Water Quality Monitoring

August 2021

Minnesota’s Water Quality Monitoring Strategy 2021-2031

Minnesota’s strategy to ensuring that our waters are monitored and evaluated; developed for the U.S. Environmental Protection Agency.

MINNESOTA POLLUTION CONTROL AGENCY

Authors

Lindsay Egge
Pam Anderson
Lee Ganske

Contributors/acknowledgements

MPCA:

Jesse Anderson, Ryan Anderson, Anna Bosch, Michael Bourdaghs, Jordan Donatell, Lindsay Egge, Michael Feist, Aaron Luckstein, Shannon Martin, Miranda Nichols, Scott Niemela, Kelly O'Hara, Cindy Penny, Tiffany Schauls, Erik Smith, Laurie Sovell, Mike Trojan, Steve Weiss, Jim Ziegler

Partner organizations:

Dan Henely, *Metropolitan Council Environmental Services*
Heather Johnson, Bill VanRyswyk, *Minnesota Department of Agriculture*
Joy Loughry, Steve Kloiber, *Minnesota Department of Natural Resources*,
Steve Robertson, Tracy Lund, *Minnesota Department of Health*

Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 |

651-296-6300 | 800-657-3864 | Or use your preferred relay service. | Info.pca@state.mn.us

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Introduction

Minnesota has an abundance of water resources – more surface water than any other of the 48 contiguous states. Minnesota boasts an estimated 105,000 miles of rivers and streams, 12,200 lakes, and 10.6 million acres of wetlands (https://www.pca.state.mn.us/sites/default/files/wq-s7-52.pdf); in addition, Minnesota has generous reserves of good quality groundwater. Plentiful, accessible water is important to Minnesota's agricultural and business economy, and is the reason that water recreation, such as fishing, canoeing and kayaking, swimming, and other pursuits, makes up a large part of the state's tourism revenue - a $16 billion dollar a year industry. However, the sheer abundance of water creates challenges for monitoring, assessing, protecting, and restoring Minnesota waters.

The Minnesota Pollution Control Agency (MPCA) and its sister agencies along with local and federal partner organizations conduct numerous surface and groundwater monitoring activities to provide information about the status of the state's water resources and to identify potential or current threats to the quality of surface and groundwater, choose options for protecting and restoring waters that are impaired, and evaluate the effectiveness of implemented management plans. The goal is to provide information to assess – and ultimately to restore or protect – the integrity of Minnesota's waters.

To be effective in conducting monitoring that will meet Minnesotan's needs for information, Minnesota needs an overall guiding strategy. The MPCA and sister agencies have been utilizing a watershed approach since 2007 as an organizing principle to guide surface and groundwater quality monitoring activities and many other aspects of water resource management. Enabling the watershed approach were passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 and passage of the Clean Water, Land and Legacy Amendment (Amendment) in 2008. The CWLA and the Amendment have provided a structure and a source of revenue that have greatly improved the ability of the MPCA and its partners to achieve the vision of clean, sustainable surface and groundwater.

This introduction provides important background for Minnesota's Water Quality Monitoring Strategy, 2021-2031. This includes an overview of the watershed approach and how it benefits the state's goals to assess, protect, and restore Minnesota's waters; a description of the monitoring types included in this Strategy; and finally a brief description of the Strategy's organization.

Minnesota's overarching approach to water management

History

While they do not govern or fund all aspects of water resource monitoring and management in Minnesota, the CWLA and the Amendment do provide critical structure, guidance, and funding.

On November 4, 2008, Minnesota voters approved the y Amendment to *protect drinking water sources; to protect, enhance, and restore wetlands, prairies, forests, and 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 Minnesota's sales and use tax rate by three-eighths of one percent on taxable sales, starting July 1, 2009, continuing through 2034. One-third of those funds are dedicated to a Clean Water Fund (CWF) to protect, enhance, and restore water quality in lakes, rivers, streams, and groundwater, with at least five percent of the fund targeted to protect drinking water sources. When passed, it was explicitly stated that these funds are to supplement, not supplant, existing funding for state agencies. Much of the work outlined in this strategy document is contingent upon funding support from the CWF.

Partnerships in protecting Minnesota’s waters

The MPCA and six other agency partners collaborate in Minnesota’s water resource management activities under the CWF:

- Minnesota Department of Natural Resources (MDNR)
- Minnesota Department of Agriculture (MDA)
- Minnesota Department of Health (MDH)
- Minnesota Board of Water and Soil Resources (BWSR)
- Minnesota Public Facilities Authority
- Metropolitan Council (Met Council)

To facilitate this collaboration, the Clean Water Fund Interagency Coordination Team (Coordination Team) was established. The purposes of the Coordination Team are:

- Coordinating state agency clean water activities to achieve CWF outcomes
- Coordinating and leveraging funding opportunities to achieve CWF purposes
- Enhancing institutional knowledge for future water management activities
- Providing consistent CWF information for public use, reporting and administrative procedures

Coordination Team members represent the perspectives of their organization and serve as spokespersons for the Coordination Team within the agency/organization that they represent. The team employs systematic water quality protection and restoration strategies for the 25-year life of the Amendment funding, using existing programs to avoid adding additional bureaucratic layers and to eliminate duplication of water management activities.

The Coordination Team has further established the following interagency sub teams to achieve sustainable management and protection of the state’s surface water and groundwater resources:

- Surface water monitoring and assessment
- Protection and restoration strategy development
- Implementation
- Research
- Groundwater and drinking water
- Measures and outcomes
- Communications

An overall system expectation is that each sub team will be integrally linked to the other sub teams to achieve the overall broad goal of protecting the state’s public health, economic health and ecosystem health.

Protecting and restoring Minnesota’s waters is a priority for all of the agencies and organizations that receive a part of the CWF. Although the agencies have varied and unique missions, partnership and coordination around water quality management activities has been occurring for years. With passage of the Amendment, this coordination has been institutionalized into a system. Because the CWF will exist for 25 years, agencies will employ adaptive management strategies to ensure the best environmental outcomes are achieved throughout the life of the funding.

The watershed approach

Beginning in 2007, the MPCA and its partners began implementing a major (8-digit hydrological unit code level) watershed approach to monitoring and managing Minnesota’s water resources. There are 80 of these major watersheds in Minnesota, most of which are defined by moderate-sized river systems.

The watershed approach involves intensively monitoring the streams and lakes within a major watershed at one time to: determine the overall health of these water resources, identify impaired waters, and identify waters in need of additional protection efforts to prevent impairments. Follow-up monitoring is then conducted in impaired sub-watersheds to determine the cause(s) of the impairments (i.e. the “stressors” impacting the biological community) and begin identification of pollutant sources and priority management zones. Watershed Restoration and Protection Strategies (WRAPS) and Total Maximum Daily Load (TMDL) studies are then written for the watershed. These in turn help guide local and state restoration and protection planning and implementation through the One Watershed One Plan process and other efforts. Regulatory activities continue throughout the process and are adjusted as needed to achieve the clean water goals.

While the watershed approach is heavily focused on surface waters, some attention has also been directed at groundwater. Part of the reason for this is the interconnectedness of groundwater and surface water in Minnesota, but it also due to the importance of groundwater as a drinking water source, for industrial uses, and for irrigation.

As of 2017, a first cycle of intensive monitoring was completed for all of Minnesota’s major watersheds. Refinements were made to sampling designs to reduce the intensity of sampling while still preserving the ability to detect change over time and complete assessments. This reduction allows for the approach to accommodate other state program and locally identified data and information gaps that will help refine restoration and protection strategies.

Types of monitoring

The purpose of this monitoring strategy is to describe all of Minnesota’s major monitoring programs for surface water and groundwater. The MPCA generally categorizes its monitoring activities according to the monitoring purpose and how the monitoring data are assessed and used. Monitoring activities usually fall into one of three “use” categories, as follows:

- **Condition monitoring***:* This type of monitoring is used to identify overall environmental status and trends by examining the condition of individual water bodies or aquifers in terms of their ability to meet established standards and criteria. Condition monitoring may include chemical, physical, or biological measures. The focus of condition monitoring is on understanding the status of the resource, identifying changes over time, and identifying and defining problems at the overall system level. Examples include: the intensive watershed monitoring conducted in Minnesota’s major watersheds; probabilistic monitoring conducted at various scales to evaluate the quality of lakes, rivers, and wetlands; and ambient groundwater quality monitoring.
- **Problem investigation monitoring***:* This monitoring involves investigating specific problems or protection concerns to allow for the development of a management approach to protect or improve the resource. Problem investigation monitoring is used to determine the specific causes of impairments to surface water, to evaluate the extent and magnitude of a contaminant plume in groundwater, and to quantify inputs/loads of contaminants to a water body from various sources. It is also used to determine the actions needed to return a resource to a condition that meets standards or goals. Examples include: stressor identification (ID) monitoring in a major watershed that contains impaired waters; monitoring of groundwater and possibly surface water at chemical release sites; and monitoring conducted for federal Clean Water Act Section 319 projects.
- **Effectiveness monitoring:** This type of monitoring is used to determine the effectiveness of a specific regulatory or voluntary management action taken to improve impaired waters or remediate contaminated groundwater. Effectiveness monitoring allows for the evaluation and refinement of a selected management or remedial action over time to ensure the approach is

ultimately successful. Examples of effectiveness monitoring are monitoring conducted following implementation of watershed protection and restoration strategies or best management practices (BMPs) at various scales, such as the subwatershed, watershed, or basin. Also, effluent monitoring that is done to assess the compliance of a facility with a permit, rule or statute (i.e. compliance tracking); in this example, the monitoring data provide information about how regulatory actions applied to a facility affect the facility's contributions to the associated water bodies (**not** the effect of the facility's contribution on the water body itself).

These definitions are important in distinguishing and understanding the purposes of various monitoring efforts; however, it should be noted there is often a degree of overlap between the various categories. This is most often the case with condition and effectiveness monitoring, as the difference between the two monitoring types is largely a matter of scale. Effectiveness monitoring is often done at the management practice scale, to evaluate specific management actions. However, this is time and cost intensive, with thousands of practices placed on the landscape. Effectiveness monitoring can also be done at larger scales in a less-refined way. That is, condition monitoring can be applied as a tool to track the system-wide effectiveness of broader environmental protection efforts. In reviewing this report, it will be important to keep in mind the monitoring type being discussed in order to understand how a particular monitoring effort fits into the overall strategy.

- **Special studies monitoring:** Some monitoring activities do not neatly fit into the monitoring types discussed above. This is especially true of special studies monitoring. This category includes a number of different lake and stream studies that are more research-focused. Examples of special studies monitoring include monitoring related to emerging issues (pharmaceuticals, wastewater compounds, etc.); monitoring related to critical toxic pollutants such as mercury; monitoring focused on specific geographic areas; and monitoring focused on a specific problem or to answer a specific question. This type of monitoring is generally characterized by a very narrow focus and a study of relatively short duration.

Organization of the strategy

Minnesota's Water Quality Monitoring Strategy 2021 – 2031 contains three main sections that discuss overall goals and objectives, surface water, and groundwater. Each section begins with a focus on water quality work specific to the MPCA. This is followed by water quality monitoring work completed by partner agencies and organizations. The surface water and groundwater sections discuss Minnesota's strategies by monitoring type: condition, problem investigation, and effectiveness. Sections focusing on data management, quality assurance, data analysis and reporting are included specific to surface water and groundwater activities. Programmatic evaluation, support, and planning close out each media type. An appendix with links to additional information is included.

Section 1: Goals and objectives

The MPCA has two important sets of goals that help chart the agency's direction; long-term goals established in 2019, and strategic goals from the 2018-2022 strategic plan. The subset of these goals addressing water quality protection and restoration, including monitoring, are provided below. Additional water quality monitoring goals related to nonpoint source pollution are outlined in the state of Minnesota's Nonpoint Source Management Plan (NSMPP).

Section 1.1: Minnesota Pollution Control Agency's long-term and strategic goals for water quality protection and restoration

Long-term goals:

- Water quality is maintained or improved
- Water quality meets statewide goals
- Pollution to Minnesota surface waters and groundwater is reduced or prevented

Strategic goals:

- Reduce chloride (salt) entering surface waters and groundwater
- Accelerate prioritized and targeted reductions in nutrient pollution by integrating strategies with local watersheds
- Achieve wastewater pollutant reduction goals and maximize cost-effectiveness of public infrastructure investment

Section 1.2: Minnesota's Nonpoint Source Management Program Plan monitoring goals

Section 319 of the Federal Clean Water Act (CWA) requires states to develop a management program "for controlling pollution added from nonpoint sources to the navigable waters within the State and improving the quality of such waters." (CWA Sec. 319 (b) (1)). The NSMPP was developed to meet this requirement along with (as well as) to satisfy the state requirement for developing a state nonpoint source pollution (NPS) control plan in Minn. Stat. § 103F.751. Minn. Stat. § 116.03, subd. 3, gives the MPCA and commissioner the authority to receive and disperse federal funding. The U.S. Environmental Protection Agency (EPA) approved Minnesota's first NPS management program in 1988. Updates and revisions of the NSMPP were completed in 1994, 2001, 2008, 2013, and a revised NSMPP is currently in development.

The goals, objectives, and strategies of the current NSMPP are specific to the Section 319-funded work and do not encompass all of the goals, objectives, and strategies of the whole of Minnesota's watershed framework and associated programs. Minnesota's Section 319 NPS NPSMPP is implicitly incorporated in the state's CWF programs and the Minnesota Water Quality Framework and are intertwined with several local, state, and federal programs. Minnesota's NSMPP, prepared by the MPCA in partnership with a consortium of federal, state, and local organizations as part of EPA's CWA Section 319 planning process, includes water quality monitoring goals related to nonpoint source pollution.

Section 2: Surface water

The following information pertains to the approaches used to monitor, evaluate, and report on lakes, flowing waters, and wetlands in Minnesota.

Section 2.1: Condition monitoring strategy

Water quality condition monitoring is the starting point in implementing the CWA-mandated process of assessing water quality, planning for water quality protection or restoration, implementation of protective or corrective measures, and follow-up effectiveness monitoring. Water quality monitoring results are used to determine whether a water body meets standards and whether water is impaired and in need of restoration or unimpaired and in need of protection.

While the overarching purpose of the MPCA's condition monitoring activities is to assess the condition of Minnesota's surface water resources, these data are also used to assess potential and actual threats to water quality, to track trends over time, and to evaluate the effectiveness of management activities taken to address impairments and other threats to water quality.

Monitoring conducted by the MPCA's citizen monitoring programs, by other local, state, and federal agencies, and data collected using remote sensing, are also used for this purpose. Work completed in partnership with other state agencies will be discussed in Section 2.5.

2.1.a Major watershed condition monitoring

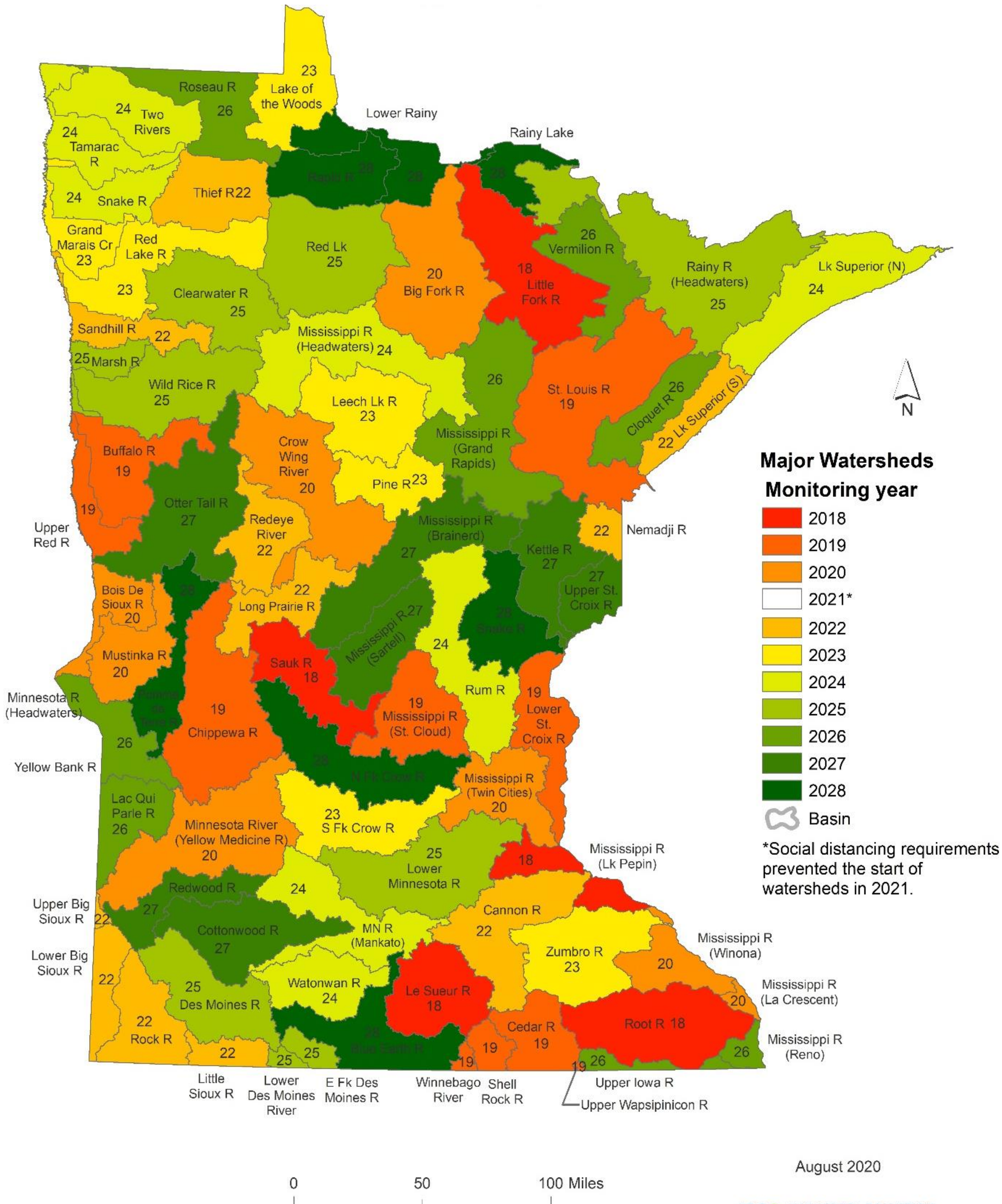
In 2007, the MPCA began organizing its statewide condition monitoring program around Minnesota's 80 major watersheds and monitoring the condition of its rivers, streams, and lakes on a watershed by watershed basis. Using this watershed approach, the MPCA conducts monitoring in an average 8 major watersheds each year. The MPCA completed monitoring of all major watersheds in 2017 and is now monitoring each major watershed for a second time using a similar monitoring schedule. The current 10-year schedule for watershed monitoring is shown in Figure 1, with more information located here: https://www.pca.state.mn.us/water/watershed-approach-restoring-and-protecting-water-quality

The intensive watershed monitoring (IWM) design governed the collection of monitoring data during the first 10-year cycle. Originally applied to rivers and streams, the MPCA adapted the concept to all monitored water body types for the purpose of the watershed approach. Additionally, the MPCA conducted year-round contaminant load monitoring (integrating stream flow and analysis of stream chemistry from grab samples) at basin, major watershed and subwatershed scales.

The second round of watershed monitoring retains the same monitoring components but incorporates sampling design modifications to accommodate slightly different monitoring objectives. Whereas the first round of monitoring was designed to characterize surface water across the state, in the second round the emphasis is to look for change in condition. Secondarily, the MPCA also wanted to better meet the monitoring needs of local partners by providing monitoring resources to support their watershed management goals. This includes meeting with, and soliciting requests for monitoring needs from, sister agencies, county soil and water conservation districts, watershed managers, and Tribal Nations.

A description of each monitoring component involved in the watershed approach, including the MPCA's efforts to incorporate wetland monitoring activities and acknowledge groundwater-surface water interactions, is provided below.

Figure 1. Schedule for lake and stream watershed monitoring 2018 through 2028



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Monitoring rivers and streams in the major watersheds

The watershed approach uses biology (fish and aquatic invertebrates), water chemistry and physical habitat indicators to determine condition. Sites in the first round of monitoring (Cycle 1, 2007 to 2017) were selected using a nested subwatershed approach whereby sites were placed at the pour points or outlets of the major watershed and its subwatersheds (i.e. aggregated HUC 12 for chemistry and HUC 14 for biology). The design provided a robust assessment of water quality without monitoring every single stream reach.

The second round of monitoring (Cycle 2, 2018 to 2028) uses the same suite of indicators but the density of monitoring sites is less. The objective is to detect change in watershed condition using a subset of the sites that were selected in the first round. The design uses the HUC 12 pour point as the location for biological stations, eliminating sites at the HUC 14 scale and results in about 1/3 fewer monitoring sites (Figure 2). The re-directed monitoring capacity allows the MPCA to work collaboratively with local partners to help meet their monitoring goals. The MPCA hosts meetings with state, local, and tribal partners to engage in a dialogue on the needs of the greater watershed and identify locations where data are needed to implement local water plans and delist waters. Through this state and local needs monitoring request process, the MPCA provides monitoring that is designed to address the specific monitoring needs of the watershed, including, but not limited to, locations at a smaller watershed scale, sonde deployments, or additional parameters.

At each chemistry monitoring location (aggregated HUC 12), sampling is conducted for two years, with a focus on phosphorus, chlorophyll-*a* (subset of sites), sediment, *E. coli*, and sonde (dissolved oxygen, pH, and temperature) measurements. Data are collected at a frequency great enough to be used to delist and list waters, fill gaps identified by modeling, track changes in priority waters near the impairment threshold, inform permit limits, and problem investigation.

Local partners can also obtain funding to complete associated monitoring through the MPCA's Surface Water Assessment Grant (SWAG) program. The SWAG program is an important part of the MPCA's overall strategy because it engages local partners in the condition monitoring and assessment process. Long term and early engagement by local stakeholders in monitoring and assessing water resources is an important element in the successful implementation of WRAPS through One Watershed One Plans. More information on SWAG can be found at: https://www.pca.state.mn.us/water/surface-water-assessment-grants.

