Minnesota’s state, federal, and regional partner agencies along with the University of Minnesota have collaborated to provide a statewide strategy to reduce levels of phosphorus and nitrogen, collectively referred to as nutrients. The public provided comments and suggestions which helped to create this final strategy. Minnesota will use the statewide strategy as a guide for reduction of nutrients. Excessive nutrient levels pose a substantial threat to Minnesota’s lakes and rivers, as well as downstream waters including the Great Lakes, Lake Winnipeg, the Mississippi River, and the Gulf of Mexico.

The Minnesota Nutrient Reduction Strategy (NRS) will guide Minnesota to achieve nitrogen and phosphorus reductions within Minnesota surface waters to enhance the health of aquatic life, protect public health and safety, increase the recreational potential of Minnesota’s numerous lakes, rivers, and streams. The NRS also addresses groundwater protection as it relates to nitrate in drinking water. In addition, nutrient reductions will benefit the Gulf of Mexico hypoxia problem and other waters downstream of Minnesota including Lake Winnipeg and Lake Superior. The theme of the overall NRS is A Path to Progress in Achieving Healthy Waters (Figure 1-2).

Figure 1-1. Major drainage basins in Minnesota.

The Minnesota Water Sustainability Framework (University of Minnesota 2011) surveyed Minnesotans’ attitudes and beliefs about water. Based on more than 4,500 surveys and 9 listening sessions around the state, the team concluded:

- Minnesotans consider providing drinking water to be the most important use of water, followed by providing ecological services, offering recreational opportunities, and meeting the needs of agriculture.
- Minnesotans rank chemical pollution; nutrients; and non-native plant, animals, and diseases the three most serious problems facing Minnesota’s waters.
- Minnesotans understand that we need to change our behavior in order to reverse the trend toward reduced water quality.
- Minnesotans equally value improving polluted lakes and rivers and protecting healthy waters.
- Minnesotans place equal importance on investing in groundwater and investing in surface waters.
- Minnesotans want to address the most serious water problems first, rather than place priority on distributing funding equitably across the state.
- Minnesotans want quantifiable measures of water quality to be communicated and accessible.
The mission of the NRS is to recognize the importance of nutrients in protecting water quality whether sources are nearby or many miles upstream. As such it provides a roadmap to address both Minnesota’s nutrient contribution to downstream waters, and, at the same time, add value for those who work on local and regional land and water nutrient-related issues within Minnesota. More specifically, the NRS mission includes the following:

1. **Complement Existing State-Level Strategies** – Several state-level plans and strategies for Minnesota water issues have been developed during recent years, and are in various stages of implementation. One goal of the NRS is to add further focus to those efforts, specifically on nutrients, thereby supplementing and coordinating among these other plans and not supplanting.
2. **Work toward Progress in Downstream Waters** – By the time nutrient problems show up in resources downstream of Minnesota such as the Gulf of Mexico or Lake Winnipeg, the contributions can be very large. Rather than comprehensively addressing the long-term goals in these downstream waters, it is beneficial to focus on making incremental progress toward restoring these waters. Minnesota is one of 12 states that have committed to develop state level nutrient reduction strategies. Even with all of these states contributing to load reductions, the level of reduction needed from any individual state can still be significant. Minnesota is approaching this challenge by establishing milestones and providing a plan to reach these meaningful interim goals. Meaningful and achievable nutrient load reduction milestones are developed that allow for better understanding of incremental and adaptive progress toward final goals. Milestones target load reductions from point and nonpoint sources impacting the Gulf of Mexico, Lake Winnipeg, Lake Pepin, Mississippi River backwaters, Lake Superior, and other downstream waters.

3. **Work toward Progress on Meeting In-state Nutrient Criteria** – Meeting Minnesota’s beneficial use water quality standards is critical to protecting the waters that Minnesotans value. Whether for recreation, consumption or other uses, Minnesota identifies with its waters in important ways. The NRS complements existing efforts to make progress toward meeting in-state nutrient criteria and proposed standards for Minnesota’s lakes and streams, and additionally provides protection to water bodies not yet assessed, or assessed as threatened (or needing protection) by nutrients or eutrophication.

