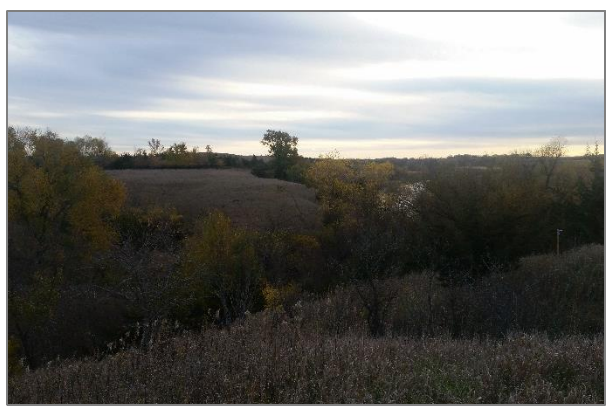
Watershed

February 2023

Draft Redwood River Watershed Restoration and Protection Strategy Report



MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Key Terms and Abbreviations

Assessment Unit Identifier (AUID): The unique water body identifier for each river reach comprised of the U.S. Geological Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life (AqL) is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to AqL if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation (AqR) if *E. coli* bacteria standards are not met. Lakes are considered impaired for impacts to AqR if total phosphorus and either chlorophyll-a or Secchi disc depth standards are not met.

Hydrologic Unit Code (HUC): A HUC is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Minnesota River Basin is assigned a HUC-4 of 0702 and the Redwood River Watershed is assigned a HUC-8 of 07030006.

Impairment: Water bodies are listed as impaired if water quality standards are not met for designated uses including AqL, AqR, and aquatic consumption.

Index of Biotic Integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the water body. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the water bodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the water bodies.

Source (or pollutant source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or biological stressor): This is a broad term that includes both pollutant sources and nonpollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact AqL.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

Executive Summary

The Redwood River Watershed is a Hydrologic Unit Code (HUC)-8 major watershed (07020006) located in southwestern Minnesota in the Minnesota River Basin (MRB) and within the Western Corn Belt Plain ecoregion. The Redwood River drains approximately 700 square miles of land in portions of Pipestone, Lincoln, Murray, Lyon, Redwood, and Yellow Medicine counties. Current land use within the watershed is dominated by agriculture (mostly row crops), followed by rangeland, developed land, wetlands, open water and forest/shrub land. Although the watershed is largely agricultural, it does contain a few cities, including Lake Benton, Marshall, and Redwood Falls.

From 2017 to 2018, intensive watershed monitoring (IWM) was contracted with the Redwood-Cottonwood Rivers Control Area (RCRCA) and also conducted by the Minnesota Pollution Control Agency (MPCA) to collect data across the Redwood River Watershed for the purpose of assessing the quality of its water resources. The IWM assessed 35 river/stream reaches for their ability to support aquatic life (AqL) and/or aquatic recreation (AqR). Of the assessed river/stream reaches, only seven were considered to be fully supporting of AqL and none fully supported AqR. Of the 18 lakes assessed in the Redwood River Watershed, 6 are determined to be impaired by nutrients (total phosphorus [TP]). Based on previous and current monitoring assessment data, there are nine turbidity/total suspended solids (TSS) impaired river/stream reaches, 13 bacteria impaired river/stream reaches, 18 macroinvertebrates Index of Biotic Integrity (IBI) impaired river/stream reaches, 15 fish IBI impaired river/stream reaches, one chloride impaired river/stream reach, and one river eutrophication impaired river/stream reach within the Redwood River Watershed.

A stressor identification (SID) report was completed for the stream AqL impairments (fish and macroinvertebrate communities). The SID report identified hydrologic alteration, connectivity, lack of physical habitat, dissolved oxygen (DO), eutrophication, TSS, and nitrates as the most common stressors to biologic communities (Redwood River Watershed SID Report, MPCA 2021). A total maximum daily load (TMDL) study (MPCA 2023) was completed to address the stream and lake AqR impairments (*E. coli* and lake nutrients) as well as the AqL impairments (TSS, chloride, and river eutrophication). A second TMDL to address the river eutrophication impairment is in development and expected to be completed in 2023.

Priority resources and strategies for the Redwood River Watershed were determined based on input and professional judgement from local partners, previous planning work, recreational use priorities, and comparing tool and model output with existing priorities outlined in county water plans. Some of the top priorities that were identified for the watershed include:

- Grade stabilization structures and practices (e.g., water and sediment control basins, grassed waterways) in high-sloped areas
- Soil health education and outreach
- Restore and protect lakes and stream reaches with high recreational use and value
    - Lake Benton and Norwegian Creek
    - Redwood River in Camden State Park
    - Lower Ramsey Creek

- Restore and protect lakes and stream reaches that are nearly impaired or barely impaired
  - Three Mile Creek Reaches 564, 565, 566
  - Clear Creek Reach 567, 568
  - School Grove Lake
  - East Twin Lake
  - Sanderson Lake
- Protect vulnerable and sensitive groundwater areas
  - City of Marshall
  - Lincoln Pipestone Rural Water

Restoration strategies for addressing the identified issues in the Redwood River Watershed SID and TMDL reports include: implementing stream and riparian buffers, tillage/residue management, adopting cover crops, and other strategies to improve soil health, rural water storage, implementing designed erosion control, and trapping best management practices (BMPs), nutrient management, pasture management, feedlot runoff controls, septic system improvements, urban stormwater runoff controls, and lake internal load management.

Strategies were also identified for lakes and streams that are currently meeting water quality to maintain and improve current conditions and protect these resources from becoming degraded or impaired. Some of the key protection initiatives identified in this report include protecting groundwater and drinking water, wildlife management areas (WMAs), and lakes and wetlands with rare and/or sensitive species. Specific locations of resource vulnerability are identified in this report and should be used to guide this process.

This watershed restoration and protection strategy (WRAPS) report is meant to serve as a foundation of technical information that can be used to assist in prioritization of water quality efforts by local governments, landowners, and other stakeholder groups. The information can be used to determine what strategies will be best to make improvements and protect good quality water resources, as well as focus those strategies to targeted locations.

The topics of each section of this report are summarized below

- **Section 1** provides background information on the Redwood River Watershed.
- **Section 2** details watershed conditions based on results from IWM, SID, and TMDL calculations.
- **Section 3** summarizes priority areas for targeting actions to improve water quality, and geographically locates where watershed restoration and protection actions could take place.
- **Section 4** documents a monitoring plan necessary to assess conditions in the watershed.

1. Watershed Background and Assessment

1.1 Watershed Approach and WRAPS

The State of Minnesota uses a "Watershed Approach" to assess and address the water quality within each of the state's 80 major watersheds, on a 10-year monitoring and assessment cycle. The first iteration of the Watershed Approach for the Redwood River Watershed has included monitoring and assessment of rivers, lakes, and wetlands (started in 2017), development of WRAPS and TMDLs, and implementation of conservation practices. Future iterations of the Watershed Approach in the Redwood River Watershed will take an adaptive management approach to maximize value for local planning and implementation efforts.

To ensure the WRAPS and other analyses appropriately represent the Redwood River Watershed, local and state natural resource and conservation professionals (referred to as the WRAPS Local Work Group [LWG]) were convened to help inform and advise on the development of the report. Much of the information presented in this report was produced in earlier Watershed Approach work, prior to the development of the WRAPS report. However, the WRAPS report presents additional data and analyses.

Key products of this WRAPS report are the HUC-8 and HUC-10 strategies tables that provide high-level strategies and estimated adoption rates necessary to restore and protect water bodies in the Redwood River Watershed. Additional tools and data layers that can be used to refine priority areas and target strategies within those priority areas are also provided within this report.

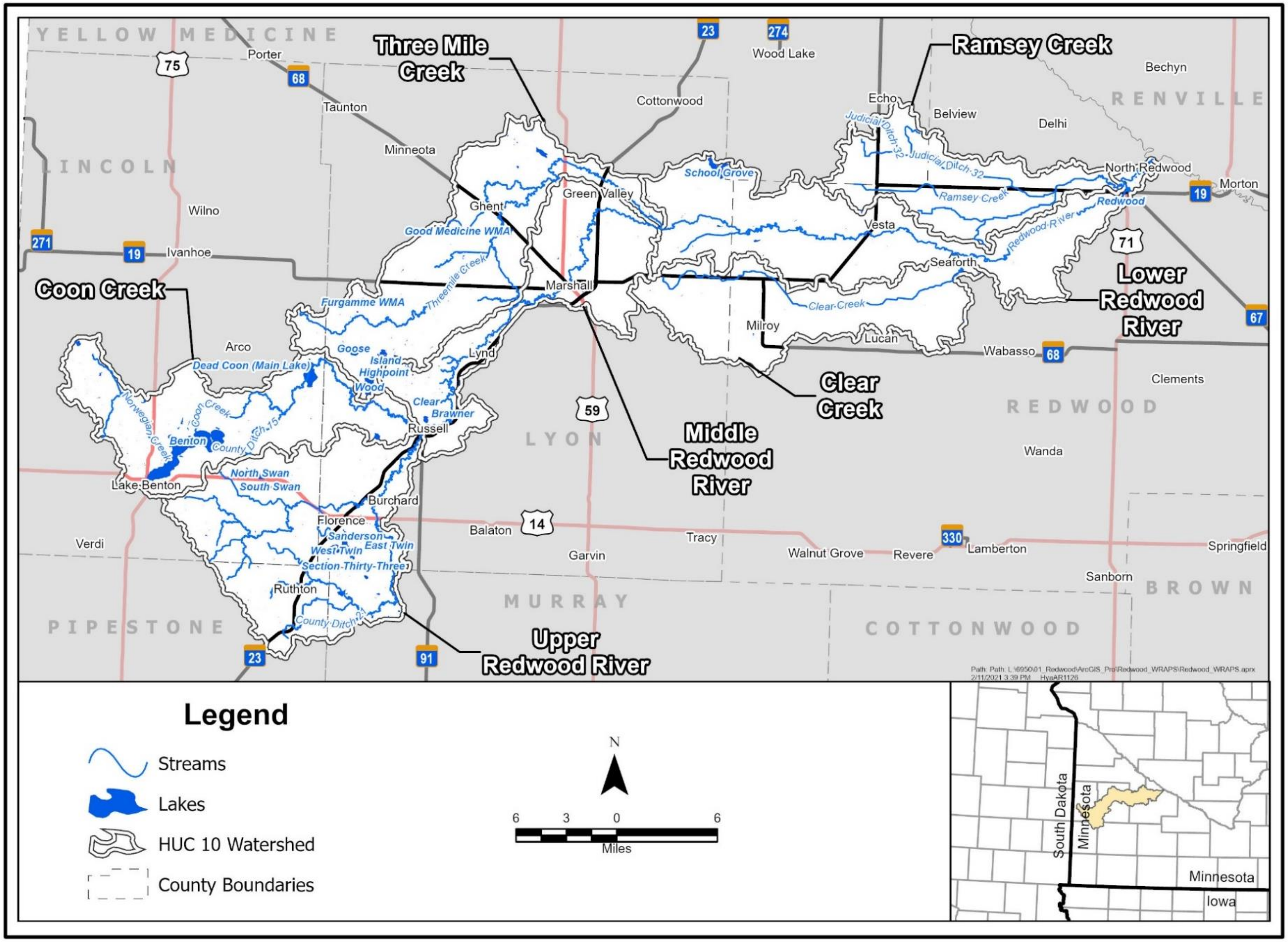
In summary, the purpose of the WRAPS report is to summarize work completed during the Watershed Approach in the Redwood River Watershed. The scope of the report is surface water bodies and their AqL and AqR beneficial uses as currently assessed by the MPCA. The primary audience for the WRAPS report is local planners, decision makers, and conservation practice implementers; watershed residents, neighboring downstream states, agricultural business, governmental agencies, and other stakeholders are additional audiences.

This WRAPS report is not a regulatory document but is legislatively required per the (updated) Clean Water Legacy legislation on WRAPS (ROS 2020). This report is designed to meet these requirements, including an opportunity for public comment, which was provided via a public notice in the State Register from February 21, 2023 to March 23, 2023. The WRAPS report summarizes an extensive amount of information. The reader may want to review the supplementary information provided (links and references in document) to fully understand the summaries and recommendations made within this document.

1.2 Watershed Description

Located in southwestern Minnesota, the Redwood River Watershed covers approximately 447,531 acres and spans six counties: Lyon (43%), Redwood (28%), Lincoln (19%), Pipestone (4%), Yellow Medicine (3%), and Murray (2%) (Figure 1). The Redwood River's headwaters are located in the Northern Glaciated Plains Level III ecoregion on the Coteau des Prairies, and the downstream portion is in the Western Corn Belt Plains Level III ecoregion. Both the Northern Glaciated Plains and the Western Corn Belt Plains are characterized by natural prairie vegetation and pothole lakes.

Figure 1. Redwood River Watershed overview.



The Redwood River flows from its headwaters near Ruthton northeast to Marshall, then cuts east to its confluence with the Minnesota River near Redwood Falls. A significant portion of the Redwood River mainstem downstream of Marshall and between its confluences with Three Mile Creek and Clear Creek, is ditched and known as Judicial Ditch 37. Three intermediate HUC-10 subwatersheds make up the length of the mainstem Redwood River: the Upper, Middle, and Lower Redwood River HUC-10 subwatersheds. Coon Creek, Three Mile Creek, Clear Creek, and Ramsey Creek are significant tributaries to the Redwood River, and their corresponding drainage areas make up the other HUC-10 subwatersheds in the Redwood River Watershed. Elevation change along the Redwood River's 128-mile path is approximately 860 feet (Figure 2), which is moderate compared to other major watersheds in the MRB. However, there are several high-gradient areas within the watershed, particularly along the transition area coming off the Coteau des Prairies in the Middle Redwood River and Three Mile Creek subwatersheds.

Many lakes exist in the watershed, being most common on the rolling terrain of the Prairie des Coteau (Figure 2 and Figure 3). 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 Twin (249 ac.), West Twin (220 ac.), Island (164 ac.), and Slough Lake (160 ac.). Numerous smaller lakes and open water wetlands occur across the major watershed. All streams in the watershed are classified as warmwater. Two stream reaches, the Redwood River in Camden State Park, and Ramsey Creek near Redwood Falls are designated Minnesota Department of Natural Resources (DNR) trout streams and are managed as seasonal put-and-take fisheries. These reaches are in high-gradient areas where springs may support cooler water temperatures for trout habitat. See Figure 28and Figure 31in the subwatershed summaries for more information.

Row crop agriculture, specifically corn and soybean, is the dominant land cover in the watershed (Figure 3). Many of the streams within the watershed have been channelized (ditched) to increase drainage of water on the landscape, and in some cases to connect isolated drainage basins to the Redwood River Watershed. A significant network of subsurface tiles drain to the Redwood River and its tributaries, impacting hydrology by exacerbating both high and low flows. Identified stressors to biological communities in the Redwood River Watershed include altered hydrology, sediment, phosphorus, nitrogen bacteria, habitat, and DO.

Several studies, reports, and plans have been written on the Redwood River Watershed. The MPCA released the Redwood River Monitoring and Assessment Report in 2020. The Redwood River Watershed SID Report was completed in 2021. The Redwood River Watershed TMDL Report was completed in 2022. All three reports are available on the MPCA Redwood River Watershed webpage. In addition, the DNR completed the Redwood River Watershed Characterization Report in 2020 (Section 3.1) and the Cottonwood and Redwood River Watersheds SID Report – Lakes in 2021. RCRCA has also conducted extensive monitoring in the Redwood River Watershed. Water quality data dating back to 2012 can be found on the RCRCA website.

Figure 2. Redwood River Watershed elevation change.

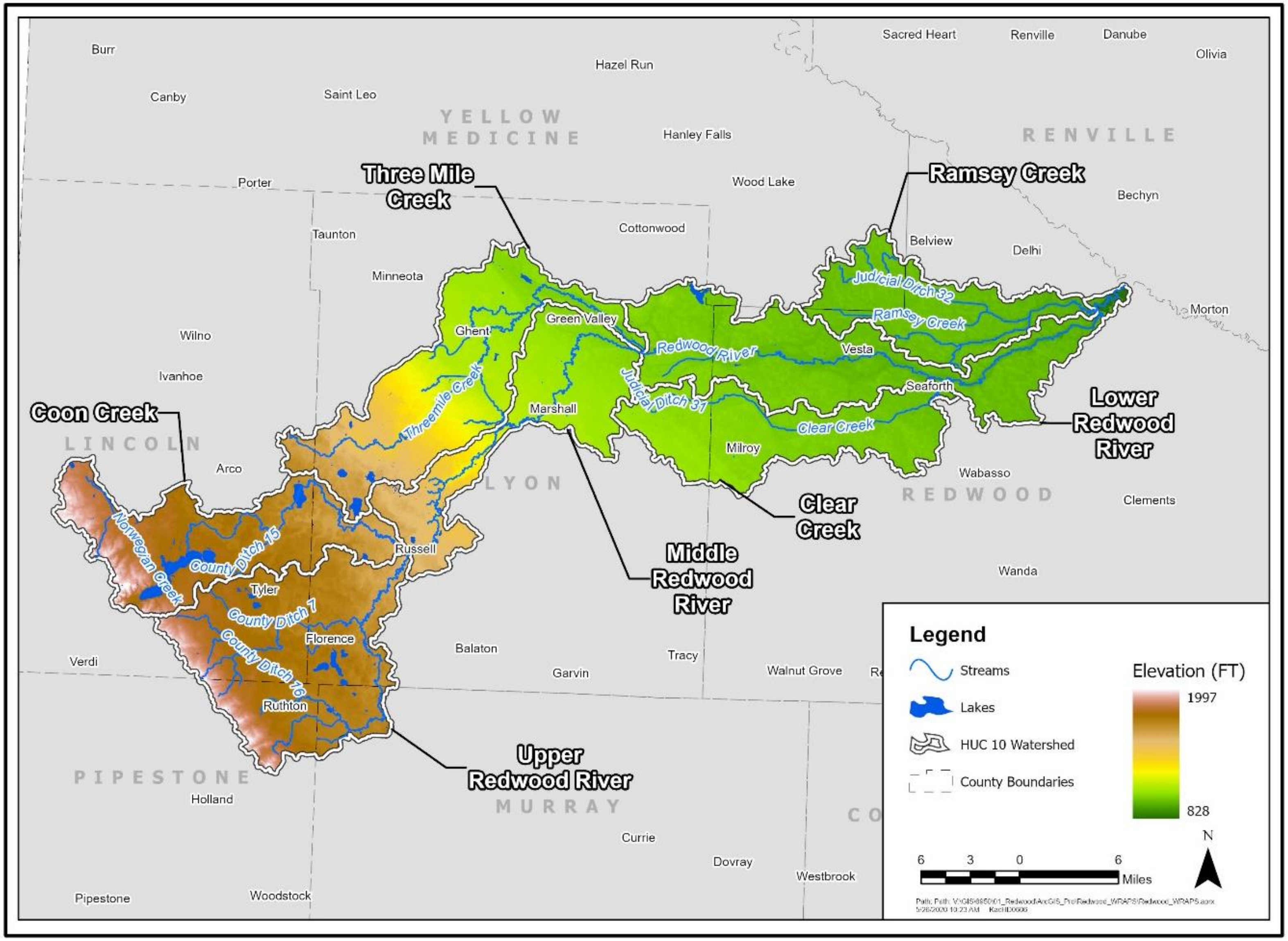
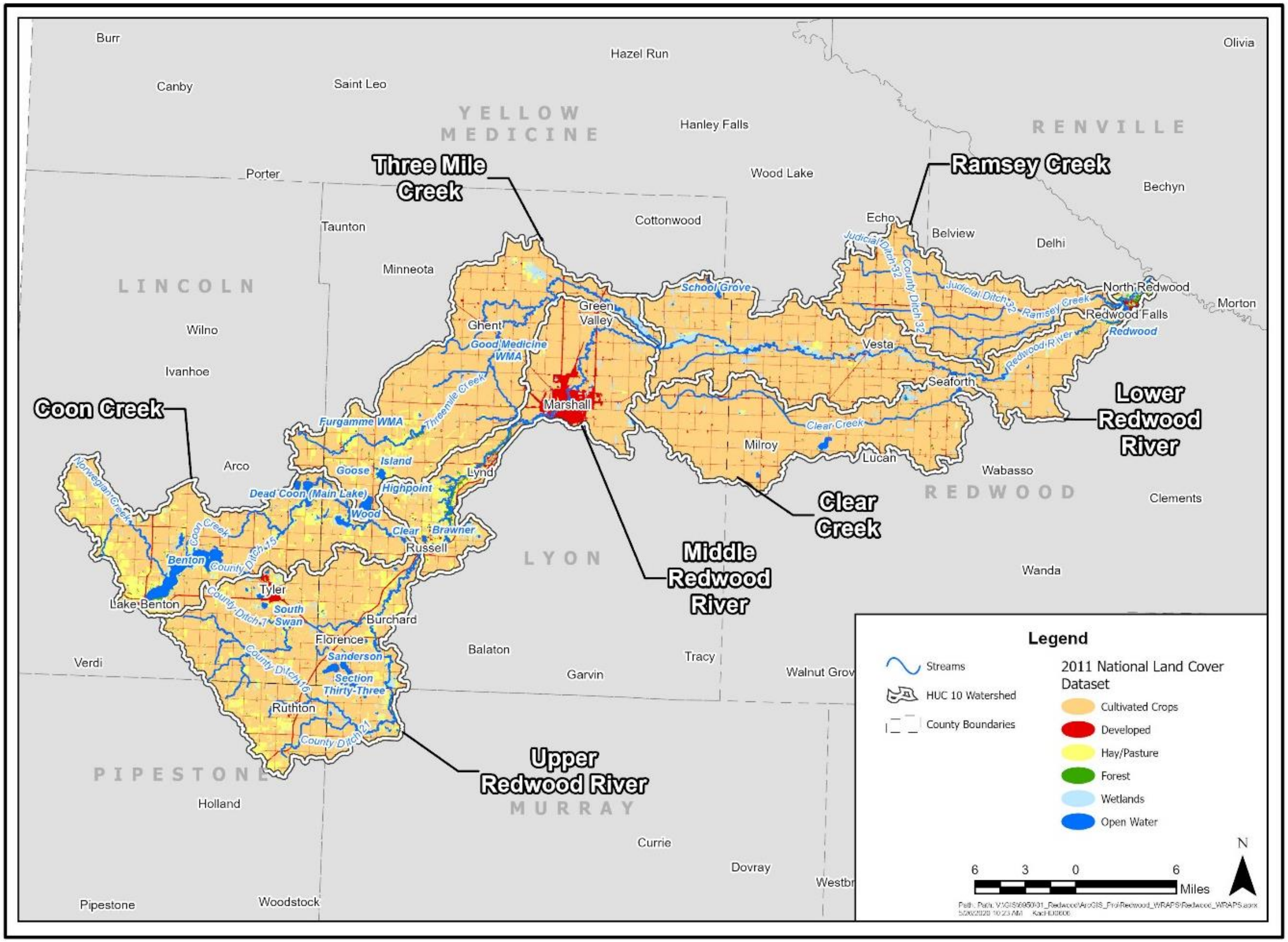


Figure 3. Redwood River Watershed land cover.