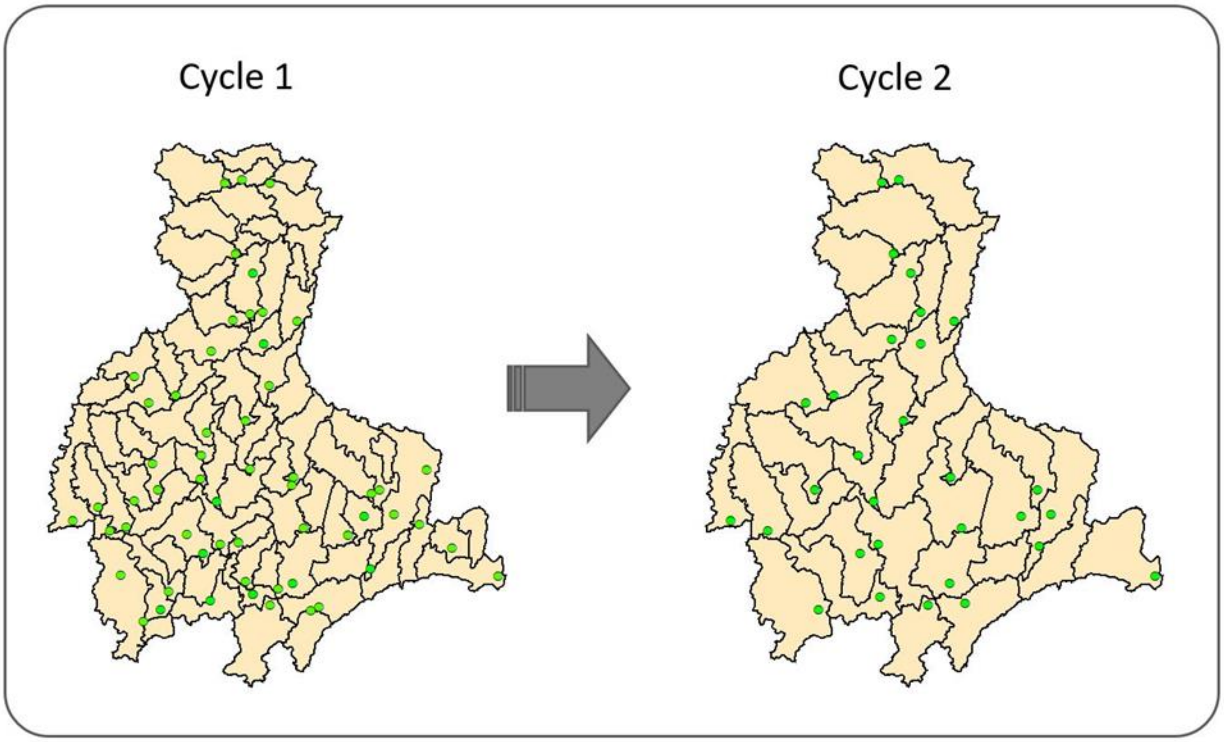
At each biological monitoring site, fish, invertebrates, and water chemistry samples are collected, and habitat quality is documented. In addition, fish are collected at the watershed outlet to provide fish tissue for analysis to evaluate human consumption concerns (aquatic consumption use).

Fish are collected using electro-shocking techniques, and invertebrates are sampled with dip nets. The water chemistry parameters are a subset of the parameters collected at the chemistry IWM sites; their main purpose is to document water chemistry conditions at the time the biological samples are collected. Fish sampling is typically conducted between mid-June and mid-September, while invertebrate sampling typically takes place between early August and late September.

Biological monitoring is an important component of the MPCA's monitoring approach. It is an effective tool for assessing water resource quality, regardless of whether the stressor impacting the stream reach is chemical, physical, or biological in nature. The biological community represented by biological samples (the number and variety of species present) provides an indication of overall stream health when compared to the index of biological integrity (IBI) appropriate for the particular stream. Biological monitoring is often able to detect water quality impairments that other monitoring methods may miss or underestimate. For more information about the MPCA's biological monitoring program, visit https://www.pca.state.mn.us/water/biological-monitoring-water-minnesota.

MPCA also completes a similar monitoring effort on Minnesota's large rivers: Mississippi, Minnesota, Red, Rainy, and St. Croix. This is based on a HUC-10 level approach and pairs biological monitoring with water quality data (bacteria, nutrients, sediment, and sonde data) for the purposes of water quality assessments.

Figure 2. Stream monitoring sites in the Snake River Watershed Cycle 1 and Cycle 2



Monitoring lakes in the major watersheds

Lake monitoring poses challenges that are different from rivers and streams. Minnesota has about 12,200 lakes greater than 10 acres in size. Of those, about 2,300 are between 100 and 500 acres, and about 700 are 500 acres or larger. Since it would be prohibitively expensive to monitor all of Minnesota's lakes – just like it would be to sample every stream reach – the MPCA has developed a lakes sampling strategy. Our strategy focuses on lakes that are publically accessible and follows the same rotating basin approach.

The MPCA's goal for the first round of monitoring was to sample all lakes 500 acres or larger. These lakes provide the largest opportunity for recreation use across Minnesota and were considered the highest priority. A portion of those between 100 and 500 acres were sampled by a mix of agency staff and local partners through pass through funding. Small lakes (10-100 acres) were only sampled if local interest and/or MDNR public accesses were available. Water chemistry sampling focuses primarily on phosphorus, chlorophyll-*a*, and Secchi transparency. A subset of sites also have nitrate, sulfate or chloride added, as necessary to complete assessments.

MPCA is prioritizing lakes that are fully supporting, but are showing declines in clarity and non-supporting lakes showing improving clarity (i.e. lakes are changing in status). Lakes that are of high local concern, based on their WRAPS document and those identified in their One Watershed One Plan or local water plan document and those that have been reported to the agency for harmful algal bloom incidents. If recent data exists, MPCA will rely on that existing data to complete assessments. Generally, these lakes will be sampled for one year out of 10, as they have historical data to aid in the assessment. Lakes that have not been assessed before will be sampled for 2 consecutive years to meet 303(d) listing requirements.

As with streams, MPCA has funds available for local partners to contract to complete lake water quality monitoring through the SWAG.

The fish-based IBI (FIBI), developed by the MDNR, is the primary tool used to assess whether a lake fully supports aquatic life. It incorporates multiple measurements of the fish community. When the measurements are added together, they produce a score that reflects the lake's biological health. Each year MDNR Fisheries staff complete approximately 130-160 FIBI surveys and assess the status of a similar number of lakes based on the data collected. Lakes are assessed as supporting aquatic life use or non-supporting of aquatic life use (impaired) based on FIBI tools and are sampled on the same rotating basin approach as the water chemistry.

For more information about monitoring of lakes, see: https://www.pca.state.mn.us/water/lake-monitoring-0 and https://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html.

In addition, to obtain a snapshot of water quality in lakes that are not sampled and to supplement the chemical and physical monitoring that is conducted on sampled lakes, the MPCA uses satellite remote sensing information and other indicators of lake water quality that may be available for individual lakes. Remote sensing is used primarily to provide an indication of lake clarity; remote sensing "snapshots" collected over time can provide an indication of changing lake clarity, at relatively low cost.

Monitoring wetlands in the major watersheds

The MPCA does not monitor wetlands using the same watershed approach as lakes and streams due to the extensive and complex nature of the state's wetland resource. There are an estimated 10.6 million wetland acres in the state ranging from forested swamps and bogs to meadows and marshes and open water wetlands. In addition, the MPCA has formally assessed only a very narrow type of depressional wetland that typically has open water and is connected to adjacent impaired streams or lakes.

Alternatively, the MPCA primarily monitors wetland quality trends on a statewide and regional basis through probabilistic monitoring surveys (see Section 2.1.C) and provides targeted wetland support monitoring as requested by monitoring and stressor identification staff.

Wetland support monitoring is used as ancillary information to help make decisions during assessment and stressor identification of lakes and streams and includes:

- Shallow lake vs. wetland determinations
- Stream channel vs. wetland determinations
- Stream channel aquatic vegetation surveys and condition assessments
- Adjacent wetland functional classification for natural background determinations
- Adjacent wetland vegetation condition assessments

Condition monitoring for trends

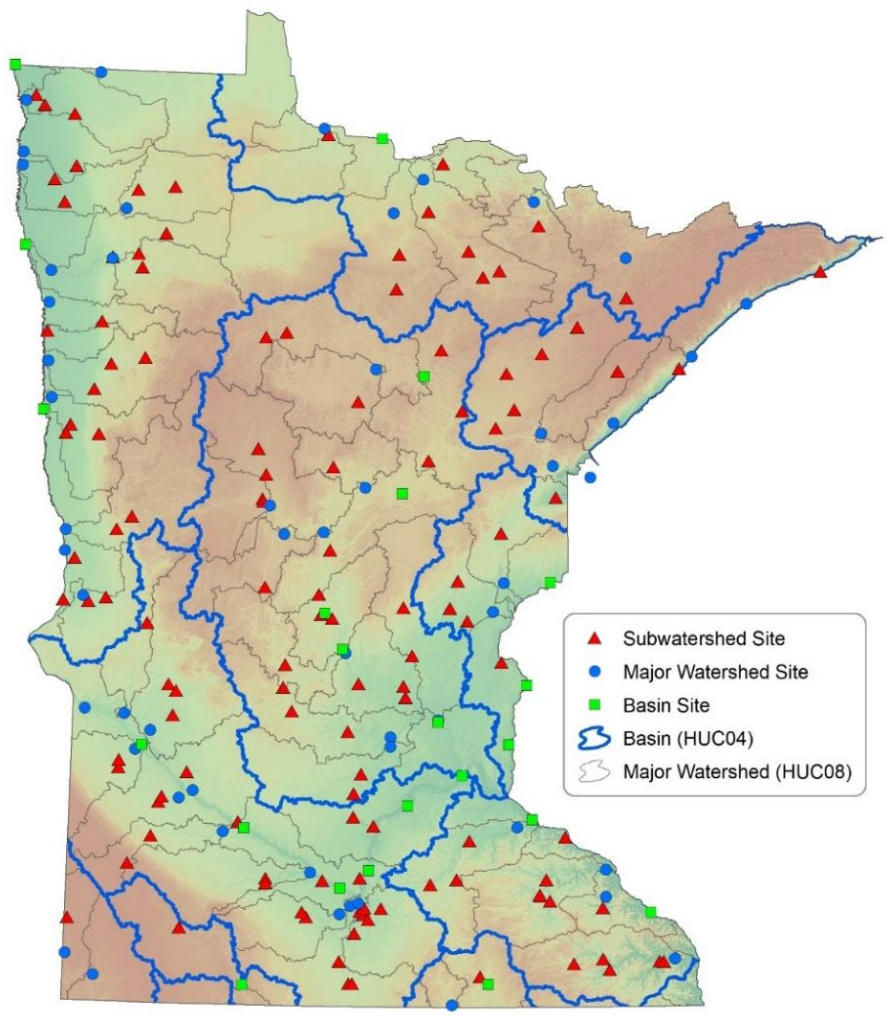
Pollutant load monitoring involves defining the amount or mass of a constituent (e.g. phosphorus, nitrate, etc.) passing through a monitoring point in the watershed over some unit of time. Contaminant loads are calculated by integrating stream flow gaging data and stream chemistry concentration data. Loads can be normalized by area or flow so watersheds of different sizes and runoff characteristics can be compared to one another. To assess change over time, it is valuable to analyze trends in both concentration and load as they each tell a different story. Trend analysis is particularly helpful in putting the IWM data into a longer term context, given that intensive monitoring occurs in each watershed 2 of every 10 years. It is also a component of monitoring the effectiveness of watershed restoration and protection plans at the broad watershed scale.

To collect the data needed to calculate pollutant loads, the MPCA relies on the Watershed Pollutant Load Monitoring Network (WPLMN) that includes permanent flow and chemistry monitoring stations at 197 river and stream stations across the state (Figure 3). Stations in the WPLMN are at three scales: basin (multiple major watersheds draining to a large river); major watershed; and subwatershed. Basin and major watershed scale stations operate year around. Subwatershed scale stations operation from ice out unit the end of October of each year.

All WPLMN stations record streamflow on a continuous basis every year, either year-round or during open water (non-ice cover) conditions. Water quality samples are also collected on a regular basis year round during these same periods, such that on-going records of load can be calculated. With this design, between 20-35 mid-stream grab samples are collected per year from each load monitoring station. Monitoring is targeted to characterize major precipitation events, particularly spring runoff; base flow conditions, which typically occur during the winter months; and background flow conditions, primarily during the summer months. The water quality samples are analyzed for total suspended solids, nitrate, phosphorus, total Kjeldahl nitrogen (subset of sites) and orthophosphate (subset of sites), pH, conductivity and transparency. These water quality and discharge data are then used to compute annual pollutant loads for nitrate plus nitrite nitrogen, total phosphorus, dissolved orthophosphate, and total suspended sediment.

The network is a partnership effort between the MPCA, MDNR, and the Met Council. A number of stations also rely on the United States Geological Survey (USGS) flow stations. Much of the monitoring completed in this network is done by local government units. MPCA passed through funds for completion of annual monitoring at these locations through the WPLMN contracts.

Figure 3. Watershed Pollutant Load Monitoring Network station locations



Locally led and volunteer citizen monitoring

Local partner and volunteer citizen monitoring are important components of the watershed approach. While the MPCA focuses its condition monitoring efforts on the major watersheds during years 1 and 2 of the 10-year schedule, local partner and volunteer citizens monitoring provides both additional data needed to complete assessments and data that are used to evaluate the status and trends of water bodies in the years between the 10-year monitoring cycles.

The MPCA coordinates two statewide volunteer citizen monitoring programs: the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). The CLMP was started in 1973 and is one of the nation's largest and longest running volunteer lake monitoring programs. The CSMP began in 1998. Volunteers in both programs primarily monitor lake and stream clarity.

The MPCA has integrated the volunteer monitoring programs into its watershed approach by recruiting and retaining volunteers to monitor lakes and streams for which condition data are desired to supplement agency assessment monitoring and to continue monitoring in the years between MPCA monitoring visits. More information about the MPCA's citizen water monitoring programs, including training materials and statewide results, is available at www.pca.state.mn.us/cmp.

Considerable monitoring occurs through locally funded efforts, such as through lake associations, lake improvement districts, and watershed districts. This data is critical to completing a statewide look at water quality. Data that is shared with the MPCA is used for water quality assessments and trend analysis.

The MPCA also participates in a county-led wetland citizen monitoring program known as the Wetland Health Evaluation Program (WHEP) http://mnwhep.org/. WHEP has operated since 1996 in Dakota County and since 2000 in Hennepin County, both located in the Twin Cities Metropolitan Area (TCMA). Local cities within each county identify wetlands they would like to have monitored and help their respective county coordinator recruit citizen volunteers. Participating cities provide funding to the counties to operate the program. The MPCA primarily provides technical expertise and training for WHEP volunteers, to enable them to identify wetland plants and invertebrates at a level sufficient to use the simplified IBIs employed by the program. Cities have found the WHEP data useful in their wetland management programs to track the impacts of development and implementation of BMPs on wetland health.

Condition monitoring and the watershed approach: looking to the future

MPCA has evaluated its network at the close of each cycle; to determine overall change needed to provide relevant data to assessment, reporting, strategy development and tracking protection and restoration efforts.

Over time, the monitoring data collected via the 10-year rotating cycle from the major watersheds will allow for tracking trends in aquatic biology. The information collected will also allow for delisting of impaired waters that now meet water quality standards and support their beneficial uses.

MPCA has begun incorporating an intentional review of sites to ensure we are collecting data in environmental justice communities. This includes evaluation of station locations and maintaining locations which provide data to those impacted areas. This evaluation may lead to the addition of sites in an environmental justice area, if our framework does not adequately represent an area. It also requires a process that ensures we have opportunities for those communities to request additional locations for data collection to meet their local needs.

Work is also underway to utilize our data to track the impacts of climate change. For example, our volunteers collect ice on and ice off data on Minnesota's lakes. Our stream monitoring networks have continuous temperature loggers and a number of stations are paired with flow. These networks provide an additional benefit above and beyond condition monitoring to provide information for planning efforts to help mitigate the effects of climate change. Additional information on climate work follows.

2.1.b Targeted monitoring activities

In addition to the major watershed monitoring described above, the MPCA carries out several other monitoring projects that provide additional information about the condition of the state's water resources. These other monitoring activities are set up for very specific purposes; however, they also contribute data that are captured in the assessment process.

Sentinel Lakes Monitoring Program

The Sentinel Lakes Monitoring Program is part of a long-term, collaborative monitoring effort that is being led by the MDNR. The program is designed to provide data that will help to detect and understand the physical, chemical and biological changes occurring in Minnesota's lakes as a result of our changing climate. The MPCA's role in this effort involves collecting and assessing water quality monitoring data from these lakes. The 25 representative lakes within the program are found throughout Minnesota's diverse ecoregions, and are stratified by depth and trophic state. Lakes are divided into two tiers, with Tier 1 lakes sampled annually and the Tier 2 lakes sampled for the 2 years we are in their respective watershed. For more information about Sentinel Lakes visit: https://www.dnr.state.mn.us/fisheries/slice/index.html. This program includes waters from EPA's Regional Monitoring Network.

Long-term Biological Monitoring Program

The MPCA uses fish and macroinvertebrate community data in conjunction with water chemistry data to assess the ecological condition of rivers and streams throughout the state. Climate change can deteriorate the effectiveness of biological indicators to make such assessments by disrupting the stressor-response relationship between watershed disturbance and aquatic communities. For example, a cold water stream may experience degradation due to increased air temperature and frequency of intense precipitation events even if the watershed lacks significant anthropogenic disturbance. To account for such effects in our biological indicators we initiated a network of long term biological monitoring sites in least-disturbed, reference watersheds across the state. Monitoring began in 2013 and the network now includes 68 sites that will be sampled biennially. Collaborations with other water resource entities are being sought to increase the amount of data collected at each site as well as the utility of this data set for others. Locations in the network are included in EPA's Regional Monitoring Network.

Chloride Monitoring Program

The MPCA started a long-term Chloride Monitoring Program in the TCMA in 2018. This focuses on lakes that are already impaired, are supporting, and are unknown to track concentrations over time. MPCA relies on the Met Council's river monitoring program to track chloride concentrations in the area's streams and rivers. While concentrations statewide are above natural background conditions, the elevated concentrations are limited to metropolitan areas impacted greatly by road salt or water softeners.

Metals Monitoring Program

MPCA tracks mercury concentrations in surface water to help track progress towards our goals identified in the mercury TMDL. This network of approximately 90 sites is sampled three times per year, on a 30 sites per year rotation. Most of the sites align with the WPLMN.

Fish Contaminant Monitoring Program

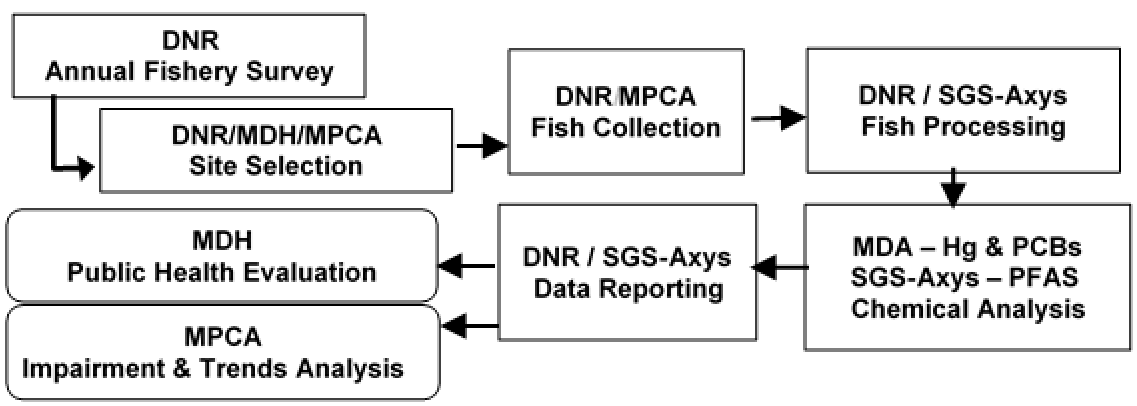
Collection of fish from Minnesota's lakes and streams for analysis of contaminants has been an activity of the MPCA's in partnership with the MDNR and the MDH since 1968. This activity was formalized in 1990 as the Fish Contaminant Monitoring Program (FCMP), which is a partnership between the MPCA, MDNR, MDA, and MDH. Together, these agencies cooperate to provide essential information concerning contaminants in fish that is used to fulfill a number of purposes. These include providing data for: development of science-based fish consumption advice; analysis of mercury cycling and trends analysis; development of water quality standards; analysis of potential harm from newly identified bioaccumulative pollutants; and determining aquatic consumption use support. The roles of the various partners and the steps in the FCMP process are depicted in Figure 4.

Specific to the aquatic consumption use support, the monitoring design involves the collection of fish at the outlet of each major watershed for analysis of mercury and polychlorinated biphenyls (PCBs). Fish contaminant monitoring is conducted as part of the biological IWM during the first year of the IWM cycle. Depending upon the watershed, additional locations may be sampled and/or the fish may be analyzed for additional contaminants.

For the analysis of mercury content, it is important to sample top carnivore species, while rough fish species are important for PCB analysis. Species preferences for top carnivores are: walleye, northern pike, smallmouth bass, channel catfish, and bluegill. Species preferences for rough fish are: common carp, redhorse sucker, and white sucker. An adequate distribution of fish size classes (edible size) is critical to characterize contamination level, since contaminant concentrations increase with fish size and/or length.

Note that the FCMP has also cooperated with EPA, the USGS, the National Park Service, and other entities to provide fish for special studies that focus on the presence of mercury, PCBs or other contaminants in fish.

Figure 4. Fish contaminant monitoring process



2.1.c Probabilistic monitoring activities

Probabilistic (or random) surveys have become an important tool for monitoring the condition of Minnesota's water resources. These surveys provide data sets that yield statistically sound, unbiased estimates of the condition of the state's water bodies, and are very helpful in determining trends in water resource condition over time.

The MPCA, with assistance and/or funding provided by EPA, has conducted probabilistic surveys of Minnesota streams since 1996. Since that time, EPA has expanded its National Aquatic Resource Surveys (NARS) program (http://water.epa.gov/type/watersheds/monitoring/nationalsurveys.cfm). This has provided the MPCA with the opportunity to expand its state-based probabilistic survey projects from streams to lakes, wetlands, and coastal waters of Lake Superior. These surveys are expected to provide a wealth of information to guide Minnesota's water protection and restoration policies. The surveys also provide MPCA staff with the opportunity to gain new expertise by working collaboratively with EPA and other state scientists; and a relatively inexpensive means to determine if new or emerging chemicals or biological indicators are sufficiently widespread to be included in the MPCA's ongoing monitoring programs.

The following paragraphs describe the EPA NARS (i.e. national) surveys that have been conducted in Minnesota, and the random surveys that are scaled to Minnesota and are conducted either independently or in conjunction with the EPA NARS surveys.

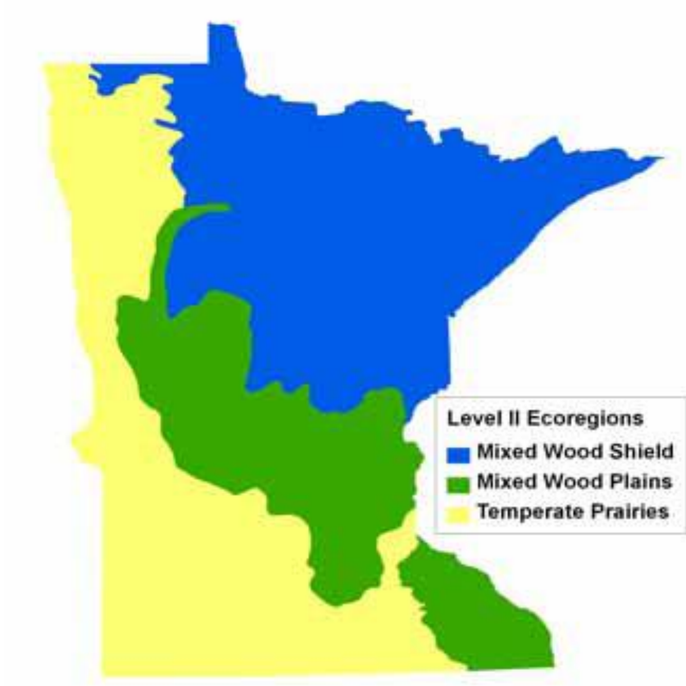
National Aquatic Resources Surveys

The EPA's NARS includes the National Rivers and Streams Assessment (NRSA), the National Lakes Assessment (NLA), the National Wetland Condition Assessment (NWCA) and the National Coastal Condition Assessment (NCCA). The EPA plans to conduct these surveys on a national basis every five years. Brief background on each of these national surveys is provided below along with additional information on state based surveys funded through the NARS program.