4. **Prioritize and Target** – Major watersheds (i.e., 8-digit hydrologic unit code [HUC8]) are prioritized on a statewide basis relative to nutrient loads and impacts, and implementation activities are targeted to ensure efficient use of resources. Geographic, land use, and best management practice (BMP) priorities are established through technical analyses, resulting in recommended reductions of phosphorus and nitrogen that account for the most substantial impacts to receiving surface waters and groundwater.

5. **Build from Existing Efforts** – Many ongoing efforts are moving the state in the right direction, however the magnitude of these efforts is not sufficient to address the loading reductions needed. At the same time other factors might be contributing toward increased loads. The NRS identifies ways to build on successes of current programs and activities so that we can achieve our local and downstream water quality goals. The NRS is a unifying and organizing step to align goals, identify the most promising strategies, and coordinate the collective activities around the state working to achieve these common goals. The intent is to simplify and support, not complicate. A successful NRS will support and work within the Minnesota Water Management Framework, total maximum daily loads (TMDLs), Agricultural Water Quality Certification, the Nitrogen Fertilizer Management Plan, as well as local and regional planning efforts.
6. **Lead to Effective Local Implementation** – The NRS is directly applicable to state, federal, and regional agencies and organizations to focus and adjust state-level and regional programs, policies, and monitoring efforts. Those agencies often have the local watershed managers and water planners as a key customer focus; therefore the NRS is intended to focus at the state level but be relevant at the local level. These customers will take the large-scale data, priorities, and recommendations and consider that information when developing localized implementation plans (i.e., for HUC8 watershed scale and smaller). Efficiencies will be gained by making large-scale information available to local watersheds. This NRS will enhance and not replace the planning work needed at the HUC8 and finer watersheds scale.

### 1.1 Driving Forces

The need for a statewide nutrient reduction strategy in Minnesota is driven by a number of federal, regional, and state initiatives coalescing at this particular point in time. At the federal level, Environmental Protection Agency’s (EPA) focus on statewide nutrient reduction planning has served as a key driving force for Minnesota’s NRS development. Regionally, Minnesota’s involvement in the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force has also served as a driving force. In the past decade, nutrient issues downstream of Minnesota have reached critical levels, including the effect of nutrients in the Gulf of Mexico which has resulted in hypoxia (low levels of oxygen), eutrophication problems in Lake Winnipeg, and nutrient concerns in the Great Lakes. Several state-level initiatives and actions have highlighted the need for a statewide strategy that ties separate but related activities together to demonstrate integration toward nutrient reductions. The following sections contain a brief discussion of each primary federal, regional, and state driving force.

#### Hypoxia Action Plan

The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force developed a *Hypoxia Action Plan* in 2001, which was revised in 2008 and describes a national strategy to reduce, mitigate, and control hypoxia in the northern Gulf of Mexico and improve water quality in the Mississippi River Basin. The Action Plan identified the following action to help achieve nutrient reduction in the Mississippi River/Gulf of Mexico watershed and work toward meeting the goals for reduction in the hypoxia zone in the Gulf of Mexico:

*Complete and implement comprehensive nitrogen and phosphorus reduction strategies for states within the Mississippi/Atchafalaya River Basin encompassing watersheds with significant contributions of nitrogen and phosphorus to the surface waters of the Mississippi/Atchafalaya River Basin, and ultimately to the Gulf of Mexico.*
This action calls for state-level nutrient reduction strategies by 2013. The strategies are intended to be collaborative, support both current and new nutrient reduction efforts, identify available funding, and specify funding needs (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2008). EPA has provided funding and assistance to many of the states to help develop these strategies, including Minnesota. The NRS applies to the entire state, a large part of which includes the basins flowing into the Mississippi River.

