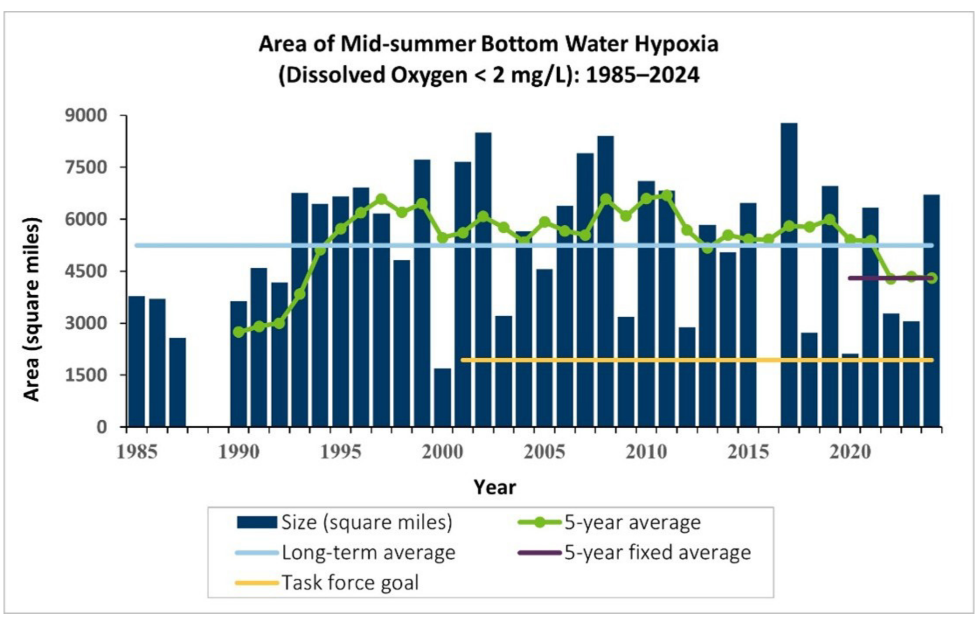


Figure 7-17. Size of the Gulf's hypoxic zone (1985–2024).



Source: NOAA 2025.

NOAA's Gulf of America Hypoxia Watch website (Figure 7-18) provides an interactive map of the hypoxic zone and provides access to annual dissolved oxygen sampling data. The USGS provides an interactive graph on the annual nutrient loads and trends for the Gulf (Figure 7-19), which is updated yearly and outlines the current trends and how they relate to the goals set by the HTF.

Figure 7-18. Gulf Hypoxia Watch web application showing 2024 hypoxic zone.

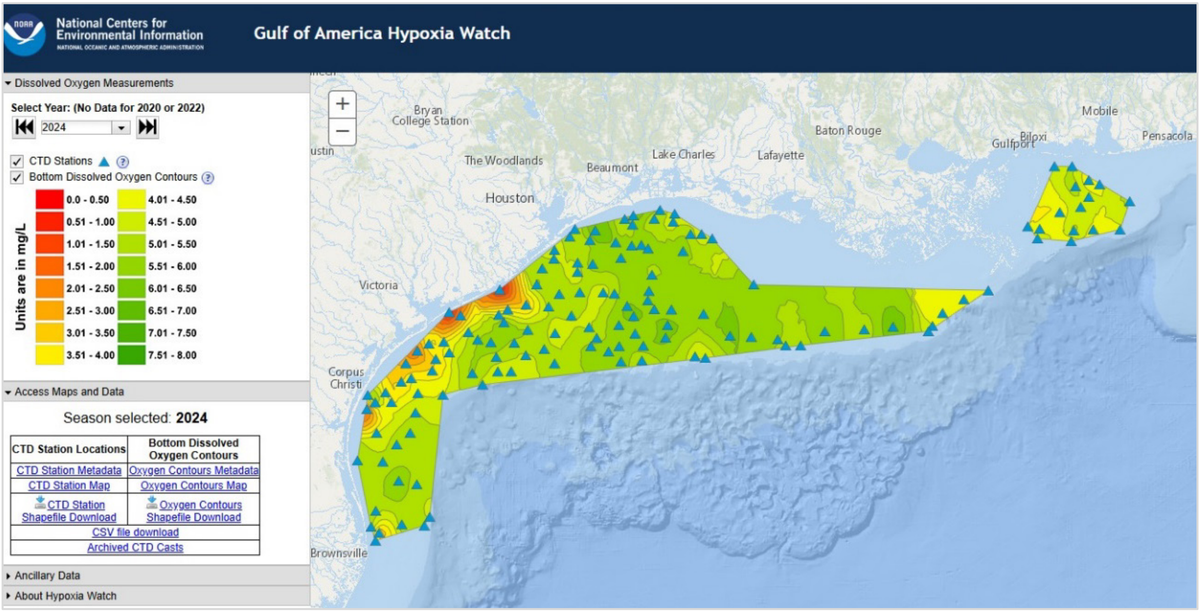
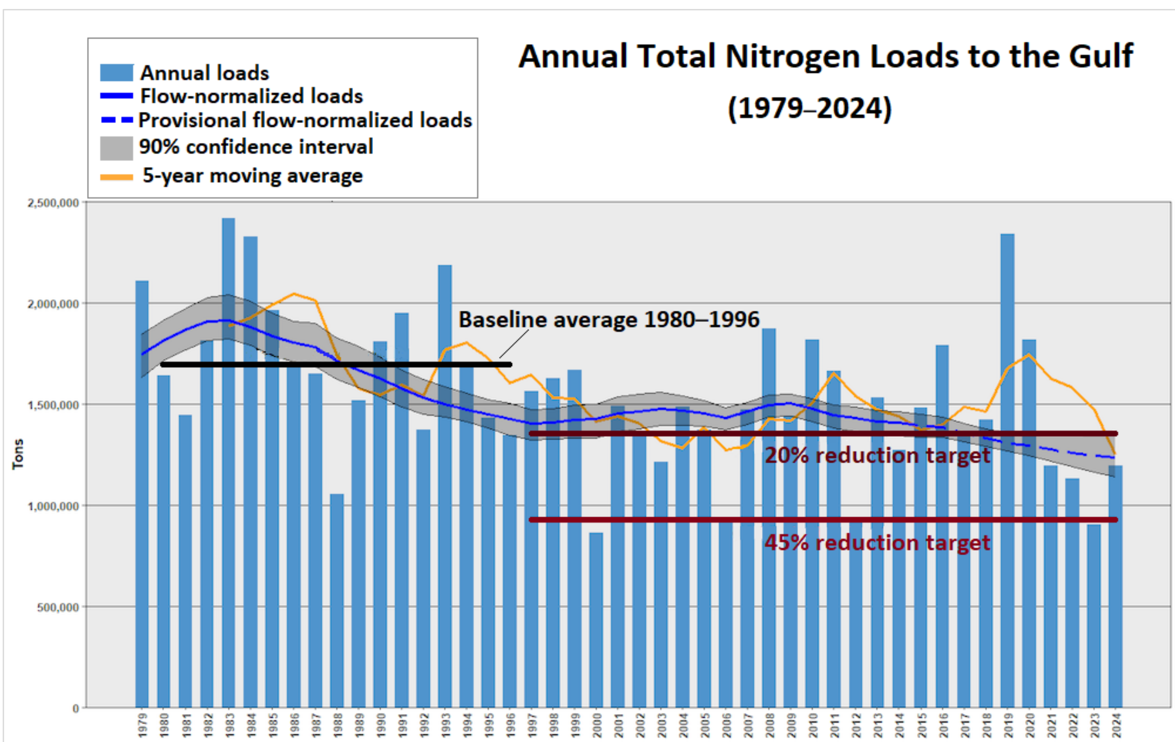


Figure 7-19. Gulf annual nutrient loads and trends.