National Rivers and Streams Assessment

The EPA's Stream Assessment was first conducted in Minnesota in 2004 looking at wadeable streams. In 2009, EPA launched the NRSA which covers all flowing waters, which is conducted over two years. EPA contractors conducted the most recent flowing waters survey in Minnesota in 2018-2019. More information about the EPA's NRSA is available at the MPCA's website: www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/water-quality-condition-monitoring/random-survey-of-the-nation-s-rivers-and-streams.html

Figure 5. Minnesota's major ecoregions



The MPCA began using random surveys to assess rivers and streams throughout Minnesota in 1996. The original organizing framework for these random surveys was the major river basins. Beginning in 2010, the MPCA changed the survey approach such that it is now a statewide design based on Minnesota's major ecoregions (Figure 5). With this design, the survey provides statistically based estimates of river and stream condition by ecoregion as well as for the state as a whole. The survey is conducted in conjunction with the EPA's NRSA flowing waters survey, which enables the MPCA to conduct the Minnesota survey as an enhancement of the national survey on an every five years basis.

With the revised design, the Minnesota Random Rivers and Streams Survey will provide more frequent estimates of condition and show more clearly if conditions are improving or degrading throughout the state (i.e., trend detection).

More detail about the survey design and past results are available at:
www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/water-quality-condition-monitoring/random-river-and-stream-surveys-in-minnesota.html

National Lakes Assessment

The EPA's NLA survey was first conducted in Minnesota in 2007, a total of 41 Minnesota lakes were randomly selected by EPA to provide a statistically sound data set for the national survey. The survey occurs in 5 year intervals. In 2012 and 2017, the MPCA intensified sampling to include 150 lakes statewide, stratified by 50 lakes in each of the state's Level 3 ecoregions (Northern Forests, Eastern Temperate Forests, and Great Plains). An up-to-date listing and overall study design is available on the EPA NLA webpage: https://www.epa.gov/national-aquatic-resource-surveys/nla.

In 2020, the MPCA published a report describing NLA water chemistry results from all three past surveys, including an on-line data viewer. More information about the NLA survey and the Minnesota results is available at: https://www.pca.state.mn.us/water/national-lakes-assessment.

The MPCA plans to participate again in the NLA Survey that is scheduled for 2022.

National Wetland Condition Assessment

The MPCA has participated in both of the 2011 and 2016 NWCA iterations. The NWCA survey design in Minnesota is fully integrated with our statewide random wetland survey—the Minnesota Wetland Condition Assessment. The MPCA plans to participate in the NWCA according to the 5-year NARS schedule with subsequent iterations in 2021 and 2026.

MPCA supplements this survey with two probabilistic surveys of depressional and all wetland types. The Minnesota Wetland Condition Assessment (MWCA) is a statewide and regional intensification of the NWCA that represents virtually all of Minnesota's extensive and very diverse wetland resource. The primary indicator is vegetation quality and two MWCA iterations have been completed in 2011-2012 and 2016. The MPCA is heavily invested and committed in probabilistic wetland monitoring and anticipates completing further MWCA iterations in conjunction with EPA's NWCA in 2021-2022 and 2026-2027.

Prior to EPA's NWCA, MPCA wetland monitoring was primarily focused on depressional wetlands (i.e., wetlands within a distinct basin) that typically have permanent open water and marsh vegetation. Depressional wetlands are a small but iconic part of the wetland resource and the MPCA conducted some of the first probabilistic wetland monitoring surveys in the nation (with EPA design assistance) with invertebrates, vegetation, and water chemistry as primary indicators. The first depressional probabilistic survey was completed in the Redwood River watershed in 2003. Subsequently, the MPCA initiated a statewide and regional depressional wetland probabilistic survey in 2007-09.

The statewide depressional wetland probabilistic survey has evolved into the Depressional Wetland Quality Assessment (DWQA) with subsequent iterations completed in 2012 and 2017. The DWQA is now focused geographically on the Mixed Wood Plains and Temperate Prairies ecoregions (Figure 5) where depressional wetlands are a more common component of the wetland resource. The MPCA anticipates completing future DWQA iterations in 2023 and 2028.

More detail about the surveys is available at: https://www.pca.state.mn.us/water/wetland-monitoring.

National Coastal Condition Assessment

Monitoring for the EPA's NCCA on Minnesota's Lake Superior shoreline previously occurred in 2010 and 2015. MPCA lacked the resources to effectively conduct NCCA work for these surveys; contractors completed the work for EPA. In preparation for NCCA 2020, MPCA took on direct involvement in planning and execution, which is underway at this time. MPCA is partnering with MDNR to conduct the sampling at eight sites on the north shore of Lake Superior. Two of the eight sites sampled in 2021 are revisited locations from 2015 and 2010, while one is a revisit station solely from 2015. Monitoring data collected in NCCA 2020-2021 will include samples from surface water, bottom sediment and fish tissue.

More information related to the EPA NCCA is available at: https://www.epa.gov/national-aquatic-resource-surveys/ncca.

2.1.d Special studies monitoring

The MPCA plans to stay abreast of newly recognized environmental contaminants and other issues that have the potential to cause known or suspected adverse ecological or human health effects but are not well understood, to help inform lawmakers, regulators, the public, and industry. The Legislature approved funding for some of these efforts in recent biennial budgets. Partnering with other scientists at universities, state agencies, and federal agencies, the MPCA is conducting the following specific investigations.

Harmful algal blooms

MPCA relies on research institutes for intensive monitoring on harmful algal blooms. Agency monitoring is currently is limited to participating in collection of samples paired with the NARS program and in response to human health or animal death incidents. We do not manage inland beaches and do not have the capacity to sample at a high enough frequency to adequately monitor for the presence of harmful algal blooms. There is an interagency workgroup that has been in place since 2004, to ensure collaboration between agencies when an incident is reported, to learn from research, and to work to improve communication and resources for the public. More information can be found at: https://www.pca.state.mn.us/water/blue-green-algae-and-harmful-algal-blooms.

Pharmaceuticals, household and industrial-use products

Over the past two decades, the MPCA has been collaborating with researchers to monitor the presence of pharmaceuticals, personal care products, and other wastewater associated chemicals in Minnesota's waters. Several of these studies included an analysis of how fish are affected by these chemicals.

The first state reconnaissance study by the USGS, the MPCA and the MDH showed that industrial and household-use compounds and pharmaceuticals are present in streams, groundwater, wastewater and landfill effluents. Steroids, nonprescription drugs, and insect repellents were the chemical groups most frequently detected, with detergent degradates and plasticizers measured in the highest concentrations.

In the decade since that study, MPCA has undertaken surveys for pharmaceuticals and personal care products (PPCPs) in conjunction with EPA’s national randomized surveys of lakes, rivers, and streams, which uses a generalized random tessellation stratified design to choose the water bodies. This design allows for surveys that can be stratified by multiple lake size classes while maintaining a spatial balance throughout the state. The surveys have included the sampling of 50 lakes in 2012 and 2017, and 50 rivers in 2014. Another rivers and streams survey will be completed in summer 2021.

These investigations have clearly demonstrated that PCPPs such as antibiotics and antidepressants, the pesticide DEET, alkylphenols, and the disinfectant triclosan are widespread in our lakes, rivers, and streams. Many of these chemicals are endocrine active, mimicking naturally occurring hormones. Concern is growing over the effect these chemicals may have on fish and wildlife and human health at very low concentration, and is discussed further below. Studies associated with this work can be found at https://www.pca.state.mn.us/sites/default/files/lrp-ei-3sy10.pdf.

Endocrine disrupting compounds

Building on the results of the two decades of research on pharmaceuticals, household, and industrial products in the aquatic environment described above, scientists from the MPCA and several collaborators continue to investigate the significance, sources, and occurrence of compounds with endocrine-disrupting activity in Minnesota’s waste streams and waters.

Endocrine disruption is a broad term referring to both natural and synthetic compounds that cause adverse effects in humans, fish, or wildlife by mimicking or altering the endocrine systems of organisms. Originally, studies of endocrine disrupting chemicals, or more accurately termed endocrine active chemicals, focused on those chemicals affecting the estrogenic, androgenic (testosterone), or thyroid systems of humans and wildlife. However, the scope of interest has expanded to include other signaling chemicals in humans and wildlife, such as neurochemicals.

Another randomized study of 50 river and stream locations is planned for 2021 focusing on these emerging contaminants in surface water.

Per- and Polyfluoroalkyl Substances (PFAS)

Previously referred to as perfluorinated chemicals, PFAS are a family of over 6,000 synthetic chemicals that have been used for decades to make products that resist heat, oil, stains, grease, and water. Since the early 2000s, some companies in the fluorochemical industry have worked with the EPA to phase out the production and use of the long-chain perfluoroalkyl compounds and their precursors, but chemicals in this class are still used in many products, including fire-fighting foams, lubricants, packaging, metal-plating, clothing, and other consumer and industrial products. Perfluorochemicals (PFCs) are widespread and persistent in the environment and they have been found in animals and people all over the globe.

Concern over PFAS exposure from fish consumption has motivated continued monitoring of fish tissue and surface water around the state. In 2018, paired water and fish samples were collected in 70 waters statewide (a mix of previously tested waters and untested metro waters) and evaluated for 13 PFAS. Based on those results, there are more than 60 waters with PFAS concentrations warranting retesting and further investigation. The MPCA intends to continue sampling previously tested waters and untested waters. In 2021, MPCA will sample fish tissue, water, and sediment at 20 total sites – 15 previously tested sites that showed elevated higher levels of PFAS and five previously untested sites. Analysis will include 40 PFAS compounds and lower reporting limits than previous studies.

There is significant work to be done in continuing to monitor PFAS in Minnesota's water resources and developing strategies to ensure that PFAS levels in water are safe for human health and aquatic life. The MPCA is working in an integrated way, across the MPCA and MDH, MDNR, and MDA, to develop approaches to effectively address this complex environmental problem statewide. MPCA has hired a PFAS Coordinator to lead the PFAS Lateral Team and guide the development of a cross-agency PFAS Action Plan. The MPCA is also partnering with other states to share information on environmental monitoring results, regulatory strategies, and solutions to the unique technical challenges posed by PFAS. Minnesota is a member of the PFAS Great Lakes Taskforce, which includes representatives from U.S. States and Canadian Provinces in the Great Lakes Watershed. Minnesota is also regularly sharing information with New England State associations working on PFAS and other national groups like the Environmental Council of States and the Interstate Technology and Regulatory Council. Finally, MPCA and MDH are actively partnering with EPA's Office of Research and Development to conduct state of the art research and develop new tools that will be implementable in our State. More details can be found at: https://www.pca.state.mn.us/waste/what-minnesota-doing-about-pfas

Additional information on PFAS in Minnesota may be found on the MDH website at: https://www.health.state.mn.us/communities/environment/hazardous/topics/pfcs.html and on page 19 of the 2020 Integrated Report: https://www.pca.state.mn.us/sites/default/files/wq-s7-52.pdf.

Section 2.2: Problem investigation monitoring strategy

Problem investigation monitoring is used to investigate a specific problem or protection concern in order to develop management approaches for improving or protecting the resource. Problem investigation monitoring is also used to identify the specific causes of a problem and to quantify inputs or loads from various sources – both point and nonpoint.

Within the watershed approach, problem investigation monitoring is a key step that occurs after condition monitoring and assessment are completed to identify the stressors that are causing the impairments (i.e. stressor ID monitoring). The subwatershed load monitoring that is conducted as part of the watershed approach is also a form of problem investigation monitoring, in that it provides critical information that is used both to diagnose stressors and prepare TMDL calculations used in developing watershed restoration and protection strategies. Finally, the MPCA and partners conduct problem investigation monitoring to evaluate regulatory concerns (e.g. National Pollutant Discharge Elimination System [NPDES]) or localized water quality concerns (e.g. lake eutrophication). More information is provided below.

2.2.a Stressor identification monitoring

Stressor ID is a formal and rigorous process that identifies stressors causing biological impairment of aquatic ecosystems, and provides a structure for organizing the scientific evidence supporting the conclusions (EPA, 2000). In simpler terms, it is the process of identifying the major factors causing harm to fish and other river and stream life. Stressor ID is a key component of the major watershed restoration and protection projects being carried out under Minnesota's CWLA.

Stressor ID monitoring may include additional biological sampling, water quality/quantity monitoring, or collection of a variety of other data (e.g. stream physical or geomorphology surveys, aerial photography, etc.). With the MPCA's transition to the watershed approach, stressor ID takes place at the major watershed scale.

Stressor ID is explained further in the MPCA's TMDL protocol document for biologically impaired waters www.pca.state.mn.us/publications/wq-iw1-23.pdf, as well as on the EPA stressor ID CADDIS website: https://www.epa.gov/caddis-vol1/getting-started. Stressors specific to Minnesota are discussed further here: [https://www.pca.state.mn.us/sites/default/files/wq-ws1-27.pdf.](https://www.pca.state.mn.us/sites/default/files/wq-ws1-27.pdf)

2.2.b Pollutant load monitoring

Pollutant load monitoring (described in more detail in Section 2.1.a above) occurs at 197 river and stream monitoring stations across the state. The pollutant dynamics captured through this monitoring reveal much about sources and causes, and stress to aquatic life. Results from this monitoring are also important for the calibration and validation of watershed models. These models characteristics of watersheds, including point and non-point sources of pollution, to streamflow, water quality, and loading.

2.2.c Other problem investigation monitoring

Minnesota's strategy relies on a variety of partners to conduct problem investigation monitoring. This includes the following:

- Monitoring conducted by regulated parties in support of regulatory programs (e.g. NPDES, stormwater)

- Monitoring conducted by local partners to investigate local problems, harmful algal blooms, or protection concerns (e.g. for county water planning, by beach managers, by local lake associations, etc.)
- Monitoring conducted by the MPCA to fill gaps for special projects (e.g. fish kills, use designation, etc.)
- Monitoring conducted by other organizations to fill additional needs (e.g. Met Council Environmental Services).

Section 2.3: Effectiveness monitoring strategy

Effectiveness monitoring is used to determine the effectiveness of specific regulatory or voluntary management actions taken to improve and restore an impaired water body or bodies. Effectiveness monitoring allows for the evaluation and refinement of the implemented management approach to ensure it is ultimately successful. Effectiveness monitoring can occur at a variety of scales, from small project–based scales to the system (resource) scale.

Minnesota's effectiveness monitoring strategy relies on monitoring activities that are conducted by a variety of parties. This includes regulated parties, local implementers, MPCA contractors, the MPCA, and other organizations who conduct effectiveness monitoring to evaluate specific management practices or groups of practices in a specific area. Since the MPCA's adoption of the watershed approach, most effectiveness monitoring activities are ultimately targeted at evaluating the steps taken to improve water quality and provide long term protection of water resources within the major watersheds.

All types of effectiveness monitoring share the need to compare the collected monitoring data to other data: either previously collected monitoring data, a water quality standard, paired resources (e.g. a paired watershed study), reference sites, or differing scales. Table 1 provides examples of various types of effectiveness monitoring that are conducted in Minnesota.

In some cases, the MPCA incorporates effectiveness monitoring into ongoing project-level activities, such as in CWA Section 319 projects, and selected regulatory management programs. For example, effectiveness monitoring is used in CWA Section 319 projects to evaluate implementation plans and adapt them, as needed.

Regulatory programs rely on field collected data and models to determine effectiveness.

- Stormwater BMP effectiveness: The MPCA works with several partners to determine appropriate methods for assessing stormwater quality and effectiveness of stormwater management practices. Based on these standard assessment methods, the MPCA, Minnesota watershed districts, conservation districts, cities, and counties are conducting extensive stormwater BMP performance and urban stream monitoring and applied research.
- NPDES effluent monitoring: NPDES effluent monitoring is conducted to provide information about the effluent being discharged by a facility. The monitoring is conducted by permittees in accordance with the terms of their NPDES permit. Ultimately, the monitoring provides data for the purposes of, determining reasonable potential, developing effluent limits, compliance determination, enforcement, and water quality modeling.
- Feedlot regulatory program: This monitoring is conducted as part of enforcement case development. The monitoring design is case specific.
- Monitoring associated with land based domestic wastewater treatment and dispersal systems: The monitoring conducted in association with these systems is done to evaluate the systems' hydraulic function and treatment system effectiveness, and to determine whether the systems are meeting public health and environmental protection goals.

With the MPCA's adoption of the watershed approach, the condition monitoring conducted in the first 10-year cycle becomes dual purpose. With the development complete for WRAPS, and subsequent local water plans or One Watershed One Plans, implementation of practices in the watershed are targeted. Thus, the condition monitoring conducted in the second, and subsequent, 10-year cycles is an indication of the effectiveness of the implemented measures from the previous cycle. This monitoring will also provide data that can be used to delist impaired waters.

As these descriptions indicate, the MPCA conducts many monitoring activities to fulfill a variety of purposes. Each monitoring activity has one or more designed objectives, although in most cases the data are also used for one or more secondary purposes.

Table 1. Types, scales, and purposes of effectiveness monitoring in Minnesota

Scale	Description	Answers the questions:	Focus	Examples
Plot Scale Effectiveness	Research-level monitoring directed at individual practices in controlled setting.	Does the BMP work? What's the effect of implementing the BMP?	Focus is on inputs and outputs for a single practice. Uses statistical methods, replicates and controls.	U of M, USDA Ag Research Service efforts. Usually not MPCA.
Field Scale Effectiveness	Monitoring directed at single or sets of practices in a "real world" setting. Compliance monitoring could be considered a subset of this.	Do the BMPs work in an uncontrolled setting? Do the practices result in facility compliance?	Focus is on physical and chemical changes related to single or sets of practices; must monitor land use/land use changes, wet/dry cycles for background knowledge.	Compliance monitoring, BMP effectiveness monitoring
Project/ Program Scale Effectiveness	Monitoring directed at sets of practices or activities implemented over a larger area with multiple landowners and operators. Effectiveness is evaluated using ranges of values, rather than one specific or pass/fail value.	How much $$ was spent? How many regulations enforced, BMPs adopted? Are behaviors changing (social changes)? Are the cleanup plans working? Is water quality getting better?	Focus is on environ-mental (physical, chemical, biological), program and social indicators; measures aggregate effects and outcomes; must monitor land use/land use changes, wet/dry cycles for background knowledge.	Pre-watershed approach TMDL implementation plans, CWA Section 319 project monitoring.
System (resource) Scale Effectiveness	Monitoring directed at environmental conditions within major watersheds, major eco-regions, or statewide.	Are water quality goals and standards being met? Is the water quality getting better or worse (trends)?	Focus is on environmental (physical, chemical, biological) indicators	Condition monitoring in the major watersheds, statewide or eco-region-based, random surveys of lakes, rivers and streams and wetlands, long-term river pollutant load monitoring

Section 2.4: Surface water monitoring designs and indicators

Minnesota currently uses a mix of monitoring designs to address the varying purposes and associated data needs for its monitoring programs. Monitoring designs differ in terms of at least three variables: how the monitoring site is selected (fixed, random, self-selected/project selected); how often the sampling occurs (periodic, continuous, or targeted); and which parameters are sampled. The MPCA's condition monitoring strategy alone employs a combination of designs: three examples are provided in Table 2.

Table 2. MPCA condition monitoring design types and examples

Design Type	MPCA Monitoring Activity Example	Comments
Fixed Station	Chemistry, biological and load monitoring stations	MPCA uses for condition and trend information; over time, will provide long-term information
Random (Probabilistic)	Minnesota Random Rivers and Streams Survey, National Lakes Assessment, National Wetlands Assessment	MPCA uses random design to provide confidence in applying information to a larger area
Self-selected/Project Selected	Citizen Lake Monitoring Program, Citizen Stream Monitoring Program, Fish Contaminant Monitoring Program	Provides great degree of geographic coverage; combined with other information can be used for a variety of purposes, including as a targeting tool

2.4.a Surface water monitoring indicators

The indicators used in MPCA's monitoring activities vary by monitoring purpose. Condition monitoring for rivers and lakes, for example, includes monitoring for a standard set of chemicals, biota, and water quality characteristics, as described in the summaries of MPCA monitoring activities above. Other monitoring efforts for rivers and lakes may involve sampling for additional chemicals or water quality characteristics in order to fulfill the purpose of the specific monitoring activity.

Table 3 outlines the core indicators used for assessing the condition of Minnesota's waters. The indicators are provided by aquatic use support and type of water body. Note that the core indicators are different for streams, lakes and wetlands.

Table 3. Core indicators for assessing the condition of Minnesota's waters

Aquatic Use	Streams	Lakes	Wetlands
Aquatic Life	Fish and invertebrate IBI Ammonia Chloride Phosphorus/chlorophyll-*a* Dissolved oxygen Metals[1] Pesticides pH Temperature TSS/Transparency	Chloride Fish IBIs	Invertebrate IBI Floristic Quality Assessment
Aquatic Recreation	*E. coli*	Phosphorus Transparency Chlorophyll	N/A
Aquatic Consumption[2]	Fish PCBs Fish mercury PFCs Mercury in water column	Fish PCBs Fish mercury PFCs	N/A
Drinking water	Nitrate	Nitrate	

During monitoring activities, the MPCA records "field parameters" such as temperature, dissolved oxygen, conductivity and pH (some of which are noted in Table 4) and observational data, such as the recreational suitability of the water, and the flow and stage of the water in the case of streams. MPCA biologists also collect stream physical water body characteristics (fluvial geomorphology such as bottom type and bank stability), prevailing habitat and surrounding land use. While these physical indicators can be important considerations in assessing the condition of water bodies, they are not used on their own as the basis for determination of an impaired water use. For example, waters are not listed as impaired on the basis of habitat or hydrologic regime; however, during stressor identification, they maybe be identified as the impairment cause. For this reason, these characteristics or indicators are not included in Table 4.

With the MPCA's adoption of the watershed approach, the combination of the intensified biological sampling framework and strategically located intensive water chemistry monitoring stations provide for comprehensive assessments. In addition, these indicators form the foundation for the identification of biological stressors and are useful in documenting trends over time.

The MPCA relies on the core indicators to assess lakes for aquatic recreation use support, but also considers other parameters to fully characterize the condition of a lake for reporting purposes. For example, lake morphometry, watershed land use, and retention time are all considered when characterizing lakes for assessment and placing them in context with ecoregion expectations. In addition, temporal trends in lakes are evaluated based upon current and historic trophic status data.

[1] Metals are utilized as submitted to the agency; some are total and some are dissolved. The Agency collects very little in the way of metals parameters at this time.

[2] The MDNR collects these data in cooperation with the MDA, MDH, and MPCA, via the Minnesota FCMP.

Problem investigation and effectiveness monitoring also may require different indicators and parameters because these monitoring activities are focused on a specific problem or remedial activity that may involve additional chemicals of concern.

At a programmatic level, the MPCA tracks another set of indicators to evaluate the effectiveness of its monitoring program. Programmatic indicators used for surface water monitoring include: percent of major watersheds assessed; percent of watershed monitoring conducted by local partners; and the impairment/unimpairment rate of lakes and streams. By tracking these programmatic indicators over time, the MPCA can assess Minnesota's progress in monitoring its waters.

In the future, MPCA may consider developing additional indicators for such things as emerging issues, as well as diagnostic indicators, microbial stressors, methods comparability studies, etc.