**EPA Memo on State Nutrients Framework**

A memo issued by EPA on March 16, 2011, urged states to accelerate nutrient reduction and provided “Recommended Elements of a State Nutrients Framework” to help guide state planning activities related to nutrient reduction. Framework elements include:

1. Prioritize watersheds on a statewide basis for nitrogen and phosphorus loading reductions
2. Set watershed load reduction goals based upon best available information
3. Ensure effectiveness of National Pollutant Discharge Elimination System (NPDES) point source permits in targeted/priority subwatersheds
4. Agricultural areas
5. Stormwater and septic systems
6. Accountability and verification measures
7. Annual public reporting of implementation activities and biannual reporting of load reductions and environmental impacts associated with each management activity in a targeted watershed
8. Develop a work plan and schedule for numeric criteria development

This NRS strives to address each of the framework elements.

**In-State Surface and Groundwater Water Quality Issues**

Excessive levels of phosphorus and nitrogen present a substantial threat to Minnesota’s lakes and rivers, as well as downstream water bodies. These threats are not only to the environment, but also to drinking water and public health. Minnesota promulgated lake and reservoir eutrophication standards in 2008 and is in the process of promulgating proposed river and stream eutrophication standards in 2014. Both sets of standards include phosphorus as the cause variable along with response variables that demonstrate that phosphorus has manifested as excess algal levels. Based on the 2012 Impaired Waters List, almost 20 percent of Minnesota lakes and river segments have been assessed as impaired due to excess nutrients or nutrient-related parameters (see Chapter 2). These water bodies will be the subject
of TMDL studies and individual restoration plans designed to help achieve state water quality standards. These listings do not reflect the proposed river eutrophication standards; therefore, many more streams and rivers are anticipated to be added to future impaired waters lists.

The Minnesota Pollution Control Agency (MPCA) has assessed many Minnesota lakes and categorized them as impaired for excess nutrients (e.g., phosphorus). Sixty-five percent of the state of Minnesota is located upstream of a lake impaired by excess nutrients. As a result, MPCA is developing individual restoration plans that are designed to bring local waters into compliance with state water quality standards.

Nitrate concentrations in Minnesota groundwater also present a threat to safe drinking water supplies. Groundwater supplies drinking water to about 75 percent of all Minnesotans and almost all of the water used to irrigate the state’s crops. The inflow of groundwater also is important to maintain the water level, pollution assimilative capacity, and temperature in Minnesota’s streams, lakes, and wetlands. Central and southern Minnesota has the highest groundwater nitrate concentrations, predominantly in areas of karst as well as shallow sand and gravel aquifers. Minnesota is currently developing nitrate toxicity standards to protect aquatic life in surface waters of the state. The state is working toward adoption of these standards in about 2015.
Clean Water Land and Legacy Amendment

On November 4, 2008, Minnesota voters approved the *Clean Water, Land and Legacy Amendment* (Amendment) to the constitution to protect drinking water sources; to protect, enhance and restore wetlands, prairies, and forests, as well as fish, game, and wildlife habitat; to preserve arts and cultural heritage; to support parks and trails; and to protect, enhance and restore lakes, rivers, streams, and groundwater. The Amendment increased the sales and use tax rate by three-eighths of one percent on taxable sales, starting July 1, 2009, continuing through 2034. Of those funds, approximately 33 percent are dedicated to a Clean Water Fund to protect, enhance, and restore water quality in lakes, rivers, streams, and groundwater, with at least 5 percent of the fund targeted to protect drinking water sources. Approximately $152 million was invested in the Clean Water Fund in the first 2 years for water management activities such as monitoring, planning, and on-the-ground restoration and protection activities.

Minnesota agencies that receive Clean Water Fund dollars have released *two collaborative reports*, most recently in 2014. Overall, the report shows the state is on track with its investments, though challenges remain. The 25 measures in the report provide a snapshot of how Clean Water Fund dollars are being spent and the progress being made. The measures are organized into three sections: investment, surface water quality, and drinking water protection. These are just some of the measures that will be used to consistently track and report clean water outcomes over the life of the Amendment. Each measure has a status ranking and trend information.