The National Great Rivers Research and Education Center organization partnered with the University of Illinois to create the online Great Lakes to Gulf (GLTG) tracking system. The GLTG is an interactive website that provides curated nutrient-focused water quality information about the Mississippi River and its tributaries. GLTG takes a massive amount of complex water quality data from across geographies and standardizes, distills, and presents it in accessible and easy-to-understand formats for scientists, managers, advocates, and the interested public. This application shows nutrient levels and long-term trends throughout the Mississippi/Atchafalaya River Basin, suggests relationships between these observed trends and conservation indicators, and serves as an information hub about state efforts to improve water quality.

Figure 7-20 shows the interface to the GLTG Nutrient Trends Dashboard, and Figure 7-21 shows the GLTG Tracking nutrients in the Mississippi River Basin dashboard for states. The GLTG state nutrient tracking dashboard links back to data visualization tools that Minnesota currently has in place on the NRS website. The MPCA will work with the National Great Rivers Research and Education Center to update Minnesota-specific data and links on a quarterly basis.

Figure 7-20. Great Lakes to Gulf nutrient trends dashboard.

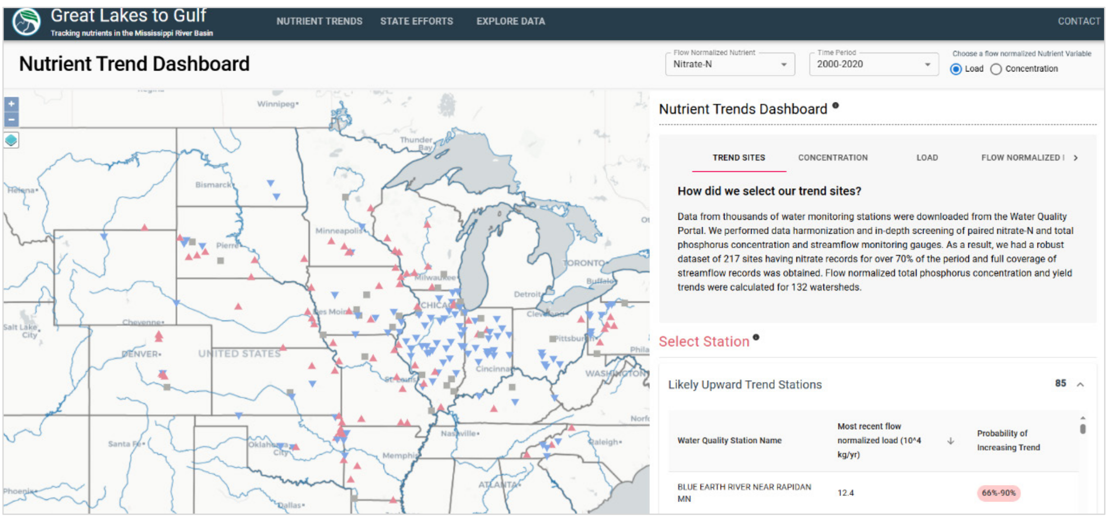
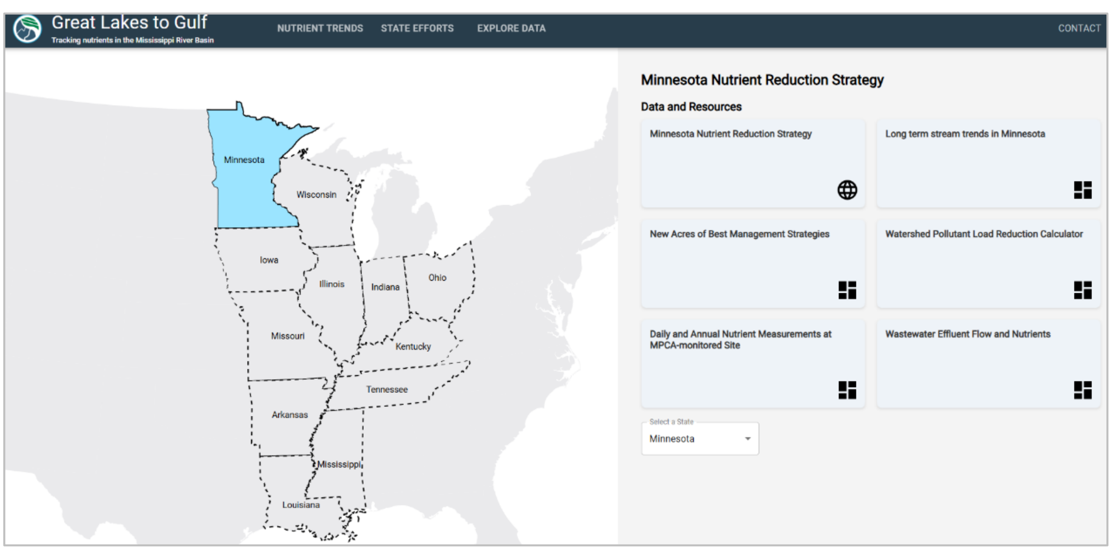


Figure 7-21. Great Lakes to Gulf state nutrient tracking dashboard.



7.7 Using progress evaluations to adjust the NRS

NRS progress will be evaluated on a periodic basis, and management strategies will be adapted to meet changing conditions to ensure that long-term goals are met. This section outlines the framework for evaluation and the steps that will be taken to make timely updates to the strategy into the future.

7.7.1 Delay between changes on land and detecting progress in water

Additional research is needed to better understand the lag between nutrient reduction actions and measurable improvements in the environment. The challenge of lag time is not Minnesota-centric and will involve the efforts of state, national, and international partners to better characterize this issue. Example factors influencing lag time responses to water quality improvements, especially at the state line and ultimately to the Gulf, Lake Winnipeg, and the Great Lakes, include:

- BMP effectiveness estimations do not accurately predict the performance of actual BMPs.
- Establishing certain practices (forestry, grasslands) requires more time.
- Long-term surface water and groundwater monitoring data are lacking in many places.
- Surface/groundwater interaction in the karst and central sands regions is complicated.
- Legacy nutrients and sediment are impacting major river systems.
- Short- and long-term climatic impacts on river flow and nutrient loading can vary.

Nationally, the USDA and EPA are conducting long-term research on lag-time impacts of nutrients on the Gulf. The USDA Agricultural Research Service and NRCS are working to understand the lag times for nutrient reduction from agricultural fields, the regional impacts of lag times at various watershed scales, and downstream legacy phosphorus and nitrogen issues within the main channel and coastal wetland areas near the Gulf. USDA is also looking at the lag time of nutrients through the Conservation Effects Assessment Project, which is a long-term program to quantify the effects of BMPs on working lands in varying landscapes across the nation (Tomer et al. 2014; Roland et al. 2022).