Section 2.5: External organization monitoring

The following provides a brief description of the monitoring purposes, designs and activities of other Minnesota organizations involved in surface water quality monitoring: the Minnesota Department of Agriculture (MDA); the Minnesota Department of Natural Resources (MDNR), the Minnesota Department of Health (MDH); and the Metropolitan Council Environmental Services (MCES). The MPCA and other state agencies with responsibility for water resource management in Minnesota have been coordinating their monitoring activities via the Clean Water Fund Interagency Coordination Team's Surface Water Monitoring subteam to make the best and most efficient use of the new funding opportunities that became available with establishment of the Clean Water Fund (CWF). Monitoring activities that have previously been described because of MPCA's participation will not be described in detail in this section.

2.5.a Minnesota Department of Agriculture surface water quality monitoring activities

The primary goal of MDA's surface water monitoring activities is to provide information on the impact of pesticides in Minnesota's surface waters as directed by the Minnesota Pesticide Control Law, Minn. Stat. ch. 18B. Protection of Minnesota's citizens and water resources from pesticides is the fundamental purpose of this goal. To achieve this goal the following objectives have been identified:

- Measure pesticide concentrations in representative streams and rivers in agricultural and urban areas of Minnesota.
- Provide analysis of pesticide concentration dynamics (magnitude, duration and frequency of detections) at locations that have demonstrated the potential to exceed standards or other relevant numeric criteria.
- Collect other relevant information related to pesticide fate and transport such as flow, persistence and use.
- Compile, analyze and disseminate the information developed through the monitoring program to policy makers, scientists, and citizens.
- Document the effectiveness of actions taken to prevent or minimize the impacts associated with pesticides and nutrients and verify that water body impacts are, indeed, minimized or do not lead to impairments of use.
- Monitor for nutrients along with pesticides and conduct special monitoring activities specifically to evaluate fertilizer BMPs.

MDA has developed regionally based water quality monitoring networks for the purpose of collecting and reporting groundwater and surface water monitoring data. These 10 Pesticide Monitoring Regions (PMRs) are based on areas of similar agricultural practices, soils, geology, hydrology and climate (Figure 6). Minimal pesticide monitoring occurs in the north-central and northeast portions of the state (PMRs 2 and 3) due to limited agriculture and pesticide use.

In 2006, the MDA began monitoring surface water utilizing the tiered structure defined and described in an MDA Surface Water Monitoring Design Document which is available at: http://www.mda.state.mn.us/monitoring. Within the tiered structure, there are three different levels (tiers) of monitoring intensity. Tier 1 locations are distributed throughout agricultural areas of the state, targeting a minimum of four Tier 1 per PMR. Tier 1 locations are sampled eight times during the growing season from May 1 through August 31. The objective is to provide a general assessment of water quality during peak pesticide application and detection periods from watersheds throughout the state. At Tier 2 and 3 site locations, the frequency of sampling increases to provide better information for duration assessment or the length of time pesticide concentrations remain at a particular level. In response to water body impairments for the insecticide chlorpyrifos the MDA also added an enhanced Tier 2 level for locations where chlorpyrifos was detected in previous monitoring. Enhanced Tier 2 locations receive an additional sample collection period during August, the month when chlorpyrifos is typically applied to agricultural fields and detected in surface water.

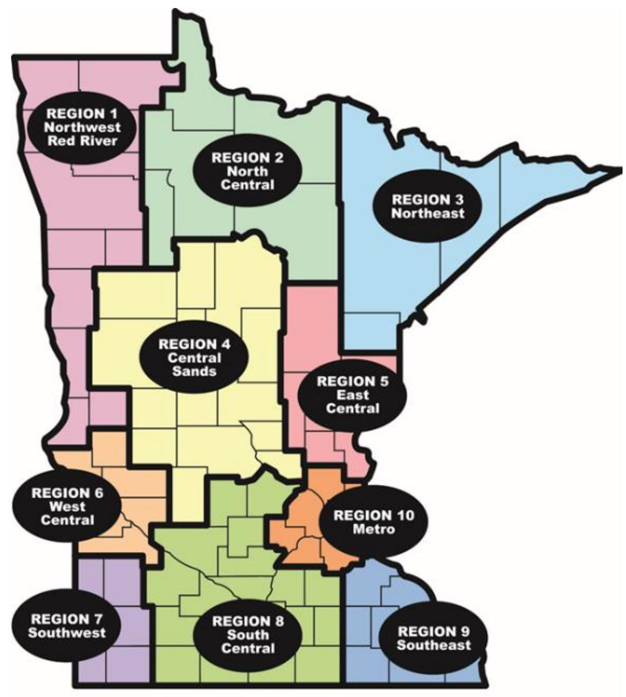


Figure 6. MDA water quality monitoring regions

The MDA's long-term intensive surface water monitoring efforts (known as Tier 3) has historically focused on two primary areas of the state: southeastern Minnesota and south-central Minnesota. In 2009, an additional Tier 3 location was established in the Red River Valley in northwestern Minnesota on the Buffalo River near Georgetown. In 2010 there were seven MDA Tier 3 monitoring sites in operation, three of which are located in the Minnesota River Basin, three in southeastern Minnesota and one in the Red River Basin. Surface water monitoring at most of the intensively monitored sites includes equal-time increment) composite sample collection during storm flow periods using stage activated automated samplers. Since 2006, the MDA has made an effort to collect storm flow samples on an equal-time increment basis at Tier 3 sites to generate data that were more readily comparable to duration-based standards or reference values. Base flow periods are typically characterized by grab samples collected between storm events. Two of the Tier 3 sites were reduced to Tier 2 sites in 2019 due to complications of maintaining automated sampling equipment on large rivers.

The MDA routinely analyzes samples for over 165 different pesticide related chemicals in groundwater and surface water and most are quantified in the lower parts per trillion range. There has also been an increase in the number of samples analyzed by the MDA laboratory in recent years.

The MDA and MPCA meet annually to review pesticide water quality data collected from surface water bodies. The MPCA formally assesses the data for possible inclusion on the Impaired Water 303(d)

Lists for water bodies that have violated a water quality standard. The data can also be used to remove a reach from the impaired waters list as well.

The MDA has also developed a network of edge-of-field monitoring stations throughout the agricultural areas of the state to determine the amount of nutrients and sediment leaving small watersheds. The information collected from Discovery Farms Minnesota and other edge-of-field monitoring conducted by MDA should prove useful for MPCA's assessment and implementation strategies to better quantify and estimate pollutant contributions from agricultural landscapes.

The MDA publishes a report of the monitoring results every year. These reports are made available on the Minnesota Water Research Digital Library, on MDA's monitoring reports webpage and are provided to the MPCA, MDH, MDNR, and other interested agencies, organizations or the general public.

2.5.b Minnesota Department of Natural Resources surface water quality monitoring activities

Two of MDNR's core missions are to conserve and manage the state's natural resources, including its surface water resources, and provide for commercial uses of natural resources in a way that creates a sustainable quality of life. Since the MPCA and MDNR require similar types of data to carry out their statutory responsibilities, the agencies collaborate on how water quality, water quantity and aquatic community status are measured, including: planning their instrument deployment; instrument maintenance; and data collection, storage and evaluation activities. This collaboration ensures the highest degree of efficiency and effectiveness.

Minnesota Department of Natural Resources stream hydrology

The Division of Ecological and Water Resources (DEWR) collects data and provides information on stream flows in Minnesota that is needed to carry out the MDNR's statutory responsibilities and water management programs. Primary clientele are: MDNR staff who use stream flow information to make permit decisions and monitor flooding; the MPCA who uses stream flow information to calculate pollutant loads for TMDL studies and other uses; consulting engineering firms; and other MDNR staff, state agencies, local governments, researchers, and members of the public who need stream flow information for water planning and management decisions.

The MDNR installs, upgrades, and calibrates stream gages and collects, compiles, analyzes and distributes the hydrologic data collected at the gaging stations. These stations include many of the gaging stations located at the state's major watersheds (8-digit HUC) and associated subwatersheds that are part of the MPCA's Major Watershed Load Monitoring Network. The MDNR's gaging station network also includes stations that provide data for an interagency Flood Forecasting/Warning system. The stream gaging data are used by the MDNR to evaluate trends in stream base flow conditions, determine the frequency and magnitude of floods and low flows, and assist in assessing changes in watershed condition that may be caused by land use change or changes in climate. The MDNR also uses the stream gaging data to develop hydrologic models to evaluate problems involving surface/ groundwater interactions and to make decisions regarding suspensions of certain water appropriation permits.

The continuous flow data are available to state agencies and the public via the Cooperative Stream Gaging website, also jointly operated and maintained by the MDNR and MPCA. The Cooperative Stream Gaging website provides a portal for state agencies and the public to access real-time stream flow data, site photos, water quality information, and other information. The website is available at this location: http://www.MDNR.state.mn.us/waters/csg/index.html.

Examples of information available from the Cooperative Stream Gaging website include:

- Streamflow gage location, site characteristics, reader, type of gage, and drainage area
- Stage/discharge rating curves and equations
- Stream flows
- Hourly headwater and tailwater readings
- Flow statistics
- Flood damage stages

Minnesota Department of Natural Resources lake hydrology

The DEWR collects information about lake levels that is used by the MDNR to determine the control elevations of public waters. The primary means for obtaining this information is the MDNR's Lake Level Minnesota Program, which recruits volunteer citizens and local partner organizations to collect and report lake levels measurements at more than 900 locations throughout the state. Each spring, MDNR DEWR staff reset and survey the lake gages at each monitoring location to prepare them for the field season. The volunteer citizens and local organizations then monitor lake levels using the gages throughout the open water season.

The lake level data are available on the MDNR's website through a searchable tool called Lake Finder. Lake Finder makes data for more than 4,500 lakes and rivers throughout Minnesota immediately available to state agency staff, local units of government and residents. Lake Finder data include: fish species and abundance, lake depth maps, lake water quality data and lake water clarity data (from the MPCA), satellite-based water clarity information (from the University of Minnesota), lake notes, and fish consumption advice (from the MDH). Lake Finder also provides information about lakes infested with invasive species.

Other lake-related activities

Sustaining Lakes in a Changing Environment Program

The Division of Fish and Wildlife administers this statewide, collaborative long-term lake monitoring program that assesses status and trends of lake ecosystem indicators in selected lakes that are representative of the state's most common aquatic environments. The information gathered through this program will be used to develop management approaches that can mitigate or minimize negative impacts caused by conventional "high-impact" residential development and agriculture, aquatic plant removal, invasive species and climate change. The MPCA is MDNR's primary partner on this project. More information about the Sustaining Lakes in a Changing Environment (SLICE) Program is available: http://www.MDNR.state.mn.us/fisheries/slice/index.html

Fish Contaminant Monitoring Program

Division of Ecological and Water Resources chairs the interagency team that makes up Minnesota's Fish Contaminant Monitoring Program. The team coordinates staff and financial resources to provide essential data that are used by several agencies for a number of purposes, including: developing science-based fish-consumption advice; evaluating mercury cycling, analyzing water quality trends, developing water quality standards, and evaluating the potential harm of newly identified bioaccumulative pollutants. The MDNR is responsible for fish collection, processing, and data analysis, as well as other aspects of the program. More information about the FCMP is available: http://www.MDNR.state.mn.us/eco/fcmcs/index.html

Lake Index of Biological Integrity

The MDNR's divisions of Fish & Wildlife and Ecological and Water Resources collect information on game fish populations and aquatic plant communities in lakes to inform its efforts to manage fish and waterfowl populations. Recently MDNR began augmenting their data collection to inform water quality assessment efforts by developing an IBI. This is the same approach the MPCA uses to help determine whether streams, rivers, and wetlands in Minnesota are impacted by water pollution (http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/biological-monitoring/about-biological-monitoring/about-biological-monitoring.html).

The MDNR has developed a FIBI for certain lake types in Minnesota and is currently focused on expanding the tool so that it can be used throughout the state. The primary use of the lake IBI is to identify lakes that may have water quality impairments; work that will contribute directly to assessment efforts. Further development of the lake IBI involves sampling a wide range of lakes, from high-quality systems to those with significant water quality impacts, plus detailed statistical analysis to understand how community structure and composition changes in response to water quality. The MDNR is also evaluating whether existing aquatic plant assessment data are sufficient to support IBI development.

Other Minnesota Department of Natural Resources Monitoring

To support MDNR's statutory responsibilities in the areas of wildlife management, the MDNR conducts monitoring and performs assessments of lakes, streams and wetlands for the purpose of evaluating wildlife and ecological health.

The Section of Wildlife's Shallow Lakes Program surveys shallow lakes across the state every summer. These surveys include: aquatic vegetation, water depth, and water clarity. A water chemistry sample is analyzed for total phosphorus and conductivity. Observations of wildlife use are also recorded. These data provide baseline information on wildlife habitat conditions and help determine management actions. Subsequent surveys document results of management actions to determine management success, develop adaptive management strategies, and show the public results of management.

A subset of 45 shallow lakes is monitored on a regular and ongoing basis. On these lakes, vegetation surveys are conducted every third year and waterfowl use is monitored every fall.

To support MDNR's statutory responsibility to protect and preserve rare species and improve biodiversity the Division of Ecological and Water Resources is inventorying the distribution of rare resources and high quality natural communities across Minnesota and tracking changes in the abundance of key populations and communities.

Finally, to help maintain the ecosystems services that healthy aquatic ecosystems provide, the MDNR's divisions of Ecological and Water Resources and Fish & Wildlife are collecting and organizing data to describe the status of five key aquatic ecosystem attributes, their biotic communities, water quality, hydrology, geomorphology, and connectivity. The Watershed Assessment Tool (http://www.MDNR.state.mn.us/watershed_tool/index.html) is a platform that organizes and helps interpret data layers that describe aquatic ecosystem health. The MPCA uses these data when evaluating water bodies that are in need of restoration and protection, as part of the stressor ID process.

2.5.c Metropolitan Council Environmental Services surface water quality monitoring activities

The Water Resources Section of the MCES conducts water quality monitoring of rivers, streams, and lakes in the TCMA. Monitoring is conducted through several programs as described below; additional details can be found at https://metrocouncil.org/Wastewater-Water/Services/Water-Quality-Management.aspx.

Large river monitoring

The large river monitoring program originated in 1927 when a predecessor agency began assessing the water quality of the Mississippi River after it had been declared a public health hazard. The monitoring program has evolved over the years to reflect changing needs and water quality issues. Today, monitoring is conducted to meet NPDES permit requirements, assess the performance and effectiveness of MCES wastewater treatment plants, measure river water quality compliance with state water quality standards and criteria, determine the biological health of large river ecosystems, and obtain information on the sources and water quality impacts of nonpoint source pollutants. The large river monitoring program is comprised of sub-programs as described below.

- Continuous monitoring - The automatic monitoring network was initiated in 1973 as a cooperative program with the USGS. The network consists of continuous water quality monitoring stations located along the Mississippi and Minnesota Rivers. The monitors continuously measure and record dissolved oxygen, temperature, pH, and specific conductance of the two rivers. These variables are good indicators of river quality, the effectiveness of treatment plant operations, and problems caused or aggravated by diurnal (24-hour cyclic) phenomena.
- Grab sampling - On a weekly to biweekly basis, river samples are manually collected at additional fixed sites on the Mississippi, Minnesota, and St. Croix Rivers and are analyzed for numerous variables that cannot be measured by the automatic monitors. Conventional monitoring more fully characterizes water quality and helps to determine specific sources and levels of pollution. Analytical laboratory work is conducted by MCES' laboratory.
    - Trace metals are collected quarterly and organic compounds collected every other year. Results of these analyses help determine the extent and nature of any toxics problems that may exist and help determine the effectiveness of the MCES Industrial Waste/Pollution Prevention program.

- Along the Mississippi River, grab monitoring sites are located between Anoka on the north end and Lock and Dam No. 3 near Red Wing on the south end of the TCMA. The Minnesota River monitoring begins at Jordan near the western boundary of the TCMA and ends near the confluence with the Mississippi River. The St. Croix River is monitored at two locations, upstream of the St. Croix Valley Plant at Stillwater, Minnesota and near the river mouth at Prescott, Wisconsin.

- Biological monitoring - Biological monitoring serves as a useful screening tool for assessing the integrated effects of water pollution on aquatic organisms. The composition of the macroinvertebrate communities reflects water quality and is indicative of the various stresses to the ecosystem. On an annual basis, biological stations are monitored using MPCA protocols (Hester-Dendy deployments) on the Mississippi and Minnesota Rivers. Taxonomic identification, organism counts, and diversity index calculations are performed.

Tributary river and stream monitoring

The tributary river and stream program started in 1989 to understand non-point source (NPS) pollution in the TCMA. The original focus was on collecting information on water quality for the tributaries to the Minnesota River. In 1995 the program was expanded to include monitoring stations across the TCMA in collaboration with local partnerships through our Watershed Outlet Monitoring Program (WOMP). WOMP differs from the NPS. For the streams in WOMP, local organizations conduct most of the field work and MCES coordinates work on tasks for flow measurements, equipment programming, and event sampling. WOMP was expanded again in 1998 with funding from the Interagency Water Monitoring Initiative (IWMI). IWMI funding ceased in 2007, but funding from the MPCA continues to this day and supports a portion of the MCES Tributary River and Stream Program.

- Continuous monitoring of physical parameters - Continuous automatic monitoring of stream flow, stage (water height), conductivity, and temperature is conducted at 22 stream stations.
- Automated sampling of pollutants - Conducted at the same stations and as a complement to the continuous monitoring, event sampling occurs when automated samplers are triggered by a runoff event and subsequently collect a composited water sample during the course of the event hydrograph, for analysis of a wide variety of nonpoint source pollutants. These samples are analyzed by the MCES laboratory.
- Grab sampling - Grab samples are also collected at the tributary river and stream sites and supplement the information obtained from automatic monitoring and sampling. Grab samples are collected every other week to characterize water quality during both baseflow and runoff event conditions. These samples are analyzed by the MCES laboratory.
- Biological monitoring - Stream biological and habitat monitoring is designed to be co-located as close as possible with an existing stream water quality location. Biological monitoring is used to assess integrated impacts of non-point source pollution and progress of watershed management. Biological monitoring is completed using MPCA protocols in order to ensure data is collected in manner acceptable for use by the MPCA for their impairment assessment work. Every tributary river and stream biological monitoring location is sampled annually in August-September unless flows prohibit monitoring in a safe manner.

Lake monitoring

The Met Council has conducted water quality monitoring of TCMA lakes since 1980. Monitoring is completed by MCES staff as well as citizen volunteers through our lake Citizen Assisted Monitoring Program (CAMP). The purpose of the Lake Monitoring Program is to provide scientifically valid water quality data and information for the Council and our partners (federal, state, regional, local communities, and citizens of the region) to help effectively manage the lakes of the region. CAMP was added to the lake program to efficiently expand regional coverage and better address local priorities while engaging citizen-scientists that promote water quality advocacy.

- CAMP involves coordination, training, and laboratory analysis by MCES staff and volunteer coordination performed by a local sponsor (often a local community or watershed organization). A citizen scientist volunteer conducts the sampling, usually at a lake they live on or nearby and have easy access to. This monitoring includes collecting a surface sample, taking a Secchi reading, and recording other characteristic observations like smell and color.
- MCES staff lake monitoring work is more intensive monitoring on a subset of prioritized lakes in the TCMA each year (every other week, April-October), generally around six lakes per year. The monitoring includes depth profiling with a field meter and a shallow and deep-water quality sample.

2.5.d Minnesota Department of Health surface water quality monitoring activities

Surface water quality monitoring activities support the mission of the MDH, "to protect, maintain, and improve the health of all Minnesotans," by providing data that are used to evaluate the level of contaminants in surface water used as drinking water sources. These data help verify compliance with federal and state regulations, establish baseline water quality conditions for drinking water sources, inform the process for producing health based guidance, and guide development of water supply planning efforts to safeguard our drinking water. The following paragraphs provide additional information about MDH's surface water quality monitoring activities.

Drinking water protection – regulatory compliance monitoring

MDH assists approximately 6700 community and non-community public water systems to provide safe and adequate drinking water as outlined in the federal Safe Drinking Water Act (SDWA). Of these systems, about 106 rely on surface water as a source of drinking water. MDH staff and laboratory personnel collect and analyze water samples from public water systems for required parameters on a schedule that set based on system type (community or non-community), population served, and past pollutant detection, as defined by the SDWA.

Drinking water protection – non-regulatory, investigative monitoring

Most MDH investigative monitoring of drinking water sources involve a mix of systems that use groundwater and those that use surface water. Surface water investigations typically occur when contaminants of concern either exceed federal or state-defined limits or concentrations fluctuate too quickly for treatment plants to be able to filter those contaminants to design specifications. To date these investigations have studied seasonal nitrate concentration trends, high turbidity flow impacts on treated drinking water quality, and the prevalence of emerging contaminants in drinking water source waterbodies. MDH staff are also engaged in monitoring activities of groundwater systems that are impacted by surface water, on time frames and at quantities that might require systems to implement surface water treatment. More detail on some of these specific monitoring projects can be found in the MDH section of the groundwater monitoring section of this report.

Section 2.6: Monitoring quality assurance

Nearly all decisions made to protect, maintain, and improve surface water quality are based on the monitoring data that are collected to assess its condition. For this reason, it is imperative that the MPCA has quality assurance/quality control standards for these data.

The MPCA's quality assurance/quality control coordinators oversee implementation of the agency's quality assurance/quality control standards. This includes data collection, selection of laboratories, selection of parameters to be measured, the consistency of data analysis and confidence in data quality. In addition, local partners and others, submitting data to the MPCA for use in assessment, are required to submit a Quality Assurance Project/Program Plan, as well as to follow the data collection, management, and reporting requirements specified in the MPCA's *Volunteer Surface Water Monitoring Guide*.

The MPCA's Quality Management Plan was approved by the EPA in 2018. For monitoring projects, the MPCA and its partners follow the Quality Management Plan in implementing monitoring protocols. The MPCA's Quality Management Plan is available here: https://www.pca.state.mn.us/sites/default/files/p-eao2-15.pdf.

Section 2.7: Data management

The monitoring data collected by the MPCA and others are stored and made available to scientists, citizens, and other interested parties in a variety of ways. This section describes the primary data storage repositories where water quality monitoring data are stored.

EQuIS

MPCA utilizes the EQuIS system to store discrete water quality data. This information is uploaded to the Water Quality Exchange so it is available through EPA's national data warehouse and the larger National Water Quality Portal https://www.waterqualitydata.us/. Data are also available to the public through MPCA's Environmental Data Access site: https://webapp.pca.state.mn.us/surface-water/search.

The MDA and some programs within the MDNR utilize EQuIS for their data storage system.

WISKI

Time-series surface water, flow, groundwater, and climate data are stored, managed and made available to agency staff in WISKI, a database and data processing software package. The MPCA and MDNR are partners in operating and maintaining the WISKI system.

Some of the data (primarily streamflow) is currently available to the public through the MDNR/MPCA Cooperative Stream Gaging website at: www.MDNR.state.mn.us/waters/csg/index.html. Efforts are underway to expand public access to more of the data.

MCES uses their own instance of WISKI for their data management and quality control processes. Discrete water chemistry data along with real-time continuous data are shared on MCES' Electronic Information Management System. MCES is working on sharing approved chemistry data to EPA's Water Quality Exchange system where it can easily be accessed by the MPCA for assessments.

Access database for biological data

The MPCA uses a custom, in-house Access™ database to store the fish, invertebrate, and vegetation data collected from Minnesota's streams, lakes and wetlands. The chemical data collected at the time of biological sample collection are stored in EQuIS.

