Watershed health

June 2020

# Redwood River Watershed Monitoring and Assessment Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Redwood Cottonwood River Control Area

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CLEAN WATER LAND & LEGACY AMENDMENT

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# List of acronyms

**CD** County Ditch

**CI** Confidence Interval

**CLMP** Citizen Lake Monitoring Program

**CR** County Road

**CSAH** County State Aid Highway

**CSMP** Citizen Stream Monitoring Program

**CWA** Clean Water Act

**DNR** Minnesota Department of Natural Resources

**DOP** Dissolved Orthophosphate

**E** Eutrophic

**EQuIS** Environmental Quality Information System

**EX** Exceeds Criteria (Bacteria)

**EXP** Exceeds Criteria, Potential Impairment

**EXS** Exceeds Criteria, Potential Severe Impairment

**FS** Full Support

**FWMC** Flow Weighted Mean Concentration

**H** Hypereutrophic

**HUC** Hydrologic Unit Code

**IBI** Index of Biotic Integrity

**IF** Insufficient Information

**K** Potassium

**LRVW** Limited Resource Value Water

**M** Mesotrophic

**MCES** Metropolitan Council Environmental Services

**MDA** Minnesota Department of Agriculture

**MDH** Minnesota Department of Health

**MINLEAP** Minnesota Lake Eutrophication Analysis Procedure

**MPCA** Minnesota Pollution Control Agency

**MSHA** Minnesota Stream Habitat Assessment

**MTS** Meets the Standard

**N** Nitrogen

**Nitrate-N** Nitrate Plus Nitrite Nitrogen

**NA** Not Assessed

**NHD** National Hydrologic Dataset

**NH3** Ammonia

**NS** Not Supporting

**NT** No Trend

**OP** Orthophosphate

**P** Phosphorous

**PCB** Poly Chlorinated Biphenyls

**PWI** Protected Waters Inventory

**RNR** River Nutrient Region

**SWAG** Surface Water Assessment Grant

**SWCD** Soil and Water Conservation District

**SWUD** State Water Use Database

**TALU** Tiered Aquatic Life Uses

**TKN** Total Kjeldahl Nitrogen

**TMDL** Total Maximum Daily Load

**TP** Total Phosphorous

**TSS** Total Suspended Solids

**USGS** United States Geological Survey

**WID** Waterbody Identification Number

**WPLMN** Watershed Pollutant Load Monitoring Network

# Executive summary

Within the Redwood River Watershed, degraded conditions were common, with 74% of the monitored streams failing to meet aquatic life use standards. Poor fish communities contributed to 56% of the aquatic life impaired reaches, while poor macroinvertebrate communities contributed to 49% of the impaired reaches. Both communities contributed to aquatic life impairment on 37% of the reaches. Four reaches had existing aquatic life impairments based on the fish community. Three of these reaches had current data confirming previous impairments, while one reach was not sampled in this survey. There were no previous aquatic life use impairments based on macroinvertebrates. Fish species considered tolerant of pollution often contributed to reaches failing aquatic life use standards. Tolerant fish species are some of the most abundant fish in the watershed, and in many streams, they were the dominant species collected in the sample. The primary issues negatively impacting fish and macroinvertebrate communities within the watershed include excess sediment, lack of habitat, altered hydrology, excess nutrients, and fish barriers.

Of the monitored streams, 20% of the reaches were supporting aquatic life uses. These seven reaches had fish assemblages supporting aquatic life use criteria, while the macroinvertebrate assemblage was supporting on six of these reaches. Two of these reaches were general use, while four of the reaches were modified use. Eight of the 45 fish species sampled in the watershed are considered sensitive species.

Recreational water quality of the majority of lakes in the watershed are poor due in part to disturbed land uses in the contributing watershed. Previous lake impairments were confirmed by newer data, and two new lakes were added to the impaired waters list for poor recreational water quality. Restoring shallow basins containing excessive nutrient loads will provide a complex challenge. East and West Twin Lakes are the best examples of recreational water quality in the watershed and should be protected from future degradation. Fish community data available during this effort provided the basis for aquatic life use assessment of lakes, resulting in four lake impairments based on poor fish community health. Example indicators of poor fish community health include dominance of pollution tolerant species, lack of species diversity in the food web, and uneven distribution of biomass within the lakes food web.

Past assessment of the Redwood River resulted in numerous suspended solid impairments. Extensive new data for these impaired reaches confirms that poor water quality persists. Excessive suspended sediment in riverine systems is often linked with altered hydrology. Poor surface water storage associated with artificial drainage, and channelization, results in bank sloughing, channel incision and erosion. Increased sedimentation can cover vital spawning habitat for aquatic communities and decrease feeding success while changing the natural hydrologic conditions. Total phosphorus was unusually high throughout the entire river system, response to elevated nutrients was observed triggering a previous impairment on a downstream reach. High levels of nutrients can result in excessive algae growth both in the water column and on stream substrates, and can contribute to wide swings in dissolved oxygen concentrations, while also covering fish habitat. Previous surveys of bacterial contamination resulted in numerous listings for recreational use, and newer data confirms these initial assessments. TMDL efforts are underway to address water quality issues on these previously listed streams.

Protection of groundwater quantity and quality is an important consideration within the watershed. Issues affecting groundwater quality include high levels of naturally occurring elements, as well as chloride and nitrate from human activities. Quantity is at risk due to increasing groundwater and surface water withdrawals. Continued monitoring of this resource will further inform conservation efforts.

For wetlands within the Redwood River Watershed, as much as 70% of the wetlands have been lost across the watershed from historic acreage. Of the remaining wetlands, degradation is common, with as much as an estimated 82% of the wetlands in fair to poor conditions based on vegetation surveys, while as much as an estimated 57% of the wetlands are in fair to poor conditions based on the macroinvertebrate community. Protection of the remaining high quality wetlands from hydrologic alteration and invasive species should be an important consideration within the watershed.

# Introduction

Water is one of Minnesota's most abundant and precious resources. The Minnesota Pollution Control Agency (MPCA) is charged under both federal and state law with the responsibility of protecting the water quality of Minnesota's water resources. MPCA's water management efforts are tied to the 1972 Federal Clean Water Act (CWA) which requires states to adopt water quality standards to protect their water resources and the designated uses of those waters, such as for drinking water, recreation, fish consumption and aquatic life. States are required to provide a summary of the status of their surface waters and develop a list of waterbodies that do not meet established standards. Such waters are referred to as "impaired waters" and the state must make appropriate plans to restore these waters, including the development of total maximum daily loads (TMDLs). A TMDL is a comprehensive study determining the assimilative capacity of a waterbody, identifying all pollution sources causing or contributing to impairment, and an estimation of the reductions needed to restore a water body so that it can once again support its designated use.

The MPCA currently conducts a variety of surface water monitoring activities that support our overall mission of helping Minnesotans protect the environment. To successfully prevent and address problems, decision makers need good information regarding the status of the resources, potential and actual threats, options for addressing the threats and data on the effectiveness of management actions. The MPCA's monitoring efforts are focused on providing that critical information. Overall, the MPCA is striving to provide information to assess, and ultimately, to restore or protect the integrity of Minnesota's waters.

The passage of Minnesota's Clean Water Legacy Act  in 2006 provided a policy framework and the initial resources for state and local governments to accelerate efforts to monitor, assess, restore and protect surface waters. This work is implemented on an on-going basis with funding from the Clean Water Fund created by the passage of the Clean Water Land, and Legacy Amendment to the state constitution. To facilitate the best use of agency and local resources, the MPCA has developed a watershed monitoring strategy which uses an effective and efficient integration of agency and local water monitoring programs to assess the condition of Minnesota's surface waters, and to allow for coordinated development and implementation of water quality restoration and improvement projects.

The strategy behind the watershed monitoring approach is to intensively monitor streams and lakes within a major watershed to determine the overall health of water resources, identify impaired waters, and to identify waters in need of additional protection. The benefit of the approach is the opportunity to begin to address most, if not all, impairments through a coordinated TMDL process at the watershed scale, rather than the reach-by-reach and parameter-by-parameter approach often historically employed. The watershed approach will more effectively address multiple impairments resulting from the cumulative effects of point and non-point sources of pollution and further the CWA goal of protecting and restoring the quality of Minnesota's water resources.

This watershed-wide monitoring approach was implemented in the Redwood River Watershed beginning in the summer of 2017. This report provides a summary of all water quality assessment results in the Redwood River Watershed and incorporates all data available for the assessment process including watershed monitoring, volunteer monitoring and monitoring conducted by local government units.

# The watershed monitoring approach

The watershed approach is a 10-year rotation for monitoring and assessing waters of the state on the level of Minnesota's 80 major watersheds. The major benefit of this approach is the integration of monitoring resources to provide a more complete and systematic assessment of water quality at a geographic scale useful for the development and implementation of effective TMDLs, project planning, effectiveness monitoring and protection strategies. The following paragraphs provide details on each of the four principal monitoring components of the watershed approach. For additional information see: Watershed Approach to Condition Monitoring and Assessment (MPCA 2008) (http://www.pca.state.mn.us/publications/wq-s1-27.pdf).

## Watershed pollutant load monitoring

The Watershed Pollutant Load Monitoring Network (WPLMN) is a long-term statewide river monitoring network initiated in 2007 and designed to obtain pollutant load information from 199 river monitoring sites throughout Minnesota. Monitoring sites span three ranges of scale:

- ***Basin*** – major river main stem sites along the Mississippi, Minnesota, Rainy, Red, Des Moines, Cedar and St. Croix rivers
- ***Major watershed*** – tributaries draining to major rivers with an average drainage area of 1,350 square miles (8-digit HUC scale)
- ***Subwatershed*** – major branches or nodes within major watersheds with average drainage areas of approximately 300-500 square miles

The program utilizes state and federal agencies, universities, local partners, and MPCA staff to collect water quality and flow data to calculate nitrogen, phosphorus, and sediment pollutant loads.

## Intensive watershed monitoring

The intensive watershed monitoring strategy utilizes a nested watershed design allowing the sampling of streams within watersheds from a coarse to a fine scale (Figure 1). Each watershed scale is defined by a hydrologic unit code (HUC). These HUCs define watershed boundaries for waterbodies within a similar geographic and hydrologic extent. The foundation of this approach is the 80 major watersheds (8-HUC) within Minnesota. Using this approach many of the smaller headwaters and tributaries to the main stem river are sampled in a systematic way so that a more holistic assessment of the watershed can be conducted and problem areas identified without monitoring every stream reach. Each major watershed is the focus of attention for at least one year within the 10-year cycle.

River/stream sites are selected near the outlet of each of three watershed scales, 8-HUC, aggregated 12-HUC and 14-HUC (Figure 1). Within each scale, different water uses are assessed based on the opportunity for that use (i.e., fishing, swimming, supporting aquatic life such as fish and insects). The major river watershed is represented by the 8-HUC scale. The outlet of the major 8-HUC watershed (purple dot in Figure 2) is sampled for biology (fish and macroinvertebrates), water chemistry and fish contaminants to allow for the assessment of aquatic life, aquatic recreation and aquatic consumption use support. The aggregated 12-HUC is the next smaller subwatershed scale which generally consists of major tributary streams with drainage areas ranging from 75 to 150 $mi^2$. Each aggregated 12-HUC outlet (green dots in Figure 2) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use support. Within each aggregated 12-HUC, smaller watersheds (14 HUCs, typically 10-20 mi²), are sampled at each outlet that flows into the major aggregated 12-HUC tributaries. Each of these minor subwatershed outlets is sampled for biology to assess aquatic life use support (red dots in Figure 2).

**Figure 1. The Intensive Watershed Monitoring Design.**

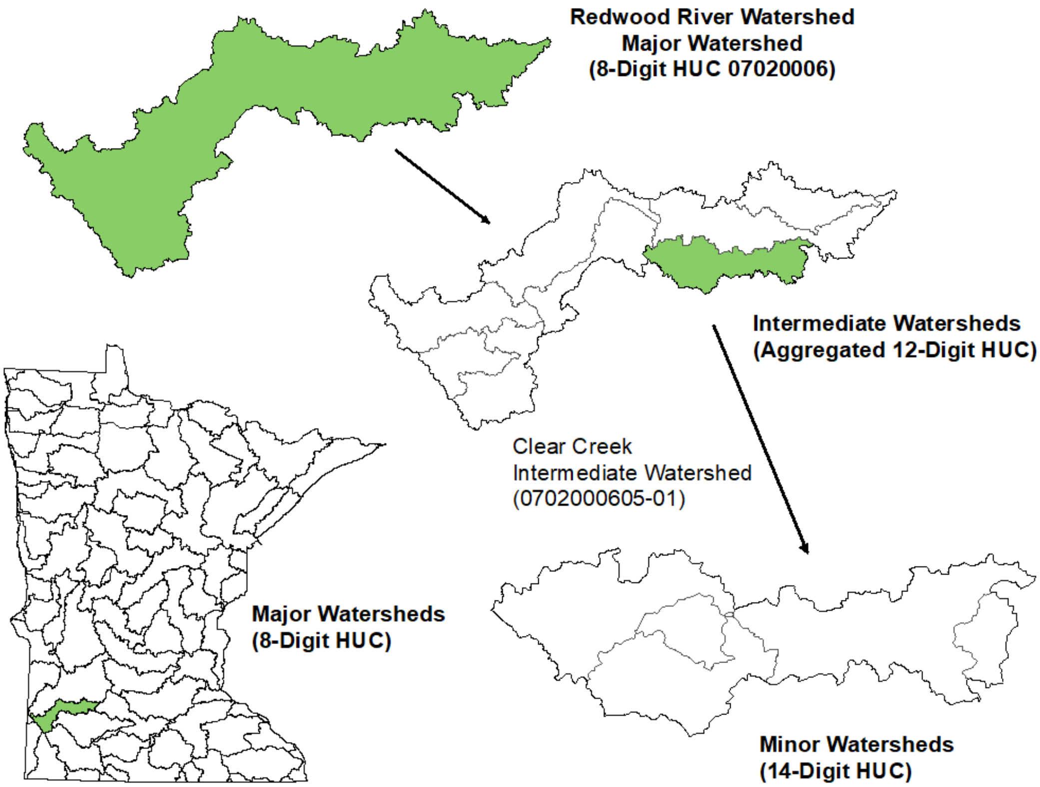
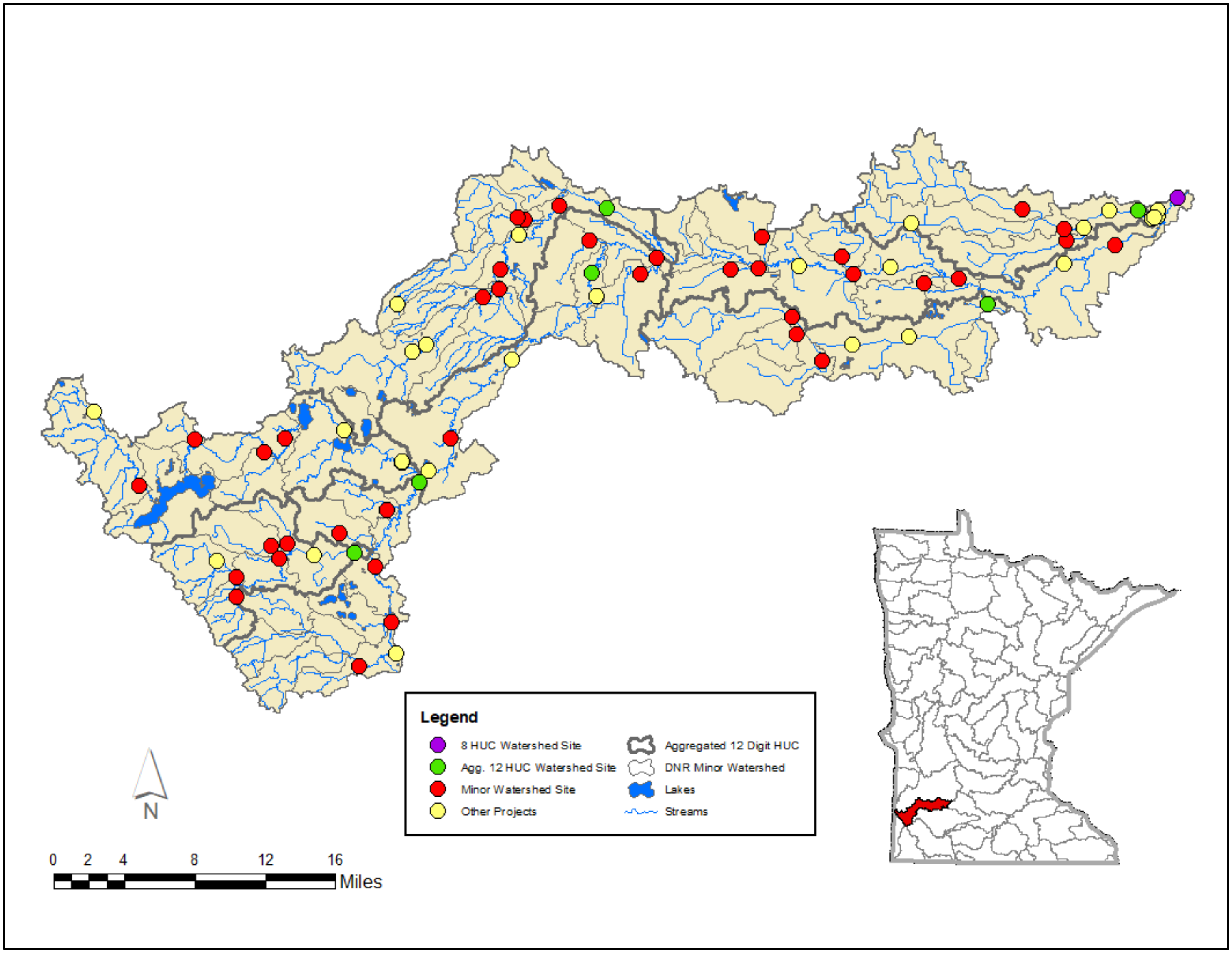


**Figure 2. Intensive watershed monitoring sites for streams in the Redwood River Watershed.**



## Lake monitoring

Lakes most heavily used for recreation are monitored for water chemistry to determine if recreational uses, such as swimming and wading, are being supported and where applicable, where fish community health can be determined. Lakes are prioritized by size (greater than 100 acres), accessibility (can the public access the lakes), and presence of recreational use.

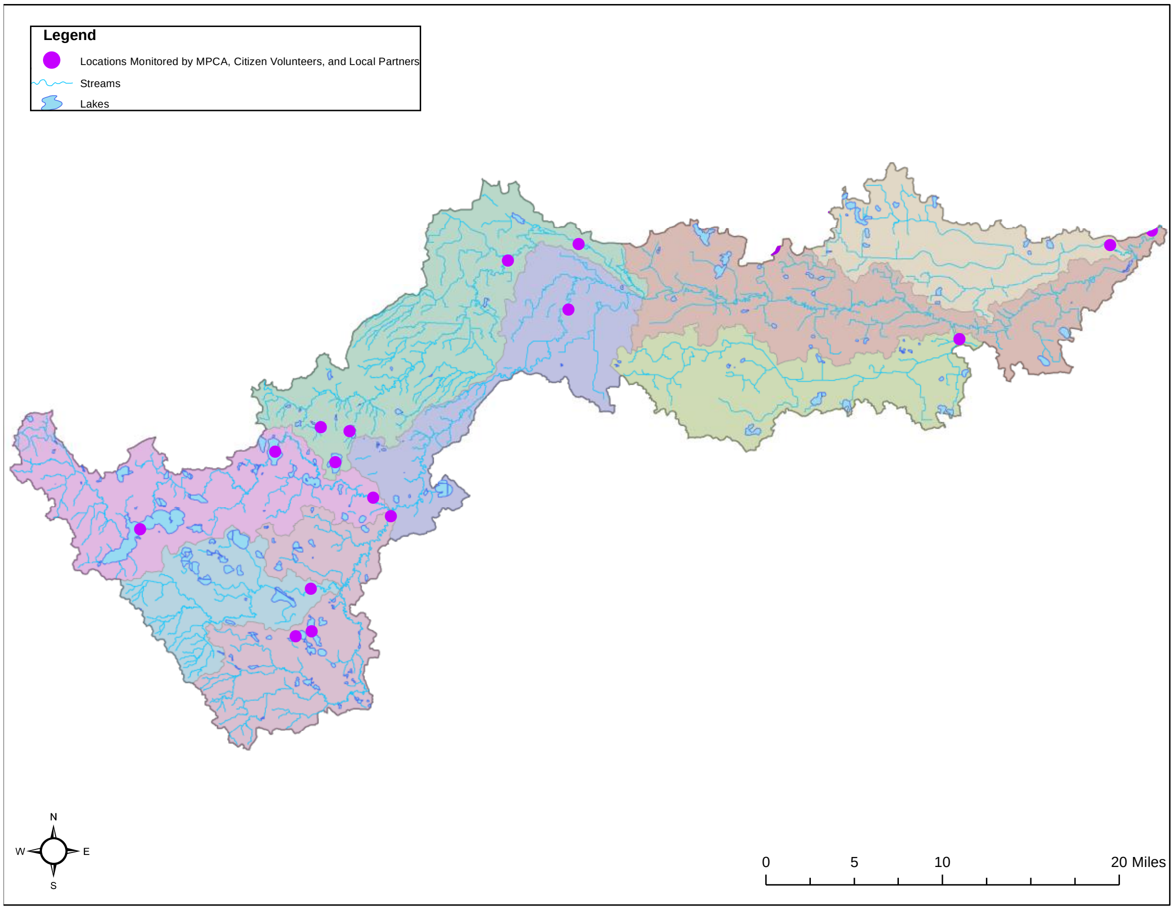
Specific locations for sites sampled as part of the intensive monitoring effort in the Redwood River Watershed are shown in Figure 2 and are listed in Appendices 2.1 and 2.2.

## Citizen and local monitoring

Citizen and local monitoring is an important component of the watershed approach. The MPCA and its local partners jointly select the stream sites and lakes to be included in the intensive watershed monitoring process. Funding passes from MPCA through Surface Water Assessment Grants (SWAGs) to local groups such as counties, soil and water conservation districts (SWCDs), watershed districts, nonprofits and educational institutions to support lake and stream water chemistry monitoring. Local partners use the same monitoring protocols as the MPCA, and all monitoring data from SWAG projects are combined with the MPCA's to assess the condition of Minnesota lakes and streams. Preplanning and coordination of sampling with local citizens and governments helps focus monitoring where it will be most effective for assessment and observing long-term trends. This allows citizens/governments the ability to see how their efforts are used to inform water quality decisions and track how management efforts affect change. Many SWAG grantees invite citizen participation in their monitoring projects and their combined participation greatly expand our overall capacity to conduct sampling.

The MPCA also coordinates two programs aimed at encouraging long term citizen surface water monitoring: the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). Like the permanent load monitoring network, having citizen volunteers monitor a given lake or stream site monthly and from year to year can provide the long-term picture needed to help evaluate current status and trends. Citizen monitoring is especially effective at helping to track water quality changes that occur in the years between intensive monitoring years. Figure 3 provides an illustration of the locations where citizen monitoring data were used for assessment in the Redwood River Watershed.

**Figure 3. Monitoring locations of local groups, citizens and the MPCA lake monitoring staff in the Redwood River Watershed.**




# Assessment methodology

The CWA requires states to report on the condition of the waters of the state every two years. This biennial report to Congress contains an updated list of surface waters that are determined to be supporting or non-supporting of their designated uses as evaluated by the comparison of monitoring data to criteria specified by Minnesota Water Quality Standards (Minn. R. Ch. 7050 2008; https://www.revisor.leg.state.mn.us/rules/?id=7050). The assessment and listing process involves dozens of MPCA staff, other state agencies and local partners. The goal of this effort is to use the best data and best science available to assess the condition of Minnesota's water resources. For a thorough review of the assessment methodologies see: *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List (MPCA 2012)*. https://www.pca.state.mn.us/sites/default/files/wq-iw1-04.pdf.

## Water quality standards

Water quality standards are the fundamental benchmarks by which the quality of surface waters are measured and used to determine impairment. These standards can be numeric or narrative in nature and define the concentrations or conditions of surface waters that allow them to meet their designated beneficial uses, such as for fishing (aquatic life), swimming (aquatic recreation) or human consumption (aquatic consumption). All surface waters in Minnesota, including lakes, rivers, streams and wetlands are protected for aquatic life and recreation where these uses are attainable. Numeric water quality standards represent concentrations of specific pollutants in water that protect a specific designated use.

Narrative standards are statements of conditions in and on the water, such as biological condition, that protect their designated uses.

Protection of aquatic recreation means the maintenance of conditions safe and suitable for swimming and other forms of water recreation. In streams, aquatic recreation is assessed by measuring the concentration of *E. coli* bacteria in the water. To determine if a lake supports aquatic recreational activities its trophic status is evaluated, using total phosphorus, Secchi depth and chlorophyll-a as indicators. Lakes that are enriched with nutrients and have abundant algal growth are eutrophic and do not support aquatic recreation.

Protection of consumption means protecting citizens who eat fish from Minnesota waters or receive their drinking water from waterbodies protected for this beneficial use. The concentrations of mercury and polychlorinated biphenyls (PCBs) in fish tissue are used to evaluate whether or not fish are safe to eat in a lake or stream and to issue recommendations regarding the frequency that fish from a particular water body can be safely consumed. For lakes, rivers and streams that are protected as a source of drinking water the MPCA primarily measures the concentration of nitrate in the water column to assess this designated use.

Protection of aquatic life means the maintenance of a healthy aquatic community, including fish, macroinvertebrates, and plants. Biological monitoring, the sampling of aquatic organisms, is a direct means to assess aquatic life use support, as the aquatic community tends to integrate the effects of all pollutants and stressors over time. To effectively use biological indicators, the MPCA employs the Index of Biotic Integrity (IBI). This index is a scientifically validated combination of measurements of the biological community (called metrics). An IBI is comprised of multiple metrics that measure different aspects of aquatic communities (e.g., dominance by pollution tolerant species, loss of habitat specialists). Metric scores are summed together and the resulting index score characterizes the biological integrity or "health" of a site. The MPCA has developed stream IBIs for (fish and macroinvertebrates) since these communities can respond differently to various types of pollution. The MPCA also uses a lake fish IBI developed by the Minnesota Department of Natural Resources (DNR) to determine if lakes are meeting aquatic life use. Because the lakes, rivers, and streams in Minnesota are physically, chemically, and biologically diverse, IBI's are developed separately for different stream classes and lake class groups to account for this natural variation. Further interpretation of biological community data is provided by an assessment threshold or biocriteria against which an IBI score can be compared within a given stream class. In general, an IBI score above this threshold is indicative of aquatic life use support, while a score below this threshold is indicative of non-support. Additionally, chemical parameters are measured and assessed against numeric standards developed to be protective of aquatic life. For streams, these include pH, dissolved oxygen, un-ionized ammonia nitrogen, chloride, total suspended solids, pesticides, and river eutrophication. For lakes, pesticides and chlorides contribute to the overall aquatic life use assessment.

Protection for aquatic life uses in streams and rivers are divided into three tiers: Exceptional, General, and Modified. Exceptional Use waters support fish and macroinvertebrate communities that have minimal changes in structure and function from the natural condition. General use waters harbor "good" assemblages of fish and macroinvertebrates that can be characterized as having an overall balanced distribution of the assemblages and with the ecosystem functions largely maintained through redundant attributes. Modified use waters have been extensively altered through legacy physical modifications which limit the ability of the biological communities to attain the General use. Currently the Modified use is only applied to streams with channels that have been directly altered by humans (e.g., maintained for drainage). These tiered aquatic life uses are determined before assessment based on the attainment of the applicable biological criteria and/or an assessment of the habitat (MPCA 2015).

For additional information, see: http://www.pca.state.mn.us/index.php/water/water-permits-and-rules/water-rulemaking/tiered-aquatic-life-use-talu-framework.html).

**Table 1. Tiered aquatic life use standards.**

| Tiered aquatic life use | Acronym | Use class code | Description |
|---|---|---|---|
| Warm water General | WWg | 2Bg | Warm water Stream protected for aquatic life and recreation, capable of supporting and maintaining a balanced, integrated, adaptive community of warm or cool water aquatic organisms that meet or exceed the General use biological criteria. |
| Warm water Modified | WWm | 2Bm | Warm water Stream protected for aquatic life and recreation, physically altered watercourses (e.g., channelized streams) capable of supporting and maintaining a balanced, integrated, adaptive community of warm or cool water aquatic organisms that meet or exceed the Modified use biological criteria, but are incapable of meeting the General use biological criteria as determined by a Use Attainability Analysis |
| Warm water Exceptional | WWe | 2Be | Warm water Stream protected for aquatic life and recreation, capable of supporting and maintaining an exceptional and balanced, integrated, adaptive community of warm or cool water aquatic organisms that meet or exceed the Exceptional Use biological criteria. |
| Coldwater General | CWg | 2Ag | Coldwater Stream protected for aquatic life and recreation, capable of supporting and maintaining a balanced, integrated, adaptive community of cold water aquatic organisms that meet or exceed the General use biological criteria. |
| Coldwater Exceptional | CWe | 2Ae | Coldwater Stream protected for aquatic life and recreation, capable of supporting and maintaining an exceptional and balanced, integrated, adaptive community of cold water aquatic organisms that meet or exceed the Exceptional Use biological criteria. |

A small percentage of stream miles in the state (~1% of 92,000 miles) have been individually evaluated and re-classified as a Class 7 Limited Resource Value Water (LRVW). These streams have previously demonstrated that the existing and potential aquatic community is severely limited and cannot achieve aquatic life standards either by: a) natural conditions as exhibited by poor water quality characteristics, lack of habitat or lack of water; b) the quality of the resource has been significantly altered by human activity and the effect is essentially irreversible; or c) there are limited recreational opportunities (such as fishing, swimming, wading or boating) in and on the water resource. While not being protective of aquatic life, LRVWs are still protected for industrial, agricultural, navigation and other uses. Class 7 waters are also protected for aesthetic qualities (e.g., odor), secondary body contact, and groundwater for use as a potable water supply. To protect these uses, Class 7 waters have standards for bacteria, pH, dissolved oxygen and toxic pollutants.

## Assessment units

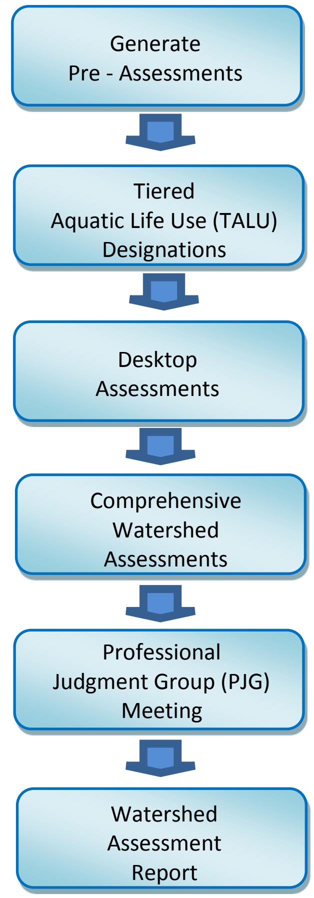
Assessments of use support in Minnesota are made for individual waterbodies. The waterbody unit used for river systems, lakes and wetlands is called the "assessment unit". A stream or river assessment unit usually extends from one significant tributary stream to another or from the headwaters to the first tributary. A stream "reach" may be further divided into two or more assessment reaches when there is a change in use classification (as defined in Minn. R., ch. 7050) or when there is a significant morphological feature, such as a dam or lake, within the reach. Therefore, a stream or river is often segmented into multiple assessment units that are variable in length. The MPCA is using the 1:24,000 scale high resolution National Hydrologic Dataset (NHD) to define and index stream, lake and wetland assessment units. Each river or stream reach is identified by a unique waterbody identifier (known as its WID), comprised of the USGS eight-digit hydrologic unit code (8-HUC) plus a three-character code that is unique within each HUC. Lake and wetland identifiers are assigned by the DNR. The Protected Waters Inventory (PWI) provides the identification numbers for lake, reservoirs and wetlands. These identification numbers serve as the WID and are composed of an eight-digit number indicating county, lake and bay for each basin.

It is for these specific stream reaches or lakes that the data are evaluated for potential use impairment. Therefore, any assessment of use support would be limited to the individual assessment unit. The major exception to this is the listing of rivers for contaminants in fish tissue (aquatic consumption). Over the course of time it takes fish, particularly game fish, to grow to “catchable” size and accumulate unacceptable levels of pollutants, there is a good chance they have traveled a considerable distance. The impaired reach is defined by the location of significant barriers to fish movement such as dams upstream and downstream of the sampled reach and thus often includes several assessment units.

## Determining use attainment

For beneficial uses related to human health, such as drinking water or aquatic recreation, the relationship is well understood and thus the assessment process is a relatively simple comparison of monitoring data to numeric standards. In contrast, assessing whether a waterbody supports a healthy aquatic community is not as straightforward and often requires multiple lines of evidence to make use attainment decisions with a high degree of certainty. Incorporating a multiple lines of evidence approach into MPCA's assessment process has been evolving over the past few years. The current process used to assess the aquatic life use of rivers and streams is outlined below and in Figure 4.

**Figure 4. Flowchart of aquatic life use assessment process.**




The first step in the aquatic life assessment process is largely an automated process performed by logic programmed into a database application where all data from the 10 year assessment window is gathered; the results are referred to as 'Pre-Assessments'. Data filtered into the "Pre-Assessment" process is then reviewed to insure that data is valid and appropriate for assessment purposes. Tiered aquatic life use designations are determined before data is assessed based on the attainment of the applicable biological criteria and/or an assessment of the habitat. Stream reaches are assigned the highest aquatic life use attained by both biological assemblages on or after November 28, 1975. Streams that do not attain the Exceptional or General use for both assemblages undergo a Use Attainability Analysis (UAA) to determine if a lower use is appropriate. A Modified use can be proposed if the UAA demonstrates that the General use is not attainable as a result of legal human activities (e.g., drainage maintenance, channel stabilization) which are limiting the biological assemblages through altered habitat. Decisions to propose a new use are made through UAA workgroups which include watershed project managers and biology leads. The final approval to change a designated use is through formal rulemaking.

The next step in the aquatic life assessment process is a comparison of the monitoring data to water quality standards. Pre-assessments are then reviewed by either a biologist or water quality professional, depending on whether the parameter is biological or chemical in nature. These reviews are conducted at the workstation of each reviewer (i.e., desktop) using computer applications to analyze the data for potential temporal or spatial trends as well as gain a better understanding of any extenuating circumstances that should be considered (e.g., flow, time/date of data collection, or habitat).

The next step in the process is a Comprehensive Watershed Assessment meeting where reviewers convene to discuss the results of their desktop assessments for each individual waterbody. Implementing a comprehensive approach to water quality assessment requires a means of organizing and evaluating information to formulate a conclusion utilizing multiple lines of evidence. Occasionally, the evidence stemming from individual parameters are not in agreement and would result in discrepant assessments if the parameters were evaluated independently. However, the overall assessment considers each piece of evidence to make a use attainment determination based on the preponderance of information available. See the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List* (MPCA 2016) https://www.pca.state.mn.us/sites/default/files/wq-iw1-04j.pdf for guidelines and factors considered when making such determinations.

The last step in the assessment process is the Professional Judgment Group meeting. At this meeting results are shared and discussed with entities outside of the MPCA that may have been involved in data collection or that might be responsible for local watershed reports and project planning. Information obtained during this meeting may be used to revise previous use attainment decisions (e.g., sampling events that may have been uncharacteristic due to annual climate or flow variation, local factors such as impoundments that do not represent the majority of conditions on the WID). Waterbodies that do not meet standards and therefore do not attain one or more of their designated uses are considered impaired waters and are placed on the draft 303(d) Impaired Waters List. Assessment results are also included in watershed monitoring and assessment reports.

# Watershed overview

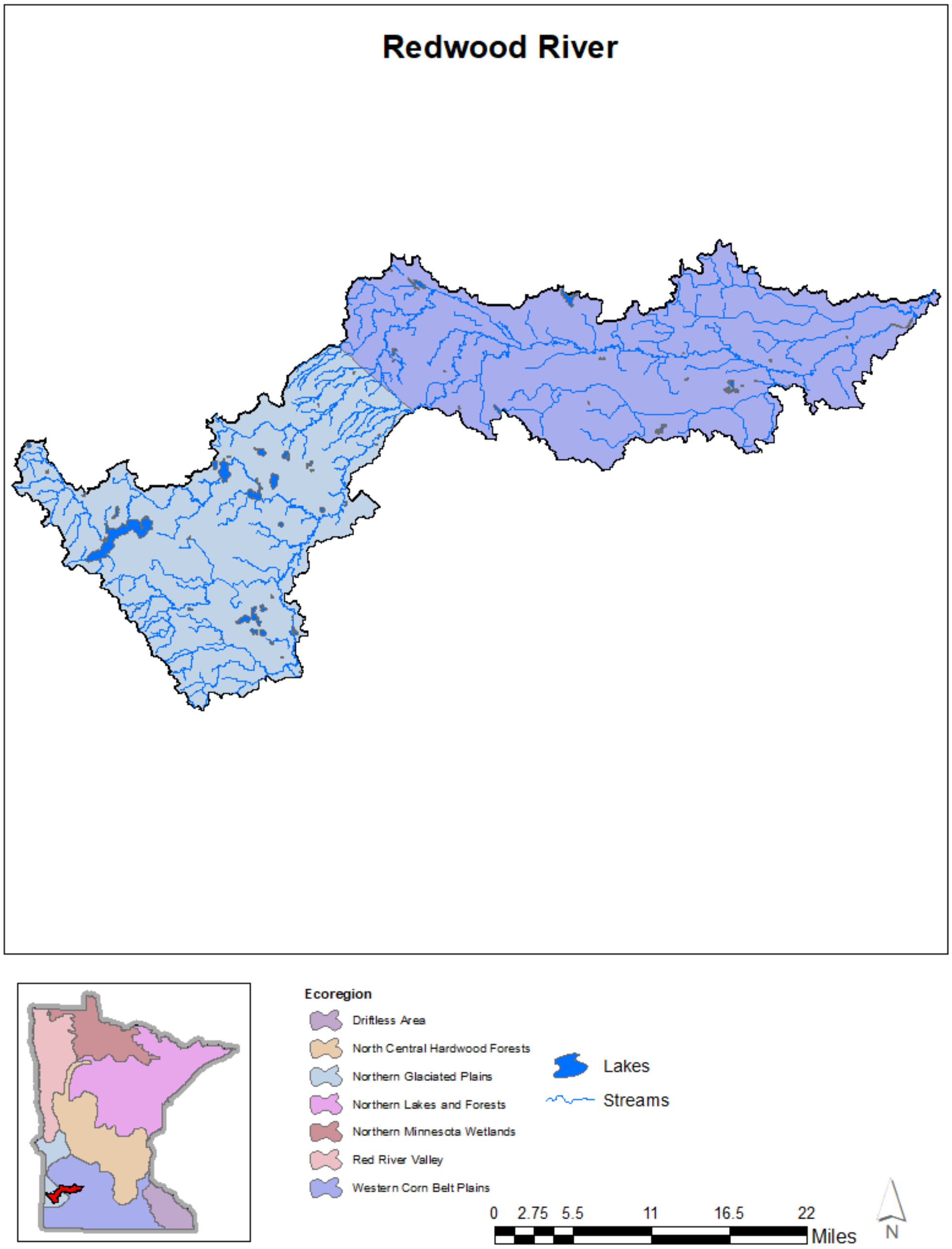
Located in southwest Minnesota, the Redwood River, a tributary to the Minnesota River, is the smallest major watershed within the Minnesota River Basin. Stretching from the town of Lake Benton to Redwood Falls, the Redwood River Watershed is the sixth major watershed downstream from the origin of the Minnesota River. Upstream on the Minnesota River next to the Redwood River is the Yellow Medicine – Hawk Creek Watershed. Just downstream on the Minnesota River is the Minnesota River – Mankato major watershed. Much of the southern border of the watershed is the Cottonwood River major watershed, and a small portion of the Des Moines River Watershed. The southwest border of the Redwood River Watershed is the Buffalo Ridge and across that is the Missouri River basin.

Covering 699 sq. mi. (448,000 ac.) on the south side of the Minnesota River. This 8-digit HUC (07020006) encompasses an area roughly 65 miles west to east, and about 33 miles north to south. The width of the watershed ranges between less than a mile near its mouth, to approximately 22 miles wide, with an average width of approximately 10 miles. The western most point of the watershed is only a few miles from the state of South Dakota.

Six Minnesota counties are found in this watershed. Lyon County (43%) makes up the largest portion of the watershed, followed by Redwood County (28%), and Lincoln County (19%) (DNR 2017b). Pipestone (4%), Yellow Medicine (3%), and Murray (2%) Counties make up the remainder of the watershed (DNR 2017b).