Minnesota’s Clean Water Road Map was released in 2014 and is “a set of goals for protecting and restoring Minnesota’s water resources during the 25-year life of the Clean Water, Land and Legacy Amendment. Clean Water Roadmap goals are based on currently available data and are intended to be ambitious, yet achievable. Progress in meeting these goals will require significant investment from the Clean Water Fund established by the Amendment, combined with historical water resource funding from other sources.” Goals are provided for four high-level indicators that describe surface water quality, groundwater quality, and groundwater quantity.
Minnesota Water Management Framework — Watershed Approach to Protecting and Restoring Water Quality in Minnesota’s Watersheds

The Minnesota Water Management Framework (Framework) lays out the state’s plan to implement watershed-based planning efforts that will over the next 10 years result in locally-led water quality improvement plans. The Framework is a high-level, multi-agency, collaborative perspective on managing Minnesota’s water resources.

Minnesota’s water resource management efforts are tied to the goals of the 1972 Clean Water Act (CWA) for restoring and protecting the multiple beneficial uses, including recreation, drinking water, fish consumption, and ecological integrity of America’s waters. The CWA requires states to do the following:

- Assign designated beneficial uses to waters and develop water quality standards to protect those uses.
- Monitor and assess their waters.
- List waters that do not meet water quality standards.
- Identify pollutant sources and reductions in pollution discharges needed to achieve standards.
- Develop a plan to implement water restoration and protection activities.

The passage of Minnesota’s Clean Water Legacy Act (CWLA) in 2006 provided a policy framework and resources to state and local governments to accelerate efforts to monitor, assess, and restore impaired waters, and to protect unimpaired waters.

The CWLA and the recently established Clean Water Fund has changed how Minnesota approaches water quality, allowing a systematic approach in addressing impaired waters and protection efforts in unimpaired waters. Minnesota’s watershed program has rapidly evolved from a singular focus on TMDLs to a watershed approach that will lead to comprehensive restoration and protection strategies for each of the state’s major (HUC8) watersheds described in comprehensive watershed management plans (e.g., One Watershed One Plan). The Framework describes how Minnesota agencies aim to streamline water management by systematically and predictably delivering data, research, and analysis and empowering local action (Figure 1-3).
Chapter 1. Development of the Minnesota Nutrient Reduction Strategy

The red arrow emphasizes the important connection between state water programs and local water management. Local partners are involved - and often lead - in each stage in this framework.

Ongoing Local Implementation is at the heart of the state’s overall strategy for clean water. Actions must be prioritized, targeted, and measurable in order to ensure limited resources are spent where they are needed most. The rest of the cycle supports effective implementation.

Monitoring and Assessment determines the condition of the state’s ground and surface waters and informs future implementation actions. The state's “watershed approach” systematically assesses the condition of lakes and streams on a 10-year cycle. Groundwater monitoring and assessment is more varied in space and time.

Water Resource Characterization and Problem Investigation delves into the science to analyze and synthesize data so that key interactions, stressors, and threats are understood. In this step, watershed and groundwater models and maps are developed to help inform strategies.

Watershed Restoration and Protection Strategies (WRAPS) and Groundwater Restoration and Protection Strategies include the development of strategies and high level plans, “packaged” at the 8-digit HUC scale (81 major watersheds in Minnesota). These strategies identify priorities in each major watershed and inform local planning.

Figure 1-3. Minnesota Water Management Framework
The Comprehensive Watershed Management Plan is where information comes together in a local commitment for prioritized, targeted, and measurable action. Local priorities and knowledge are used to refine the broad-scale WRAPS and other assessments into locally based strategies for clean and sustainable water.