Algae in Lake Ponchartrain along the Gulf Coast

The impact of nitrate contamination on groundwater is a persistent issue in Minnesota. High nitrate levels in groundwater resources affect drinking water supplies and become significant sources of nitrate to surface waters. Interpreting groundwater nitrate concentrations and trends is often complicated by a lack of understanding of groundwater residence time, which is the time it takes for nitrate to move from the land surface into and through the groundwater before it reaches various points of measurement, such as wells, springs, and cold-water trout streams. A recent peer-reviewed study by the Minnesota Geological Survey, the MDA, and the DNR investigated groundwater residence time and how it affects nitrate trends in wells, springs, and streams in southeastern Minnesota, a region characterized by agricultural and karst landscapes (Kuehner et al. 2025). The key findings of this work include:

- Groundwater residence times vary by spring and well depth:
  - Shallow springs (< 60 meters) have one to two decades of residence time.
  - Deeper springs have two to four decades of residence time.
- Similar trends were found in domestic wells based on hydrogeologic conditions.

- Residence times significantly differ by geologic setting and are correlated with depth.
- Groundwater supplies in many springs and wells in southeastern Minnesota typically have modern ages ranging from 10 to 40 years.
- Legacy contaminants, such as nitrate and alachlor ethane sulfonic acid, have not yet fully migrated into deeper aquifers, where residence times can range from decades to millennia.

Lag time issues for local, regional, and national surface water and groundwater nutrient impacts will continue to be studied in the future, and these findings will help guide NRS actions and goals. The state agencies and the UMN will work collaboratively to develop specific research needs to better understand local and state-line nutrient lag-time issues.

7.7.2 Plan for evaluating progress

Periodic assessment of program performance and evaluation of the progress made toward interim and long-term goals and objectives will be critical to the success of the NRS. These assessments will determine whether the state is on course and if any adjustments are needed along the way. Performance should be assessed by a permanent NRS work group, comprised of interagency partners, the Met Council, and UMN. This work group will evaluate whether the following remain adequate: the supporting data and research used for trend analyses, the level and pace of practice adoption, and the progress toward achieving goals based on defined metrics and indicators.

Conducting biomonitoring in the Cedar River

Many of these metrics are included in existing reporting structures at both the state and federal levels. Minnesota's participation in the HTF and the IJC for both the Red River/Lake of the Woods and Lake Superior provides a schedule through which progress toward downstream water quality goals can be assessed (Table 7-9). Extensive in-state reporting is done through the Clean Water Fund Performance Report as well as through the WRAPS Update cycle and CWMP reporting with 1W1P (Table 7-10).

Table 7-9. Downstream evaluation schedule.

Report	Schedule
IRRWB and International Rainy-Lake of the Woods Watershed Board	Annually in August
Gulf HTF	Annually at HTF meetings
Gulf HTF Report to Congress	Biannually in late fall
Lakewide Action and Management Plans for the Great Lakes, Lake Superior annual reports, and Great Lakes Commission annual report	Annually in summer

Table 7-10. In-state evaluation schedule.

Report	Schedule
WRAPS	As updated
Clean Water Fund performance report	Biennially
1W1P	As amended

The NRS work group should evaluate downstream water quality reports as they are released, looking for indicators of potential problems, such as abrupt changes in water quality data or downward shifts in practice adoption rates. While the annual and biannual reports do not cover a long enough period to provide trend data, they can offer insight into resource management conditions and inform consideration and adjustment of the NRS.

The reporting for WRAPS products and 1W1P is extensive; however, no standardized process currently exists for sharing nutrient-related content from these state programs with the NRS. Because WRAPS products and 1W1P are the key water quality program delivery platforms, it is necessary to include these watershed-level results in NRS evaluations to determine the status of most water quality practice adoption progress in the state. It is recommended that MPCA, as the manager of the WRAPS Update process, and the BWSR, the manager of 1W1P, collaborate with the permanent interagency NRS work group to develop a plan to allow WRAPS Updates and 1W1P reporting to be easily provided to those evaluating the NRS. This plan should consider:

- **Timing of the WRAPS Update cycle and NRS evaluations**. The beginning of the 2025 NRS revisions in 2023 coincided with the completion of Cycle 1 of the WRAPS process, allowing for a greater level of analysis of NRS work at the local watershed level. If possible, NRS progress should be evaluated as WRAPS Update cycles are concluding.
- **Major basin scale**. Because the nutrient reduction goals are different for Lake Winnipeg, Lake Superior, and the Mississippi River, considering the WRAPS Update documents and 1W1P outcomes by basin could be an efficient way to organize reporting.
- **Minimal additional effort**. WRAPS Updates and 1W1P are complex and extensive processes. Including their data in NRS evaluations should involve minimal effort from those involved in WRAPS Updates and 1W1P.

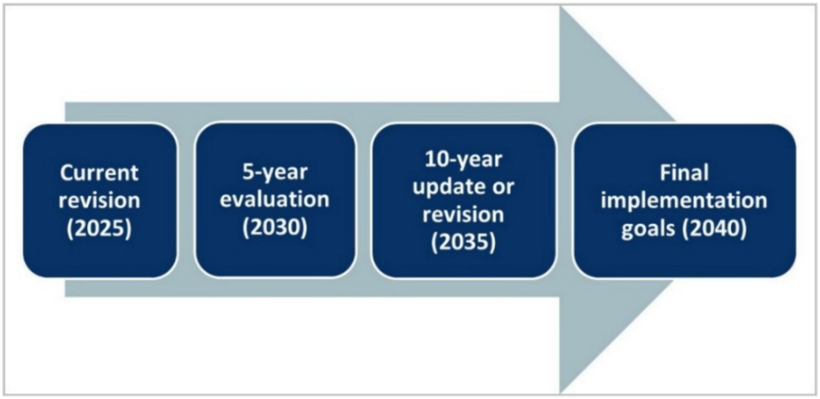
7.7.3 Process and considerations for adjusting the NRS

The NRS was designed to evolve over time. For example, the current revision of the NRS brings in new research, monitoring data, trend analyses, and technology that update the scientific foundations of the strategy. This foundation is critical to creating and maintaining a substantial document such as the NRS. As funding allows, an iterative approach should continue to be taken to update key water quality datasets, the effectiveness of practices based on peer-reviewed research, and the dashboard and tracking systems.

Based on the past decade of work, the NRS should continue to be evaluated at 5-year intervals by the permanent NRS work group to determine if any components of the NRS need updates or revisions based on new data, research, changes in national or international goals and objectives, or other external factors, such as new or changing regulations. The focus at the 5-year intervals will be to update for any significant changes in river load monitoring data and major changes in progress towards goals. MPCA will lead the effort of reporting back findings of the status of the NRS at the 5-year interval to NRS partners and the public.

At the 10-year interval, a more comprehensive evaluation of the NRS will take place, which will be led by the NRS Steering Committee. The Steering Committee will review the summary NRS data from the reporting listed in Section 7.3.2, the 5-year update, and the annual tracking on the NRS Dashboard to provide the scope, direction, and level of effort for the update process. At that point in the future, more significant updates to the NRS will be anticipated to reflect future data, analyses, and policies. The focus will be on the areas of the NRS that are in the greatest need of updating; an update of the entire NRS should not be necessary. Progress toward meeting Minnesota’s overall 2040 implementation goals and the use of the NRS beyond 2040 will be considered in 2035 when the 10-year evaluation is conducted (Figure 7-22).

Figure 7-22. Long-term NRS process timeline.