1.3 Environmental Justice

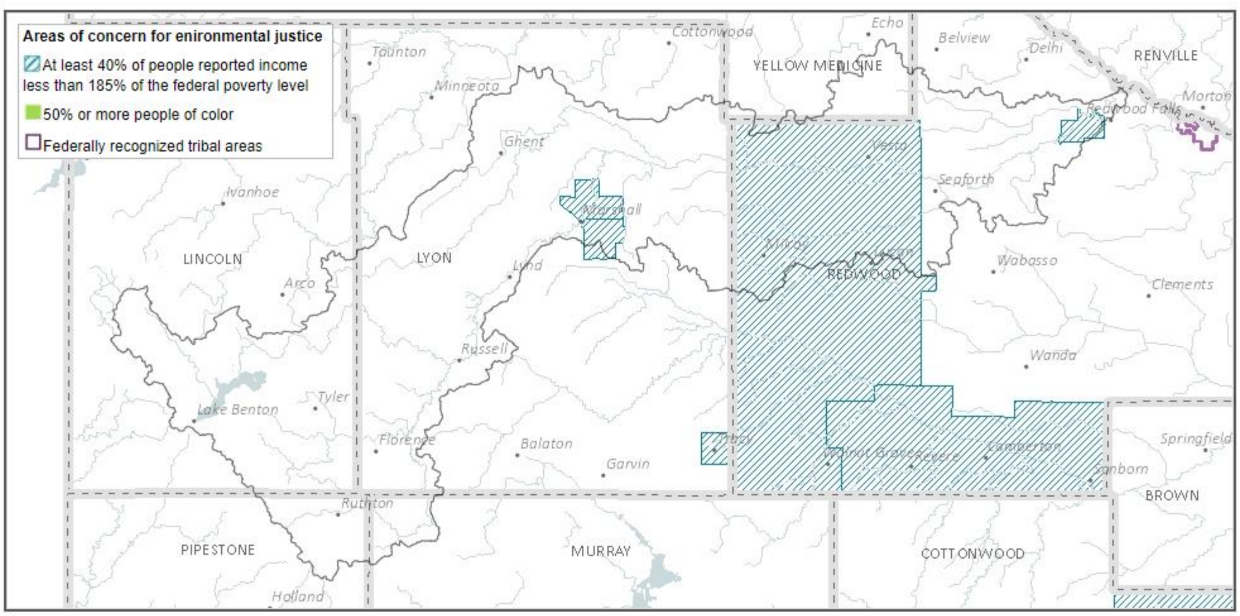
The MPCA is committed to making sure that pollution does not have a disproportionate impact on any group of people — the principle of environmental justice. This means that all people — regardless of their race, color, national origin, or income — benefit from equitable levels of environmental protection and equitable opportunities to participate in decisions that may affect their environment or health. The MPCA strives to provide fair treatment and meaningful involvement with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, strategies, and policies.

The MPCA uses the U.S. Census tract as the geographic unit to identify areas of environmental justice concerns. The agency considers a census tract to be an area of concern for environmental justice if it meets one or both of these demographic criteria:

- The number of people of color is greater than 50%; or,
- more than 40% of the households have a household income of less than 185% of the federal poverty level.

Three areas were identified in the Redwood River Watershed as areas of environmental justice concerns based on the percentage of residents living below the poverty level including parts of Marshall and Redwood Falls (Figure 4).

Figure 4. Areas of environmental justice concerns in the Redwood River Watershed.



Additionally, the MPCA considers communities within Tribal boundaries as areas of concern. This is an initial first step to identify areas where additional consideration or effort is needed to evaluate the potential for disproportionate adverse impacts, to consider ways to reduce those impacts, and to ensure meaningful community engagement as described in MPCA's environmental justice framework. No part of the Redwood River Watershed in Minnesota is located within the boundary of a Native American Reservation (USCB 2018). However, Brown, Cottonwood, Lyon, Murray, and Redwood Counties are of interest for the Lower Sioux Indian Community of Minnesota.

Additional information on the locations of areas of environmental justice concerns across the state and the MPCA's commitment to environmental justice can be found on the MPCA website.

1.4 Assessing Water Quality

Assessing water quality is a complex process with many steps including: developing water quality standards, monitoring the water, ensuring the monitoring data set is comprehensive and accurately represents the resources, comparing the data to the standards, and local professional review. A summary of the MPCA process is below.

Water Quality Standards

Waters throughout the state are not likely to be as pristine as they would be under undisturbed, "natural background" conditions. However, water bodies are still expected to support designated (or beneficial) uses including fishing (AqL), swimming (AqR), and eating of fish (aquatic consumption). Water quality standards (also referred to simply as "standards") are set after extensive review of data about the pollutant concentrations that support different designated uses, as well as estimation of natural background water quality conditions.

Water Quality Monitoring and Assessment

To determine if water quality is supporting its designated use, data on the water body are compared to relevant standards. When pollutants/parameters in a water body meet the standard (usually when the monitored water quality is better than the water quality standard), the water body is considered supporting of beneficial uses. When pollutants/parameters in a water body do not meet the water quality standard, the water body is considered impaired. If the monitoring data sample size is not robust enough to ensure that the data adequately represent typical conditions within the water body, or if monitoring results seem unclear regarding the condition of the water body, an assessment is delayed until further data are collected; this is referred to as an inconclusive or insufficient finding. More details on standards, and the monitoring and assessment process are available in the Redwood River Watershed Monitoring and Assessment Report (MPCA 2020a).

Several different parameters are considered for the assessment of each designated use. For AqR assessment, streams are monitored for bacteria and lakes are monitored for clarity and algae-fueling phosphorus. For AqL assessment, streams are monitored for both AqL populations and several pollutants that are harmful to these populations. Lakes are monitored for AqL populations (fish populations). A water is considered impaired for AqL populations (referred to as "bio-impaired") when low or imbalanced fish or bug populations are found (as determined by the IBI score).

This WRAPS report summarizes the water quality monitoring and assessment results; however, the full report is available at Redwood River Watershed Monitoring and Assessment Report (MPCA 2020a).

Stressor Identification

When streams are found to be bio-impaired, the cause of bio-impairment is studied and identified in a process called SID. This process identifies the parameters negatively affecting the AqL populations, referred to as "stressors". Stressors can be pollutants like nitrate, phosphorus, or sediment or nonpollutants like degraded habitat or high flow. Stressors are identified using the Causal

Analysis/Diagnosis Decision Information System (CADDIS; EPA 2019) process. In short, stressors are identified based on the characteristics of the aquatic community in tandem with water quality information and other observations. This WRAPS report summarizes the SID results. The full Redwood River Watershed SID Report is available on the MPCA website.

Computer Modeling

While monitoring for pollutants and stressors is generally extensive, not every stream or lake can be monitored due to financial and logistical constraints. Computer modeling can extrapolate the known conditions of the watershed to areas with less monitoring data. Computer models, such as Hydrological Simulation Program - FORTRAN (HSPF; USGS 2014), represent complex natural phenomena with numeric estimates and equations of natural features and processes. HSPF incorporates data including stream pollutant monitoring, land use, weather, and soil type to estimate flow, sediment, and nutrient conditions within the watershed. Building a Picture of a Watershed (MPCA 2014a) explains the model's uses and development. Information on the HSPF development, calibration, and validation in the Redwood River Watershed are available in the Cottonwood and Redwood Watersheds HSPF Model Extension (Tetra Tech 2019). The Redwood River Watershed HSPF model can be utilized through the Scenario Application Manager (SAM; RESPEC 2021), a user-friendly graphical user interface developed to utilize the HSPF model to run BMP implementation scenarios and is available for download.

HSPF model data provide a reasonable estimate of pollutant concentrations across watersheds. The output can be used for source assessment, TMDL calculations, and prioritizing and targeting conservation efforts. However, these data are not used for impairment assessments since monitoring data are required for those assessments. Modeled pollutant and stressor yields are presented throughout this report and will be indicated as such.

For additional Redwood River Watershed technical resources, see Appendix E.

2. Watershed Conditions

2.1 Condition Status

This report addresses waters for restoration and protection of AqL uses based on the fishery, macroinvertebrate community, and AqR uses based on bacteria levels, nutrient levels, and water clarity. Waters that are listed as impaired are addressed through restoration strategies and TMDL studies. Waters that are not impaired are addressed through protection strategies to help maintain and improve water quality and recreation opportunities to prevent and/or reverse downward trends (see Section 3.3).

Mercury in fish tissue is a concern for streams and lakes in the Redwood River Watershed. Eight reaches of the Redwood River and four lakes (Dead Coon, Benton, Redwood, School Grove) are listed as impaired by mercury in fish tissue and are covered under the Minnesota Statewide Mercury TMDL (MPCA 2007). Mercury fish tissue concentrations and sample years are shown in Table 18 of the Redwood River Watershed Monitoring and Assessment Report (MPCA 2020a). With the exception of School Grove Lake, which was listed as impaired in 2020, all of the mercury impairments in the Redwood River Watershed were added to the impaired waters list in 1998. More recent data indicates mercury concentrations have fluctuated in the Redwood River water column ranging between 0.4 through 10.3 ng/L (period of record 2012 through 2018). Additional fish tissue testing is warranted at the next available opportunity.

Streams

Thirty-nine of the 48 stream reaches in the Redwood River Watershed were assessed for aquatic use (Table 1; Figure 2 in the Redwood River Watershed Monitoring and Assessment Report [MPCA 2020a]). Eight reaches fully supported AqL and no streams fully supported AqR. Throughout the watershed, 28 reaches were nonsupporting of AqL and/or recreation. Of those reaches, 30 were nonsupporting of AqL and 14 were nonsupporting of AqR.

Of the seven fully supporting reaches, two are general use reaches, while five are modified use reaches. Of the reaches impaired for AqL use, substandard fish assemblages contributed to the impairment designation on 15 reaches (5 modified use), while substandard macroinvertebrates assemblages contributed to the designation of 18 (7 modified use) impaired reaches. Four reaches had existing IBI impairments. Nine reaches had existing impairments for AqL based on water chemistry parameters, the most common of which is TSS. All 13 of the stream reaches assessed for AqR did not support state water quality standards for bacteria (i.e., fecal coliform or *E. coli*) and were determined as impaired.

Figure 5 and Table 1 provide general summaries of the assessment results for the Redwood River Watershed. A complete list of the results of the stream assessments, which includes all available data on the stream reaches within each watershed, can be found in the Monitoring and Assessment Report (MPCA 2020a).

Figure 5. Impairments in the Redwood River Watershed.

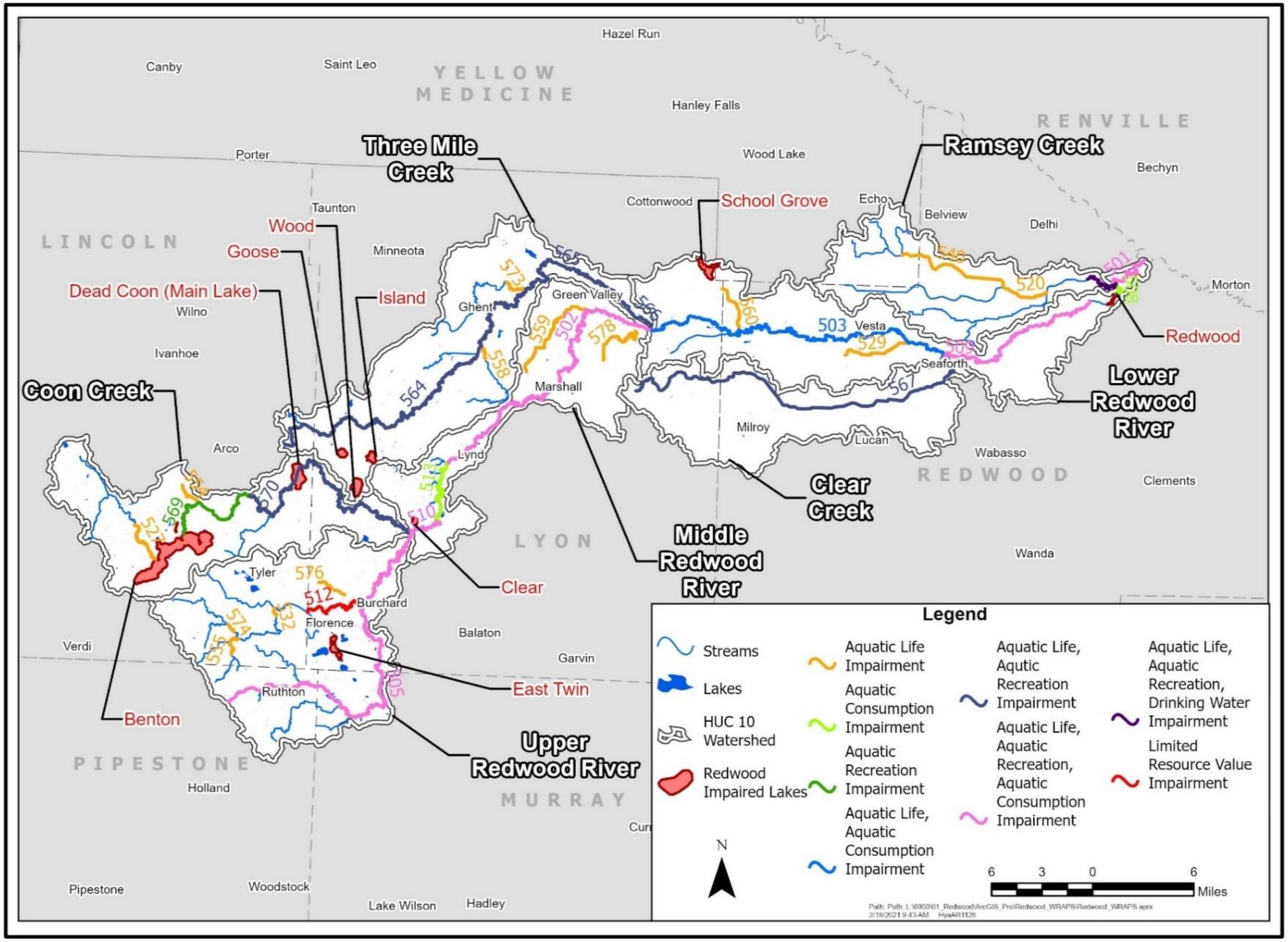


Table 1. Assessment status of river and stream reaches in the Redwood River Watershed based on 2009 – 2018 data.

HUC-10 Subwatershed	# Total Reaches	# Assessed Reaches	AqL Use		AqR Use		IF
			FS	NS	FS	NS	
Upper Redwood River	9	7	2	5	0	2	4
Coon Creek	4	4	0	3	0	2	0
Middle Redwood River	5	5	1	4	0	2	0
Three Mile Creek	6	6	1	5	0	3	0
Clear Creek	4	4	2	2	0	2	0
Ramsey Creek	6	3	0	3	0	1	2
Lower Redwood River	8	6	1	5	0	1	2
JD 12	6	4	1	3	0	1	5

FS = fully supporting, i.e., found to meet the water quality standard; NS = not supporting, i.e., does not meet the water quality standard, and therefore, is impaired; IF = insufficient data, i.e., the data collected were insufficient to make a finding

Lakes

Lakes are assessed for AqR use based on ecoregion-specific water quality standards for TP, chlorophyll-*a* (chl-*a*) (i.e., the green pigment found in algae), and Secchi transparency depth (i.e., water clarity). To be listed as impaired, a lake must fail to meet water quality standards for TP and either chl-*a* or Secchi depth.

There are 18 lakes in the Redwood River Watershed that have surface areas greater than 10 acres. Of these lakes, eight have enough water quality information to conduct a formal assessment of AqR (Table 2). Two lakes were found to fully support AqR while six did not. West and East Twin Lakes were the only lakes that fully supports AqR and are key lakes to protect from future water quality degradation (See Section 2.5).

Lake Redwood (64-0058-00) is the downstream impoundment of the Redwood River in Redwood Falls. Lake Redwood was previously deemed impaired in 2006 for AqR use based on assessment of the available water quality for the lake (MPCA 2020a). In 2016, a MPCA review team determined that Lake Redwood's short water residence (approximately nine days) suggests hydrology of the basin currently functions more like a river than a lake. Thus, the criteria for Lake Redwood being assessed as a recreational lake was not met and it was removed from the 2016 Impaired Waters List. A reclamation project began in 2022 to restore Lake Redwood to improve water quality and recreation. See Section 2.5 for further discussion of this project.

Since 2013, the MPCA, in coordination with the DNR, has substantially increased the use of biological monitoring and assessment to determine and report the condition of the State's lakes. This includes sampling fish communities of multiple lakes throughout a major watershed. The fish-based lake IBI (FIBI) utilizes data from trap net and gill net surveys, which focus on the gamefish community, as well as nearshore surveys which focus on the nongame fish community. From this data, a FIBI score can be calculated, which provides a measure of overall fish community health. The DNR developed four FIBI tools to assess many different types of lakes throughout the state. More information on the FIBI can be found at the DNR Lake Index of Biological Integrity website. Four monitored lakes were found to be impaired for AqL uses in the Redwood River Watershed: East Twin, Dead Coon, Benton, and Wood Lakes (See Section 2.3).

Table 2 below summarizes the ability of the assessed lakes to support AqR uses and AqL in the Redwood River Watershed. A complete list of the results of the AqR lake assessments can be found in the Redwood River Watershed Monitoring and Assessment Report (MPCA 2020a) and the lake FIBI results can be found in the Cottonwood and Redwood River Watersheds SID Report – Lakes (DNR 2021).

Table 2. Assessment status of the lakes in the Redwood River Watershed based on 2009 – 2018 data.

HUC-10 Subwatershed	Lakes >10 Acres	AqL Use		AqR Use		IF
		FS	NS	FS	NS	
Upper Redwood River	7	0	1	2	0	5
Coon Creek	4	0	2	0	2	3
Middle Redwood River	2	0	0	0	1	3
Three Mile Creek	3	0	1	0	2	3
Clear Creek	0	--	--	--	--	--
Ramsey Creek	0	--	--	--	--	--
Lower Redwood River	2	0	0	0	1	1

FS = fully supporting, i.e., found to meet the water quality standard; NS = not supporting, i.e., does not meet water quality standards, and therefore, is impaired; IF = insufficient data, i.e., the data collected were insufficient to make a finding

The Redwood River and three lakes in the watershed (Dead Coon, Benton, Redwood) have been tested for polychlorinated biphenyls (PCBs) and all were near or below the reporting limit (Table 18 in the Redwood River Watershed Monitoring and Assessment Report [MPCA 2020a]). These water bodies 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.

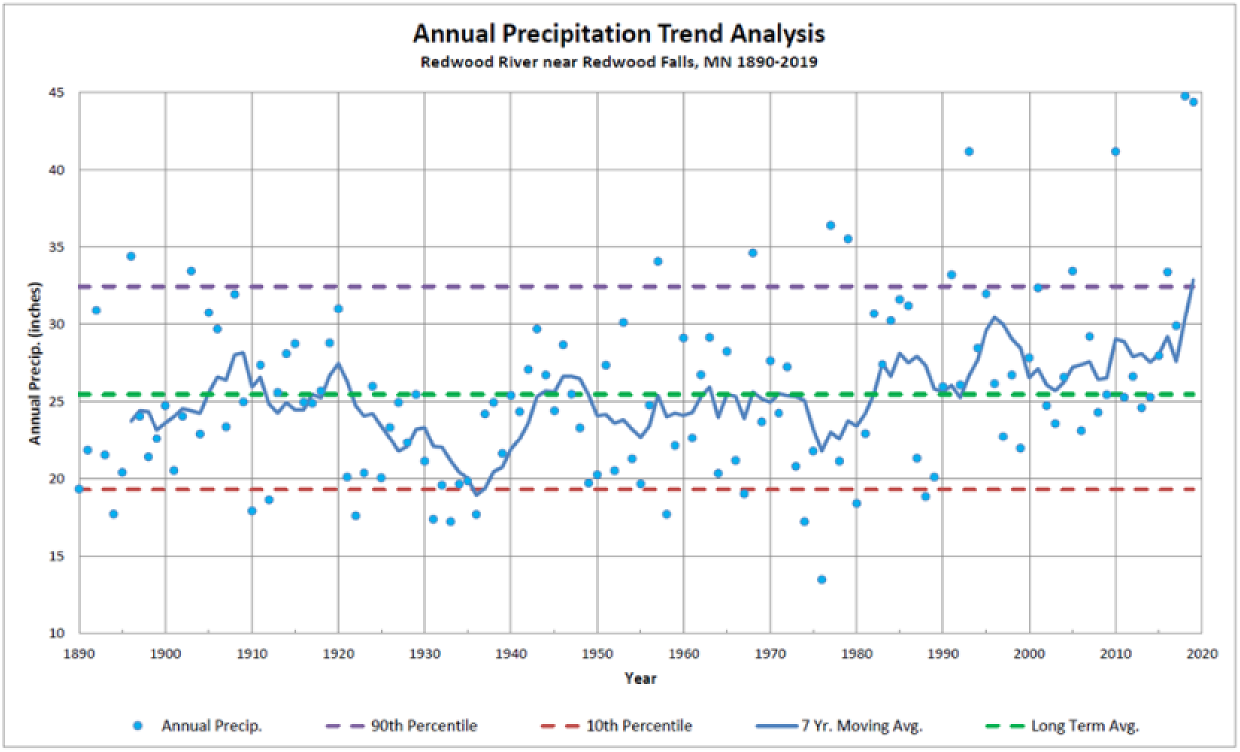
2.2 Watershed Trends

Precipitation

Precipitation in the Redwood River Watershed is typical of northern climates, with most of the yearly precipitation falling during summer months, from June through August (DNR 2019). Observed precipitation trends in Minnesota have shown that larger, more frequent extreme precipitation events are occurring state-wide (DNR Climate Change Website).

Long-term precipitation data for the Redwood River Watershed were analyzed in the Redwood River Characterization Report (DNR 2020). Data were acquired through the Minnesota State Climatology Office from the Redwood River near Redwood Falls stream gage site. The watershed's overall yearly precipitation average for the period of record (1890 through 2019) was 25.5 inches. For the same gage, the average annual precipitation from 1890 through 1981 was 24.1 inches, and from 1982 through 2019 was 28.7 inches. The seven-year moving average has exceeded the long-term average of 25.5 inches every year since the early 1990s (Figure 6). Comparisons of historic averages and the seven-year moving average indicate a recent increase in average annual precipitation for the watershed.

Figure 6. Annual precipitation trends in the Redwood River Watershed (DNR 2020).



Rainfall trend data have also been aggregated through the Midwestern Regional Climate Center. Gage stations were selected based on location in or near the Redwood River Watershed and available period of record. Gage station data were aggregated for the Redwood Falls Municipal Airport, Lamberton Southwest Research and Outreach Center, as well as the Marshall and Tracy weather stations. Precipitation data were tabulated annually for the period of record from 1965 through 2019, and for the months of May through October over the period of record 2009 through 2019, and annually for the years 1965 through 2019. Further maximum daily (24 hour) totals were also charted. Gage station data for all locations are included in Appendix C.

Water Quality

Year-to-year weather variations affect water quality conditions and data; for this reason, analyzing long-term data trends is important for gaining insight into changes occurring in a water body over time. The MPCA's Watershed Pollutant Load Monitoring Network (WPLMN) has established three long-term monitoring locations on the Redwood River: Russell (CR15; S000-696), Marshall (300th St; S001-203), and Redwood Falls (Knox Ave; S001-679). The data associated with these sites can be accessed via the WPLMN Data Viewer, which shows the location of long-term monitoring sites throughout the state. It includes links to the MPCA's Environmental Data Access portal that contains all submitted monitoring data for the entire period of record, including more recent data through 2022. The most downstream monitoring location, Redwood Falls station S001-679, has the longest and most complete monitoring record of the three WPLMN stations. The MPCA recently analyzed flow-corrected water quality concentration trends at this station for nitrate, total phosphorus, and total suspended solids (Table 3). Results of the trend analysis suggest that the Redwood River has demonstrated decreasing trends in total suspended solids over last 20 years (2000 through 2019) and total phosphorus over the last 12 years (2008 through 2019). These decreasing trends are likely the result of increased non-point source

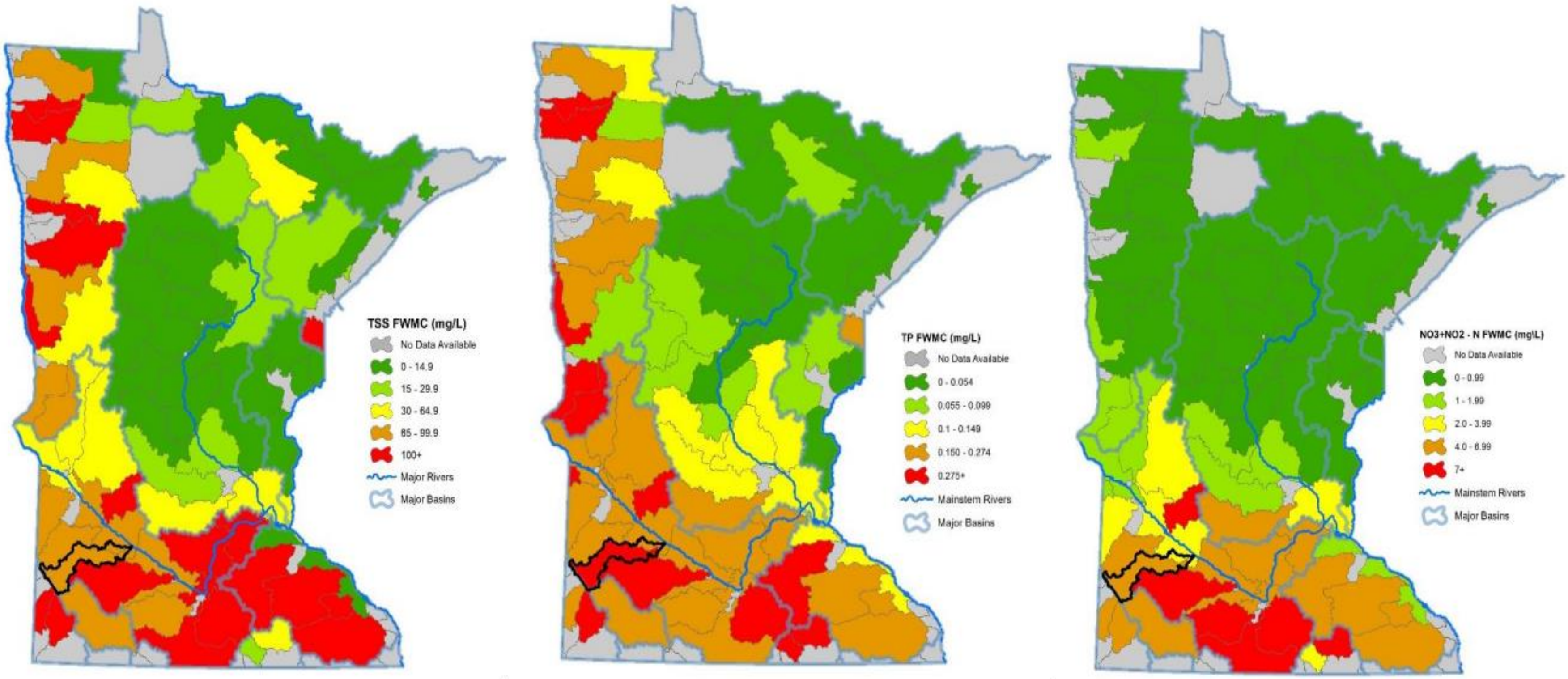
BMPs implemented by local partners and significant reductions in wastewater effluent total phosphorus loads.