The NRS provides recognition that many of the watershed nutrients manifest as problems downstream of the HUC8 watersheds in regional lakes, reservoirs, national waters and international waters. It is important, therefore, that comprehensive watershed management plans address the contribution of nutrients to waters within their HUC8 watershed as well as downstream waters.

**Groundwater Protection and the Nitrogen Fertilizer Management Plan**

The Comprehensive Groundwater Protection Act of 1989 (Minnesota Statute § 103H) provided direction and authority for water resource protection in Minnesota and especially with regard to nitrogen fertilizer management in Minnesota. This was a result of three separate but related components of the Act: (1) development of a groundwater protection goal; (2) enhanced regulatory authority for fertilizer practices within the Minnesota Department of Agriculture (MDA); and (3) development of a Nitrogen Fertilizer Management Plan (NFMP) by MDA.

The NFMP is the state’s blueprint for prevention or minimization of the impacts of nitrogen fertilizer on groundwater. The plan must include both voluntary components and provisions for the development of nitrogen fertilizer use restrictions if the implementation of BMPs proves to be ineffective.

Many aspects of the NFMP have been implemented since the adoption of the original NFMP in 1990. In 2010 the MDA began a process to revise the plan to reflect current activities and interagency water protection planning and implementation work, and to better align it with current water resource conditions and program resources.
The following are excerpts from the Draft Plan’s Executive Summary written by MDA (2013):

The intent of the Nitrogen Fertilizer Management Plan is to prevent, evaluate, and mitigate nonpoint source pollution from nitrogen fertilizer in groundwater. The plan must include components promoting prevention and developing appropriate responses to the detection of nitrogen fertilizer in groundwater. The strategies in the NFMP are based on voluntary BMPs, intended to engage local communities in protecting groundwater from nitrate contamination.

The general approach to addressing nitrate in groundwater in Minnesota is to: (1) promote nitrogen fertilizer BMPs to protect groundwater with greater efforts in vulnerable areas to prevent groundwater problems from occurring (ongoing); (2) monitor private wells on a township scale over a 10-year period or use existing monitoring data to identify areas with nitrate concerns; (3) conduct a detailed assessment of water quality in these areas to determine the severity and priority of the problem; and, 4) conduct mitigation actions in high-priority areas using a phased approach starting with voluntary actions and progressing to regulatory actions if necessary.

Prevention is significantly emphasized because once groundwater is contaminated; it can be extremely difficult, expensive, and very slow to remediate. Prevention activities within the NFMP are ongoing regardless of the status of mitigation for nitrate in groundwater. A variety of activities can be utilized in order to achieve the NFMP prevention goal including BMPs, alternative management tools, wellhead protection, education and promotion, and local water plans. A Nitrogen Fertilizer Education and Promotion Team will be developed to assist MDA with the coordination of prevention activities and programs.

The goal of mitigation is to minimize the source of pollution to the greatest extent practicable and, at a minimum, to reduce nitrate contamination to below the drinking water standard (10 milligrams per liter or 10 mg/L) so the groundwater is not restricted for human consumption. The mitigation strategy is based on the prevention strategy, but implemented over a defined area and at a higher level of effort and intensity. It is intended to have significant local involvement and leadership, especially through the participation of local farmers.
Red River and Lake Winnipeg Nutrient Strategy

The International Red River Board (IRRB) recognized that excessive nutrients such as phosphorus and nitrogen are one of the greatest water quality issues facing the international Red River watershed and Lake Winnipeg. While all jurisdictions within the watershed have various regulatory frameworks, plans, and approaches in place to reduce the contribution of nutrients to water, the development of an enhanced, coordinated, and systematic strategy across jurisdictional boundaries is desirable. Working with the Red River Basin Commission (RRBC), the IRRB has convened a group to coordinate development of a nutrient strategy that encompasses the three jurisdictions that cover the majority of the Red River basin: Minnesota, North Dakota and Manitoba. The goal is to attain water quality in the Red River that meets the needs of all of the jurisdictions. Implementation of the strategy will be done separately in each jurisdiction, but coordinated through the IRRB and the RRBC. Implementation in Minnesota will be guided by the NRS. Communication between those working on Minnesota’s NRS and those working on the IRRB’s strategy has ensured compatibility between the two efforts. Communication and coordination will continue as the strategies are implemented within the basin.
1.2 Collaborative Process