7.8 Summary of key action steps for NRS tracking

- Evaluate the measures and metrics for tracking progress periodically and expand future efforts if needed.
- Adjust the existing data visualization tools and develop new ones to better inform the public about tracking progress on key metrics and indicators of success.
- Develop and maintain user-friendly dashboards, websites, and tools that help NRS partners, the public, and the education community track progress. Identify existing and new datasets that would enhance the ability to track NRS progress and deploy solutions to bring data to the public.
- Coordinate with the HTF states and regional partners to develop consistent tracking systems that work together to identify future tracking needs and strategies to fill knowledge and data gaps.
- Develop strategies and methods to better track the agricultural, urban, and forestry sectors' private adoption of practices and build on and improve existing practice databases. Combining data capturing the private adoption of practices and the adoption of practices through government programs will be key to gauging long-term success in meeting the goals outlined in the NRS.
- Continue to improve approaches and expand networks related to the human dimension for change. Expand landowner and partner surveys to all sectors (e.g., agriculture, urban, forestry) to better understand the needs and abilities of these sectors to meet NRS goals over time.
- Expand NRS outreach and education efforts and employ methods and actions to incorporate NRS partner and public feedback on a continual basis.
- Maintain a permanent interagency NRS work group to take ownership of the NRS progress tracking and evaluation.
- Create a process to regularly share WRAPS and 1W1P findings and outcomes with the NRS work group to evaluate NRS progress from Minnesota's watershed approach.
- Use existing reporting mechanisms and available tracking tools as the basis for specific NRS reporting to avoid duplicating effort.

7.9 NRS support documents

- Appendix 7-1: University of Minnesota Core Indicators and Social Measures Guide: A Guide to Track and Monitor Human Dimensions for Conservation Action
- Appendix 7-2: Supplemental Visualization Tools and Applications for Tracking Nutrients

Chapter 8
NRS Approach to Achieving Goals

8.1 Building on recent progress

Chapters 1 through 7 document the tremendous progress Minnesota has made on nutrient-related work during the past decade. The 2025 NRS aimed to assess foundational advancements and identify where work should be intensified. In reviewing past progress, the following were regarded as key markers of NRS success.

Monitoring

- The monitoring of nutrients in water has greatly increased, as has our understanding of water quality needs and trends.
- Monitoring shows phosphorus loads have been reduced by over 30% in the Mississippi River.
- Phosphorus concentrations are decreasing in more lakes and rivers than are increasing, and lake water clarity is improving.
- There are indications that the TN in rivers and nitrate in groundwater have begun to decrease in some parts of the state.

Planning and delivery systems established

- Minnesota's Water Management Framework has been developed and implemented, which included completing all 80 WRAPS, most local watershed management plans (i.e., 1W1P), and many GRAPS, in addition to the 32 watershed plans already existing in the Twin Cities Metro Area.
- Cropland BMP adoption has accelerated since 2014, with improvements tracked on more than 4 million acres during the past decade (2014–2023).
- Multiple partnership projects have been completed on soil health, with support from the Minnesota Office for Soil Health and working in conjunction with the UMN. County and regional soil health programs have had success connecting with landowners, streamlining processes, and greatly increasing the adoption rate of practices (e.g., Minnesota Soil Health Coalition, Olmsted County Soil Health Program, and Wilkin County Soil Health Program).
- Fertilizer application rates are becoming more closely aligned with UMN recommendations. The private industry 4R Nutrient Stewardship Certification Program was launched in Minnesota in 2022.
- The MAWQCP has certified over 1.2 million acres of cropland, and many improvements have been added to these lands since certification.

Programs initiated and advanced

- The Clean Water Fund has provided the resources needed to monitor and assess waters across the state, develop strategies and plans, and accelerate the implementation and adoption of practices and actions to achieve water quality goals at multiple scales.
- Wastewater phosphorus discharges have been reduced by over 70% across Minnesota.

- MPCA's stormwater program has maintained the momentum generated by the MIDS (established in 2013) and built an innovative stormwater program that has been integrated into the WRAPS and 1W1P programs.
- The MPCA feedlot program has reduced runoff from animal holding facilities and has increased permit requirements to reduce nutrient losses from land application of manure sites.
- MDA developed and adopted the Groundwater Protection Rule. Fertilizer application restrictions have been fully implemented for fall fertilizer in areas vulnerable to groundwater.
- Failing septic and onsite treatment systems that endanger groundwater continue to be repaired and replaced, fully meeting the goals laid out in the 2014 NRS.
- The riparian buffer law has been fully implemented, requiring vegetated buffers or equivalent measures along all public waters and ditches.

Research, development, and tracking provide new insight

- State agencies have developed several online trackers to share data more broadly and allow easier assessment of progress for program implementation, practice adoption, and changes in water quality.
- New models and tools have been developed to support nutrient strategies, planning, and reporting outcomes across multiple scales for a broader range of practices.
- An active research program on practice effectiveness, nutrient management, and human dimension at the UMN continues to support NRS implementation.
- Over the last 10 years, the Forever Green Initiative was founded, has developed over 15 perennial or living cover crops, and is providing commercialization and market development support for these crops.

8.2 Remaining challenges

While this progress will enable Minnesota to continue toward water quality goals, many challenges remain. Minnesota still needs an average nitrogen reduction of approximately 40% (in TN loads and nitrate concentrations), especially in areas with row crops and vulnerable groundwater or tile drainage. Watersheds draining to lakes and rivers with in-state eutrophication impairments will also require an average phosphorus reduction of 40%. Many other waters need protection because they are sensitive to phosphorus additions.

One of the key challenges facing Minnesota is the cost. As shown in chapters 4 and 5, the cost to achieve and maintain nutrient reductions in both urban and rural environments in Minnesota is large, estimated at more than $1 billion per year. While Clean Water funds are currently available to help support a fraction of this reduction, the CWLLA expires in 2034. Federal funding for these programs is not consistent, and local funding is insufficient.

Cost is not the only challenge. The inertia of the current agricultural system, including complexities of the federal crop insurance programs, lender rules, and existing markets, can significantly impact the adoption of needed agricultural conservation practices and cropping system changes. The federal Farm Bill is also a major driver of cropping systems and conservation programs, and Minnesota has a limited ability to effect substantial change in federal policies. Government programs—even state and federal combined—cannot create enough change to reach the nutrient reduction goals, and substantial engagement by private industry and landowners is needed.

Technological challenges also remain. Increasing research in agricultural and urban areas is needed, along with education and networks for sharing learnings among peers.

The NRS identifies important strategies and approaches to overcome these daunting challenges. Without implementing most of the NRS strategies, there is little chance of achieving the TN load and nitrate concentration goals outlined in the NRS chapters 2 and 3 or finishing the job with phosphorus. However, by combining the strategies and approaches discussed in chapters 4, 5, and 6, Minnesota should be able to reach its goals over time.

8.3 Next steps: an updated roadmap for NRS success

Chapters 2 through 7 of this report describe, by topic, the next steps for incrementally working toward final goals for both in-state and downstream needs. This chapter brings those steps together to form an overarching NRS roadmap to accelerate progress to achieve final goals.

Chapter 8 asks five important questions about how Minnesota can achieve its goals, and the answer to each question frames the path forward:

- Question 1: Where is the most work needed?
- Question 2: Which practices does Minnesota need to add or modify?
- Question 3: What programs and initiatives should be used to scale-up practice adoption?
- Question 4: Who is going to ensure that strategies move forward?
- Question 5: When will Minnesota be able to reach its goals?