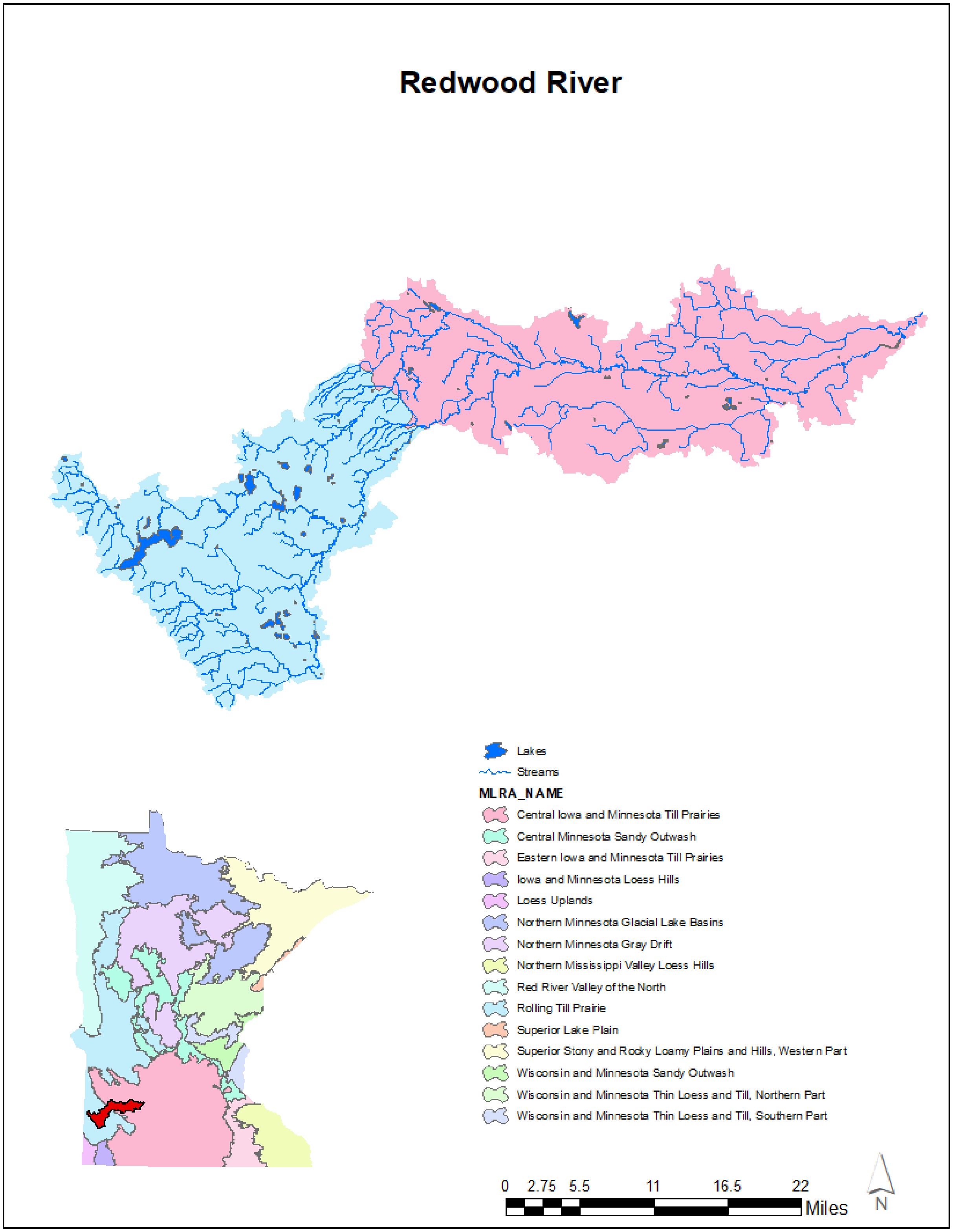
Most of the Redwood River major watershed is split between two U.S. Environmental Protection Agency (EPA) Level III ecoregions, the Northern Glaciated Plains and the Westerns Corn Belt Plains (Figure 5). The southwestern half of the watershed, which lies on the Coteau des Prairie is part of the Northern Glaciated Plains. It can be characterized by irregular, glacially formed topography, low to moderate annual precipitation, and a relatively short growing season (Omernik and Gallant 1988). The rest of the watershed from approximately Marshall and east to the Minnesota River falls within the Western Corn Belt Plains. Much of this ecoregion can be characterized by level to gently rolling dissected glacial till plains, hilly loess plains, and morainal hills (Omernik and Gallant 1988).

**Figure 5. The Redwood River Watershed within the Northern Glaciated Plains and Western Corn Belt Plains ecoregion of Southwestern Minnesota.**




Similar to the EPA level II ecoregions, the U.S Department of Agriculture characterizes major land resource areas. Present on the landscape in a similar pattern at the EPA Level III Ecoregions, the Redwood River Watershed consists of Rolling Till Prairies southwest of Marshall, and Central Iowa and Minnesota Till Prairies to the east of Marshall (Figure 6).Both of these land resources areas support natural prairie vegetation, and have prevalent prairie "potholes" (USDA 2006). Cropland, especially for corn and soybeans, is a dominant land use in both of the land resource areas (USDA 2006). Common resource concerns for the areas include wind erosion, water erosion, maintaining soil organic matter and productivity, and excess surface and subsurface water (USDA 2006).

**Figure 6. Major Land Resource Areas (MLRA) in the Redwood River Watershed.**




## Land use summary

The largest component of land use within the Redwood River major watershed is agriculture. Cropland accounts for 78% of the watershed area. Corn and soybeans are the predominate crop within the watershed. Watershed area broken down by crop type includes: 38% corn, 36% soybeans, almost 2% cultivated perennials, 1% small grains, and less than 1% sugerbeets, with 23% of watershed area not cultivated (DNR 2017b). Cropland within the watershed is more intensive in the Western Corn Belt Plains/Central Iowa and Minnesota Till Prairie ecoregion and land resource area in the eastern portion of the watershed.

The second largest component of land use is rangeland, which accounts for 9% of the major watershed area. Rangeland can be natural prairie, hay, or oftentimes grazed pasture. Rangeland within the watershed is more prevalent on the Coteau des Prairie and its slopes, which correspond with the Northern Glaciated Plains/Rolling Till Prairie ecoregion and land resource area.

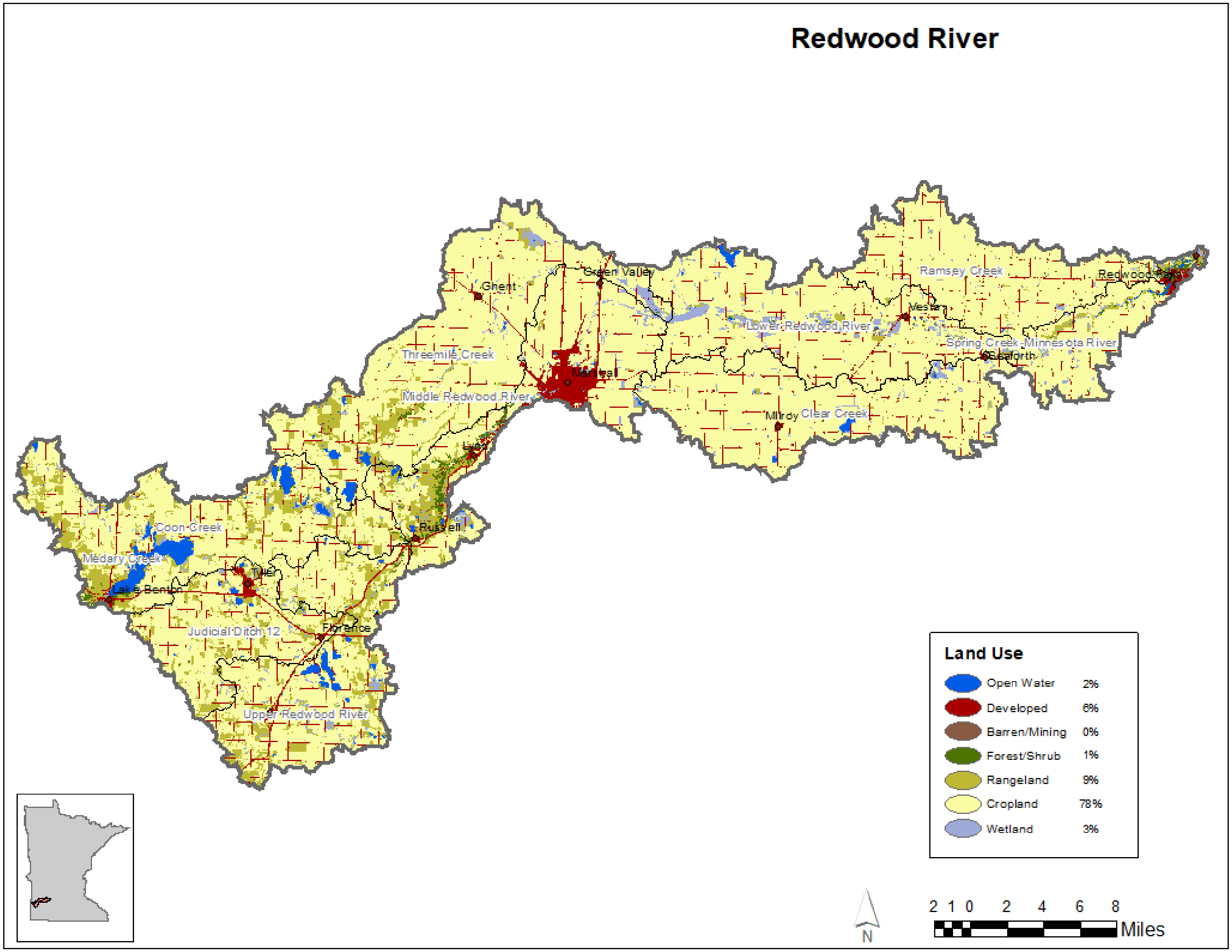
With this major watersheds location in a region historically dominated by prairie, today forest only accounts for approximately 1% of the watershed area. Like in the past, most of the forested areas are located along the Redwood River itself, especially as the Redwood River descends off of the Coteau des Prairie, as well as into to the Minnesota River valley. Some forest can also be found as a corridor along other streams within the watershed.

Within the Redwood River Watershed, lakes are mostly found in the southwest, on the more rolling terrain of the Coteau des Prairie. Overall, open water only accounts for about 2% of the overall watershed area. The entire watershed lies within a region of the state with abundant prairie potholes. Based on the 2011 National Land use Cover Database, wetlands comprise 3% of the watershed area.

Development accounts for 6% of the watershed area. As of the 2010 census, 23,709 people reside within the watershed, which is about 34 people per sq. mi. (DNR 2017c). Marshall is the largest town with a population of 13,600, followed by Redwood Falls with a population of 5,254 (DNR 2017c). Other towns within the watershed include Ruthton, Tyler, Florence, Lake Benton, Russell, Lynd, Ghent, Milroy, Seaforth, and Vesta. Areas that are barren/mining account for less than 1% of the watershed.

Since the time of European settlement, much of the watershed has changed. A vast area that was originally tallgrass prairie was converted to agriculture, and draining almost all wetlands to create even more cropland. Many miles of streams were channelized to form drainage ditch networks. Drainage ditches were often created to drain many of the wetlands, as well as to straighten what were sinuous streams to speed the movement of excess water off the landscape. Based on Land Survey notes from the 1890's, Marschner's Pre-European Settlement Vegetation Map characterizes the land cover of the watershed previous to European settlement (DNR 2017b). Prior to settlement, 87% of the watershed was covered by prairie and wet prairie comprised approximately an additional 9%. Lakes cover approximately 2%, which is similar to the modern day percentage (DNR 2017b). Forest made up a slightly higher percentage historically with almost 2% of the watershed area river bottom forest, and less than 1% oak openings and barrens (DNR 2017b).

**Figure 7. Land use in the Redwood River Watershed.**



## Surface water hydrology

The Redwood River begins near the town of Ruthton on the Coteau des Prairie near the Buffalo Ridge. From the headwaters, the river flows in a northeasterly direction down the slope of the Coteau des Prairie towards Marshall. Just downstream from Marshall, the river turns in an easterly direction towards Redwood Falls, and the confluence with the Minnesota River. River length is a total of 128 miles. One notable natural feature on the Redwood River is the 40-foot Ramsey Falls within Redwood Falls. As the river begins to descend into the Minnesota River Valley, the Redwood River goes through a bedrock walled gorge within the town of Redwood Falls.

Three intermediate (aggregated 12-HUC) watersheds make up the length of the mainstem Redwood River: the Upper, Middle, and Lower Redwood River aggregated 12-HUC watersheds. Judicial 12, Coon Creek, Threemile Creek, Clear Creek, and Ramsey Creek are significant tributaries to the Redwood River, and their corresponding subwatersheds make up the remainder of major watershed.

All of the streams within the watershed are classified as warmwater streams. Two reaches, the Redwood River in Camden State Park, and Ramsey Creek near Redwood Fall are designated DNR trout streams, and are managed as seasonal put and take fisheries. These reaches occur in higher gradient areas, the escarpment of the Coteau des Prairie for the Redwood River and the Minnesota River valley bluff for Ramsey Creek, where springs may be abundant enough to support a cooler thermal regime to allow trout to survive for some time in summer.

With the significant presence of agriculture within the Redwood River Watershed, many of the streams have been channelized (ditched) to increase drainage of excess water on the landscape. Based on the MPCA's Altered Watercourse Project, over half (52%) of the stream reach lengths have been altered by humans within the major watershed. Channelization on the landscape often occurs with close proximity to cropland, often times areas that are relatively level with poor drainage. Within this watershed, channelization seems to be most common in the Western Corn Belt Plains/Central Iowa and Minnesota Till Prairie ecoregion and land resource area. This watershed is about the third least ditched watershed within the Minnesota River basin. Natural stream reach lengths comprise 39% of the reach lengths in the watershed. Much of the length of the mainstem Redwood River, with the exception of a few portions on the length between Marshall and Redwood Falls, is a natural channel. Natural channels often occur in areas of steeper terrain were cropland is absent. Many of the natural channels occur on the more rolling terrain of the Coteau des Prairie and its escarpment. Impounded reaches are minimal in the Redwood River Watershed, with the most notable reach being the Redwood River through Redwood Lake (54 ac.), which is formed by a dam on the Redwood River where MN 19 crosses the river. Up to 9% of the stream reach lengths fall under the no definable channel category. Many of these reaches are intermittent grass waterways, indistinguishable channels through wetlands, and sometimes channels that are underground as part of a drain tile network.

Another significant portion of the Redwood River major watershed is the network of subsurface drain tiles. Drain tiles are often put in to increase cropland acreage and productivity, and usually have significant impacts on stream hydrology. Streams fed by large networks of drain tile oftentimes have increased flow overall. In the case of rainfall events, tile fed streams often experience shortened duration, but substantially increased in magnitude high flows. During times of drought, streams within extensive drain tile networks will see more extreme low flows.

Many lakes occur in the watershed, being most common on the rolling terrain on the Prairie des Coteau. The largest of the lakes is Lake Benton (2,646 ac.), in the far western portion of the watershed. Other larger lakes include: Dead Coon (539 ac.), Wood (323 ac.), School Grove (337 ac.), East (249 ac.) and West Twin (220 ac.) lakes, Island (164 ac.), and Slough Lake (160 ac.). Numerous smaller lakes and open water wetlands occur across the major watershed.

**Figure 8. Map of percent altered streams by major watershed (8-HUC).**

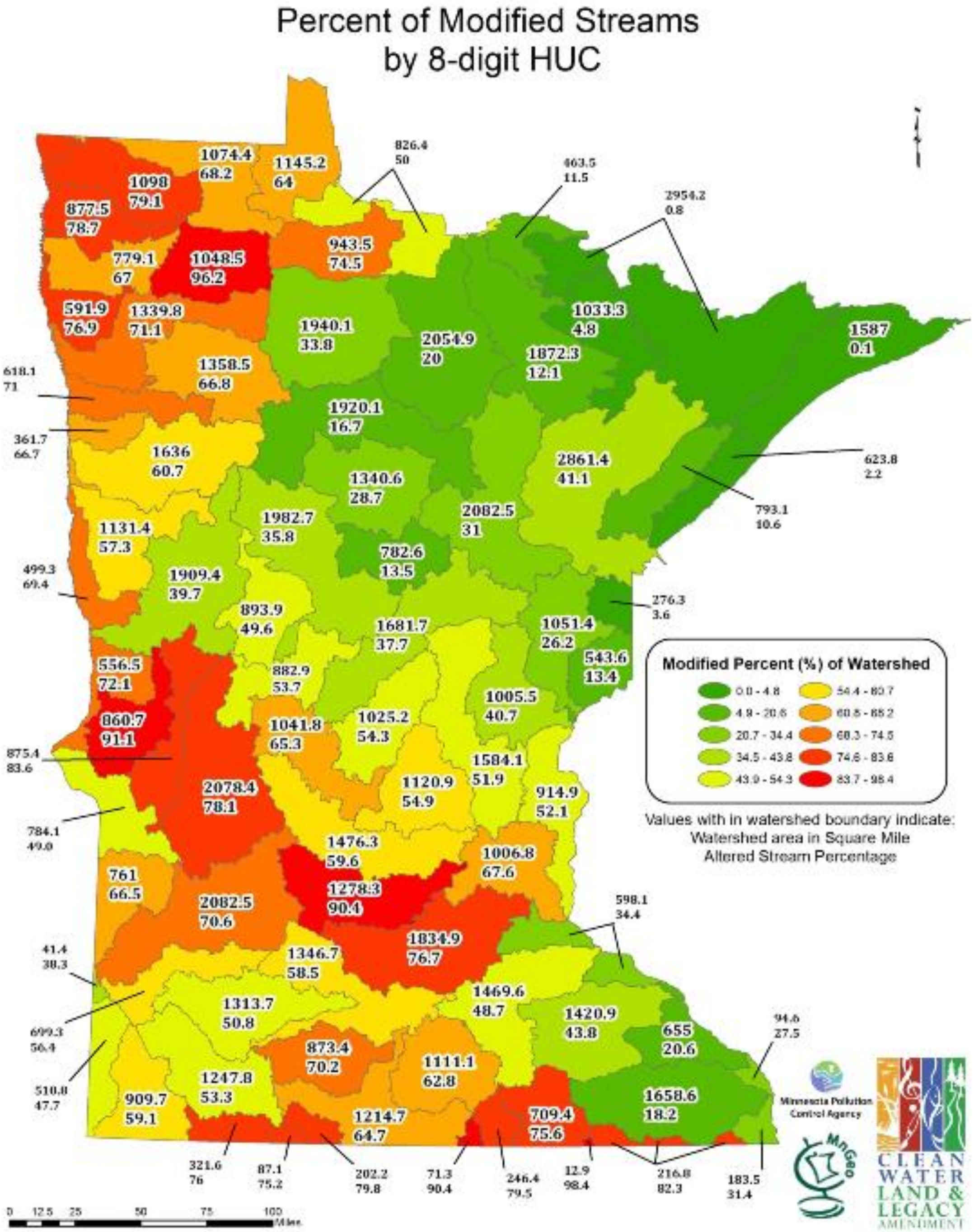
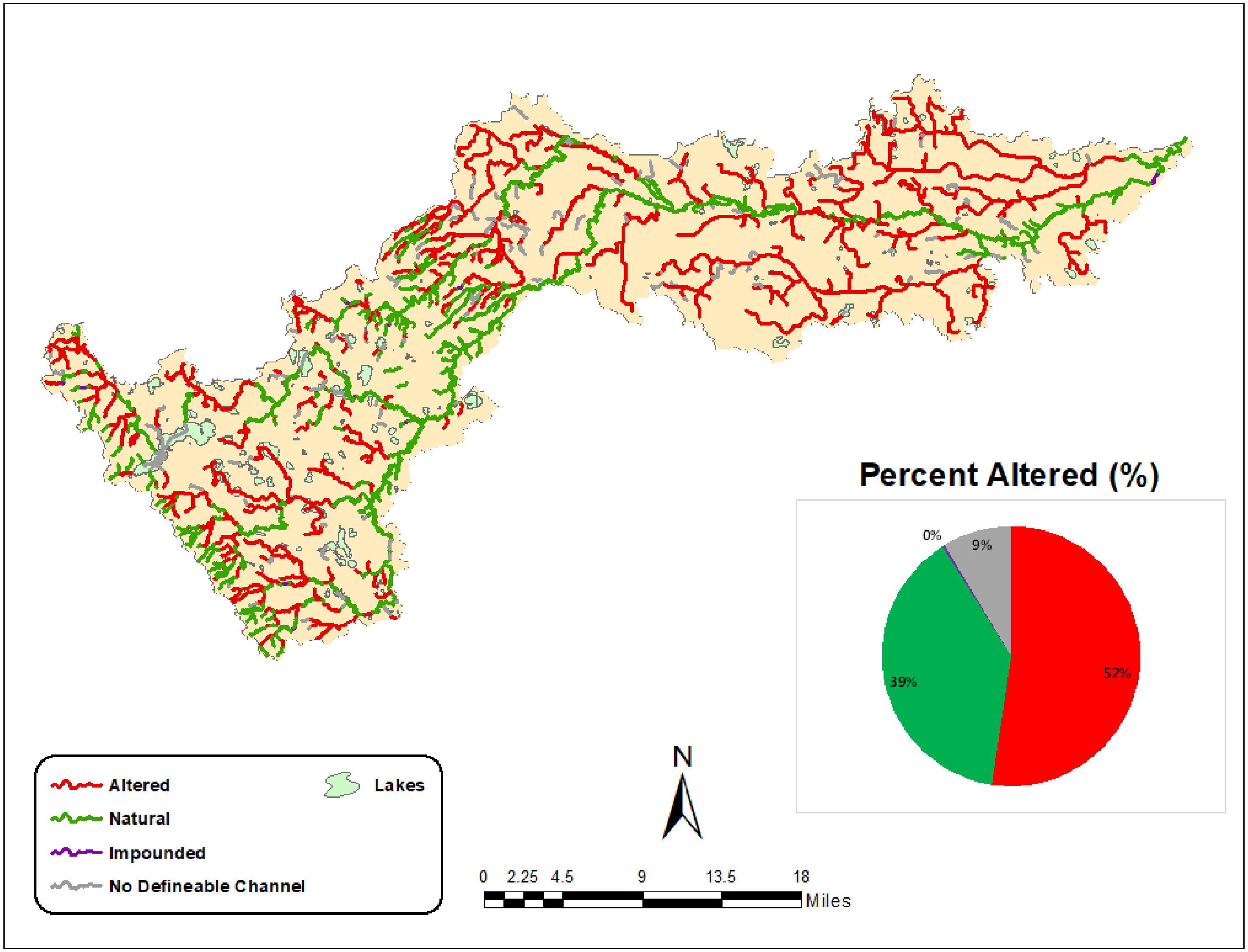


**Figure 9. Comparison of natural to altered streams in the Redwood River Watershed (percentages derived from the Statewide Altered Water Course project).**

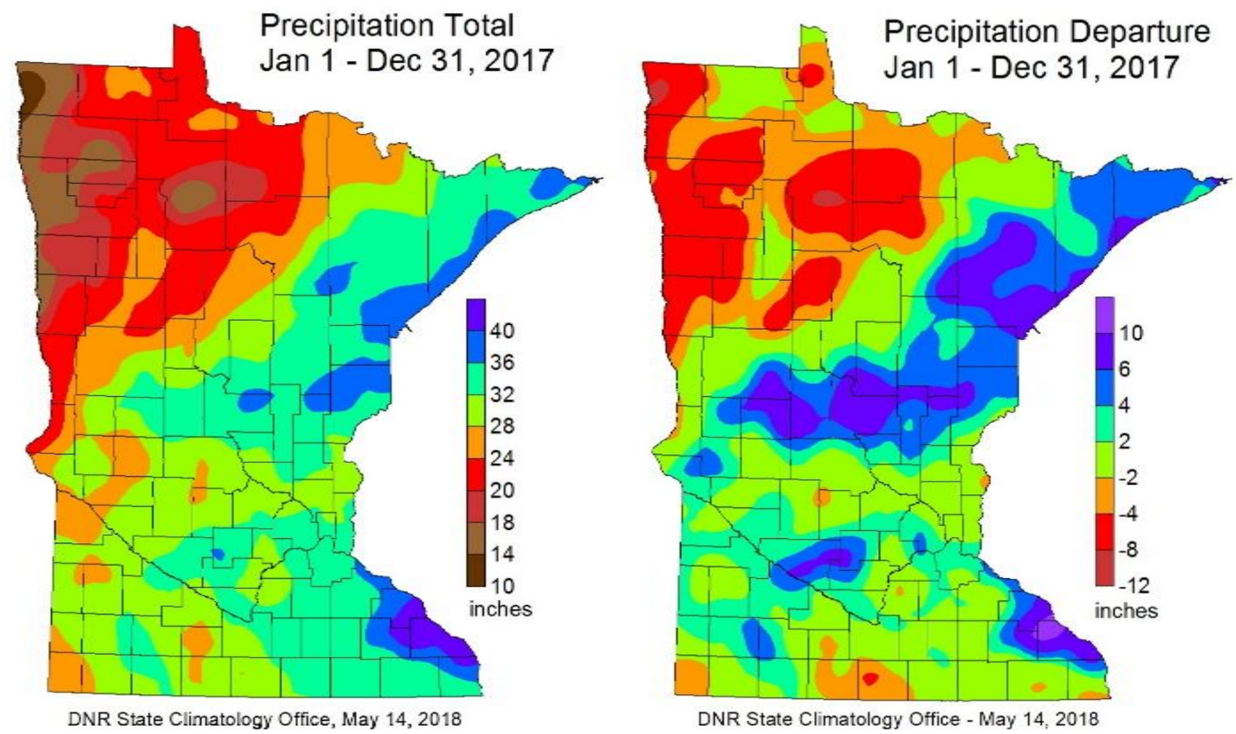


## Climate and precipitation

The average annual temperature for the State of Minnesota is 41.6˚F. For the Redwood River Watershed, the annual average is 44.76 ˚F, the average summer (June-August) temperature is 70.1˚F and the average winter (December-February) temperature is 16.96˚F (DNR: Minnesota State Climatology Office, 2020).

Precipitation is an important source of water input to a watershed. Figure 10 displays two representations of precipitation for calendar year 2017. On the left is total precipitation, showing the typical pattern of increasing precipitation toward the southeastern portion of the state. According to this figure, the Redwood River Watershed area received 29.05 inches of precipitation in 2017. The display on the right shows the amount that precipitation levels departed from normal. In 2017, watershed area experienced 2-4 inches above normal precipitation.

**Figure 10. Statewide precipitation total (left) and precipitation departure (right) during 2017 (Source: DNR State Climatology Office, 2019b)**




The Redwood River Watershed is located within the Southwest precipitation region. Figure 11 and Figure 12 display the areal average representation of precipitation in Southwest Minnesota for 20 and 100 years, respectively. An areal average is a spatial average of all the precipitation data collected within a certain area presented as a single dataset. Though rainfall can vary in intensity and time of year, rainfall totals in the Southwest region display no significant trend over the last 20 years. However, precipitation in Southwest Minnesota exhibits a significant rising trend over the past 100 years ($p<0.01$). This is a strong trend and matches similar trends throughout Minnesota.

**Figure 11. Precipitation trends in Southwest Minnesota (1997-2017) with five-year running average (Source: WRCC, 2020).**

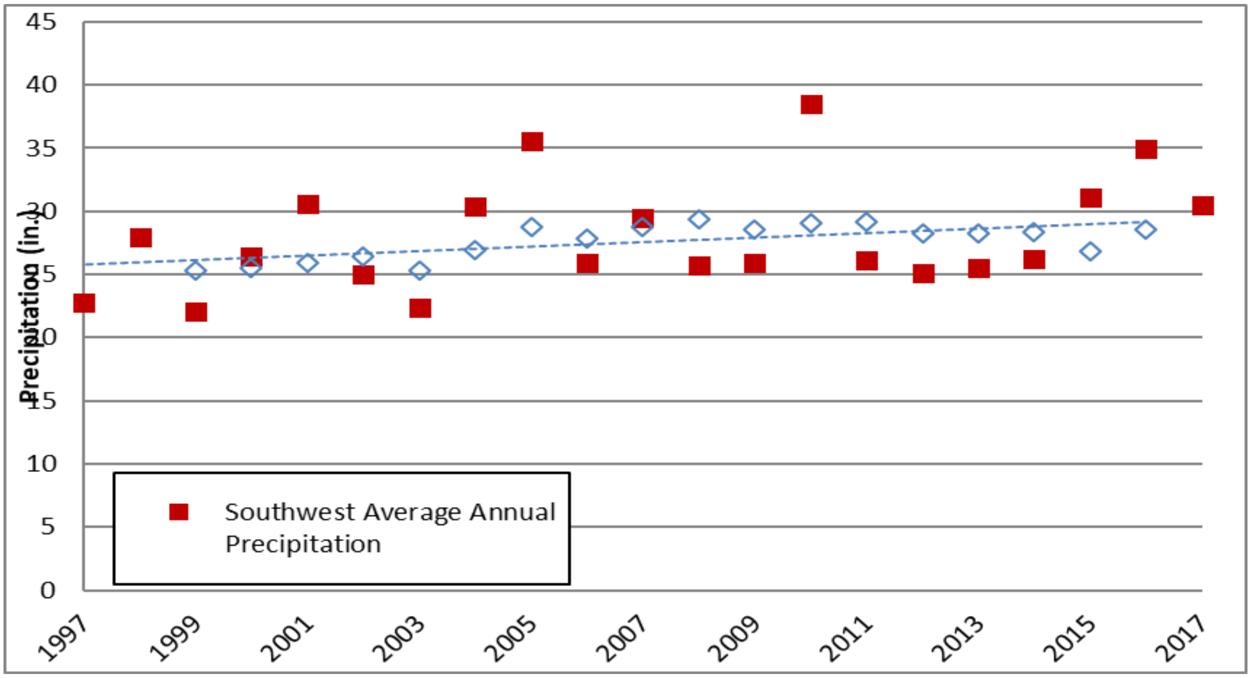
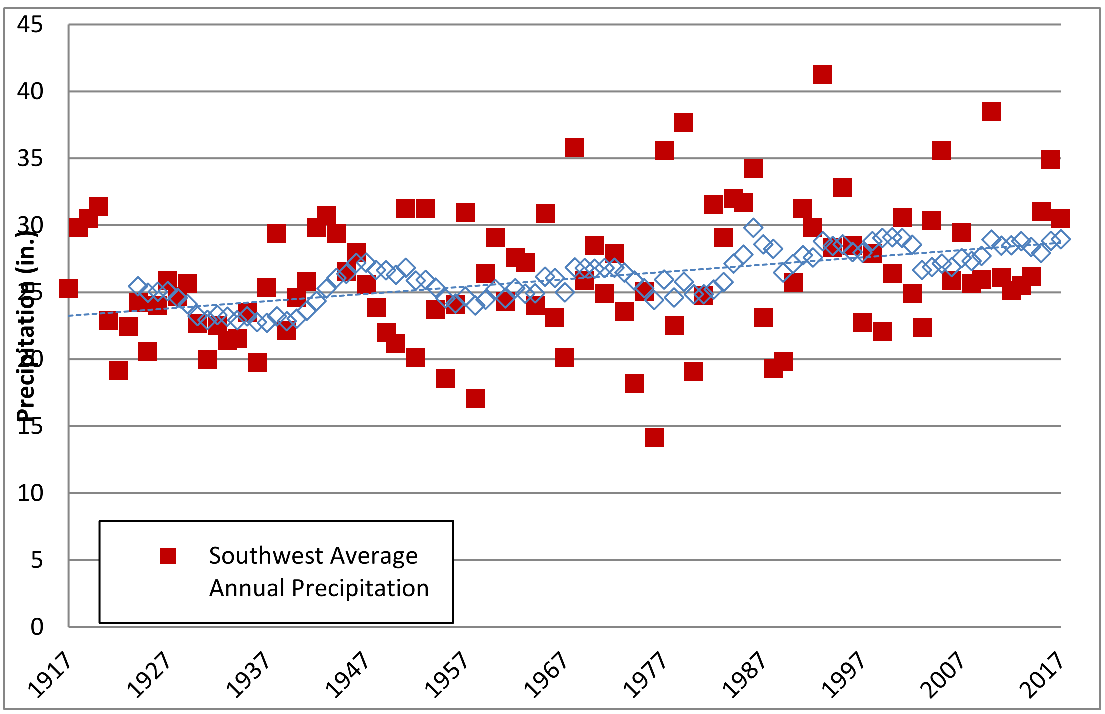



**Figure 12. Precipitation trends in Southwest Minnesota (1917-2017) with 10-year running average (Source: WRCC, 2020).**



## Hydrogeology and groundwater quality

Hydrogeology is the study of the interaction, distribution and movement of groundwater through the rocks and soil of the earth. The geology of a region strongly influences the quantity of groundwater available, the quality of the water, the sensitivity of the water to pollution, and how quickly the water will be able to recharge and replenish the source aquifer. This branch of geology is important to understand as it indicates how to manage groundwater withdrawal and land use and can determine if mitigation is necessary.

The Redwood River Watershed contains features of Minnesota's Western groundwater province. The Western province is characterized by clayey drift overlying Cretaceous and Precambrian bedrock. The drift and Cretaceous bedrock contain sand and sandstone aquifers of limited extent. (DNR, 2017)

### Groundwater Potential Recharge

Groundwater recharge is one of the most important parameters in the calculation of water budgets, which are used in general hydrologic assessments, aquifer recharge studies, groundwater models, and water quality protection. Recharge is a highly variable parameter, both spatially and temporally, making accurate estimates at a regional scale difficult to produce. The MPCA contracted the US Geological Survey to develop a statewide estimate of recharge using the SWB – Soil-Water-Balance Code. The result is a gridded data structure of spatially distributed recharge estimates that can be easily integrated into regional groundwater studies. The full report of the project as well as the gridded data files are available at: https://gisdata.mn.gov/dataset/geos-gw-recharge-1996-2010-mean.

Recharge of these aquifers is important and limited to areas located at topographic highs, those with surficial sand and gravel deposits, and those along the bedrock-surficial deposit interface. Typically, recharge rates in unconfined aquifers are estimated at 20 to 25% of precipitation received, but can be less than 10% of precipitation where glacial clays or till are present (USGS, 2007). For the Redwood River Watershed, the average annual potential recharge rate to surficial materials ranges from 0.99 – 7.6 inches per year, with a mean of 3.60 inches per year. The statewide average potential recharge is estimated to be four inches per year with 85% of all recharge ranging from three to eight inches per year (USGS, 2015).

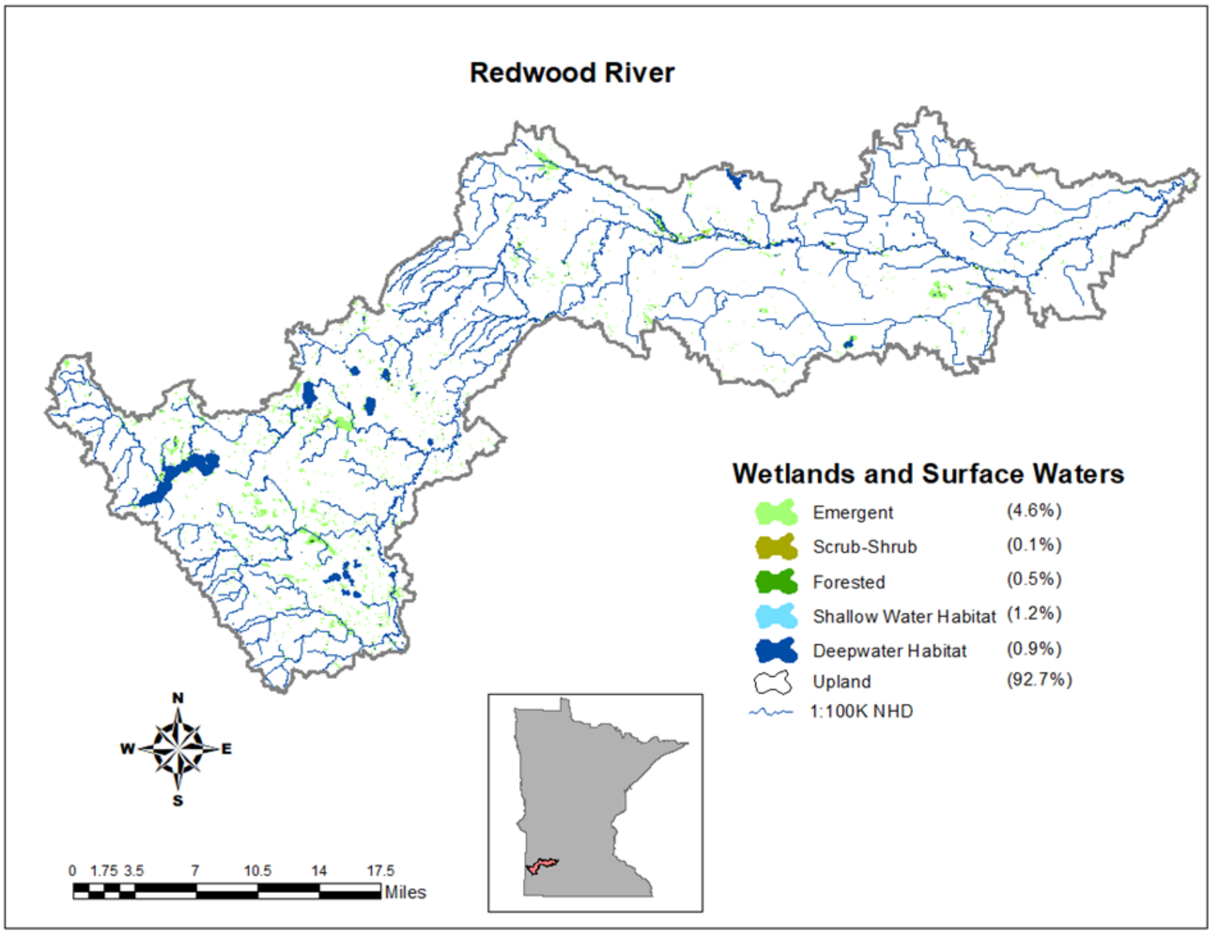
## Wetlands

Excluding open water portions of lakes and rivers, the Redwood River Watershed supports an estimated 28,716 acres of wetland, which is equivalent to 7.3% of the total watershed area (Figure 13). Emergent wetlands make up almost three-quarters (72%) of the total wetland area. The second most extensive wetland type is shallow open-water wetland habitats (ponds and deep marshes) which comprise nearly one fifth of the total wetland area or 2.3% of the watershed area. Forested wetlands make up about 8.1% of the wetland area and shrub dominated wetlands make up 1.8% of the total watershed area. An estimated 11.3% of the wetland area is comprised of wetlands with temporary hydrology which are routinely farmed in dry years (PEM1Af). Most of these farmed wetlands are small and usually exhibit temporary hydrology. Ninety five percent of them are less than 8.9 acres with an average size of 2.32 acres and a median (most common) size of 1 acre. Genet and Olsen (2008) similarly reported significant estimates of small farmed wetlands in the Redwood Watershed. They also reported wetlands < 1 hectares (2.47 ac) were the most frequently converted (drained) wetland size in the Redwood Watershed during the period ca. 1980 to 2003.

The estimates of wetland extent and distribution observations are mostly derived from the statewide Minnesota National Wetland Inventory (NWI). Using the Minnesota NWI Kloiber et al (2019) present a summary of wetland extent by county or major watershed as reported here. For more information about Minnesota's NWI update project, visit: http://www.dnr.state.mn.us/eco/wetlands/nwi_proj.html.