When compared with other major watersheds throughout the state, average annual TSS, TP, and nitrite/nitrate flow-weighted mean concentrations (FWMCs) are 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 7). See discussion on pages 74 through 77 of the Redwood River Watershed Monitoring and Assessment Report (MPCA 2020a) for more information on results of the WPLMN for the Redwood River

Table 3. Flow-corrected water quality concentration trends for the Redwood River near Redwood Falls (S001-679).

Parameter	2000-2019 Trend	2008-2019 Trend
Nitrate (NO2+NO3)	No significant trend	No significant trend
Total phosphorus	No significant trend	Significant decreasing trend
Total suspended solids	Significant decreasing trend	No significant trend

Figure 7. Redwood River Watershed TSS, TP and nitrite/nitrate FWMCs.



The MPCA completes annual trend analyses 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 incorporates any agency and partner data submitted to the Environmental Quality Information System (EQuIS). The calculated trends use a Seasonal Kendall statistical test for waters with a minimum of eight years of Secchi disk measurement in lakes and Secchi tube measurements in streams.

The Redwood River Watershed has one [Volunteer Water Monitoring](#) site (S004-285) located on Three Mile Creek. Transparency data at other sites in the Redwood River Watershed have been taken by state and local staff. Four sites on the Redwood River and one site on Three Mile Creek have long-term trends of decreasing water transparency ($p \leq 0.05$). Water clarity data indicated no trend at all other monitored locations. Locations and results are shown below in Table 4.

Table 4. Trends in stream and lake transparency in the Redwood River Watershed 2008-2018.

HUC-10 Subwatershed	Water Body Name	Station ID	Trend
41-0043-00	Lake Benton	41-0043-00-203	No trend
41-0021-01	Dead Coon Lake	41-0021-01-101	No trend
07020006-501	Redwood River	S000-299	Degrading ↓
07020006-502	Redwood River	S001-203	Degrading ↓
07020006-509	Redwood River	S001-679	Degrading ↓
07020006-510	Redwood River	S000696	Degrading ↓
07020006-564	Three Mile Creek	S004-285	No trend
07020006-565	Three Mile Creek	S002-313	Degrading ↓
07020006-568	Clear Creek	S002-311	No trend

2.3 Stressors and Sources

In order to develop appropriate strategies for restoring or protecting the aquatic biological communities of water bodies, the stressors and sources impacting or threatening them must be identified and evaluated. SID is conducted for stream/river reaches with either fish or macroinvertebrate biota impairments and lakes with fish impairments. SID encompasses the evaluation of both pollutant and nonpollutant (e.g., altered hydrology, fish passage, habitat) factors as potential stressors. Pollutant source assessments are done where a biological SID process identifies a pollutant as a stressor, as well as for the typical pollutant impairment listings. Section 3 provides further detail on stressors and pollutant sources.

Stressors of Biologically Impaired Lakes

When lake biological impairments are found, stressors to the aquatic community must be identified. Five lakes in the Redwood River Watershed were assessed for determining the support of AqL by the Minnesota DNR and four of them were found to not support AqL based on FIBI scores (2020 303(d) Impaired Waters List): Benton, Dead Coon, Wood, and East Twin Lakes (Figure 5). Island Lake was assessed but had insufficient information to make an assessment decision; however, the lake is considered vulnerable to future impairment.

Candidate causes for the biological impairments were examined in the [Cottonwood and Redwood River Lake SID Report (DNR 2021)](#). Eutrophication (excess nutrients) was identified as the primary stress to lake AqL in the watershed. The assessed lakes contain relatively high levels of nutrients and are located in watersheds with high land use disturbance (i.e., greater than 40%). Eutrophication has detrimental effects on aquatic biology through changes to aquatic plant diversity and abundance, restructuring of plankton communities, and negative impacts to vegetation-dwelling and sight-feeding predatory fishes.

Stressors of Biologically Impaired Stream and River Reaches

There are 27 stream reaches in the Redwood River Watershed impaired for AqL due to poor biological communities. To identify probable stressors causing these impairments, an intensive field survey and data evaluation was conducted by the MPCA in 2019 and 2020. The resulting Redwood River Watershed SID Report (MPCA 2021) provides detailed information and weight of evidence analysis to link stressors to the impairments. Potential candidate causes of the impairments that were ruled out based on a review of available data include: pH, stream temperature, pesticides, and heavy metals toxicity. The following stressors that are potential candidate causes were examined in more detail: altered hydrology, loss of connectivity, loss of physical habitat, low DO concentrations, eutrophication, TSS, nitrate concentrations, and chloride/conductivity toxicity. Table 5 summarizes the primary stressors for the Redwood River Watershed biota-impaired reaches. Eutrophication was the most common stressor to the biology followed closely by altered hydrology, nitrate, and habitat. Chloride was only identified as a potential stressor in Reach 502.

Table 5. Primary stressors to AqL in biologically-impaired stream reaches in the Redwood River Watershed.

HUC-10 Subwatershed	AUID (Last 3 digits)	Type of water-body	Biological impairment	Primary stressor							
				Altered Hydrology	Connectivity	Habitat	Dissolved Oxygen	Eutrophication	Suspended Solids	Nitrate	Chloride/Conductivity
Upper Redwood River	505	river	Fish and macroinvertebrate	✓	×	✓	✓	✓	✓	O	
	576	ditch	Fish and macroinvertebrate	✓	×	O	✓	✓	O	✓	
	555	stream	Fish	✓	O	O	O	O	✓	O	
	574	stream	Macroinvertebrate	✓	✓	O	O	✓	O	✓	
	532	stream	Fish and macroinvertebrate	✓	×	✓	O	O	O	✓	
Coon Creek	527	stream	Fish and macroinvertebrate	✓	✓	✓	O	✓	O	O	
	554	ditch	Fish	✓	✓	✓	O	✓	O	✓	
	570	stream	Fish and macroinvertebrate	✓	✓	✓	✓	✓	✓	O	
Middle Redwood River	502	river	Fish and macroinvertebrate	O	O	✓	O	✓	✓	✓	O
	559	stream	Fish	✓	✓	✓	✓	✓	O	O	
	578	ditch	Fish and macroinvertebrate	✓	✓	✓	O	✓	O	✓	

HUC-10 Subwatershed	AUID (Last 3 digits)	Type of water-body	Biological impairment	Primary stressor							
				Altered Hydrology	Connectivity	Habitat	Dissolved Oxygen	Eutrophication	Suspended Solids	Nitrate	Chloride/Conductivity
Three Mile Creek	564	stream	Fish and macroinvertebrate	O	×	✓	✓	✓	✓	O	
	558	stream	Macroinvertebrate	✓	✓	✓	O	O	O	O	
	573	stream	Fish and macroinvertebrate	✓	×	×	O	✓	O	✓	
Clear Creek	568	stream	Macroinvertebrate	×	×	×	×	✓	✓	✓	
Ramsey Creek	540	ditch	Macroinvertebrate	✓	✓	✓	O	✓	✓	✓	
	520	ditch	Fish	O	✓	✓	O	✓	O	✓	
	521	stream	Fish and macroinvertebrate	×	✓	O	×	O	✓	✓	
Lower Redwood River	503	river	Macroinvertebrate	✓	×	✓	O	✓	✓	✓	
	560	ditch	Macroinvertebrate	✓	✓	✓	✓	✓	O	✓	
	529	ditch	Macroinvertebrate	✓	✓	✓	✓	O	O	✓	
	509	river	Fish	O	✓	O	O	✓	✓	✓	
	501	river	Macroinvertebrate	×	×	O	×	O	✓	✓	

✓ = A stressor, × = Not a stressor, O = Inconclusive

Pollutant Sources

This section summarizes the sources of pollutants (such as sediment and phosphorus) to lakes and streams in the Redwood River Watershed, including point sources (such as wastewater treatment plants) or nonpoint sources (such as runoff from the land). The HSPF model is a comprehensive, mechanistic model of watershed hydrology and water quality that allows the integrated simulation of point sources, land and soil contaminant runoff processes, and in-stream hydraulic and sediment-chemical interactions. Redwood River Watershed HSPF model results (Tetra Tech 2019) were used to evaluate the relative magnitude of nonpoint versus point sources in the Redwood River Watershed, as demonstrated in Table 6. In general, nonpoint source pollution represents the dominant pathway for sediment and nutrient export to most streams and lakes throughout each major subwatershed. HSPF does not model bacteria and therefore was not used to estimate *E. coli* sources. More information about the HSPF model is provided in Section 3.2 of this report.

Table 6. HSPF estimated source contributions of sediment, TP, and total nitrogen (TN) for each major HUC-10 subwatershed in the Redwood River Watershed for HSPF-SAM (Version 1.0) model averaging period 1996 - 2017.

HUC-10 Subwatershed	Nonpoint Sources					Point Sources
	Forest and Wetland	Pasture and Grassland	Cropland	Developed	Stream Bed/ Bank/Bluff	
Sediment (TSS, tons/year)						
Upper Redwood River	7	133	2,242	264	2,690	6
Coon Creek	7	119	1,910	128	1,898	-
Middle Redwood River	6	25	855	352	2,939	61
Three Mile Creek	5	25	1,390	112	3,072	<1
Clear Creek	3	2	2,020	145	1,917	<1
Ramsey Creek	2	2	1,388	99	2,191	-
Lower Redwood River	10	20	2,360	180	21,559	<1
Phosphorus (TP, lbs/year)						
Upper Redwood River	15	410	23,992	940	310	725
Coon Creek	13	355	16,847	495	237	-
Middle Redwood River	17	155	15,758	2,455	173	90,006*
Three Mile Creek	12	176	25,827	558	411	123
Clear Creek	7	8	23,769	479	232	123
Ramsey Creek	5	10	17,108	367	303	-
Lower Redwood River	23	63	27,170	774	3,147	129
Nitrogen (TN, lbs/year)						
Upper Redwood River	4,038	30,539	797,879	33,770	<1	1,688
Coon Creek	3,375	26,192	558,210	20,554	<1	-
Middle Redwood River	3,425	12,645	486,986	51,834	-	204,022
Three Mile Creek	3,042	14,479	846,688	21,077	10	232
Clear Creek	1,818	586	741,127	18,535	-	295
Ramsey Creek	891	774	556,244	15,389	3	-
Lower Redwood River	5,241	4,808	887,609	26,852	100	208

*Point source P loads have decreased over time and are currently substantially lower than this value which reflects average point source loading from 1996-2017.

Section 3.6 of the Redwood River Watershed TMDL Study (MPCA 2023a) provides a thorough description of the relative contribution of point and nonpoint phosphorus sources to the watershed's impaired lakes. The TMDL study also identified point and nonpoint bacteria and sediment sources to the watershed's impaired streams. Below is a brief discussion of the major point and nonpoint sources that have been identified in these watersheds. Other sources and practices to reduce pollutant contributions are discussed in Section 3.3.

Point Sources

Point sources are regulated through National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) permits. Regulations of NPDES permits vary, depending on the type of point source. Some permittees are not allowed to discharge (e.g., Confined Animal Feedlot Operations (CAFO) permits), some are allowed to discharge but must treat and measure effluent pollutants to ensure permit requirements are met (e.g., wastewater treatment plant permits), and some permits only allow discharge under special circumstances or require the use of BMPs to limit the discharge of pollutants (e.g., construction permits).

Municipal and Industrial Wastewater

There are eight permitted municipal wastewater treatment facilities (WWTF) and two industrial WWTFs in the Redwood River Watershed (Table 7). These facilities discharge directly to or are located upstream of an impaired reach. Individual TSS, *E. coli*, chloride, and/or phosphorus wasteload allocations (WLAs) were provided for each facility in the various TMDL studies that have been completed in the Redwood River Watershed. Based on review of data available on the MPCA's Wastewater Data Browser, all facilities are currently meeting the WLA requirements set forth in the Redwood River Watershed TMDL report for TSS and *E. coli*. The two continuous discharging facilities, ADM – Marshall and Marshall WWTP, currently exceed the phosphorus WLAs set forth in the draft Redwood River RES TMDL Report (in progress). Currently, effluent chloride concentrations for ADM Corn Processing – Marshall and Marshall WWTP routinely exceeded the chronic standard. Marshall will be assigned an effluent limit by MPCA based on the water quality standard, which will be consistent with the Redwood River Watershed TMDL Report. ADM Corn Processing – Marshall's permit currently contains a chloride effluent limit, which will be evaluated by the MPCA for consistency with the facility's chloride WLA in the Redwood River Watershed TMDL Report.

Table 7. Point sources in the Redwood River Watershed.

HUC-10 Subwatershed	Name	Permit #	Type	Pollutant Reduction Required in TMDL
Upper Redwood River	Ruthton WWTP	MNG580105	Domestic	No
	Tyler WWTP	MNG580116	Domestic	No
Coon Creek	None	NA	NA	NA
Middle Redwood River	ADM Corn Processing – Marshall	MN0057037	Industrial	Yes
	Lynd WWTP	MNG580030	Domestic	No
	Marshall WWTP	MN0022179	Domestic	Yes
	Russell WWTP	MNG580062	Domestic	No
	Magellan Pipeline Co LP - Marshall	MN0059838	Industrial	No
Three Mile Creek	Ghent WWTP	MNG580121	Domestic	No
Clear Creek	Milroy WWTP	MNG580124	Domestic	No
Ramsey Creek	None	NA	NA	NA
Lower Redwood River	Vesta WWTP	MNG580043	Domestic	No

Municipal, Construction, and Industrial Stormwater

Stormwater systems in some communities, dependent on size and location, are regulated under the Municipal Separate Storm Sewer System (MS4) program, which requires the use of BMPs to reduce pollutants. The city of Marshall (MS400241; population 13,628) and Redwood Falls (MS400236; population 5,102) are in the central and eastern portion of the watershed, respectively (Figure 3). Both the City of Marshall and Redwood Falls are subject to the MPCA's MS4 Permit program. The municipal stormwater permit holds permittees responsible for stormwater discharging from the conveyance system they own and/or operate. The conveyance system includes ditches, roads, storm sewers, stormwater ponds, etc. Under the NPDES stormwater program, permitted MS4 entities are required to obtain a permit, then develop and implement an MS4 Stormwater Pollution Prevention Program (SWPPP), which outlines a plan to reduce pollutant discharges, protect water quality, and satisfy water quality requirements in the Clean Water Act. An annual report is submitted to the MPCA each year by the permittee documenting progress on implementation of the SWPPP.

Construction stormwater is regulated through an NPDES permit. Untreated stormwater that runs off construction sites often carries sediment to surface water bodies. Because phosphorus travels adsorbed to sediment, construction sites can also be a source of phosphorus to surface waters. Phase II of the stormwater rules adopted by the U.S. Environmental Protection Agency (EPA) requires an NPDES permit for a construction activity that disturbs one acre or more of soil; a permit is needed for smaller sites if the activity is either part of a larger development or if the MPCA determines that the activity poses a risk to water resources. Coverage under the construction stormwater general permit requires sediment and erosion control measures that reduce stormwater pollution during and after construction activities.

Industrial stormwater is regulated through an NPDES permit when stormwater discharges have the potential to come into contact with materials and activities associated with the industrial activity. It is estimated that a small percent of the project area is permitted through the industrial stormwater permit, and industrial stormwater is not considered a significant source. On average, there is one permitted industrial stormwater site in every 23 square miles of the Redwood River Watershed.

Based on watershed-wide data, on average, less than 0.4% of the watershed area is permitted under the construction and industrial stormwater permit in any given year. Thus, construction and industrial stormwater was not considered a significant source of sediment, phosphorus, chloride, or bacteria throughout the Redwood River Watershed.

Animal Feeding Operations

Livestock animals are potential sources of bacteria, phosphorus, and nitrogen to streams in the Redwood River Watershed, particularly when direct access is not restricted and/or where feeding structures are located adjacent to riparian areas.

Minn. R. ch. 7020 governs the permitting, standards for discharge, design, construction, operation, and closure of animal feeding operations (AFOs) throughout Minnesota. An AFO is a site where animals are confined for 45 days or more in a 12-month period and vegetative cover is not maintained.

CAFO is an EPA definition that implies not only a certain number of animals but also specific animal types. CAFO size is based on number of animals (head count) and can include large, medium, and small CAFOs. For example, 2,500 head of swine weighing 55 pounds or more is considered a large CAFO and 1,000 head of cattle other than mature dairy or veal calves are a large CAFO; but a site with 2,499 head of swine weighing 55 pounds or more or a site with 999 head of cattle other than mature dairy would be considered a medium CAFO. The MPCA currently uses the federal definition of a CAFO in its permit requirements of animal feedlots along with the definition of animal unit (AU). In Minnesota, a NPDES permit is required for facilities that exceed any of the federal large CAFO threshold numbers and discharges to waters of the United States. SDS permits are required for any facility that has a capacity of

1,000 AU or more. Facilities required to obtain SDS permit coverage may choose to obtain NPDES coverage in lieu of the SDS permit. CAFOs with less than 1,000 AU capacity that do not discharge to waters of the United States are not required to obtain NPDES Permit coverage.

CAFO production areas need to be designed, constructed, operated, and maintained to contain all manure, manure-contaminated runoff, or process wastewater, and direct precipitation. CAFOs and AFOs with 1,000 or more AUs must be designed to contain all manure and manure contaminated runoff from precipitation events of less than a 25-year - 24-hour storm event. Having and complying with an NPDES permit allows some enforcement protection if a facility discharges due to a 25-year - 24-hour precipitation event (approximately 5.2" in 24 hours) and the discharge does not contribute to a water quality impairment. Large CAFOs permitted with an SDS permit or those not covered by a permit must contain all runoff, regardless of the precipitation event. Therefore, many large CAFOs in Minnesota have chosen to have an NPDES permit, even if discharges have not occurred in the past at the facility. A current manure management plan (MMP), which complies with Minn. R. 7020.2225, and the respective permit is required for all CAFOs and AFOs with 1,000 or more AUs. Additionally, MMP requirements for CAFOs are more stringent than for smaller feedlots. CAFOs are inspected by the MPCA in accordance with the MPCA NPDES Compliance Monitoring Strategy approved by the EPA. All CAFOs (NPDES permitted, SDS permitted, and not required to be permitted) are inspected by the MPCA on a routine basis with an appropriate mix of field inspections, offsite monitoring, and compliance assistance.

Feedlots under 1,000 AUs and those that are not federally defined large CAFOs do not operate with permits; however, the requirements under Minn. R. chs. 7020, 7050, and 7060 still apply. In Minnesota, feedlots with greater than 50 AUs, or greater than 10 AUs in shoreland areas, are required to register with the state. Facilities with fewer AUs are not required to register with the state. Feedlot registration enables the County and the MPCA to communicate directly with feedlot owners regarding all aspects of feedlot management including technical requirements, permitting, inspections and corrective action. Registration also helps ensure that surface waters are not contaminated by the runoff from feeding facilities, manure storage or stockpiles, and cropland with improperly applied manure. Livestock are also part of hobby farms, which are small-scale farms that are not large enough to require registration but may have small-scale feeding operations and associated manure application or stockpiles.

In the Redwood River Watershed, Redwood County is the only county that is not delegated to administer feedlot-related activities such as permitting, inspections, and compliance/enforcement. Lincoln, Pipestone, Lyon, Yellow Medicine, and Murray counties are delegated counties and therefore administer a county feedlot program based on the requirements of the Minn. R. 7020, Feedlot Rules. These counties have the responsibility for implementing state feedlot regulations for facilities with fewer than 1,000 AUs and do not meet the federal definition of a large CAFO that are not subject to state or federal operating permit requirements. Responsibilities include registration, permitting, education and assistance, and complaint follow-up.

The MPCA maintains a feedlot registration database that contains feedlot locations and numbers and types of animals in CAFOs and registered feedlots. The database includes the maximum number of animals that each registered feedlot can hold; therefore, the actual number of livestock in registered facilities is likely lower. The MPCA registered feedlot database indicates there are approximately 352 active feedlot facilities with over 86,000 livestock AUs throughout the Redwood River Watershed as of 2018 (Figure 8), which is representative of conditions at the time of watershed assessment and TMDL development. Table 8 summarizes facility type and livestock numbers for each impaired reach, lake, and the entire watershed. In the Redwood River Watershed, there are 28 feedlots located within 1,000 feet of a lake or 300 feet of a stream or river, an area generally defined as shoreland.

Figure 8. MPCA registered feedlots in the Redwood River Watershed (data from 2018).

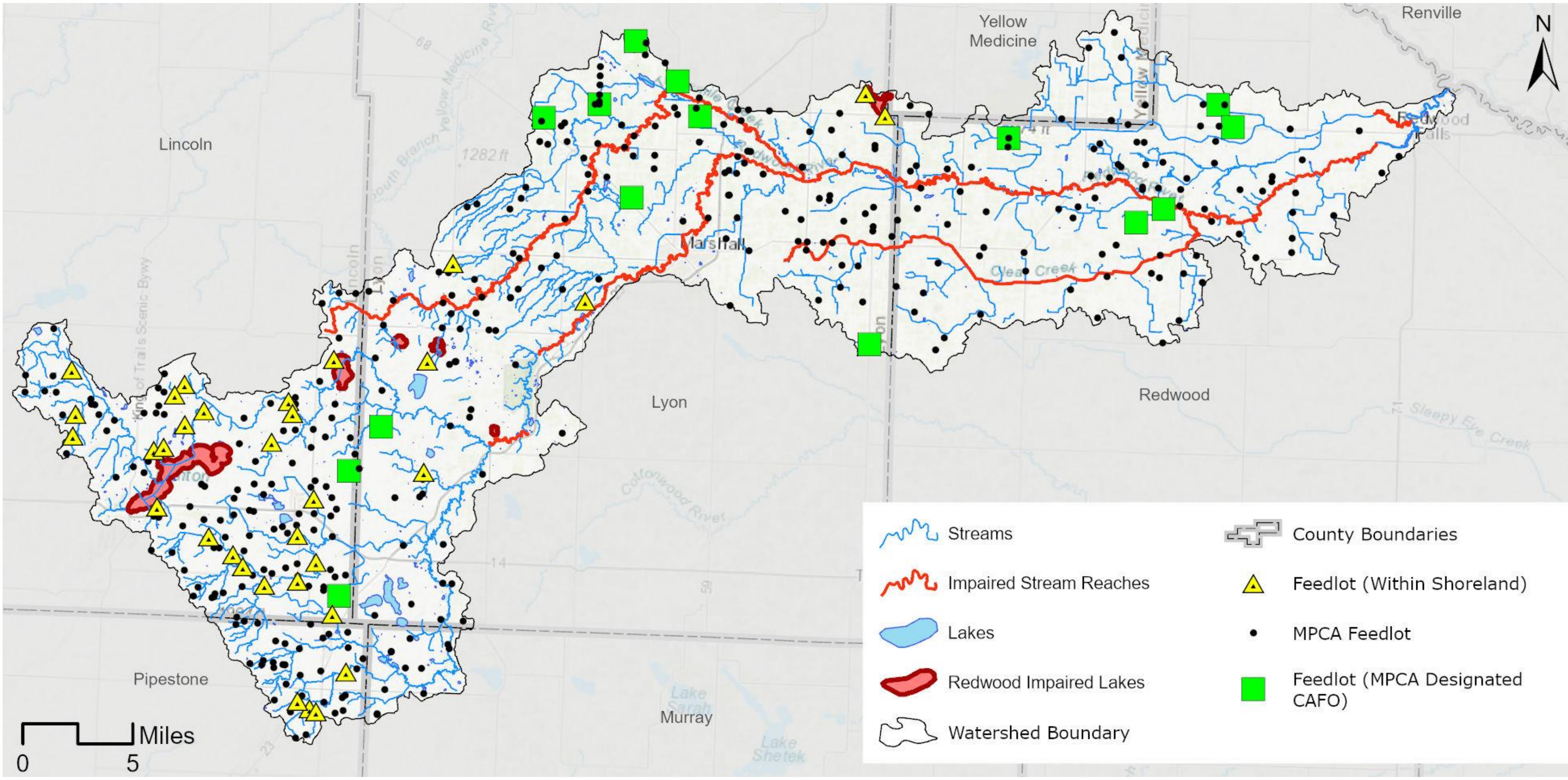


Table 8. MPCA active registered feedlots and feedlot type for each impaired lake and *E. coli* impaired reach in the Redwood River Watershed (data from 2018).