Question 1: Where is the most work needed?

The most work needed to address both local water quality needs and commitments to neighbors downstream of Minnesota is in the following priority areas:

- Nitrate leaching reduction in areas with vulnerable groundwater under row crop production, including sandy soils, karst geology, and other shallow soils above bedrock.
- Nitrate loss reduction to surface waters in tile-drained lands under row crop production and cities discharging high nitrate loads in treated wastewater effluent.
- Phosphorus runoff reduction in priority watersheds draining into lakes and rivers with eutrophication concerns.

The priority watersheds for the above nutrient reduction needs are specified in chapters 2 and 3. The practices needed to successfully achieve the work specified in each focus area are explained in more detail under Question 2, below.

Question 2: Which practices does Minnesota need to add or modify?

The following practice changes are needed to achieve the goals for each of the focus areas outlined under Question 1, above:

1. Nitrate leaching loss reduction in vulnerable groundwater areas with row crops

Needed practice modifications include:

a. **Increase the duration of CLC across the landscape**. Provide more CLC by growing cover crops and relay crops after the first crop of the season is harvested, changing crop rotations to add small grains (e.g., locally sourced oats) and perennial crops, and converting to perennial crops and pastures on lands less profitable for row crop production.
b. **Nitrogen fertilizer and manure application efficiencies**. Some room for progress exists in improving application rates, timing, and forms. Profitable nutrient management practices should be the starting point and the minimum expectation on all vulnerable lands; some of these

practices are required by existing rules or permits. Research will help increase farmers' abilities to more precisely match nitrogen additions with crop nitrogen requirements in a climate with more extremes. Even with improvements, only incremental water quality gains will be made with fertilizer and manure applications. In most of these vulnerable areas, modifying cropping systems and living cover, as noted above, will also be needed to achieve goals.

2. Nitrate loss reduction to surface waters from tile-drained lands under row crop production and cities discharging high nitrate loads in treated wastewater effluent.

Needed practice modifications for tile-drained lands include:

a. **Nitrogen fertilizer and manure application efficiencies.** Described in #1b, above.
b. **Increase the duration of CLC across the landscape**. Similar to #1a, above. However, drained lands are often some of the most profitable lands for row crop production, and cover crops following row crops will typically be more feasible than changing to perennials on such high-value/high-productivity lands.
c. **Drainage water management and treatment**. In some locations, cropping system modifications are not projected to be feasible or sufficient to meet the goals, and drainage water management/treatment practices at edge-of-field locations will be needed. Practices such as wetland construction and drainage water recycling, which have multiple benefits, should be prioritized first; these should be followed by other practices, such as controlled drainage, saturated buffers, and denitrifying bioreactors.
d. **Water storage**. Other options for water storage, in addition to wetlands and drainage water recycling noted in 2c, can also be used to reduce nitrate. In the Red River Valley, water impoundment capital improvement projects serve to reduce flooding and provide secondary benefits of reducing nitrate. Drainage water can also be stored in old river oxbows, reconnected floodplains, soils with soil health improvement, and other areas.

Needed practice modifications for nitrate reduction from cities discharging high nitrate in treated wastewater effluent:

a. **Nitrogen management plans and optimizing** existing wastewater infrastructure will help cities and industry denitrify and remove nitrogen while maintaining past phosphorus improvements. Initially, lower cost approaches and improvements at facilities that impact streams already impaired by nitrate should be emphasized. Over time, the use of higher cost approaches may be needed to reduce nitrate from wastewater discharge, as described in Chapter 4.

3. Phosphorus runoff reduction in priority watersheds draining into lakes and rivers with eutrophication concerns.

Some of the practices used to achieve the nitrate reductions in #1 and #2 above, when supplemented by widespread reduced tillage and phosphorus fertilizer/manure management, will help Minnesota reach many of the NRS TP load goals. However, additional practices will be needed in many watersheds with impaired lakes and rivers, including watersheds that have few local impairments but contribute elevated phosphorus to the Red River and eutrophication-impaired Lake Winnipeg. The needed practices in these areas will vary with the magnitude of reduction needed, the phosphorus sources and pathways to waters, and the potential to achieve multiple benefits from the practices.

Important practices to be considered through local watershed evaluation include:

a. **Reduced tillage**. Emphasis on high-residue tillage (e.g., strip-till and no-till).
b. **In-field phosphorus fertilizer management**. Subsurface placement, using UMN-recommended rates based on soil phosphorus testing, and drawing down of high-phosphorus soils, etc.

c. **Manure application precautions**. Immediate incorporation or injection, reduce the risk of soil phosphorus build-up to high levels, use phosphorus-based manure (instead of nitrogen-based) applications on very high-phosphorus testing soils, etc.

d. **CLC practices**. Same practices used to reduce nitrate losses as described in #1a and #2b, above.

e. **Other soil conservation and soil health practices**. Practices to reduce erosion and slow down runoff (e.g., contour strip-cropping, prairie strips, grassed waterways) on agricultural lands.

f. **Practices that reduce streambank and gulley erosion**. Stream restoration, off- or on-channel water storage, bank stabilization, buffers, two-stage ditches, near-channel gully/ravine stabilization, grade control structures, etc.

g. **Practices that reduce wind erosion**. Reduce wind erosion and the subsequent deposition of high-phosphorus topsoil in channels and lakes (e.g., windbreaks, reduced tillage, cover crops/other CLC).

h. **Replace or repair failing septic systems**. Address leaking systems, especially those near waters or releasing effluent to the ground surface.

i. **Manure storage***.* Increase capacity to store manure for longer periods of time and reduce the need for spreading manure during times more prone to runoff risk.

j. **Stormwater management**. As described in the Agricultural BMP Handbook and Minnesota Stormwater Handbook, including MIDS.

Practices needed for flat lands, such as in the Red River Valley, will be somewhat different than those for sloping lands. Practices to reduce streambank erosion and other near-channel sediment will be important in the Red River Valley, along with practices to reduce wind erosion and CLC designed for colder climates and shorter growing seasons.

4. Protection of sensitive waters

Phosphorus loss protective measures are important in watersheds with waters particularly sensitive to relatively small phosphorus additions, including Lake Superior and priority lakes having a high benefit-to-cost ratio when reducing and managing phosphorus (see Section 3.2.1). Minnesota's many high-quality lakes need continued and enhanced protection in watersheds draining into these waters. The Minnesota NRS would fail if it met only the large river phosphorus load reduction goals while not also protecting the many lakes that are in relatively good condition but remain highly vulnerable to phosphorus inputs.

Boating on Lake Pepin

In addition to the other phosphorus reduction approaches noted above, Minnesota should support protection of waters from excess phosphorus through:

- Good forest harvesting practice education and implementation.
- Forest and peatland preservation/restoration programs.
- Practices to reduce streambank erosion, as outlined in Section 5.5.4 and Appendix 5-5.
- Implementation of other lake protection strategies developed as part of the Water Management Framework and Twin Cities Metro Area watershed plans.

Question 3: What programs and initiatives should be used to scale-up practice adoption?