The MPCA and MDNR are coordinating to ensure that the database each agency uses to store information on biological samples allows for data sharing. MPCA is currently moving its biological data into the KiEco module of WISKI.

Section 2.8: Data analysis

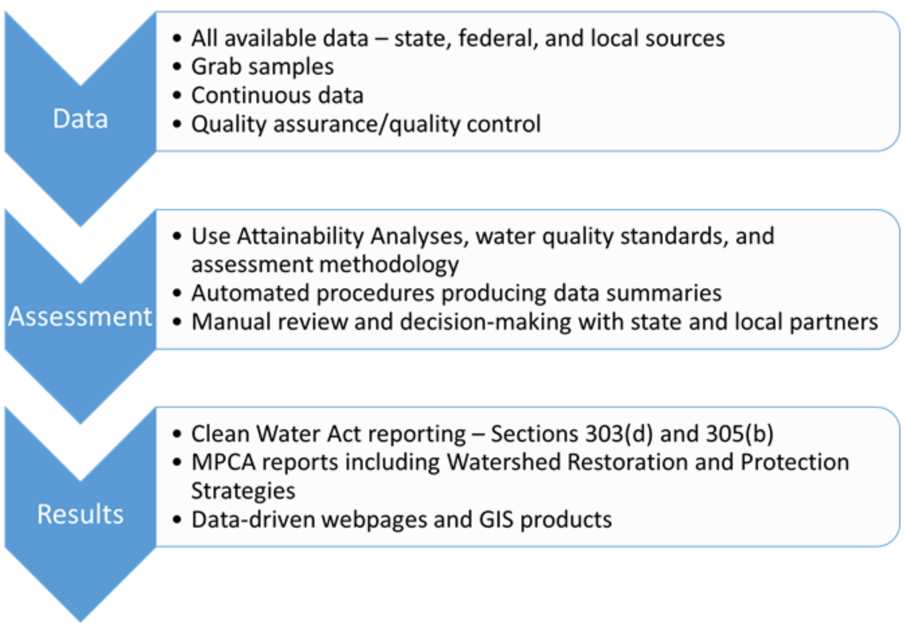
This section contains a description of the principal data analysis activities conducted by the MPCA. These include comparison of monitoring data against standards; calculation of water quality trends; and calculation of loads.

2.8.a Comparison to standards

Through the integrated assessment process, which includes requirements of Section 305(b) and 303(d) of the CWA, Minnesota assesses water quality monitoring data and compares them against state water quality standards. This is done to ensure that the state's waters are able to support aquatic life, aquatic consumption, and aquatic recreation uses.

Minnesota uses all available data to conduct the annual assessment process; this includes data collected by the MPCA, and data collected by other governmental agencies, local partners, and volunteers. The data must be collected within the 10-year period preceding the assessment year to be valid for assessment purposes. Figure 7 illustrates the data and considerations that are part of the assessment process.

Figure 7. Process for Minnesota's 303(d) level assessments



The formal process the MPCA follows to conduct water quality assessments through the 2020 Impaired Waters List is documented in *the Guidance Manual for Assessing the Quality of Minnesota Surface Water* https://www.pca.state.mn.us/sites/default/files/wq-iw1-04k.pdf.

2.8.b Evaluation of water quality trends

The MPCA evaluates water quality trends in Minnesota's surface waters through two different efforts: 1) analysis of data from a number of specifically chosen, long-term monitoring sites from across the state, and 2) analysis of the large quantities of data collected by volunteers through the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP).

The Watershed Pollutant Load Monitoring Network (WPLMN) has provided a well-distributed set of monitoring sites from which data will be collected on an on-going basis; the monitoring stations are now be used to provide information about long-term water quality trends in Minnesota, discussed more below. In addition, the Sentinel Lakes and Long-term biological monitoring program will provide a body of data that can be used to calculate trends over time in lakes and stream biology.

For the second effort, the MPCA uses lake and stream water clarity data collected by citizen volunteers across the state. Lake transparency is monitored using Secchi disks; stream transparency is monitored using a Secchi tube. More information about the measurements and methods used to calculate transparency and trends are provided below.

2.8.b.1 Calculating loading of nutrients and suspended solids

The MPCA uses FLUX32, an interactive program originally developed by Dr. Bill Walker and the U.S. Army Corps of Engineers (USACE) and upgraded to a Windows platform by the MPCA and USACE, for estimating the loadings of nutrients and suspended solids passing a river sampling station over a given period of time. These estimates can be used in formulating nutrient balances over annual or seasonal averaging periods. Data requirements include: 1) grab-sample nutrient concentrations and associated discharge, and 2) a complete flow record for the period of interest (mean daily flows).

Flow is usually determined by routinely measuring the stage, or water height, while simultaneously measuring discharge over a wide range of flow conditions. A rating curve [mathematical equation(s)] is then computed to convert stage to discharge. Once a gaging station is established, stage measurements are made using automatic equipment and converted to flow by computer programs. However, flow measurements continue to be taken every four to five weeks to verify the integrity of the curve and to account for shifts in the curve (i.e. due to deposition or scour of bed material) that occur over time.

Twenty to thirty-five mid-stream grab samples are collected per site per year depending on stream type, condition and season length, with sampling frequency greatest during periods of moderate to high flow. Because positive correlations between concentration and flow exist for many of the monitored analytes, computation of accurate load estimates requires frequent sampling during major runoff events to characterize shifting concentration/flow relationships and between storm differences that may occur in these relationships. Low flow periods are also sampled and are well represented, but sampling frequency tends to be less as concentrations are generally more stable when compared to periods of elevated flow. Despite discharge related differences in sample collection frequency, this staggered approach to sampling generally results in samples being well distributed over the entire range of flows.

Using site-specific calculation techniques, FLUX maps the flow/concentration relationship developed from the sample record onto the entire flow record to calculate total mass discharge and associated error statistics. An option to stratify the data into groups based upon flow, date, and/or season is also included.

In addition to providing for load trend analysis, the intensive sampling regime and streamflow required for load calculations produces data excellent for concentration trend analysis. Both are important for a full understanding of water quality trends.

2.8.b.2 Lake transparency trends

Secchi transparency is a low-cost water quality indicator that is easily collected by volunteers and has a long history of use on many Minnesota lakes. For most lakes in Minnesota, Secchi transparency provides an indirect measure of the amount of algae in the water, which is related to the lake’s trophic status (nutrient richness), a rough measure of water quality. For these reasons, the MPCA annually analyzes its Secchi transparency dataset to determine trends in lake water quality over time.

The statistical trend analysis performed by the MPCA requires that a lake have a minimum of eight years and 50 points of Secchi disk data collected between May and September. Lake transparency may vary from year to year in response to changes in rainfall amounts, watershed runoff and many other factors. Using datasets with more than eight years of data help to account for these factors.

All applicable Secchi transparency data from the MPCA's water quality database are used in the annual assessments. The majority of these data are collected by the hundreds of volunteers in the MPCA's CLMP.

A combination of customized code and the Mann-Kendall Test, Seasonal and Regional Kendall Tests Seasonal (Package "rkt") was used to create the CLMP trend analysis process. The package contains the rtk function, which computes the Mann-Kendall test (MK) and the Seasonal and the Regional Kendall Tests (SKT and RKT) to determine if a trend can be detected in the dataset, and then it uses the Theil-Sen's slope estimator to draw the trend line through the data points.

2.8.b.3 Stream transparency trends

Like Secchi transparency in lakes, stream transparency is a low-cost water quality indicator that is easily collected by volunteers. Stream transparency is an indirect measure of the amount of *dissolved* and *suspended* materials present in water. For most streams in Minnesota, the amount of solids suspended in the water is the most important factor: the more suspended materials, the lower the water transparency. In streams and rivers, soil particles (predominantly silts and clays) have the strongest influence on transparency, as water flows downstream, carrying and depositing this sediment. Too much sediment in the water is a significant pollutant itself, whether it is suspended in the water column or deposited on stream bottoms. Suspended sediment reduces light penetration, which is needed for the growth of beneficial aquatic plants. It also interferes with the ability of fish to see and capture their prey. For these reasons, the MPCA conducts an annual analysis of its stream transparency dataset to determine trends in stream water clarity over time.

All available water clarity data from the MPCA's water quality database are used in the annual trend analysis. The majority of these data are collected by volunteers in the MPCA's CSMP. A Tobit regression model, which accounts for the limit of the Secchi tube to detect transparency readings of 100 cm or less, is applied to the water clarity and estimated stage data for stream stations that meet minimum data requirements.

Section 2.9: Data Reporting

The monitoring data collected by the MPCA and others are stored and made available to scientists, citizens, and other interested parties in a variety of ways.

Environmental Data Access

Easily accessible monitoring data help Minnesotans play an active role in protecting and improving their environment. The MPCA's Environmental Data Access (EDA) system, available since 2003, allows users to view and download environmental data that are collected and stored by the agency and its partner organizations. The interactive, web-based system includes a web map where monitoring locations are displayed geographically.

The EDA's surface water section displays data from surface water monitoring sites located around Minnesota using either a map-based or text-based search. You can also view the conditions of lakes, rivers or streams that have had their water quality assessed.

Using EDA's tools, users can:

- Quickly access statewide water quality data on a site-by-site basis
- Display site-specific data by specifying the name of a lake, river, or other related location
- View impairment(s) and how it impacts recreation, aquatic life, and drinking water

All data included are thoroughly quality assured before they are made available on the site. More information about EDA, and a link to the EDA system, can be found here: https://www.pca.state.mn.us/eda-surface-water-data.

Watershed webpages

MPCA hosts an interactive feature on its website that uses a map to help users identify the watershed they live or play in. Once located, users will have access to information about the watershed, including data from water bodies in it, lists of projects planned or underway, MPCA or partner contacts, and a host of other watershed-specific details. The watershed pages can be accessed here: https://www.pca.state.mn.us/water/watersheds.

Reports

Currently, much of the MPCA's data reporting occurs through the preparation of reports that provide context and interpretation of the monitoring data that have been collected; most of these reports are available via the MPCA's website.

These reports fulfill a range of purposes. They include watershed assessment reports and updates, special study reports, technical reports, newsletters, legislative reports, and EPA-required reports. The following paragraphs highlight some of the monitoring data-based, surface water quality reports prepared by the MPCA, with web links where they are available.

- Continuing Planning Process Report is a report states are required to prepare under Section 303(e) of the Clean Water Act (CWA) to describe the processes and procedures they will use in their water quality planning activities in order to carry out the requirements of the CWA. The MPCA updated its Continuing Planning Process in 2010 to incorporate the watershed approach, and it was approved by EPA in early 2011: http://www.pca.state.mn.us/index.php/view-document.html?gid=15647
- Major watershed assessment reports: Major watershed assessment reports are prepared for each major watershed when the two years of intensive watershed monitoring (years 1 and 2 of the 10-year cycle) are complete and the data have been assessed. These reports are designed to provide a summary of all relevant data from the major watersheds for use in stressor ID work and watershed protection and restoration strategy development. The MPCA began issuing these reports in mid-2011. They can be accessed through the watershed webpages at: https://www.pca.state.mn.us/water/watersheds.
- National and state statistical surveys: The MPCA participates in EPA's National Aquatic Resource Surveys (NARS). Information on the NARS National Lakes Assessment (NLA) as well as the results from the Minnesota enhancement of NLA that examine statewide patterns in various chemical, physical and biological parameters can be found at https://www.pca.state.mn.us/water/national-lakes-assessment. Information from the other NARS (i.e., wetlands, flowing waters) with results from the broader, state based surveys conducted at the same time, are available at https://www.pca.state.mn.us/water/random-survey-nations-rivers-and-streams and https://www.pca.state.mn.us/water/wetland-monitoring.
- Annual reports of the CLMP and CSMP on the transparency of Minnesota lakes and streams: The individual site and statewide summary reports are distributed to volunteers and are available on the agency's website at: https://www.pca.state.mn.us/water/volunteer-monitoring-reports-and-data. In addition, the MPCA prepares periodic newsletters for citizen volunteers called the Transparency Times which can be viewed online at https://www.pca.state.mn.us/water/transparency-times.

- 2020 Minnesota Water Quality – Narrative report to Congress of the United States: The MPCA began providing the Water Quality Integrated Report to the EPA in 2004. This report combines the requirements of Sections 305(b) and 303(d) through a biennially (even years) electronic report accompanied by an abbreviated narrative report. The report and list are submitted to EPA in April of even-numbered years. The most recent report is available here: https://www.pca.state.mn.us/sites/default/files/wq-s7-52.pdf
- Watershed Achievements Report, annual report to the U.S. Environmental Protection Agency (EPA) on CWA Section 319 and Clean Water Partnership projects in Minnesota, describes Minnesota's efforts to protect, maintain and improve the state's waters by reducing nonpoint source water pollution. The report is submitted annually to EPA and is excerpted as needed for use in providing information to Minnesota's legislature and other decision-making bodies. https://www.pca.state.mn.us/water/watershed-achievements-report
- Minnesota Nonpoint Source Management Program Plan: A report to EPA required under Section 319 of the CWA. This report provides information on nonpoint source pollution and strategies for improving water resources; it is updated about every 5 years based on determination of need. https://www.pca.state.mn.us/water/minnesota-nonpoint-source-management-program-plan

A variety of fact sheets, guidance documents, technical reports, and other publications relating to water are available on the MPCA's website: https://www.pca.state.mn.us/water/guidance-and-technical-information.

Section 2.10: Programmatic evaluation

The MPCA's shift to the watershed approach has provided a unifying framework for organizing and refining the water quality monitoring, planning, and implementation activities that are its mission. Just as important, establishment of the Clean Water Fund (CWF) has led to a new level of interagency coordination and cooperation, and a desire on the part of state agencies, citizens and the legislature to ensure the wise and efficient use of the resources provided.

The MPCA has and continues to make extensive use of process improvement tools to find more effective ways to conduct its work. Most recently this included a major revision to monitoring design and development and implementation of a site solicitation and ranking process to incorporate local monitoring needs into the monitoring plan for a given watershed.

The MPCA also conducts annual program assessments as part of its Environmental Performance Partnership Agreement with EPA Region 5 and the MPCA Strategic Plan and Long-term Goals. Progress with respect to the MPCA Strategic Plan goals and objectives is evaluated each spring with review of the agency's long term goals; and each fall with a review of the agency's current strategic goals.

In addition to these internal program evaluations, the state Clean Water Council (CWC) prepares biennial legislative reports that provide information on the activities for which CWF money has been or will be spent for the current biennium, and the activities for which money is recommended to be spent in the next biennium. The biennial report also incorporates an implementation plan that explains Minnesota's framework for identifying and cleaning up impaired waters, addressing general procedures and timeframes, and establishing priorities. The Legislative Coordinating Committee has established a website via which anyone can search for information about projects on which the CWF monies (as well as other state funds directed towards the environment) are being spent (http://www.legacy.leg.mn/) to provide transparency to Minnesotans.

In support of these efforts, the MPCA and its sister agencies on the CWF Interagency Coordination Team report on the effectiveness of CWF expenditures and related outcomes. The CWF Performance Report is updated in January of even years: https://www.legacy.mn.gov/funds/clean-water-fund/clean-water-fund-performance-reports.

Section 2.11: General support and infrastructure planning

The MPCA continues to rely primarily on the support of the state CWF to support monitoring activities. A small portion of federal funds also support staff in a variety of monitoring positions that existed prior to the establishment of the state fund. The CWF will remain our primary source of funding for this next iteration of the strategy.

At this time, Minnesota has two needs it considers high priority to continue implementation of its Water Quality Monitoring Strategy. The first centers on making the monitoring and other data collected in support of watershed assessment, protection, and restoration more readily available to water resource professionals and citizens alike. The MPCA is addressing these needs through data driven webpages. The second need involves continued support and partnership from EPA as Minnesota progresses in its adoption and implementation of new water quality criteria and standards.

New web-based data retrievals

Since 2003, the MPCA has provided web-based access to water quality monitoring data via its Environmental Data Access webpages. Over time, the MPCA has developed web-based retrieval of other kinds of data to meet common information needs. For example, visitors to the MPCA website are able to:

- Examine information regarding the MPCA's assessment of a given waterbody, including the parameters that were evaluated, protection and prioritization recommendations, and use level attainment information via the assessment results viewer (launching January 2021).
- Search the Impaired Waters List online to determine the impairments in a geographic area and the status of MPCA activities to address them. https://www.pca.state.mn.us/water/impaired-waters-viewer-iwav
- Retrieve lists of MPCA restoration/protection studies ("TMDL projects"), e.g., by geographic area or project status through the Healthier Watersheds application. https://www.pca.state.mn.us/water/healthier-watersheds

Continuing EPA partnership and support

As the MPCA and its partners endeavor to improve the way we monitor, assess, protect and restore Minnesota's waters, we need the continued partnership and support of EPA. The MPCA looks forward to future conversations with EPA as we continue to advance the watershed approach, and develop and implement new criteria and standards

Section 2.12: Gaps

With our framework generally designed to capture information at a watershed scale, we have identified areas where we need additional information at a statewide scale. For instance, changes to standards or the implementation of those standards has necessitated the addition of parameters (sulfate, dissolved organic carbon) at a statewide scale to allow the agency to complete standards or assessment work.

Another area for consideration is the transition of monitoring from the St. Louis River Area of Concern, at the end of the Beneficial Use Impairment status in 2025 to our condition monitoring program. This will require utilizing supplemental monitoring from the 2025 NARS Coastal Survey to evaluate the resource into the future.

There is also consideration of trying to provide continuous data at more locations, in particular for nitrate. There would be benefits to surface water drinking water suppliers and to allow the agencies to better track progress against our Nutrient Reduction Strategy while reducing the amount of grab samples needed.

Work is underway through the Interagency Monitoring and Assessment subteam to determine additional gaps that may be present in our overall state monitoring framework.

Section 3: Groundwater

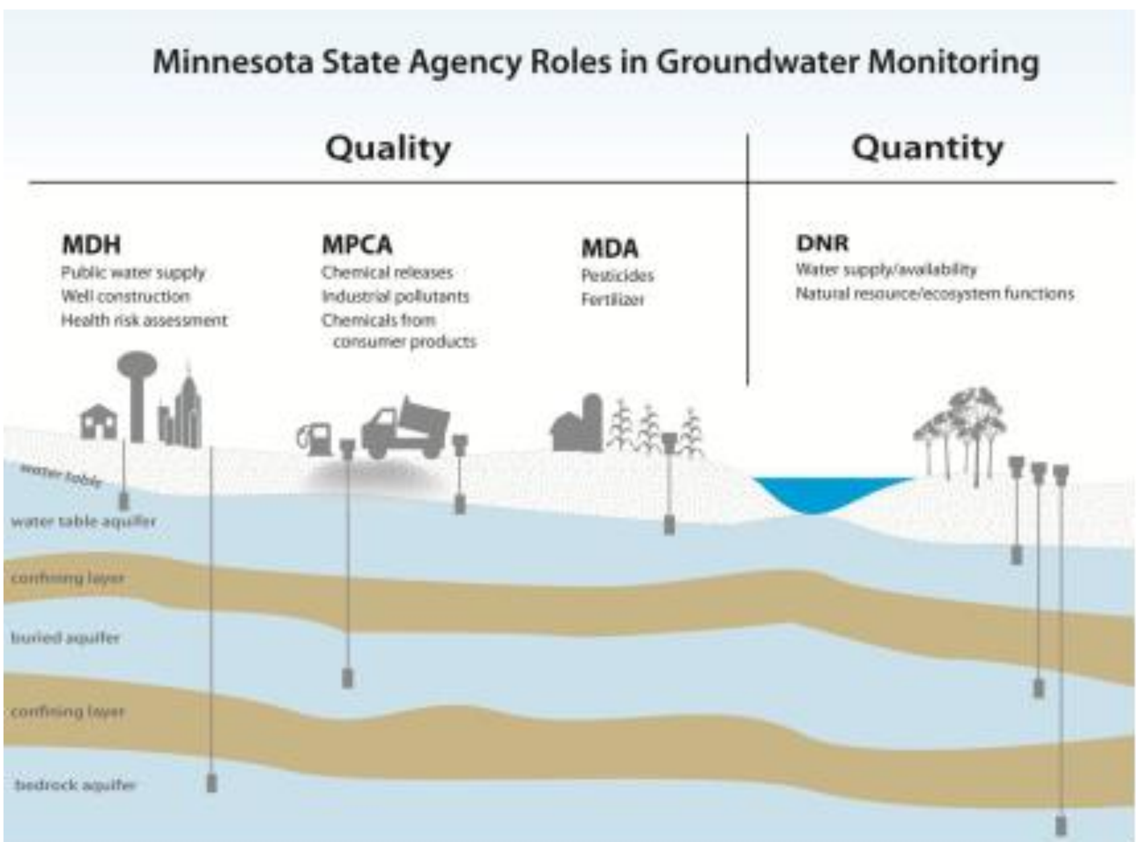
The following information pertains to the approaches used to monitor, evaluate, and report groundwater resources in Minnesota.

Section 3.1 Minnesota's multi-agency approach to monitoring groundwater

The Minnesota Pollution Control Agency (MPCA), Minnesota Department of Agriculture (MDA), and Minnesota Department of Health (MDH) each have important statutory responsibilities in protecting the quality of Minnesota's groundwater, while the Minnesota Department of Natural Resources (MDNR) is primarily responsible for protecting the quantity of groundwater.

The MPCA and MDA conduct groundwater condition monitoring to assess ambient groundwater quality. The MDH conducts groundwater quality monitoring in order to regulate public and private water supply wells and to evaluate the risk to human health from contaminants in groundwater. Since 2004, the MPCA, MDA, and MDH have coordinated their monitoring activities in accordance with the Integrated Ground Water Monitoring Strategy, which is outlined in a Memorandum of Agreement dated February 11, 2004, (Attachment 2). The primary roles of Minnesota's state agencies in monitoring groundwater are illustrated in Figure 8 below.

Figure 8. Groundwater monitoring responsibilities of Minnesota state agencies



The MPCA, MDA, MDH, and MDNR, together with the Metropolitan Council (Met Council) and BWSR, have coordinated groundwater monitoring and related activities through the Clean Water Fund Interagency Coordination Team (Coordination Team) subteam for groundwater/drinking water, which meets on a monthly basis.

Section 3.2: Condition monitoring strategy

The MPCA's condition monitoring strategy for groundwater is based upon its statutory responsibility to protect the quality of Minnesota's groundwater, as described above. Detailed information concerning the purpose, design and indicators of the agency's groundwater condition monitoring activity is provided below.

3.2.a Condition monitoring purposes

The overarching purpose of Minnesota's condition monitoring activities is to evaluate the quality of Minnesota's groundwater resources. These data can also be used to evaluate potential and/or actual threats to groundwater quality and to monitor groundwater quality trends over time. This type of monitoring is commonly referred to as ambient groundwater monitoring, because the monitoring is designed to measure the overall or general quality of the groundwater, not localized pollution sources such as chemical spills or hazardous waste sites.