Impaired Reach/Lake	Impairment Type	Total Operations		CAFOs		Open Lots		Shoreland		Open Lots in Shoreland	
		Count	AUs	Operations	AUs	Operations	AUs	Operations	AUs	Operations	AUs
Redwood River Reach 510	*E. coli*	158	22,215	1	7,100	142	18,417	23	2,420	22	1,880
Redwood River Reach 521	*E. coli*	21	9,188	2	2,340	13	2,994	--	--	--	--
Benton Lake	Nutrients	25	3,234	--	--	23	3,209	5	631	5	631
Dead Coon Lake	Nutrients	47	5,914	--	--	43	5,859	12	931	12	931
Goose Lake	Nutrients	0	0	--	--	--	--	--	--	--	--
School Grove Lake	Nutrients	2	200	--	--	2	200	2	200	2	200
Clear Lake	Nutrients	0	0	--	--	--	--	--	--	--	--
Redwood River Watershed	**All**	**352**	**86,514**	**8**	**10,750**	**282**	**54,954**	**28**	**3,556**	**27**	**3,016**

Nonpoint Sources

Nonpoint sources of pollution, unlike pollution from industrial and municipal wastewater treatment plants, can come from many different sources. Nonpoint source pollution is accumulated by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries natural and human-made pollutants, finally depositing them into lakes and streams. Common nonpoint pollutant sources in the Redwood River Watershed are summarized below. Specific strategies to address nonpoint pollutant sources are discussed in Section 3.3.

Watershed Runoff

Nonpoint pollutant loads in rural areas can come from nonpermitted sources such as sediment erosion from upland fields, tile drainage, gully erosion, and livestock pastures in riparian zones (Schottler et al. 2013). Runoff from these sources can carry sediment, bacteria, phosphorus, and other nutrients to surface waters. Upland nonpoint sources of sediment, nitrate, and phosphorus were evaluated using the Redwood HSPF Model (Tetra Tech 2019). The results provide hourly runoff flow rates, sediment concentrations, and nutrient concentrations, along with other water quality constituents, at the outlet of any modeled subwatershed for the model time period of 1996 through 2017. Model documentation contains additional details about model development and calibration (Tetra Tech 2019). Within each subwatershed, the upland areas are separated into multiple land use categories and are further parameterized based on hydrologic soil group. Simulated loads from upland areas represent the pollutant loads that are delivered to the modeled stream or lake; the loading rates do not represent field-scale soil loss estimates.

Overall, across the entire Redwood River HUC-8 Watershed, approximately 25% of the TSS load, 59% of the TP load, and 92% of the TN load is from cultivated crops and hay/pasture lands that were identified in the 2016 National Land Cover Database (NLCD) land use layer. Relative contributions by source vary widely between individual reaches.

Altered Hydrology

Near-channel sources of sediment and nutrients are those near the stream channel, including bluffs, banks, ravines, and the stream channel itself. Hydrologic changes in the landscape and altered precipitation patterns driven by climate change can lead to increased nitrate, TSS, and sediment-bound phosphorus in surface waters. Subsurface drainage tiling, channelization of waterways, land cover alteration, and increases in impervious surfaces all decrease detention time in the watershed and increase flow from fields and in streams. Draining and tiling wetland areas can decrease water storage on the landscape, which can lead to lower evapotranspiration and increased river flow (Schottler et al. 2013).

The straightening and ditching of natural rivers increase the slope of the original watercourse and moves water off the land at a higher velocity in a shorter amount of time. These changes to the way water moves through a watershed and how it makes its way into a river can lead to increases in water velocity, scouring of the river channel, and increased erosion of the riverbanks (Schottler et al. 2013, Lenhart et al. 2013).

HSPF model output suggests approximately 72% of the TSS load, 2% of the TP load, and <1% of the TN load at the outlet of the Redwood River Watershed comes from near-channel sources. Additionally, the

Redwood River Watershed Characterization Report (DNR 2020) provides an in-depth discussion of the processes, sources, and potential strategies to address near-channel sources in the Redwood River Watershed. This report includes the following components: characterization of the watershed, analysis of historical and existing hydrological data, assessment of geomorphic conditions and stream connectivity throughout the watershed. The report recommends three areas of focus with accompanying implementation practices for addressing hydrology in the Redwood River Watershed:

- **Upland restoration**
  - Increase water storage (temporary and long-term)
  - Increase perennial vegetation
  - Increase soil organic matter
- **In- and near-channel**
  - Stabilize banks that endanger infrastructure
  - Re-size bridges and culverts to allow flood flows on the floodplain, when applicable
  - Reconnect areas with longitudinal barriers to fish passage
- **Protection**
  - Existing lakes, wetlands, and wet marshes should be protected
  - Protect areas of significant groundwater-surface water interaction
  - Protect areas that are already enrolled in conservation programs or other BMPs
  - Protect areas that have been shown to remain stable over time

Runoff from Manure Application

Manure is a by-product of animal production and large numbers of animals create large quantities of manure. This manure is usually stockpiled and then spread over agricultural fields to help fertilize the soil. When stored and applied properly, this beneficial re-use of manure provides a natural source for crop nutrition. Manure, however, can pose water quality concerns when it is not applied properly or when leaks or spills happen from nearby fields, storage pits, lagoons, tanks, etc. Animal waste contains high amounts of fecal bacteria, phosphorus, and nitrogen. When delivered to surface and groundwater, it can cause high bacteria levels, eutrophication, and oxygen demand (i.e., low oxygen levels) that negatively impacts human health, aquatic organisms, and AqR.

The Minnesota Feedlot rules include regulations regarding the requirements for MMPs and land application of manure. The MPCA has developed templates, guides, and standards for the development and implementation of MMPs, manure nutrient management, and application rates. MMPs are required when producers apply for a feedlot permit, or when a facility has 300 or more AUs and does not use a licensed commercial applicator. MMPs are designed to help ensure that application rates do not exceed crop nutrient needs, and that setbacks from waters and drain tile intakes are observed.

Based on the MPCA feedlot staff analysis of feedlot demographics, knowledge, and actual observations, there was significant amount of late winter solid manure application (before the ground thaws) in the Redwood River Watershed. During this time, the manure can be a source of nutrients and pathogens in rivers and streams, especially during precipitation events. For feedlots with NPDES permits, surface applied solid manure is prohibited during the month of March. Winter application of manure (December through February) for permitted sites requires fields to be approved in their MMP, prior to manure application, and the feedlot owner/operator must follow a standard list of setbacks and BMPs.

Winter application of surface applied liquid manure is prohibited except for emergency manure application as defined by the NPDES permit. "Winter application" refers to application of manure to frozen or snow-covered soils, except below the soil surface (Minn. R. 7001).

Short term stockpile sites are defined in Minn. R. ch. 7020 and are considered temporary. Any stockpile kept for longer than a year must be registered with the MPCA and would be identified as part of a feedlot facility. Because of the temporary status of the short-term stockpile sites, and the fact they are usually very near or at the land application area, they are included with the land applied manure.

Incorporating manure is the preferred BMP for land application of manure and should result in less runoff losses. Nutrient loads modeled by HSPF are calibrated using monitored, in-stream water quality data at several points throughout the watershed and manure contributions to nutrient loads are therefore implicit.

Natural Bacterial Reproduction and Wildlife

It has been suggested that *E. coli* bacteria has the capability to reproduce naturally in water and sediment and therefore should be considered when identifying bacteria sources. Two Minnesota studies describe the presence and growth of "naturalized" or "indigenous" strains of *E. coli* in watershed soils (Ishii et al. 2010), and ditch sediment and water (Sadowsky et al. 2015). The latter study, supported with Clean Water, Land, and Legacy funding, was conducted in the Seven Mile Creek Watershed, an agricultural landscape in south central Minnesota. DNA fingerprinting of *E. coli* from sediment and water samples collected in Seven Mile Creek from 2008 through 2010 resulted in the identification of 1,568 isolates comprised of 452 different *E. coli* strains. Of these strains, approximately 64% were represented by a single isolate, suggesting new or transient sources of *E. coli*. The remaining 36% of strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. Discussions with the primary author of the Seven Mile Creek study suggest that while 36% might be used as a rough indicator of "background" levels of bacteria at this site during the study period, this percentage is not directly transferable to the concentration and count data of *E. coli* used in water quality standards and TMDLs. Additionally, because the study is not definitive as to the ultimate origins of this bacteria, it would not be appropriate to consider it as "natural" background.

Below is a summary of other studies that have found the persistence of *E. coli* in soil, beach sand, and sediments throughout the year in the United States without the continuous presence of sewage or mammalian sources:

- An Alaskan study (Adhikari et al. 2007) found that total coliform bacteria in soil were able to survive for six months in subfreezing conditions.
- A study in Michigan (Marino and Gannon 1991) documented survival and growth of fecal coliform in storm sewer sediment.
- Two studies in Maryland (Park et al. 2016; Pachepsky et al. 2017) demonstrated that release of *E. coli* from streambed sediments during baseflow periods is substantial and that water column

E. coli concentrations are dependent on not only land management practices but also in-stream processes.

Wildlife, which includes deer and waterfowl, also represents a small portion of the bacteria produced in the impaired reach watersheds. These could include but are not limited to open water areas with high waterfowl densities and lawns or golf courses near streams where geese or other waterfowl congregate.

Failing Septic Systems

Failing subsurface sewage treatment systems (SSTS) near waterways can be a source of bacteria, phosphorus, and nitrogen to streams and lakes, especially during low flow periods when these sources continue to discharge, and runoff driven sources are not active. SSTS can fail for a variety of reasons including excessive water use, poor design, physical damage, and lack of maintenance. Common limitations that contribute to failure include seasonal high-water table, fine-grained soils, bedrock, and fragipan (i.e., altered subsurface soil layer that restricts water flow and root penetration). SSTS can fail hydraulically through surface breakouts or hydrologically from inadequate soil filtration.

The MPCA differentiates between systems that fail to protect groundwater (FTPGW) and those that are an imminent threat to public health and safety (ITPHS). Generally, FTPGW systems are those that do not provide adequate treatment and may contaminate groundwater. For example, a system deemed failing to protect groundwater may have a functioning, intact tank and soil absorption system, but fails to protect groundwater by providing a less than sufficient amount of unsaturated soil between where the sewage is discharged and the periodically saturated soil level or bedrock. FTPGW systems can also include, but are not limited to the following:

- Seepage pits/cesspools/drywells/leaching pits
- Systems with less than the required vertical separation
- Systems not abandoned in accordance with Minn. R. 7080.2500

Systems considered ITPHS are severely failing or were never designed to provide adequate raw sewage treatment. These include SSTS and straight pipe systems that transport raw or partially treated sewage directly to a lake, stream, drainage system, or ground surface. ITPHS systems can include, but are not limited to the following:

- Straight pipes
- Sewage surfacing in the yard
- Sewage backing up into the home
- Unsafe tank lids
- Structurally unsound tanks
- Unsafe electrical conditions

The exact number and status of SSTSs in the Redwood River Watershed is unknown. However, counties provide regular estimates of FTPGW and ITPHS compliance rates to the MPCA. Table 9 shows estimates of FTPGW and ITPHS systems in the each of the counties included in the Redwood River Watershed (MPCA personal communication 2018). It should be noted that these rates are county-wide estimates and were developed using a wide range of methods and resources and are intended for planning purposes only.

Table 9. Estimated SSTS compliance rates by county (MPCA personal communication 2018).

County	FTPGW SSTS	ITPHS SSTS
Lincoln	40%	16%
Lyon	24%	5%
Murray	15%	10%
Pipestone	9%	46%
Redwood	30%	5%
Yellow Medicine	15%	15%

Note: Estimated compliance rates reported by county and supplied to MPCA. Intended for planning purposes only.

Atmospheric Deposition

Atmospheric deposition represents the phosphorus that is bound to particulates in the atmosphere and is deposited directly onto surface waters. Atmospheric inputs of phosphorus from wet and dry deposition can be estimated using published rates based on annual precipitation (Barr Engineering 2004). The atmospheric deposition values used for dry (< 25 inches), average, and wet precipitation years (>38 inches) are 24.9, 26.8, and 29.0 kilograms (kg)/kilometer (km)^2-year, respectively. These values are equivalent to 0.22, 0.24, and 0.26 pounds/acre/year for dry, average, and wet years, respectively. Atmospheric deposition does not represent a significant source of phosphorus to the water bodies in the Redwood River Watershed.

Lake Internal Loading

For many lakes, especially shallow lakes, internal loading can represent a significant portion of the annual TP load. Internal load can come from several sources including soluble phosphorus release from the sediment, rough fish (i.e., common carp), submerged aquatic vegetation (SAV), wind resuspension and physical disturbances such as motorized boat traffic.

Phosphorus source assessment and modeling done for the Redwood River Watershed TMDL Report suggest that internal loading in five of the six impaired lakes (Benton, Dead Coon, Goose, Clear, and School Grove) may constitute a significant portion of the lake's annual phosphorus budget and reductions will likely be needed to meet water quality standards and TMDL goals. Since internal phosphorus loading is typically the result of excessive watershed loading, it is expected that internal load in these lakes will decline when the TMDL external load reduction goals are achieved. Section 3.3 discusses strategies to manage sources of internal load if they continue to be a problem after substantial progress has made toward achieving external load reduction goals.

Upstream Lakes and Streams

A few of the impaired lakes and streams in the Redwood River Watershed receive a significant amount of their phosphorus load from upstream lakes and major stream reaches. For these lakes and stream reaches, restoration and protection efforts should focus on improving upstream watershed conditions and water quality.

2.4 TMDL Summary

A TMDL is a calculation of how much of a pollutant a lake or stream can receive before it fails to meet state water quality standards. These standards are based on the beneficial uses that a given water can support, which include AqR and AqL. TMDL studies are required by the Clean Water Act for all impaired lakes and streams. The Redwood River Watershed TMDL Report (MPCA 2022a) was drafted in conjunction with this WRAPS document addressing six impaired lakes and 13 impaired stream/river reaches throughout the Redwood River Watershed (Table 10). Other TMDL studies completed in the watershed include the Redwood River Fecal Coliform TMDL Report (RCRCA 2013), and the Minnesota River and Greater Blue Earth River Basin TMDL for TSS (MPCA 2020b). Collectively, these TMDL studies cover at least one impaired water body in each of the seven HUC-10 subwatersheds of the Redwood River Watershed (Table 10). For more details on these TMDL studies, refer to the TMDL documents on the MPCA webpage. See Appendix B for the pollutant loading, LA/WLA, and the load reduction goals needed to meet water quality standards for impairments addressed in the Redwood River Watershed TMDL (MPCA 2023a) report.

Impairments not caused by pollutants, such as AqL use impairment for macroinvertebrate IBI caused by degraded physical habitat, were not addressed through the TMDL process. Loading computations (TMDLs) are not required or appropriate for such impairments. The strategies in Section 3 of this report also cover streams and lakes with non-TMDL related impairments.

Table 10. Summary of impaired lakes and streams with completed TMDLs in the Redwood River Watershed.

HUC-10 Subwatershed	Stream or Lake Name	Reach AUID (Last 3 digits) or Lake ID	Pollutant(s)	Year TMDL Completed
Upper Redwood River	Redwood River	505	Bacteria	2014
	Tyler Creek[2]	512	Bacteria	2014
Coon Creek	Coon Creek	569 & 570	Bacteria	2014
	Lake Benton	41-0043-00	Lake Nutrients	2023 [3]
	Dead Coon (Main Lake)	41-0021-01	Lake Nutrients	2023 [3]
Middle Redwood River	Redwood River	502	TSS, Chloride, Bacteria	2023 [3], 2023 [3], 2014
	Redwood River	510	TSS, Bacteria	2023 [3], 2023 [3]
	Clear Lake	42-0055-00	Lake Nutrients	2023 [3]
Three Mile Creek	Three Mile Creek	564, 565 & 566 [1]	TSS, Bacteria	2023 [3], 2014
	Goose Lake	42-0093-00	Lake Nutrients	2023 [3]
	Island Lake	42-0096-00	Lake Nutrients	2023 [3]
Clear Creek	Clear Creek	567 & 568 [4]	TSS, Bacteria	2023 [3], 2014
Ramsey Creek	Ramsey Creek	521	Bacteria	2023 [3]
Lower Redwood River	Redwood River	501	TSS, Bacteria	2020, 2014
	Redwood River	503	TSS	2023 [3]
	Redwood River	509	TSS, Bacteria	2023 [3], 2014
	School Grove Lake	42-0002-00	Lake Nutrients	2023 [3]

[1] Three Mile Creek Reach 504 was split into three separate reaches, 564, 565 and 566, for the 2020 303(d) impaired waters list assessment process.

[2] Uses the Class 7: Limited Resource Value fecal coliform water quality standard of 1,000 CFU/100mL standard.

[3] Pending EPA approval.

[4] Clear Creek Reach 506 was split into two separate reaches, 567, and 568, for the 2020 303(d) impaired waters list assessment process.

2.5 Protection Considerations

Although most assessed water bodies in the Redwood River Watershed do not meet water quality standards, there are a handful of streams and lakes that fully support AqL and/or AqR. Protecting streams, lakes, wetlands, groundwater, and other resources from degradation is typically more cost effective than trying to restore resources after they become degraded. This section provides a brief discussion of some of the reports, tools, and information that are available to guide protection efforts in the Redwood River Watershed. All of the items highlighted below are based on input and work done by state agencies and local partners and were used to guide the identification and prioritization of strategies in Section 3.3.

Stream Protection

Recently, the MPCA, DNR, and other state agencies worked together to develop a Stream Protection and Prioritization Tool that can be used to generate a prioritized list of streams. The list is based on the results of water quality assessments, the level of risk posed from near shore areas, the level of risk posed from the contributing watershed, and the level of protection already in place in the watershed (Figure 6). The tool utilizes state-wide data coverages; therefore, additional local information must be weighed including factors such as forest management practices, potential development trends, and mining impacts.

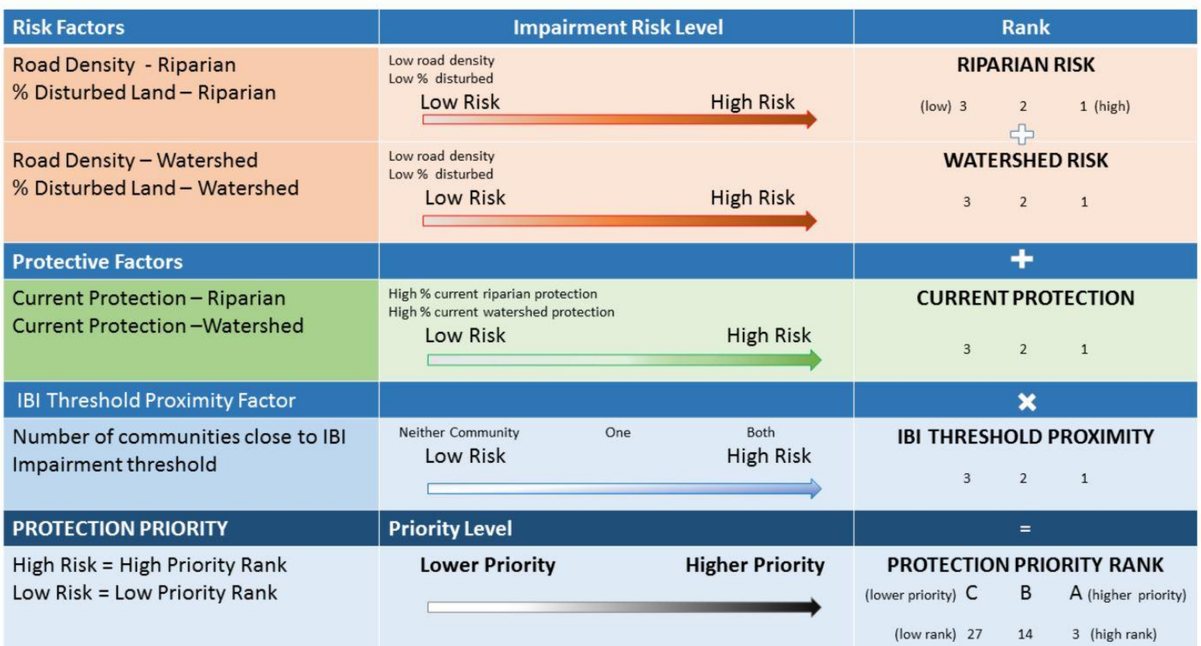
The process is limited to streams that have water quality assessments that include fish and/or macroinvertebrates and the streams must be meeting water quality standards – i.e., they are fully supporting of AqL. The first step considers how close these communities are to being impaired or degraded.

The second step looks at near shore (riparian) risks to healthy stream communities. In developing the tool, the following parameters were considered: the presence of steep slopes, percent altered streams, percent wetland loss, road density, population density, population change, feedlots, septic system density, and a variety of land use categories (percent agriculture, percent row crop, percent impervious surface, percent undeveloped). This analysis indicates that road density and disturbed land use (cultivated and urban uses) can best predict impacts or changes in stream biological health. These same risks are then also evaluated for the larger, upstream watershed.

The third step looks at how well protected the near shore areas and upstream watershed already are. To complete this step, analysis of lands in public ownership or with public easements is conducted.

A prioritized list of streams is then generated for the entire watershed. The list may then be further prioritized by splitting out, or separately considering, modified streams (ditches), general use streams (good biology and habitat), and exceptional streams (best biological communities and habitat).

Figure 9. Stream protection and prioritization tool matrix.



The Stream Protection and Prioritization Tool was applied (where applicable) to all the nonimpaired stream reaches throughout the Redwood River Watershed (Redwood River Watershed Monitoring and Assessment Report [MPCA 2020a]). Once all of the nonimpaired stream reaches in the watershed were ranked and prioritized, they were grouped into priority categories by splitting the list into thirds; the top third are high priority (A), the next third are medium priority (B), and the final third are low priority (C). Seven stream reaches in the Redwood River Watershed had the required data and information for assessment using the tool (Table 11 and Figure 10). Of these stream reaches, five were identified as Priority A (highest priority for protection) since their riparian risk is relatively high and their current level of protection is low to medium. The Priority A streams include one General Use Stream and four Modified Use Streams. The tool also identified two Priority B streams that have moderate riparian risk and/or currently have some level of protection. A more detailed list of protection streams can be found in Appendix A.

Figure 10. Streams, lakes, wetlands, and WMAs identified for protection in the Redwood River Watershed.