NRS Pathways to Success

Success will require that NRS efforts build on the following programs and initiatives:

1. Minnesota's Water Management Framework
2. CLC campaign
3. Existing regulatory programs
4. Successful agricultural programs
5. Wastewater Nitrogen Reduction Strategy
6. Research and development efforts
7. Coordinating ecosystem frameworks
8. NRS funding strategy

What programs, initiatives, and approaches are needed to increase the use of practices in the priority situations highlighted above? The NRS provides a recommended path forward to overcome major challenges and achieve the in-state and downstream nutrient goals.

Successful implementation of the recommendations will require collaborative work and commitments by local, state, federal, and private industry organizations, along with individuals. A long-term, comprehensive approach that considers both state-level and broader societal factors (as noted in Section 5.3.2) is essential for achieving sustainable agriculture and water quality.

The following eight NRS pathways build on the many excellent existing programs and approaches for addressing nutrient reduction in waters. While the first two pathways have the most potential to impact nutrient reductions, building on each of the strategies identified below will be important for achieving nitrogen loss reduction across landscape scales and completing work to reduce phosphorus in priority small-scale watersheds and river basins flowing out of the state.

1. Increase support of Minnesota's Water Management Framework

Minnesota's Water Management Framework, described in Chapter 6, is a well-established system to address local challenges and priorities with nonpoint sources of nutrients. Minnesota will need to sustain and expand ongoing conservation practice delivery through comprehensive local watershed management planning and supportive state, federal, and private efforts that tailor practices to the local conditions and situation.

However, the Minnesota Water Management Framework will need more support to address the landscape-scale magnitude of nitrogen reduction needed in tile-drained and vulnerable groundwater row crop regions, along with regional efforts to reduce phosphorus into the Red River. Broad-scale planning and implementation support is needed to drive existing local and regional efforts and programs to the next level. The 2025 NRS recommends that Minnesota invest in developing and strengthening planning and implementation support for the Water Management Framework through multiple initiatives aimed at:

a. Increasing workforce capacity and training for local government and private industry staff to assist landowners in adopting new conservation practices and actions.

b. Streamlining practice delivery, reporting, and funding systems to facilitate accelerated practice adoption.

c. Making streamlined agricultural practice installation programs easy to initiate and fund, especially for drainage water management and treatment practices.

d. Supporting and strengthening private industry involvement and public-private partnerships.

e. Showcasing and replicating successful elements of existing local/regional soil health programs.

f. Expanding soil health and water storage grant opportunities, including impoundments of high-nitrate water for flood control, nutrient reduction, and other co-benefits.

g. Reaching absentee landowners with conservation and soil health strategies/incentives.

h. Strengthening connections between practices and goals identified in the NRS with WRAPS Updates, CWMPs through the 1W1P program, Twin Cities Metro Area watershed plans, and GRAPS to meet nutrient reduction goals at multiple geographic scales.
i. Increasing support for data and analysis, technical training, and tracking and decision support tools for watersheds to help achieve the magnitudes of nutrient reduction identified in chapters 2 and 3.

Each of these areas of support is described in more detail in Section 5.4.2.

2. Initiate a campaign to vastly increase continuous living cover

Organize and initiate a CLC campaign, including market-based CLCs and traditional cover crops, with efforts on multiple fronts to implement what we know will work now, while increasing efforts to develop new cropping systems, markets, and infrastructure for the future. Nitrogen water quality goals cannot be fully achieved without transformative changes in cropping system rotations and more months of living cover throughout the year. Such changes are also important for completing phosphorus reduction work, reducing wind and water erosion, and improving other ecosystem services.

The foundations laid by the Forever Green Initiative and others will lead to an expansion of CLC crops. However, increased support will be needed to scale-up harvestable/marketable CLC crops to meet the broader economic and environmental needs of Minnesota. A CLC campaign will help move the state toward achieving an additional million acres of living cover adoption, with the long-range aspirational goals of reaching over 10 million acres across Minnesota. The development of a CLC index tracking system, as described in Chapter 7, will enable the tracking of progress over time.

A work group should be organized to develop this campaign and identify specific next steps for developing living cover crops and their markets, as well as a phased strategy for promoting and implementing living cover practices during the next 15 to 25 years. Financial challenges and opportunities, additional markets, incentives, social and human dimension factors, performance-based policy options, multiple ecosystem service benefits, and integrated crop and livestock systems should all be evaluated. More details are provided in Section 5.4.2

3. Fully implement recently adopted or strengthened regulations

During the past decade, several laws, rules, and permits were created or modified to reduce nitrogen and phosphorus in waters. Continued implementation of the following requirements is needed as part of a comprehensive set of nutrient reduction approaches:

a. **Fall fertilizer application restrictions** in groundwater-vulnerable areas through the Groundwater Protection Rule administered by MDA. *Note:* this program is fully implemented and should be maintained.
b. **Supporting communities with high nitrate in groundwater** through continued implementation and enforcement of the Groundwater Protection Rule, alongside local and state support efforts.
c. **MPCA feedlot regulatory program** requirements for manure spreading, including recently strengthened permitting restrictions for manure spreading from larger feedlots during summer, early fall, and winter, and late fall in vulnerable groundwater areas (see Section 5.5.1). *Note:* MPCA feedlot rules were also recently opened for revisions, with one of the goals to further protect waters from nitrate.

d. **Minnesota Riparian Buffer Law** requiring vegetative buffers, or equivalent practices, along all public waters and ditches. *Note:* Requirements have been met at more than 99% of public waters; maintenance of these practices will be needed in the future.

In addition to the more recently added or modified regulations, continued work is needed to fully implement and maintain requirements for feedlots (Section 5.5.1), septic systems (Section 5.5.2), municipal and industrial wastewater (Section 4.1), urban stormwater and lawn fertilizers (Section 4.2), and other existing regulatory programs affecting nutrients.

4. Support and expand existing successful agricultural practice improvement programs.

MAWQCP has proven that it can scale-up to over a million acres of certified lands and increase new adoption of BMPs. The NRS recommends continued and expanded MAWQCP progress so that it can reach millions of acres of Minnesota farmland, including rented farmland. An expanded emphasis on nitrogen should be considered to further promote and incentivize the types of practices that can reduce nitrate leaching in areas at risk for groundwater nitrate contamination. Also, criteria should be considered for a self-monitoring approach for tile-line drainage waters to quantify the level of nutrient reduction benefits achieved from drainage water management practices. The UMN Nitrogen Smart certification should also be considered for endorsement through this program.

Several additional county and regional soil health programs have been very successful in Minnesota and other upper Midwest states, as described in Section 5.3.1. These programs should be showcased, brought to other parts of the state, made flexible for farmers, streamlined, and financially supported.

Communities with high nitrate in groundwater should be supported through continued implementation and enforcement of Part 2 of the Groundwater Protection Rule, alongside local and state support efforts.

Statewide soil health initiatives, the Minnesota Office for Soil Health Program, and MDA’s Soil Health Financial Assistance grants need to continue and be expanded.

Private industry leadership and support are critical for achieving NRS goals. The NRS encourages continued work by private industry to promote nitrogen BMPs through private industry programs such as the Minnesota 4R Nutrient Stewardship Certification Program.