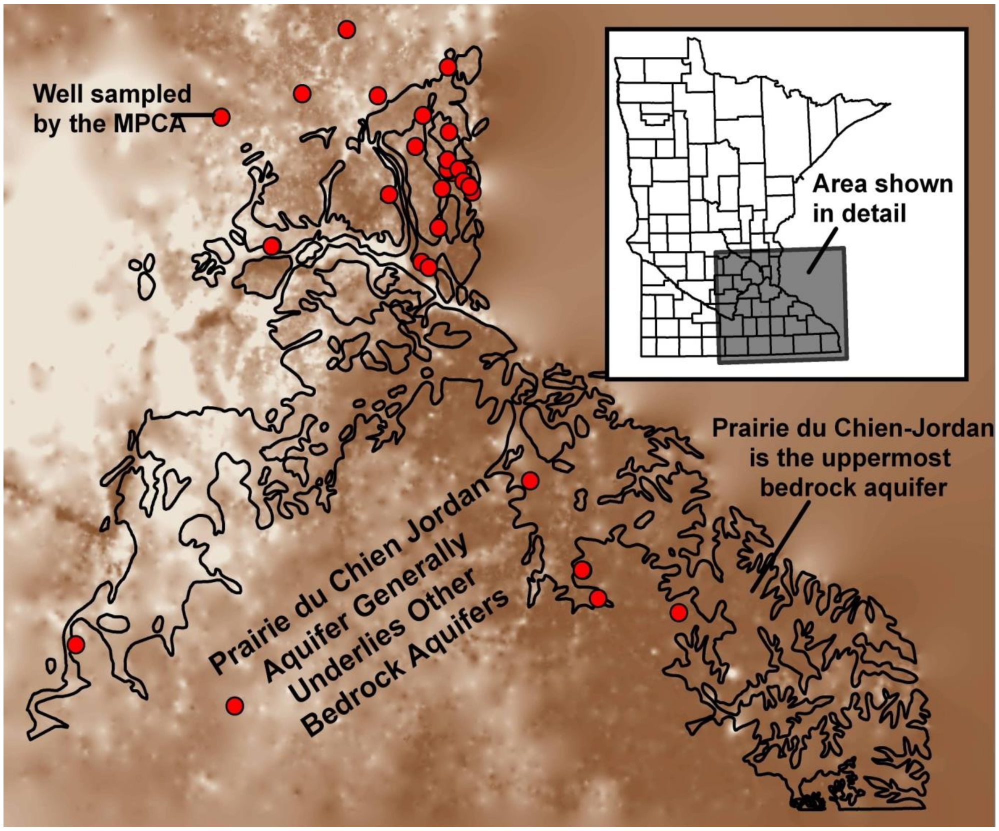
The MPCA and MDA cooperate to conduct statewide condition monitoring of Minnesota's groundwater quality in accordance with the 2004 Memorandum of Agreement. The agencies divide their groundwater quality monitoring responsibilities as follows: the MPCA conducts condition monitoring to assess non-agricultural contaminants, primarily in urban parts of the state. The MDA conducts condition monitoring to assess agricultural chemicals (e.g. pesticides and fertilizers), primarily in agricultural regions of the state.

Both the MPCA and MDA's condition monitoring activities target aquifers that are vulnerable to anthropogenic (human - made) contamination. Minnesota has many other aquifers and aquifer systems, however, most are located deep below the land surface, and many are protected by confining beds that retard the flow of groundwater and any associated contamination. These circumstances plus age-dating of groundwater suggests that previous MPCA groundwater quality sampling efforts adequately represents the current quality of these aquifers. For information on the quality of near-surface aquifers, summary reports can be found at: https://www.pca.state.mn.us/sites/default/files/wq-am1-10.pdf and https://wrl.mnpals.net/islandora/object/WRLrepository%3A3580/datastream/PDF/view.

3.2.b Condition monitoring designs

The MPCA's ambient groundwater condition monitoring focuses on aquifers in urban and undeveloped parts of the state that are vulnerable to anthropogenic contamination. The MPCA monitors the condition in two key aquifers: 1) the Paleozoic-age, Prairie du Chien Jordan formation, an extensive bedrock formation; and 2) the Quaternary age, sand and gravel aquifers. These are the two most heavily used aquifers in the state in terms of the amount of groundwater that is withdrawn to supply water for domestic use and agricultural purposes. The Prairie du Chien-Jordan aquifer consists of the Paleozoic era fractured dolomite of the Prairie du Chien Group and the underlying Jordan sandstone; it is the uppermost geologic unit in the southeastern part of the state, where it is visible in roadcuts, eroded valleys, and quarries (Figure 9). In these areas, soil overlying the aquifers tends to be thin as well as permeable, such that it readily transmits water. The other monitored aquifers, the Quaternary sand and gravel (also known as glacial drift) aquifers, are located across Minnesota but are concentrated in the central part of the state (Figure 10).

Figure 9. Well locations sampled by the MPCA ambient groundwater quality monitoring network in the Prairie du Chien-Jordan aquifer [Surficial geology and depth to bedrock data from the Minnesota Geological Survey. Darker areas show where the aquifer is closer to the land surface].



Quaternary sand and gravel aquifer network design

The MPCA commonly refers to its network of Quaternary sand and gravel wells as the "Early Warning Network," because these wells are designed to monitor the uppermost portion of the aquifers where groundwater is most vulnerable to contamination. The wells provide an early indication of any groundwater contamination that may eventually seep to other underlying aquifers and also any emerging groundwater quality trends, which is important to protection of the state's groundwater resources.

The Early Warning Network was developed using a random stratified statistical design that discerns the effects of land-use setting and the natural composition of the aquifer on groundwater quality (Figure 11). The Quaternary sand and gravel aquifer composition varies according to the provenance of the glacial materials that formed the particular aquifer. Glacial deposits originating from the northwest typically are carbonaceous, yellow brown to gray in color, and contain shale. In contrast, glacial deposits originating from the northeast generally are siliceous, reddish in color, and do not contain shale (Figure 10). These differences in composition affect the natural water quality of the aquifers and also may affect contaminant attenuation.

The Early Warning Network targets four land use/land cover settings: 1) sewered residential areas, 2) unsewered residential areas, 3) commercial/industrial areas, and 4) undeveloped areas. (Agricultural land use is not included since the MDA monitors groundwater quality in agricultural areas.) Wells included in the revised network are required to be located within fairly homogeneous settings in terms of both glacial lobe provenance and land use/land cover.

Figure 10. Quaternary surficial sand and gravel aquifers in Minnesota by composition [Data from the Minnesota Geological Survey. Aquifers composed of materials classified as a mixed origin are not shown].

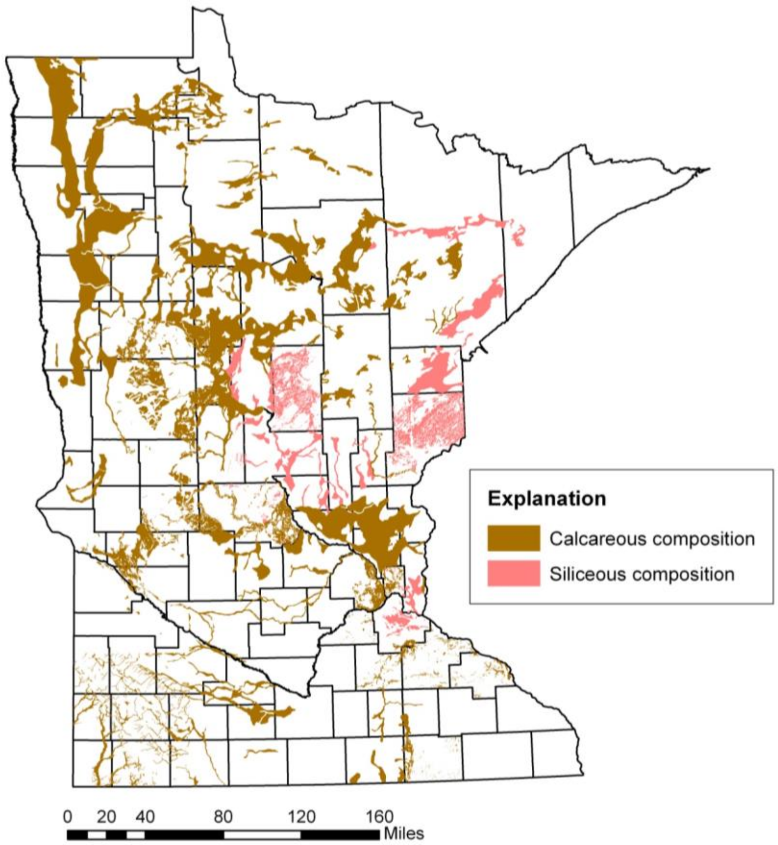
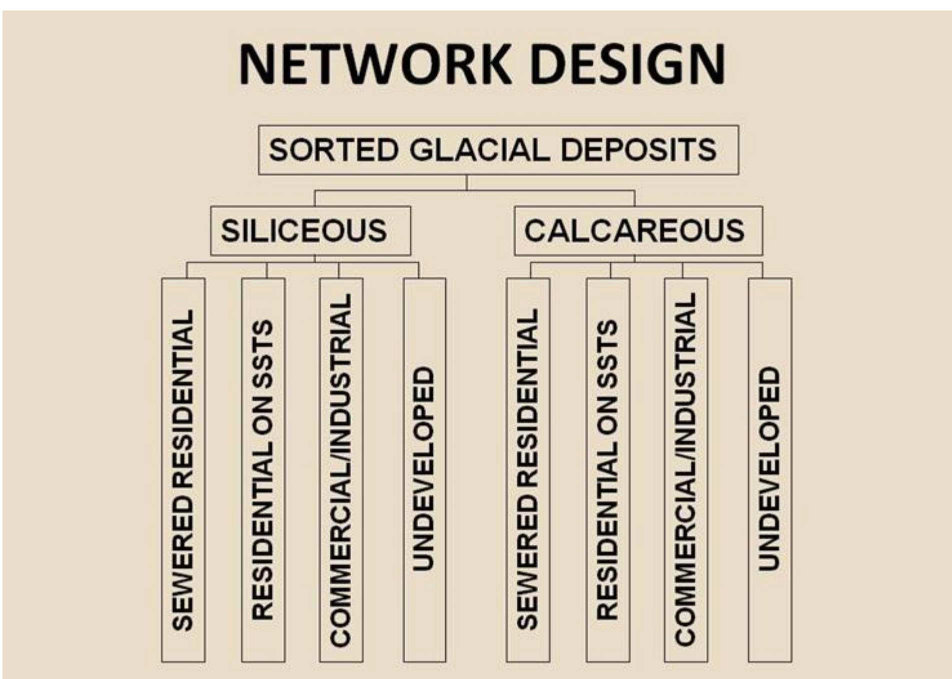


Figure 11. Random stratified statistical design of the quaternary sand and gravel aquifer network



The Ambient Groundwater Quality Monitoring Network requires a total of 200 wells to meet the statistical requirements associated with fully implementing the revised shallow Quaternary aquifer network. This includes 25 wells in each glacial lobe provenance/land use setting combination (Figure 11). Well installation is nearly complete.

Prairie du Chien-Jordan aquifer network design

The Prairie du Chien-Jordan aquifer network design expands the geographic coverage to improve regional characterization of water-quality conditions and track trends throughout the area where the aquifer is most susceptible to contamination. Although the network consists primarily of existing domestic wells, since these wells typically describe water-quality conditions in the upper part of the aquifer. The Prairie du Chien-Jordan network will include 53 wells located approximately 10 miles apart in the area targeted for monitoring. Based on the MPCA's analysis, 42 existing wells meeting the design criteria are available for sampling, leaving just 11 wells to be installed. These wells likely will be installed through coordinated efforts between the MPCA and MDNR to select well locations that will serve the needs of both agencies, as possible. Five new wells are being proposed in 2020-2021 to provide coverage that is currently absent in the southeastern part of the state.

National Groundwater Monitoring Network Pilot Study

Concurrent with planning for implementation of its Ambient Groundwater Quality Monitoring Network Improvement Plan, the MPCA partnered with the MDNR to conduct one of five pilot studies nationally for the National Groundwater Monitoring Network (NGWMN) that was started by the Subcommittee on Groundwater of the Federal Advisory Committee on Water Information (ACWI). The ACWI is an administratively inactive committee that advised the federal government on the effectiveness of the current National programs to meet water information needs. The purpose of the pilot study was to test the concepts and approaches for a proposed national groundwater monitoring network. A number of wells in the MPCA's Ambient Groundwater Quality Monitoring Network are candidates for inclusion in the proposed NGWMN. As of 2020, the NGWMN continued to receive federal funding to encourage other partners, including those in Minnesota, to participate in the network and for the long-term operation and maintenance of the network. The Minnesota Pilot Study report is available on the MDNR's website at the following address:
http://files.MDNR.state.mn.us/publications/waters/mn_ngwmn_pilot_project_final_report_march_2011.pdf

Chloride monitoring

As chloride has gained considerable attention as a contaminant of concern the network has provided information on historic chloride concentrations while helping the program to plan for a more intensive chloride monitoring schedule to track how it moves from surface application through the groundwater system. The GW Network deployed downhole conductivity meters into selected wells in the summer of 2018. These tools (Solinst Levelogger Edge) collect groundwater elevation, temperature, and conductivity information continuously at a predetermined interval. The conductivity values can be used to estimate chloride concentrations. These tools have been placed in over 20 wells in the Ambient Network, and three wells in the Sentinel Lakes Network. Water samples are collected once a year in the former, and six times a year in the latter network. Analysis of the data from the three Sentinel Lakes wells shows a strong correlation between field-determined specific conductance and lab measured chloride.

3.2.c Condition monitoring indicators

Groundwater quality samples from the MPCA's Ambient Groundwater Monitoring Network are collected annually from all network wells. Unlike surface waters, all groundwater in Minnesota is protected as an actual or potential source of drinking water. As a result, samples are analyzed for a wider suite of indicators of natural and anthropogenic contamination than surface water.

Approximately 100 indicators are analyzed from each sample collected from the network, including nutrients, major ions, metals, and a suite of 68 volatile organic compounds (Tables 4 and 5). Some of these chemicals, such as nitrate, benzene, cadmium, and chloroform, are primary indicators of drinking-water quality and have published health-based guidance. Other indicators are analyzed to facilitate data interpretations. Water temperature, pH, specific conductance, alkalinity, and dissolved oxygen concentrations also are measured in the field to facilitate the interpretation of these data.

In addition, approximately 40 ambient network wells are sampled each year to determine concentrations of endocrine disrupting compounds, pharmaceuticals, personal care products, fire retardants, detergent breakdown products, hormones and other emerging contaminants of interest. These contaminants are measured in the groundwater to: 1) determine the occurrence and distribution of these contaminants in the groundwater system, 2) quantify any temporal trends in concentrations, and 3) evaluate, in conjunction with other data collected as part of ambient monitoring, the sources of contaminants in the groundwater. This monitoring is part of a larger statewide effort to determine the occurrence and distribution of emerging contaminants in the hydrologic system.

MPCA has conducted special projects to leverage the ambient network to monitor PFAS. In 2013, the roughly 200 wells that comprised the network at that time were sampled for PFAS, followed by a more limited sampling in 2017. The results of this were reported in *The Condition of Minnesota's Groundwater Quality, 2013-2017* (Kroening and Vaughan, 2019) available at: https://www.pca.state.mn.us/sites/default/files/wq-am1-10.pdf. Most recently, another full sampling of the network was conducted in 2019. Preliminary review of those results reveal that 60% of wells had detectable PFAS, with 9 wells showing concentrations of perfluorooctanic acid or PFOS exceeding health-based guidance values. This monitoring effort has revealed that PFAS are present in areas with no known sources of contamination.

Because of the high cost of these analyses, the actual number and plan for sampling the network wells will be modified from year to year based on analysis of the results received. Standard monitoring parameter monitoring frequency may be reevaluated after a baseline of five sampling events has been completed

Table 4. Parameters analyzed in water samples from the ambient groundwater quality monitoring network

Aluminum	Cobalt	Organic plus ammonia nitrogen
Arsenic	Copper	Phosphorus
Ammonia nitrogen	Iron	Potassium
Barium	Lead	Silver
Beryllium	Lithium	Sodium
Boron	Magnesium	Strontium
Bromide	Manganese	Sulfate
Cadmium	Molybdenum	Titanium
Calcium	Nickel	Vanadium
Chloride	Nitrate plus nitrite nitrogen	Zinc
Chromium	Organic carbon	

Table 5. Volatile organic compounds analyzed in water samples from the ambient groundwater quality monitoring network

Acetone	1,3-Dichlorobenzene	Methyl tertiary butyl ether (MTBE)
Allyl chloride	1,4-Dichlorobenzene	Naphthalene
Benzene	Dichlorodifluoromethane	n-Propylbenzene
Bromobenzene	1,1-Dichloroethane	Styrene
Bromochloromethane	1,2-Dichloroethane	1,1,1,2-Tetrachloroethane
Bromodichloromethane	1,1-Dichloroethene	1,1,2,2-Tetrachloroethane
Bromoform	cis-1,2-Dichloroethene	Tetrachloroethene
Bromomethane	trans-1,2-Dichloroethene	Tetrahydrofuran (THF)
n-Butylbenzene	Dichlorofluoromethane	Toluene
sec-Butylbenzene	1,2-Dichloropropane	1,2,3-Trichlorobenzene
tert-Butylbenzene	1,3-Dichloropropane	1,2,4-Trichlorobenzene
Carbon tetrachloride	2,2-Dichloropropane	1,1,1-Trichloroethane
Chlorobenzene	1,1-Dichloropropene	1,1,2-Trichloroethane
Chlorodibromomethane	cis-1,3-Dichloropropene	Trichloroethene (TCE)
Chloroethane	trans-1,3-Dichloropropene	Trichlorofluoromethane
Chloroform	Ethylbenzene	1,2,3-Trichloropropane
Chloromethane	Ethyl ether	1,1,2-Trichlorotrifluoroethane
2-Chlorotoluene	Hexachlorobutadiene	1,2,4-Trimethylbenzene
4-Chlorotoluene	Isopropylbenzene	1,3,5-Trimethylbenzene
1,2-Dibromo-3-chloropropane (DBCP)	p-Isopropyltoluene	Vinyl chloride
1,2-Dibromoethane (EDB)	Methylene chloride	o-Xylene
Dibromomethane	Methyl ethyl ketone (MEK)	p&m-Xylene
1,2-Dichlorobenzene	Methyl isobutyl ketone (MIBK)	

Section 3.3: Problem investigation monitoring strategy

Problem investigation monitoring typically focuses on groundwater that is at risk for or is known to be contaminated by a spill, chemical release site, or other mechanism, or is of special interest because it is an aquifer that is a source of drinking water.

Whereas condition monitoring with the Ambient Groundwater Monitoring Network has a statewide scope, the focus of most problem investigation monitoring is more localized, because it is focused on determining the cause, source, severity, and extent of a site-specific groundwater contamination concern. Problem investigation monitoring seeks to gather aquifer characteristics and determine the rate, path of groundwater flow, and extent and magnitude of contamination. Problem investigation monitoring gathers information needed to assess human and environmental risks associated with the contamination and provides information needed to design groundwater cleanup systems, if required.

Most problem investigation monitoring at the MPCA is conducted by the MPCA's Superfund, Resource Conservation and Recovery Act (RCRA), Closed Landfill, and Petroleum Remediation programs (Remediation Division). These programs are responsible for the core remediation and emergency response programs of the agency. The MPCA Remediation Division focuses on environmentally effective, cost efficient clean-up and long-term maintenance of contamination sites. While these programs deal with issues broader than groundwater contamination (e.g. soil contamination, soil vapor releases, etc.), investigation of the potential effect of contaminant releases on groundwater and identification and clean up of groundwater contamination that exceeds risk-based standards is a fundamental purpose of the programs.

More information about the MPCA's Remediation programs is available here: http://www.pca.state.mn.us/index.php/waste/waste-and-cleanup/cleanup-programs-and-topics/cleanup-programs/cleanup-programs.html. Risk-based site assessment guidance documents used by the Petroleum Remediation, RCRA and Superfund programs, and Voluntary Investigation and Cleanup Program, including guidance documents for groundwater investigation and cleanup, can be accessed through this link: http://www.pca.state.mn.us/index.php/waste/waste-and-cleanup/cleanup-programs-and-topics/topics/risk-based-site-evaluation-process-guidance-documents.html?menuid=&redirect=1

Section 3.4: Effectiveness monitoring strategy

Effectiveness monitoring is designed to measure the actual impact of resource management decisions, such as implementation of BMPs. Effectiveness monitoring involves monitoring both before and after implementation, and is conducted in specific locations to provide a measure of whether, and to what extent, responses to a problem were successful.

Groundwater effectiveness monitoring is conducted by the MPCA Remediation Division to demonstrate the effectiveness of remedial actions taken to address impacted soil and groundwater at a site. Over time, the MPCA's Ambient Groundwater Monitoring Network will provide data that can be used to evaluate the overall effect of non-agricultural anthropogenic activities on Minnesota's groundwater quality.

The MPCA has also been working to identify data needed to assess the effectiveness of BMPs used to protect groundwater by programs that do not routinely conduct effectiveness monitoring. These programs include:

- Subsurface sewage treatment systems
- Animal feedlots
- Biosolids
- Land and water quality permits for land applied industrial wastewaters and by–products
- Stormwater
- Solid waste demolition landfills
- Municipal inflow and infiltration

The most recent report on groundwater BMP effectiveness was produced in 2019, and work implementing the report recommendations continues.
https://www.pca.state.mn.us/sites/default/files/wq-gw1-08.pdf

Section 3.5: External organization monitoring

This section provides a brief description of the monitoring purposes, designs and activities of other Minnesota organizations involved in groundwater quality monitoring: MDA, MDNR, and MDH.

Recall that the MPCA and other state agencies with responsibility for water resource management in Minnesota have been coordinating their monitoring activities via the Interagency Groundwater/Drinking Water Coordination Team to make the best and most efficient use of available funding. Monitoring activities that have previously been described because of MPCA's participation will not be described in detail in this section.

3.5.a Minnesota Department of Agriculture groundwater quality monitoring

The overall goal of the pesticide groundwater monitoring program is to determine the impacts of pesticides on vulnerable groundwater in agricultural areas and select urban areas in Minnesota. The desire of MDA decision makers is to have a regionalized assessment that may be used to make sub-state level comparisons of, and decisions on, the impacts of pesticides to vulnerable groundwater resources. Direction for groundwater monitoring by the MDA is derived from the Minnesota Pesticide Control Law (Minn. Stat. ch. 18B) and the Minnesota Groundwater Protection Act (Minn. Stat. ch. 103H).

The groundwater monitoring program has been designed to satisfy the following three primary goals:

- Monitor and assess the impacts of pesticides to the most vulnerable groundwater using the MDA Pesticide Monitoring Regions (PMRs) displayed in Figure 7.
- Determine pesticide detection frequency, concentration and trends in the established PMRs where there is significant pesticide use.
- Evaluate the need for pesticide BMPs and other pesticide management plan activities in the various regions of the state.

The MDA began monitoring groundwater in November 1985 and redesigned the network in 1998. New monitoring wells were installed in 1999, and the MDA began sampling the re-designed monitoring network in January 2000. The current program is established around the goal of providing the information necessary to manage pesticide use for water quality protection on a sub-state, regional basis. Each monitoring site is established to evaluate pesticide impacts to the most vulnerable groundwater conditions in their associated PMR. The first network was established in PMR 4 (central sands), which contains the majority of sites in the program. It was designed for the purpose of tracking trends over time. PMRs 1, 5, 6, 7, and 8 were started in 2004. PMR 9 groundwater has been sampled via naturally occurring springs since 1993. Monitoring of natural springs in PMR 9 is accompanied by sampling of domestic drinking water wells, which started in 2009. PMRs 2 and 3 are not currently monitored for groundwater due to very limited agricultural production in these heavily forested regions. Network design, sampling protocols, well locations, sampling schedules, and so forth, are available in the program's groundwater design document and annual work plans on the MDA website at: www.mda.state.mn.us/monitoring.