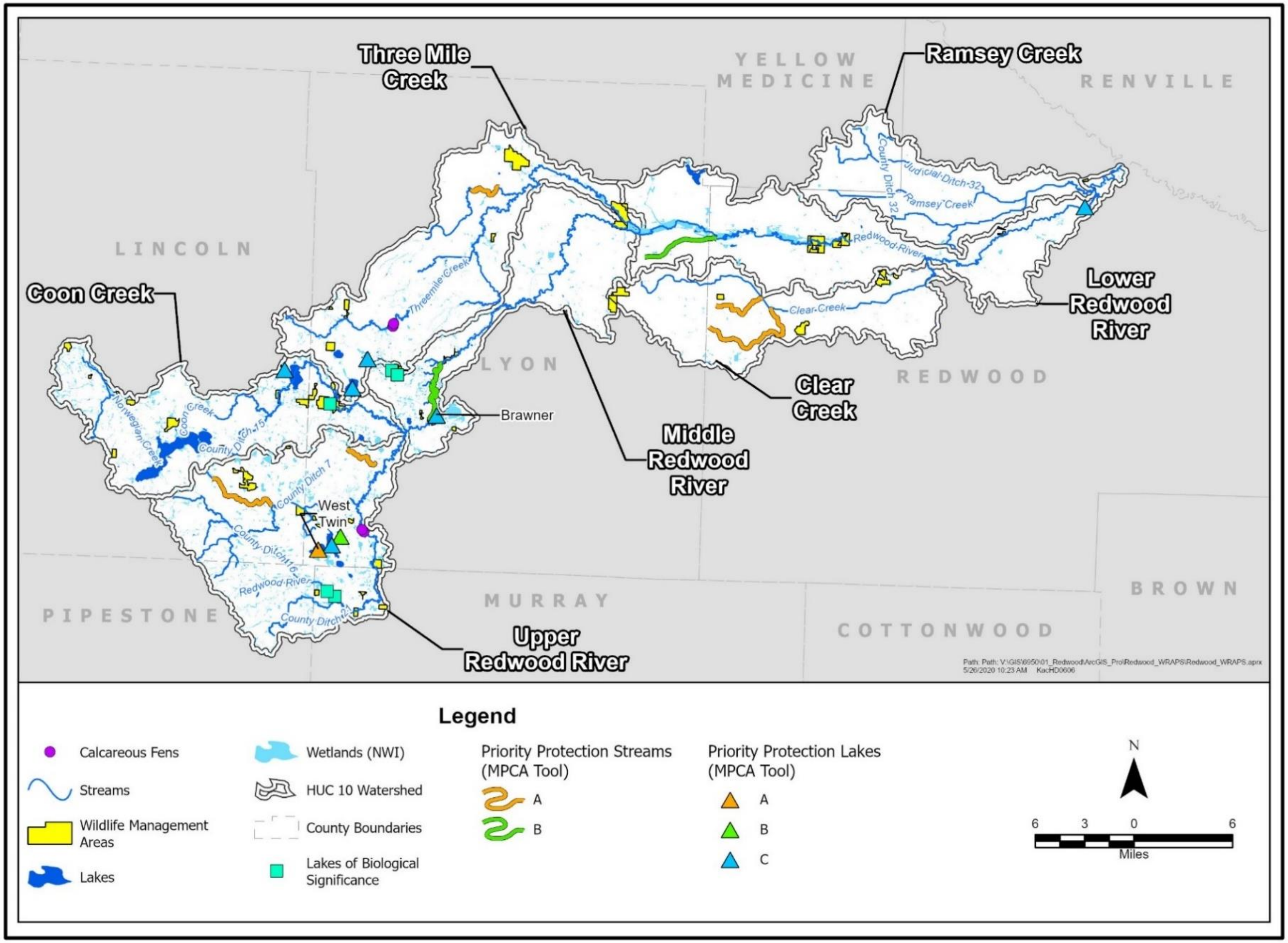


Table 11. Stream protection and prioritization tool results for the Redwood River Watershed (data from assessment period 2009 – 2018).

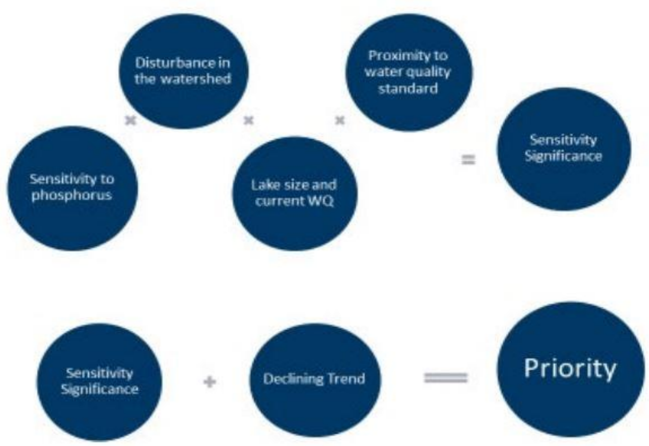
HUC-10 Subwatershed	Stream Name	Reach AUID	Riparian Risk	Watershed Risk	Current Protection Level	Protection Priority Class
Clear Creek	Unnamed Creek	562	med/high	high	low	A
	Judicial Ditch 14 & 15	517	high	high	low	A
Three Mile Creek	Unnamed Creek	572	high	high	low	A
Upper Redwood River	Unnamed Creek	580	high	high	low	A
	County Ditch 7	556	high	high	med/low	A
Middle Redwood River	Redwood River	513	high	high	med	B
Ramsey Creek	Unnamed Creek	561	med/high	high	med/low	B

As discussed in Section 1, all streams within the Redwood River Watershed are classified as warmwater streams. However, the Redwood River in Camden State Park, and Ramsey Creek near Redwood Falls, are designated DNR trout streams, and are managed as seasonal put and take fisheries. The higher stream gradient in Camden State Park, and groundwater springs in Ramsey Creek, support a cooler thermal regime to allow trout to survive for some time in summer. These reaches should also be targeted for protection considerations.

Lake Protection

The MPCA and other state agencies have also developed a Lake Protection and Prioritization Tool to generate a prioritized list of protection lakes in each major watershed throughout the State. The analysis is based on water quality assessment results, the amount of clarity lost if phosphorus is added, the amount of land use disturbance, lake size, and what is known about current trends in water quality.

Figure 11. Lake Protection and Prioritization Tool Framework.



The prioritization process (Figure 11) is limited to lakes that have completed water quality assessments and that are currently meeting water quality standards – i.e., they are considered fully supporting for AqR. The first step considers how much lake clarity would be lost with an increase of 100 lbs of phosphorus to the lake. This is also known as the lake's phosphorus sensitivity.

The second step considers the significance of this sensitivity – i.e., the likelihood that this increase in phosphorus would occur. Factors considered include the percentage of disturbed land use (cultivated and urban uses), the amount of surface area of the lake, the current phosphorus concentration and loading to the lake, and the proximity of the lake to the impairment threshold. Any information on declining trends in water quality are also considered.

The third step for lakes results in a prioritized list of lakes, each with a load reduction goal. The goal is calculated as a 5% reduction in predicted phosphorus loading (pounds/year) for any given lake. The goal is not regulatory; it is intended to give local groups a value to aim for, in lieu of just maintaining current phosphorus levels. This provides a way to measure progress over time for a given lake; estimated load reductions in phosphorus can be tracked as new practices are implemented.

Once all the nonimpaired lakes in the watershed have been ranked and prioritized, they are grouped into priority categories: high priority (A), medium priority (B), and lower priority (C). One lake in the Redwood River Watershed was identified as Priority A (West Twin), one lake was identified as Priority B Sanderson), and six lakes were identified as Priority C (Table 12; Figure 10). Many of the Priority C lakes do not have enough water quality data to fully assess impairment status and the available data suggest they may actually be considered impaired if more data were available. Additional data needs for the nonassessed lakes vary, but a minimum of eight individual data points for TP, Chl-*a*, and Secchi are required over a minimum of two years (MPCA 2022b). The results of this analysis were presented to the LWG and served as a starting point for lake protection prioritization.

Table 12. Lake protection and prioritization tool results for the Redwood River Watershed (data from assessment period 2009 – 2018).

HUC-10 Subwatershed	Lake Name	WID	Mean TP (µg/L)	Transparency Trend[1]	Percent Disturbed Land	Protection Priority Class
Upper Redwood River	West Twin	42-0074-00	42	N/A	93%	A
	Sanderson	42-0071-00	82	N/A	97%	B
Coon Creek	Slough	41-0022-00	156	N/A	53%	C
Middle Redwood River	Brawner	42-0054-00	32	N/A	65%	C
	Clear	42-0055-00	125	N/A	35%	C
Upper Redwood River	East Twin	42-0070-00	83	N/A	88%	C
Three Mile Creek	Wood	42-0078-00	161	N/A	96%	C
Lower Redwood River	Redwood	64-0058-00	379	N/A	86%	C

[1] N/A = Not enough data at this time to evaluate trends

The Redwood River Watershed stakeholder group identified several other lakes throughout the watershed that could be targeted for protection. The stakeholder group's list of protection lakes is presented in Table 13 and Figure 10 and was developed using the following considerations:

- Lakes on the Minnesota DNR list of priority shallow lakes could be considered protection lakes. There are 19 lakes in the Redwood River Watershed on the priority shallow lakes list, 5 of which are currently impaired and therefore should be considered restoration lakes.

- Lakes that have been identified as lakes of biological significance by the Minnesota DNR Ecological and Water Resources Division could be considered for protection. This designation is based on the presence of unique plant or animal communities (including aquatic plants, fish, birds, and amphibians) and are divided into three classes (outstanding, high, or moderate) based on biological significance. There are currently five lakes of biological significance in the Redwood River Watershed. Three of these lakes (Coon Creek Marsh [42-0081-00], Highpoint [42-0089-00], and Schrunk Slough [42-0102-00]) are classified as "Outstanding", and two lakes (Unnamed [51-0124-00] and Unnamed [51-124-00]) are classified as "High".
- Brawner Lake (42-0054-00) in Lyon County is an old gravel pit that was periodically drained for maintenance through a nearby control structure. In 2015, a leak was discovered within the metal conduit pipe of the lake's outlet control structure. The leak slowed and eventually stopped allowing the lake level to stabilize, and the lake was added to the priority funding list by the DNR Dam Safety Unit. However, in 2017, the lake was completely drained when the metal conduit collapsed which caused the lake's outlet control structure to fail (Figure 12). A $350,000 appropriation within the State Bonding Bill was passed in 2017 for rehabilitation of Brawner Lake that includes efforts to restore permanent water levels. This project is nearing completion by the DNR and is scheduled for completion in the spring of 2023. Water quality data from Brawner Lake that was collected prior to the lake being drained in 2017 indicates the potential for good recreational water quality, and therefore the rehabilitation project is a priority to protect and support public use of this resource.

Figure 12. Brawner Lake following outlet failure (6/21/2017)

- Lake Redwood was created in 1902 when A.C. Burmeister dammed the Redwood River to power his grist mill and he brought electricity to the city around 1910. The 67-acre lake on the western edge of Redwood Falls provides water for the city's hydroelectric power plant and was once very prolific and the center of recreation. After a century of sedimentation, the once 20-foot depth has decreased to less than 3 feet on average. (RCRCA 1993).

  A local/state/federal investment of over $9 million of BMPs, water quality monitoring and educational programming has occurred within the watershed since 1993 through a series of MPCA Clean Water Partnership Diagnostic Studies and Implementation grants. The 1.5 feet per year of sediment accumulation has successfully been reduced by 75% to 1.5 inches per year.

With continued restoration and protection efforts, this rate will continue to decrease as the reservoir once again achieves status as a lake.

In 2019, the state legislature appropriated $7.3 million in Capital Investment funds to RCRCA for the Lake Redwood Reclamation and Enhancement Project. This funding, when combined with a $900,000 commitment from the City of Redwood Falls, sets a sediment goal removal of 650,000 cubic yards to bring the lake to its original depth. JF Brennan, Inc. began dredging in May of 2022 with engineering support from Houston Engineering, Inc. As of October of 2022, all dredging activities have been completed in Redwood Lake.

Figure 13. Lake Redwood Dam (Houston Engineering Inc. 2018).

Table 13. Lakes identified as priorities for protection by the Redwood River Watershed stakeholders.

HUC-10 Subwatershed	Lake Name	Lake ID
Upper Redwood River	West Twin	42-0074-00
Upper Redwood River	East Twin	42-0070-00
Upper Redwood River	Sanderson	42-0071-00
Coon Creek	Slough	41-0022-00
Middle Redwood River	Brawner	42-0054-00
Middle Redwood River	Highpoint	42-0089-00
Lower Redwood River	Redwood	07-0200-06

Protection strategies for the lakes identified as priorities are included in Table 18 through Table 24.

Wildlife Management Areas

Currently, there are 40 WMAs that have a portion of, or are entirely within, the Redwood River Watershed (Figure 10). The WMAs in the Redwood River Watershed individually range in size from less than 20 acres to just over 1,000 acres, and collectively cover more than 8,000 acres of the watershed. Nearly all WMAs in the Redwood River Watershed are comprised of restored wetlands, prairie/grassland complexes, or a combination of these resources.

WMAs are part of Minnesota's outdoor recreation system and are established to protect those lands and waters that have a high potential for wildlife production, public hunting, trapping, fishing, and other recreational uses. Thousands of hunters use these public wildlife lands throughout the state each year. They are the backbone to DNR's wildlife management efforts in Minnesota and are key to:

- protecting wildlife habitat for future generations,
- providing citizens with opportunities for hunting, fishing, and wildlife watching and
- promoting important wildlife-based tourism in the state.

Minnesota's Legislature and sportsmen have funded WMA land acquisition in a multitude of different ways. The mainstay of funding has been the surcharge on the small game hunting license. Hunting license fees, bonding funds, Reinvest in Minnesota (RIM) funds, including Critical Habitat License Plate dollars, and Environmental and Natural Resources Trust Fund (ENRTF) funds have also been used to buy WMAs. Conservation groups also donate land and money to support the acquisition of WMA lands. Another major source of WMA acquisition funding available to DNR and private conservation partners is the Outdoor Heritage Fund. The Outdoor Heritage Fund is one of several created by the Clean Water, Land and Legacy Amendment to the State constitution in 2008. Under this amendment, one-third of the funds generated by the sales tax authorized is dedicated to the Clean Water Fund (CWF), a secure funding mechanism with the explicit purpose of supporting water quality improvement projects.

Continued management efforts on existing WMA lands and acquisition of new parcels will be critical to maintaining quality wildlife habitat and water quality in Minnesota. According to a 2002 Citizen's Advisory Committee Report on the direction the WMA system should take, acquisition efforts should be accelerated with a long-term 50-year goal of acquiring 702,200 acres of new WMA lands.

Wetland Protection

Drainage of wetlands over the past century and a half has resulted in extensive portions of the Redwood River Watershed being developed into one of the most productive agricultural regions of Minnesota. Estimates of historic wetland extent were derived by MPCA using drainage class assignments from the soil survey (MPCA 2020a). This analysis suggests all seven of the Redwood HUC-10 subwatersheds have experienced significant wetland loss, of at least 70% conversion, mostly due to drainage. The least amount of wetland conversion has occurred in the westernmost HUC-10 subwatersheds – Coon Creek and the Upper Redwood River. These subwatersheds have higher slopes and rockier glacial till making them somewhat less conducive to high productivity row cropping practices. Subwatersheds further downstream along the Redwood River corridor are more conducive to row cropping practices and have experienced wetland conversion rates of over 85% compared with the original wetland extent.

Of the wetlands that do remain in the watershed, it is estimated that 82% are in fair to poor condition, and 11% are in good condition, using vegetation indicators (estimates based on statewide probabilistic surveys for the temperate prairie ecoregions; MPCA 2020a). Wetlands are affected by many pollutants and related stressors, and it is often very difficult and costly to rehabilitate wetlands that are in a degraded condition. Thus, it will be more cost effective in the Redwood River Watershed to focus on identifying and protecting the few remaining high-quality wetlands. Management practices to limit additional wetland hydrologic alterations 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. The enrollment of functioning wetlands in priority areas in available programs such as CRP to restore or enhance the wetlands and permanently or temporarily protect them through conservation easements could also help preserve wetland functions that benefit water quality in the watershed.

One wetland type that should be considered for protection in the Redwood River Watershed is seasonally flooded wetlands. Seasonally flooded wetlands are frequently farmed and are commonly only inundated with surface water for short periods of time following snowmelt in the spring and precipitation events during the growing season, yet they can provide important wetland functions such as flood storage. The protection or management of these wetlands, even if only temporarily or seasonally during critical periods while still allowing for cropping under most conditions, could allow for the benefits of the functions of these wetlands. Management of drainage systems in these types of wetlands to allow for temporary flood storage during early season flooding events prior to cropping could provide a seasonal benefit to the watershed. These wetlands also provide important habitat for migratory waterfowl and other wildlife early in the season, and the management of these wetlands would benefit these wildlife species as well. It is estimated 11.3% of the current wetland area in the watershed (~3,200 acres) is comprised of wetlands with temporary hydrology, which are routinely farmed in dry years. Approximately 95% of these farmed wetlands are less than 8.9 acres in size and the average and median sizes are 2 acres and 1 acre, respectively (MPCA 2020a). Genet and Olsen (2008) reported that seasonally flooded wetlands < 1 hectares (~2.5 acres) were the most frequently converted wetland size in the Redwood River Watershed from 1980 to 2003.

Calcareous fens are another wetland type that should be targeted for protection in the Redwood River Watershed. Calcareous fens are one of the rarest wetland communities in Minnesota and are characterized by 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 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 impacts to water quality (MPCA 2020a).

Four calcareous fens occur in the Redwood River Watershed, all of them in Lyon County (Figure 8). Two of the calcareous fens (Island Lake 23-a and Island Lake 23-b) are located in the Three Mile Creek HUC-10 Subwatershed and two of them known as Shelburne 22 (two units) are in the Upper Redwood River HUC-10 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). Protection strategies for wetlands are identified in Table 17 through Table 24.

Groundwater and Drinking Water Protection

The main supply of drinking water to the residents and businesses in the Redwood River Watershed is groundwater – either from private wells, community wells, or rural water supplier. It is important to protect and keep water on the land as much as possible throughout the watershed, particularly certain areas that are sensitive to groundwater pollution. The Environmental Health Division of the Minnesota Department of Health administers numerous programs of interest to local water management planning including drinking water protection and wellhead protection among others.

In the Redwood River Watershed, there are several communities that have potential vulnerable drinking water systems. The community of Marshall has a vulnerable drinking water system that indicates a connection and influence from surface water in the watershed. Lincoln Pipestone Rural Water and Redwood Falls vulnerable wellfields are on the edge of the watershed. Contaminants on the surface can move into the drinking water aquifers more quickly in these areas. There is also the potential for contamination through unused and abandoned wells. In contrast, the community of Ruthton has low vulnerability to contamination which means the deep aquifers the community draws it water from are fairly-well protected. Ensuring abundant and high-quality supplies of groundwater is critical, especially considering altered hydrology and the impacts on groundwater recharge.

The following table illustrates the number and size of Wellhead Protection Areas (WHPAs) and Drinking Waters Supply Management Areas (DWSMAs) within the Redwood River HUC-10 subwatersheds. The table also includes the areas within each subwatershed that are vulnerable to groundwater contamination.

Table 14. Summary of groundwater and drinking water features in the Redwood River Watershed.

HUC-10 Subwatershed	WHPAs / DWSMAs	WHPA (acres)	DWSMA (acres)	Vulnerable Groundwater Areas (acres)
Upper Redwood River	Lincoln Pipestone Rural Water–Holland, Ruthton	1,525	442	2,669
Coon Creek	Lincoln Pipestone Rural Water–Verdi	108	2	1,588
Middle Redwood River	Marshall	1,380	418	6,369
Three Mile Creek	Marshall	45	--	2,917
Clear Creek	Marshall Dudley	484	106	3,090
Ramsey Creek	--	--	--	5,093
Lower Redwood River	Redwood Falls	106	--	11,916

Figure 9 below depicts the geographic location and extent of the WHPAs, DWSMAs, and vulnerable groundwater areas. Vulnerability of groundwater and near-surface materials throughout the state was determined by estimating the transmission time of water through 3 feet of soil and 7 feet of surficial geology, to a depth of 10 feet from the land surface. Areas with very low transmission times are more sensitive to pollution whereas areas with high transmission times are less sensitive to pollution. Similarly, the statewide vulnerable groundwater area Geographic Information Systems (GIS) layer was developed by the Minnesota Department of Agriculture (MDA) by overlaying DNR and U.S. Department of Agriculture (USDA) Natural Resources Conservations Services (NRCS) soil maps to identify areas with coarse textured soils, shallow bedrock, and karst geology. There are no karst features in the Redwood River Watershed, however, there are several areas with coarse textured soils and/or shallow bedrock.

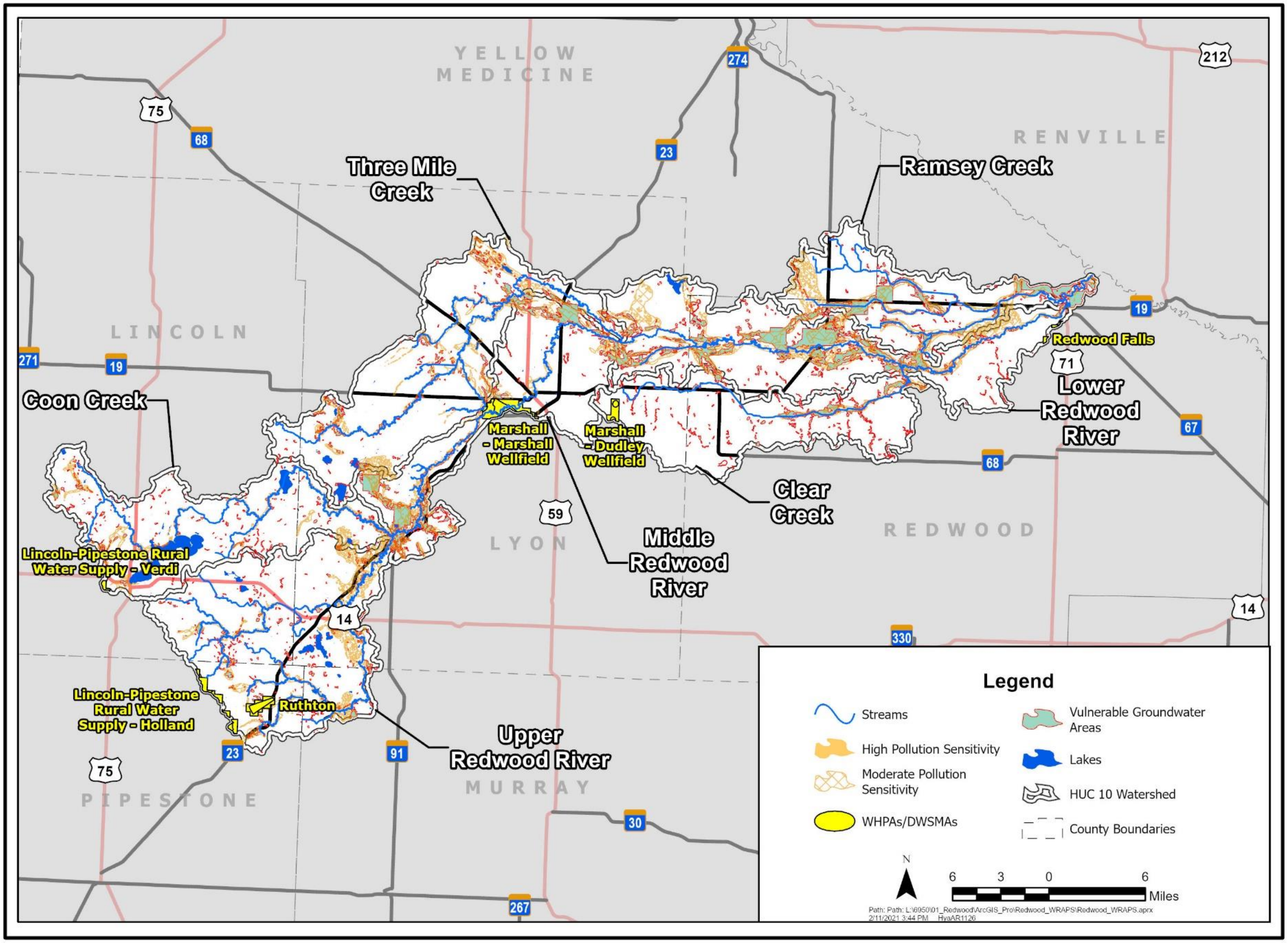
Protection strategies that should be considered for vulnerable groundwater areas include:

- Focus nitrogen BMPs in or near vulnerable DWSMAs due to the mutual benefits of protecting drinking water supplies as well as surface water resources

- Further identify vulnerable features by expanding the existing inventory
- Increase water quality monitoring or target existing local monitoring in vulnerable and sensitive groundwater areas
- Plant vegetative buffers, increase living cover, and improve soil health through cover crops and reduced tillage
- Promote SSTS compliance through education, maintenance, and inspection
- Education and outreach to farmers and feedlot operators regarding nutrient management in vulnerable areas
- Alternative type drainage intakes
- Well sealing (abandoned, contaminated, insufficient water, etc.)