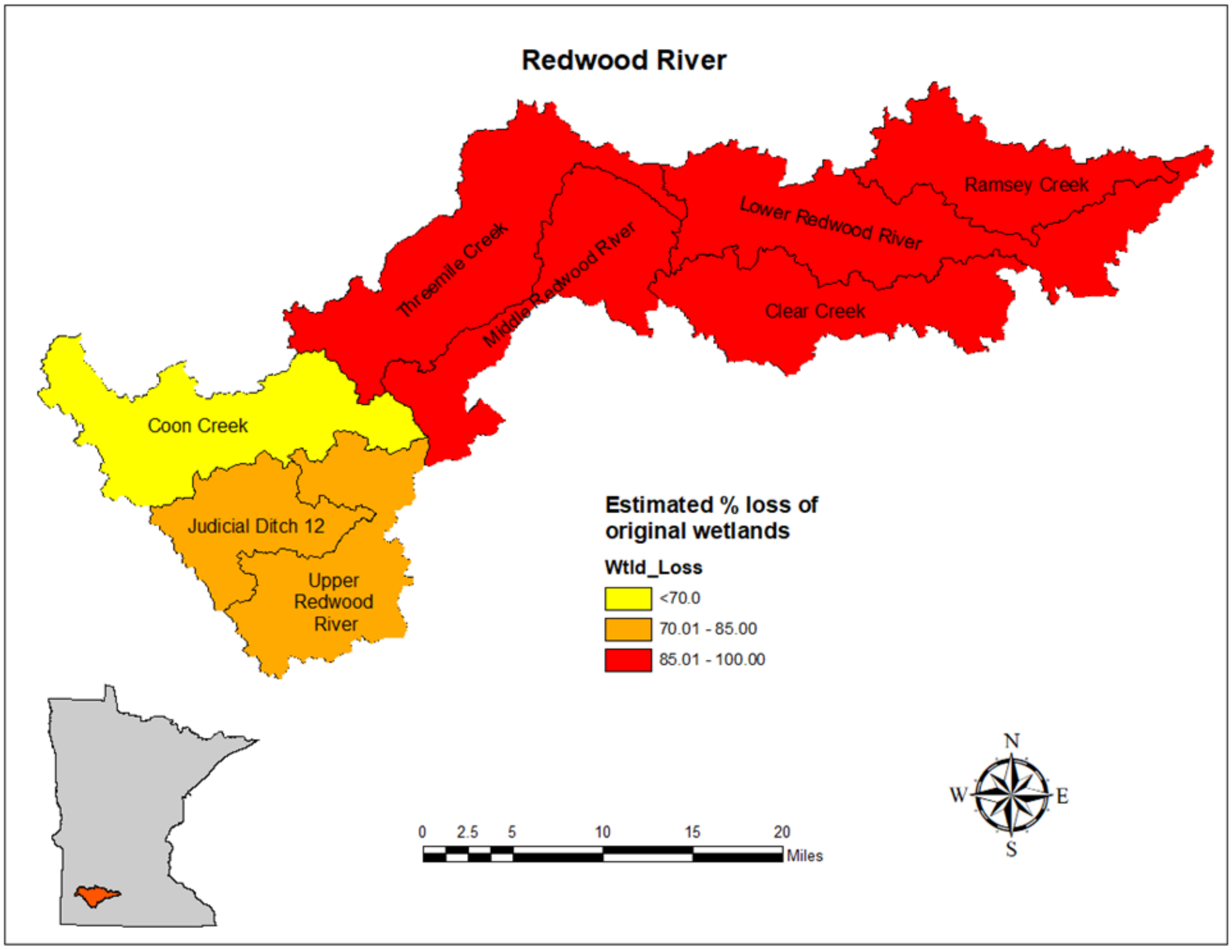
The Redwood Watershed headwaters drain a portion of the eastern edge of the Coteau des Prairies. The coteau rising to over 800 feet in elevation compared to the surrounding landscape is a significant landscape feature in Southwestern Minnesota. The Coteau crosses southwest MN, including the western edge of the Redwood River Watershed, and extends northwest into South Dakota and to the southeast into Iowa. East of the Coteau, the topography in much of the Redwood River Watershed is gently rolling to flat with the recent geology of the watershed dominated by ground moraine derived from the Des Moines glaciation lobe. Ground moraine typically results in extensive networks of isolated and often interconnected shallow wetlands and small lakes. Much of Minnesota's portion of the prairie pothole region is characterized by ground moraine. The entire Redwood River Watershed is within the prairie pothole region. The watershed also occurs entirely within the Temperate Prairies Ecoregion.

**Figure 13. Wetlands and other surface water features in the Redwood River Watershed. Wetland data is from the Minnesota National Wetlands Inventory (circa 2011 data).**




Drainage, of wetlands over the past century and a half has resulted in extensive portions of the Redwood River Watershed being one of the most productive agricultural regions of Minnesota. At the same time this widespread drainage has greatly altered the historic natural hydrology of the watershed. Estimates of historic wetland extent can be derived using drainage class assignments from the digital soil survey (SSURGO). SSURGO soil map units (MU) classed as 'Poorly Drained' or 'Very-Poorly Drained' were used as proxies for historic wetland extent. These results were then compared to contemporary wetland extent estimates from Minnesota's updated NWI to produce wetland loss estimates as a percentage at the HUC12 subwatershed scale. Figure 14 illustrates the relative amount of wetland conversion that has occurred across the Redwood River Watershed. Findings from this analysis show all eight of the Redwood 12HUC subwatersheds have experienced significant wetland loss, of nearly 70%, or more conversion rates, mostly due to drainage. The least amount of wetland conversion has occurred in the westernmost three subwatersheds – Coon Creek, Judicial Ditch 12 and the Upper Redwood River. These three subwatersheds have more slope and rockier glacial till making them somewhat less conducive to high productivity row cropping practices. Subwatersheds further down along the Redwood River corridor are better suited to row cropping practices and have experienced wetland conversion rates of over 85% compared with the original wetland extent.

**Figure 14. Estimated wetland conversion (loss) rates between historic wetland extent based on SSURGO soil data and ca. 2011 wetland data. Presented at a HUC 12 subwatershed scale.**



### Special Wetland Features in the Redwood River Watershed

Calcareous fens are one of the rarest wetland communities in Minnesota. Calcareous fens are mostly saturated soil wetlands underlain by deep accumulations of peat resulting from ground water discharges which are high in alkaline ions, particularly calcium and magnesium. The constant water supply and rich mineral content characteristic of calcareous fens commonly supports a diverse assemblage of rare and unique plants. Calcareous fens are dominated by narrow-leafed grass-like plants including sedges, grasses and specially adapted forbs. Because of their rareness and sensitivity to disturbance, calcareous fens in Minnesota are specially designated in State Water Quality Standards to be protected from water quality impacts.

Four calcareous fens occur in the Redwood Watershed, all of them in Lyon County. Two of the calcareous fens (Island Lake 23-a and Island Lake 23-b) are located in the Threemile Creek subwatershed and two of them known as Shelburne 22 (two units) are in the Upper Redwood River subwatershed. All four of these calcareous fens are recognized in State Water Quality Standards, Minn. R. ch. 7050.0335 subp 2 to be unlisted restricted discharge Outstanding Resource Value Waters (ORVWs).

# Watershed-wide data collection methodology

## Lake water sampling

Redwood-Cottonwood Rivers Control Area (RCRCA) sampled School Grove and Clear lakes in 2017 and 2018, as part of the Clean Water Legacy Surface Water Monitoring project for the purpose of enhancing the dataset for lake assessment of aquatic recreation. Sampling methods are similar among monitoring groups and are described in the document entitled "*MPCA Standard Operating Procedure for Lake Water Quality*" found at http://www.pca.state.mn.us/publications/wq-s1-16.pdf. The lake recreation use assessment requires eight observations/samples within a 10-year period (June to September) for phosphorus, chlorophyll-a and Secchi depth.

## Stream water sampling

Eight water chemistry stations were sampled from May thru September in 2017, and again June thru August of 2018 to provide sufficient water chemistry data to assess all components of the aquatic life and recreation use standards. Following the IWM design, water chemistry stations were placed at the outlet of each aggregated 12 HUC subwatershed that was >40 square miles in area (purple circles and green circles/triangles in Figure 2). A surface water assessment grant was awarded to the RCRCA to conduct water chemistry monitoring. (See Appendix 2.1 for locations of stream water chemistry monitoring sites. See Appendix 1 for definitions of stream chemistry analytes monitored in this study).

### Stream flow methodology

The MPCA and DNR joint stream water quantity and quality monitoring data for dozens of sites across the state on major rivers, at the mouths of most of the state's major watersheds, and at the mouths of some aggregated 12-HUC subwatersheds are available at the DNR/MPCA Cooperative Stream Gaging webpage at: http://www.dnr.state.mn.us/waters/csg/index.html.

## Lake biological sampling

A total of five lakes were monitored for fish community health in the Redwood River Watershed. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2019 assessment was collected in 2017 and 2018. Waterbody assessments to determine aquatic life use support were completed for five WIDs.

To measure the health of aquatic life at each lake, a fish IBI was calculated based on monitoring data collected in the lake. A fish classification framework was developed to account for natural variation in community structure which is attributed to area, maximum depth, alkalinity, shoreline complexity, and geographic location. As a result, an IBI is available for four different groups of lake classes (Schupp Lake Classification, DNR). Each IBI class uses a unique suite of metrics, scoring functions, impairment thresholds, and confidence intervals (CIs). IBI scores higher than the impairment threshold and upper CI indicate that the lake supports aquatic life. Scores below the impairment threshold and lower CI indicate that the lake does not support aquatic life. When an IBI score falls within the upper and lower confidence limits additional information may be considered when making the impairment decision such as the consideration of potential local and watershed stressors and additional monitoring information (e.g., water chemistry, physical habitat, plant surveys, and observations of local land use activities).

## Stream biological sampling

The biological monitoring component of the intensive watershed monitoring in the Redwood River Watershed was completed during the summer of 2017. A total of 31 sites were newly established across the watershed and sampled. These sites were located near the outlets of most minor HUC-14 watersheds. In addition, 12 existing biological monitoring stations within the watershed were revisited in 2017. These monitoring stations were initially established as part of a random Minnesota River Basin wide survey in 1990-1992, or as part of a 2007 survey which investigated the quality of channelized streams with intact riparian zones. Due to periods of higher than normal flows and the logistics of sampling watersheds across the state, six stations were unable to be sampled for fish during the 2017 monitoring effort. These stations occurred in the Coon Creek subwatershed, and the Lower Redwood River subwatershed. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2019 assessment was collected in 2017. A total of 34 WIDs were sampled for biology in the Redwood River Watershed. Waterbody assessments to determine aquatic life use support were conducted for 34 WIDs. Biological information that was not used in the assessment process will be crucial to the stressor identification process and will also be used as a basis for long term trend results in subsequent reporting cycles.

To measure the health of aquatic life at each biological monitoring station, indices of biological integrity (IBIs), specifically Fish and Macroinvertebrate IBIs, were calculated based on monitoring data collected for each of these communities. A fish and macroinvertebrate classification framework was developed to account for natural variation in community structure which is attributed to geographic region, watershed drainage area, water temperature and stream gradient. As a result, Minnesota's streams and rivers were divided into seven distinct warm water classes and two cold water classes, with each class having its own unique Fish IBI and Macroinvertebrate IBI. Each IBI class uses a unique suite of metrics, scoring functions, impairment thresholds, and confidence intervals (CIs) (For IBI classes, thresholds and CIs, see Appendix 3.1). IBI scores higher than the impairment threshold and upper CI indicate that the stream reach supports aquatic life. Contrarily, scores below the impairment threshold and lower CI indicate that the stream reach does not support aquatic life. When an IBI score falls within the upper and lower confidence limits additional information may be considered when making the impairment decision such as the consideration of potential local and watershed stressors and additional monitoring information (e.g., water chemistry, physical habitat, observations of local land use activities). For IBI results for each individual biological monitoring station, see Appendices 4.1 and 4.2.

## Fish contaminants

Minnesota Department of Natural Resource (DNR) fisheries staff collect most of the fish for the Interagency Fish Contaminant Monitoring Program. In addition, MPCA's biomonitoring staff collect up to five piscivorous (top predator) fish and five forage fish near the HUC8 pour point, as part of the Intensive Watershed Monitoring. All fish collected by the MPCA are analyzed for mercury and the two largest individual fish of each species are analyzed for polychlorinated biphenyls (PCBs).

Captured fish are wrapped in aluminum foil and frozen until they were thawed, scaled (or skinned), filleted, and ground to a homogenized tissue sample. Homogenized fillets are placed in 60 mL glass jars with Teflon™ lids and frozen until thawed for lab analysis. The Minnesota Department of Agriculture Laboratory analyzes the samples for mercury and PCBs. Fish tested for poly- and perfluoroalkyl substances (PFAS) are shipped to SGS-AXYS Analytical Laboratory, which analyze homogenized fish fillets for 13 PFAS. Of the measured PFAS, only perfluorooctane sulfonate (PFOS) is reported here because it bioaccumulates in fish to levels that are potentially toxic and a reference dose has been developed.

From the fish contaminant analyses, MPCA determines which waters exceed impairment thresholds. The Impaired Waters List is prepared by the MPCA and submitted every even year to the U.S. EPA. MPCA has included waters impaired for contaminants in fish on the Impaired Waters List since 1998. Impairment assessment for PCBs (and PFOS when tested) in fish tissue is based on the fish consumption advisories prepared by the Minnesota Department of Health (MDH). If the consumption advice is to restrict consumption of a particular fish species to less than a meal per week the MPCA considers the lake or river impaired. The threshold concentration for impairment (minimum concentration for consumption advice of one meal per month) is an average fillet concentration of 0.22 mg/kg for PCBs and 0.200 mg/kg for PFOS.

Monitoring of fish contaminants in the 1970s and 1980s showed high concentrations of PCBs were primarily a concern downstream of large urban areas in large rivers, such as the Mississippi River, and in Lake Superior. Therefore, PCBs are now tested where high concentrations in fish were measured in the past and the major watersheds are screened for PCBs in the watershed monitoring collections.

Before 2008, mercury in fish tissue was assessed for water quality impairment based on MDH's fish consumption advisory, the same as PCBs. With the adoption of a water quality standard for mercury in edible fish tissue, a waterbody is classified as impaired for mercury in fish tissue if 10%of the fish samples (measured as the 90th percentile) exceed 0.2 mg/kg of mercury. At least five fish samples of the same species are required to make this assessment for a single year.

## Pollutant load monitoring

Intensive water quality sampling occurs at all WPLMN sites. Thirty-five samples per year are allocated for basin and major watershed sites and 25 samples per season (ice out through October 31) for subwatershed sites. Because concentrations typically rise with streamflow for many of the monitored pollutants, and because of the added influence elevated flows have on pollutant load estimates, sampling frequency is greatest during periods of moderate to high flow. All major snowmelt and rainfall events are sampled. Low flow periods are also sampled although sampling frequency is reduced as pollutant concentrations are generally more stable when compared to periods of elevated flow.

Water sample results and daily average flow data are coupled in the $FLUX_{32}$ pollutant load model to estimate the transport (load) of nutrients and other water quality constituents past a sampling station over a given period of time. Loads and flow weighted mean concentrations (FWMCs) are calculated for total suspended solids (TSS), total phosphorus (TP), dissolved orthophosphate (DOP), nitrate plus nitrite nitrogen ($NO_3$+$NO_2$-N), and total Kjeldahl nitrogen (TKN).

More information can be found at the WPLMN website.

## Groundwater monitoring

### Groundwater Quality

The MPCA's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of chemicals including nutrients, metals, and volatile organic compounds. These Ambient wells represent a mix of deeper domestic wells and shallow monitoring wells. The shallow wells interact with surface waters and exhibit impacts from human activities more rapidly. Available data from federal, state and local partners are used to supplement reviews of groundwater quality in the region.

### Groundwater Quantity

Monitoring wells from the DNR Observation Well Network track the elevation of groundwater across the state. The elevation of groundwater is measured as depth to water in feet and reflects the fluctuation of the water table as it rises and falls with seasonal variations and anthropogenic influences. Data from these wells and others are available at:
http://www.dnr.state.mn.us/waters/groundwater_section/obwell/waterleveldata.html.

### Groundwater/Surface Water Withdrawals

The Department of Natural Resources permits all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons/day or 1 million gallons/year. Permit holders are required to track water use and report back to the DNR yearly. Information on the program and the program database are found at: http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html.

### Stream Flow

The MPCA and DNR jointly monitor stream water quantity and quality at dozens of sites across the state on major rivers, at the mouths of most of the state's major watersheds, and at the mouths of some aggregated 12-HUC subwatersheds. Information and data on these sites are available at the DNR/MPCA Cooperative Stream Gaging webpage at: http://www.dnr.state.mn.us/waters/csg/index.html.

## Wetland monitoring

The MPCA is actively developing methods and building capacity to conduct wetland quality monitoring and assessment. Our primary approach is biological monitoring—where changes in biological communities may indicate a response to human-caused impacts. The MPCA has developed Indices of Biological Integrity (IBIs) to monitor the macroinvertebrate condition of depressional wetlands with open water. MPCA is also using Floristic Quality Assessment (FQA) to assess vegetation condition in all of Minnesota's wetland types. For more information about the wetland monitoring (including technical background reports and sampling procedures), please visit the MPCA Wetland monitoring and assessment webpage.

The MPCA currently does not monitor wetlands systematically by watershed. Rather, the MPCA is using probabilistic monitoring to assess status and trends of wetland quality in the state and by major ecoregion. Probabilistic monitoring refers to the process of randomly selecting sites to monitor and achieve an unbiased estimate of the resource. Regional probabilistic survey results can provide a reasonable approximation of the current wetland quality in the watershed.

# Individual aggregated 12-HUC subwatershed results

## Aggregated 12-HUC subwatersheds

Assessment results for aquatic life and recreation use are presented for each Aggregated HUC-12 subwatershed within the Redwood River Watershed. The primary objective is to portray all the full support and impairment listings within an aggregated 12-HUC subwatershed resulting from the complex and multi-step assessment and listing process. This scale provides a robust assessment of water quality condition at a practical size for the development, management, and implementation of effective TMDLs and protection strategies. The graphics presented for each of the aggregated HUC-12 subwatersheds contain the assessment results from the 2019 Assessment Cycle as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2017 intensive watershed monitoring effort, but also considers available data from the last ten years.

The proceeding pages provide an account of each aggregated HUC-12 subwatershed. Each account includes a brief description of the aggregated HUC-12 subwatershed, and summary tables of the results for each of the following: a) stream aquatic life and aquatic recreation assessments, and b) lake aquatic life and recreation assessments. Following the tables is a narrative summary of the assessment results and pertinent water quality projects completed or planned for the aggregated HUC-12 subwatershed. A brief description of each of the summary tables is provided below.

### Stream assessments

A table is provided in each section summarizing aquatic life and aquatic recreation assessments of all assessable stream reaches within the aggregated HUC-12 subwatershed (i.e., where sufficient information was available to make an assessment). Primarily, these tables reflect the results of the 2012 assessment process (2014 U.S. Environmental Protection Agency [EPA] reporting cycle); however, impairments from previous assessment cycles are also included and are distinguished from new impairments via cell shading (see footnote section of each table). These tables also denote the results of comparing each individual aquatic life and aquatic recreation indicator to their respective criteria (i.e., standards); determinations made during the desktop phase of the assessment process (see Figure 4). Assessment of aquatic life is derived from the analysis of biological (fish and macroinvertebrate IBIs), dissolved oxygen, total suspended solids, chloride, pH, total phosphorus, chlorophyll-a, biochemical oxygen demand and un-ionized ammonia ($NH_3$) data, while the assessment of aquatic recreation in streams is based solely on bacteria (Escherichia coli) data. Included in each table is the specific aquatic life use classification for each stream reach: cold water community (2A) or cool or warm water community (2B). Where applicable and sufficient data exists, assessments of other designated uses (e.g., class 7, drinking water, aquatic consumption) are discussed in the summary section of each aggregated HUC-12 subwatershed as well as in the Watershed-wide results and discussion section.

### Lake assessments

A summary of lake water quality is provided in the aggregated HUC-12 subwatershed sections where available data exists. This includes aquatic recreation (phosphorus, chlorophyll-a, and Secchi) and aquatic life, where available (chloride and fish IBI). Similar to streams, parameter level and over all use decisions are included in the table.

## Upper Redwood River Aggregated 12-HUC HUC 0702000601-01

The Upper Redwood River (0702000601-01) aggregated 12-HUC (Figure 15) is the southernmost subwatershed and is the headwaters of the Redwood River. Predominately consisting of the Redwood River flowing northeast, the subwatershed encompasses 80 sq. mi. (51,000 acres). Counties that make up the subwatershed include Pipestone, Murray, Lincoln, and Lyon. All of the stream reaches are considered warmwater with 45% of the reach lengths are considered altered while 49% of the reach lengths are natural channels. Impounded reaches make up less than 1%, while reaches considered no definable channel 5%. Six stations were sampled for biology within the subwatershed.

Land use within the subwatershed is predominately cropland (71%), followed by rangeland (18%). Developed land use comprises 6% of the watershed, with the town of Ruthton present within the subwatershed. Wetlands comprise 3%, while forest less than 1% of the watershed area. Open water accounts for 2% of subwatershed area, and includes East Twin Lake (356 acres), West Twin Lake (220 acres), and Section Thirty-Three Lake (98 acres).

**Table 2. Aquatic life and recreation assessments on stream reaches: Upper Redwood River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.**

| WID<br>***Reach name***,<br>*Reach description* | Biological Station ID | Reach length (miles) | Use class* | Aquatic life indicators: Fish IBI | Invert IBI | Dissolved oxygen | TSS | Secchi Tube | Chloride | pH | Ammonia -$NH_3$ | Pesticides *** | Eutrophication | Aquatic life | Aquatic rec. (Bacteria) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **07020006-576, County Ditch 31**, *Unnamed cr to -96.035 44.262* | 17MN210 | 1.86 | WWm | EXS | EXS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-580, Unnamed Creek**, *Unnamed cr to -95.996 44.288* | 17MN211 | 2.75 | WWm | MTS | MTS | IF | IF | IF | -- | IF | IF | -- | IF | SUP | -- |
| **07020006-505, Redwood River**, *Headwaters to Coon Cr* | 17MN203, 17MN234, 92MN022, 92MN025 | 39.07 | WWg | EXS | EXS | IC | EXS | MTS | MTS | MTS | MTS | -- | IC | IMP | IMP |

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information

Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IC** = Inconclusive Information, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)

Key for Cell Shading: = existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water

*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

**Table 3. Lake assessments: Upper Redwood River Aggregated 12-HUC.**

| Lake name | DNR ID | Area (acres) | Max depth (ft) | Assessment method | Ecoregion | Secchi trend | Aquatic life indicators: | | | Aquatic recreation indicators: | | | Aquatic life use | Aquatic recreation use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish IBI | Chloride | Pesticides *** | Total phosphorus | Chlorophyll-a | Secchi | | |
| East Twin | 42-0070-00 | 249 | 22 | Deep Water | NGP | I | NS | MTS | -- | MTS | MTS | MTS | NS | FS |
| Sanderson | 42-0071-00 | 85 | 6 | Shallow Water | NGP | -- | -- | -- | -- | IF | -- | IF | -- | IF |
| West Twin | 42-0074-00 | 220 | 10 | Shallow Water | NGP | -- | -- | MTS | -- | MTS | MTS | MTS | -- | FS |
| Unnamed | 51-0091-00 | 6 | -- | Shallow Water | NGP | -- | -- | -- | -- | IF | -- | -- | -- | IF |

Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, **--** = not enough data
Abbreviations for Indicator Evaluations: **--** = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

## Summary

Three reaches within the Upper Redwood River aggregated 12-HUC were assessed for aquatic life use using fish and macroinvertebrate data (Table 2, Figure 15). One reach was found to be supporting of aquatic life use, while two reaches were found to be impaired for aquatic life use. Of the impaired reaches, County Ditch 31 is a new impairment, while the Redwood River is an existing impairment.

County Ditch 31 was found to have impaired fish and invertebrate communities, with FIBI and MIBI scores below the respective modified use class threshold. Habitat conditions for the aquatic communities were poor with low MSHA scores between the fish and macroinvertebrate sampling visits. Abundant algae and duckweed observed at the time of sampling suggests nutrient problems, and also explains the presence of an invertebrate community similar to that found in a wetland. The aquatic communities may also be stressed by potential diurnal oxygen swings with a DO saturation of 267% recorded at the time of one of the samples.

Unnamed Creek had fish and macroinvertebrate communities fully supporting for aquatic life using modified use class criteria. In 2017, the fish sample scored above the modified use upper confidence interval, and one sensitive fish species was found. The invertebrate score fell above the modified use threshold, within the upper confidence limit.

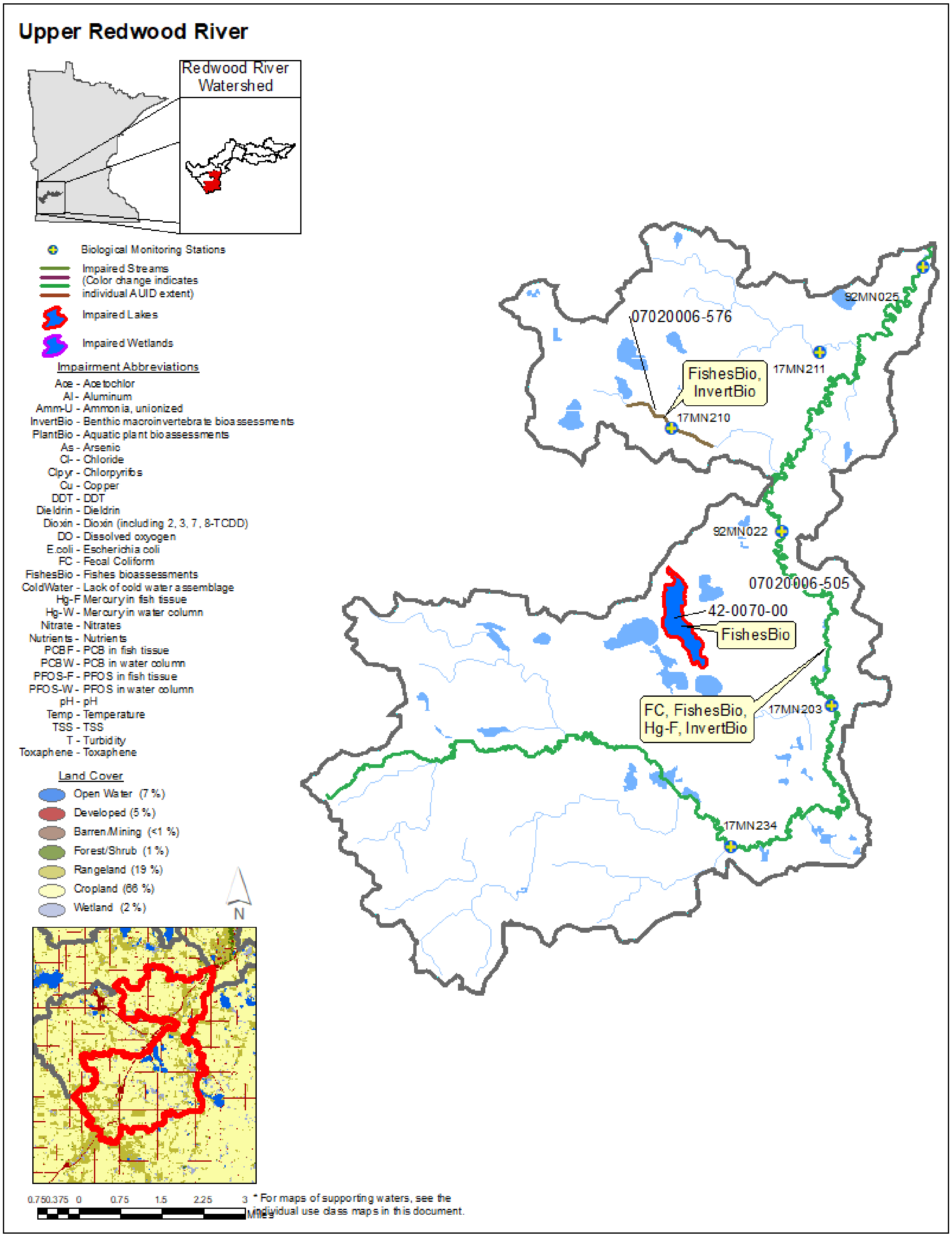
The headwaters of the Redwood River had an existing aquatic life impairment for the fish community from 2002. Current data from the 2017 monitoring effort confirmed this impairment, with both FIBI and MIBI scores from multiple stations falling below the general use threshold, and oftentimes below the lower confidence interval. While the reach scores poorly overall, habitat conditions, as well as FIBI and MIBI scores, trend in an upward direction as drainage area increases. This could correspond to more sustained flow conditions, as well as the tendency to leave riparian areas intact in larger streams.

Extensive data available from the headwaters reach of the Redwood River collected during intensive watershed monitoring efforts in 2017 and 2018. River nutrient and algae growth information fall close to impairment standards that would indicate poor conditions for aquatic life use. An impairment was not added for river nutrients during this effort, given the entire picture of the Redwood River. These reaches should be considered vulnerable to future nutrient impairment. Suspended solid concentrations had a small number of violations represented across all months and years in the dataset. Clarity data paired with suspended solid sampling events does not confirm the high sediment concentrations, source of suspended sediment could be organic. This headwaters reach is likely showing early signs of downstream problems in the Redwood River with suspended solids, an impairment was not added due to conflicting clarity data. Downstream watershed restoration and protection plans should considered work in the headwaters area to address elevated suspended sediment in turn improving conditions in this reach as well. Previous bacteria assessment resulted in an aquatic recreation use impairment, newer data indicates bacterial contamination persists.

Four lakes had assessment level data available for gauging aquatic recreation use condition. East and West Twin had data indicating good conditions for recreational use based on data collected in 2017 and 2018. Both are benefitting from small contributing watersheds due to their location in headwaters area of this watershed. An increasing trend in water clarity was detected in East Twin. Prioritization and protection tools identify both lakes as priority "A" waters, meaning controlling and reducing additional phosphorus inputs would benefit water quality significantly. Both lakes should be considered vulnerable to future recreational use impairment, developing protection strategies in these areas will be vital to preventing future degradation. Two smaller lakes had data available from smaller monitoring efforts, insufficient data was available during this assessment cycle for a confident assessment of recreation use condition.

The DNR conducted fish community inventory surveys in 2016 on East Twin Lake to provide data for aquatic life use during this assessment effort. Both surveys scored well below goals for aquatic communities set for this lake type. Low numbers of insectivore species observed, low proportion of insectivores, and low proportion of biomass from habitat dependent top carnivores negatively impacted the biological index scores below goals. Landscape disturbance in the contributing watershed and shoreline habitat quality could be area for stressor identification to explore. East Twin Lake was added to the impaired waters list for poor aquatic community health during this assessment cycle.

**Figure 15. Currently listed impaired waters by parameter and land use characteristics in the Upper Redwood River Aggregated 12-HUC.**



## Judicial Ditch 12 Aggregated 12-HUC HUC 0702000601-02

Judicial Ditch 12 (0702000601-02) aggregated 12-HUC (Figure 16) is the first and smallest subwatershed tributary to join the Redwood River. The predominant flow of streams is to the east, and includes the primary stream reach Judicial Ditch 12 (Tyler Creek), as well as County Ditch 14 and County Ditch 7. The subwatershed is 50 sq. mi. (32,000 acres) of mostly Lincoln County, but includes portions of Pipestone and Lyon Counties. With the exception of two-limited resource value waters stream reaches, all of the stream reaches are considered warmwater. Altered channels make up 54% of the stream reach lengths, while natural channels consist of 41% and no definable channel 4% of reaches. Four stations were sampled for biology.

Within the subwatershed, cropland (73%) is the dominant land use, followed by rangeland (16%). Forested areas account for less than 1% of watershed area. Wetlands comprise 2%, while open water less than 1% of the watershed. Lakes present include North Swan Lake (103 ac.) and South Swan Lake (109 ac.). The towns of Tyler and Florence lie within the subwatershed with developed areas comprising 7% of subwatershed area.

**Table 4. Aquatic life and recreation assessments on stream reaches: Judicial Ditch 12 Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.**

| **WID** ***Reach name***, *Reach description* | **Biological station ID** | **Reach length (miles)** | **Use class** | **Aquatic life indicators:** Fish IBI | Invert IBI | Dissolved oxygen | TSS | Secchi Tube | Chloride | pH | Ammonia -$NH_3$ | Pesticides *** | Eutrophication | **Aquatic life** | **Aquatic rec. (Bacteria)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **07020006-574, Unnamed Creek**, *Unnamed cr to T109 R44W S20, south line* | 17MN206 | 0.67 | WWm | MTS | EXS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-555, Unnamed Creek**, *Unnamed cr to Unnamed cr* | 17MN205 | 2.03 | WWg | EXS | -- | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-532, *Unnamed Creek***, *CD 2 to CD 7* | 17MN207 | 0.68 | WWg | EXS | EXS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-556, County Ditch 7**, *CD 40 to Unnamed cr* | 17MN209 | 5.28 | WWm | MTS | -- | IF | IF | IF | -- | IF | IF | -- | IF | SUP | -- |
| **07020006-515, County Ditch 14**, *T110 R44W S33, south line to JD 12* | | 6.09 | LRVW | -- | -- | -- | -- | -- | -- | IF | IF | -- | -- | -- | -- |
| **07020006-512, Judicial Ditch 12 (Tyler Creek)**, *CD 14 to Redwood R* | | 6.33 | LRVW | -- | -- | -- | -- | -- | -- | MTS | MTS | -- | -- | -- | IMP |

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2016 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐ = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

**Table 5. Lake water aquatic recreation assessments: Judicial Ditch 12 Aggregated 12-HUC.**

| Lake name | DNR ID | Area (acres) | Max depth (ft) | Assessment method | Ecoregion | Secchi Trend | Aquatic life indicators: | | | Aquatic recreation indicators: | | | Aquatic life use | Aquatic recreation use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish IBI | Chloride | Pesticides *** | Total phosphorus | Chlorophyll-a | Secchi | | |
| North Swan | 41-0004-00 | -- | -- | Shallow Lake | NGP | -- | -- | -- | -- | IF | IF | -- | -- | IF |
| South Swan | 41-0010-00 | -- | -- | Shallow Lake | NGP | -- | -- | -- | -- | IF | IF | -- | -- | IF |

Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, **--** = not enough data
Abbreviations for Indicator Evaluations: **--** = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

## Summary

Within the Judicial Ditch 12 aggregated 12-HUC, 4 reaches were assessed for aquatic life using fish community data (Table 4, Figure 16). Of those 4 reaches, macroinvertebrate data was included in assessments of two of those reaches. One reach was found to be supporting for aquatic life use based on fish data. Three reaches were impaired for aquatic life. Two reaches are Limited Resource Value Waters and were not assessed for aquatic life.

Unnamed Creek (-574) fish community data meets aquatic life use standards with an FIBI score above the modified use threshold for a low gradient fish class stream. Among the fish sampled in 2017, two darter species were present, with one of them considered sensitive. Macroinvertebrate data failed to meet modified aquatic life use standards, with scores falling below the modified use threshold, below the confidence interval. The macroinvertebrate community suffered from having very low diversity, very high numbers of intolerant taxa, and a community reflective of a poor quality wetland, with no EPT taxa.

Unnamed Creek (-555) was only sampled for fish in 2017. Of the sample, 92% of the fish were of species considered tolerant. With a fish community dominated by tolerant taxa, the FIBI score for this reach was below the lower confidence interval for general use, resulting in this reach being impaired for aquatic life based on fish community data.

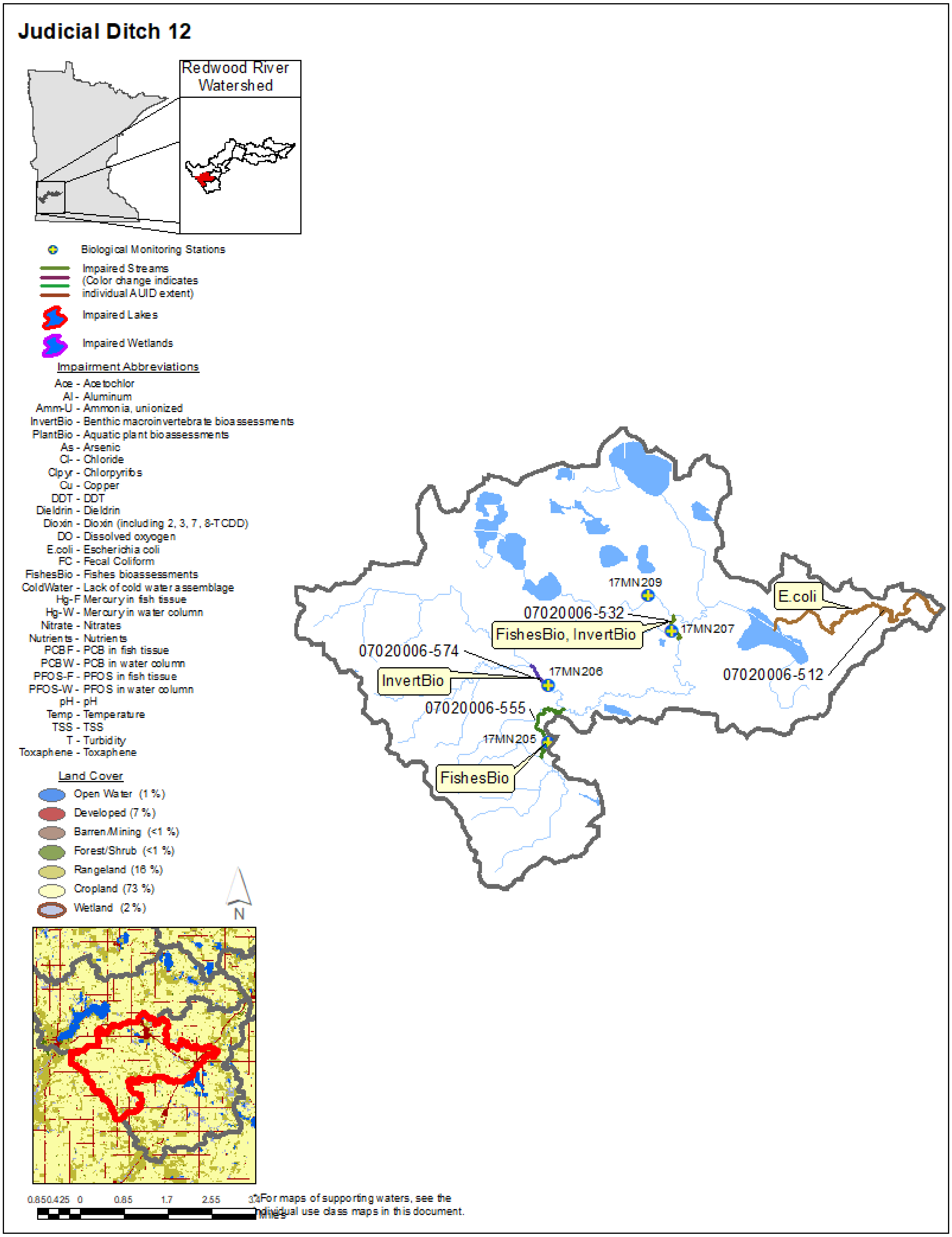
Both fish and macroinvertebrates were sampled on Unnamed Creek (-532) in 2017. Similar to Unnamed Creek (-555), the fish community in this reach was also dominated by tolerant species, failing to meet general use aquatic life criteria despite a lower threshold for low gradient fish class streams. The MIBI fell below the general use threshold, within the lower confidence interval. The macroinvertebrates looked much better than at Unnamed Creek (-574), with a more typical stream community, but low numbers of intolerant taxa and filterers depressed the MIBI score.

With only the fish community sampled in 2017, County Ditch 7 was found to be supporting of aquatic life, based on modified use criteria. With one sensitive fish species collected, the FIBI scored above the upper confidence interval.

Largest water chemistry dataset available for the downstream reach of Judicial Ditch 12 (Tyler Creek), this reach is designated Limited Resource Value with less stringent standards. Bacterial contamination indicative of poor water quality resulted in a new impairment during this assessment effort. Smaller tributaries to Judicial Ditch 12 had limited datasets for complete water chemistry assessment.

Two lakes had single data points collected in 2015 by DNR shallow lake program crews. North Swan and South Swan are not lake types typically targeted through intensive watershed monitoring efforts for aquatic recreation use check-ups. Overall, insufficient information for a complete assessment of recreational use designations of these waterbodies.

**Figure 16. Currently listed impaired waters by parameter and land use characteristics in the Judicial Ditch 12 Aggregated 12-HUC.**



## Coon Creek Aggregated 12-HUC HUC 0702000602-01

Coon Creek (0702000602-01) aggregated 12-HUC (Figure 17) subwatershed is the second largest tributary to the Redwood River. It is also the westernmost subwatershed within the major watershed. Drainage area encompasses 97 sq. mi. (62,000 ac.) of Lincoln and Lyon Counties. Coon Creek is the primary watercourse within the subwatershed, as well as its tributary Judicial Ditch 30. Norwegian Creek is a significant tributary to Lake Benton. All of the streams are considered warmwater. Natural stream reaches account for 44 % of the reach lengths, while altered channels 41 % of reach lengths. No definable channel comprises 14 % of reach lengths, and impounded less than 1 %. Five stations were sampled for biology.

Land use within the watershed is mostly cropland (66%), followed by rangeland (19%). Developed land accounts for 5% of the subwatershed area, with the town of Lake Benton present. Only a small portion of the watershed is wetland (2%), and even less is forested (<1%). Lake Benton (2,699 ac.) is the largest lake found within the subwatershed, along with Dead Coon Lake (547 ac.). Open water comprises 7% of the watershed area.