**Interagency Coordination Team**

Successful implementation of the NRS will require broad agency support, coordination, and collaboration. An interagency coordination team (ICT) supported development of the NRS and is expected to support its implementation. The ICT consists of representatives from various agencies and organizations that administer key nutrient reduction programs or implement programs that support decisions affecting nutrient loads. The ICT structure includes a high-level Steering Committee composed of senior agency managers and a work group composed of agency program managers. Two sector-specific focus groups were also formed to provide input and direction on NRS development. The Agricultural Sector group includes representation from MDA, Natural Resource Conservation Service (NRCS), Board of Water and Soil Resources (BWSR), MPCA, and University of Minnesota. The Point Source Sector group includes representation from MPCA and Metropolitan Council. Each of these groups met twice to identify potential strategies for nutrient reduction.

**Public Involvement**

Public input on the draft NRS was obtained through a formal public comment period which began on October 7, 2013 and extended through December 18, 2013. Outreach activities included draft NRS availability through the *project website* along with summary facts sheets, a series of open houses, presentations, question and answer sessions, and one-on-one discussions. Hundreds of interested residents, agency and other governmental staff, elected officials, and advisors attended over 25 different events during the public comment period which provided the opportunity to learn about the NRS and provide input. A total of 85 comment letters were submitted by individuals or organizations. Many changes were made to update the NRS based on input by commenters.
1.3 Building Blocks

This NRS was developed from several existing foundational efforts which estimated the river nutrient loads, nutrient sources, and effectiveness of BMPs for nutrient reductions. Below are some of these key technical building blocks:

- Phosphorus Source Assessment
- Nitrogen in Minnesota Surface Waters, Conditions, Trends, Sources, and Reductions Report
- Spatially Referenced Regressions on Watershed (SPARROW) Modeling
- Conservation Effects Assessment Project
- Major Watershed Load Monitoring Network
- Major River Monitoring by Metropolitan Council Environmental Services, Manitoba and U. S. Geological Survey (USGS)
- BMP Effectiveness Manuals and Models

Phosphorus Source Assessment

In 2003 concerns about the phosphorus content of automatic dishwashing detergents prompted the passage of legislation requiring a comprehensive study of all of the sources and amounts of phosphorus entering publicly owned treatment works and, ultimately, Minnesota surface waters. The assessment conducted for the MPCA by Barr Engineering (2004), with assistance from the University of Minnesota and others, estimated how much phosphorus enters Minnesota’s lakes, wetlands, rivers and streams, and where it comes from in each of the state’s 10 basins.

The detailed assessment of phosphorus sources report, along with two updates to the study, was used for certain parts of NRS development. In 2007 the phosphorus atmospheric deposition amounts were updated (Barr Engineering 2007), and in 2012 the MPCA updated the phosphorus wastewater point source discharge amounts based on wastewater discharge monitoring reports.

Nitrogen in Minnesota Surface Waters Report

In 2013 the MPCA released Nitrogen in Minnesota Surface Waters, Conditions, Trends, Sources, and Reductions describing the nitrogen conditions in Minnesota’s surface waters, along with the sources, pathways, trends, and potential ways to reduce nitrogen in waters (MPCA 2013a). The report was developed in response to concerns about nitrogen in Minnesota’s surface waters, including: (1) toxic effects of nitrate on aquatic life, (2) increasing nitrogen concentrations in the Mississippi River combined with nitrogen’s role in causing the hypoxic zone in the Gulf of Mexico, and (3) the discovery
that some Minnesota streams exceed the 10 milligrams per liter (mg/l) standard established to protect potential drinking water sources. The report was developed by the MPCA, University of Minnesota, and USGS. Several parts of the report were used in the NRS, including the nitrogen sources to surface waters assessment, river nitrogen load based on monitoring and modeling, and practices to reduce nitrogen in waters.