The MDA has developed the Groundwater Protection rule (Minn. R. 1573.001) to minimize potential sources of nitrate pollution to the state's groundwater and protect drinking water. "The rule restricts fall application of nitrogen fertilizer in areas vulnerable to contamination, and it outlines steps to reduce the severity of the problem in areas where nitrate in public water supply wells is already elevated" (MDA 2020). More information can be found on the MDA website. For land application of manure, restrictions of fall application in areas vulnerable to contamination apply to feedlots with NPDES permits (large operations with greater than or equal to 1,000 AUs).

Figure 14. Groundwater protection areas in the Redwood River Watershed (WHPAs, DWSMAs, vulnerable and sensitive groundwater areas).



3. Strategies for Restoration and Protection

The Clean Water Legacy Act (CWLA) (ROS 2020) requires that WRAPS reports contain strategies that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources, including water quality goals, strategies, and targets by parameter of concern, and an example of the scales and timeline of adoption to meet water quality protection and restoration goals.

This section of the WRAPS report provides the results of such prioritization and strategy development. Because many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the watershed, it is imperative to create social capital (trust, networks, and positive relationships) with those who will be needed to voluntarily implement BMPs. Thus, effective ongoing public participation and civic engagement is critical for making progress toward clean water.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts and professional judgment based on what is known at this time and should be considered approximate. The strategies are not prescriptive, but instead represent one path to achieving pollutant reductions needed to meet the watershed goals and targets. Furthermore, many strategies are predicated on securing funding. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation, and course correction.

3.1 Targeting of Geographic Areas

The following section describes the information and tools gathered throughout the Redwood River WRAPS project to develop restoration and protection strategies for the lakes and streams throughout the watershed. Follow-up field reconnaissance will be the next part of the process to validate the identified areas potentially needing work.

It is understood that management needs for the Redwood River Watershed exceed available resources, and therefore prioritization and focus is necessary to achieve goals in high priority areas. The following subsections highlight previous plans, reports, studies, methods, and tools that can be used to help prioritize issues of concern and geographic areas in the watershed for restoration and protection. Later in the report, tables of management strategies were drafted to include those management approaches deemed most important. While this information provides substantial direction, it is expected that local water management authorities will further define the highest priority projects and geographic areas based on scientific, social, political, and financial considerations.

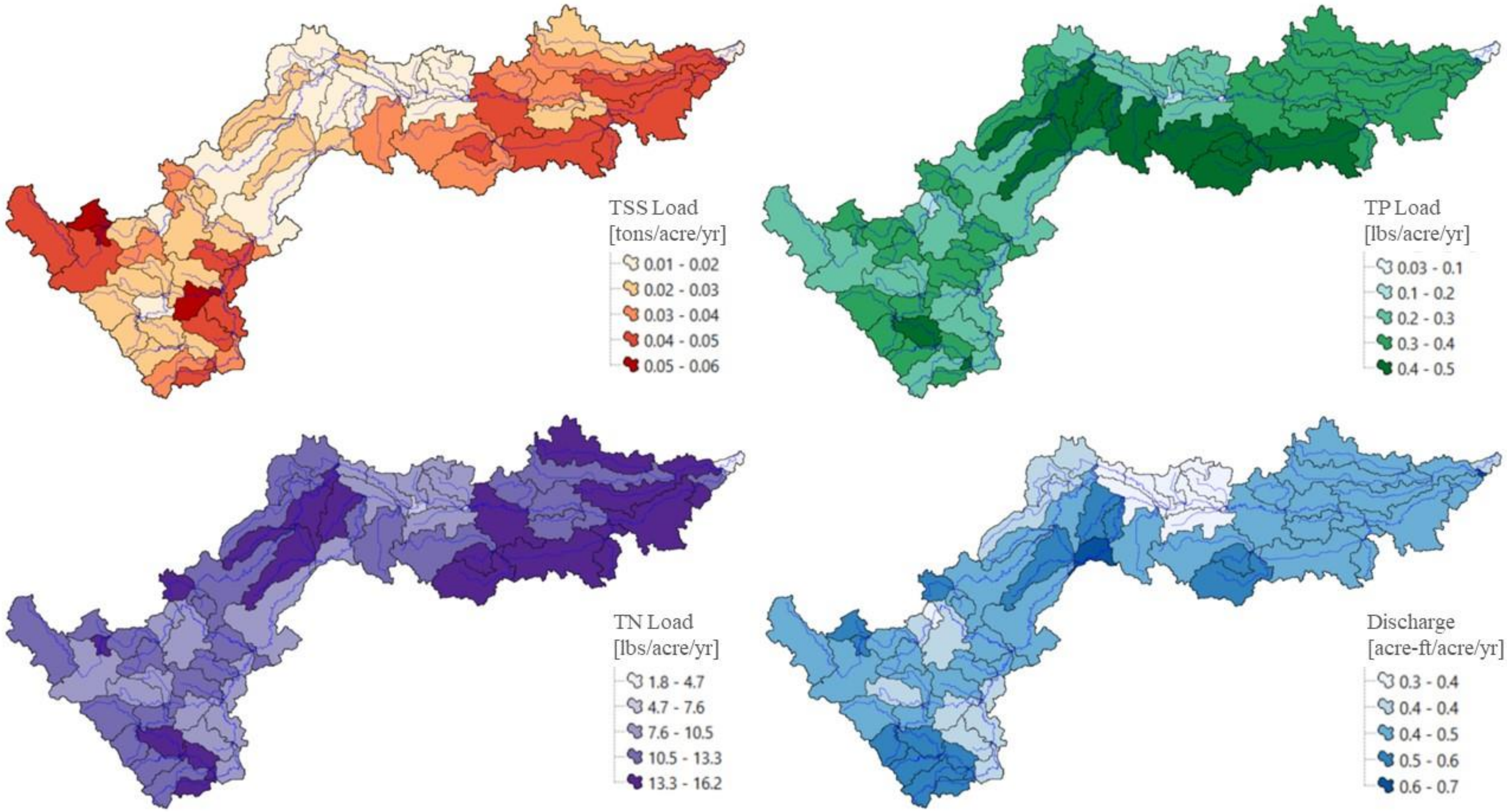
Hydrologic Simulation Program-FORTRAN

HSPF is a large-basin, watershed computer model that simulates nonpoint source runoff and water quality in urban and rural landscapes. The Redwood River Watershed HSPF model incorporates real-world meteorological data and is calibrated to real-world stream flow and water quality data. HSPF model development includes the addition of point source data in the watershed, including both domestic and industrial WWTFs.

HSPF was used to predict the relative magnitude of runoff, TSS, TP, and TN pollution generated in each subwatershed of the Redwood River Watershed. The HSPF model was also used to evaluate the extent of contributions from point, nonpoint, and atmospheric sources where necessary. Development of the HSPF model helps to better understand existing water quality conditions and predict how water quality might change under different land management practices and/or climatic changes at the subwatershed scale. HSPF also provides a means to evaluate the impacts of alternative management strategies to reduce these loads and improve water quality conditions.

Runoff, TSS, TP, and TN yields predicted from the HSPF model in the Redwood River Watershed are mapped in Figure 15. Darker shaded areas on the maps indicate areas of the watershed with higher yields (unit/area/year) for water and pollutants. The yield maps are generally consistent with each other. For example, subwatersheds with high yields for TSS are typically also areas with high yields for TP. This suggests implementing BMPs in these areas could have the potential for multiple benefits to water quality. Implementation focus on areas with higher yields, especially when there is overlap with waters of local importance, is a potential way to prioritize restoration efforts in the watershed.

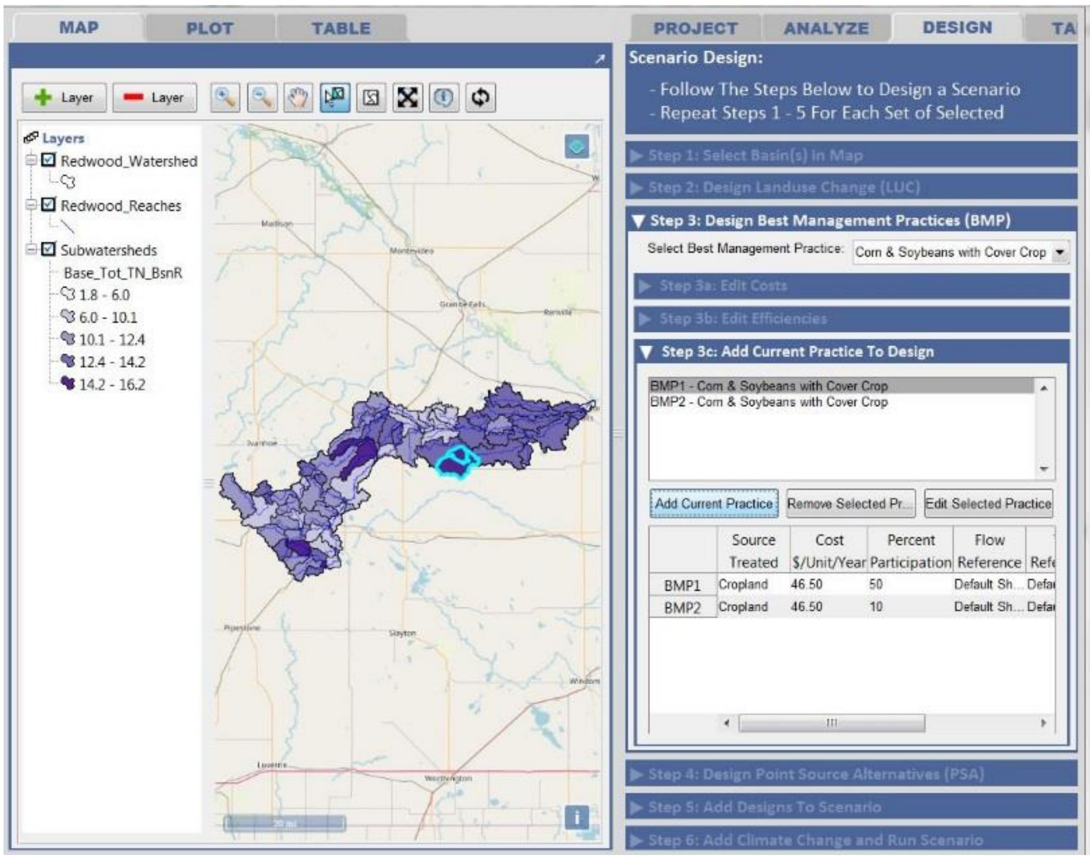
Figure 15. HSPF-predicted unit area loading rates for TSS (upper left), TP (upper right), TN (lower left), and discharge (lower right) for each HSPF reach subwatershed in the Redwood River Watershed (1997 – 2017).



HSPF-SAM

The SAM is a graphical interface to the HSPF model application (Figure 16). The SAM decision-support tool provides a user-friendly, comprehensive approach to analyze HSPF results graphically and spatially, design and simulate alternative scenarios with HSPF. It also allows the user to develop cost optimized scenarios based on user-defined water quality targets. HSPF-SAM simplifies the complexities of the HSPF model into transparent estimates of the significant pollutant sources while allowing users to apply their local knowledge and expertise of watershed planning and implementation.

Figure 16. HSPF-SAM tool interface for the Redwood River Watershed.



Some of the main features of HSPF-SAM include:

- Ability to access model results and assess watershed conditions,
- GIS components that interface with the HSPF model to simulate the transport and fate of pollutants,
- Contains a BMP database with adjustable efficiencies and costs,
- Ability to generate multiple implementation scenarios to test the impact of various BMPs in various subwatersheds and
- Ability to create and compare different BMP cost/benefit scenarios.

The Redwood River Watershed HSPF-SAM tool is available for download through the MPCA/RESPEC File Share Website.

Redwood River Watershed Hydrologic Conditioning and Terrain Analysis

The Redwood River Watershed was one of three watersheds analyzed in the Southwest Prairie Technical Service Area (SW TSA) Digital Elevation Model (DEM) Conditioning and Terrain Analysis project along with the West Fork Des Moines and Cottonwood River watersheds (HEI 2015). The goal of the project was to identify strategic locations in these watersheds for BMPs that were effective at reducing sediment loads to downstream water resources. This was achieved through a process referred to as terrain analysis which uses GIS and high-resolution topographic data collected using Light Detection and Ranging (LiDAR) technology combined with soil and land use information to identify critical areas across the watershed where erosion and sediment loss caused by surface water runoff may be the greatest. This hydrologic conditioning and terrain analysis, which was completed by Houston Engineering in 2015, developed the following products that would be useful for the next stage of watershed planning and implementation (e.g., 1W1P):

- A hydrologically conditioned DEM for the entire Redwood River Watershed that accurately depicts the flow of water across the landscape and can be used in BMP targeting tools such as the Prioritize, Target, and Measure Application (PTMApp) and the Agricultural Conservation Planning Framework (ACPF).
- Stream Power Index values which provide a relative indication of the erosive power of overland, concentrated, and surface water runoff across the landscape (Figure 17). This analysis can be used to locate areas with high potential for erosion and gully formation. The colors on Figure 17 indicate relative susceptibility to overland erosion with red being the highest and blue being the lowest. The western half as well as the mouth of the Redwood River Watershed are most prone to overland erosion.
- Sediment yield analysis using the Revised Universal Soil Loss Equation (RUSLE) to identify areas in the watershed with higher potential for sediment loading to surface waters (Figure 18). The colors on Figure 18 indicate relative potential for sediment loading with red being the highest and blue being the lowest. The western half of the Redwood River Watershed has a higher concentration of areas with greater potential for sediment loading.
- Compound Topographic Index (CTI) analysis to identify priority “wet areas” (i.e., flat slopes with relatively large contributing areas) for potential wetland management and restoration (Figure 19). The colors on Figure 19 indicate relative potential for wetland management and restoration with red being the highest and green being the lowest. The eastern half of the Redwood River Watershed, with its flatter topography, has greater potential for water storage through wetlands.

The final report and associated GIS products (i.e., maps and geodatabases) for the Redwood River Watershed Hydrologic Conditioning and Terrain Analysis Project (HEI 2015) are available upon request from RCRCA.

Figure 17. Redwood River Watershed catchment scale Stream Power Index (SPI) and rankings.

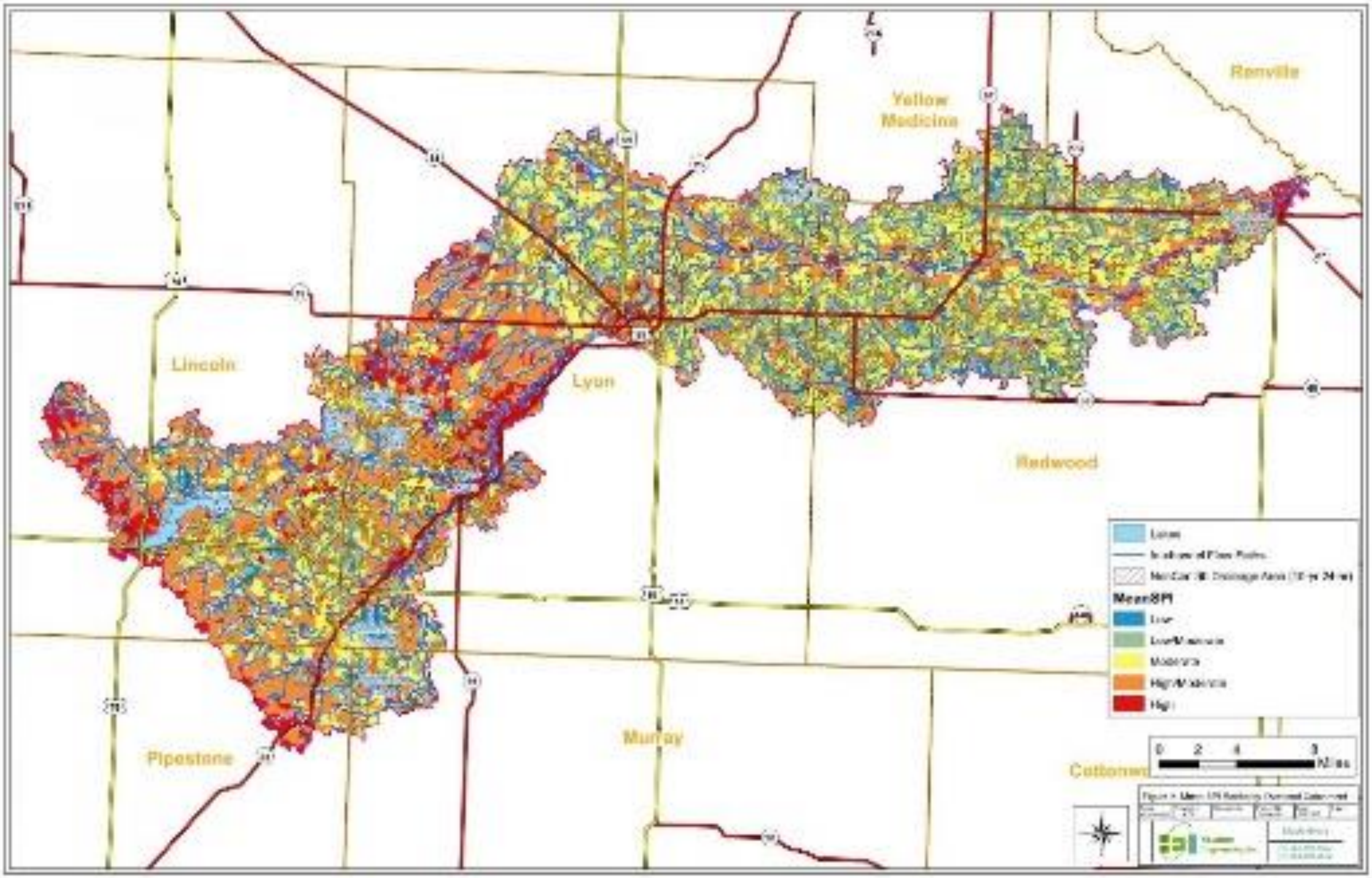


Figure 18. Redwood River Watershed catchment scale sediment yield and rankings.

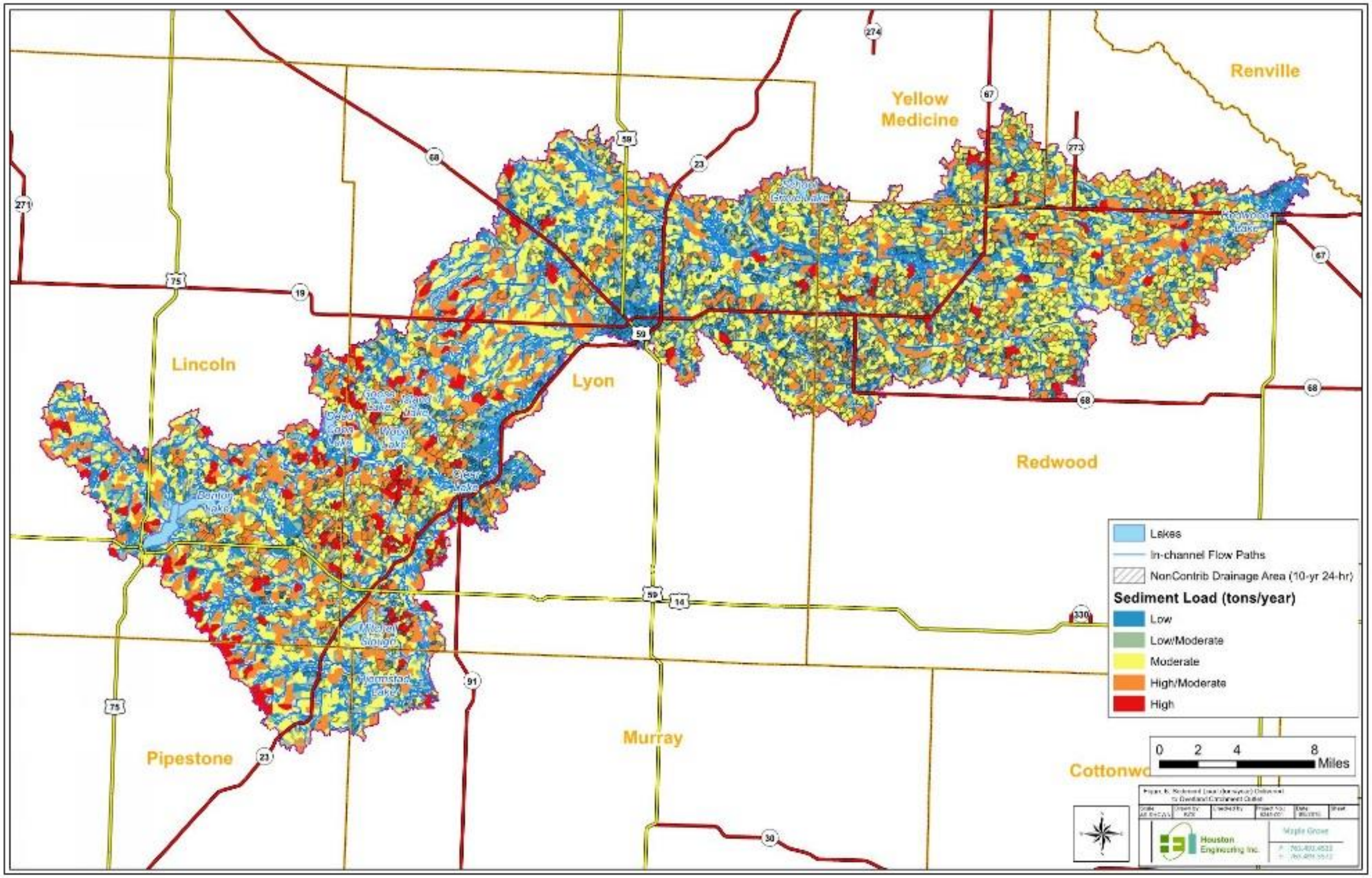
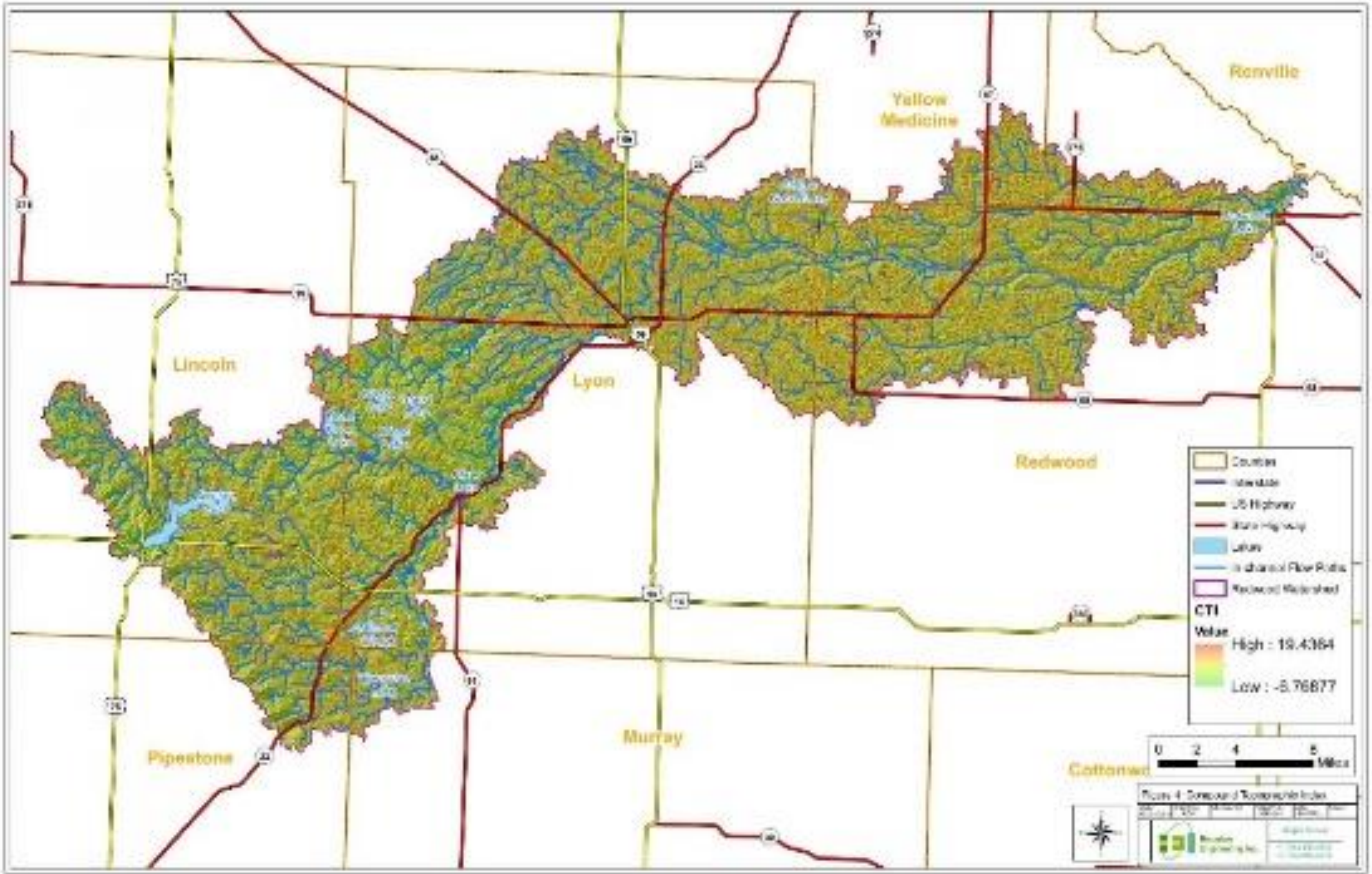