5. Implement the Wastewater Nitrogen Reduction Strategy

Building on the successes with wastewater phosphorus reduction, Minnesota aims to reduce wastewater TN discharges through the MPCA’s permitting program and associated wastewater nitrogen reduction strategy. Emphasis in the strategy is on where the treated effluent discharge either harms local aquatic life or contributes large amounts of nitrogen to waters downstream of Minnesota. Important elements for success will be further developed, including:

a. **Water quality trading frameworks and initiatives** to help offset the cost of wastewater nutrient reductions and provide financial incentives for implementing nonpoint source BMPs for nitrogen reduction. Trading may also support the development of urban-rural partnerships to advance the comprehensive, regional water quality planning and projects needed to meet both in-state and out-of-state NRS goals.
b. **Technological advancements and innovations** to feasibly treat nutrients in conjunction with emerging contaminants. Successful technologies and approaches to reduce wastewater nitrogen should be shared with other HTF states.
c. **Funding support advocacy** through state agencies and local governments for the funding of wastewater projects through state and federal sources.

Other elements of the MPCA Wastewater Nitrogen Reduction Strategy are described in Section 4.1.

6. Increase research and development

Enough research has been completed in the past to enable Minnesota to move forward in promoting and implementing numerous practices. We know the practices work. And yet, to reach the landscape levels of change needed, considerably more research is required, along with demonstration projects and pilot programs for existing and emerging technologies and practices. Examples of where additional research is needed include:

a. **Wastewater nitrogen removal solutions** for feasible reductions of nitrogen, along with phosphorus and multiple other contaminants. Minnesota should partner with other HTF states to research this topic to maximize the use of limited research funds and identify solutions needed in other states as well.
b. **Drainage water recycling** designs, siting, economics and hydrologic management to benefit agricultural production and water quality during years of precipitation extremes.
c. **Cropland nutrient addition strategies and technologies** to increase efficiencies through precision technologies are needed in a climate shifting to more extremes and in a state with such diverse soil and climatic conditions. Greatly increase research that supports a more soil-specific regional approach for determining crop nitrogen needs and adjust the timing of application to variable spring weather conditions.
d. **Living cover practices and cropping systems** to provide sustainable food, fiber, energy sources, and multiple ecosystem service benefits. Continued research is needed to develop crops and associated markets that can work alongside corn and soybeans and compete financially with those crops.
e. **Constructed wetlands siting and design** to best treat tile drainage water nitrate and provide co-benefits for wildlife.
f. **Strategies to reduce near-channel sediment** are needed. To meet phosphorus load reduction goals in some watersheds, the erosion of streambanks, river bluffs, ravines, and gulleys will need to be substantially reduced. Practice effectiveness and feasibility need further examination.
g. **Nitrogen cycling in Lake Superior** is not well understood, and more research is needed to evaluate fate and transport in nearshore and deep-water environments.

Many other areas of research are needed, as described in Section 5.1 and appendices 5-1 and 5-2. Along with research, it is important to identify and implement the best ways to share research results and other on-farm learning experiences with the agricultural community. Long-standing NRS-related research and education support at the UMN should be continued.

7. Promote practices to work on combinations of ecological problems together

Minnesota should build on its recent efforts to develop frameworks for climate action, soil health, and water storage, and associated funding by promoting practices that help address multiple ecosystem and agricultural goals. Many of the practices identified in the NRS will yield multiple benefits while also improving drinking water, reducing lake and river eutrophication, supporting aquatic life (positively affecting fisheries and recreation), and reducing hypoxia in downstream waters. Additional potential benefits include:

a. Resilience to precipitation extremes and soil erosion
b. Long-term agricultural sustainability and profitability
c. Soil health improvement
d. Air quality improvement

e. Sediment reduction in rivers and downstream lakes
f. Wildlife habitat and pollinator habitat
g. Flood reduction through water storage, such as impoundments in the Red River Basin
h. Protection of environmental heritage for future generations

Practices' multiple benefits are described in more detail in Section 5.1.3. The cost and effort to increase the number of nutrient-related practices for waters can often be further justified when considering the full range of benefits expected when various practices are adopted.

8. Develop an NRS funding strategy

Conduct an economic analysis that will inform the development of a strategy for funding the needed practice changes and additions. Recommended parts of the economic analysis include:

a. Building from information in chapters 4 and 5, assess the total costs to rural landowners, city residents, and government agencies to implement the practices identified in chapters 4 and 5.
b. Estimating the economic benefits to society of the adoption of the practices in chapters 4 and 5, including benefits to local and downstream water quality and the additional multiple benefits to society expected from these practices apart from nutrient reduction in waters. Compare the societal benefits to the cost of implementation.
c. Identifying funding options for adding the NRS practices to the landscape, including positives, negatives, and unintended consequences/risks associated with the options. Make recommendations on the best ways to pay for the practices.

The NRS partner organizations should evaluate the above analyses and develop a strategy for ongoing funding. While Minnesota currently has partial funding for certain NRS implementation measures, much more funding will be needed both before and after the 2034 end date of the Legacy Act Clean Water Fund monies.

Question 4: Who is going to ensure that strategies move forward?

The NRS is a multiple-agency strategy with responsibility shared by leadership from several state organizations that use the NRS as a tool for implementing the improvement measures in the strategy. The following organizations and approaches will increase assurance that recommendations made in the NRS will move forward:

a. MPCA will coordinate with agency partners to develop and maintain user-friendly dashboards, websites, and tools that help NRS partners, the public, and the education community track progress (see details in Chapter 7). MPCA and BWSR will also develop and implement methods to better track agricultural, urban, and forestry sector private adoption of practices. Interpretive and interactive reports will be produced by the MPCA and other agencies that led the NRS development.
b. Initiate a regularly held workshop series with a long-standing NRS work group for training in NRS tools and tracking systems, sharing new findings, and assessing and recommending needed adjustments to NRS approaches.
c. Accountability to other states and provinces will be maintained through Minnesota's continued involvement on the Gulf HTF, IRRWB, International Rainy-Lake of the Wood Watershed Board, and the Great Lakes Commission. The U.S. Congress receives biannual HTF reports, which also describe progress made in each of the HTF states, including Minnesota. The MPCA, MDA, and BWSR participate in the HTF, and the MPCA submits reporting materials on behalf of Minnesota.

d. The MDA, working in partnership with the UMN and BWSR, will organize and lead the work group to design the CLC Campaign and initiate implementation efforts as funding allows.
e. The MPCA will initiate the economic and policy analysis described above, working in conjunction with the UMN, MDA, USDA NRCS, private industries, and other organizations.
f. BWSR will lead the strengthening of the Water Management Framework efforts discussed in chapters 5 and 6 and summarized in Chapter 8, working closely with MPCA, MDA, DNR, MDH, and other organizations. Implementing several of the initiatives is dependent on funding.
g. Each agency responsible for the many laws and rules noted in the NRS will ensure full implementation, including MPCA, MDA, MDH, BWSR, DNR, and others.
h. The MPCA will coordinate with the Met Council, USGS, MDA, and others to ensure continued nutrient concentration and load monitoring, trend analysis, and interpretation.
i. UMN, working in collaboration with state agencies, will seek funding to address the priority research needs.
j. The Interagency Water Management Team will oversee implementation of the entire NRS to ensure priority elements are moving forward. This team, along with the NRS work group, will reconvene the multiple-organization NRS Steering Team for important NRS updates/reports.

While there are no legislative or legal requirements directing the implementation of the NRS as a whole, several key NRS implementation programs are directed through state requirements and funding sources.

Question 5: When will the goals be achieved?