**SPARROW Modeling**

Results from the SPARROW model, which the USGS developed and maintained, was used for this study to estimate nitrogen and phosphorus loads and to estimate nutrient contributions from different sources in Minnesota. The *Nitrogen in Minnesota Surface Waters, Conditions, Trends, Sources, and Reductions* report (MPCA 2013a) contains a chapter on SPARROW modeling for nitrogen in Minnesota.

The SPARROW model integrates water monitoring data with landscape information to predict long-term average constituent loads that are delivered to downstream receiving waters. The SPARROW models are designed to provide information that describes the spatial distribution of water quality throughout a regional network of stream reaches. SPARROW also tracks the attenuation of nutrients during their downstream transport from each source. Models are developed by statistically relating measured stream nutrient loads with geographic characteristics observed in the watershed.

Nutrient estimates for Minnesota were based upon the SPARROW Major River Basin 3 (MRB3) model that Robertson and Saad (2011) developed. The authors used water quality data from 1970 to 2007 to estimate representative loads expected in 2002 at each site. The SPARROW model for the Upper Midwest (Robertson and Saad 2011) incorporates five different nutrient sources, five climatic and landscape factors that influence delivery to streams, and nutrient removal in streams and reservoirs.

SPARROW results were used in certain parts of the NRS to provide comparable watershed nutrient yield and loading data, inform sources of nutrients, and estimate loading in the Lake Superior and Rainy River watersheds.

**Conservation Effects Assessment Project**

The U. S. Department of Agriculture NRCS Conservation Effects Assessment Project (CEAP) estimated the benefits of the 2002 Farm Bill’s increase in conservation funding at a national, regional, and watershed scale. The Upper Mississippi River Basin was one of 13 basins studied in the CEAP. Total nitrogen and phosphorus loading values were estimated for five scenarios: background (no cultivated land), current conditions (2003–2006), no conservation practices, treatment of critical undertreated
cropland, and treatment of all undertreated cropland conditions. The latter two scenarios dealt with increasing treatment for undertreated areas and, more specifically, simulated the effects of structural conservation practices, residue and tillage management, and nutrient management.

The recommendations from the CEAP analysis help to inform the general approach to the NRS. Compared to current conditions (based on a 2003 to 2006 operator survey), the study recommends a greater focus on applying conserving practices to undertreated land. The study also recommends complete and consistent use of nutrient management, including appropriate rate, form, timing, and method of application, especially for nitrogen loss in subsurface flows (USDA 2012a).

**Watershed Pollutant Load Monitoring Network**

The Watershed Pollutant Load Monitoring Network (WPLMN) is a multi-agency effort led by the MPCA to measure and compare regional differences and long-term trends in water quality among Minnesota’s major rivers including the Red, Rainy, St. Croix, Minnesota, and Mississippi and the outlets of major HUC8 tributaries draining to these rivers. The network was established in 2007. Site-specific streamflow data from USGS and Minnesota Department of Natural Resources (DNR) flow gauging stations is combined with water quality data that the Metropolitan Council Environmental Services, local monitoring organizations, and MPCA staff collected to compute annual pollutant loads at river monitoring sites across Minnesota.

The WPLMN has been collecting water quality at an increasing number of locations since 2007, reaching 79 monitoring sites by 2010. The design scale is focused toward, but not limited to, monitoring HUC8 watershed outlets within the state. Strategic major river mainstem sites are included to determine basin loads and assist with statewide mass balance calculations. Annual water quality and daily average discharge data were coupled in the Flux32 pollutant load model, which Dr. Bill Walker originally developed and the U.S. Army Corps of Engineers and MPCA recently upgraded, to create concentration/flow regression equations to estimate pollutant concentrations and loads on days when samples were not collected. Primary output includes annual and daily pollutant loads and flow weighted mean concentrations (pollutant load/total flow volume). Loads and flow weighted mean concentrations are calculated annually for total suspended solids (TSS), phosphorus, dissolved orthophosphate, nitrate plus nitrite nitrogen (NO3+NO2-N) and total Kjeldahl nitrogen (TKN). The NO3+NO2-N is added to TKN to represent total nitrogen.