The MDA now routinely analyzes samples for over 165 different pesticide related chemicals in groundwater and surface water and most are quantified in the lower parts per trillion range. There has also been an increase in the number of samples analyzed by the MDA laboratory in recent years.

The MDA also monitors nitrate and pesticides in groundwater utilizing private drinking water wells through three different programs: 1) Township Testing; 2) Private Well Pesticide Sampling; and 3) two regional private well monitoring networks. Between 2013 and 2020, the Township Testing Program (TTP) has analyzed nitrate concentration in over 32,000 private wells in areas with vulnerable groundwater and row crop agriculture. The goal of TTP is to characterize nitrate concentrations at the township scale to guide future BMP promotion and provide education and outreach to private well owners in at risk areas. Local partners (County and Soil and Water Conservation District staff) are engaged and coordinate much of the sampling and initial well owner outreach. Well owners with detectable levels of nitrate in their drinking water are offered free follow-up nitrate and pesticide testing by MDA staff through the Private Well Pesticide Sampling Project. Between 2016 and 2019, the MDA collected over 5,000 pesticide samples from private wells and a contract laboratory analyzed them for over 125 different pesticide related chemicals. The goal of this project is to provide information to well owners about pesticide presence in their drinking water and provide additional information to MDA and MDH about pesticide presence in deeper groundwater in agricultural areas. The MDA also coordinates two regional nitrate private well monitoring networks in southeastern Minnesota counties and in the Central Sand Plains. These networks of several hundred private wells each are sampled annually and allow for long-term assessment of nitrate concentration trends in each region.

The MDA publishes various reports of monitoring results generally on an annual basis. These reports are made available on the Minnesota Digital Water Research Library (https://wrl.mnpals.net/) and on MDA's monitoring and Assessment webpage under *Reports and Resources* at: https://www.mda.state.mn.us/monitoring/.

3.5.b Minnesota Department of Health groundwater quality monitoring activities

Groundwater quality monitoring activities support the mission of the MDH, "to protect, maintain, and improve the health of all Minnesotans," by providing data that are used to evaluate the level of contaminants in groundwater used for drinking water. These data help verify compliance with federal and state regulations, establish baseline water quality conditions for drinking water sources, inform the process for producing health based guidance, and guide development of groundwater models and vulnerability assessments for source water protection and other water supply planning efforts to safeguard our drinking water. The following paragraphs provide additional information about MDH's groundwater quality monitoring activities.

Drinking water protection – regulatory compliance monitoring

MDH assists approximately 6,700 community and non-community public water systems to provide safe and adequate drinking water as outlined in the federal SDWA. Most of these systems utilize a groundwater source of supply. MDH staff and laboratory personnel collect and analyze water samples from public water systems for required parameters on a schedule that is dependent on the type of water system. Factors that influence the schedule and required parameters conform to SDWA criteria. They include well vulnerability, system type (community or non-community) and population served.

MDH also regulates the construction, repair, and sealing of wells and borings, and regulates new wells that are used for potable uses. Minnesota's Water Well Construction Code (Minn. R. 4725) requires that newly constructed drinking water wells be sampled and tested by a certified laboratory for arsenic, coliform bacteria and nitrate to ensure a safe water supply; the analytical results must be sent to MDH as well as the well owner.

Drinking water protection – non-regulatory, investigative sampling

In addition to assisting Minnesota's public water systems in meeting SDWA requirements, MDH works with public water systems to conduct investigative sampling for contaminants and chemical indicators not outlined in the SDWA. Ninety-eight percent of public water systems in Minnesota rely on groundwater as the source. Investigative sampling helps to protect the groundwater sources of drinking water through activities designed to identify potential threats and prevent contamination. Groundwater monitoring is essential to provide the hydrogeological and geochemical data utilized in developing the wellhead protection plan and for aquifer-specific drinking water quality by watershed. Ongoing monitoring of the groundwater used for public drinking water supplies is an integral component of ensuring that safe drinking water is protected against future contamination.

Groundwater monitoring conducted by MDH in support of public water supply protection includes monitoring for various indicators of groundwater vulnerability, residence time, and preferred recharge pathways (e.g. tritium and stable isotopes of water). Wells that capture young water are more susceptible to contamination from activities at the land surface than those that capture older water. In settings where surface water bodies are thought to recharge the groundwater aquifers supplying public wells, the MDH also samples for the stable isotopes of water. These stable isotope results can be used to confirm or refute whether recharge is occurring and determine how much of the water pumped by a well originated at a lake or stream. These results are critical for accurate delineation and effective management of wellhead protection areas.

MDH is also involved in other source water protection monitoring initiatives that are focused on specific issues or geographic areas. Several of these are highlighted below.

Unregulated contaminants monitoring

From the standpoint of MDH and drinking water utilities, unregulated contaminants are those that lack specific water quality standards (e.g., Maximum Contaminant Levels or MCLs). MCLs exist for approximately 100 compounds. The set of compounds that are known to exist in the environment is far larger and grows regularly because research into contaminants of emerging concern (CEC) is active and on-going. Some of these contaminants have known health impacts to humans. Investigative monitoring to assess the occurrence and distribution of CEC is important to help understand the scope and scale of such contamination, to guide the development of health-based guidance, to inform other best management practices to avoid or limit occurrence in drinking water sources, and to provide solid information to maintain trust and confidence in public drinking water systems.

MDH currently lacks firm capacity to conduct CEC monitoring on a regular basis. Instead, current efforts have been carried out as part of specific projects, some of which are described below.

Federal unregulated contaminants monitoring rule sampling

Federal rules require public water systems meeting certain size criteria to collect samples and have them analyzed for approximately 30 unregulated contaminants as identified in a national nomination and vetting process. Sampling sites consist of public water systems served by both surface water and groundwater. MDH coordinates unregulated contaminants monitoring rule sampling in Minnesota. Up to 2020, there have been four rounds of this mandated sampling. A fifth is in the planning stage and will start in 2023. MDH obtains the data and evaluates the results – EPA compiles results on a national level. See: https://www.epa.gov/dwucmr.

Minnesota's unregulated contaminants monitoring project

With the support of the Environmental and Natural Resources Trust Fund, MDH initiated a project in 2018 to sample selected public water systems at risk of impact from several different classes of unregulated contaminants. Three networks of sampling sites comprised of public water system sources (wells or intakes) was established. The first consisted of systems that use surface water for supply. Public water systems with vulnerable wells in close proximity to potential wastewater sources comprise the second network. The third network is made of vulnerable wells in close proximity to agricultural land uses. Parameters selected for analysis varied depending on the network and the likely types of sources. Sampling was conducted at both the source and at the entry point. Major parameter classes included pharmaceuticals, personal care products, pesticides, industrial contaminants (i.e., PFAS), and hormones. Sampling was completed in 2019. Results and reporting are expected to be complete in 2021. For more information, see:
https://www.health.state.mn.us/communities/environment/water/unregcontam.html.

Pathogen (aka virus) project
From 2014-2016, MDH sampled 145 public water supply wells for 23 pathogens and microbial indicators, including viruses, bacteria, and protozoa. The results indicate that genetic material from these organisms is widespread in groundwater, although transient in nature. On-going projects are currently underway to assess the potential pathways for microbial occurrence in wells so MDH can better safeguard consumers of well water from pathogen exposure.

Per- and poly-fluorinated alkyl substances
MDH collaborates with public water systems, other state programs, federal partners and local governments on the investigation and response to potential threats to water supplies from emerging contaminants, such as per- and poly-fluorinated alkyl substances (PFAS). Various strategies are being employed to sample all community water systems for selected PFAS compounds by 2025. These efforts will start in 2020 in a targeted fashion. This work will rely on data and information of known PFAS presence in the environment from MPCA and others to identify high-risk locations for sampling.

In the eastern portion of the TCMA, the MDH has collaborated with the MPCA to sample over 1,000 private wells in multiple areas of Washington County to determine the extent of PFBA (i.e. one of the PFAS compounds) in the aquifers, and continues to work with the MPCA to monitor over 400 of those wells.

3.5.c Minnesota Department of Natural Resources groundwater quality monitoring activities

The MDNR's statutory responsibilities with regard to groundwater are centered on monitoring and managing groundwater levels, groundwater availability and the long-term sustainability of Minnesota's groundwater and surface water resources. MDNR maintains a Groundwater Observation Well Network, conducts aquifer tests, develops county groundwater atlases and administers the preliminary well assessment program and a water appropriations permit program. As part of this work, the MDNR collects groundwater quality data under specific circumstances, which are described below.

- MDNR has maintained a statewide groundwater level monitoring network since 1944. There are approximately 1,140 actively measured wells with over 700 instrumented to collect hourly level data. The original network was comprised of wells owned by others such as communities or irrigators and wells adopted from completed USGS studies. Starting in the late 2000s dedicated funding allowed for planned network expansion to study specific aquifers and areas of groundwater management concern. Legislative Commission on Minnesota Resources funds were used to install wells to study the edge of the Mt. Simon aquifer and Clean Water Funds were specifically dedicated to fill gaps in the bedrock aquifers located in the TCMA. MDNR's goal is to add 50 new observation wells each year; prioritized around the state in areas of known high use, areas that serve public water supplies, and areas with little information. When possible and as funding allows, new wells in the network are intended to be constructed to enable water quality sampling in addition collection of water level data.
- As part of an on-going cooperative effort with the Minnesota Geological Survey, the MDNR prepares the groundwater atlas which includes pollution sensitivity of the aquifers in each county. As a part of that effort, groundwater sampling is done at selected wells to better understand groundwater movement and to support groundwater sensitivity mapping. Approximately 80 to 100 wells are sampled in each investigated county to determine major ion, trace element, and tritium concentrations. Stable isotope concentrations of oxygen and hydrogen are also analyzed to better understand recharge conditions. A few wells suspected of having very old water in each project area are sampled and analyzed for carbon-14 age dating.

The MDNR maintains a database of water chemistry and isotope data from more than 3,900 wells.

- MDNR offers access to the observation well network for water quality studies. A recent example is partnering with MDH for their Pathogen Project using a well in Cottage Grove. USGS has installed real-time data equipment and MDH is using that data to determine when they need to sample the well for water quality.
- MDNR and MPCA have partnered with the USGS in their NNGWMN since their pilot in 2010. The NGWMN is a network of selected wells from federal, multistate, state, and local groundwater monitoring networks brought together under a set of defining principles and is designed to provide information essential for national and regional scale decisions to be made about current groundwater management and future groundwater development. MDNR created a database connection to the NGWMN and supplies information for approximately 375 wells in Minnesota. NGWMN also has awarded MDNR funds to drill new observation wells in areas of interest for both networks.

Section 3.6: Groundwater monitoring quality assurance

Nearly all decisions made to protect and maintain groundwater quality are based on the monitoring data that are collected to assess its condition. For this reason, it is imperative that the MPCA has quality assurance/quality control standards for these data.

The MPCA's quality assurance/quality control coordinators oversee implementation of the agency’s quality assurance/quality control standards. This includes data collection, selection of laboratories, selection of parameters to be measured, the consistency of data analysis and confidence in data quality.

The MPCA’s Quality Management Plan was approved by the EPA in 2018 and is available here: https://www.pca.state.mn.us/sites/default/files/p-eao2-15.pdf.

Section 3.7 Groundwater data management

The MPCA and MDA now store the groundwater quality data that they each collect in the same database; Environmental Quality Information System or EQuIS. The MDNR’s County Well Atlas Program also is in the process of transitioning the storage of their groundwater quality data to this same database.

Public data is made available for download at the MPCA Environmental Data Access website at: https://www.pca.state.mn.us/quick-links/eda-surface-water-data, and the National Water Quality Portal at https://www.waterqualitydata.us/.

Section 3.8 Data analysis

The MPCA analyzes its ambient groundwater quality data to determine its suitability to serve as drinking water, describe the condition of the state’s groundwater, and quantify any changes in the quality of this resource. A variety of visualization and statistical methods are used to meet these varied goals.

All groundwater quality data from the MPCA Ambient Groundwater Monitoring Network are compared to applicable health-based guidance by the MDH or MCLs set for drinking water by the EPA. The health based guidance values derived by the MDH include health risk limits, health based values, and risk assessment advice. Health risk limits and health based values are chemical concentrations in drinking water that pose little or no health risk to humans. Health risk limits differ from health based values in that they are promulgated. Risk assessment advice is generally similar to health risk limits and health based values; but these values may be qualitative and have greater uncertainty.

The overall condition of Minnesota's groundwater is determined separately for the Quaternary sand and gravel wells in the Early Warning Network and the Prairie du Chien Jordan formation aquifers. This approach is used because the natural quality of the state's aquifers varies due to the differing geologic compositions and groundwater residence times.

When the Early Warning Network is completed, monitoring data collected from the Quaternary sand and gravel wells will be analyzed to show spatial differences in chemical concentrations and quantify any differences in groundwater quality underlying typical urban and undeveloped land use settings. Spatial differences will be shown by maps of chemical concentrations by the well location. Differences among the typical urban and land use settings will be shown by box plots of chemical concentrations by land use setting. These differences in median chemical concentrations among these settings will be quantified using a non-parametric statistical technique, such as the Kruskal-Wallis test.

The data from the other aquifers monitored by the MPCA's Ambient Groundwater Monitoring Network will be analyzed to show spatial differences in chemical concentrations. This will be done using maps of concentrations by well location.

The volatile organic compound and contaminants of emerging concern data will be analyzed to determine the frequency of detection and the maximum concentration. The detection frequencies are calculated using the reporting limit for each indicator and a common reporting for the entire suite of chemicals. A common reporting limit also is used to calculate detection frequencies because some chemicals may appear to be detected more frequently in the groundwater compared to others because they can be analyzed at a low reporting limit. The limits used to calculate the detection frequency will be raised if laboratory or field quality assurance data indication contamination.

Section 3.9 Data reporting

The ambient groundwater quality data collected by the MPCA are stored and made available to scientists, citizens, and other interested parties in a variety of ways.

Environmental Data Access

The MPCA's Environmental Data Access (EDA) system allows users to view and download groundwater quality data. The EDA's groundwater section displays data from the MPCA's Ambient Groundwater Monitoring Network and Closed Landfill Monitoring program. EDA has the choice of a map-based or text-based search. Using the map-based search, the user can view the sampling dates and analytical results for specific wells. More information about EDA, and a link to the EDA system, can be found here: https://www.pca.state.mn.us/water/groundwater-data.

Prepared reports

Much of the MPCA's groundwater quality data reporting occurs through the preparation of reports that provide context and interpretation of the monitoring data that were collected. Most of these reports are available on the MPCA's website.

These reports fulfill a range of purposes. They include a condition monitoring report, major watershed assessment reports, and a groundwater monitoring status report. The following paragraphs highlight some of the monitoring data-based, groundwater quality reports, with web links where they are available.

- **Groundwater condition reports:** The MPCA publishes a report every five years describing the general condition of the state's groundwater. This report is designed to provide an assessment of current condition of the Minnesota's groundwater resources that are vulnerable to contamination and eventually will identify any emerging trends in water quality. The scope of the reports generally is limited to information collected by the MPCA and MDA ambient groundwater monitoring networks. https://www.pca.state.mn.us/sites/default/files/wq-am1-10.pdf
- **Groundwater monitoring status reports:** These reports are prepared every five years for the Environmental Quality Board (EQB) to meet the requirements of the Groundwater Protection Act (Minn. Stat. ch. 103H.175). These reports are designed to report on the status of groundwater monitoring by the MPCA and other agencies with groundwater responsibilities. The EQB is required to use the information provided by the MPCA and other agencies when preparing its reports on water issues and priorities for the Legislature.

Section 3.10: Programmatic evaluation

As described previously in Section 2.10, the MPCA undertakes annual internal program assessments and also is accountable to the state Clean Water Council for monies it has received for its groundwater quality monitoring activities. A review of the network and its assumptions, protocols, practices, and outcomes was conducted in 2018-2019. To ensure the ambient network continues to meet its purpose of monitoring and reporting on groundwater condition and trends from non-agricultural pollutants, groundwater staff identified six areas of focus and related actions for the network.

- Adjust sampling schedule and parameters
- Address MPCA/Governor's initiatives
- Improve data visibility and communication
- Re-direction of drilling funds and network expansion
- Remote Monitoring
- Revisit network design
- Continued confirmation and innovation of statistical methods

In addition, the MPCA participates in interagency coordination teams that are intended to eliminate duplication of effort in state agency activities and avoid creation of additional layers of bureaucracy.

Section 3.11: General support and infrastructure planning

MPCA relies primarily on the state Clean Water Fund (CWF) to support the ambient groundwater monitoring work. The program currently has just under five staff. Federal dollars help support staff positions that existed prior to the development of the fund.

Over the last 10 years, the MPCA has implemented the groundwater monitoring design identified for its groundwater condition monitoring activities, and anticipates that funding to continue to operate the network at current levels will generally be available via the CWF.

An area of need identified previously is staffing. The demands on MPCA staff dedicated to groundwater condition monitoring activities have greatly increased during implementation of the network improvements described in this section. MPCA has generally met these demands through increased used of seasonal staff (student workers) during the summer monitoring season.

The demand for information and interpretation of groundwater monitoring data are also increasing; this trend is expected to continue as the broader set of monitoring data now being collected is better able to support a variety of groundwater quality information needs. The MPCA recently hired a position focused on groundwater data mapping and visualization.

Moreover, the agency's adoption of the watershed approach has resulted in the collection of data that clearly demonstrate the significant impact groundwater has on surface water resources, in terms of quality, quantity, or both. The relationship of groundwater to surface water quality and its importance to watershed restoration and protection plans represents an additional demand on MPCA (and all agency) groundwater staff.

Appendix 1: Memorandum of Agreement on groundwater monitoring in Minnesota

AGREEMENT
TO OPERATE
AN INTEGRATED GROUND WATER QUALITY MONITORING SYSTEM
FOR THE STATE OF MINNESOTA

The Minnesota Department of Agriculture, Minnesota Pollution Control Agency and Minnesota Department of Health (Agencies) agree that the attached document *Integrated Ground Water Quality Monitoring Strategy*, dated February 11, 2004, represents the Agencies' joint plan for conducting ground water quality monitoring on a statewide basis in Minnesota.

The plan outlines the Agencies' different purposes, goals and roles in ground water quality monitoring based on their individual state and federal authorities and requirements.

The plan identifies how the monitoring conducted by the Agencies will be conducted in an integrated fashion providing a comprehensive, statewide assessment of ground water quality resources for the future. The plan also establishes inter-agency cooperation in shared monitoring design, sample collection, sampling location selection, evaluation of sensitive areas, and data management to ensure efficiencies in the system.

The plan provides for an annual review of the ground water quality monitoring system to allow for modifications, along with a five-year evaluation, at which time this agreement will be updated.

By signing this agreement, the Agencies commit to fulfilling the monitoring activities outlined in this plan in cooperation with the other agencies. An individual agency may choose to terminate its participation in this agreement with 30 day notice to the other Agencies.

Signed,

Gene Hugoson **Commissioner** **Department of Agriculture**	**Sheryl A. Corrigan** **Commissioner** **Pollution Control Agency**	**Dianne M. Mandernach** **Commissioner** **Department of Health**
2-18-04 Date	2/18/04 Date	2/18/04 Date

INTEGRATED GROUND WATER QUALITY MONITORING STRATEGY: MINNESOTA DEPARTMENT OF AGRICULTURE, MINNESOTA DEPARTMENT OF HEALTH AND MINNESOTA POLLUTION CONTROL AGENCY FEBRUARY 11, 2004

Three agencies – the Minnesota Department of Health, Minnesota Department of Agriculture and the Minnesota Pollution Control Agency – have primary responsibility for monitoring the quality of ground water statewide. This document represents an overall strategy for conducting statewide ambient ground water quality monitoring, and is agreed to by the three agencies to represent their operational plan.

MONITORING PURPOSES, GOALS AND ROLES

Among the three agencies there are different, yet very closely related, purposes for conducting ground water monitoring. All three agencies use monitoring data to provide information necessary to assess – and ultimately restore or protect – the quality of Minnesota's ground water and drinking water resources.

The three agencies also share a common mission to share data with each other and other entities that manage ground water resources, and to share information from monitoring to educate the public about threats that ground water contamination presents to Minnesotans.

Beyond these general purposes for conducting ground water monitoring, each agency has individual, more specific purposes, based on the agency's statutory mandates (see table).

The Minnesota Department of Agriculture monitors to provide information on the impacts of the routine use of agricultural chemicals (pesticides and fertilizers) on the quality of Minnesota's water resources. The Department's monitoring goals/objectives are:

- to measure the status and trends in occurrence and concentration of pesticides and nutrients (from fertilizer) in water resources of the state;
- to evaluate attributes associated with ground water quality conditions that may cause or reduce ground water degradation by pesticides and nutrients;
- to provide scientifically and legally defensible information from which the efficacy of pesticide and nutrient management plans and practices may be determined; and
- to investigate the causes of agricultural chemical contamination and evaluate the effectiveness of Best Management Practices (BMPs) and any necessary Water Resource Protection Requirements (WRPRs).

The Minnesota Department of Health monitors to ensure all Minnesotans have safe drinking water and to understand current contaminant levels and trends in water quality that may pose significant health concerns for those drinking it. The Department's monitoring goals/objectives are:

- to assess public water supplies to ensure contaminants are below levels that present a human health threat;
- to assess private water supply wells to ensure that new wells meet minimal water quality standards and that the owners of private wells understand the health risks associated with contaminants that are detected in their well water;
- to evaluate the risk to human health arising from the presence of human-caused and naturally-occurring contaminants in groundwater; and
- to assist local health departments with addressing the human health impacts related to the contamination of public and private water supply wells.

The Minnesota Pollution Control Agency monitors to provide information on the impacts of non-agricultural chemicals on water resources. The Agency's monitoring goals/objectives are:

- to assess the status and trends of Minnesota's ground water system for non-agricultural impacts;
- to determine specific causes of impairments and to quantify inputs from sources;
- to investigate specific problems, and to design management approaches to protect or improve ground water resources; and
- to evaluate the effectiveness of regulatory or voluntary management actions.

MONITORING ROLES

The differences in monitoring purposes and goals result from the three agencies' differing roles in ground water quality monitoring. Those roles are set by a variety of state and federal statutes governing ground water. The table below identifies the different roles.