**Table 6. Aquatic life and recreation assessments on stream reaches: Coon Creek Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.**

| WID<br>***Reach name***,<br>*Reach description* | Biological station ID | Reach length (miles) | Use class | Aquatic life indicators: Fish IBI | Invert IBI | Dissolved oxygen | TSS | Secchi Tube | Chloride | pH | Ammonia -$NH_3$ | Pesticides *** | Eutrophication | Aquatic life | Aquatic rec. (Bacteria) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **07020006-527, Norwegian Creek**, *Unnamed cr to Lk Benton* | 92MN026 | 3.74 | WWg | EXS | EXS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-554, Judicial Ditch 30**, *Unnamed ditch to Coon Cr* | 17MN231 | 1.74 | WWm | EXS | MTS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-569, Coon Creek**, *Lk Benton to -96.150 44.343* | | 9.30 | WWg | -- | -- | -- | -- | MTS | -- | -- | -- | -- | -- | IF | IMP |
| **07020006-570, Coon Creek**, *-96.150 44.343 to Redwood R* | 17MN212, 17MN240, 92MN027 | 28.42 | WWg | -- | EXS | IF | IC | MTS | MTS | MTS | MTS | -- | IF | IMP | IMP |

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IC** = Inconclusive Information, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2016 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

**Table 7. Lake assessments: Coon Creek Aggregated 12-HUC.**

| Lake name | DNR ID | Area (acres) | Max depth (ft) | Assessment method | Ecoregion | Secchi trend | Aquatic life indicators: | | | Aquatic recreation indicators: | | | Aquatic life use | Aquatic recreation use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish IBI | Chloride | Pesticides *** | Total phosphorus | Chlorophyll-a | Secchi | | |
| Dead Coon | 41-0021-01 | 536 | 9 | Shallow Lake | NGP | -- | EXS | MTS | -- | EXS | MTS | IC | NS | NS |
| Slough | 41-0022-00 | 160 | 5 | Shallow Lake | NGP | -- | -- | IF | -- | IF | IF | IF | IF | IF |
| Benton | 41-0043-00 | 2646 | 9 | Shallow Lake | NGP | -- | EXS | MTS | -- | EXS | EXS | IC | NS | NS |
| Pickeral | 41-0051-00 | 21 | -- | Shallow Lake | NGP | -- | -- | -- | -- | IF | IF | IF | -- | IF |

Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, **--** = not enough data
Abbreviations for Indicator Evaluations: **--** = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information, IC = Inconclusive Information.
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2016 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐= insufficient information.

## Summary

Three stream reaches were assessed for aquatic life within the Coon Creek aggregated 12-HUC, and were found to be impaired (Table 6, Figure 17). Two of the reaches were assessed with fish and macroinvertebrate data, while the downstream most reach of Coon Creek (-570) was assessed with only macroinvertebrate and water chemistry data for the 2019 assessment. During the 2017 monitoring effort, three stations on Coon Creek (-570) were unable to be sampled for fish due to periods of higher than normal flows, and the logistics of sampling other watersheds across the state.

A tributary to Lake Benton, Norwegian Creek was found to have impaired fish and invertebrate communities with FIBI and MIBI scores below their respective general use threshold and lower confidence interval. Of the fish sampled in 2017, tolerant (97% individuals) and very tolerant (85% individuals) fish species dominated the sample. The invertebrate community was impacted by a lack of intolerant taxa, and a low numbers of clinger and filterer taxa, indicative of a lack of sustained flows.

Judicial Ditch 30, a modified use tributary to Coon Creek, was also found to have an impaired fish community in the 2017 monitoring effort, while invertebrates showed a supporting a condition. Similar to Norwegian Creek, tolerant and very tolerant fish species comprised almost 99%

of the individuals in the sample. Invertebrates had relatively higher diversity as well as higher proportion of POET taxa (macroinvertebrates of the plecoptera, odonata, ephemeroptra, and trichopetera orders). Very poor habitat conditions in the stream also contributed to the fish impairment.

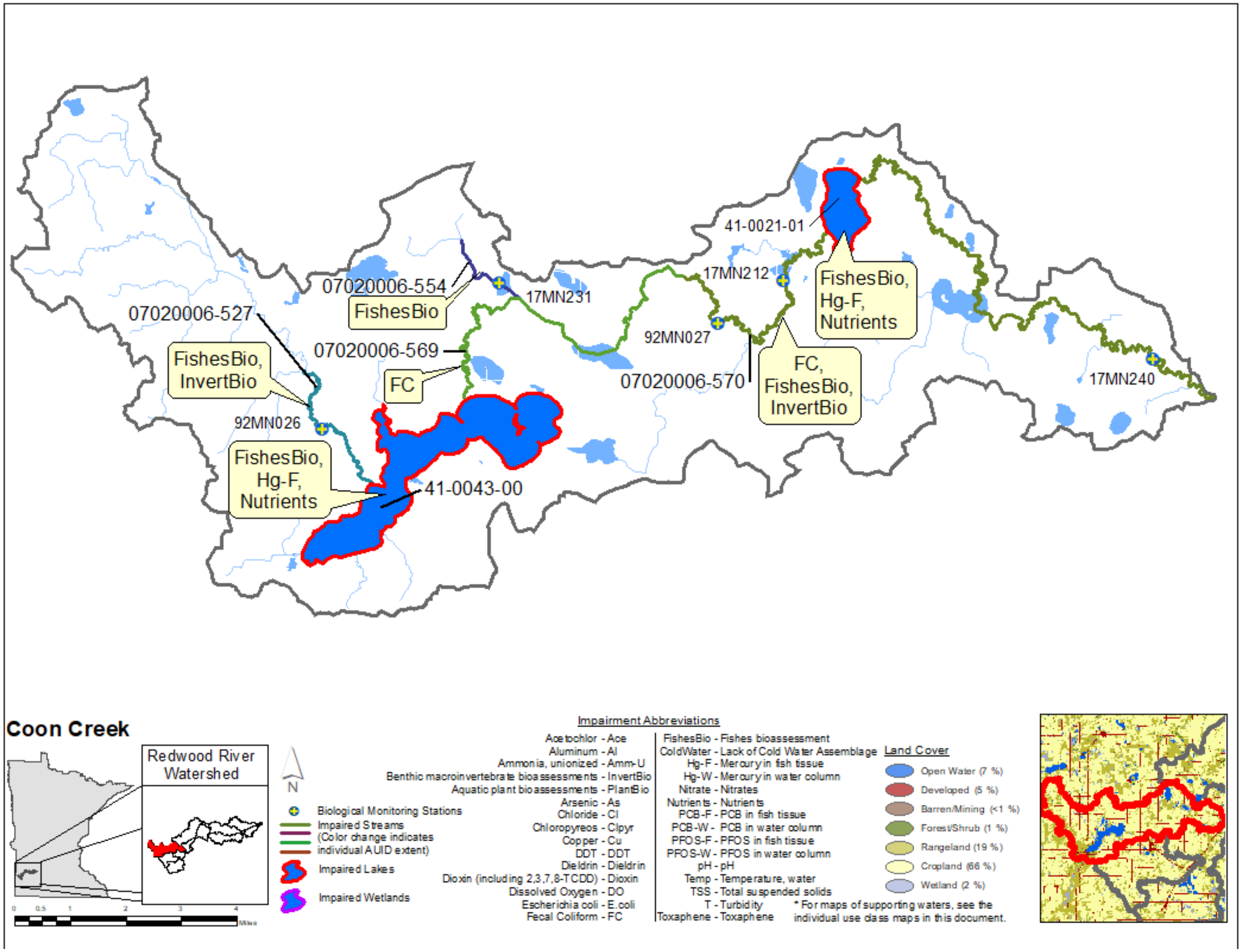
The downstream reach on Coon Creek (-570) had no current fish data from the 2017 monitoring effort but has a current impairment for fish based on previous monitoring. Three stations were sampled for invertebrates in 2017, and all reaches indicated an impaired condition, with scores below the general use threshold and confidence interval. A lack of EPT and clinger taxa contribute to the low scores. The reach was first listed as impaired in 2004, previous fish community data scored below the general use threshold. This reach is downstream of Dead Coon Lake, and water quality related issues there will impact the reach, notably with a fish kill that occurred in late summer of 2014.

Two lakes in this subwatershed had sufficient datasets for recreational use assessment. Dead Coon Lake was previously deemed impaired in 2009 based on data from 2002 and 2007. Newer phosphorus data collected during this effort is still indicative of poor recreational water quality, notable though is that response variables are meeting or close to meeting standards, which could be attribute to temporal variability or reflection of improvements. Benton is one of the larger lakes in southwestern Minnesota, previously listed 2004 for poor recreational use conditions. Newer data available from three years, excessive nutrient concentrations and algae blooms persist, clarity is near the impairment threshold which may be attributed to the specific type of algae species present in the lake. Internal loading from frequent mixing events due to the shallow basin and large fetch will present challenges to long term water quality improvements. The initial impairment decisions will remain on both lakes following this assessment effort.

Fish community surveys were conducted in 2011 and 2017 on Lake Benton to provide assessment level data for aquatic life use designation. Both surveys resulted in low biological health scores driven by low biomass of insectivores (yellow perch, centrarchrids) , high proportion of tolerant species (black bullheads, common carp) , and lack of top carnivores (northern pike). Dead Coon Lake had fish community surveys from 2013 and 2017, both resulting in fish community health scores well below establish goals for this lake type. Lack of insectivores (johnny darter, yellow perch, sunfish) and low proportion of top carnivores (northern pike) were the main drivers of the poor fish community scores. Potential stressor review indicates landscape disturbance and shoreline habitat health could be impacting aquatic communities.

Assessment level datasets available for the downstream reach of Coon Creek prior to the confluence with the Redwood River. Nutrient concentrations are elevated, but algae concentrations are low. Suspended sediment data is indicative of being on the verge of negatively impacting aquatic communities. Clarity data paired with suspended sediment violations does not confirm low clarities typically associated with high sediment levels. This reach was not listed impaired do to borderline and conflicting data, despite that final judgment, this subwatershed could be a contributing factor to the downstream impairments for suspended sediment on the Redwood River, follow-up work should continue to consider this area for potential improvement activities. Bacterial contamination appears to be persisting although individual extreme violations are not seen in the recent dataset, the initial impairment for aquatic recreation use will remain. Smaller tributaries to Coon Creek do not have complete water chemistry datasets for confident viewpoint of aquatic life use conditions.

**Figure 17. Currently listed impaired waters by parameter and land use characteristics in the Coon Creek Aggregated 12-HUC.**



## Middle Redwood River Aggregated 12-HUC HUC 0702000603-01

The Middle Redwood River (0702000603-01) aggregated 12-HUC (Figure 18) is a mainstem Redwood River subwatershed totaling 81 sq. mi. (52,000 ac.) of Lyon County. The primary watercourse is the Redwood River, which predominately flows northeast, but also includes some tributaries, most notably of these being County Ditch 60 and an Unnamed Creek. All of the stream reaches are considered warmwater, with a 7 mi. reach of the Redwood River flowing through Camden State Park a DNR designated trout stream, which is managed as a put and take trout fishery. Much of the mainstem Redwood River is a natural channel with 62% of the stream reach lengths within the subwatershed considered natural channels. Altered channels account for 32% of the reach lengths, which includes a channelized diversion on the Redwood River around the city of Marshall. No definable channel accounts for 6% of reach lengths. Eight stations were sampled for biology.

Marshall, the largest city within the major watershed can be found within this subwatershed, as well as the towns of Russell and Lynd. With these, developed land use accounts for 14% of the land use. Agriculture is also prominent, with 68% of the subwatershed cropland. Rangeland comprises 10% of the subwatershed area, while forest 3%, wetland 4%, and open water 1%. Lakes within the subwatershed include Clear Lake (63 ac.) and Brawner Lake (27 ac.). Camden State Park, the major watershed’s only state park, is also found within this subwatershed. Barren/mining accounts for less than 1% of the land use.

**Table 8. Aquatic life and recreation assessments on stream reaches: Middle Redwood River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.**

| WID *Reach name*, *Reach description* | Biological station ID | Reach length (miles) | Use class | Aquatic life indicators: Fish IBI | Invert IBI | Dissolved oxygen | TSS | Secchi Tube | Chloride | pH | Ammonia -$NH_3$ | Pesticides *** | Eutrophication | Aquatic life | Aquatic rec. (Bacteria) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **07020006-510, Redwood River**, *Coon Cr to T110 R42W S20, north line* | 15MN203 | 3.38 | WWg | MTS | MTS | IF | EXS | EXS | -- | MTS | IF | -- | IF | IMP | IMP |
| **07020006-513, Redwood River**, *T110 R42W S17, south line to T111 R42W S32, east line* | 90MN029 | 6.72 | WWg | MTS | MTS | IF | IF | IF | -- | IF | IF | -- | IF | SUP | -- |
| **07020006-559, Unnamed Creek**, *Headwaters to Redwood R* | 17MN221 | 7.55 | WWm | EXS | -- | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-578, County Ditch 60**, *Unnamed cr to -95.698 44.496* | 17MN217 | 4.22 | WWm | EXS | EXS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-502, Redwood River**, *T111 R42W S33, west line to Threemile Cr* | 92MN030, 92MN031, 92MN032, 92MN033 | 28.15 | WWg | EXS | EXS | IF | EXS | EXS | MTS | MTS | MTS | -- | IF | IMP | IMP |

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2016 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐ = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

**Table 9. Lake assessments: Middle Redwood River Aggregated 12-HUC.**

| Lake name | DNR ID | Area (acres) | Max depth (ft) | Assessment method | Ecoregion | Secchi Trend | Aquatic life indicators: | | | Aquatic recreation indicators: | | | Aquatic life use | Aquatic recreation use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish IBI | Chloride | Pesticides *** | Total phosphorus | Chlorophyll-a | Secchi | | |
| Brawner | 42-0054-00 | 27 | 18 | Deep Water | NGP | -- | -- | IF | -- | IF | IF | IF | IF | IF |
| Clear | 42-0055-00 | 63 | 11 | Shallow Water | NGP | -- | -- | IF | -- | EXS | EXS | EXS | -- | NS |

Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, **--** = not enough data
Abbreviations for Indicator Evaluations: **--** = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2016 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐= insufficient information.

## Summary

In the Middle Redwood River aggregated 12-HUC, 5 reaches were assessed for aquatic life (Table 8, Figure 18). Two stream reaches were on tributaries to the Redwood River, and were found to be impaired for aquatic life. Of the three mainstem Redwood River stream reaches, one was found to be fully supporting of aquatic life, while the upstream and downstream reaches of the Redwood River are impaired for aquatic life.

The upstream reach of the Redwood River was sampled in 2016 as part of a separate monitoring effort than the IWM effort in 2017. With relatively favorable habitat conditions on this reach, the fish community had four sensitive fish species, and tolerant fish species accounted for only 32% of the individuals in the sample. Very tolerant fish species comprised only 8% of the individuals in the sample. As a result of these high quality attributes the fish community was found to be supporting of aquatic life using general use criteria. Similarly, the macroinvertebrates had good overall diversity, and high number of POET and clinger taxa, resulting in a MIBI score above the general use threshold, above the upper confidence interval.

Just downstream, the Redwood River (-513) shown to be fully supporting for aquatic life based on fish and macroinvertebrate data. Both fish and macroinvertebrate communities exhibited FIBI scores above the general use threshold. Similar to the upstream reach on the Redwood River, good habitat conditions exist, and up to five sensitive fish species were present in the samples. Habitat conditions on this reach are likely bolstered by the higher gradient found on the slope of the Coteau des Prairie. This reach is also a DNR designated trout stream managed as a put and take fishery. Much of this reach is within Camden State Park. For the purpose of assessing aquatic life on this reach, the designation of this reach was changed to warmwater in order to better represent the aquatic community within the reach.

One of the tributaries to the Redwood River, Unnamed Creek was found to be impaired for aquatic life based on fish community data. No fish were sampled in 2017 on this modified use stream, resulting in an FIBI score of zero. No fish present is likely attributed to a five-foot barrier present a half mile downstream of the sampling location.

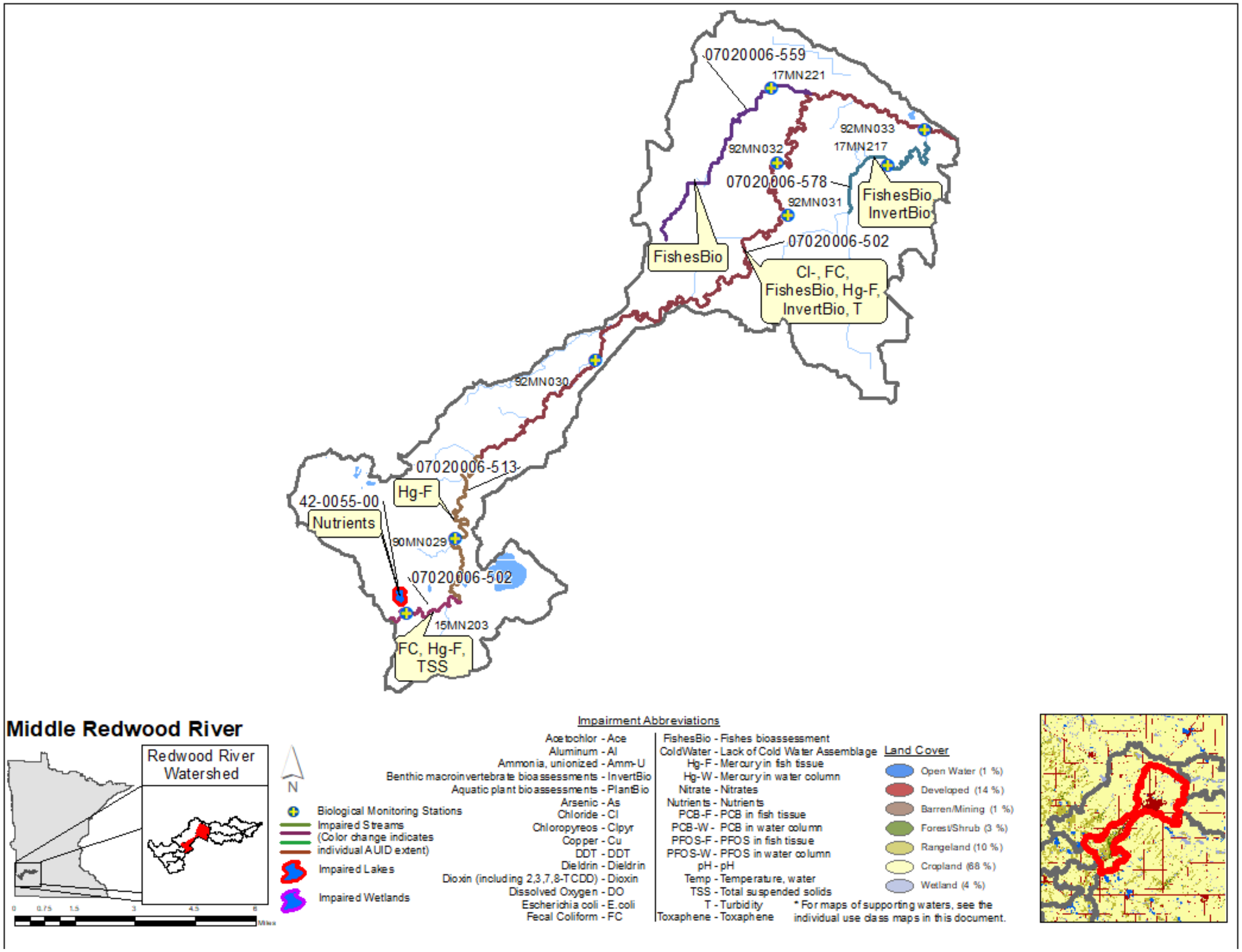
Another tributary to the Redwood River, County Ditch 60 also had impaired fish and macroinvertebrate communities based on modified use criteria. For two sampling visits, tolerant fish species comprised more than 70% of the individuals in each sample. The macroinvertebrate community was dominated by a few tolerant taxa, and lacked adequate numbers of important POET and clinger taxa.

First listed as impaired for aquatic life based on the fish community in 2002, the downstream reach of the Redwood River in this subwatershed still exhibited an impaired fish community, as well as in impaired invertebrate community, with data from 2017 monitoring. Among the four stations and numerous sampling visits representing this reach, FIBI and MIBI scores showed somewhat contrasting results. Fish scores ranged from just slightly above and below the general use threshold at the upstream stations, to below the lower confidence interval at the downstream station, while macroinvertebrates showed poor scores upstream, with improved scores moving downstream. Across this reach, the abundance of sensitive fish species seemed to decline from upstream to downstream. Likewise, the abundance of species considered very tolerant seemed to increase in a downstream direction. Despite its current status as impaired, some improvement in FIBI scores has occurred, particularly at the upstream stations. All four stations previously had FIBI scores below the lower confidence interval with monitoring that occurred in 2001 and 2005. Historic macroinvertebrate data agrees with current data; data collected previously on 92MN030 show a non-supporting macroinvertebrate condition, while data collected previously at 92MN033 show a supporting condition.

Assessment level datasets available for Clear Lake collected between 2017 and 2018; all three recreational use parameters are clearly not meeting regional standards for good water quality. Shallow nature of the basin likely leading to repeated internal loading events plus new surface water inputs. Single data point from Brawner Lake in 2017 would indicate good recreational water quality. During the assessment, it was discussed that the lake is an old gravel pit periodically drained for maintenance on a nearby control structure.

Robust water chemistry datasets available for the upstream and downstream Redwood River reaches within this subwatershed. The upstream Redwood River reach below the confluence with Coon Creek has data through a variety of monitoring projects over the entire data window, clearly indicating significantly elevated suspended sediment and phosphorus concentrations that are problematic for aquatic communities. The middle Redwood River reach has limited chemistry data but would likely exhibit similar sediment and nutrient problems given the status of the downstream reaches. The lower Redwood River reach within this subwatershed has extensive amounts of data exhibiting common patterns seen throughout this watershed. Average nutrient concentrations are astronomically high, response is not confirmed in the algal data. Suspended solid data triggered an aquatic life use impairment in 2002; newer data confirms the initial issue. Bacterial contamination persists from the initial listing based on newer data. Newer chloride data collected in 2017 since the initial chloride impairment in 2007 does not have violations, more representative monitoring across a greater period of time would be needed to ensure chloride concentrations have improved.

**Figure 18. Currently listed impaired waters by parameter and land use characteristics in the Middle Redwood River Aggregated 12-HUC.**



## Threemile Creek Aggregated 12-HUC HUC 0702000604-01

The Threemile Creek (0702000604-01) aggregated 12-HUC (Figure 19) is the largest subwatershed tributary to the Redwood River and is located in the northwest portion of the major watershed. Consisting mostly of Threemile Creek, and it's mostly unnamed tributaries, this subwatershed totals 117 sq. mi. (75,000 ac.) of mostly Lyon County, with a small portion in Lincoln County. Threemile Creek predominantly flows northeast before joining the Redwood River several miles downstream of Marshall. All of the streams are considered warmwater with 50% of the stream reach lengths considered altered, and 39% natural channels. Impounded stream reaches account for less than 1%, while no definable channel comprises 11% of the reach lengths. Seven stations were sampled for biology.

Agriculture dominates land use with 81% of the subwatershed area used for crops. Developed makes up 5%, while barren/mining less than 1% of subwatershed area. The only town present within the subwatershed is Ghent. Rangeland comprises 9%, forest 1%, wetland 3%, and open water 1% of the subwatershed area. Lakes within the subwatershed include Wood Lake (323 ac.), Island Lake (164 ac.), and Goose Lake (145 ac.).

**Table 10. Aquatic life and recreation assessments on stream reaches: Threemile Creek Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.**

| | | | | Aquatic life indicators: | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WID** ***Reach name, Reach Description*** | **Biological station ID** | **Reach length (miles)** | **Use class** | **Fish IBI** | **Invert IBI** | **Dissolved oxygen** | **TSS** | **Secchi Tube** | **Chloride** | **pH** | **Ammonia -$NH_3$** | **Pesticides ***** | **Eutrophication** | **Aquatic life** | **Aquatic rec. (Bacteria)** |
| **07020006-558, Unnamed Creek**, *Unnmaed ditch to Threemile Cr* | 17MN215 | 0.88 | WWm | MTS | EXS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-572, Unnamed Creek**, *-95.888 44.532 to -95.855 44.535* | 17MN226 | 2.45 | WWm | MTS | MTS | IF | IF | IF | -- | IF | IF | -- | IF | SUP | -- |
| **07020006-573, Unnamed Creek**, *-95.855 44.535 to Threemile Cr* | 17MN225 | 1.86 | WWg | EXS | EXS | IF | IF | IF | -- | IF | | -- | IF | IMP | -- |
| **07020006-564, Threemile Creek**, *Headwaters to T113 R41W S33, east line* | 17MN228, 17MN230, 17MN233 | 39.06 | WWg | EXS | EXS | IF | IF | MTS | -- | MTS | MTS | MTS | IF | IMP | IMP |
| **07020006-565, Threemile Creek**, *T113 R41W S34, west line to T112 R41W S12, east line* | 92MN036 | 6.19 | WWm | MTS | MTS | IF | EXS | MTS | MTS | MTS | MTS | IMP | IF | IMP | IMP |
| **07020006-566, Threemile Creek**, *T112 R40W S7, west line to Redwood R* | | 3.31 | WWg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | IMP | IMP |

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

**Table 11. Lake assessments: Threemile Creek Aggregated 12-HUC.**

| Lake name | DNR ID | Area (acres) | Max depth (ft) | Assessment method | Ecoregion | Secchi Trend | Aquatic life indicators: | | | Aquatic recreation indicators: | | | Aquatic life use | Aquatic recreation use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish IBI | Chloride | Pesticides *** | Total phosphorus | Chlorophyll-a | Secchi | | |
| Wood | 42-0078-00 | 323 | 15 | Shallow Water | NGP | -- | EXS | MTS | -- | EXS | MTS | MTS | NS | IC |
| Goose | 42-0093-00 | 145 | 8.5 | Shallow Water | NGP | -- | -- | MTS | -- | EXS | MTS | EXS | IF | NS |
| Island | 42-0096-00 | 164 | -- | Shallow Water | NGP | -- | EXS | -- | -- | EXS | EXS | EXS | IF | NS |

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains
Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2014 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐= insufficient information.

## Summary

Five reaches were assessed for aquatic life in the Threemile Creek aggregated 12-HUC (Table 10, Figure 19) with data from the 2017 monitoring effort. One reach had an existing aquatic life impairment for turbidity from 2004 with no new data. For of the stream reaches with current data were found to be impaired for aquatic life, while one reach was fully supporting.

A tributary to Threemile Creek, Unnamed Creek (-558) had a fish community supportive of the modified use standard, while the macroinvertebrate community score fell below the modified standard. Darter species made up over 50% of the fish sample, while tolerant species comprised less than 40% of the sample, resulting in FIBI scores above the modified threshold and confidence interval. A lack of clinger, filterer, and intolerant taxa, depressed the MIBI score.

Unnamed Creek (-572) was sampled once for invertebrates, and twice for fish in 2017, with all scores above the threshold, meeting the modified use criteria for both macroinvertebrates and fish.

Just downstream from Unnamed Creek (-572), Unnamed Creek (-573) is another tributary to Threemile Creek found to be impaired for aquatic life using general use criteria. Fish and macroinvertebrates sampled in 2017 resulted in FIBI and MIBI scores below the lower confidence interval. No sensitive fish species were collected, and tolerant fish species made up 75% of the individuals in the sample. Macroinverbrate community was lacking important EPT and clinger taxa, and was dominated by tolerant taxa.

On the mainstem Threemile Creek, the upstream reach (-564) showed fish and macroinvertebrate communities impaired for aquatic life with general use criteria. With three stations along its length sampled in 2017, all corresponding FIBI scores were below the lower confidence interval, and the majority of the samples consisted of tolerant fish species (70-84% of individuals). The two upstream stations showed macroinvertebrate scores below the general use threshold, and the downstream station (17MN228) scored above the threshold, above the upper confidence limit.

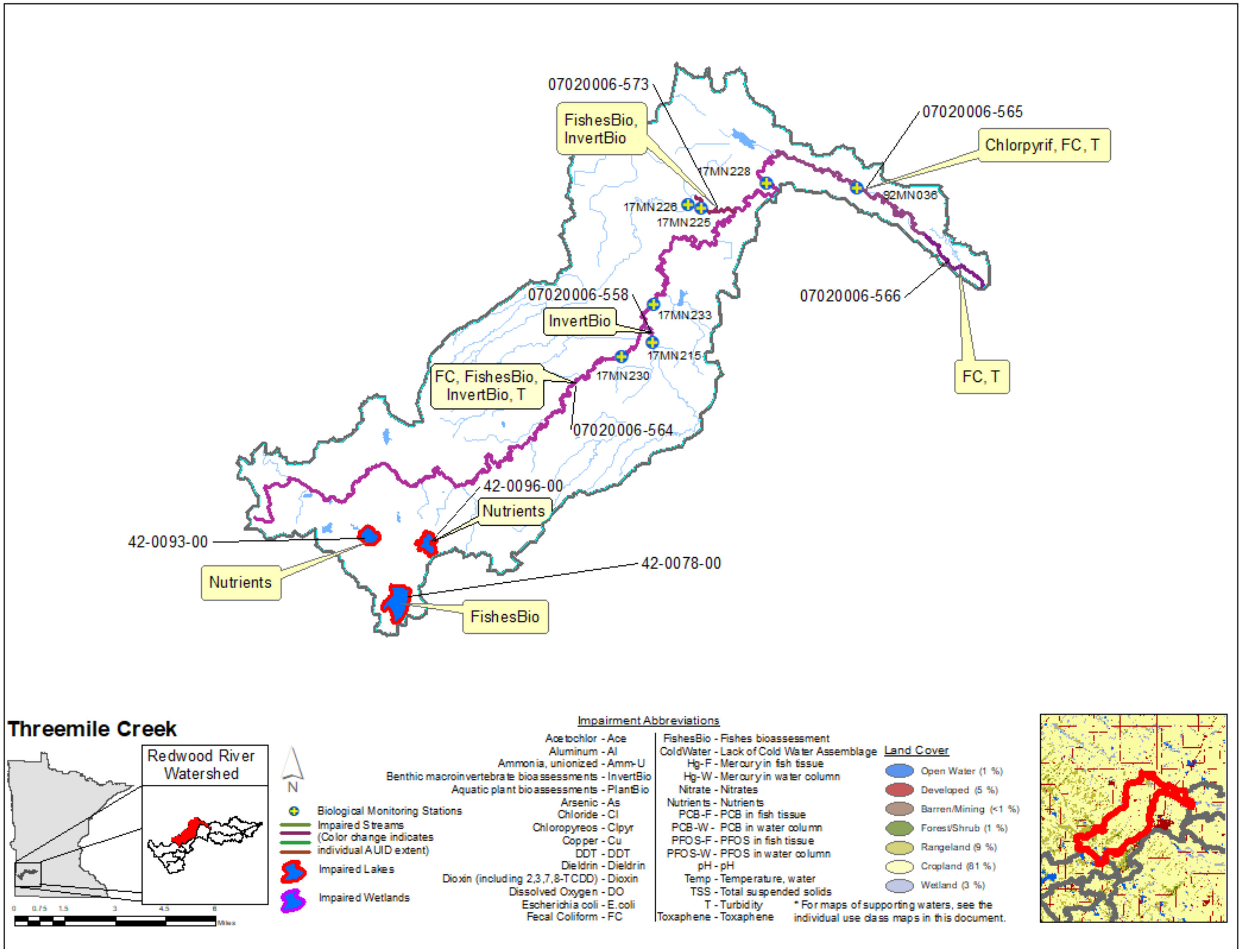
The downstream reach of Threemile Creek (-565) showed supporting fish and macroinvertebrate communities for a modified use stream. In 2017, the FIBI scored above the threshold, with one sensitive fish species collected in the sample. The MIBI scored above the modified threshold, within the upper confidence limit.

During previous assessment efforts, Threemile Creek had excess sediment in the water column and low water clarity indicative of poor water quality for supporting healthy aquatic communities. Newer data since the initial impairment shows poor water quality for aquatic community health persists considering the suspended sediment dataset, local efforts are underway to address these issues. Elevated bacterial contamination triggered a recreation use listing on Threemile Creek in 2004, newer data confirms the initial listing, restoration strategies are underway to address this issue.

Three lakes will this subwatershed had assessment level data for recreation use designation. Goose Lake was previously listed impaired in 2009 based on poor recreation conditions seen across two years of data. This lake was monitored during the 2017 and 2018 IWM effort, phosphorus and water clarity are still showing signs of poor recreation use conditions. Island Lake was sampled during the same timeframe, with all three-assessment parameters indicating poor recreation conditions for use. Wood Lake has conflicting recreation use data, nuisance algal blooms may have not been characterized well during specific monitoring dates, a confident assessment of recreation use conditions cannot be made at this time. All three basins are shallow, internal loading from frequent open water mixing events are likely playing an additional role in poor recreation conditions coupled with current surface water sources of nutrients.

Fish community surveys to gauge aquatic life health were conducted in 2012 and 2016 on Wood Lake; both indicate poor aquatic life community health. Community health scores were negatively influenced by the lack of insectivores species (Bluegill, Yellow Perch), high proportion of tolerant species (Common Carp, Black Bullhead), and low proportion of top carnivores (Largemoth Bass). Preliminary stressor identification reveals watershed disturbance and low shoreline health as potential drivers to poor conditions for healthy aquatic communities. Island Lake had fish community work done in 2017 and 2018 indicating poor fish community health. Uncertainty of winterkill conditions on this isolated lake basin prevented a confident assessment of aquatic life use conditions during this assessment effort.

**Figure 19. Currently listed impaired waters by parameter and land use characteristics in the Threemile Creek Aggregated 12-HUC.**



## Clear Creek Aggregated 12-HUC HUC 0702000605-01

Clear Creek (0702000605-01) aggregated 12-HUC (Figure 20) is the third largest (83 sq. mi., 53,000 ac.) subwatershed tributary to the Redwood River and is located south of the mainstem river between Marshall and Seaforth. Most of the subwatershed is in Redwood County, with a western smaller portion in Lyon County. Besides the main waterbody Clear Creek, the subwatershed also includes several tributaries to Clear Creek. All of the stream reaches are warmwater and channelization is prevalent with 81% of the stream reach lengths altered, and only 6% natural channels. No definable channel accounts for 13% of the stream reach lengths. Four stations were sampled for biology.

The dominant land use for the subwatershed is cropland (91%), which is the second highest percentage than most of the subwatersheds in the major watershed. Following cropland, developed areas account for 5% of subwatershed area, and wetlands 2%. Open water comprises 1% of subwatershed area, while rangeland, forest, and barren/mining comprise less than 1% of watershed area. The only towns present in the subwatershed include Milroy and Seaforth.

**Table 12. Aquatic life and recreation assessments on stream reaches: Clear Creek Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.**

| WID *Reach name, Reach description* | Biological station ID | Reach length (miles) | Use class | Aquatic life indicators: Fish IBI | Invert IBI | Dissolved oxygen | TSS | Secchi Tube | Chloride | pH | Ammonia -$NH_3$ | Pesticides *** | Eutrophication | Aquatic life | Aquatic rec. (Bacteria) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **07020006-562, Unnamed Creek**, *Headwaters to Clear Cr* | 17MN229 | 3.86 | WWg | MTS | -- | IF | IF | IF | -- | IF | IF | -- | IF | SUP | -- |
| **07020006-517, Judicial Ditch 14 & 15**, *Headwaters to Clear Cr* | 17MN213 | 7.86 | WWm | MTS | MTS | IF | IF | IF | -- | IF | IF | -- | IF | SUP | -- |
| **07020006-567, Clear Creek**, *Headwaters to -95.323 44.466* | 17MN214 | 22.80 | WWm | IC | MTS | IF | IF | MTS | -- | IF | IF | -- | IF | IMP | IMP |
| 07**020006-568, Clear Creek**, *-95.323 44.466 to Redwood R* | 92MN043 | 2.50 | WWg | MTS | EXS | IF | EXS | MTS | MTS | MTS | IC | -- | IC | IMP | IMP |

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Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

## Summary

Within the Clear Creek aggregated 12-HUC, four reaches were assessed for aquatic life (Table 12, Figure 20). Two reaches on tributaries to Clear Creek were found to be supporting of aquatic life. Two reaches on Clear Creek were found to be impaired for aquatic life.

The fish community was found to be supporting of aquatic life using general use criteria on Unnamed Creek, a tributary to Clear Creek. From the sample in 2017, the FIBI scored above the threshold and upper confidence interval. Despite being channelized at the monitoring station, habitat conditions showed some quality with the MSHA score was over 50.

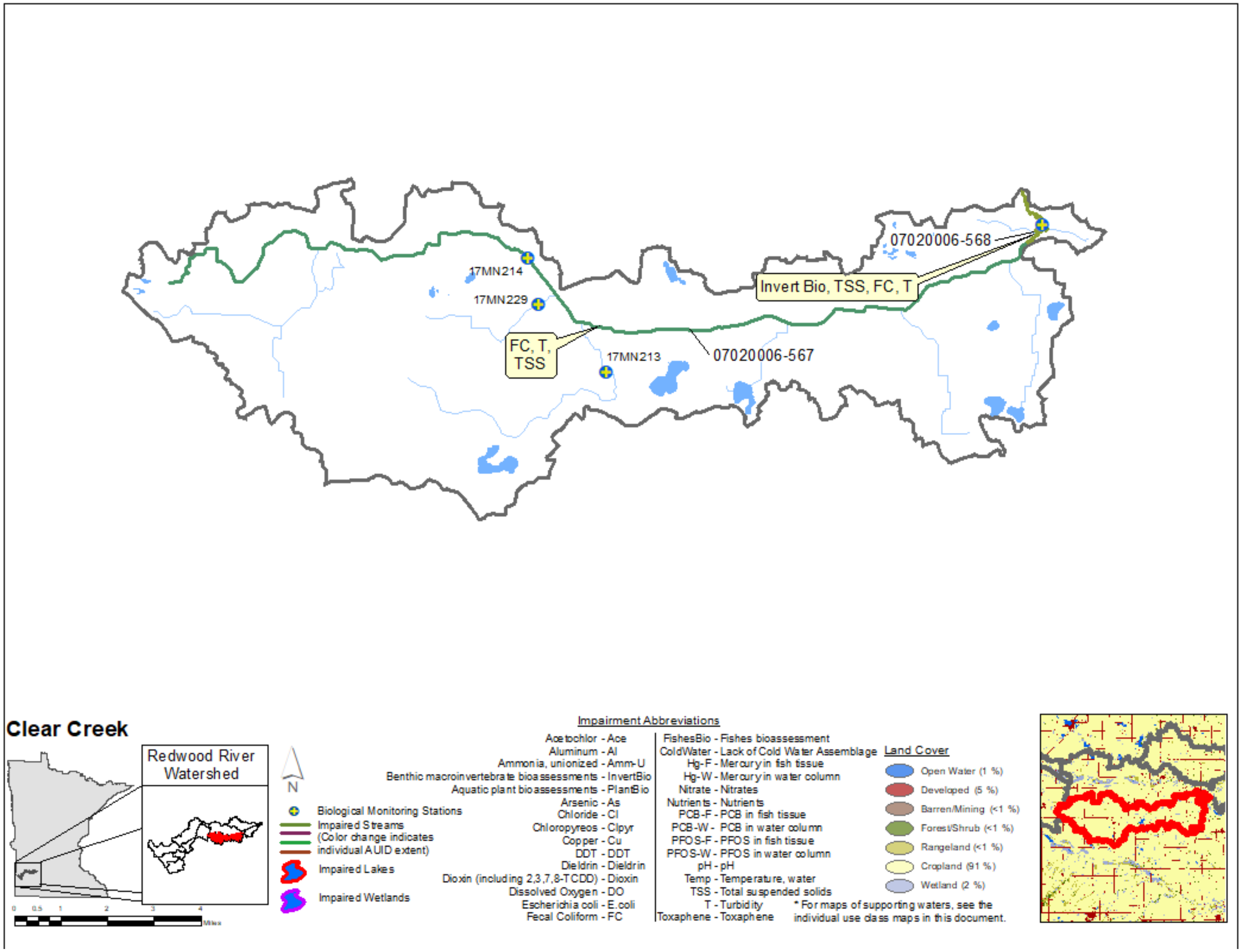
Another tributary to Clear Creek, Judicial Ditch 14 & 15, showed fish and invertebrate communities supporting of aquatic life. Both the FIBI and MIBI for the 2017 samples scored above their respective modified use threshold, and upper confidence limit.

The fish data from the single station sampled in 2017 on the upstream reach of Clear Creek was determined to be inconclusive, while the invertebrate community showed support of the modified use threshold. With the monitoring location situated near the headwaters of Clear Creek, lower portions of this 23-mile reach were not represented.

The downstream reach on Clear Creek showed a fish community supporting of aquatic life using general use criteria, while the invertebrate community was not supporting, with a score below the threshold and lower confidence interval. The FIBI score benefitted from low numbers of tolerant and very tolerant fish species. The MIBI scores was low due to a lack of overall diversity, including low numbers of POET taxa.