The NRS is designed for the long term. With over 20 million acres of rural and urban change or refinement needed, the scale is enormous. Meaningful transformation will take time. While systemic policy change, such as shifts in federal crop incentives, could accelerate progress, reforms come slowly. The passing of the Farm Bill in 1985 was a landmark for conservation programs and support for BMP implementation. New initiatives have been made through the Farm Bill in the decades since then to better support water quality efforts, but most Farm Bill updates have been incremental. More substantial changes are needed to better support nutrient reduction efforts.

The 2014 NRS identified an aspirational 2040 timeframe for meeting the final goal for the Mississippi River nutrient loads, and the 2025 NRS continues with this same final goal timeframe and also suggests this timeframe for work in the Lake Winnipeg basin. But the work won't end in 2040. Lake protection work in Lake Superior and elsewhere will continue well beyond 2040. The need to adjust to external influences will also continue well beyond 2040. Additionally, legacy nutrients and lag times will further delay our ability to see the full effects in the water following changes on the land.

Minnesota has built a strong foundation to address the problem of excess nutrients getting into waters that consists of both voluntary and regulatory programs. Many of the programs are relatively new, and the water quality results of those programs are only beginning to appear. Water quality is expected to still incrementally improve if we pursue a stay-the-course approach without accelerating the pace of progress. However, Minnesota will fall short of meeting NRS goals by 2040 without additional measures in place to accelerate the pace of change and increase the capacity for change. The NRS recommends pursuing both steady incremental progress through existing tools and adding initiatives aimed at systemic change that could shift the trajectory.

Even with all the NRS-recommended measures, Minnesota must recognize that achieving all goals by 2040 will still be very challenging. Uncertainties remain with several issues, including:

a. Outcomes and associated funding and policy recommendations that emerge from implementation of the CLC Campaign work group and the NRS practices economic and policy analysis.
b. Success of research to develop technologies and enough profitable crops to supplement Minnesota's dominant corn and soybean systems.
c. Extreme climate situation trends over the next 15 years.
d. Willingness of landowners to store and treat tile drainage waters through edge-of-field practices.
e. Federal policy, staffing, and funding that are largely out of the control of Minnesotans.

The NRS is an adaptive management strategy, meaning that progress will be checked regularly, and adjustments will be made as necessary to increase the likelihood of achieving all goals by 2040.

8.4 Conclusion

The NRS is science-based. But it is fundamentally a strategy about people. It's about the quality of life for its residents: a quality that is affected by economics, environment, degree of personal burdens, mutual trust, personal relationships, and community. Progress has been made to reduce nutrients in waters because the people of Minnesota care. The people of Minnesota care about their water, their land, and the quality of life of people within Minnesota and downstream of Minnesota. Ultimately, the people of Minnesota will determine the priority to place on NRS efforts, the desired rate of progress, and how much they are willing to invest toward solving the many nutrient-related challenges.

Pigeon River High Falls, Grand Portage, MN

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Glossary

Baseline. Represents the initial time period against which goals are compared and trends in water quality and programmatic implementation are evaluated.

Best management practices. Broadly defined as changes intentionally made on the land that will have a positive effect on water quality; BMPs include all cropland in-field, edge-of-field and continuous living cover practices, as well as practices in urban, forested, pastured and in-channel settings.

Concentration. Amount of a substance present in a specific volume of water, typically measured in milligrams per liter or micrograms per liter. Concentration represents the condition of water experienced by organisms living in the water.

Continuous living cover. CLC refers to the presence of plant cover on the soil and/or with roots in the ground that remain alive in the soil year-round. CLC can be achieved using perennial species or by planting relays or rotations of cover crops and main crops throughout the year.

Final goal (or goal). Ultimate nutrient reduction desired for water quality improvement, expressed most commonly as a percent reduction in load from a baseline or as an average load to be achieved.

Flow-normalization/flow-normalized. Method to evaluate long-term variation in concentration or load that is not associated with yearly fluctuations in river flow. Flow-normalized trends assess load change as if the flows were more uniform from year to year.

Flow-weighted mean concentration (FWMC). Represents the total load for a given time period divided by the total river flow (discharge) for that time period. Typical units are milligrams per liter (mg/l).

Geologically vulnerable. This term, when referring to aquifers, is the degree to which a groundwater system is susceptible to contamination. Vulnerability is primarily governed by the geological setting, including soil type, the depth to the water table, the depth to bedrock, and the presence of cracks and fractures in the bedrock. The presence of pathways (e.g., abandoned or poorly sealed wells) and the types of overlying land uses (e.g., agriculture, industry) also affect vulnerability by increasing the potential risk for contamination.

Hydrologic Simulation Program – FORTRAN (HSPF). Hydrologic and pollutant delivery models that have been developed and updated for most of Minnesota.

Hydrologic Unit Code (HUC). A HUC is assigned by the U. S. Geological Survey for each watershed. HUCs are organized in a nested hierarchy by size:

- **HUC-4**. Four-digit hydrologic unit code (major basin; e.g., Minnesota River Basin = 0702)
- **HUC-8**. Eight-digit hydrologic unit code (major watershed; Blue Earth River watershed = 07020009)
- **HUC-10**. 10-digit hydrologic unit code (watershed)
- **HUC-12**. 12-digit hydrologic unit code (minor watershed)

Load. Load is the total amount of a pollutant sent downstream over a certain period of time, often expressed on an annual basis as tons per year or metric tons per year. Loads are determined by multiplying pollutant concentrations by the river flow volume.

Low Flow. Low flow is the “flow of water in a stream during prolonged dry weather,” according to the World Meteorological Organization. Many states use design flow statistics, such as the 7Q10 (the lowest 7-day average flow that occurs on average once every 10 years), to define low flow for setting permit discharge limits.

Market-based continuous living cover. Market-based CLC refers specifically to harvestable CLC crops and cropping systems where, in mature markets, the sale of the CLC crop can offset the costs of producing, processing, and marketing it.

Metric tons, or MT. 1,000 kilograms, which equals 2204.62 pounds.

Milestone. An interim goal, often expressed in terms of load reduction. Milestones are used in this NRS to define loading reductions that represent environmental progress on the way to final goals.

Non-flow normalized load. The same as "load," previously defined. The amount of a nutrient flowing by a specified point on a river, typically on an annual basis.

SPARROW. USGS Spatially Referenced Regressions on Watershed (SPARROW) model.

Statistically significant. Indicates the probability (p-value) that the results of a statistical test are due to random chance. Unless otherwise indicated, significant changes or trends are where p-value < 0.05, and nonsignificant changes pr trends refer to p-value > 0.05.

Total nitrogen, or TN. The combination of all forms of nitrogen, including organic nitrogen, and ammonium, nitrite, and nitrate. In Minnesota's most polluted waters, nitrate makes up the majority of TN. In less polluted waters, organic nitrogen often represents the highest fraction of nitrogen constituents.

Total phosphorus, or TP. The combination of phosphorus attached to sediment, organic phosphorus, and dissolved phosphorus forms such as orthophosphate.

Twin Cities Metro Area. Refers to the Minneapolis–St. Paul metropolitan area, which covers nearly 3,000 square miles and encompasses seven counties, including Anoka, Hennepin, Ramsey, Washington, Carver, Scott, and Dakota counties.

Weighted Regressions on Time, Discharge, and Season (WRTDS). A method for analyzing long-term water quality trends in rivers and streams that is commonly used by the USGS. It includes a procedure called "flow-normalization" to remove the effects of year-to-year variability in river flow when assessing long-term changes in nutrient concentrations and loads.