STATE AUTHORITIES		
MDA	**MDH**	**MPCA**
MS 103H: requires MDA to monitor the use and effectiveness of agricultural best management practices	MS 144.83: grants MDH authority to ensure that public water supplies are safe to drink and adopts federal Safe Drinking Water Act monitoring requirements	MS 103H: requires MPCA to monitor the use and effectiveness of non-agricultural best management practices
MS103H: requires MDA (for agricultural chemicals) to conduct monitoring following pollution detection to evaluate pollution frequency and concentration trend	MS 103I: grants MDH authority over the construction of water supply wells and to require testing to ensure potability of newly constructed wells	MS 103H: requires MPCA (for non-agricultural chemicals) to conduct monitoring following pollution detection to evaluate pollution frequency and concentration trend

MS 18B: requires MDA to determine impact of pesticides on the environment	MS 115B: grants approval for MDH to use solid waste funds to test private water supply wells that may be impacted by municipal waste disposal sites	MS115A: authorizes MPCA to investigate the extent, character and effect of the pollution of waters; to gather data for administration of pollution laws
MS 18B; 18C; 18D; 18E; 115B : authorizes MDA to undertake monitoring to investigate agricultural point-source pollution releases		MS115B: authorizes MPCA to undertake monitoring to investigate non-agricultural pollution releases
FEDERAL REQUIREMENTS		
MDA	**MDH**	**MPCA**
Federal Insecticide Fungicide and Rodenticide Act (FIFRA): Delegates pesticide programs to MDA and requires monitoring as part of FIFRA cooperative agreements	40 CFR 141 and 142 requires that public water supplies meet potability standards and grants states primacy rights to enforce federal drinking water regulations	Federal environmental programs delegated to MPCA require monitoring as part of clean up and regulatory programs

TYPES OF MONITORING

For purposes of this document, we will discuss the three agencies' monitoring efforts in terms of three categories as follows:

- *Condition Monitoring:* This type of monitoring is used to identify overall environmental status and trends by examining the condition of individual water bodies, airsheds, or aquifers in terms of their ability to meet established standards and criteria. It may include chemical, physical or biological measures. The focus of Condition monitoring is on understanding the status of the resource, identifying changes over time, and identifying/defining problems at the overall system level.
- *Problem Investigation Monitoring:* This monitoring involves investigating specific problems to allow for the development of a management approach to protect or improve the resource. Problem Investigation monitoring is used to determine the specific causes of impairments to water or air and to quantify inputs/loads from various sources. It is also used to determine the actions needed to return a resource to a condition that meets standards or goals.
- *Effectiveness Monitoring:* This is used to determine the effectiveness of specific regulatory or voluntary management actions taken to remediate environmental problems. Effectiveness monitoring allows for the evaluation and refinement of the management

approach to ensure it is ultimately successful. Another example of Effectiveness monitoring is effluent or emissions monitoring done to assess the compliance of a facility with a permit, rule or statute (i.e. compliance tracking).

Note that there are connections between the three monitoring types. These definitions are not meant to be exclusive and rigid; there are gray areas and transitions. However, the definitions do help distinguish between the various purposes for monitoring. Perhaps the greatest area of overlap is found between Effectiveness and Condition monitoring. In this case, the difference between the two is largely a matter of scale. Effectiveness monitoring is done at the management scale to determine whether a particular management action is working. In contrast, Condition monitoring can be used to track the system-wide effectiveness of environmental protection efforts.

This strategy and operating agreement focuses primarily on Condition and Effectiveness monitoring. Also included is a brief discussion of the three agencies' Problem Investigation monitoring efforts.

Condition Monitoring Designs

To assess the status and trends of ground water quality, the three agencies have developed three individual monitoring designs that are interdependent and rely on close cooperation among the agencies, but reflect the three distinct missions of the agencies (pesticides and nutrients, nonagricultural chemicals and drinking water). An overview of these inter-relationships is shown in the table below, followed by a more detailed discussion of each agency's effort.

Relationships among Condition Monitoring Designs

MDA Pesticide/Nutrient Ambient Monitoring	Drinking Water Supply Monitoring	MPCA non-agricultural chemical ambient monitoring system
• Uses MPCA GWMAP wells, MDH non-community public supply wells, as available. • Also uses dedicated monitoring wells and naturally occurring springs • Collects non-agricultural chemical samples for MPCA along with MDA samples	• Uses community and non-community public water supply wells • Assists in collecting non-community well samples for MPCA and MDA ambient networks • Assists with developing water quality data for private wells	• Uses existing wells from remediation sites and MDH public water supply wells, as appropriate • Collects pesticide and nutrient samples in urban areas for MDA, when funding or laboratory capacity is available

1. **Assessing pesticides and nutrients in agricultural areas**

MDA has established a statewide ambient drinking water survey to evaluate if and to what extent people may be consuming pesticides from drinking water wells across the state. The project targets sampling of drinking water wells that are vulnerable to pesticide contamination. The project focuses on pesticides present in sampled wells, frequency of presence and concentrations present. The data will be used to determine areas of the state that may need additional, more detailed monitoring or development of best management practices. A detailed discussion of the methods, uses of data, design and data analysis is included as Appendix 1.

The network is based on a random 100 point grid where drinking water wells are selected. Sampling occurs once per year, and may not be repeated every year. The network is statewide, with the exception of the northeastern part of the state which has limited agriculture. With each sampling effort, a new random grid will be used. MDA will choose wells for the network from MPCA's former Ground Water Monitoring and Assessment Program (GWMAP) well set, MDH's non-community public water supply wells, and where the previous are not available, wells from the County Well Index.

MDA will sample the wells for nitrate, base neutral pesticides, and some degradates of these pesticides. Over time, the pesticides chosen for analysis may change, based on the Department's knowledge of pesticide use, new pesticide registrations and as methods are developed for additional degradates. In addition, for the first round of sampling MDA will collect samples from its network wells for MPCA, and MPCA will analyze those samples for its suite of non-agricultural contaminants. MPCA and MDA will consider the need for this additional sampling in future sampling rounds. For the non-community public water supply wells that are used, MDH will assist in securing the necessary samples, gaining permission to sample, and in screening wells for geologic sensitivity. In this way, the three agencies will be assisting each other in sample collection, resulting in a system that is efficient and comprehensive.

2. **Assessing non-agricultural chemicals in urban areas**

The MPCA is establishing a monitoring network to provide information on the quality of Minnesota's ground water and to identify trends. This network will build on the previous work done by the Ground Water Monitoring and Assessment Program. The monitoring network will focus on two areas: the presence and concentration of fuel oils, industrial solvents and other commercial and industrial organic chemicals in urban areas and concentration of nitrate in ground water beneath residential areas, particularly those serviced by septic systems.

Wells used for this network will include 100 to 150 shallow monitoring wells along with 100 to 150 deeper drinking water wells. All wells targeted will be in vulnerable aquifers. Shallow wells provide an early warning network in which we first expect to see changes in water quality. The deeper wells provide information about the quality of water that people are drinking and allow us to determine if there is a correlation between water quality trends in shallow and deep ground water. The wells used will be located in St. Cloud, the Twin Cities' area and Rochester, and the information will be used to understand ground water quality in other areas of the state as well. In addition, annually, the MPCA will sample approximately 40 wells (20 shallow, 20 deep) from locations outside these study areas.

MPCA will analyze the samples for nitrate, volatile organic chemicals and chloride. MPCA will collect samples for MDA, when requested, to analyze for urban pesticides. Wells used for this network will include upgradient wells at existing remediation sites, wells drilled by the MPCA and MDH's non-community public water supply wells.

3. Assessing Drinking Water Quality

At a system scale, MDH's public water supply monitoring system evaluates drinking water quality in the state's public water supplies. The network includes 2,600 community water supply wells and 11,000 non-community public water supplies. The wells are sampled on varying schedules from daily to every 6 years, depending on the type of water supply and the contaminant. All wells are sampled for bacteria and nitrate. Community and non-transient non-community wells are also sampled for volatile organic chemicals and synthetic organic chemicals.

Most community public water supply systems are sampled after the water is treated, so these wells are least appropriate for use by MPCA and MDA monitoring networks. MDH monitors raw water at most non-community water supplies, so some of these wells will be used in the MPCA and MDA networks. In those cases, MDH will assist in collecting the samples.

MDH also works with county health agencies to collect and interpret water quality data from private water supply wells. The purposes for this are to 1) inform the public about health risks related to contaminated private water supplies, 2) identify areas where special well construction practices are needed to prevent contamination from entering water supply wells, and 3) to identify areas of ground water contamination that may present a risk to public health. Private well testing may assist MPCA and MDA in expanding their assessment activities into areas where ground water quality presents a risk to public health and to the environment in general.

EFFECTIVENESS MONITORING DESIGNS

1. MDA regional ground water assessment program for pesticides

The MDA has established 10 water quality monitoring regions and is either currently, or will soon begin, monitoring in six of the 10 regions.

The purpose of the MDA's regional assessment program is to determine regionally specific pesticide or fertilizer best management practice needs and to measure the effects of changes in pesticide and nutrient management on ground water quality on a regional basis. The monitoring network will monitor existing wells in four regions of the state (northwest, west-central, southwest and south-central) using a random grid design in each region, with well sampling in winter and summer at a minimum of 10 wells in each region. For this program, MDA will use the most appropriate available existing wells in each of the regions. One additional regional assessment has been underway in the central sands since January 2000. The central sands regional network utilizes specifically designed and installed monitoring wells and is located in one of the state's more sensitive ground water areas. In southeastern Minnesota the MDA is evaluating pesticide impacts by sampling springs emerging from the sedimentary bedrock formations.

Information from this network will be used to establish regional baseline conditions and to develop time trend data sufficient to evaluate the success of pesticide management changes in reducing pesticide impacts. Network information may further be used to determine the need for new approaches and refinement of existing practices in pesticide management; evaluate the need for water resource protection requirements; evaluate natural factors that impact pesticide movement to sensitive ground water; and evaluate BMPs for the need for specific modifications. Additional details on this network are attached in Appendix 1.

MDA also conducts Effectiveness monitoring at a project level for point sources at its pesticide remediation sites across the state.

2. MDH Compliance Monitoring System

MDH's Public Water Supply monitoring network also serves as an Effectiveness monitoring system at a project scale. Each public water supply in the state is monitored on a routine basis for compliance with standards, as required by federal and state law. In addition, MDH also operates a compliance monitoring system for new private wells statewide, which requires one-time monitoring for bacteria and nitrate at time of drilling, to ensure compliance with standards.

MDH also requires effectiveness monitoring in special well construction areas to ensure that mandated well construction practices offset the movement of contamination into private water supply wells.

3. MPCA Effectiveness Monitoring

On a project level, MPCA conducts Effectiveness monitoring at each of its remediation sites across the state and at some of its regulated facilities (e.g., certain wastewater spray irrigation sites, certain feedlots, etc.). However, a system-level evaluation of the effectiveness of non-agricultural management practices needs to be developed.

Problem Investigation Monitoring

Problem Investigation monitoring by the three agencies is likewise tied to the differing roles and authorities. MDA conducts Problem Investigation monitoring at point source sites where agricultural chemical releases have occurred. MPCA conducts Problem Investigation monitoring at a variety of sites – Superfund sites, voluntary cleanup sites, landfills, and other regulated sites, as well as for nonpoint pollution through the Phase I diagnostic studies in the Clean Water Partnership program. MDH investigates a variety of ground water quality problems that may affect drinking water quality and human health, including monitoring around old dump sites, monitoring to study the occurrence of arsenic in drinking water systems and diagnostic monitoring as part of the Wellhead Protection Program.

Quality Assurance, Data Management, Data Analysis and Reporting

Each agency will follow its respective Quality Assurance and Data Analysis processes required for the respective type of chemical. These methods and plans are available from each agency.

For data management and reporting, the ambient network data from MPCA and MDA will be entered into STORET, a federally-driven database. This data can then be accessed through the MPCA's Environmental Data Access Initiative, which allows users to view and use the data via a GIS-based system. For the future, MPCA will work toward entering current and historic remediation ground water data into STORET. MDH will consider the use of STORET for its public water supply data, depending upon resources.

Each agency will use their data, as well as the data from other agencies, to prepare reports based on their statutory requirements and the need for sharing information with stakeholders and the public. On issues where there is mutual interest, the Agencies will coordinate interpretation of data and presentation of results to stakeholders and the public. MPCA will continue its role of coordinating a biennial report to the legislature on the status and trends in ground water quality.

Programmatic Evaluation

Annually, the three agencies will review their monitoring plans for Condition and Effectiveness monitoring, and make adjustments, as necessary. On a five year cycle, the agencies will update this operating agreement to reflect changes made to the monitoring systems over the five year period.

General Support/Infrastructure Planning

This strategy represents what the Agencies believe to be an implementable coordinated ground water quality monitoring system in Minnesota, given current resource constraints. Any additional resource reductions that should occur will impact the ability of the Agencies to implement this plan.

Appendix 1

Minnesota Department of Agriculture

2003 Monitoring Network Expansion framework

1. Statewide ambient drinking water evaluation program

a. Purpose: evaluate to what extent people may be consuming pesticides from drinking water wells across the state.

   This project targets sampling of drinking water wells for pesticides and attempts to collect samples from sites that exhibit a vulnerable condition. This is a general survey to determine if, and to what extent, the water that is developed and consumed as potable supplies may be impacted by pesticides.

b. Information need: pesticides present; frequency of presence; concentrations present

   Pesticides present
   We want to know what pesticides might be reaching drinking water sources. A pesticide is determined as present through laboratory analysis where the compound is qualitatively identifiable through Gas Chromatography and Mass Spectrometry analysis.

   Frequency of presence
   When pesticides are found to be present in drinking water, are they found at single or multiple sites? This will be determined by simple counts of samples where a pesticide is determined as present versus those where pesticides are absent.

   Concentrations present
   When pesticides are found in drinking water, how much is there? Where pesticides are found at quantifiable levels, those levels will be reported and compared among samples and sites.

c. Use of data: focus additional work including common detection determination; additional monitoring; and implementation of BMPs

   Focus additional work including common detection determination
   Data collected through this effort will be valuable for informing decision making regarding future activity, priority setting, and resource allocation. The use of the data incorporates the protection of ground water and primary decisions directing actions to affect the protection of ground water.

Additional monitoring
Data collected through this effort may be used to evaluate and direct priorities for future monitoring efforts. Monitoring needs may be identified by evaluating geographical extent and intensity of pesticide impact to drinking water sources.

Implementation of BMPs
Data collected may provide additional focus for the need for BMP implementation and evaluation efforts. The first action for ground water protection under the ground water protection act is the development, promotion, implementation and evaluation of BMPs. The statewide sampling effort may identify areas where implementation actions should be accelerated.

d. Basic design: random grid of size to result in 100 nodes across the state (excluding the northeast); closest well to grid nodes selected when determined to represent a vulnerable condition; samples collected once per year, and may not be repeated every year.

   A randomly initiated, randomly aligned grid will be generated over the area of the state of interest [all of the state except the north east and north central regions] with a density such that 100 grid nodes lie within the designated area. The grid nodes will occur at a regular interval which meets the above criteria. The point of each node will identify the geographic point to be used to initiate a search for the nearest available well for potential sampling. Well owners will be asked for permission to sample. Each identified well will be characterized at the time of sampling. Characterization will include identification of surrounding land use (i.e. agriculture, urban/suburban, rural residential, etc.); well information including, depth, diameter, use, construction, etc.)

e. Data analysis and presentation: percent detection of any pesticide; percent detection of specific pesticides; averages and ranges of pesticide concentration; location of detections; changes in above items over time

   Percent detection of any pesticide:
   Percentage of samples in which one or more pesticides were detected.

   Percent detection of specific pesticides:
   A list of pesticide analytes and the percentage of detections for each of those analytes.
   Averages and ranges of pesticide concentrations:
   Central tendency will be evaluated against the data distribution. Median and mean values will be reported for each detected analyte. Range will be reported directly for each analyte. Additional distribution information such as the interquartile range and standard deviations may also be reported when supported by the data.

   Location of detections
   Wells with detections will be highlighted on a map showing all sampled well locations. GPS readings will be collected at the time of sampling to facilitate this effort if not already collected by another entity.

Changes in percent detections or concentrations over time:
Will be evaluated over future repeated sampling efforts.

f. Implementation target date: October 2003
g. Anticipated first report of results: January 2005

2. Regional ground water assessment program

a. Purpose: measure the effects of changes in pesticide management on ground water quality on a regional basis.
b. Information need: trends in frequency of detection of specific pesticides; trends in concentration of specific pesticides (looking for trends that are long-term small magnitude to be protective); detection of new pesticides in ground water
c. Use of data: measure success of pesticide management changes at reducing pesticide impacts; determine need for new approaches and refinement of existing practices in pesticide management; evaluate need for water resource protection requirements; evaluate natural factors that impact pesticide movement to sensitive ground water; evaluate BMPs for the need for specific modifications
d. Basic design: focus on four regions (northwest, west central, southwest and south central); use central sands design paradigm of randomly established appropriately sized grids; use statewide paradigm of selecting existing wells closest to grid node; sample wells biannually (Winter, Summer); select a minimum of 10 wells per region (select replacement wells if wells become unavailable for sampling); maintain program for at least 20 years. Preference toward publicly owned wells.
e. Data analysis and presentation: detection of any pesticide; percent detection of specific pesticides; averages, ranges, quartiles of pesticide concentration; location of detections; trends in above items over time
f. Implementation target date: January 2004
g. Anticipated first report of results: January 2005

MPCA Water Monitoring Approaches
as of August 2011

Water Type	Monitoring Approach	Assessment Scale	Period of Record	# of Sites	Parameters
STREAMS	*Major Watershed Load Monitoring*	watershed, state, site	2007- (Red River Basin 2003-)	82 (1/watershed)	TSS, TSVS, turbidity, TP, DOP, TKN, NO2+NO3, chlorophyll-a/pheophytin, TOC, DOC; DO, pH, conductivity, transparency, stage, field turbidity, temp
	Biological Intensive Watershed Monitoring (IWM)	subwatershed, site, watershed, state	2006-	~60/watershed	fish, invertebrates, habitat, land use, TSS, TSVS, NO2+NO3, ammonia, TP, temp, conductivity, transparency, DO, pH, stage
	Chemistry Intensive Watershed Monitoring (IWM)	subwatershed, site, watershed, state	2006-	10-15/watershed	TSS, TSVS, TP, TKN, NO2+NO3, NH3, E. coli, transparency, conductivity, temp, pH, DO; SO4, Cl, hardness, Mg, chlorophyll-a/pheophytin on select sites
	Citizen Stream Monitoring (CSMP)	statewide, site	1998-	710 statewide	transparency
	Milestones	statewide, site	1953-1966; 1967-2010 (MPCA)	80 statewide	TSS, TSVS, TOC, BOD, TP, Chl-a, pheophytin, NH3, TKN, NO2+NO3, SO4, Cl, Hg, MeHg, transparency, turbidity, conductivity, temp, pH, DO
	National Rivers and Streams Assessment Program (NRSAP)	statewide, site	1996-2005 by basin; 2010 by ecoregion	450 by basin; 150 by ecoregion	fish, invertebrates, habitat, land use, temp, limited chemistry, PPCPs, pesticides
LAKES	*National Lake Assessment Project (NLAP)*	statewide, site	2007; next round 2012	50 statewide	TSS, TSVS, TP, chlorophyll-a, TKN, NO2+NO3, color, alkalinity, NH4, TN, TOC, DOC, ANC, anions/cations, SO4, Cl; temp, pH, DO, conductivity; other parameters as study requires
	Citizen Lake Monitoring (CLMP)	statewide, site	1973-1978 (U of MN); 1978-present (MPCA)	1235 statewide	Secchi transparency
	Remote Sensing Lake Monitoring	statewide, site	1970-2005	lakes >20 acres	transparency, using satellite imagery; model calibrated using CLMP Secchi data
	Sentinel Lakes	statewide, site	2008-2012	24 statewide	TSS, TSVS, TP, chlorophyll-a, pheophytin, TKN, NO2+NO3, color, TOC, DOC, alkalinity, SO4, Cl, Si, Ca, Mg, Na, K, Fe ; other parameters as needed
	Lake Assessment Monitoring (IWM), CLMP+	site, watershed	1985-2010; rotating watersheds 2006-	443 historic; ~100 rotating watersheds	TSS, TSVS, TP, chlorophyll-a, pheophytin, TKN, NO2+NO3, alkalinity, SO4 (May), Cl, TOC, hardness; temperature, DO, conductivity, DOP, Secchi transparency
GROUNDWATER	*Baseline Groundwater Condition Study*	statewide, site	1992-1996	954 statewide	alkalinity, Al, Sb, As, Ba, Be, Bi, B, Br, Cd, Ca, Cs, Cl, Cr, Co, Cu, DO, F, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ni, NO3, OP, redox potential, pH, P, PO4, K, Rb, Se, Si, Ag, Na, specific conductivity, Sr, SO4, S, temp, Tl, Sn, Ti, TDS, TOC, TSS, V, Zn, Zr; 68 VOCs; tritium
	Ambient Groundwater Monitoring Network	statewide (non-ag areas), site	2004-	110 now, ~350 ultimately	68 volatile organic compounds; ~100 emerging contaminants - fire retardants, DEET, fragrances, pharmaceuticals, antibiotics, hormones, plasticizers
WETLANDS	*National Wetland Condition Assesment*	statewide, site	2011	150	plant and soil type
	Comprehensive Wetland Assessment and Monitoring Strategy (depressional)	statewide, site	2007-2009	182; 100 in the future	plants, invertebrates, limited water chemistry
	Watershed Wetland Monitoring (IWM)	watershed, site	2013	10-15/watershed	plants, invertebrates

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MPCA Water Monitoring Approaches
as of August 2011

Monitoring Approach (cont.)	Sampling Frequency	Information Available 8/2011	Comments (funding, network type, site selection, etc.)
Major Watershed Load Monitoring	perpetual, ~35 samples/site/yr	statewide baseline data 2007-09 (Red River Basin 2003-)	CWF; fixed network
Biological Intensive Watershed Monitoring	once/yr; 1 yr/10 yr	baseline data for 24 watersheds	CWF; rotating watersheds
Chemistry Intensive Watershed Monitoring	2yr/10yr; 10 samples/site (full chem) yr 1; 9 samples/site (bacteria only) yr 2	baseline data for 24 watersheds	CWF; rotating watersheds; some monitoring performed locally by SWAG grant recipients in lieu of PCA monitoring
Citizen Stream Monitoring (CSMP)	weekly Apr-Sept, and rain event; rain gage	annual site/statewide trends	CWF; volunteer network
Milestones	once/month February-November (10/ yr); 2yr/5yr	trends for 4-5 decades	ended 2010; fixed network
National Rivers and Streams Assessment Program (NRSAP)	once/yr; 2yr/5yr	older data statewide by basin; new data statewide by ecoregion	federal funds, part of national assessment; random sites
National Lake Assessment Project (NLAP)	once/yr; 1yr/5yr	statewide baseline	federal funds, part of national assessment; random sites
Citizen Lake Monitoring (CLMP)	weekly May-Sept. (2 samples/month minimum)	statewide annual condition/ trends	CWF; volunteer network; CLMP+ entails water samples, as well as Secchi transparency, data used for assessments
Remote Sensing Lake Monitoring	5 year intervals from 1970 - 2005, 2008	statewide annual condition/ trends	work conducted by U of MN using satellite imagery
Sentinel Lakes	monthly May-Sept 2008-9; Apr, July, Oct 2009-2012, with additional June, Aug, and Sept monitoring for "Super Sentinel lakes"	preliminary data for 2008-2009	DNR project to determine climate change effects on select lakes; large study with many components (fisheries, habitat, wq, etc.); PCA conducts water quality monitoring portion
Lake Assessment Monitoring	monthly May-Sept	baseline data for 24 watersheds; historical data on 443 lakes back to 1985	ongoing since 1985; previously much less funding, so would only monitor ~40 lakes/yr, limited parameters; SWAG grants enable additional local monitoring.
Baseline Groundwater Condition Study	once	summary of condition of state's principal aquifers	
Ambient Groundwater Monitoring Network	once/yr	developing statewide condition/trend	CWF; fixed network
National Wetland Condition Assesment	once/yr; 1yr/5yr	future - report early 2014	federal funds, part of national assessment; random sites
Comprehensive Wetland Assessment and Monitoring Strategy	once/5 yr cycle	1 completed statewide cycle	CWF
Watershed Wetland Monitoring	once/yr; 1yr/10yr cycle	future	CWF; rotating watersheds