Past assessment of excess suspended sediment concentrations in Clear Creek triggered a new impairment for aquatic life use during this assessment cycle. Sediment concentrations from 2010 and 2011 monitoring work revealed poor conditions for supporting healthy aquatic communities. Newer data from 2017 and 2018 IWM efforts give early indications of improvements with no violations during that timeframe, more data would be needed from the initial listing station at County Road 56 near Seaforth to confidently reassess suspended sediment conditions, watershed restoration work is in progress. Bacterial contamination indicating poor recreation use condition triggered an impairment in 2008; newer data from multiple year's reveals persistent problem remain.

**Figure 20. Currently listed impaired waters by parameter and land use characteristics in the Clear Creek Aggregated 12-HUC.**



## Ramsey Creek Aggregated 12-HUC HUC 0702000606-01

Ramsey Creek (0702000606-01) aggregated 12-HUC (Figure 21) is a northeastern subwatershed within the Redwood River Watershed that drains into the Redwood River near Redwood Falls. This is the downstream most subwatershed to drain into the Redwood River before its confluence with the Minnesota River. Drainage area of this watershed encompasses 67 sq. mi. (43,000 acres) of Redwood County, and a smaller portion of Yellow Medicine County. All of the stream reaches are considered warmwater, with 88% of the stream reaches channelized. The last four mi. of Ramsey Creek, just before entering the Redwood River, is natural and managed as a put and take trout fishery by the DNR. No definable channel accounts for 5% of the reaches. Four stations were monitored for biology within the subwatershed.

Most of this watershed is rural with 92% cropland. Wetlands comprise 1%, forest 1%, rangeland 1%, and open water less than 1% of the watershed area. With the confluence of Ramsey Creek within the town of Redwood Falls, 6% of the watershed is developed. Less than 1% of the watershed area is barren/mining.

**Table 13. Aquatic life and recreation assessments on stream reaches: Ramsey Creek Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.**

| WID *Reach name, Reach description* | Biological station ID | Reach length (miles) | Use class* | Aquatic life indicators: Fish IBI | Invert IBI | Dissolved oxygen | TSS | Secchi Tube | Chloride | pH | Ammonia -$NH_3$ | Pesticides *** | Eutrophication | Aquatic life | Aquatic rec. (Bacteria) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **07020006-518, Judicial Ditch 33**, *CD 35 to Unnamed cr* | | 1.73 | WWm | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | IF | -- |
| **07020006-540, Judicial Ditch 32,** *Unnamed cr to JD 33* | 17MN227 | 7.33 | WWm | MTS | EXS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-520, Judicial Ditch 33,** *JD 32 to Ramsey Cr* | 17MN224 | 2.90 | WWm | EXS | MTS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-553, Unnamed Creek,** *Unnamed cr to Ramsey Cr* | 17MN222 | 5.36 | WWm | EXS | MTS | IF | IF | IF | -- | IF | IF | -- | IF | IC | -- |
| **07020006-524, Ramsey Creek**, *JD 33 to T113 R36W S34, east line* | | 2.92 | WWm | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | IF | -- |
| **07020006-521, Ramsey Creek,** *T113 R36W S35, west line to Redwood R* | 09MN091, 92MN047 | 3.68 | WWg | EXS | EXS | IF | MTS | MTS | MTS | MTS | MTS | -- | MTS | IMP | IMP |

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Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2014 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐= insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

## Summary

The Ramsey Creek aggregated 12-HUC includes four reaches assessed for aquatic life use, with fish and invertebrates (Table 13, Figure 21). Three of those reaches were found to be impaired. The only reach not impaired, Unnamed Creek, was determined to be inconclusive.

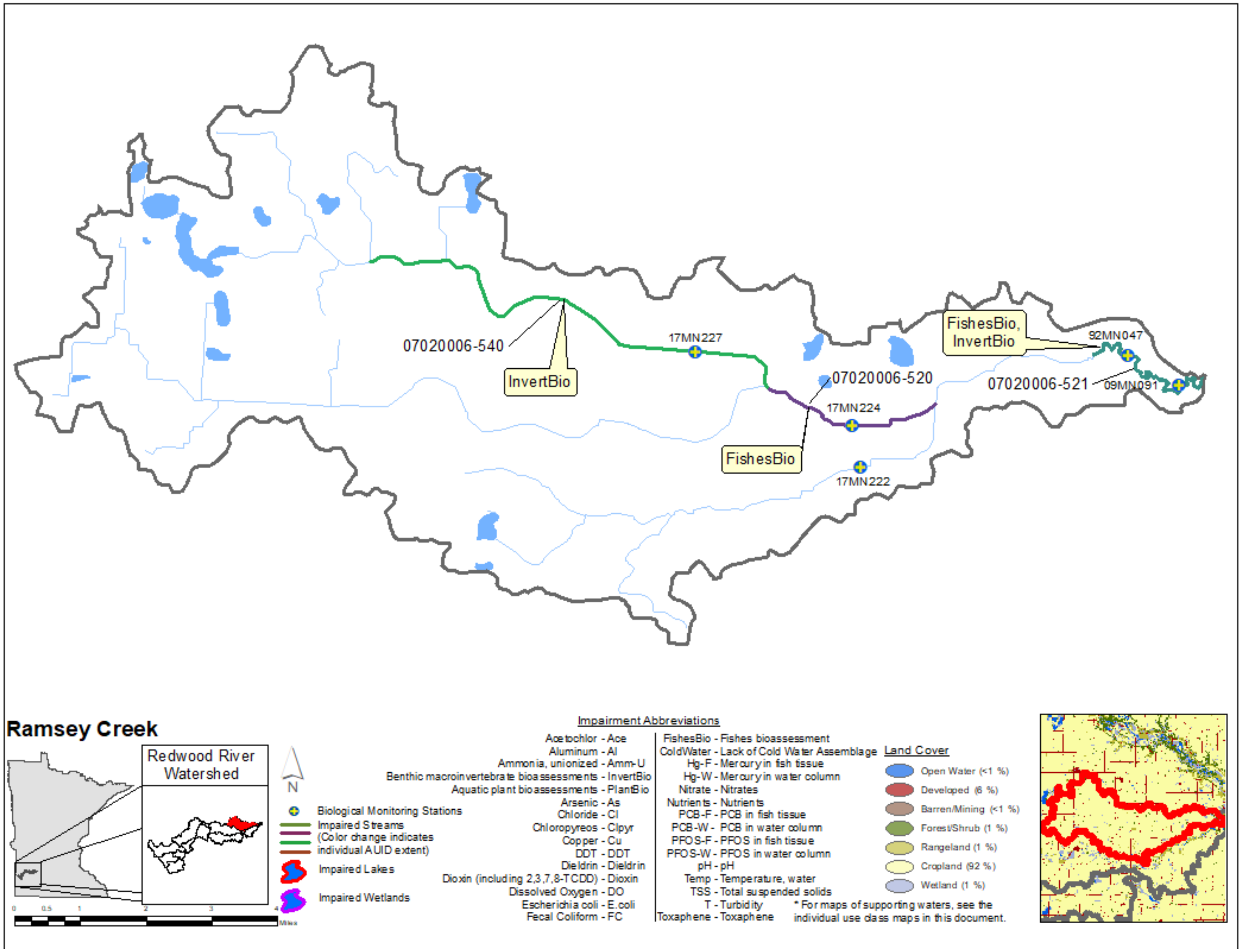
In 2017, Judicial Ditch 32 had a supporting fish community for the modified use class, with the FIBI score above upper confidence interval. Fish species utilizing riffles represented 40% of the individuals in the sample and tolerant fish made up only 7% of the sample. The invertebrate community was impaired at Judicial 32. Poor habitat and below average water quality conditions lead to an invertebrate community with low diversity, and dominance by tolerant taxa.

Just downstream, Judicial Ditch 33 had an impaired fish community, using the modified use threshold, based on data from station 17MN224 sampled twice in 2017. All of the fish species collected in these samples were considered tolerant of pollution. In contrast, the invertebrate community at Judicial Ditch 33 scored above the threshold for each of two samples that were collected. Improved habitat, better water quality, and a more stable stream channel likely contributed to the higher invertebrate community scores. There was much higher overall diversity, and a prevalence of more sensitive EPT taxa compared to the upstream reach.

The downstream most reach of Ramsey Creek is a DNR designated trout stream managed as a seasonal put and take fishery. For assessment purposes, a change to a warmwater designation is recommended to better represent the aquatic community present in the stream. The fish community data indicates impairment using the general use threshold. Despite good habitat conditions in this natural channel, fish community data showed a prevalence of tolerant fish species present in the stream. The invertebrate community in Ramsey Creek showed two differing conditions, with the upstream reach scoring well below the threshold, while the downstream reach scored above. The lower scoring portion of the reach agrees with the corresponding legacy of poor fish scores, and similarly, does not reflect the above average habitat conditions. Low diversity and dominance by tolerant organisms suggest that poor water quality conditions are impacting the biological community. The lower end of this reach shows a much different invertebrate community, with much higher overall diversity, and a prevalence of intolerant EPT taxa.

Assessable water chemistry data was available on the downstream reach of Ramsey Creek. Phosphorus and response algae data are meeting regional standards. Nitrate concentrations are elevated in the stream while suspended sediment concentrations are low. Bacteria concentrations are elevated, resulting in a new impairment on the reach.

**Figure 21. Currently listed impaired waters by parameter and land use characteristics in the Ramsey Creek Aggregated 12-HUC.**



## Lower Redwood River Aggregated 12-HUC HUC 0702000607-01

The Lower Redwood River (0702000607-01) aggregated 12-HUC (Figure 22) is the largest subwatershed within the Redwood River major watershed. Covering 123 sq. mi. (79,000 ac.) of Redwood, Lyon, and a small portion of Yellow Medicine counties. This mainstem subwatershed predominantly flows east to Redwood Falls, where the Redwood River joins the Minnesota River. The primary watercourse is the Redwood River, although the subwatershed includes some tributaries to the mainstem such as Judicial Ditch 3, County Ditch 92, and County Ditch 33. All of the streams are classified as warmwater. Channelization, especially in the tributaries is prevalent, with 50% of the stream reach lengths altered, while natural channels account for 44% of the reach lengths. Much of the natural channels occur along the Redwood River mainstem. Six percent of the reach lengths are considered no definable channel, and less than 1% impounded. A prominent natural feature on the Redwood River is the 45-foot waterfall present within Ramsey Park in Redwood Falls. Five stations were sampled for biology.

A considerable portion of the subwatershed is devoted to agriculture, with 91% of the area used for crops. Development comprises 5% of the subwatershed area, with the major watershed's second largest town, Redwood Falls present. The town of Vesta is also found within the watershed. Wetlands account for 2%, while open water 1% of the subwatershed area. Lakes found within the subwatershed include School Grove (337 ac.), and Redwood Lake (54 ac.), an impoundment of the Redwood River formed by a dam within Redwood Falls. Forest, rangeland, and barren/mining make up less than 1% of subwatershed area.

**Table 14. Aquatic life and recreation assessments on stream reaches: Lower Redwood River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.**

| WID<br>***Reach name***,<br>*Reach description* | Biological station ID | Reach length (miles) | Use class | Aquatic life indicators: Fish IBI | Invert IBI | Dissolved oxygen | TSS | Secchi Tube | Chloride | pH | Ammonia -$NH_3$ | Pesticides *** | Eutrophication | Aquatic life | Aquatic rec. (Bacteria) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **07020006-561, Unnamed Creek**, *Headwaters to Redwood R* | 17MN218 | 4.86 | WWm | MTS | MTS | IF | IF | IF | -- | IF | IF | -- | IF | SUP | -- |
| **07020006-560, Judicial Ditch 3**, *Headwaters to Redwood R* | 17MN223 | 3.09 | WWm | MTS | EXS | IF | IF | IF | -- | IF | IF | -- | IF | IMP | -- |
| **07020006-563, County Ditch 92**, *CD 32 to Redwood R* | | 1.25 | WWg | -- | -- | IF | IF | IF | -- | IF | IF | -- | IF | IF | -- |
| **07020006-529, County Ditch 33**, *Headwaters to Redwood R* | 91MN040 | 4.42 | WWm | MTS | MTS | IF | IF | IF | -- | IF | IF | -- | IF | SUP | -- |
| **07020006-503, Redwood River**, *Threemile Cr to Clear Cr* | 17MN219, 92MN037, 92MN038, 92MN041 | 29.49 | WWg | EXS | EXS | IF | IF | IF | -- | IC | IF | -- | IF | IMP | -- |
| **07020006-509, Redwood River**, *Clear Cr to Redwood Lk* | 92MN044, 92MN045 | 14 | WWg | EXS | MTS | IF | EXS | EXS | MTS | MTS | MTS | IC | IF | IMP | IMP |
| **07020006-508, Redwood River**, *Dam to Ramsey Cr* | | 1.32 | WWg | -- | -- | -- | -- | MTS | -- | -- | -- | -- | -- | IF | -- |
| **07020006-501, Redwood River**, *Ramsey Cr to Minnesota R* | 17MN200, 92MN049 | 4.13 | WWg | MTS | EXS | IF | EXS | MTS | MTS | MTS | MTS | | IC | IMP | IMP |

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2014 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐= insufficient information.

Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water

*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

**Table 15. Lake assessments: Lower Redwood River Aggregated 12-HUC.**

| Lake name | DNR ID | Area (acres) | Max depth (ft) | Assessment method | Ecoregion | Secchi Trend | Aquatic life indicators: | | | Aquatic recreation indicators: | | | Aquatic life use | Aquatic recreation use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish IBI | Chloride | Pesticides *** | Total phosphorus | Chlorophyll-a | Secchi | | |
| School Grove | 42-0002-00 | 337 | 11 | Shallow Water | WCBP | -- | NA | IF | -- | IF | IF | IF | -- | NS |
| Redwood | 64-0058-00 | 54 | -- | -- | WCBP | -- | -- | -- | -- | NA | NA | NA | -- | NA |

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains

Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data

Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information

Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)

Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

## Summary

Within the Lower Redwood River aggregated 12-HUC, six reaches were assessed for aquatic life (Table 14, Figure 22). Two reaches, a tributary to the Redwood River and County Ditch 33, were found to be supporting for aquatic life, while four reaches are impaired for aquatic life. Three stations on the Redwood River (-509 and -501) mainstem were unable to be sampled during the 2017 monitoring effort due to higher than normal flows, and sampling crews being unable to visit during normal flows.

A tributary to the Redwood River, Unnamed Creek was supporting of aquatic life using modified use criteria. Fish community data scored above the upper confidence interval, macroinvertebrate data scored within the upper confidence limit.

Another tributary, Judicial Ditch 3 showed a supporting fish community, and a non-supporting macroinvertebrate community. Fish data from the only station on the reach scored above the modified use threshold for the low gradient fish class, while macroinvertebrates scored below the modified use threshold, within the lower confidence limit.

Similar to Unnamed Creek, County Ditch 33 is another tributary to the Redwood River with a supporting fish community, and a supporting macroinvertebrate community. Fish data on this reach scored above the upper confidence interval of the modified used threshold, while macroinvertebrates above the modified use threshold, within the lower confidence interval. One sensitive fish species was found.

Previously listed as impaired using fish community data in 2002, current fish community data collected in 2017 for the Redwood River (-503) confirms this impairment. Across multiple stations, and including fish visits from 2010 and 2017, fish data consistently scored below the general use threshold. Fish considered detritivores made up significant portions of the fish samples with 46-72% of the individuals. Previously collected macroinvertebrate data show supporting scores, while current macroinvertebrate community data show non supporting conditions at the most upstream and downstream stations in the WID, with the middle station (92MN037) scoring just above the general use threshold.

The next downstream reach on the Redwood River (-509) also exhibited an impaired fish community. Unable to be sampled for fish in 2017, fish community data for this reach from 2010 showed an FIBI score below the lower confidence interval for general use. Tolerant and very tolerant fish species made up a significant portion of the fish sample. In contrast, both historical and current macroinvertebrate data collected on this WID show supporting conditions.

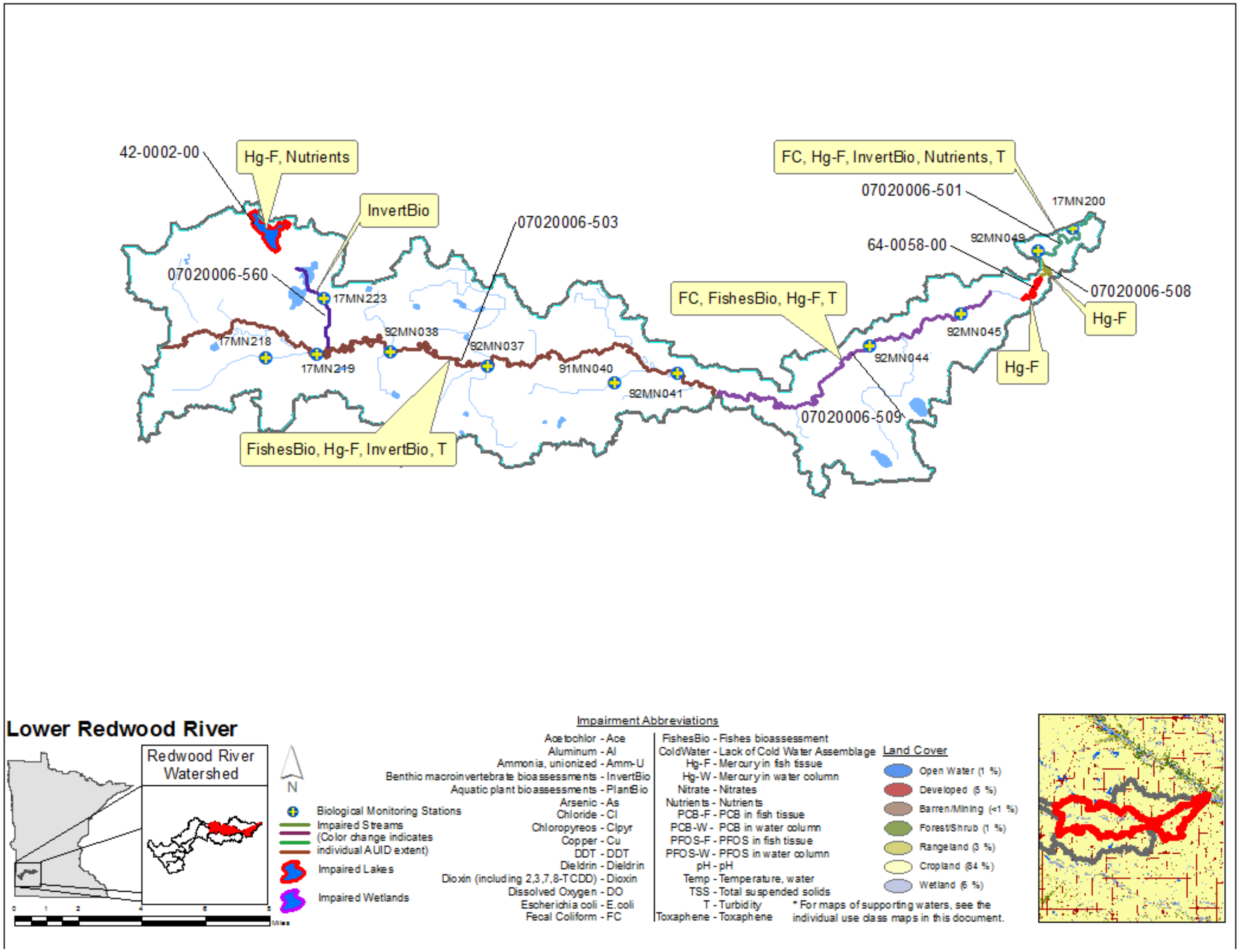
The downstream most reach on the Redwood River (-501) was last sampled for fish in 2010, and showed a fish community supporting of aquatic life using general use criteria. With good habitat conditions present, fish community data scored above the threshold and upper confidence interval. Out of 22 fish species sampled that year, only three species collected were considered tolerant, making up less than 30% of the individuals in the sample. Among the species collected were four darter species, and six species that are considered sensitive. Macroinvertebrate data collected at the upstream station (92MN049) shows a non-supporting condition in 2001, 2009 and 2010, similarly the data collected at the downstream most station (17MN200), show a condition just below the general use standard. The excellent habitat at both stations, suggests water quality conditions are having an impact on the macroinvertebrate community.

Extensive chemistry datasets available for the majority of downstream Redwood River reaches. A long history of monitoring and assessment indicates poor water quality for healthy aquatic communities, resulting in suspended sediment and nutrient impairments being previously added. Extensive newer datasets for suspended solids and clarity confirm the initial listing and a common pattern of poor water quality for healthy aquatic communities seen throughout almost all reaches of the river from headwaters to the confluence with the Minnesota River. Average nutrient concentrations are unusually high for rivers in this region of the state, response data available during this assessment cycle is conflicting. When the nutrient response data is considered with flow data, it becomes clear that response to excess nutrients is much more likely during summertime low flow periods when water temperature and residence time is increased. Bacterial contamination was considered during past assessment efforts, resulting downstream impairment on the Redwood River. Where newer bacteria data is available, persistently high concentrations indicative of poor recreational use conditions are still obvious. Restoration work is underway to addressing a number of water quality issues common throughout the entire Redwood River basin.

The downstream impoundment of the Redwood River known as Redwood Lake was previously deemed impaired in 2006 for aquatic recreation use based on grossly violating assessment parameters. In 2016, a requested to consider the short water residence of the impoundment as an important signal of this basin functioning more in river water quality that a lake. Residence time was found to be 9 days, not fitting the criteria for an assessable recreational lake then was removed from the 2016 impaired waters list. School Grove Lake was previously found to have poor recreation water quality in during a 2009 assessment. Newer data was available from 2017, conditions during that year met water quality goals for recreation use. More data would be needed to confirm an actual improvement in conditions in case 2017 was an anomalous year in the dataset.

School Grove Lake was sampled in 2017 for aquatic community health. During the following assessment this lake was deemed not assessable due to numerous winterkill events in recent history. No reliable tool for assessing the aquatic life health of winterkill lakes is available at this time.

**Figure 22. Currently listed impaired waters by parameter and land use characteristics in the Lower Redwood River Aggregated 12-HUC.**



# Watershed-wide results and discussion

Assessment results and data summaries are included below for the entire HUC-8 watershed unit of the Redwood River Watershed, grouped by sample type. Summaries are provided for lakes, streams, and rivers in the watershed for the following: aquatic life and recreation uses, aquatic consumption results, load monitoring data results, and transparency trends. Waters identified as priorities for protection or restoration work were also identified. Additionally, groundwater and wetland monitoring results are included where applicable.

Following the results are a series of graphics that provide an overall summary of assessment results by designated use, impaired waters, and fully supporting waters within the entire Redwood River Watershed.

## Stream water quality

Thirty five of the 42 stream WIDs were assessed (Table 16) Of the assessed streams, only seven streams were considered to be fully supporting of aquatic life and no streams were fully supporting of aquatic recreation. Two WIDs were classified as limited resource waters and assessed accordingly.

Throughout the watersheds, 28 WIDs are non-supporting for aquatic life and/or recreation. Of those WIDs, 27 are non-supporting for aquatic life and 12 are non-supporting for aquatic recreation.

Out of the 35 WIDs assessed, 7 reaches were supporting for aquatic life, 27 are impaired for aquatic life. For the fully supporting reaches, two occurred on general use reaches, while 5 occurred on modified use reaches. Of the reaches impaired for aquatic life, fish assemblages contributed to the impairment on 15 reaches (5 modified use), while macroinvertebrates contributed to 18 (7 modified use) impaired reaches. Four reaches were previously impaired for aquatic life which will be carried forward, three of these with current data. There are no previous impairments for macroinvertebrates. Nine reaches had existing impairments for aquatic life based on water chemistry parameters, of these the most common is turbidity. None of these impairments will be delisted. No stream reaches were supporting of aquatic recreation, 13 reaches are impaired for aquatic recreation, all of these were existing impairments.

**Table 16. Assessment summary for stream water quality in the Redwood River Watershed.**

| | | | | Supporting | | Non-supporting | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Watershed** | **Area (acres)** | **# Total WIDs** | **# Assessed WIDs** | **# Aquatic life** | **# Aquatic recreation** | **# Aquatic life** | **# Aquatic recreation** | **Insufficient data** | **# Delistings** |
| Redwood River **HUC 8** | **447,531** | **42** | **35** | **8** | **0** | **26** | **13** | **4** | **0** |
| *Upper Redwood River* | 51,439 | 3 | 3 | 1 | 0 | 2 | 1 | 0 | 0 |
| *Judicial Ditch 12* | 32,191 | 6 (2 LRV) | 4 | 1 | 0 | 3 | 1 | 0 | 0 |
| *Coon Creek* | 62,138 | 4 | 4 | 0 | 0 | 3 | 2 | 0 | 0 |
| *Middle Redwood River* | 52,051 | 5 | 5 | 1 | 0 | 4 | 2 | 0 | 0 |
| *Threemile Creek* | 75,084 | 6 | 6 | 1 | 0 | 5 | 3 | 0 | 0 |
| *Clear Creek* | 53,233 | 4 | 4 | 2 | 0 | 2 | 2 | 0 | 0 |
| *Ramsey Creek* | 42,629 | 6 | 3 | 0 | 0 | 3 | 1 | 2 | 0 |
| *Lower Redwood River* | 78,765 | 8 | 6 | 2 | 0 | 4 | 1 | 2 | 0 |

## Lake water quality

Eighteen lakes over ten acres within the Redwood River Watershed had some type of assessment data available to consider during this effort. Two lakes stood out as having the highest recreational quality (West and East Twin), these basins should be viewed as important to any protection projects looking to curb future water quality degradation. Four lakes had previous recreational use impairments from past assessment efforts (Dead Coon, Benton, Goose, School Grove), two basins were found to have poor recreation quality (Clear, Island) and deemed impaired during this assessment effort. This effort was the first time complete aquatic life use assessments where possible using fish community information from lakes. Four new lakes (East twin, Dead Coon, Benton, Wood) were found to be impaired based on the degraded fish communities found during monitoring efforts.

**Table 17. Assessment summary for lake water chemistry in the Redwood River Watershed.**

| | | | Supporting | | Non-supporting | | | |
|---|---|---|---|---|---|---|---|---|
| **Watershed** | **Area (acres)** | **Lakes >10 acres** | **# Aquatic life** | **# Aquatic recreation** | **# Aquatic life** | **# Aquatic recreation** | **Insufficient data** | **# Delistings** |
| Redwood River **HUC 8** | 447,531 | 18 | 0 | 2 | 4 | 6 | 15 | 0 |
| Judicial Ditch 12 (Tyler Creek) | 32,168 | 2 | 0 | 0 | 0 | 0 | 2 | 0 |
| Upper Redwood River | 51,405 | 5 | 0 | 2 | 1 | 0 | 3 | 0 |
| Coon Creek | 62,083 | 4 | 0 | 0 | 2 | 2 | 3 | 0 |
| Middle Redwood River | 52,027 | 2 | 0 | 0 | 0 | 1 | 3 | 0 |
| Threemile Creek | 75,049 | 3 | 0 | 0 | 1 | 2 | 3 | 0 |
| Lower Redwood River | 78,751 | 2 | 0 | 0 | 0 | 1 | 1 | 0 |
| Judicial Ditch 12 (Tyler Creek) | 32,168 | 2 | 0 | 0 | 0 | 0 | 2 | 0 |

## Fish contaminant results

Mercury and polychlorinated biphenyls (PCBs) were analyzed in fish tissue samples collected from the Redwood River in 1990 and 1995 and from four lakes in the watershed from 1992 to 2017 (Table 18). All eight WIDs of the Redwood River and the four lakes are listed as impaired for mercury in fish tissue and are covered under the Minnesota Statewide Mercury TMDL. The highest mercury concentrations in the Redwood River were in walleye collected in 1995; four fish in two composites had mercury concentrations of 0.200 ppm and 0.530 ppm. There is a good chance that retesting Walleye and other species in the Redwood River would indicate the mercury levels have dropped below the 0.2 ppm fish tissue standard; therefore, the Redwood River should be retested at the next available opportunity. Dead Coon Lake was last sampled in 2013 and results for four Northern Pike and one Walleye show the lake remains impaired for mercury in fish tissue. Benton Lake was last sampled in 2013 as well, with results indicating mercury concentrations have declined—maximum concentration in Walleye was 0.990 ppm and in 2013, 0.253 ppm. The next time Benton Lake is tested for mercury the lake will be assessed for possible delisting from the Impaired Waters List. Redwood Lake was last sampled in 2006 and several species had mercury well above the 0.2 ppm standard. The highest mercury concentration was 0.811 ppm in a Channel Catfish. The lake is overdue for a retesting of mercury in the fish. School Grove Lake was first tested in 2017 and all 8 Walleye were above the 0.2 ppm mercury standard; consequently, the lake was added to the 2020 draft Impaired Waters List.

The Redwood River and three of the lakes had been tested for PCBs and all were near or below the reporting limit. These waterbodies do not need to be retested for PCBs. Fish collected from School Grove Lake in 2017 were not analyzed for PCBs; the next fish collection from this lake should include testing for PCBs.

**Table 18. Fish contaminants: summary of fish length, mercury, PCBs and PFOS by waterway-species-year**

| WID | Waterway | Species | Year | Anatomy | Total Fish | Number Samples | Length (in) | | | Mercury (mg/kg) | | | PCBs (mg/kg) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Mean | Min | Max | Mean | Min | Max | N | Mean | Max | < RL |
| 07020006-501, 502, 503, 505, 508, 509, 510, 513 | REDWOOD R.* | Common Carp | 1990 | FILSK | 5 | 2 | 20.4 | 18.8 | 21.9 | 0.111 | 0.071 | 0.150 | 2 | 0.019 | 0.02 | |
| | | | 1995 | FILSK | 20 | 5 | 20.9 | 16.5 | 26.1 | 0.154 | 0.100 | 0.200 | 1 | 0.07 | 0.07 | |
| | | Channel Catfish | 1990 | FILET | 1 | 1 | 19.5 | 19.5 | 19.5 | 0.240 | 0.240 | 0.240 | 1 | 0.016 | 0.016 | |
| | | | 1995 | FILET | 7 | 1 | 24.5 | 24.5 | 24.5 | 0.260 | 0.260 | 0.260 | 1 | 0.06 | 0.06 | |
| | | Redhorse sp. | 1995 | FILSK | 7 | 3 | 17.6 | 14.0 | 20.5 | 0.227 | 0.180 | 0.270 | | | | |
| | | Walleye | 1995 | FILSK | 4 | 2 | 14.8 | 10.7 | 18.8 | 0.365 | 0.200 | 0.530 | 1 | 0.04 | 0.04 | |
| | | White Sucker | 1995 | FILSK | 2 | 1 | 15.4 | 15.4 | 15.4 | 0.160 | 0.160 | 0.160 | | | | |
| 41-0021-00 | DEAD COON | Common Carp | 1993 | FILSK | 7 | 2 | 19.3 | 15.9 | 22.7 | 0.114 | 0.087 | 0.140 | 1 | 0.01 | 0.01 | Y |
| | | Northern Pike | 2013 | FILSK | 4 | 4 | 20.6 | 19.5 | 21.0 | 0.344 | 0.309 | 0.398 | | | | |
| | | Walleye | 1993 | FILSK | 3 | 3 | 16.6 | 10.2 | 24.3 | 0.213 | 0.078 | 0.460 | 1 | 0.016 | 0.016 | |
| | | | 2001 | FILSK | 22 | 22 | 15.6 | 9.7 | 25.4 | 0.235 | 0.084 | 0.770 | | | | |
| | | | 2009 | FILSK | 13 | 13 | 14.8 | 12.6 | 18.2 | 0.103 | 0.070 | 0.159 | | | | |
| | | | 2013 | FILSK | 1 | 1 | 14.7 | 14.7 | 14.7 | 0.268 | 0.268 | 0.268 | | | | |
| | | Yellow Perch | 1993 | FILSK | 1 | 1 | 11.6 | 11.6 | 11.6 | 0.064 | 0.064 | 0.064 | | | | |
| | | | 2001 | WHORG | 10 | 3 | 7.7 | 6.6 | 9.0 | 0.051 | 0.050 | 0.052 | | | | |
| 41-0043-00 | BENTON | Black Crappie | 1992 | FILSK | 8 | 1 | 10.0 | 10.0 | 10.0 | 0.220 | 0.220 | 0.220 | | | | |
| | | Walleye | 1992 | FILSK | 21 | 4 | 19.6 | 12.9 | 27.0 | 0.548 | 0.200 | 0.990 | 1 | 0.01 | 0.01 | Y |
| | | | 2000 | FILSK | 24 | 24 | 18.4 | 12.7 | 27.0 | 0.428 | 0.220 | 0.900 | | | | |
| | | | 2006 | FILSK | 22 | 22 | 17.6 | 10.8 | 25.9 | 0.455 | 0.050 | 0.992 | | | | |
| | | | 2009 | FILSK | 12 | 12 | 14.1 | 12.4 | 15.1 | 0.151 | 0.136 | 0.189 | | | | |
| | | | 2013 | FILSK | 14 | 14 | 14.5 | 12.0 | 18.0 | 0.138 | 0.103 | 0.253 | | | | |
| | | White Sucker | 1992 | FILSK | 4 | 1 | 16.9 | 16.9 | 16.9 | 0.100 | 0.100 | 0.100 | 1 | 0.01 | 0.01 | Y |

| WID | Waterway | Species | Year | Anatomy | Total Fish | Number Samples | Length (in) | | | Mercury (mg/kg) | | | PCBs (mg/kg) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Mean | Min | Max | Mean | Min | Max | N | Mean | Max | < RL |
| 41-0043-00 | BENTON | Yellow Perch | 2000 | WHORG | 10 | 10 | 5.7 | 5.4 | 6.0 | 0.016 | 0.010 | 0.030 | | | | |
| | | | 2006 | WHORG | 6 | 6 | 10.0 | 9.0 | 10.8 | 0.063 | 0.033 | 0.089 | | | | |
| 42-0002-00 | SCHOOL GROVE | Common Carp | 2017 | FILSK | 5 | 1 | 21.2 | 21.2 | 21.2 | 0.067 | 0.067 | 0.067 | | | | |
| | | Walleye | 2017 | FILSK | 8 | 8 | 17.6 | 14.6 | 22.5 | 0.357 | 0.324 | 0.434 | | | | |
| | | Yellow Perch | 2017 | FILSK | 10 | 1 | 9.2 | 9.2 | 9.2 | 0.106 | 0.106 | 0.106 | | | | |
| 64-0058-00 | REDWOOD | Black Bullhead | 2006 | FILET | 2 | 1 | 11.1 | 11.1 | 11.1 | 0.216 | 0.216 | 0.216 | | | | |
| | | Black Crappie | 2006 | FILSK | 3 | 1 | 9.8 | 9.8 | 9.8 | 0.096 | 0.096 | 0.096 | | | | |
| | | Common Carp | 2006 | FILSK | 8 | 2 | 22.4 | 20.4 | 24.4 | 0.287 | 0.220 | 0.353 | | | | |
| | | Channel Catfish | 2006 | FILET | 5 | 5 | 20.0 | 17.8 | 22.9 | 0.371 | 0.185 | 0.811 | | | | |
| | | Northern Pike | 1992 | FILSK | 5 | 1 | 18.7 | 18.7 | 18.7 | 0.160 | 0.160 | 0.160 | 1 | 0.01 | 0.01 | Y |
| | | | 2006 | FILSK | 2 | 2 | 23.0 | 21.0 | 25.0 | 0.184 | 0.154 | 0.214 | | | | |
| | | Redhorse sp. | 1992 | FILSK | 11 | 2 | 14.9 | 13.8 | 16.0 | 0.165 | 0.160 | 0.170 | 1 | 0.028 | 0.028 | |
| | | Walleye | 2006 | FILSK | 2 | 2 | 23.5 | 23.0 | 24.0 | 0.542 | 0.430 | 0.654 | | | | |
| | | White Crappie | 1992 | FILSK | 7 | 1 | 8.6 | 8.6 | 8.6 | 0.220 | 0.220 | 0.220 | | | | |

* Impaired for mercury in fish tissue as of 2020 Draft Impaired Waters Inventory; categorized as EPA Category 4a for waters covered by the Statewide Mercury TMDL.

** Impaired for mercury in fish tissue as of 2020 Draft Impaired Waters Inventory; categorized as EPA Category 5 for waters needing a TMDL.

1 Anatomy codes: PLUG—dorsal muscle plug without skin; FILSK – fillet with skin; FILET—fillet without skin; WHORG—whole organism

## Pollutant load monitoring

The WPLMN has three sites within the Redwood River Watershed as shown in Table 19.

**Table 19. WPLMN Stream Monitoring Sites for the Redwood River Watershed.**

| Site Type | Stream Name | USGS ID | DNR/MPCA ID | EQuIS ID |
|---|---|---|---|---|
| Major Watershed | Redwood River nr Redwood Falls, Minnesota | 05316500 | E27035001 | S001-679 |
| Subwatershed | Redwood River at Russell, CR15 | 05314973 | H27043001 | S000-696 |
| Subwatershed | Redwood River nr Marshall, 300th St | 05315050 | W27043003 | S001-203 |

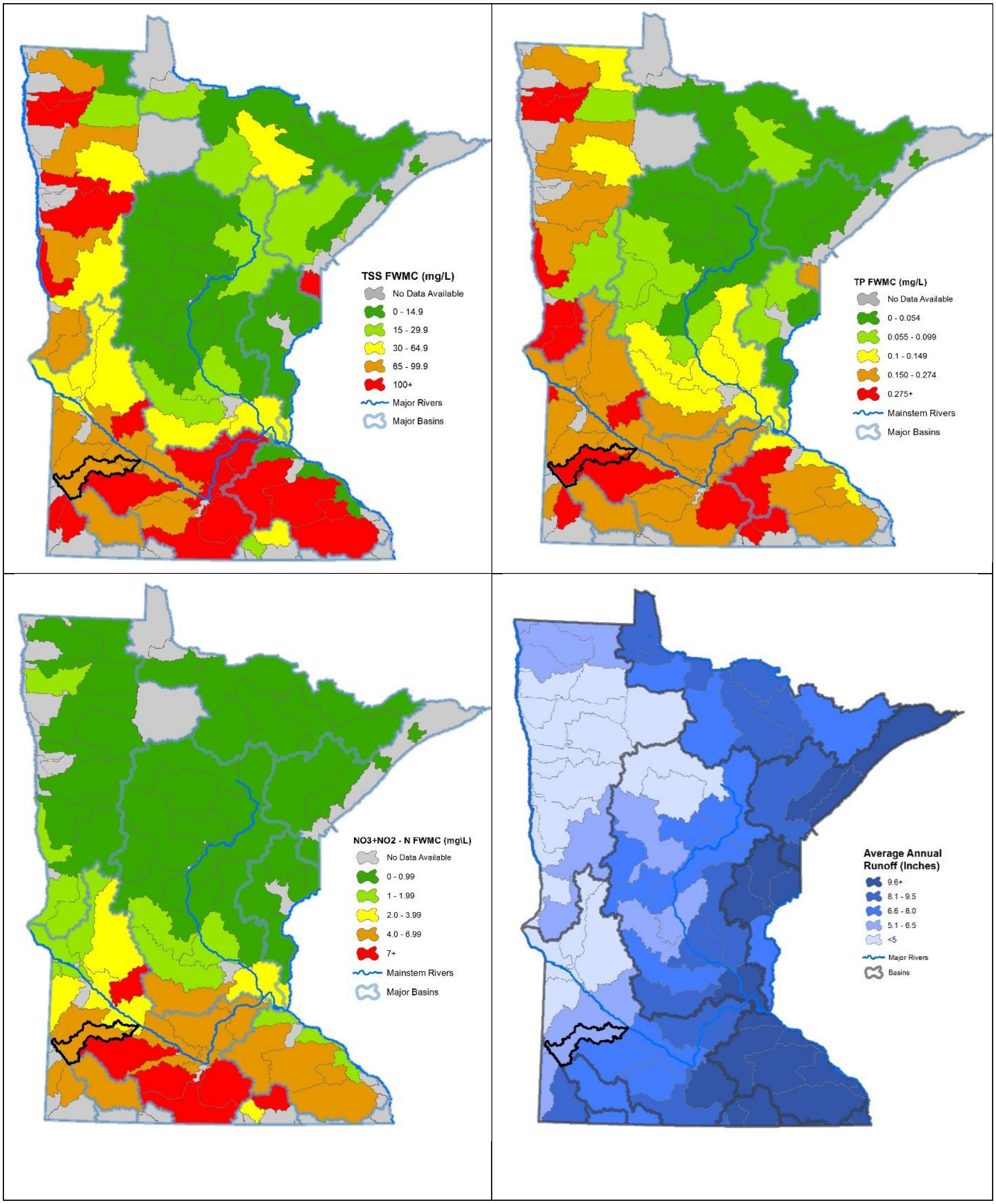
Average annual FWMCs of TSS, TP, and NO3+NO2-N for major watershed stations statewide are presented below (Figure 23), with the Redwood River Watershed highlighted. Water runoff, a significant factor in pollutant loading, is also shown. Water runoff is the portion of annual precipitation that makes it to a river or stream; this can be expressed in inches.