These data were compared to SPARROW model results, but were not used directly in NRS development. These data will be critical to future iterations of the NRS as long-term monitoring data become available for the majority of HUC8 major watersheds.
Major River Monitoring by Metropolitan Council Environmental Services, Manitoba, and USGS

Long-term monitoring of nutrients in rivers by three agencies was used for calculating nutrient loads. Table 1-1 summarizes these long-term monitoring efforts. Chapter 3 summarizes these data. Each of these efforts continues to collect data, and therefore newer data are available than presented in the NRS.

Table 1-1. Major river monitoring efforts

<table>
<thead>
<tr>
<th>Monitoring program</th>
<th>Lead agency</th>
<th>Watershed/stream locations</th>
<th>Years</th>
<th>Load estimation methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term Resource Monitoring Program</td>
<td>USGS</td>
<td>Mississippi River Upstream and Downstream of Lake Pepin; Mississippi River near Iowa at Lock and Dams 7 and 8</td>
<td>1991–2010</td>
<td>MPCA used multiple year regressions in Flux32.</td>
</tr>
<tr>
<td>Metropolitan Council Major Rivers Monitoring Program</td>
<td>Metropolitan Council Environmental Services</td>
<td>Mississippi River at Anoka and Prescott; Minnesota River at Jordan; St. Croix River at Stillwater</td>
<td>1980–2010</td>
<td>Met Council used 1-year concentration/flow data and a single year’s flow to calculate loads in Flux32.</td>
</tr>
<tr>
<td>Red River</td>
<td>Manitoba Conservation and Water Stewardship and Environment Canada (CWSEC)</td>
<td>Emerson Manitoba</td>
<td>1994–2007</td>
<td>Manitoba CWSEC used monthly water quality and flow data (average of daily) for full period to estimate monthly and annual loads.</td>
</tr>
</tbody>
</table>

Mississippi River at St. Cloud

Photo Credit: MPCA
Best Management Practices for Nutrient Reduction

The effectiveness of BMPs and conservation practices for reducing nutrient loads to surface waters was evaluated from several sources. Three key sources of information for agricultural BMPs included: (1) Minnesota AgBMP Handbook; (2) Iowa State University literature review; and (3) University of Minnesota Nitrogen Best Management Practice watershed planning tool (NBMP).

MDA’s Clean Water Research Program funded the *Minnesota AgBMP Handbook* (Miller et al. 2012). The handbook describes different BMPs and associated research findings concerning the effect that individual BMPs can be expected to have on reducing pollutants to surface waters, including nutrients.

Iowa recently completed an extensive review of Upper Midwest studies on the effectiveness of nitrogen removal when using various individual and collective BMPs (Iowa State University 2013). This report, part of the *Iowa Nutrient Reduction Strategy*, was developed by a team of scientists led by Iowa State University.

The University of Minnesota developed the *NBMP tool* to enable water resource planners developing either state-level or watershed-level nitrogen reduction strategies to gauge the potential for reducing nitrogen loads to surface waters from cropland, and to assess the potential costs of achieving various reduction goals. The tool merges information on nitrogen reduction with landscape adoption limitations and economics. The tool allows water resource managers and planners to approximate the percent reduction of nitrogen entering surface waters when either a single BMP is applied across the watershed or a suite of BMPs is adopted at specified levels across the watershed. The tool also enables the user to identify which BMPs will be most cost-effective for achieving nitrogen reductions. The spreadsheet was not designed for individual land owner decisions, but rather for large-scale watershed or state-level assessments.