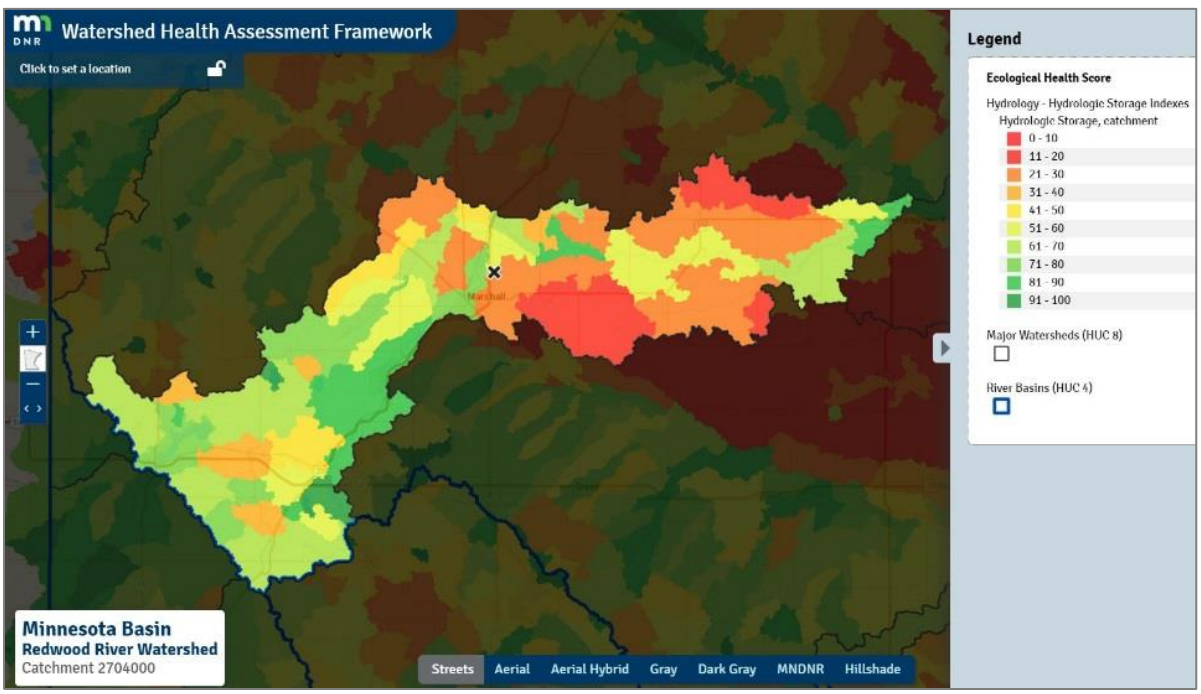
Figure 19. Redwood River Watershed catchment scale CTI.



Watershed Health Assessment Framework (WHAF)

The DNR developed the [Watershed Health Assessment Framework (WHAF)](), which provides a comprehensive overview of the ecological health of Minnesota's watersheds. The WHAF is based on a "whole-system" approach that explores how all parts of the system work together to provide a healthy watershed. The WHAF divides the watershed's ecological processes into five components: biology, connectivity, geomorphology, hydrology, and water quality. A suite of watershed health index scores on a scale of 1 to 100 have been calculated that represent many of the ecological relationships within and between the 5 components. For example, Figure 20 shows how areas within the Redwood River Watershed score for hydrologic storage features. Areas scoring low (red; 0 to 10) have very few storage features remaining while areas scoring high (green; 91 to 100) have many remaining storage features. Local resource professionals can use this information to prioritize restoration of protection activities to achieve water quality goals. Scores for each of the components can also be averaged for an overall watershed health score. The scores for each of Minnesota's 80 major watersheds have been built into a statewide GIS database that provides a baseline health condition report for each of the 80 major watersheds in the state. The Redwood River Watershed has a watershed health score of 44 (1 to 100), which is typical of most of the other watersheds in the MRB, but lower than most watersheds in the northern part of Minnesota.

Figure 20. Hydrologic storage analysis by individual catchment for the Redwood River Watershed using the DNR's online WHAF tool.



Redwood River Watershed Characterization Report

As part of the State of Minnesota's watershed approach, the DNR produces watershed characterization reports which analyze historical and existing hydrologic data, assess geomorphic conditions within the watershed, and assess stream connectivity. The Redwood River Watershed Characterization Report (DNR 2020) provides insight on hydrology, geomorphology, and connectivity in the watershed as well as management practices that will help restore watershed health. The report utilized both desktop and field methods for characterization and assessment of the river and its tributaries and drainage area.

In order to continue to restore and protect the Redwood River Watershed, the DNR outlines a tiered approach that: 1) preserves native fish and invertbrate communities; 2) restores, enhances, and creates larger habitat networks; and 3) incorporates BMPs into the agricultural landscape. Restoration efforts in the watershed should be system-wide and focus on the source of degradation (e.g., altered hydrology, land use) as opposed to the effects (e.g., streambank erosion). When planning restoration and protection practices in the Redwood River Watershed, it is important to consider all five components (biology, connectivity, geomorphology, hydrology, and water quality) of a healthy watershed, and therefore practices that promote multiple benefits across the five componenets should be prioritized. The DNR identifies various strategies throughout the watershed that will help store water and reduce flood events that are accelerating river/stream instability throughout the watershed. Some of the identified strategies include:

- Establish, maintain, and/or protect deep rooted native perennial vegetation in the riparian corridor,
- Increase water storage by restoring wetlands, reconnecting floodplains (e.g., constructed two-stage ditches and/or limiting ditch maintenance when possible to allow floodplain benches to form), improving soil health, protecting existing water features, and installing other multi-purpose drainage management practices,
- Utilize natural channel design techniques to restore streams to their stable form,
- Properly size road crossings to match stream conditions and prevent fish barriers,
- Limit livestock access to streams and implement rotational grazing practices, and
- Implement BMPs to reduce excess nutrient and sediment runoff

The report also cautions against the installation of in-stream structures unless the bank is an anomaly to the system, if infrastructure is in jeopardy, or if an opportunity arises to re-meander a historically channelized stream. Funding should be prioritized to first address the cause of instability (e.g., altered hydrology, historic channelization) instead of the symptom (e.g., eroding bank, trees in the river). Prioritization of work should be based on specific goals and objectives, location in the watershed, constraints, size of project, addressing the cause of the problem, likelihood of success of the project, and the project's ability to address all (or multiple) watershed health components. The following is a list of in- and near-channel strategies that could be considered for priority locations, as they are identified, within the Redwood River Watershed:

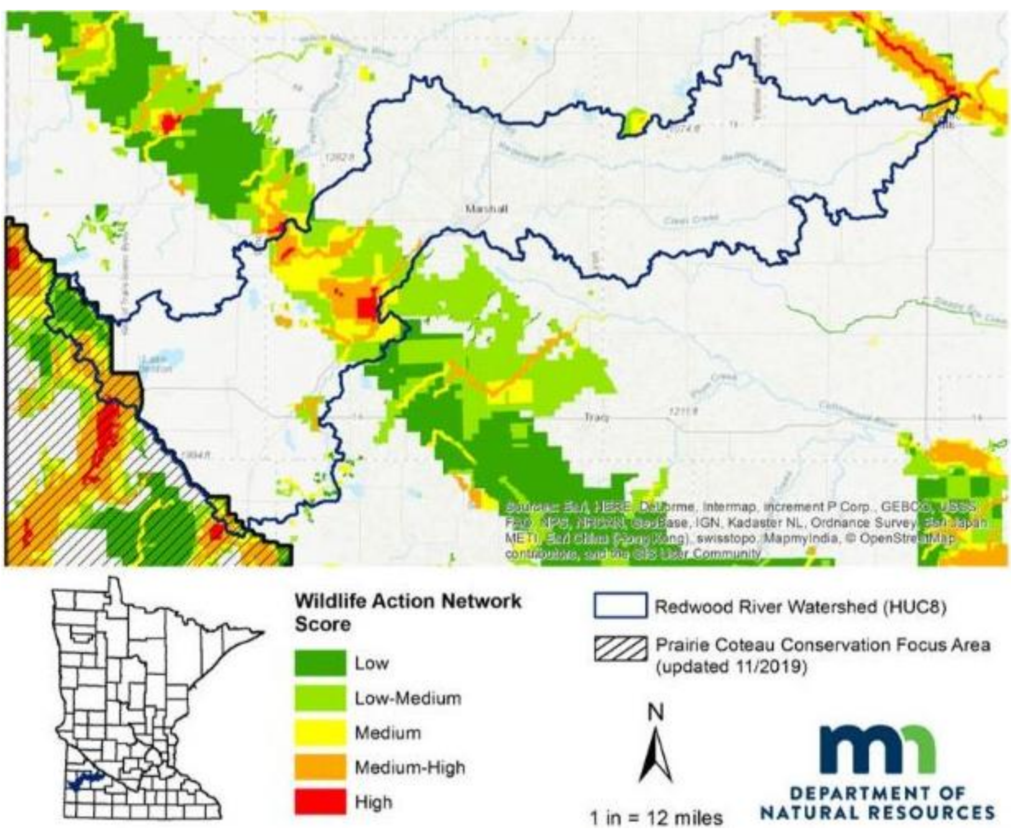
- Stabilize banks that endanger infrastructure through planting of perennial vegetation along stream channels, protecting the toe of the bank with natural materials when possible (e.g., toe-wood), and installing grade-control structures (i.e., constructed riffles and cross-vanes).
- Re-size bridges and culverts to allow flood flows on the floodplain by properly sizing the crossing for the bankfull channel and installing multiple relief culverts along the floodplain for locations with wide floodplains.

- Reconnect areas with longitudinal barries to fish passage by removing retrofit dams and replacing perched culverts.
- Analyze the necessity and amount of sediment removal in private and public ditch cleanout projects as this forces the aquatic environment to reset when done.

Minnesota State Wildlife Action Plan

Minnesota's Wildlife Action Plan (2015-2025) focuses on conservation and protection for rare, declining, or vulnerable nongame wildlife species. This includes certain birds, mammals, reptiles, amphibians, fish, and mussels and other invertebrates. The plan focuses on prioritizing efforts within connected habitat networks to assist species movement and adaption as a result of climate change. It also provides a framework to advocate for the preservation of biological diversity through the acquisition, preservation, and management of important wildlife habitats. The Wildlife Action Network (WAN) within the plan is comprised of terrestrial and aquatic habitat cores and corridors to support biological diversity and ecosystem resilience with a focus on Species of Greatest Conservation Need (SGCN). The mapped WAN illustrates high, medium-high, medium, low-medium, and low scores based on SGCN population viability, SGCN richness, spatially prioritized Sites of Biodiversity Significance, Lakes of Biological Significance, and Stream Indices of Biological Integrity. Focusing conservation efforts within the mapped WAN, especially the high to medium priority zones (i.e., red, yellow, and orange polygons; Figure 21), will result in projects and practices with multiple environmental benefits (i.e., protecting and restoring perennial vegetation for habitat enhancement and for clean water). Additional information on the Minnesota Wildlife Action Plan can be found on the following webpage: https://www.dnr.state.mn.us/mnwap/index.html.

Figure 21. Minnesota State Wildlife Action Plan priority areas for the Redwood River Watershed.



Minnesota Prairie Conservation Plan

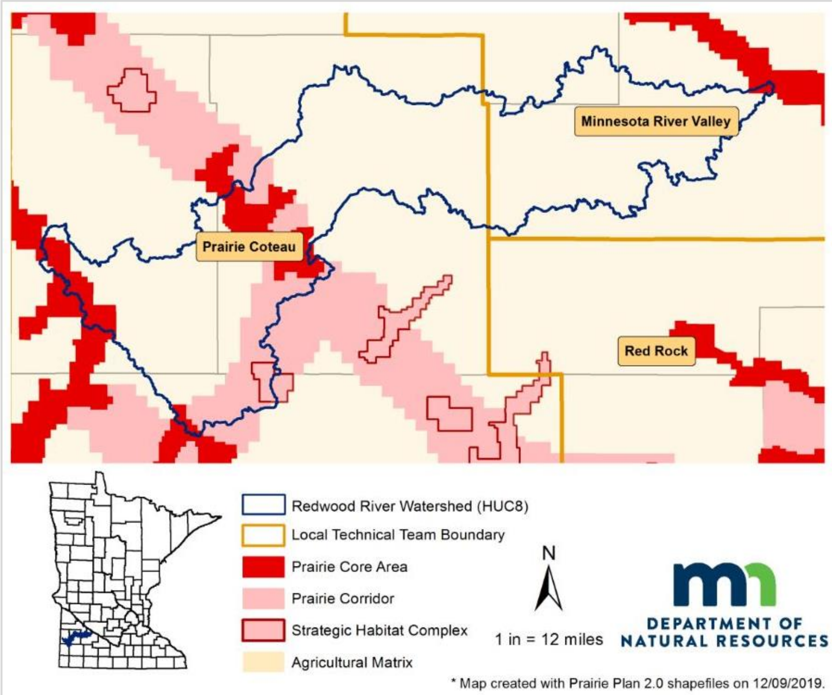
Native prairie, other grasslands, and wetlands provide habitat for many species and are key components of functional landscapes. Prairie habitats once covered one third of Minnesota but presently less than 1% remain (Nature Conservancy 2018). The Minnesota Prairie Conservation Plan developed by state and federal agencies as well as state and federal environmental organizations, is a habitat plan for native prairie grassland, and wetlands in the Prairie Region of western Minnesota with the goal to protect, restore, and enhance remaining native prairie, other grassland, and wetland habitat. In strategic locations, the Prairie Plan has identified key prairie core areas (i.e., high concentration of native prairie), corridors, and habitat complexes to create a connected landscape for wildlife and provide opportunities for sustainable grass-based agriculture such as grazing and haying.

There are six main aspects of the work:

- Implementation by multi-disciplinary Local Technical Teams in prairie focus areas,
- Secure permanent protection of high-quality prairie landscapes, including native prairies, wetlands, and other habitats,
- Retain restored and natural grassland in these landscapes,
- Enhance the quality and function of prairie habitat using prescribed fire, conservation grazing, haying, invasive species control, and woody plant removal,
- Secure the resources needed to monitor progress, assess results, and implement adaptive strategies that increase success and efficiency, and
- Integrate the efforts of the Prairie Plan Local Technical Teams to increase success and efficiency.

The Redwood River Watershed includes three local technical teams (Figure 22): Prairie Coteau, Red Rock, and Minnesota River Valley. These established and active Prairie Plan Local Technical Teams are available to assist and provide support to the Redwood River Watershed and its landowners to achieve wildlife value and water quality goals through targeted placement of perennial vegetation or other agricultural BMPs. This could serve as an important resource as the Redwood River Watershed moves into the watershed planning and implementation phase. Contact the DNR for more information.

Figure 22. Prairie Conservation Plan areas in the Redwood River Watershed.



Redwood River Subwatershed Analysis

During the early stages of the development of this WRAPS, the Redwood River Watershed LWG expressed an interest in creating individual subwatershed summaries that conveyed information about the watershed at smaller, more defined scales than is typically done in WRAPS reports. An example summary is included in Appendix D and all of the summaries can be found on the RCRCA's Redwood River Webpage. The primary goal of the subwatershed summaries is to provide a tool to educate and inform local resource managers of relevant features and characteristics of each subwatershed in the Redwood River Watershed. As discussed throughout this section, there are several studies, assessments, tools, and models that have been completed for the Redwood River Watershed. This information was compiled during this WRAPS project and used to inform each individual subwatershed summary. This process, referred to as the Redwood River Subwatershed Analysis, is summarized below.

- **Scale**. It was decided by the LWG that the Redwood River Subwatershed Analysis would be presented at the HUC-12 subwatershed scale. There are 24 individual HUC-12 subwatersheds in the Redwood River Watershed that range in size from approximately 11,000 acres to 36,000 acres. The LWG determined the HUC-12 scale was an ideal scale to help facilitate future watershed planning discussions and develop targeted and measurable outcomes.
- **Data and Information**. A summary of the assessment data, GIS layers, and modeling tools that were compiled for the Redwood River Subwatershed Analysis are presented in Appendix D. Most of the data and information that was compiled for the subwatershed analysis was created by various agencies and therefore available through online sources. The compiled data were aggregated by HUC-12 subwatershed and organized in tabular format (Excel spreadsheet) as well as an online interactive GIS mapping tool.

- **Subwatershed Summaries.** Two-page summaries were created for each of the 24 HUC-12 subwatersheds in the Redwood River Watershed (Appendix D). The first page of each summary is a general map of the subwatershed that shows county boundaries, city boundaries, impaired and unimpaired water bodies, elevation change across the subwatershed, and general location of the HUC-12 subwatershed in the greater Redwood River Watershed. The second page includes text, figures, and graphics depicting the general subwatershed characteristics, pollutant sources, TMDL reductions, and a list of general restoration and protection strategies for the subwatershed. These summaries provide a general overview and description of the subwatershed, the primary issues of concern, and strategies needed for improvement.

The two-page summaries are intended to be concise, readable, and easy to interpret for a wide range of audiences. The primary goal for these summaries was to provide a starting point for future subwatershed planning and implementation efforts. If desired, the summaries may be appended to include more specific subwatershed goals and implementation plans as developed during the One Watershed, One Plan (1W1P) process and/or other local water plans.

3.2 Civic engagement

Redwood-Cottonwood Rivers Control Area

The RCRCA was formed in 1983 as a joint powers organization comprised of eight counties and eight SWCDs. The JPO was created to prevent the development of a watershed district, as the individual counties desired more local input and control into the watershed's activities. RCRCA has been very successful at securing grant funding to analyze and assess both the Redwood River and Cottonwood River watersheds and secure implementation funding for the construction of BMPs. One of the organization's goals was to see the dredging of Lake Redwood to restore it to its original depth and vitality as a lake. RCRCA, in cooperation with partner groups and landowners, works to improve water quality, reduce erosion, and enhance recreational opportunities by providing education, outreach, monitoring and technical assistance within the watershed boundaries. The RCRCA was highly engaged in each step of this Redwood River WRAPS project, including monitoring, document review, and hosting meetings.

Accomplishments and Future Plans

The MPCA partnered with eight local governmental units in the Redwood River Watershed (Lincoln County and SWCD, Lyon County and SWCD, Murray County and SWCD, and Redwood County and SWCD) to directly advance civic engagement throughout the watershed for much of the duration of this project. Through the partnership, the MPCA provided grant funds for the local partners to engage directly with watershed residents and landowners on a variety of water quality topics. These projects were successful in helping local watershed partners connect with watershed residents to build relationships that will be integral in implementing the strategies described in this report. Three meetings were held across the Redwood River Watershed to discuss impairments and possible strategies to address them. In addition to these meetings, an introductory meeting was held for elected officials to describe the watershed approach with the goal of having the elected officials to have a better understanding of the work that will be done. The work begun under these projects will continue as implementation continues throughout the Redwood River Watershed. Section 3.3 provides a description as to what has been done in the watershed.

Public Notice for Comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* from February 21, 2023 through March 23, 2023. There were XXX comments received and responded to as a result of the notice.

3.3 Restoration and Protection Strategies

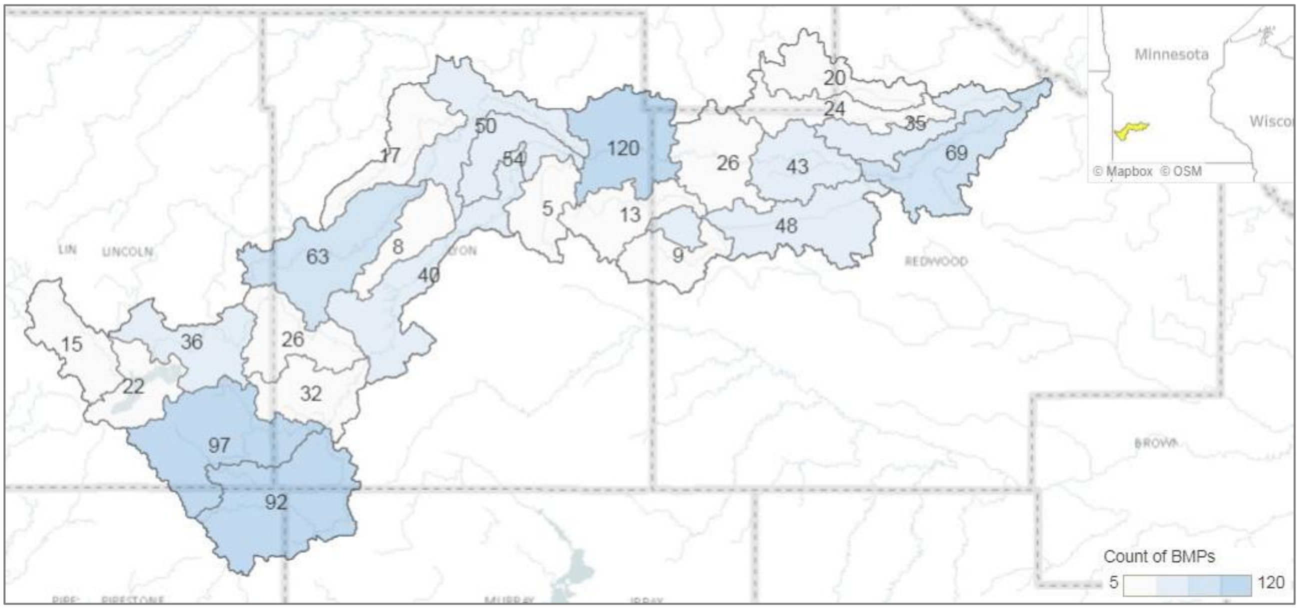
Work Done to Date

To date, some agricultural and urban runoff in the Redwood River Watershed has been reduced through the implementation of conservation practices and stormwater BMPs. As discussed in Section 2.2, the Redwood River has seen long-term reductions in sediment, ammonia, and biochemical oxygen demand over the last 50 years (Table 3). The MPCA Healthier Watersheds Accountability Report shows that over 1,000 BMPs were installed and reported through federal, state, and locally funded programs and grants in the Redwood River Watershed between 2004 and 2021. Table 15 summarizes the major types of BMPs that have been implemented throughout the watershed, while Figure 24 shows the total number of BMPs per subwatershed.

Table 15. Reported BMPs in the Redwood River Watershed by BMP type (2004-2021).

BMP Type	Total BMPs
Nutrient Management (Cropland)	252
Tillage/Residue Management	216
Designed Erosion Control	272
Buffers and Filters	106
Converting Land to Perennials	85
Stream Banks, Bluffs, and Ravines	46
Living Cover to Crops in Fall/Spring	108
Septic System Improvements	53
Pasture Management	37
Tile Inlet Improvements	37
Drainage Ditch Modifications	21
Tile Drainage Treatment/Storage	11
Habitat and Stream Connectivity	9
Crop Rotation	6

Figure 23. Number of reported BMPs in the Redwood River Watershed (2004-2018).