As a general rule, elevated levels of TSS and NO3+NO2-N are regarded as nonpoint source derived pollutants originating from many small diffuse sources such as urban or agricultural runoff. Excess TP can be attributed to both nonpoint as well as point sources such as industrial or wastewater treatment plants. Major nonpoint sources of phosphorus include dissolved phosphorus from fertilizers and phosphorus adsorbed to and transported with sediment during runoff.

Excessive TSS, TP, and NO3+NO2-N in surface waters impacts fish and other aquatic life, as well as fishing, swimming and other recreational uses. High levels of NO3+NO2-N is a concern for drinking water.

When compared with other major watersheds throughout the state, Figure 23 shows the average annual TSS, TP, and NO3+NO2-N FWMCs to be several times higher for the Redwood River Watershed than watersheds in north central and northeast Minnesota, but in line with the agriculturally rich watersheds found in the northwest and southern regions of the state.

**Figure 23. 2007-2016 Average annual TSS, TP, and NO3-NO2-N flow weighted mean concentrations, and runoff by major watershed.**



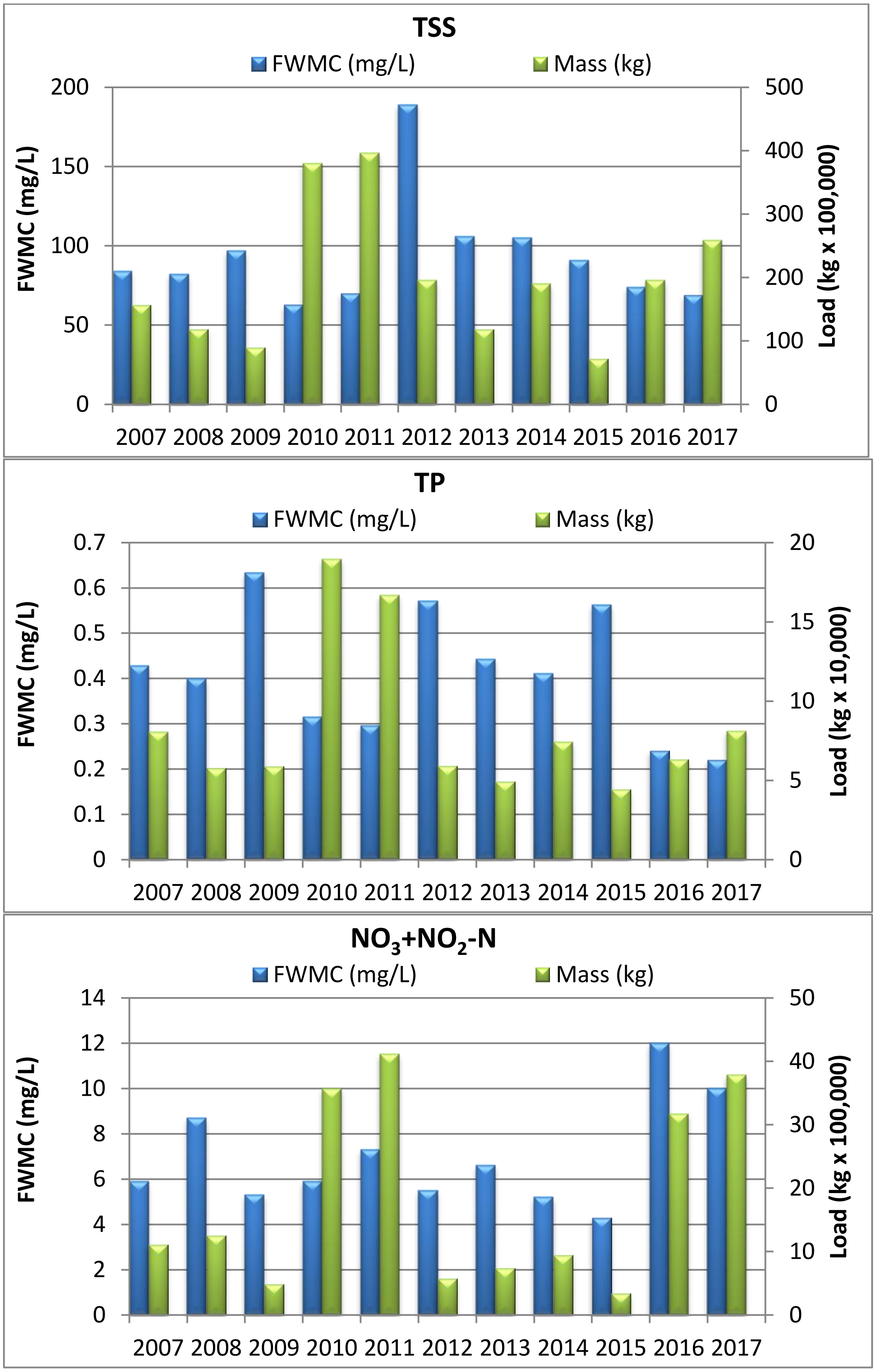
More information, including results for subwatershed stations, can be found at the WPLMN website.

Substantial year-to-year variability in water quality occurs for most rivers and streams, including the Redwood River. Results for individual years are shown in the charts below (Figure 24).

For TSS and TP, the greatest pollutant loads were measured in 2010 and 2011 and were largely climate driven. Both spring and early fall floods occurred in 2010 with the fall event recording the fifth highest streamflow since 1910. A flood of similar proportion occurred during the spring of 2011 and was the seventh largest event on record for the Redwood River. In 2012, there were intense rain events that occurred early in the growing season which caused high concentrations of TSS. For TP, the highest concentrations of the year are often during the winter months and are related to wastewater treatment plant (WWTP) discharge. The city of Marshall WWTP was upgraded in 2016 which resulted in a reduction of the FWMC. High TP can also occur during ice out conditions. Phosphorus sources during this period include eroded sediment and dissolved phosphorus leached from: frozen soils, crop residue and other vegetation.

Annual $NO_3$+$NO_2$-N flow weighted mean concentrations and loads are complex and variable. Factors influencing year-to-year differences include total annual precipitation, drainage tile density, timing of runoff events and fertilizer application rates.

**Figure 24. TSS, TP, and NO3+NO2-N Flow Weighted Mean Concentrations and Loads for the Redwood River near Redwood Falls, Minnesota.**



## Groundwater monitoring

### Groundwater quality

Approximately 75% of Minnesota's population receives their drinking water from groundwater, so clean groundwater is essential to the health of its residents. The Minnesota Pollution Control Agency's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of chemicals including nutrients, metals, and volatile organic compounds. These Ambient Groundwater wells represent a mix of deeper domestic wells and shallow monitoring wells. The shallow wells interact with surface waters and exhibit impacts from human activities more rapidly. Available data from federal, state and local partners are used to supplement reviews of groundwater quality in the region.

There are no MPCA Ambient Groundwater Monitoring wells within the Redwood River Watershed. Data from past sampling in this area of the state indicated manganese and boron were the two most important naturally occurring chemicals of concern. Nitrate was the chemical of most concern from human sources. (MPCA, 1999)

Another source of information on groundwater quality comes from the Minnesota Department of Health (MDH). Mandatory testing for arsenic, a naturally occurring but potentially harmful contaminant for humans, of all newly constructed wells has found that an average of 10% of all wells installed from 2008 to 2018 have arsenic levels above the MCL for drinking water of 10 micrograms per liter (MDH, 2020a). The Redwood River Watershed, in Minnesota, is encompassed mostly by Lyon (48%) Redwood (28.5%) and Lincoln (19.3%). The frequency of arsenic levels above the MCL in new wells in those counties was, respectively, 22.8%, 20.7% and 19%. (MDH 2020b).

### Groundwater Quantity

The DNR maintains a statewide network of water level wells to assess groundwater resources, evaluate trends and plan for the future. While there are a number of deep wells within the Redwood River Watershed, a shallower, water table well is more reactive to recharge and withdrawals. Groundwater elevations from wells #616876 near Lynd (Figure 25) and #708361 near Vesta (Figure 26) are displayed below. Fluctuations in water level are common and expected with seasonal change and varied precipitation. Both wells show a statistically significant increasing trend.

**Figure 25. Water table elevations in Well #616876 near Lynd, 1998-2017.**

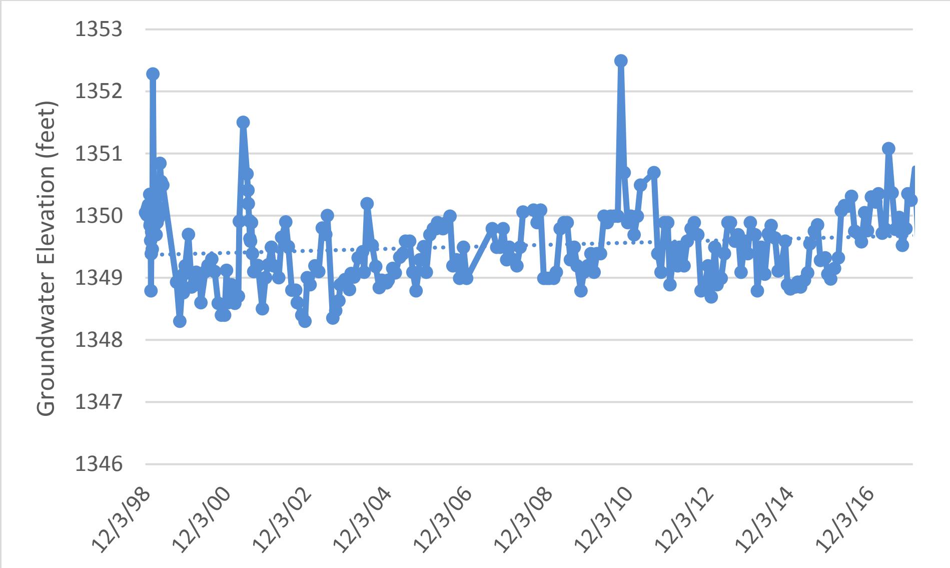
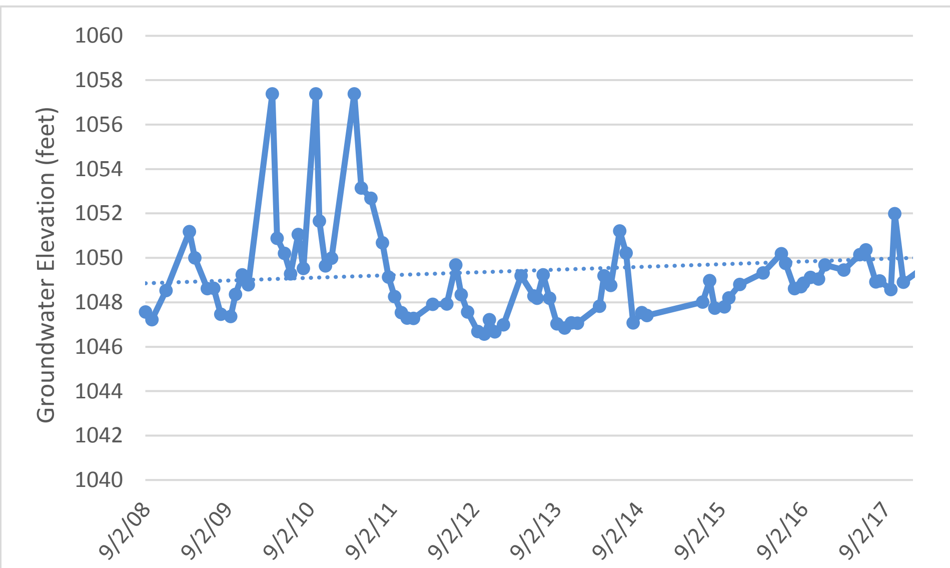



**Figure 26. Water table elevations in Well #708361 near Vesta, 2008-2017.**




The Department of Natural Resources also permits all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons per day or one million gallons per year. Permit holders are required to track water use and report back to the DNR annually. The changes in withdrawal volume detailed in this groundwater report are a representation of water use and demand in the watershed and are taken into consideration when the DNR issues permits for water withdrawals. Other factors not discussed in this report but considered when issuing permits include: interactions between individual withdrawal locations, cumulative effects of withdrawals from individual aquifers, and potential interactions between aquifers. This holistic approach to water allocations is necessary to ensure the sustainability of Minnesota's groundwater resources.

The largest permitted consumers of water in the state are (in order) power generation, water supply. According to the most recent data from the DNR Permitting and Reporting System (MPARS), the largest use categories for withdrawals within the Redwood River Watershed are were "Special Categories" [largely livestock watering] (64%) and water supply (16%). (DNR, 2019a)

[Figure 27](#) displays total high capacity withdrawal locations within the watershed with active permit status in 2017. Permitted groundwater withdrawals are displayed below as blue squares and surface water withdrawals as red triangles. During 1997 to 2017, groundwater withdrawals within the Redwood River Watershed exhibit a significant decreasing trend ($p<0.01$) and surface water withdrawals have increased very significantly ($p<0.001$) ([Figure 28](#)).

**Figure 27. Locations of active status permitted high capacity withdrawals in 2016 within the Redwood River Watershed (DNR, 2019a).**

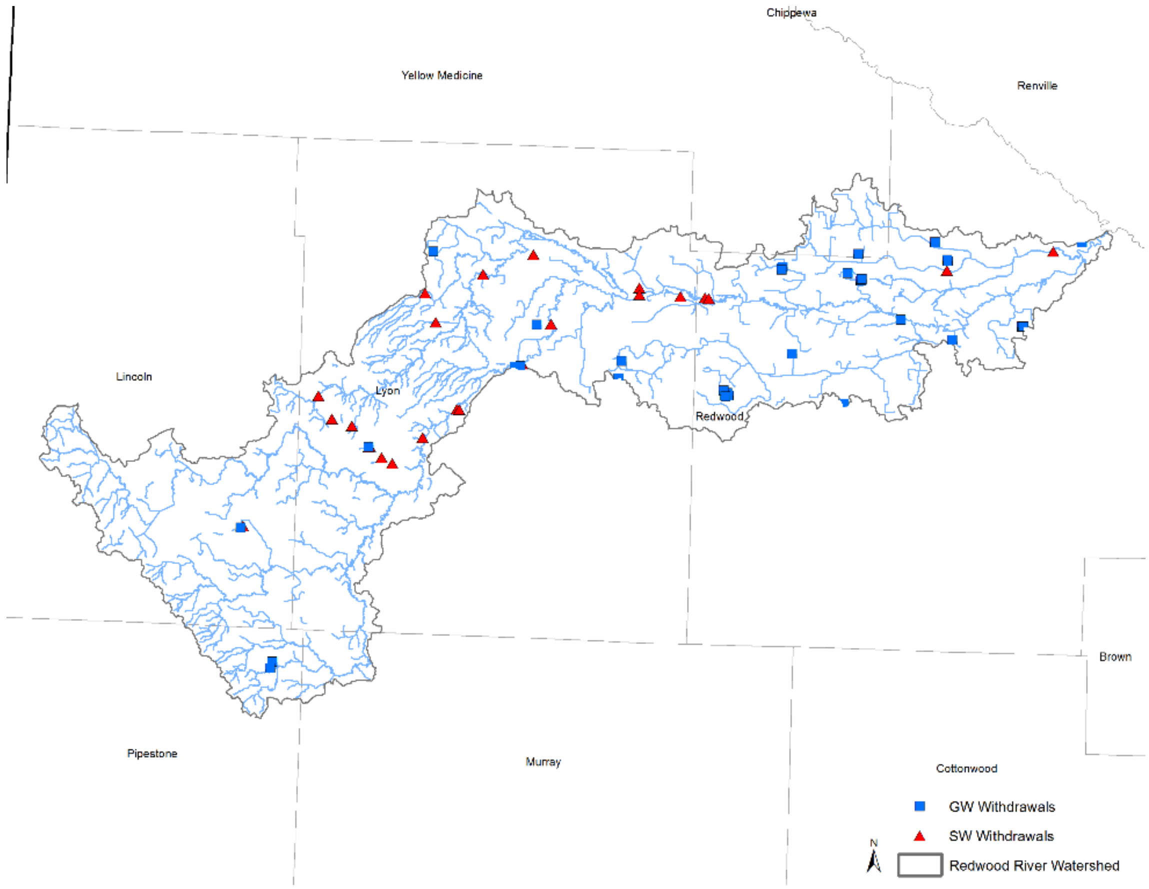
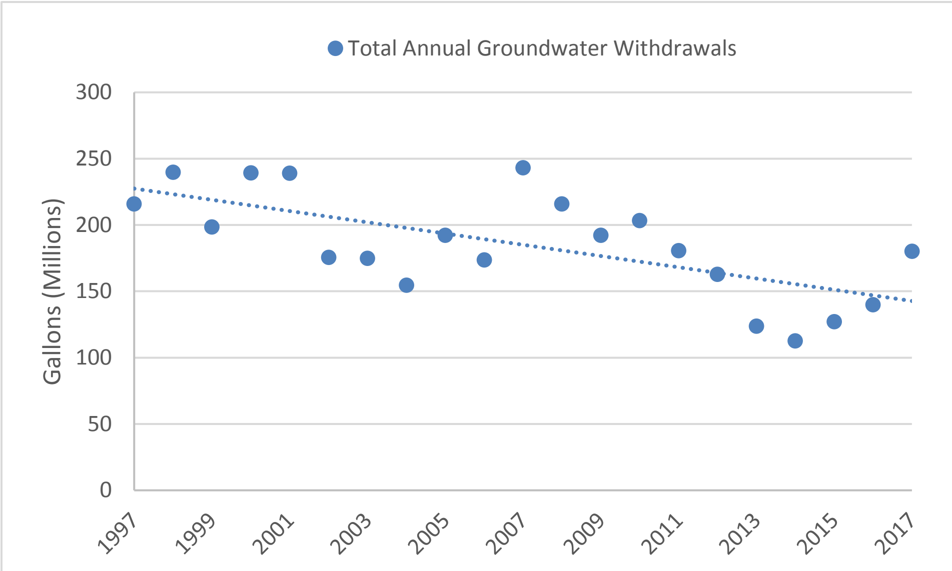
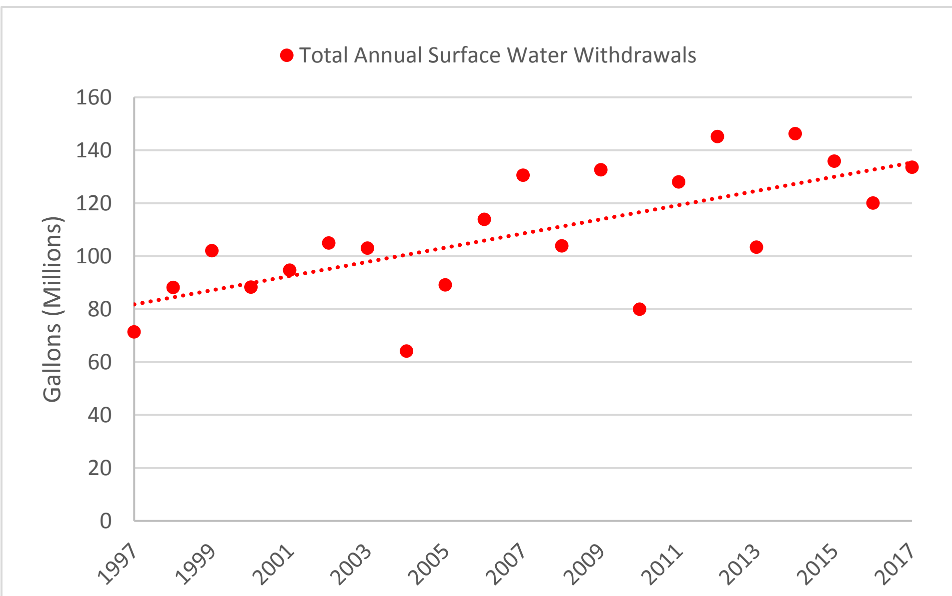


**Figure 28. Total annual groundwater (above) and surface water (below) withdrawals in the Redwood River Watershed (1997-2017).**




## Stream flow

Stream flow data from the United States Geological Survey's real-time streamflow gaging stations on the Redwood River in Marshall, Minnesota and downstream near Redwood Falls, Minnesota were analyzed for mean annual discharge and summer (July and August) monthly mean discharge from 1997-2017 (Figure 29 and Figure 30). The data fluctuate, but these changes illustrate seasonality of flow and responses to precipitation and are not statistically significant. By way of comparison at a state level, summer month flows have declined at a statistically significant rate at a majority of streams selected randomly for a study of statewide trends (Streitz, 2011).

**Figure 29. Average Annual (top) and Summer mean discharge for the Redwood River near Marshall, Minnesota (1997-2017) (Source: USGS 2020a).**

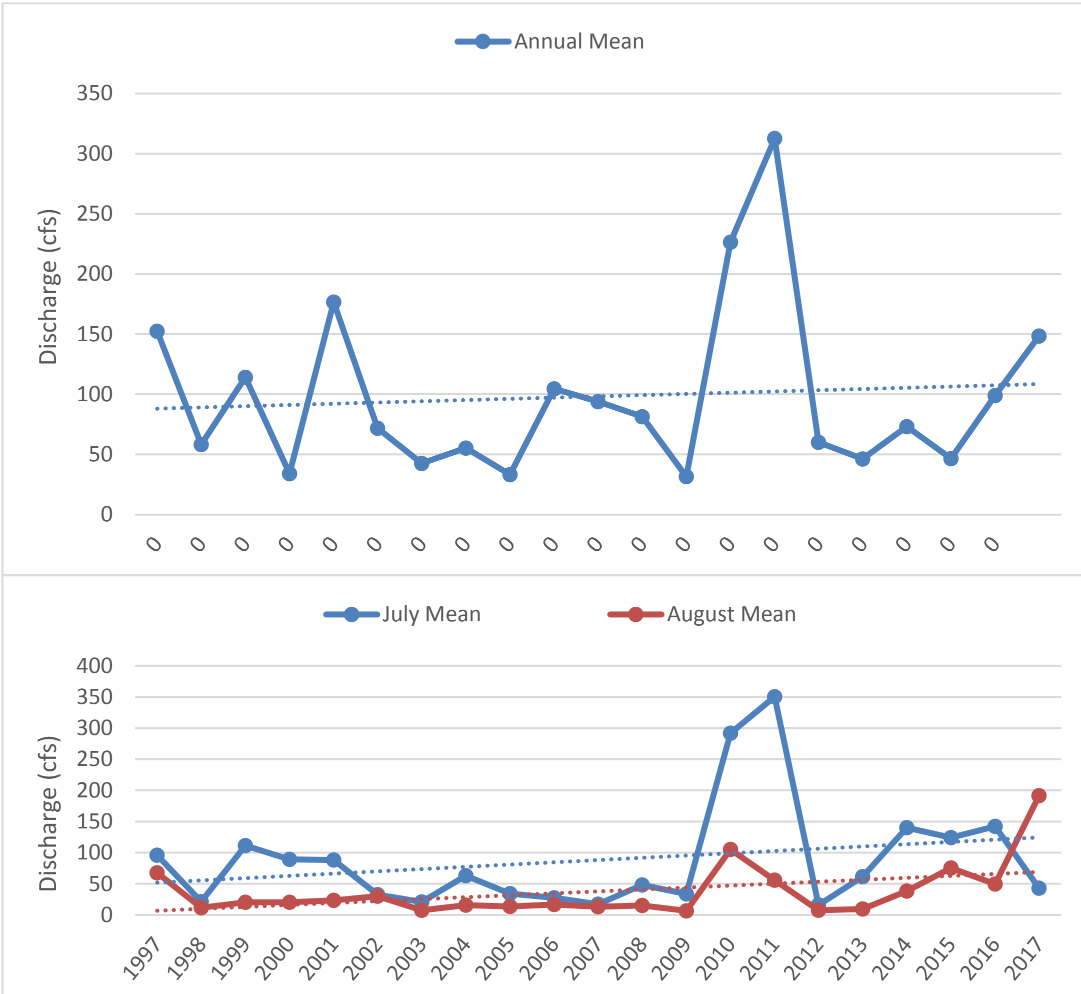
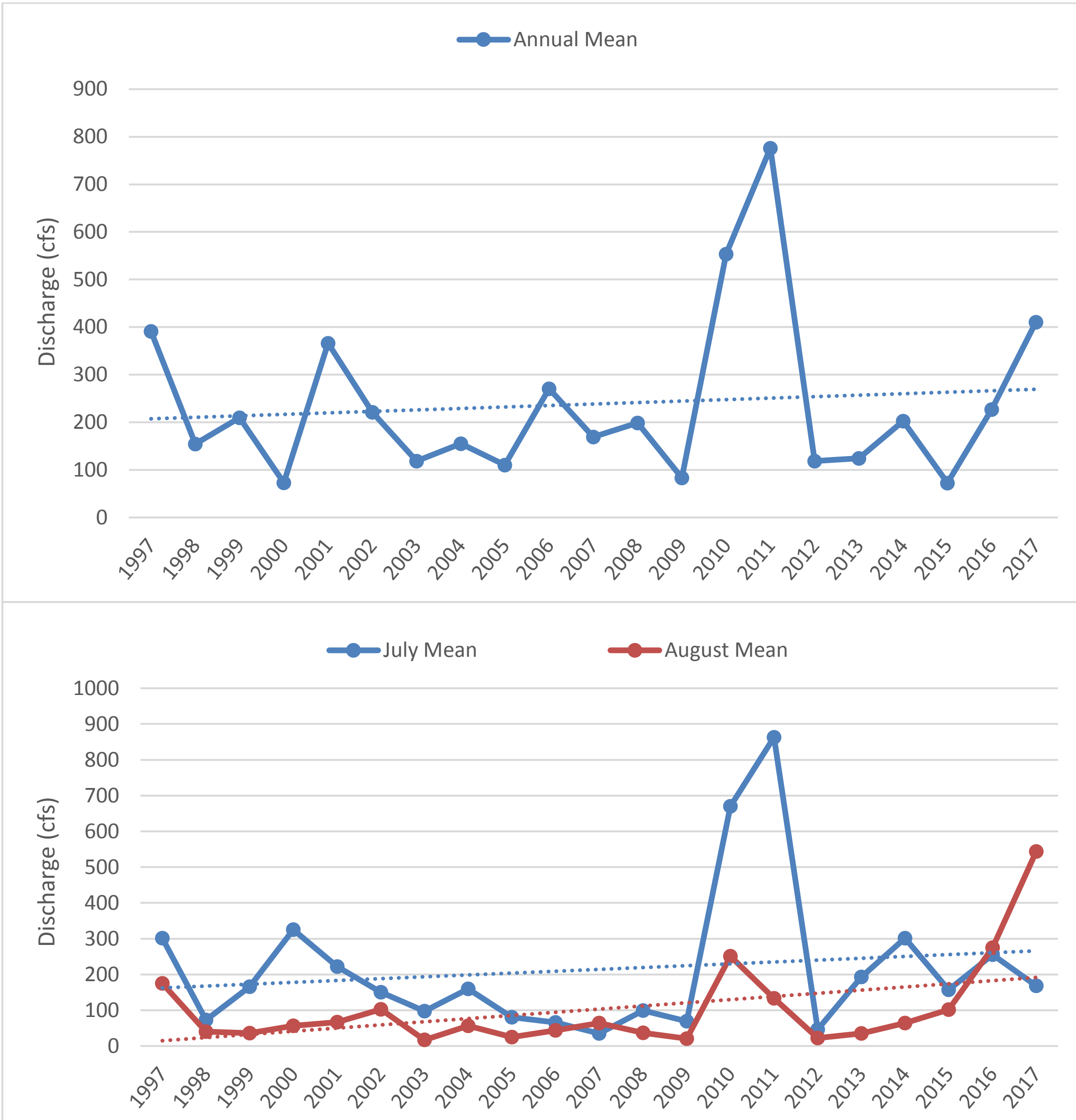


**Figure 30. Average Annual (top) and Summer (bottom) mean discharge for the Redwood River near Redwood Falls, Minnesota (1997-2017) (Source: USGS 2020b).**



## Wetland condition

As noted earlier, the Redwood River Watershed occurs entirely within the Temperate Prairies ecoregion. As discussed in the methods section, the MPCA uses two biological indicators (invertebrates and vegetation) to access wetland quality. Based on plant community floristic quality, 82% of wetlands in the Temperate Prairies Ecoregion are estimated to be in fair or poor condition and an estimated 11% are in good condition (Table 20). In contrast the wetland invertebrate condition indicator in the Temperate Prairies ecoregion, found 41% of the wetlands are in Good condition and 57% are in either Fair or Poor condition.

**Table 20. Biological wetland condition statewide and by major ecoregions according to vegetation and invertebrate indicators. Vegetation results are expressed by extent (i.e., percentage of wetland acres) and include essentially all wetland types (MPCA 2015). Invertebrate results represent natural depressional wetlands (e.g., prairie potholes) that typically have open water and are expressed as the percentage of wetland basins (Genet 2015). Depressional wetland monitoring is focused in Mixed Wood Plains and Temperate Prairie ecoregions (as opposed to statewide) where it is a more prevalent type.**

| **Vegetation Condition in All Wetland Community Types** | | | |
|---|---|---|---|
| Condition Category | Statewide | Mixed Wood Plains Ecoregion | Temperate Prairies Ecoregion |
| Exceptional | 49% | 6% | 7% |
| Good | 18% | 12% | 11% |
| Fair | 23% | 42% | 40% |
| Poor | 10% | 40% | 42% |

| **Invertebrate Condition in Depressional Wetlands** | | |
|---|---|---|
| Condition Category | Mixed Wood Plains & Temperate Prairies Ecoregion combined | Temperate Prairies Ecoregion |
| Good | 43% | 44% |
| Fair | 27% | 23% |
| Poor | 29% | 32% |

Wetlands in the Temperate Prairies are commonly dominated by invasive plants, particularly narrow-leaf cattail (*Typha angustifolia*), hybrid cattail (*Typha* X *glauca*), and reed canary grass (*Phalaris arundinacea*). These invasive plants often outcompete native species due to their tolerance of nutrient enrichment, hydrologic alterations and toxic pollutants such as chlorides (Galatowisch 2012) and thus strongly influence the composition and structure of the wetland plant community.

Wetlands are an important part of watershed and water quality protection and restoration. Wetlands are affected by many pollutants and related stressors and it is often very difficult and costly to rehabilitate wetlands that are in an impoverished condition. Thus, it will be more cost effective in the Redwood River Watershed, as well as other HUC8 watersheds in the prairie region to focus on protecting the few remaining high quality wetlands. Management practices to limit additional wetland hydrologic alternations and efforts to reduce the spread of invasive species promise to be the most cost effective ways to protect and restore water quality in the Redwood River watershed.

**Figure 31. Stream Tiered Aquatic Life Use Designations in the Redwood River Watershed.**

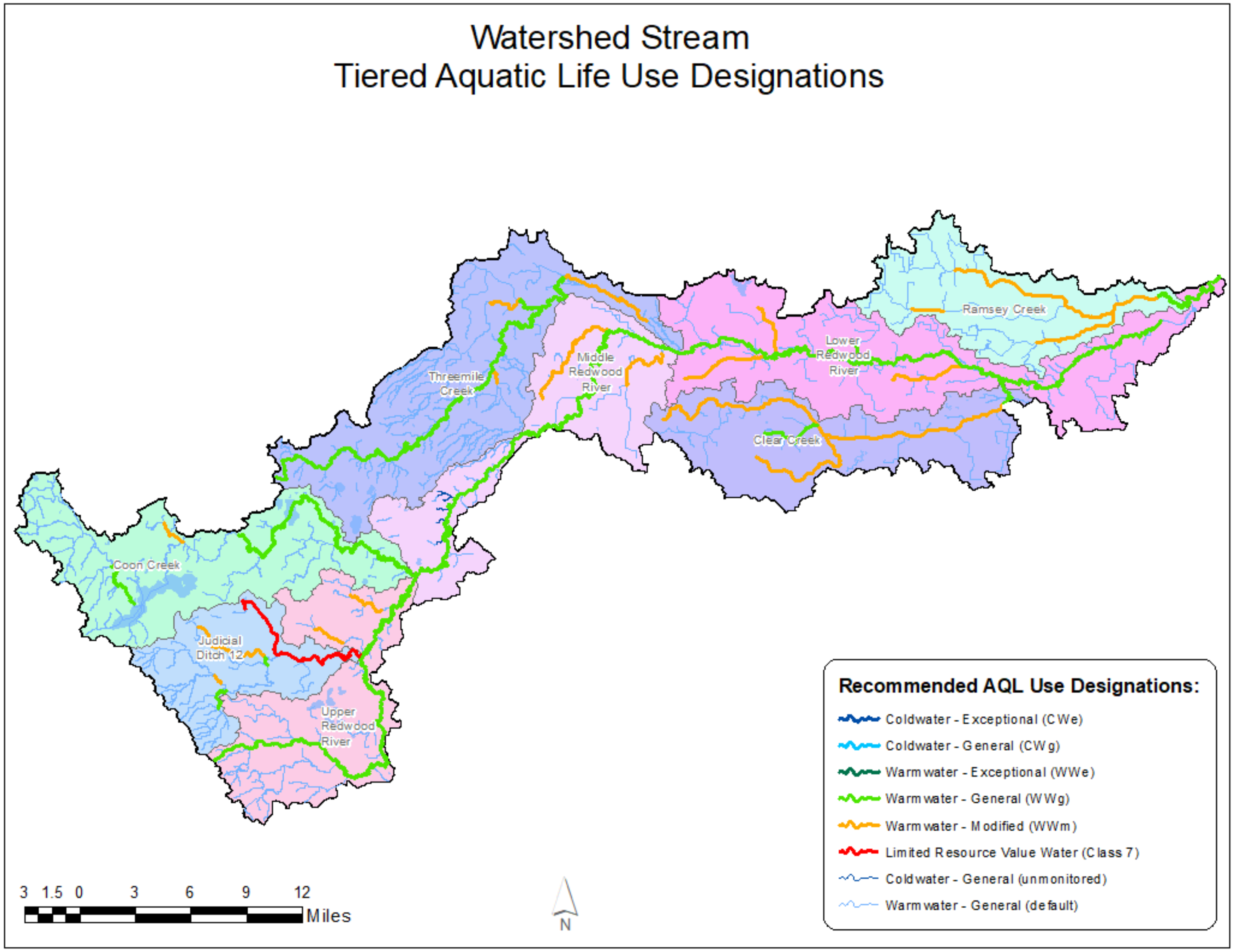


**Figure 32. Fully supporting waters by designated use in the Redwood River Watershed.**

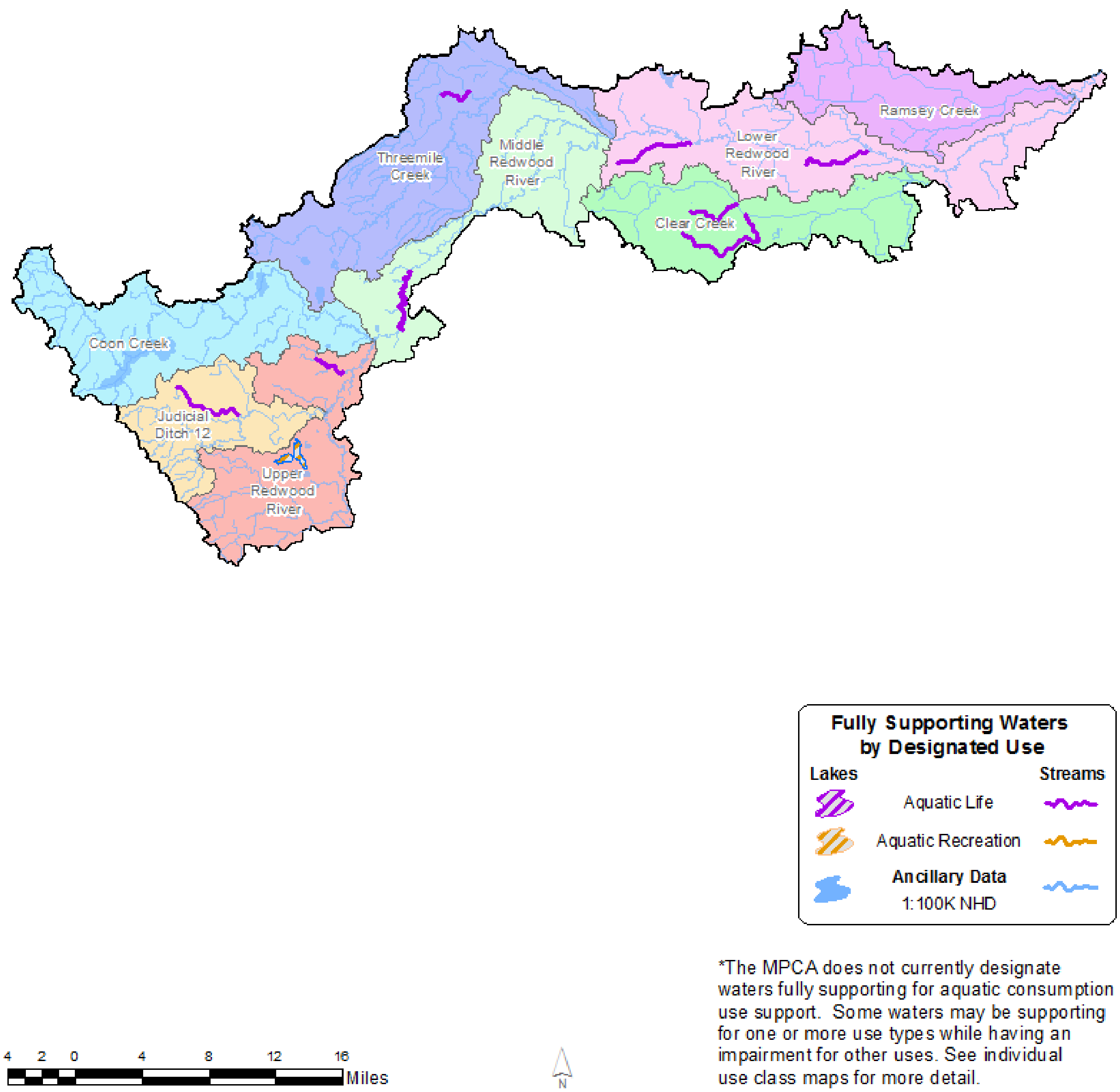


**Figure 33. Impaired waters by designated use in the Redwood River Watershed.**

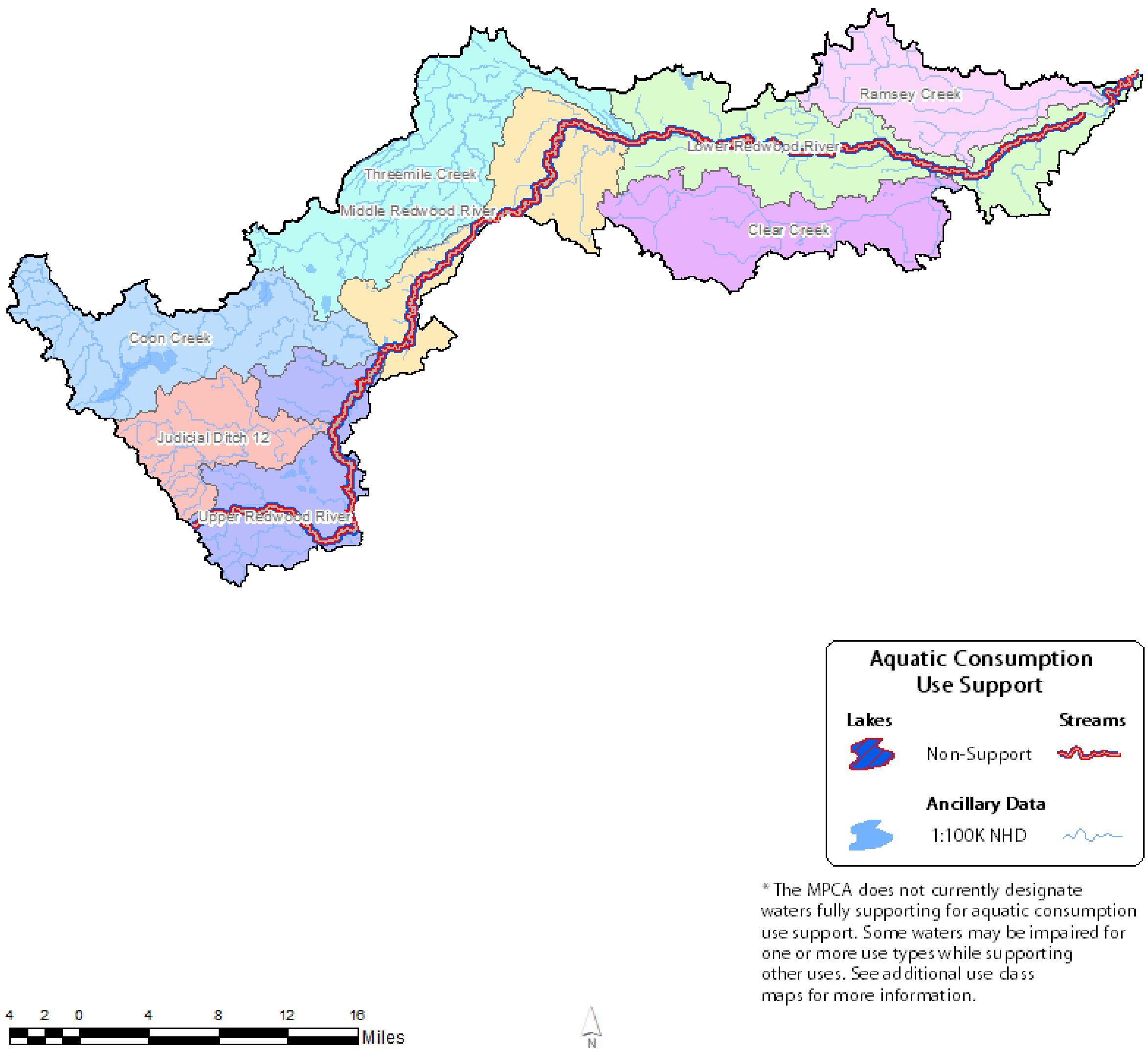


**Figure 34. Aquatic consumption use support in the Redwood River Watershed.**

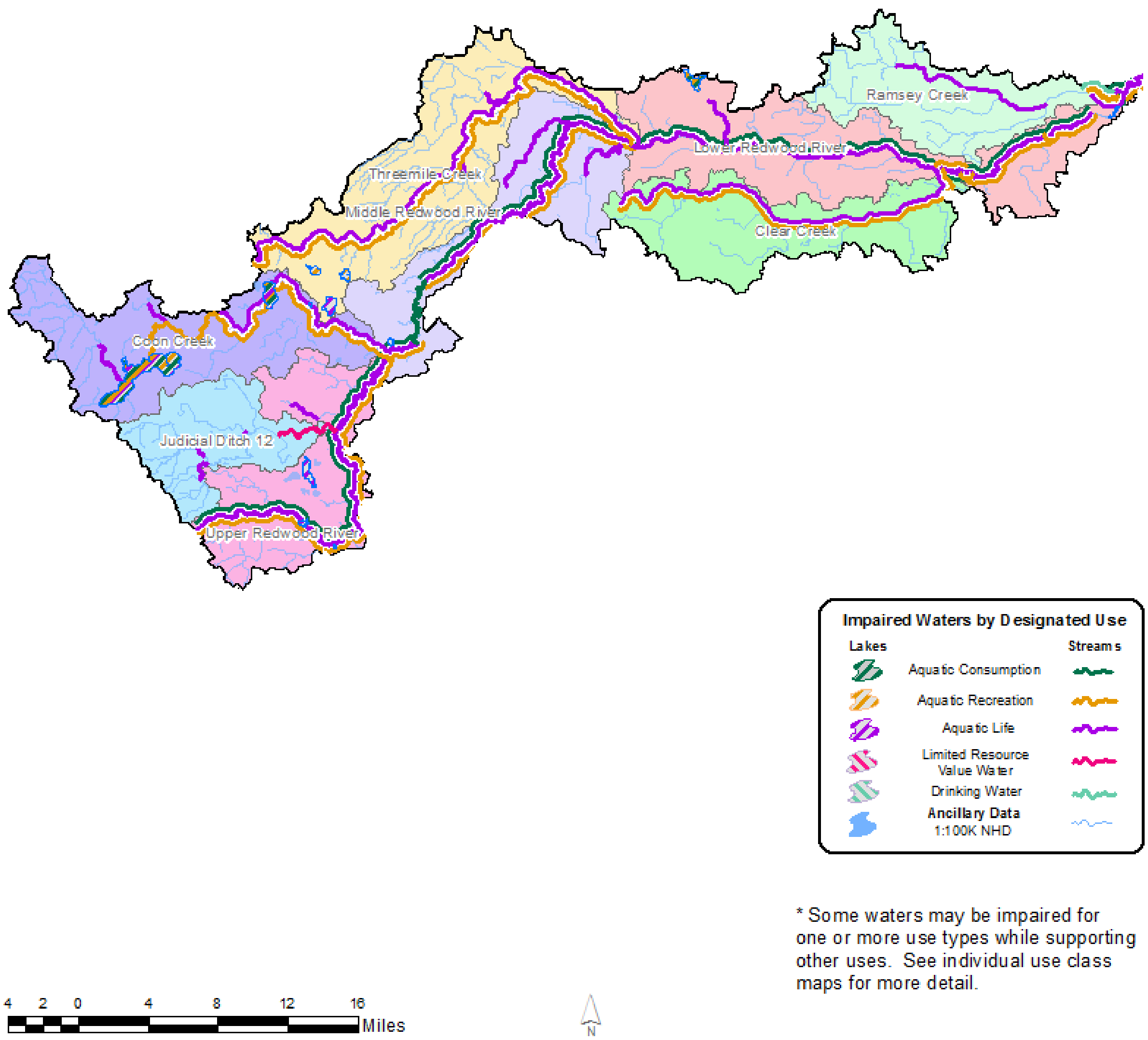


**Figure 35. Aquatic life use support in the Redwood River Watershed.**

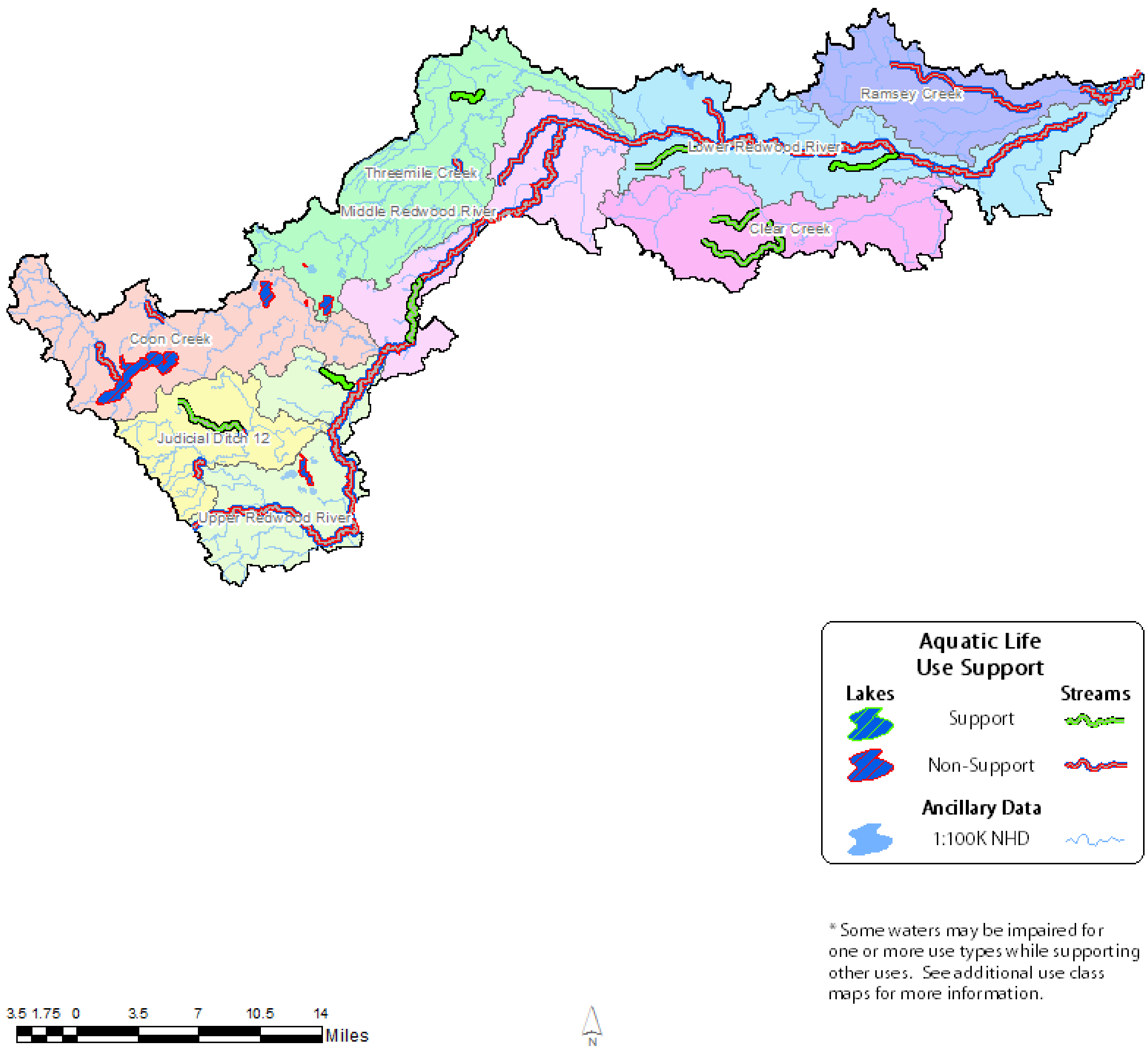
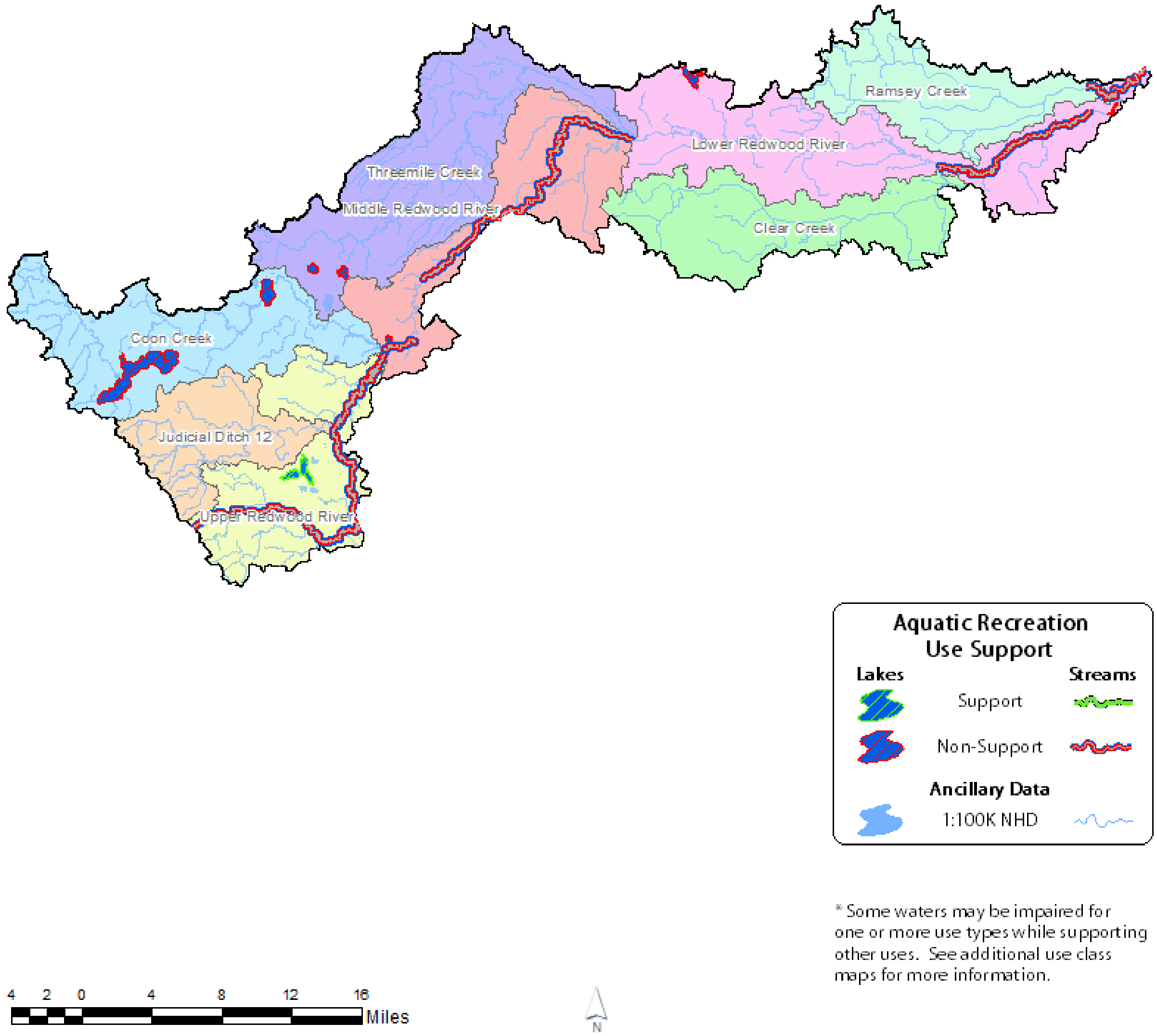


Figure 36. Aquatic recreation use support in the Redwood River Watershed.



## Transparency trends for the Redwood River Watershed

MPCA completes annual trend analysis on lakes and streams across the state based on long-term transparency measurements. The data collection for this work relies heavily on volunteers across the state and also incorporates any agency and partner data submitted to EQuIS.

The trends are calculated using a Seasonal Kendall statistical test for waters with a minimum of eight years of transparency data; Secchi disk measurements in lakes and Secchi tube measurements in streams.

Citizen volunteer monitoring occurred at one location on Threemile Creek. Numerous stations on the Redwood River and one station on Threemile Creek have long term trends of decreasing water clarity. Water clarity has shown no trend on Dead Coon Lake and Lake Benton.

**Table 21. Water Clarity Trends.**

| Redwood River HUC 07020006 | Streams | Lakes |
|---|---|---|
| **Number of sites w/increasing trend** | 0 | 0 |
| **Number of sites w/decreasing trend** | 9 | 0 |
| **Number of sites w/no trend** | 6 | 2 |

In June 2014, the MPCA published its final trend analysis of river monitoring data located statewide based on the historical Milestones Network. The network is a collection of 80 monitoring locations on rivers and streams across the state with good, long-term water quality data. The period of record is generally more than 30 years, through 2010, with monitoring at some sites going back to the 1950s. While the network of sites is not necessarily representative of Minnesota's rivers and streams as a whole, they do provide a valuable and widespread historical record for many of the state's waters. Starting in 2017, the MPCA will be switching to the Pollutant Load Monitoring Network for long term trend analysis on rivers and streams. Data from this program has much more robust sampling and will cover over 100 sites across the state.

## Priority Waters for Protection and Restoration in the Redwood River Watershed

The MPCA, DNR, and BWSR have developed methods to help identify waters that are high priority for protection and restoration activities. Protecting lakes and streams from degradation requires consideration of how human activities impact the lands draining to the water. In addition, helping to determine the risk for degradation allows for prioritization to occur; so limited resources can be directed to waters that would benefit most from implementation efforts.

The results of the analysis are provided to watershed project teams for use during WRAPS and One Watershed One Plan or other local water plan development. The results of the analysis are considered a preliminary sorting of possible protection priorities and should be followed by a discussion and evaluation with other resource agencies, project partners and stakeholders. Other factors that are typically considered during the protection prioritization process include: whether a water has an active lake or river association, is publically accessible, presence of wild rice, presence of invasive, rare or endangered species, as well as land use information and/or threats from proposed development. Opportunities to gain or enhance multiple natural resource benefits ("benefit stacking") is another consideration during the final protection analysis. Waterbodies identified during the assessment process as vulnerable to impairment are also included in the summary below.

The results for selected indicators and the risk priority ranking for each lake are shown in Appendix 6. Protection priority should be given to lakes that are particularly sensitive to an increase in phosphorus with a documented decline in water quality (measured by Secchi transparency), a comparatively high percentage of developed land use in the area, or monitored phosphorus concentrations close to the water quality standard. In the Redwood River Watershed, highest protection priority is suggested for West Twin and Sanderson Lakes.

The results for selected indicators and risk priority ranking for each stream are shown in Appendix 7. Stream protection is driven by how close the stream is to having an impaired biological community, density of roads and disturbed land use in the immediate and larger drainage area, and how much land is protected in the watershed. In Redwood River Watershed, two General use streams were identified as high priority: A and B. In addition five smaller Modified use streams scored A or B for protection efforts. While these streams currently meet standards, work done to maintain current condition is important to prevent impairment in the future.

East Twin Lake is a noteworthy outlier of good water quality during monitoring events in 2017 and 2018, the basin should be considered for future protection efforts given the relatively poor quality of lakes in this region and the potential for degradation.

# Summaries and recommendations

Human activities within the Redwood River major watershed have had a significant impact on the health of waterbodies found there. Of the 35 stream reaches assessed for aquatic life, 74% (26) were found to not support healthy aquatic communities. Degraded fish assemblages contributed to 56% (15) of the aquatic life impairments, seven of which were on modified use reaches. Macroinvertebrates contributed to 49% (17) of impairments, with six of these on modified use reaches. Ten (37%) of the impaired reaches had both fish and macroinvertebrates assemblages failing to meet aquatic life standards. Four reaches had existing aquatic life impairments based on the fish community, and current fish community data confirmed these impairments. One of these reaches was not sampled during the current monitoring effort; the existing impairment will carry forward. There were no existing aquatic life impairments based on macroinvertebrates.

One factor affecting fish community IBI scores is the prevalence of fish species tolerant of pollution. Of the five most abundant fish species found in this monitoring effort (in order of abundance): creek chub, blacknose dace, common shiner, white sucker, and fathead minnow, all are considered generalist which are able to survive in a variety of conditions and environments. Tolerant and very tolerant species are also found in the top five fish in abundance. Creek chubs, blacknose dace, white sucker, and fathead minnow are all considered tolerant of pollution. Fathead minnows are also considered very tolerant of pollution. When tolerant species make up the majority of a fish sample, IBI score are typically lower.

Similarly, the frequency of occurrence and abundance of tolerant taxa has a significant impact on macroinvertebrate IBI scores. The five most abundantly collected organisms (Hyallela, Physella, Tricorythodes, Polypedilum, Cheumatopsyche), are all considered pollution tolerant organisms and all are tolerant of low dissolved oxygen, and suspended sediment. The most frequently encountered taxa Hyallela, Physella, Thienemannimyia Gr., Polypedilum, Cheumatopsyche) are similarly pollution tolerant taxa.

Many issues contribute to degraded fish and invertebrate communities in streams. Altered hydrology from channelization and drain tile contribute to in stream erosion and sedimentation. Low flows can also be more pronounced with altered hydrology, negatively impacting fish and invertebrate communities. Climate change can also threaten streams with more frequent extreme flood events. Habitat availability can be a problem in streams, especially channelized reaches. Surrounding land use and riparian conditions can also have negative impacts on fish and invertebrate communities. Barriers to fish movement such as dams and perched culverts can also lead to degraded fish communities.

Seven stream reaches were fully supporting for aquatic life based on the fish assemblage. A supporting macroinvertebrate assemblage contributed to six of those reaches. Two of these reaches were on general use stream reaches, while five were on modified use reaches. Of the 45 fish species recorded with this monitoring effort, eight sensitive species were collected. These sensitive species, with their order of abundance in parentheses, include: Iowa darter ($10^{th}$), fantail darter ($12^{th}$), hornyhead chub ($17^{th}$), northern hogsucker ($20^{th}$), slenderhead darter ($36^{th}$), smallmouth bass ($38^{th}$), rainbow darter ($44^{th}$), and stonecat ($45^{th}$). Seven very intolerant invertebrate taxa were found, all in very low abundance and frequency. They included the stoneflies Acroneuria and Taeniopteryx, and the caddisflies Helicopsyche and Oxyethira, the mayfly Acerpenna, and the midges Tribelos, and Stempellinella. No federally endangered or species of concern were collected, nor were any state threatened or species of concern. Protection strategies could prevent these streams from degradation in the future.

Historical monitoring and assessment of the Redwood River Watershed had identified significant water quality issues before IWM efforts in 2017 and 2018. The current assessment effort has made it clear that past issues related to excess suspended solids and nutrients remain a significant problem that need to be addressed in order to improve water quality for aquatic life. Considering newer data, all Redwood River reaches previously on the impaired waters list for suspended solids will remain. Sediment loads carried by most of the main tributaries in the Minnesota River basin have consistently contributed to poor water quality, drastically impacting natural hydrology and impairing the function of aquatic communities. Preserving surface water storage in the uplands can reduce the magnitude of high surface water runoff events, which leads to increased bank instability, decreased channel incision, and decreased sediment loading. Stream buffers can provide a means for surface water runoff to infiltrate naturally. A basin wide TMDL effort is in progress to address the large scale and complex water quality issues in the watershed. Nutrient concentrations, specifically total phosphorus, were measured at unusually high concentrations in the Redwood River across the 10-year period of record considered in the assessment process. Where nutrient response data was available, increased algae concentrations were observed during low flow periods, which triggered an impairment in 2016 in one of the downstream reaches of the Redwood River. Nutrient rich waters are common in most major watersheds in the Minnesota River basin, this can lead to increased biological oxygen demand, highly fluctuating dissolved oxygen concentrations, and decreased habitat availability from overgrowth of aquatic vegetation. Collaborative efforts between water management groups is key to assembling a successful, watershed scale restoration plan. A shared understanding of the objectives and funding sources will be essential for reaching long term milestones in water quality improvement.

Many streams in this watershed had past assessments indicating poor conditions for recreational water use. Newer data from these reaches confirms that bacterial contamination persists. TMDL efforts and protection strategies are ongoing, attempting to address the problems causing poor recreational water quality. Concentrated animal activity within streams and adjacent flood plain is typically associated with high bacteria levels. Limiting the access of high concentrations of livestock to these areas could potentially lower bacteria levels. Additionally, investigations into the compliance of private septic systems could potentially address elevated bacteria concentrations.

The majority of lakes within this watershed show stresses related to disturbed land use within their contributing watershed; nutrient loading, dense algal blooms and low water clarity are common problems. Previously impaired lakes with poor recreational water quality had newer data confirming initial conditions; these lakes will remain on the impaired waters list. East and West Twin Lakes appear to be the best examples of good recreational water quality in the watershed, both should be protected from degradation into future impairment. Recreation levels are severely impacted when lakes have frequent heavy algae blooms throughout the summer months. These blooms are fueled by unnaturally elevated nutrient concentrations. Poor recreational use potential can result in reduced economic benefits to local businesses that rely on healthy recreational opportunities in the area. Controlling the nutrient inputs to these lakes can engage citizens at a local level. Keeping native shoreline buffers intact, preventing yard waste input, maintaining complaint septic systems, and reducing or eliminating fertilizer use are all potential practices to investigate locally. Addressing larger scale issues such as altered surface hydrology and overland runoff would be potential areas for improvement as well. In some cases, internal loading on shallow lake basins can be difficult to manage. Devoting time and financial resources to develop long term restoration and protection strategies will be required for these lakes to see water quality improvements.

Fish community index data available for lakes allowed for assessment of aquatic life use not possible in previous assessments within this watershed. Four lakes were added to the impaired waters list as impaired for aquatic life based on poor fish community health. Tolerant taxa such as common carp, black bullhead and fathead minnow were abundant and dominated the biomass in some lakes, resulting in low biological index scores. While other lakes lack food web diversity with low proportion of top carnivores and insectivore fish species. Protecting and improving aquatic habitat both in-lake and on adjacent shoreline is key to promoting strong natural reproduction and a healthy food web to provide the building blocks for diverse aquatic communities. Increased watershed disturbance has been linked as a negative influence to fish community health.

Groundwater protection should be considered both for quantity and quality. Groundwater quality concerns are primarily related to potentially high levels of naturally-occurring elements in drinking water as well as chloride and nitrate from human activities. The concerns for quantity are based on a comparison of the amount of water being withdrawn versus the amount of water being recharged to the aquifer. Groundwater withdrawals and surface water withdrawals in the watershed have both increased significantly in recent years. Despite these increases, groundwater levels have increased with statistical significance in monitored locations, this is most likely due to increased precipitation levels over the past decade. Continued attention to water users and additional monitoring of groundwater quantity will provide the information needed to conserve the resource in the watershed.

Significant wetland loss has occurred in the Redwood River Watershed, approaching 70% across the watershed. The fewest losses have occurred in the Coon Creek, Judicial Ditch 12, and Upper Redwood River subwatersheds, where slopes are steeper and rocky, glacial till is less conducive for row crop agriculture. Up to 85% of the wetlands have been lost further down in the watershed. A probabilistic survey of the condition of wetland plant communities in the temperate prairies ecoregion, estimate 82% of the wetlands are in fair to poor condition, and 11% are in good condition. Macroinvertebrate indicators show that 55% of the wetlands are in fair to poor condition, while 44% are in good condition. Focusing on protecting the few remaining high quality wetlands from hydrologic alteration and invasive species should be an important watershed management consideration.

Significant, valuable water resources are found within the Redwood River Watershed and its productive agricultural landscape. Protection of the groundwater, lakes, streams, and wetlands within the watershed will help to maintain or improve water quality throughout the watershed. These resources face many threats, including climate change, altered hydrology, sedimentation, excess nutrients, and invasive species. Considering the potential impacts of climate change and the more frequent flooding events that have been occurring, efforts to better manage water inputs from drainage systems, and increasing water storage on the landscape, will help minimize the effects of altered hydrology. Cover crops, conservation tillage, improving riparian corridors, and maintaining buffer strips can all help reduce sediment from erosion. Improving nutrient management on surrounding agricultural lands can help curb excess nutrients from degrading the areas water resources. Maintaining or improving the quality of the water resources within the watershed through best management practices should be an important watershed management consideration.

# Literature cited


Galatowitsch, S.A. 2012. Why invasive species stymie wetland restoration; Society of Wetland Scientists Research Brief, No. 2012-0001. 4 pp. http://www.sws.org/ResearchBrief/galatowitsch_2012_0001.pdf.

Genet, J.A. and A.R. Olsen. 2008. Assessing depressional wetland quantity and quality using a probabilistic sampling design in the Redwood River Watershed, Minnesota, USA. Wetlands 28(2), pp 324-335.

Genet, J. 2015. Status and Trends of Wetlands in Minnesota: Depressional Wetland Quality Assessment (2007-2012). Minnesota Pollution Control Agency, St. Paul, MN. https://www.pca.state.mn.us/sites/default/files/wq-bwm1-08.pdf

Minnesota Department of Health (2020a), Arsenic in Private Wells: Facts & Figures. Retrieved from https://data.web.health.state.mn.us/web/mndata/arsenic_wells

Minnesota Department of Health (2020b), Private Wells – Arsenic: MDPH Data Access. Retrieved from https://mndatamaps.web.health.state.mn.us/interactive/wells.html

Minnesota Department of Natural Resources (2017a), Groundwater Provinces. Retrieved from http://dnr.state.mn.us/groundwater/provinces/index.html

Minnesota Department of Natural Resources (2017b), Watershed Context Report: Redwood River. Retrieved from http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/context_report_major_27.pdf

Minnesota Department of Natural Resources (2017c), Watershed Report Card: Redwood River. Retrieved from http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_27.pdf

Minnesota Department of Natural Resources (2019a), Water use- Water Appropriations Permit Program. Retrieved from http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

Minnesota Department of Natural Resources: State Climatology Office (2019b), Annual Precipitation Maps. Retrieved from http://www.dnr.state.mn.us/climate/historical/annual_precipitation_maps.html

Minnesota Department of Natural Resources: State Climatology Office (2020), Climate. Retrieved from http://www.dnr.state.mn.us/faq/mnfacts/climate.html

Minnesota Pollution Control Agency (1999), Baseline Water Quality of Minnesota's Principal Aquifers: Region 4, Southwest Minnesota.

Minnesota Pollution Control Agency (MPCA). 2007b. Minnesota Statewide Mercury Total Maximum Daily Load. Minnesota Pollution Control Agency, St. Paul, Minnesota.

Minnesota Pollution Control Agency (MPCA). 2008a. Watershed Approach to Condition Monitoring and Assessment. Appendix 5.2 *in* Biennial Report of the Clean Water Council. Minnesota Pollution Control Agency, St. Paul, Minnesota.

Minnesota Pollution Control Agency (MPCA). 2010a. Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity). http://www.pca.state.mn.us/index.php/view-document.html?gid=14922.

Minnesota Pollution Control Agency (MPCA). Guidance Manual for Assessing the Quality of Minnesota Surface Water for the Determination of Impairment: 305(b) Report and 303(d) List. Environmental Outcomes Division, Minnesota Pollution Control Agency, St. Paul, Minnesota.

Minnesota Pollution Control Agency (MPCA). 2010d. Minnesota Milestone River Monitoring Report. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/streams-and-rivers/minnesota-milestone-river-monitoring-program.html.

Minnesota Pollution Control Agency (MPCA). 2010e. Regionalization of Minnesota's Rivers for Application of River Nutrient Criteria. http://www.pca.state.mn.us/index.php/view-document.html?gid=6072.

Minnesota Pollution Control Agency (MPCA). 2015. Status and Trends of Wetlands in Minnesota: vegetation quality baseline. https://www.pca.state.mn.us/sites/default/files/wq-bwm1-09.pdf.

Minnesota Pollution Control Agency (MPCA). 2015. Technical guidance for designating aquatic life uses in Minnesota streams and rivers. Minnesota Pollution Control Agency, St. Paul, MN (Available at: https://www.pca.state.mn.us/sites/default/files/wq-s6-34.pdf).

Minnesota Pollution Control Agency (MPCA). 2017. Incorporating Lake Protection Strategies into WRAPS Reports.

Minnesota Rules Chapter 7050. 2008. Standards for the Protection of the Quality and Purity of the Waters of the State. Revisor of Statutes and Minnesota Pollution Control Agency, St. Paul, Minnesota.

Omernik, James A., and Gallant, Alisa L. 1988. Ecoregions of the Upper Midwest States. U.S. Environmental Protection Agency, Corvallis, OR. NSI Technology Services Corporation, Corvallis, OR.

Streitz, A. (2011), Minnesota Pollution Control Agency. Retrieved from http://www.mgwa.org/newsletter/mgwa2011-4.pdf

United States Department of Agriculture (USDA). 2006. Major Land Resource Areas Explorer Custom Report: Central Feed Grains and Livestock Region, Central Iowa and Minnesota Till Prairies, Rolling Till Prairie. Data Source: USDA Agriculture Handbook 296. Retrieved from http://apps.cei.psu.edu/mlra/

United States Geological Survey (2007), Ground Water Recharge in Minnesota. Retrieved from http://pubs.usgs.gov/fs/2007/3002/pdf/FS2007-3002_web.pdf

United States Geological Survey (2015), Mean Annual Potential Groundwater Recharge Rates from 1996-2010 for Minnesota. Methodology documented in Smith, E.A. and Westernbroek, S.M., 2015 Potential groundwater recharge for the state of Minnesota using the Soil-Water-Balance model, 1996-2010: U.S. Geological Survey Investigations Report 2015-5038. Using: ArcGIS [GIS software]. Version 10.3.1. Redlands, CA: Environmental Systems Research Institute. Retrieved from https://conservancy.umn.edu/handle/11299/60085

United States Geological Survey (2020a), National Water Information System: Web Interface. USGS 05315000 Redwood River near Marshall, MN. Retrieved from https://waterdata.usgs.gov/nwis/inventory/?site_no=05315000

United States Geological Survey (2020b), National Water Information System: Web Interface. USGS 05316500 Redwood River near Redwood Falls, MN. Retrieved from https://waterdata.usgs.gov/mn/nwis/inventory/?site_no=05316500

Western Regional Climate Center (WRCC) (2020), U.S.A. Divisional Climate Data. Retrieved from http://www.wrcc.dri.edu/spi/divplot1map.html

# Appendix 1 – Water chemistry definitions

**Dissolved oxygen (DO) -** Oxygen dissolved in water required by aquatic life for metabolism. Dissolved oxygen enters into water from the atmosphere by diffusion and from algae and aquatic plants when they photosynthesize. Dissolved oxygen is removed from the water when organisms metabolize or breathe. Low DO often occurs when organic matter or nutrient inputs are high, and light inputs are low.

***Escherichia coli (E. coli)*** - A type of fecal coliform bacteria that comes from human and animal waste. *E. coli* levels aid in the determination of whether or not fresh water is safe for recreation. Disease-causing bacteria, viruses and protozoans may be present in water that has elevated levels of *E. coli*.

**Nitrate plus Nitrite – Nitrogen -** Nitrate and nitrite-nitrogen are inorganic forms of nitrogen present within the environment that are formed through the oxidation of ammonia-nitrogen by nitrifying bacteria (nitrification). Ammonia-nitrogen is found in fertilizers, septic systems and animal waste. Once converted from ammonia-nitrogen to nitrate and nitrite-nitrogen, these species can stimulate excessive levels of algae in streams. Because nitrate and nitrite-nitrogen are water soluble, transport to surface waters is enhanced through agricultural drainage. The ability of nitrite-nitrogen to be readily converted to nitrate-nitrogen is the basis for the combined laboratory analysis of nitrate plus nitrite-nitrogen (nitrate-N), with nitrite-nitrogen typically making up a small proportion of the combined total concentration. These and other forms of nitrogen exist naturally in aquatic environments; however, concentrations can vary drastically depending on season, biological activity, and anthropogenic inputs.

**Orthophosphate** - Orthophosphate (OP) is a water soluble form of phosphorus that is readily available to algae (bioavailable). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from wastewater treatment plants, noncompliant septic systems and fertilizers in urban and agricultural runoff.

**pH** - A measure of the level of acidity in water. Rainfall is naturally acidic, but fossil fuel combustion has made rain more acid. The acidity of rainfall is often reduced by other elements in the soil. As such, water running into streams is often neutralized to a level acceptable for most aquatic life. Only when neutralizing elements in soils are depleted, or if rain enters streams directly, does stream acidity increase.

**Total Kjeldahl nitrogen (TKN) -** The combination of organically bound nitrogen and ammonia in wastewater. TKN is usually much higher in untreated waste samples then in effluent samples.

**Total phosphorus (TP) -** Nitrogen (N), phosphorus (P) and potassium (K) are essential macronutrients and are required for growth by all animals and plants. Increasing the amount of phosphorus entering the system therefore increases the growth of aquatic plants and other organisms. Excessive levels of Phosphorous over stimulate aquatic growth and resulting in the progressive deterioration of water quality from overstimulation of nutrients, called eutrophication. Elevated levels of phosphorus can result in: increased algae growth, reduced water clarity, reduced oxygen in the water, fish kills, altered fisheries and toxins from cyanobacteria (blue green algae) which can affect human and animal health.

**Total suspended solids (TSS) –** TSS and turbidity are highly correlated. Turbidity is a measure of the lack of transparency or "cloudiness" of water due to the presence of suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter and plankton or other microscopic organisms. The greater the level of TSS, the murkier the water appears and the higher the measured turbidity.

Higher turbidity results in less light penetration which may harm beneficial aquatic species and may favor undesirable algae species. An overabundance of algae can lead to increases in turbidity, further compounding the problem.

**Unionized ammonia (NH3) -** Ammonia is present in aquatic systems mainly as the dissociated ion $NH4^+$, which is rapidly taken up by phytoplankton and other aquatic plants for growth. Ammonia is an excretory product of aquatic animals. As it comes in contact with water, ammonia dissociates into $NH4^+$ ions and $^-OH$ ions (ammonium hydroxide). If pH levels increase, the ammonium hydroxide becomes toxic to both plants and animals.

# Appendix 2.1 – Intensive watershed monitoring water chemistry stations in the Redwood River Watershed

| EQuIS ID | Biological station ID | WID | Waterbody name | Location | Aggregated 12-digit HUC |
|---|---|---|---|---|---|
| S000-299 | 17MN200 | 07020006-501 | Redwood River | At CR 101/River Rd, 1 mi. N of Redwood Falls | Lower Redwood River |
| S001-203 | 17MN201 | 07020006-502 | Redwood River | At Twp RD near CR67 0.5 Mi NE of Marshall | Middle Redwood River |
| S002-313 | 92MN036 | 07020006-565 | Threemile Creek | At CR 67/270th Ave, 6 mi. N of Marshall | Threemile Creek |
| S002-314 | 92MN028 | 07020006-570 | Coon Creek | At CR 66/190th St, 1.5 mi. NW of Russell | Coon Creek |
| S003-703 | 92MN025 | 07020006-505 | Redwood River | At MN 23, 1 mi. SW of Russel | Upper Re |
| S004-387 | 92MN047 | 07020006-521 | Ramsey Creek | At CSAH 17/Laser Ave, 1 mi. W of Redwood Falls | Ramsey Creek |
| S009-454 | 92MN043 | 07020006-568 | Clear Creek | At 290th St, .5 mi. SE of Seaforth | Clear Creek |
| S014-261 | 92MN025 | 07020006-512 | Judicial Ditch 12 (Tyler Creek) | At 125TH Ave, 3/4 mi N of Florence | Judicial Ditch 12 |

# Appendix 2.2 – Intensive watershed monitoring biological monitoring stations in the Redwood River Watershed

| WID | Biological station ID | Waterbody name | Biological station location | County | Aggregated 12-digit HUC |
|---|---|---|---|---|---|
| 07020006-501 | 17MN200 | Redwood River | Upstream of CR 101 (River Rd), 1 mi. N of Redwood Falls | Redwood | Lower Redwood River |
| 07020006-502 | 92MN032 | Redwood River | Adjacent to 300th St, 3 mi. N of Marshall | Lyon | Middle Redwood River |
| 07020006-502 | 92MN033 | Redwood River | Adjacent to 310th St, 6 mi. NE of Marshall | Lyon | Middle Redwood River |
| 07020006-503 | 17MN219 | Redwood River | Downstream of CR 51, 5.5 mi. NW of Millroy | Redwood | Lower Redwood River |
| 07020006-503 | 92MN037 | Redwood River | Downstream of CR 59, 3 mi. W of Vesta | Redwood | Lower Redwood River |
| 07020006-503 | 92MN041 | Redwood River | Upstream of CR 56, 3.5 mi. SE of Vesta | Redwood | Lower Redwood River |
| 07020006-505 | 17MN203 | Redwood River | Upstream of Lyon Murray Rd, 5.5 mi. NE of Ruthton | Murray | Upper Redwood River |
| 07020006-505 | 17MN234 | Redwood River | Downstream of 20th Ave, 4 mi. SE of Ruthton | Murray | Upper Redwood River |
| 07020006-505 | 92MN022 | Redwood River | Downstream of Hwy 14, 2 mi. E of Florence | Lyon | Upper Redwood River |
| 07020006-505 | 92MN025 | Redwood River | Upstream of Hwy 23, 0.5 mi. SW of Russel | Lyon | Upper Redwood River |
| 07020006-509 | 92MN045 | Redwood River | Upstream of CSAH 17, 3.5 mi. SW of Redwood Falls | Redwood | Lower Redwood River |
| 07020006-512 | 92MN024 | Tyler Creek | Upstream of Hwy 23, 1 mi. NE of Florence | Lyon | Judicial Ditch 12 |
| 07020006-513 | 90MN029 | Redwood River | Adjacent to Camden State Park Rd, 2 mi. NE of Russel | Lyon | Middle Redwood River |
| 07020006-515 | 17MN232 | County Ditch 14 | Upstream of 140th St, 2 mi. SE of Tyler | Lincoln | Judicial Ditch 12 |
| 07020006-517 | 17MN213 | Judicial Ditch 14/15 | Downstream of 255th St, 2.5 mi. E of Milroy | Redwood | Clear Creek |
| 07020006-520 | 17MN224 | Judicial Ditch 33 | Upstream of CSAH 6, 6 mi. W of Redwood Falls | Redwood | Ramsey Creek |
| 07020006-521 | 92MN047 | Ramsey Creek | Downstream of CSAH 17 (Laser Ave), 1 mi. W of Redwood Falls | Redwood | Ramsey Creek |

| WID | Biological station ID | Waterbody name | Biological station location | County | Aggregated 12-digit HUC |
|---|---|---|---|---|---|
| 07020006-527 | 92MN026 | Norwegian Creek | Upstream of Hwy 75, 2.5 mi. N of Lake Benton | Lincoln | Coon Creek |
| 07020006-529 | 91MN040 | County Ditch 33 | Downstream of Fairview Ave, 1.5 mi. SE of Vesta | Redwood | Lower Redwood River |
| 07020006-532 | 17MN207 | Unnamed Creek | Upstream of 132nd St, 2 mi. S of Tyler | Lincoln | Judicial Ditch 12 |
| 07020006-540 | 17MN227 | Judicial Ditch 32 | Upstream of CSAH 19, 5.5 mi. NE of Seaforth | Redwood | Ramsey Creek |
| 07020006-553 | 17MN222 | Unnamed Ditch | Downstream of CSAH 6, 5.5 mi. W of Redwood Falls | Redwood | Ramsey Creek |
| 07020006-554 | 17MN231 | Judicial Ditch 30 | Downstream of CR 110, 6 mi. NE of Lake Benton. | Lincoln | Coon Creek |
| 07020006-555 | 17MN205 | Unnamed Ditch | Upstream of CR 117, 4.5 mi. SW of Tyler | Lincoln | Judicial Ditch 12 |
| 07020006-556 | 17MN209 | County Ditch 7 | Downstream of CSAH 7, 1.5 mi. S of Tyler | Lincoln | Judicial Ditch 12 |
| 07020006-558 | 17MN215 | Trib. to Threemile Creek | Upstream of 290th St, 3 mi. S of Ghent | Lyon | Threemile Creek |
| 07020006-559 | 17MN221 | Trib. to Redwood River | Downstream of 260th Ave, 4.5 mi. N of Marshall | Lyon | Middle Redwood River |
| 07020006-560 | 17MN223 | Judicial Ditch 3 | Downstream of 325th St, 8 mi. W of Vesta | Redwood | Lower Redwood River |
| 07020006-561 | 17MN218 | Trib. to Redwood River | Downstream of 340th Ave, 6 mi. NW of Millroy | Lyon | Lower Redwood River |
| 07020006-562 | 17MN229 | Unnamed Ditch | Upstream of 270th St, 2 mi. NE of Milroy | Redwood | Clear Creek |
| 07020006-563 | 17MN220 | County Ditch 92 | Downstream of CSAH 30, 3.5 mi. W of Vesta | Redwood | Lower Redwood River |
| 07020006-564 | 17MN228 | Threemile Creek | Upstream of 340th St, 4.5 mi. NE of Ghent | Lyon | Threemile Creek |
| 07020006-564 | 17MN230 | Threemile Creek | Downstream of 200th Ave, 3 mi. S of Ghent | Lyon | Threemile Creek |
| 07020006-564 | 17MN233 | Threemile Creek | Downstream of 300th St, 2 mi. SE of Ghent | Lyon | Threemile Creek |
| 07020006-565 | 92MN036 | Three Mile Creek | Upstream of CR 67 (270th Ave), 6.5 mi. N of Marshall | Lyon | Threemile Creek |
| 07020006-567 | 17MN214 | Clear Creek | Downstream of MN 19, 3 mi. N of Millroy | Redwood | Clear Creek |
| 07020006-568 | 92MN043 | Clear Creek | Upstream of 290th St, 0.5 mi. SE of Seaforth | Redwood | Clear Creek |
| 07020006-570 | 17MN212 | Coon Creek | Downstream of 200th St, 4.5 mi. N of Tyler | Lincoln | Coon Creek |
| 07020006-570 | 17MN240 | Coon Creek | Downstream of CR 66 (190th St), 2 mi. NW of Russell | Lyon | Coon Creek |
| 07020006-570 | 92MN027 | Coon Creek | Upstream of 260th Ave, 4 mi. N of Tyler | Lincoln | Coon Creek |

| WID | Biological station ID | Waterbody name | Biological station location | County | Aggregated 12-digit HUC |
|---|---|---|---|---|---|
| 07020006-572 | 17MN226 | Unnamed Creek | Downstream of 330th St, 2 mi. NE of Ghent | Lyon | Threemile Creek |
| 07020006-573 | 17MN225 | Unnamed Creek | Downstream of 330th St, 2.5 mi. NE of Ghent | Lyon | Threemile Creek |
| 07020006-574 | 17MN206 | Unnamed Creek | Upstream of CSAH 9, 3.5 mi. SW of Tyler | Lincoln | Judicial Ditch 12 |
| 07020006-576 | 17MN210 | County Ditch 31 | Upstream of 125th Ave, 4.5 mi. E of Tyler | Lyon | Upper Redwood River |
| 07020006-578 | 17MN217 | County Ditch 60 | Upstream of 290th Ave, 4.5 mi. NE of Marshall | Lyon | Middle Redwood River |
| 07020006-580 | 17MN211 | Trib. to Redwood River | Downstream of 150th Ave, 3.5 mi. SW of Russel | Lyon | Upper Redwood River |

# Appendix 3.1 – Minnesota statewide IBI thresholds and confidence limits

| Class # | Class name | Use class | Exceptional use threshold | General use threshold | Modified use threshold | Confidence limit |
|---|---|---|---|---|---|---|
| **Fish** | | | | | | |
| 1 | Southern Rivers | 2B | 71 | 49 | NA | ±11 |
| 2 | Southern Streams | 2B | 66 | 50 | 35 | ±9 |
| 3 | Southern Headwaters | 2B | 74 | 55 | 33 | ±7 |
| 10 | Southern Coldwater | 2A | 82 | 50 | NA | ±9 |
| 4 | Northern Rivers | 2B | 67 | 38 | NA | ±9 |
| 5 | Northern Streams | 2B | 61 | 47 | 35 | ±9 |
| 6 | Northern Headwaters | 2B | 68 | 42 | 23 | ±16 |
| 7 | Low Gradient | 2B | 70 | 42 | 15 | ±10 |
| 11 | Northern Coldwater | 2A | 60 | 35 | NA | ±10 |
| | | | | | | |
| **Invertebrates** | | | | | | |
| 1 | Northern Forest Rivers | 2B | 77 | 49 | NA | ±10.8 |
| 2 | Prairie Forest Rivers | 2B | 63 | 31 | NA | ±10.8 |
| 3 | Northern Forest Streams RR | 2B | 82 | 53 | NA | ±12.6 |
| 4 | Northern Forest Streams GP | 2B | 76 | 51 | 37 | ±13.6 |
| 5 | Southern Streams RR | 2B | 62 | 37 | 24 | ±12.6 |
| 6 | Southern Forest Streams GP | 2B | 66 | 43 | 30 | ±13.6 |
| 7 | Prairie Streams GP | 2B | 69 | 41 | 22 | ±13.6 |
| 8 | Northern Coldwater | 2A | 52 | 32 | NA | ±12.4 |
| 9 | Southern Coldwater | 2A | 72 | 43 | NA | ±13.8 |

# Appendix 3.2 – Biological monitoring results – fish IBI (assessable reaches)

| National Hydrography Dataset (NHD) Assessment Segment WID | Biological station ID | Stream segment name | Drainage area Mi$^2$ | Fish class |
|---|---|---|---|---|
| **HUC 12: 0702000601-01 (Upper Redwood River)** | | | | |
| 07020006-505 | 17MN234 | Redwood River | 35.46 | 7 |
| 07020006-505 | 17MN203 | Redwood River | 40.2 | 2 |
| 07020006-580 | 17MN211 | Trib. to Redwood River | 6.67 | 3 |
| 07020006-576 | 17MN210 | County Ditch 31 | 6.33 | 3 |
| 07020006-505 | 92MN022 | Redwood River | 55.66 | 2 |
| 07020006-505 | 92MN025 | Redwood River | 130.29 | 2 |
| **HUC 12: 0702000601-02 (Judicial Ditch 12)** | | | | |
| 07020006-556 | 17MN209 | County Ditch 7 | 8.24 | 3 |
| 07020006-532 | 17MN207 | Unnamed Creek | 25.79 | 7 |
| 07020006-574 | 17MN206 | Unnamed Creek | 12.15 | 7 |
| 07020006-555 | 17MN205 | Unnamed Ditch | 5.77 | 3 |
| **HUC 12: 0702000602-01 (Coon Creek)** | | | | |
| 07020006-527 | 92MN026 | Norwegian Creek | 22.53 | 3 |
| 07020006-554 | 17MN231 | Judicial Ditch 30 | 5.28 | 3 |
| **HUC 12: 0702000603-01 (Middle Redwood River)** | | | | |
| 07020006-502 | 92MN032 | Redwood River | 266.76 | 2 |
| 07020006-502 | 92MN032 | Redwood River | 266.76 | 2 |
| 07020006-510 | 15MN203 | Redwood River | 230.34 | 2 |
| 07020006-502 | 92MN033 | Redwood River | 308.18 | 1 |
| 07020006-578 | 17MN217 | County Ditch 60 | 15.35 | 3 |
| 07020006-578 | 17MN217 | County Ditch 60 | 15.35 | 3 |
| 07020006-559 | 17MN221 | Trib. to Redwood River | 7.38 | 3 |
| 07020006-513 | 90MN029 | Redwood River | 244.73 | 2 |

| National Hydrography Dataset (NHD) Assessment Segment WID | Biological station ID | Stream segment name | Drainage area Mi² | Fish class |
|---|---|---|---|---|
| **HUC 12: 0702000604-01 (Threemile Creek)** | | | | |
| 07020006-572 | 17MN226 | Unnamed Creek | 14.15 | 3 |
| 07020006-558 | 17MN215 | Trib. to Threemile Creek | 16.76 | 3 |
| 07020006-564 | 17MN228 | Threemile Creek | 98.12 | 2 |
| 07020006-565 | 92MN036 | Three Mile Creek | 111.57 | 2 |
| 07020006-564 | 17MN233 | Threemile Creek | 62.54 | 2 |
| 07020006-564 | 17MN230 | Threemile Creek | 35.78 | 2 |
| 07020006-572 | 17MN226 | Unnamed Creek | 14.15 | 3 |
| 07020006-573 | 17MN225 | Unnamed Creek | 23.52 | 3 |
| **HUC 12: 0702000605-01 (Clear Creek)** | | | | |
| 07020006-568 | 92MN043 | Clear Creek | 82.64 | 2 |
| 07020006-562 | 17MN229 | Unnamed Ditch | 5.94 | 3 |
| 07020006-567 | 17MN214 | Clear Creek | 22 | 7 |
| 07020006-517 | 17MN213 | Judicial Ditch 14/15 | 16.09 | 3 |
| **HUC 12: 0702000606-01 (Ramsey Creek)** | | | | |
| 07020006-540 | 17MN227 | Judicial Ditch 32 | 19.14 | 3 |
| 07020006-520 | 17MN224 | Judicial Ditch 33 | 43.61 | 2 |
| 07020006-521 | 92MN047 | Ramsey Creek | 65.53 | 2 |
| 07020006-553 | 17MN222 | Unnamed Ditch | 14.01 | 7 |
| 07020006-520 | 17MN224 | Judicial Ditch 33 | 43.61 | 2 |
| 07020006-540 | 17MN227 | Judicial Ditch 32 | 19.14 | 3 |
| **HUC 12: 0702000607-01 (Lower Redwood River)** | | | | |
| 07020006-561 | 17MN218 | Trib. to Redwood River | 6.74 | 3 |
| 07020006-503 | 17MN219 | Redwood River | 449.77 | 1 |
| 07020006-529 | 91MN040 | County Ditch 33 | 7.52 | 3 |
| 07020006-560 | 17MN223 | Judicial Ditch 3 | 11.2 | 7 |
| 07020006-503 | 92MN037 | Redwood River | 481.96 | 1 |

# Appendix 3.3 – Biological monitoring results-macroinvertebrate IBI (assessable reaches)

| National Hydrography Dataset (NHD) Assessment Segment WID | Biological station ID | Stream segment name | Drainage area Mi$^2$ | Invert class | Threshold | MIBI | Visit date |
|---|---|---|---|---|---|---|---|
| **HUC 12: 0702000601-01 (Upper Redwood River)** | | | | | | | |
| 07020006-576 | 17MN210 | County Ditch 31 | 6.33 | Prairie Streams GP | 22 | 16.48 | 8/2/2017 |
| 07020006-505 | 92MN022 | Redwood River | 55.66 | Southern Streams RR | 37 | 13.97 | 8/3/2010 |
| 07020006-505 | 92MN022 | Redwood River | 55.66 | Southern Streams RR | 37 | 27.88 | 8/1/2017 |
| 07020006-505 | 92MN025 | Redwood River | 130.29 | Southern Streams RR | 37 | 16.71 | 8/3/2010 |
| 07020006-505 | 92MN025 | Redwood River | 130.29 | Southern Streams RR | 37 | 29.56 | 8/3/2017 |
| 07020006-580 | 17MN211 | Trib. to Redwood River | 6.67 | Prairie Streams GP | 22 | 27.57 | 8/1/2017 |
| 07020006-505 | 17MN234 | Redwood River | 35.46 | Prairie Streams GP | 41 | 5.15 | 8/1/2017 |
| 07020006-505 | 17MN203 | Redwood River | 40.20 | Prairie Streams GP | 41 | 18.18 | 8/1/2017 |
| **HUC 12: 0702000601-02 (Judicial Ditch 12)** | | | | | | | |
| 07020006-574 | 17MN207 | Unnamed Creek | 25.79 | Prairie Streams GP | 41 | 34.45 | 8/2/2017 |
| 07020006-574 | 17MN206 | Unnamed Creek | 12.15 | Prairie Streams GP | 22 | 2.30 | 8/1/2017 |
| **HUC 12: 0702000602-01 (Coon Creek)** | | | | | | | |
| 07020006-570 | 17MN240 | Coon Creek | 93.58 | Southern Streams RR | 37 | 21.69 | 8/3/2017 |
| 07020006-570 | 92MN027 | Coon Creek | 58.36 | Southern Streams RR | 37 | 21.04 | 8/1/2017 |
| 07020006-570 | 17MN212 | Coon Creek | 68.12 | Southern Streams RR | 37 | 18.65 | 8/1/2017 |
| 07020006-554 | 17MN231 | Judicial Ditch 30 | 5.28 | Prairie Streams GP | 22 | 29.17 | 8/1/2017 |
| 07020006-527 | 92MN026 | Norwegian Creek | 22.53 | Prairie Streams GP | 41 | 18.40 | 8/1/2017 |
| **HUC 12: 0702000603-01 (Middle Redwood River)** | | | | | | | |
| 07020006-502 | 92MN033 | Redwood River | 308.18 | Prairie Streams GP | 41 | 41.56 | 8/24/2010 |
| 07020006-502 | 92MN033 | Redwood River | 308.18 | Prairie Streams GP | 41 | 34.41 | 7/31/2017 |
| 07020006-510 | 15MN203 | Redwood River | 230.34 | Prairie Streams GP | 41 | 58.34 | 8/17/2015 |
| 07020006-513 | 90MN029 | Redwood River | 244.73 | Southern Streams RR | 37 | 43.70 | 8/2/2017 |
| 07020006-502 | 92MN032 | Redwood River | 266.76 | Southern Streams RR | 37 | 49.24 | 8/3/2017 |
| 07020006-502 | 92MN030 | Redwood River | 255.43 | Southern Streams RR | 37 | 23.68 | 8/3/2010 |
| 07020006-578 | 17MN217 | County Ditch 60 | 15.35 | Southern Streams RR | 24 | 14.80 | 7/31/2017 |
| **HUC 12: 0702000604-01 (Threemile Creek)** | | | | | | | |
| 07020006-564 | 17MN230 | Threemile Creek | 35.78 | Prairie Streams GP | 41 | 31.48 | 8/2/2017 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 07020006-558 | 17MN215 | Trib. to Threemile Creek | 16.76 | Prairie Streams GP | 22 | 18.84 | 8/2/2017 |
| 07020006-573 | 17MN225 | Unnamed Creek | 23.52 | Southern Streams RR | 37 | 18.51 | 7/31/2017 |
| 07020006-564 | 17MN233 | Threemile Creek | 62.54 | Prairie Streams GP | 41 | 34.19 | 8/2/2017 |
| 07020006-564 | 17MN228 | Threemile Creek | 98.12 | Prairie Streams GP | 41 | 57.65 | 8/2/2017 |
| 07020006-565 | 92MN036 | Three Mile Creek | 111.57 | Southern Streams RR | 24 | 25.07 | 7/31/2017 |
| 07020006-572 | 17MN226 | Unnamed Creek | 14.15 | Southern Streams RR | 24 | 29.40 | 8/2/2017 |
| **HUC 12: 0702000605-01 (Clear Creek)** | | | | | | | |
| 07020006-567 | 17MN214 | Clear Creek | 22.00 | Prairie Streams GP | 22 | 27.12 | 8/1/2017 |
| 07020006-517 | 17MN213 | Judicial Ditch 14/15 | 16.09 | Prairie Streams GP | 22 | 36.17 | 8/1/2017 |
| 07020006-568 | 92MN043 | Clear Creek | 82.64 | Southern Streams RR | 37 | 10.69 | 8/2/2017 |
| **HUC 12: 0702000606-01 (Ramsey Creek)** | | | | | | | |
| 07020006-553 | 17MN222 | Unnamed Ditch | 14.01 | Prairie Streams GP | 22 | 22.25 | 8/2/2017 |
| 07020006-521 | 92MN047 | Ramsey Creek | 65.53 | Southern Streams RR | 37 | 13.80 | 8/8/2017 |
| 07020006-520 | 17MN224 | Judicial Ditch 33 | 43.61 | Prairie Streams GP | 22 | 38.83 | 8/2/2017 |
| 07020006-540 | 17MN227 | Judicial Ditch 32 | 19.14 | Prairie Streams GP | 22 | 18.37 | 8/2/2017 |
| 07020006-520 | 17MN224 | Judicial Ditch 33 | 43.61 | Prairie Streams GP | 22 | 48.09 | 8/2/2017 |
| **HUC 12: 0702000607-01 (Lower Redwood River)** | | | | | | | |
| 07020006-509 | 92MN044 | Redwood River | 610.18 | Prairie Forest Rivers | 31 | 2.71 | 8/2/2010 |
| 07020006-509 | 92MN045 | Redwood River | 623.51 | Prairie Forest Rivers | 31 | 35.48 | 8/8/2017 |
| 07020006-501 | 92MN049 | Redwood River | 696.90 | Prairie Forest Rivers | 31 | 24.86 | 8/2/2010 |
| 07020006-501 | 17MN200 | Redwood River | 698.36 | Prairie Forest Rivers | 31 | 31.30 | 8/8/2017 |
| 07020006-561 | 17MN218 | Trib. to Redwood River | 6.74 | Prairie Streams GP | 22 | 30.66 | 8/1/2017 |
| 07020006-560 | 17MN223 | Judicial Ditch 3 | 11.20 | Prairie Streams GP | 22 | 16.73 | 8/1/2017 |
| 07020006-503 | 92MN041 | Redwood River | 511.32 | Prairie Forest Rivers | 31 | 23.24 | 8/2/2017 |
| 07020006-529 | 91MN040 | County Ditch 33 | 7.52 | Prairie Streams GP | 22 | 20.23 | 8/1/2017 |
| 07020006-503 | 92MN037 | Redwood River | 481.96 | Prairie Streams GP | 41 | 41.84 | 8/1/2017 |
| 07020006-503 | 17MN219 | Redwood River | 449.77 | Southern Streams RR | 37 | 33.09 | 8/1/2017 |

# Appendix 4.1 – Fish species found during biological monitoring surveys

| Common name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Banded Darter | 1 | 4 |
| Bigmouth Shiner | 27 | 675 |
| Black Bullhead | 11 | 49 |
| Black Crappie | 3 | 3 |
| Blacknose Dace | 36 | 2277 |
| Blackside Darter | 12 | 57 |
| Bluegill | 7 | 83 |
| Bluntnose Minnow | 29 | 1160 |
| Brassy Minnow | 28 | 1038 |
| Brook Stickleback | 27 | 916 |
| Brown Trout | 1 | 6 |
| Central Stoneroller | 23 | 1088 |
| Channel Catfish | 12 | 170 |
| Common Carp | 25 | 287 |
| Common Shiner | 24 | 2081 |
| Creek Chub | 40 | 2449 |
| Emerald Shiner | 1 | 24 |
| Fantail Darter | 9 | 664 |
| Fathead Minnow | 30 | 1645 |
| Freshwater Drum | 1 | 2 |
| Gen: Redhorses | 1 | 5 |
| Gizzard Shad | 1 | 42 |
| Golden Redhorse | 16 | 188 |
| Green Sunfish | 28 | 323 |
| Hornyhead Chub | 10 | 293 |
| Hybrid Sunfish | 1 | 1 |
| Iowa Darter | 14 | 788 |
| Johnny Darter | 37 | 653 |
| Largemouth Bass | 11 | 30 |
| Northern Hogsucker | 13 | 244 |
| Northern Pike | 10 | 29 |
| Orangespotted Sunfish | 21 | 108 |
| Rainbow Darter | 1 | 1 |
| Sand Shiner | 10 | 319 |
| Shorthead Redhorse | 3 | 16 |
| Shortnose Gar | 1 | 4 |
| Silver Redhorse | 9 | 36 |
| Slenderhead Darter | 2 | 6 |
| Smallmouth Bass | 1 | 5 |

| Common name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Spotfin Shiner | 17 | 436 |
| Stonecat | 1 | 1 |
| Tadpole Madtom | 24 | 176 |
| Walleye | 14 | 76 |
| White Sucker | 37 | 1809 |
| Yellow Perch | 11 | 268 |

# Appendix 4.2 – Macroinvertebrate species found during biological monitoring surveys

| Taxonomic name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Ablabesmyia | 15 | 30 |
| Acari | 34 | 104 |
| Acentrella | 3 | 13 |
| Acentrella parvula | 9 | 23 |
| Acentrella turbida | 1 | 4 |
| Acerpenna | 1 | 1 |
| Acroneuria | 6 | 9 |
| Aeshna | 4 | 4 |
| Aeshna umbrosa | 4 | 4 |
| Aeshnidae | 7 | 7 |
| Agabus | 2 | 2 |
| Amphipoda | 3 | 4 |
| Anacaena | 1 | 1 |
| Anafroptilum | 1 | 1 |
| Anax junius | 1 | 1 |
| Argia | 1 | 2 |
| Atherix | 9 | 40 |
| Atrichopogon | 1 | 2 |
| Baetidae | 4 | 33 |
| Baetis | 6 | 148 |
| Baetis brunneicolor | 1 | 1 |
| Baetis flavistriga | 8 | 25 |
| Baetis intercalaris | 19 | 320 |
| Baetis longipalpus | 8 | 74 |
| Belostoma | 1 | 1 |
| Belostoma flumineum | 13 | 17 |
| Brachycentrus | 1 | 2 |
| Brachycentrus numerosus | 1 | 1 |
| Branchiobdellida | 8 | 68 |
| Brillia | 8 | 22 |
| Caenis | 7 | 46 |
| Caenis diminuta | 23 | 431 |
| Caenis hilaris | 1 | 19 |
| Callibaetis | 6 | 10 |
| Calopterygidae | 7 | 22 |
| Calopteryx | 4 | 14 |
| Calopteryx aequabilis | 1 | 1 |
| Cambaridae | 3 | 3 |
| Cambarus | 1 | 1 |
| Ceratopogonidae | 2 | 2 |

| Taxonomic name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Ceratopogoninae | 5 | 9 |
| Ceratopsyche | 11 | 296 |
| Ceratopsyche morosa | 19 | 834 |
| Cheumatopsyche | 33 | 838 |
| Chironomini | 10 | 27 |

| Taxonomic name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Chironomus | 5 | 9 |
| Cladotanytarsus | 7 | 12 |
| Coenagrionidae | 24 | 388 |
| Conchapelopia | 5 | 5 |
| Corixidae | 11 | 92 |
| Corynoneura | 5 | 13 |
| Crambidae | 3 | 3 |
| Cricotopus | 26 | 188 |
| Cryptochironomus | 12 | 23 |
| Cryptotendipes | 3 | 5 |
| Cyphon | 1 | 1 |
| Dicranota | 3 | 8 |
| Dicrotendipes | 22 | 618 |
| Dubiraphia | 29 | 352 |
| Elmidae | 3 | 7 |
| Empididae | 13 | 31 |
| Enallagma | 2 | 12 |
| Endochironomus | 4 | 7 |
| Enochrus | 3 | 4 |
| Ephoron | 2 | 2 |
| Ephydridae | 12 | 31 |
| Fallceon | 21 | 525 |
| Ferrissia | 11 | 111 |
| Fossaria rustica | 1 | 1 |
| Gerridae | 3 | 3 |
| Glyptotendipes | 6 | 35 |
| Gomphidae | 2 | 2 |
| Gomphus | 1 | 1 |
| Gyraulus | 3 | 10 |
| Haliplus | 9 | 39 |
| Helichus | 3 | 4 |
| Helicopsyche borealis | 2 | 4 |
| Helopelopia | 1 | 1 |
| Hemerodromia | 17 | 63 |
| Heptagenia | 17 | 160 |

| Taxonomic name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Heptageniidae | 6 | 28 |
| Hetaerina | 7 | 25 |
| Hetaerina americana | 1 | 1 |
| Hexagenia | 2 | 4 |
| Hirudinea | 15 | 33 |
| Hyalella | 34 | 1367 |
| Hydrobiidae | 1 | 1 |
| Hydropsyche | 5 | 10 |
| Hydropsyche betteni | 6 | 33 |
| Hydropsyche orris | 1 | 1 |

| Taxonomic name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Hydropsyche placoda | 5 | 65 |
| Hydropsyche simulans | 5 | 59 |
| Hydropsychidae | 20 | 83 |
| Hydroptila | 30 | 245 |
| Hydroptilidae | 13 | 43 |
| Hydrozoa | 4 | 4 |
| Ilybius | 2 | 2 |
| Isonychia | 18 | 73 |
| Kloosia/Harnischia | 1 | 1 |
| Labiobaetis dardanus | 11 | 103 |
| Labiobaetis frondalis | 9 | 20 |
| Labiobaetis propinquus | 4 | 5 |
| Labrundinia | 18 | 105 |
| Leptoceridae | 6 | 9 |
| Leucrocuta | 3 | 4 |
| Limnophyes | 5 | 8 |
| Liodessus | 4 | 6 |
| Lymnaeidae | 8 | 13 |
| Maccaffertium | 16 | 61 |
| Maccaffertium mediopunctatum | 2 | 4 |
| Macronychus | 2 | 4 |
| Macronychus glabratus | 12 | 123 |
| Mayatrichia | 1 | 12 |
| Mayatrichia ayama | 3 | 11 |
| Merragata | 1 | 1 |
| Mesovelia | 12 | 17 |
| Metrobates | 3 | 4 |
| Micropsectra | 12 | 138 |
| Microtendipes | 3 | 5 |
| Microvelia | 4 | 4 |
| Muscidae | 1 | 1 |
| Nanocladius | 5 | 16 |
| Nectopsyche | 4 | 24 |
| Nectopsyche candida | 6 | 116 |
| Nectopsyche diarina | 16 | 185 |
| Nemata | 4 | 8 |
| Nematoda | 1 | 1 |
| Nematomorpha | 1 | 1 |
| Neoplasta | 1 | 1 |
| Neoplea striola | 4 | 7 |
| Neotrichia | 2 | 8 |
| Nilotanypus | 6 | 8 |

| Taxonomic name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Notonecta | 1 | 1 |
| Ochrotrichia | 4 | 13 |
| Ochthebius | 1 | 1 |

| Taxonomic name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Odontomyia /Hedriodiscus | 2 | 2 |
| Oecetis | 1 | 1 |
| Oecetis avara | 2 | 2 |
| Oecetis furva | 1 | 1 |
| Oecetis testacea | 1 | 1 |
| Oligochaeta | 32 | 394 |
| Optioservus | 5 | 17 |
| Orconectes | 33 | 183 |
| Orthocladiinae | 7 | 11 |
| Orthocladius | 13 | 48 |
| Oxyethira | 1 | 1 |
| Palmacorixa | 2 | 5 |
| Parachironomus | 1 | 1 |
| Paracladopelma | 1 | 1 |
| Paracloeodes | 1 | 5 |
| Paracymus | 1 | 1 |
| Parakiefferiella | 7 | 13 |
| Paralauterborniella nigrohalterale | 2 | 2 |
| Paramerina | 1 | 2 |
| Paratanytarsus | 25 | 367 |
| Paratendipes | 11 | 57 |
| Peltodytes | 3 | 4 |
| Phaenopsectra | 10 | 13 |
| Physa | 4 | 27 |
| Physella | 36 | 1258 |
| Pisidiidae | 19 | 62 |
| Planorbella | 3 | 76 |
| Planorbidae | 1 | 1 |
| Platambus | 2 | 2 |
| Plauditus | 2 | 5 |
| Polypedilum | 41 | 889 |
| Potamyia flava | 1 | 3 |
| Procladius | 8 | 24 |
| Procloeon | 3 | 3 |
| Pseudocloeon | 3 | 70 |
| Pseudosuccinea | 1 | 3 |

| Taxonomic name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Pseudosuccinea columella | 3 | 10 |
| Pteronarcys | 7 | 7 |
| Pycnopsyche | 2 | 3 |
| Rhagovelia | 4 | 24 |
| Rheocricotopus | 7 | 16 |
| Rheotanytarsus | 28 | 156 |
| Rheumatobates | 2 | 2 |
| Sciomyzidae | 2 | 2 |
| Scirtes | 3 | 15 |

| Taxonomic name | Quantity of stations where present | Quantity of individuals collected |
|---|---|---|
| Scirtidae | 2 | 2 |
| Sialis | 2 | 2 |
| Sigara | 3 | 15 |
| Simulium | 22 | 241 |
| Stagnicola | 4 | 90 |
| Stempellinella | 1 | 1 |
| Stenacron | 10 | 53 |
| Stenelmis | 27 | 339 |
| Stenochironomus | 4 | 10 |
| Stictochironomus | 1 | 21 |
| Tanypodinae | 8 | 21 |
| Tanypus | 2 | 2 |
| Tanytarsini | 13 | 50 |
| Tanytarsus | 18 | 84 |
| Thienemanniella | 19 | 46 |
| Thienemannimyia | 4 | 27 |
| Thienemannimyia Gr. | 35 | 319 |
| Tipula | 2 | 2 |
| Trepaxonemata | 1 | 1 |
| Tribelos | 2 | 2 |
| Trichocorixa | 4 | 29 |
| Trichoptera | 1 | 1 |
| Tricorythodes | 24 | 1243 |
| Tropisternus | 1 | 1 |
| Tvetenia | 4 | 8 |
| Zavrelimyia | 9 | 69 |

# Appendix 5 – Minnesota Stream Habitat Assessment results

Habitat information documented during each fish sampling visit is provided. This table convey the results of the Minnesota Stream Habitat Assessment (MSHA) survey, which evaluates the section of stream sampled for biology and can provide an indication of potential stressors (e.g., siltation, eutrophication) impacting fish and macroinvertebrate communities. The MSHA score is comprised of five scoring categories including adjacent land use, riparian zone, substrate, fish cover and channel morphology, which are summed for a total possible score of 100 points. Scores for each category, a summation of the total MSHA score, and a narrative habitat condition rating are provided in the tables for each biological monitoring station. Where multiple visits occur at the same station, the scores from each visit have been averaged. The final row in each table displays average MSHA scores and a rating for the aggregated HUC-12 subwatershed.

| # Visits | Biological station ID | Reach name | Land use | Riparian | Substrate | Fish cover | Channel morph. | MSHA score | MSHA rating |
|---|---|---|---|---|---|---|---|---|---|
| **Average Habitat Results: *Upper Redwood*** | | | 0.43 | 8.04 | 10.25 | 11.29 | 16.71 | 46.72 | **Fair** |
| 2 | 17MN203 | Redwood | 0 | 9.5 | 6.5 | 8.5 | 14 | 38.5 | **Poor** |
| 2 | 17MN210 | County Ditch | 0 | 7 | 3.1 | 11 | 4.5 | 25.6 | **Poor** |
| 2 | 17MN211 | Trib. to | 0 | 7 | 7.5 | 12.5 | 18 | 45 | **Fair** |
| 2 | 17MN234 | Redwood | 0 | 8 | 6 | 13 | 15 | 42 | **Poor** |
| 3 | 92MN022 | Redwood | 0.83 | 7.33 | 14.52 | 12.33 | 19.67 | 54.68 | **Fair** |
| 3 | 92MN025 | Redwood | 1.17 | 9.17 | 17.93 | 10.33 | 24 | 62.6 | **Fair** |
| **Average Habitat Results: *Judicial Ditch 12*** | | | 0.68 | 9.5 | 9.52 | 9.55 | 9.91 | 39.15 | **Poor** |
| 1 | 17MN205 | Unnamed | 0 | 12 | 11.75 | 11 | 13 | 47.75 | **Fair** |
| 2 | 17MN206 | Unnamed | 0.75 | 9.5 | 7.5 | 8 | 5.5 | 31.25 | **Poor** |
| 2 | 17MN207 | Unnamed | 1.25 | 9 | 9.9 | 9 | 9 | 38.15 | **Poor** |
| 1 | 17MN209 | County Ditch | 0 | 12.5 | 7 | 11 | 8 | 38.5 | **Poor** |
| 3 | 17MN232 | County Ditch | 0.5 | 9.67 | 6.67 | 8.33 | 3.67 | 28.83 | **Poor** |
| 2 | 92MN024 | Tyler Creek | 1 | 7 | 15.57 | 12 | 24 | 59.58 | **Fair** |
| **Average Habitat Results: *Coon Creek*** | | | 0 | 7.57 | 11.83 | 9.86 | 14 | 43.26 | **Poor** |
| 1 | 17MN212 | Coon Creek | 0 | 5 | 11 | 5 | 14 | 35 | **Poor** |
| 2 | 17MN231 | Judicial Ditch | 0 | 8.5 | 6.25 | 10.5 | 5 | 30.25 | **Poor** |
| 1 | 17MN240 | Coon Creek | 0 | 8 | 19.9 | 14 | 32 | 73.9 | **Good** |
| 2 | 92MN026 | Norwegian | 0 | 7 | 11.5 | 12 | 13.5 | 44 | **Poor** |
| 1 | 92MN027 | Coon Creek | 0 | 9 | 16.4 | 5 | 15 | 45.4 | **Fair** |
| **Average Habitat Results: *Middle Redwood*** | | | 1.53 | 7.59 | 16.41 | 10.76 | 18.53 | 54.82 | **Fair** |
| 2 | 15MN203 | Redwood | 1.75 | 8 | 16.75 | 12.5 | 22.5 | 61.5 | **Fair** |
| 3 | 17MN217 | County Ditch | 0 | 6.33 | 15.35 | 10.33 | 11 | 43.02 | **Poor** |
| 1 | 17MN221 | Trib. to | 0 | 9 | 10 | 11 | 3 | 33 | **Poor** |
| 3 | 90MN029 | Redwood | 4.17 | 8.33 | 20.88 | 14 | 29.33 | 76.72 | **Good** |
| 1 | 92MN030 | Redwood | 2.5 | 9.5 | 21.8 | 7 | 33 | 73.8 | **Good** |
| 1 | 92MN031 | Redwood | 1.25 | 9 | 15.05 | 6 | 17 | 48.3 | **Fair** |
| 3 | 92MN032 | Redwood | 0 | 6.67 | 16.05 | 11.67 | 16.33 | 50.72 | **Fair** |
| 3 | 92MN033 | Redwood | 2.08 | 7.17 | 13.93 | 8.67 | 15.67 | 47.52 | **Fair** |
| **Average Habitat Results: *Threemile Creek*** | | | 0 | 8.21 | 12.76 | 10.5 | 14.21 | 45.69 | **Fair** |
| 2 | 17MN215 | Trib. to | 0 | 8 | 7 | 5 | 3.5 | 23.5 | **Poor** |
| 2 | 17MN225 | Unnamed | 0 | 8.75 | 20.3 | 12.5 | 21.5 | 63.05 | **Fair** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 17MN226 | Unnamed | 0 | 8.5 | 16.52 | 11 | 17 | 53.02 | Fair |
| 2 | 17MN228 | Threemile | 0 | 6.75 | 9.15 | 15 | 16.5 | 47.4 | Fair |
| 2 | 17MN230 | Threemile | 0 | 9.5 | 11.2 | 13.5 | 16.5 | 50.7 | Fair |
| 2 | 17MN233 | Threemile | 0 | 6.75 | 11.7 | 5.5 | 8 | 31.95 | Poor |
| 2 | 92MN036 | Three Mile | 0 | 10 | 10.45 | 11 | 16 | 47.45 | Fair |
| **Average Habitat Results: *Clear Creek*** | | | 0.21 | 8.43 | 14.61 | 9 | 13 | 45.25 | Fair |
| 2 | 17MN213 | Judicial Ditch | 0 | 7.75 | 13.85 | 9.5 | 8.5 | 39.6 | Poor |
| 2 | 17MN214 | Clear Creek | 0 | 6.5 | 10.7 | 8 | 10 | 35.2 | Poor |
| 1 | 17MN229 | Unnamed | 0 | 11.5 | 17 | 11 | 12 | 51.5 | Fair |
| 2 | 92MN043 | Clear Creek | 0.75 | 9.5 | 18.07 | 8.5 | 21 | 57.82 | Fair |
| **Average Habitat Results: *Ramsey Creek*** | | | 0.11 | 7.33 | 11.47 | 10.11 | 11 | 40.02 | Poor |
| 2 | 17MN222 | Unnamed | 0 | 7.25 | 7.7 | 11.5 | 8.5 | 34.95 | Poor |
| 3 | 17MN224 | Judicial Ditch | 0 | 8 | 13.43 | 9 | 9.33 | 39.77 | Poor |
| 2 | 17MN227 | Judicial Ditch | 0 | 6 | 7 | 7 | 2.5 | 22.5 | Poor |
| 2 | 92MN047 | Ramsey | 0.5 | 7.75 | 16.75 | 13.5 | 24.5 | 63 | Fair |
| **Average Habitat Results: *Lower Redwood*** | | | 0.63 | 8.03 | 12.26 | 8.17 | 15.56 | 44.64 | Poor |
| 1 | 17MN200 | Redwood | 0 | 11 | 19.2 | 9 | 32 | 71.2 | Good |
| 2 | 17MN218 | Trib. to | 0 | 8.25 | 8.15 | 9 | 9.5 | 34.9 | Poor |
| 2 | 17MN219 | Redwood | 1.25 | 6.75 | 16.63 | 9.5 | 17 | 51.13 | Fair |
| 1 | 17MN220 | County Ditch | 0 | 8 | 1 | 1 | 3 | 13 | Poor |
| 2 | 17MN223 | Judicial Ditch | 0 | 6.5 | 1.5 | 3.5 | 6 | 17.5 | Poor |
| 2 | 91MN040 | County Ditch | 0 | 7.75 | 7 | 11.5 | 6 | 32.25 | Poor |
| 2 | 92MN037 | Redwood | 1.88 | 8 | 8.5 | 7 | 12.5 | 37.88 | Poor |
| 1 | 92MN038 | Redwood | 0 | 5 | 18 | 8 | 14 | 45 | Fair |
| 2 | 92MN041 | Redwood | 0 | 9 | 19.08 | 8.5 | 18.5 | 55.08 | Fair |
| 1 | 92MN044 | Redwood | 0 | 9.5 | 19.1 | 12 | 33 | 73.6 | Good |
| 1 | 92MN045 | Redwood | 0 | 10 | 19.45 | 8 | 28 | 65.45 | Fair |
| 1 | 92MN049 | Redwood | 5 | 8.5 | 22.25 | 11 | 31 | 77.75 | Good |

Qualitative habitat ratings

= Good: MSHA score above the median of the least-disturbed sites (MSHA>66)

= Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45 < MSHA < 66)

= Poor: MSHA score below the median of the most-disturbed sites (MSHA<45)

# Appendix 6 – Lake protection and prioritization results

| Lake ID | Lake Name | Mean TP | Trend | % Disturbed Land Use | 5% load reduction goal | Priority |
|---|---|---|---|---|---|---|
| 41-0021-01 | Dead Coon (Main Lake) | 182 | No evidence of trend | 76% | 1,058 | Impaired |
| 41-0022-00 | Slough | 156 | | 53% | 9 | C |
| 41-0043-00 | Benton | 298 | No evidence of trend | 70% | 1,165 | Impaired |
| 42-0002-00 | School Grove | 99 | | 95% | 30 | Impaired |
| 42-0054-00 | Brawner | 32 | | 65% | 11 | C |
| 42-0055-00 | Clear | 125 | | 35% | 10 | C |
| 42-0070-00 | East Twin | 83 | | 88% | 11 | C |
| 42-0071-00 | Sanderson | 82 | | 97% | 5 | B |
| 42-0074-00 | West Twin | 42 | | 93% | 9 | A |
| 42-0078-00 | Wood | 161 | | 96% | 31 | C |
| 42-0093-00 | Goose | 143 | | 85% | 67 | Impaired |
| 42-0096-00 | Island | 119 | | 70% | 23 | C |
| 64-0058-00 | Redwood | 379 | | 86% | 10,992 | C |

# Appendix 7 – Stream protection and prioritization results

| WID | Stream Name | TALU | Cold/Warm | Community Nearly Impaired | Riparian Risk | Watershed Risk | Current Protection Level | Protection Priority Class |
|---|---|---|---|---|---|---|---|---|
| 07020006-562 | Unnamed Creek | General | warm | neither | med/high | high | low | A |
| 07020006-513 | Redwood River | General | warm | neither | high | high | medium | B |
| 07020006-517 | Judicial Ditch 14 & 15 | Modified | warm | neither | high | high | low | A |
| 07020006-572 | Unnamed Creek | Modified | warm | neither | high | high | low | A |
| 07020006-580 | Unnamed Creek | Modified | warm | neither | high | high | low | A |
| 07020006-556 | County Ditch 7 | Modified | warm | neither | high | high | med/low | A |
| 07020006-561 | Unnamed Creek | Modified | warm | neither | med/high | high | med/low | B |