Further, two MDA led initiatives - [The Nutrient Management Initiative Program](#) (NMI) and [The Agricultural Water Quality Certification Program](#) (MAWQCP) – have engaged farmers and increased agricultural BMP adoption in the Redwood River Watershed. The NMI Program has provided financial incentives for participants to conduct on-farm trials for fertilizer rate management. A total of 31 nutrient trials took place in the Redwood and Cottonwood Watersheds between 2006 and 2019. MAWQCP is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect water quality. Those who implement and maintain sufficient approved farm management practices are certified and in turn obtain regulatory certainty for a period of 10 years. As of January 31, 2023, the Redwood River Watershed has 17,112 acres enrolled in the MAWQCP. BMPs implemented to-date through this program include:

- 22 alternative/closed tile intakes
- 15 sediment basins
- 26.6 acres of filter strips
- 365 acres of residue management
- 113 acres of nutrient management
- 2,400 acres nitrogen BMPs
- 913 acres phosphorus BMPs
- 147 acres cover crops
- 577 acres conservation cover

Strategies

While a significant amount of BMPs and watershed improvements have been done to-date in the Redwood River Watershed, more is needed. The following strategies were identified as key strategies to restore and protect lakes, streams, and groundwater in the Redwood River Watershed. These strategies were identified through stakeholder input during the WRAPS process as well as individual county water plans, the Redwood River Watershed Characterization Report, and other local planning efforts. We acknowledge that a combination of BMPs (also referred to as layered BMP suites, stacked BMPs, or BMP treatment trains) that include multiple key strategies discussed below will likely be necessary within each subwatershed to address the widespread surface water impairments throughout the Redwood River Watershed. The combinations of BMPs discussed throughout this WRAPS report were derived from Minnesota's Nutrient Reduction Strategy (NRS) (MPCA 2015) and related tools. As such, they were vetted by a statewide engagement process prior to being applied in the Redwood River Watershed.

Agricultural Practices

Although agricultural land often contributes higher levels of pollutants/stressors compared to undisturbed land, the impacts can be reduced by adequately managing/mitigating with sufficient BMPs. As demonstrated by sustainable agriculture (USC 2018), farming and clean water do not have to be mutually exclusive. A farm that incorporates nutrient management practices, conservation tillage, cover crops, grassed waterways, and buffers will contribute substantially less pollutants/stressors than if those BMPs were not used.

The National Resource Conservation Service (NRCS) has long adopted a systems approach to addressing agricultural nonpoint source pollution. This approach, known as Avoiding, Controlling, and Trapping (ACT), encourages producers to implement a system of practices, where appropriate, that can effectively protect specific high-priority resource concerns in selected watersheds. Below is a brief discussion of the types of practices that fit within each component of this approach.

<u>Avoiding</u>

Avoidance helps manage nutrients and sediment source control from agricultural lands, including animal production facilities. This includes any practices that help producers avoid pollution by reducing the amount of nutrients available in runoff or leaching into groundwater and surface water resources. General planning considerations to support Avoiding include:

- Applying fertilizer (chemical, manure, etc.) in accordance with MDA application guidelines
- Developing a nutrient management plan to identify nitrogen and phosphorus management actions that will reduce losses
- Crediting other sources of nitrogen and phosphorus (e.g., previous legume crops, organic matter) when calculating optimal nutrient application rates
- Properly storing fertilizer (e.g., storage building with impermeable floors)
- Composting manure to reduce the overall volume for disposal

<u>Controlling</u>

Controlling refers to land treatment in fields or facilities that prevents the loss of pollutants to groundwater and surface water. This includes practices such as conservation tillage and residue management, which improve infiltration, reduces runoff, and controls erosion. Specific practices such as No-till/Strip-till/Direct Seed (329) and Mulch Tillage (345) are foundation practices of this method. Practices such as Cover Crop (340) will also do double duty by helping with Avoidance as well as

Controlling. Terraces (600), Stripcropping (585), and Grassed Waterways (412) also help control erosion and may manage runoff to reduce nutrient loading. Other practices and planning considerations to support Controlling include implementing crop rotations to minimize use of fertilizer, and the use of precision irrigation systems to apply water uniformly and with greater efficiency to reduce water loss and pollutant transport.

There is growing awareness of the role that soil biology plays in sustaining crop productivity and supporting healthy ecosystems. "Soil livestock" - the soil bacteria, fungi, protozoa, nematodes, arthropods, earthworms, and other animals that live in or move through the soil -- are critical to soil health. They can support decomposition and nutrient cycling, control soil erosion, improve water availability, and protect crops from pests and diseases.

The basic principles of soil health include (source – BWSR):

- **Minimize soil disturbance**. Tillage, overgrazing, or misapplication of farm inputs can result in bare or compacted soil, disrupted soil habitat, increased soil temperature, and increased runoff and erosion.
- **Keep the soil covered as much as possible**. Living plants and mulch buffer the soil from weather extremes.
- **Maximize plant diversity**. Crop rotations and cover crops support diverse soil microorganisms and the soil food web.
- **Keep living roots in the soil throughout the year**. The soil/root interface, or rhizosphere, is where the most intense microbial activity takes place, feeding soil microbes and the soil food web.
- **Integrate livestock where possible**. Controlled grazing can improve soil health through hoof action, insect consumption, gleaning following harvest, and direct application of manure where feasible.

Thus, building and maintaining soil health, through controlling practices such as reduced tillage and cover crops, has the potential to improve agricultural profitability by reducing input costs and increasing productivity. At the same time, soil health helps protect water resources by increasing the water holding capacity of soil and reducing the transport of pollutants to streams and lakes.

Research, education, outreach, and decision-making tools to support soil health practices have increased throughout the region in recent years and farmers and other land managers are becoming more interested in implementing soil health practices and initiatives. There are various university groups and federal and state agencies that have soil health programs and resources available to support farmers and land managers. Some of these programs and resources include: NRCS's Soil Health Resources, the Soil Health Institute, Midwest Cover Crop Council (MCCC), Sustainable Agriculture Research & Education (SARE), Minnesota Farming Association of Minnesota Soil Health Portal, University of Minnesota Extension, the University of Minnesota Forever Green Initiative, and the Minnesota Office for Soil Health (MOSH).

Another group that is very active in soil health initiatives throughout Southwest Minnesota is the Minnesota Soil Health Coalition. This Coalition is a farmer led and driven organization dedicated to provide education, farmer to farmer mentoring, networking, and plain language technical information. Two key goals of the coalition are to provide farmer to farmer mentoring and soil health testing that compiles management, economic, and agronomic data to more quickly provide real world information to the producers of Minnesota.

Trapping

Trapping is the last line of defense to trap or treat pollutants within the field or at the edge of field prior to being delivered to downstream water bodies. Common Trapping practices and planning considerations include:

- Wetland enhancement and/or restoration
- Ponds and other structures for on-site water control
- Planting riparian buffers and filter strips
- Grade stabilization structures and water and sediment control basins
- Establishing windbreaks/shelterbelts
- Perennial vegetative buffers of 50 feet along lakes, rivers, and streams and 16.5 feet along ditches

Maintaining 50-foot wide perennial vegetative buffers along lakes, rivers and streams, and 16.5-foot wide buffers along ditches is required by Minn. Stat. § 103F.48, commonly referred to as the Minnesota Buffer Law. Buffer compliance rates for the counties of the Redwood Watershed are at or above 97%. Visit the BWSR Buffer Compliance Rates webpage for more information.

Drainage Management

Minnesota drainage law is found in Minn. Stat. ch. 103.E. Counties within the Redwood River Watershed have varying levels of ditch record management. Drainage systems in Minnesota are managed under the jurisdiction of one of several authorities. The three most common are: a county board of commissioners, a joint county drainage authority, or a watershed district board of managers. When a drainage system is located entirely in one county, the jurisdictional authority is a county board of commissioners. When a drainage system crosses over into another county, that drainage system is under the jurisdiction of a joint county drainage authority. When an organized watershed district is present, the drainage system falls under the purview of the watershed district.

Improvements to public drainage systems require drainage authorities to prepare preliminary and final engineering reports that are submitted to DNR. The DNR provides advisory letters in response to the engineering reports to identify additional areas of investigation and any relevant DNR regulatory requirements. The MPCA coordinates with DNR in the development of the response letters to identify concerns related to water quality and aquatic biology. Increased flows and altered hydrology are often identified as a source of water quality impairments and stressors to aquatic biology. Drainage improvement projects represent an opportunity to incorporate water storage practices and other BMPs that can help offset total and peak flow increases.

There are various grant opportunities, programs, and initiatives available to ditch authorities to improve their drainage system in ways that also promote storage, water quality, and other benefits. One example is BWSR's Clean Water Fund (CWF) Multipurpose Drainage Management (MDM) grant. This grant supports the use of various practices and designs to achieve multiple water management goals, including supporting beneficial use, flood control, water quality, drainage, and wildlife habitat (aquatic and terrestrial). Due to substantial agricultural drainage infrastructure, MDM will be vital for the Redwood River Watershed to achieve the goals described above and to protect and improve drainage systems in a way that reduces future maintenance. Both rural and urban multipurpose water management can involve reducing runoff volume, peak flows, erosion, sedimentation, and nutrient transport, as well as increasing infiltration, evapotranspiration, and wildlife habitat. Specific MDM practices include but are not limited to: side inlets (410), wetland restorations (657), water and sediment control basins (638), grassed waterways (412), saturated buffers (604), and controlled subsurface drainage (554 and 587).

Feedlot Management

All feedlots in Minnesota are regulated by Minn. R. ch. 7020. The MPCA has regulatory authority of feedlots but counties may choose to participate in a delegation of the feedlot regulatory authority to the local unit of government. Delegated counties are then able to enforce Minn. R. ch. 7020 (along with any other local rules and regulations) within their respective counties for facilities that are under the CAFO threshold. In the Redwood River Watershed, the counties of Lincoln, Pipestone, Murray, Lyon, and Yellow Medicine are delegated the feedlot regulatory authority. The only nondelegated county in the Redwood River Watershed is Redwood County. The counties and MPCA will continue to implement the feedlot program and work with produces on MMPs.

SSTS (Septic System) Improvements

SSTS, commonly known as septic systems, are regulated by Minn. Stat. §§ 115.55 and 115.56. Counties and other LGUs that regulate SSTS must meet the requirements for local SSTS programs in Minn. R. ch. 7082. Counties and other LGUs must adopt and implement SSTS ordinances in compliance with Minn. R. chs. 7080 - 7083.

These regulations detail:

- Minimum technical standards for individual and mid-size SSTS.
- A framework for LGU to administer SSTS programs.
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee.

Counties and other LGUs enforce Minn. R. chs. 7080 through 7083 through their local SSTS ordinance and issue permits for systems designed with flows up to 10,000 gallons per day. There are approximately 200 LGUs across Minnesota and depending on the location, an LGU may be a county, city, township, or sewer district. LGU SSTS ordinances vary across the state. Some require SSTS compliance inspections prior to property transfer, require permits for SSTS repair and septic tank maintenance, and may have other requirements which are stricter than the state regulations.

<u>SSTS Assessments</u>

The counties that comprise the Redwood River Watershed have the following septic assessment criteria:

- Murray - sale or property transfer requires inspection as does addition of “living area”

- Pipestone – sale, property transfer, or bedroom addition requires inspection
- Redwood - any permit in shoreland or bedroom addition requires inspection
- Lyon – sale or property transfer
- Lincoln – sale or property transfer with 12-month window to determine which party will be responsible for upgrade
- Yellow Medicine – bedroom addition requires inspection

SSTS Upgrades/Replacement process

The upgrade or replacement process for septic systems generally is uniform across the state. Counties and other LGUs must adopt and implement SSTS ordinances in compliance with Minn. R. chs. 7080 through 7083. In general, the upgrade process includes an application, soils verification, a septic design, permit and final inspection including as-built record of what was installed.

SSTS Fix-up Funds

Funds can come from a variety of sources including but not limited to special property tax assessments, grants, the MPCA Clean Water Partnership Low-interest Loan Program, and the AgBMP Loan Program which is administered through the county or SWCD. Most counties across the state have low interest loan programs for qualified residents to upgrade failing septic systems. The counties that comprise the Redwood River Watershed have the following septic system loan options:

- Murray – low interest loans and low-income grants when available
- Pipestone - low interest loans and low-income grants when available
- Redwood – low interest loans
- Lyon - low interest loans
- Lincoln - low interest loans
- Yellow Medicine – income-based grants and low interest loans

SSTS Maintenance and Education

The MPCA suggests that septic tanks be evaluated at least every three years and pumped free of solids. The rate of solids accumulation is dependent on many factors. The University of Minnesota Extension developed a septic system owner's guide to counties for distribution to residents at a reduced cost. Counties also provide a variety of digital and physical educational sources for residents to ensure proper SSTS operation and maintenance.

Culvert Replacement and Other Barriers

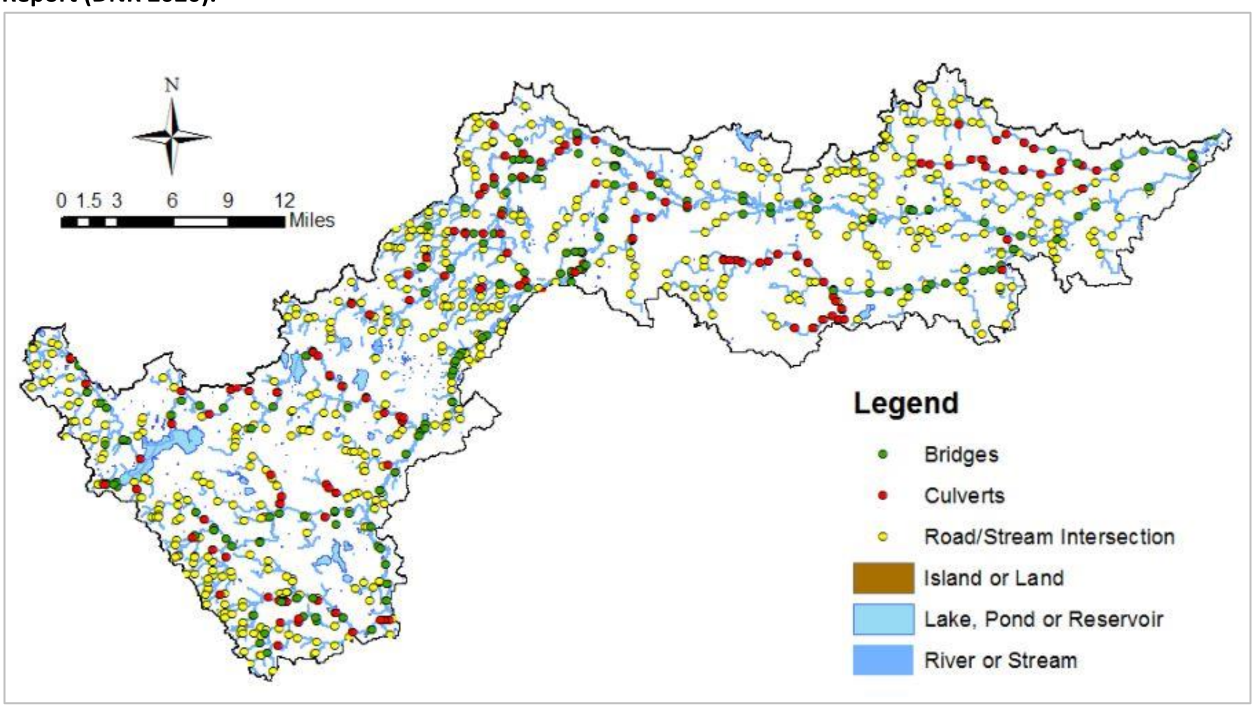
DNR staff, as part of the Redwood River Watershed Characterization Report, reviewed the Minnesota Department of Transportation (MNDOT) bridge and culvert GIS dataset to determine that there are 154 bridges and 131 culverts on perennial streams within the Redwood River Watershed (Figure 25). Further GIS analysis of stream lines and road lines, however, indicated that there may be as many as 779 road and stream intersections that have some form of crossing within the Redwood River Watershed. Bridges and culverts can have drastic impacts on rivers and streams, especially when improperly sized.

Improperly sized bridges and culverts can create flood flow confinement (FFC), which can cause channel widening, alter sediment transport capacity, and sediment deposition (Zytkovicz and Murtada 2013). DNR staff also conducted an extensive review of historic records to determine that there are 28 dams within the Redwood River Watershed. Twenty of these structures were determined to be barriers to fish passage. Additionally, six other structures were probable barriers, and two other structures were possible barriers; however, it was not possible to make a final determination from the limited amount of information and photographs within the structure's files.

Road crossing projects should implement proper culvert and bridge sizing for the river or stream to allow for water and sediment movement throughout the watershed. Strategies to consider, but not limited to, may include:

- Improperly sized culverts and bridges can affect the river or stream channel downstream and lead to excess sediment supply and habitat degradation.
- Floodplain culverts should be placed at bankfull elevations across the floodplain in order to restore longitudinal connectivity of the floodplain and reduce flood flow confinement.
- Proper bridge sizing and floodplain culverts will help to restore travel corridors for riparian animals in many instances so that they do no need to cross busy highways; a situation dangerous to humans and animals.
- Abandoned road and railroad bridges should be removed in order to reduce channel constriction. Furthermore, the associated road and railroad grades should be leveled in order to restore floodplain connectivity

Figure 24. Location of bridges and culverts as identified in the Redwood River Watershed Characterization Report (DNR 2020).



Urban Stormwater Management

Although land cover in the Redwood River Watershed is predominantly cultivated crops, there are a few large cities located throughout the watershed. The city of Marshall (MS400241; population 12,735) and Redwood Falls (MS400236; population 5,459) are located in the central and eastern portion of the watershed, respectively. These cities are the only communities in the watershed that are subject to the MPCA's MS4 Permit program. There are also 12 smaller municipalities throughout the Redwood River Watershed that are not subject to MS4 permits (Figure 1).

While urban areas often yield higher levels of pollutants/stressors than natural areas, it has been demonstrated throughout the State that city stormwater systems can be designed and built for zero or minimal runoff depending on the size and intensity of the rain event. The Minnesota Stormwater Manual (MPCA 2014c) is a comprehensive resource for urban and residential BMPs. This resource includes links to specific urban BMP strategies, studies, calculators, special considerations for Minnesota, as well as links regarding industrial and stormwater programs.

Wastewater Treatment Improvements

Recently, the State of Minnesota placed a chloride (salt) limitation on the permit given to the City of Marshall WWTF. Effluent from the Marshall WWTF discharges to Redwood River Reach 502 which is currently impaired by chloride (Figure 4). The permit requires the water entering the Redwood River following treatment to contain less than 261 mg/l by 2024. A 2017 study (Marshall WTP Softening Enhancement Project) estimated that 11,356 pounds per day on average and 15,881 pounds per day maximum, enter Redwood River Reach 502. Of this amount, the study estimated that 75% of the salt comes from softening units being recharged using salt in residential, commercial, and light industrial.

The study concluded that the most economical way to attain that chloride limitation is to keep the chloride (salt) from entering the wastewater in the first place. Various options were investigated, and it was determined that the best strategy would be for the city to introduce a centralized lime softening process that adds soda ash to reduce the water hardness from the 50 grains as it enters the water plant, to 8 grains following the new type of process. The city informed residents about the change, and a considerable number said they would turn off or reduce their use of in-home or on-site equipment if the city achieved the lower hardness levels. The Marshall Water Treatment Plant has initiated operations of a new system that provides the City of Marshall with water softened to approximately 8 grains of hardness. The Water Treatment Plant previously provides partially softened water with a hardness of approximately 35 grains.

In-Lake Management

There are eight lakes in the Redwood River Watershed that have been assessed for AqR, all of which are considered shallow lakes by DNR definition (maximum depth of 15 feet or less, or greater than 80% littoral area). Shallow lakes are ecologically different from deep lakes in that they have a greater proportion of sediment area to lake volume, allowing potentially larger sediment contributions to nutrient loads and higher potential sediment resuspension that can decrease water clarity. Biological organisms also play a greater role in maintaining water quality. Rough fish, especially carp, can uproot SAV and stir up sediment. SAV helps stabilize the sediment, reducing the amount that can be resuspended and cloud water clarity. SAV also provides refuge for zooplankton, a group of small crustaceans that consumes algae.

All these interactions in shallow lakes occur within a theoretical paradigm of two alternative stable states: a clear water, macrophyte-dominated state and a turbid water, algae-dominated state (Scheffer 2004). The clear water state is characterized by low algal biomass, an abundant and diverse SAV community, a balanced fish community (if any) and large bodied zooplankton daphnia. Alternatively, the turbid water state is characterized by high phytoplankton biomass, little to no SAV, and an imbalanced fish community often dominated by common carp, bullheads, and/or fathead minnow. Shallow lakes often exist in an area of hysteresis with the lake flipping between the clear and turbid water states due to sudden changes in the fish community. The persistence of the clear water state is often the favored outcome of management activities but can be difficult to maintain in agricultural landscapes. Understanding and identifying the potential mechanisms driving the state of water quality in a shallow lake is critical to successful and sustained management of shallow lakes.

Within the Redwood River Watershed, six of the eight assessed lakes are considered impaired by nutrients (phosphorus), suggesting they are currently in a turbid water state. TMDL studies were completed on all six of these lakes. The TMDL reports indicate five of the six impaired lakes will need some level of internal load reduction to be flipped to a clear water state and meet state water quality standards. While the TMDL studies provide an estimate of the total internal phosphorus (mass) load reductions needed for each lake, the studies do not identify or quantify each potential internal source/driver. The DNR has performed biological assessments on many of the impaired lakes throughout the watershed through fish surveys, fish IBIs, vegetation surveys, and vegetation Floristic Quality Assessments. While these assessments are helpful, a more detailed analysis/study will be needed on each lake to identify specific biological (fish and vegetation), physical (hydrology, wind), and/or chemical (sediment chemistry) factors driving internal load in each lake, and a list of management strategies (i.e., lake drawdown, rough fish removals/barriers, plant management, sediment P inactivation) to address these drivers. The MPCA recommends feasibility studies for any lakes in which water level drawdown or chemical treatment is considered. The Minnesota State and Regional Government Review of Internal Phosphorus Load Control (MPCA 2020c) paper provides more information on internal phosphorus load BMPs and considerations.

Climate Protection Co-benefit of Strategies

Many agricultural BMPs that reduce the load of nutrients and sediment to receiving waters also act to decrease emissions of greenhouse gases (GHGs) to the air. Agriculture is the third-largest emitting sector of GHGs in Minnesota. Important sources of GHGs from crop production include the application of manure and nitrogen fertilizer to cropland, soil organic carbon oxidation resulting from cropland tillage, and carbon dioxide (CO_2) emissions from fossil fuel used to power agricultural machinery or in the production of agricultural chemicals. Reduction in the application of nitrogen to cropland through optimized fertilizer application rates, timing, and placement is a source reduction strategy; while conservation cover, riparian buffers, vegetative filter strips, field borders, and cover crops reduce GHG emissions as compared to cropland with conventional tillage.

The NRCS has developed a ranking tool (linked below) for cropland BMPs that can be used by LGUs to consider ancillary GHG effects when selecting BMPs for nutrient and sediment control. Practices with a high potential for GHG avoidance include conservation cover, forage and biomass planting, no-till and strip-till tillage, multi-story cropping, nutrient management, silvopasture establishment, other tree and shrub establishment, and shelterbelt establishment. Practices with a medium-high potential to mitigate

GHG emissions include contour buffer strips, riparian forest buffers, vegetative buffers and shelterbelt renovation. A longer, more detailed assessment of cropland BMP effects on GHG emissions can be found at COMET-Planner: Carbon and Greenhouse Gas Evaluation for NRDC Conservation Practice Planning.

Funding Sources

There are a variety of funding sources to help cover some of the cost to implement practices that reduce pollutants from entering surface waters and groundwater. Below are a variety of programs that contain web links to the programs and contacts for each entity. The contacts for each grant program can assist in the determination of eligibility for each program, as well as funding requirements and amounts available.

- Agriculture BMP Loan Program (MDA)
- Agricultural Water Quality Certification Program (MDA)
- Clean Water Fund Grants (BWSR)
- Clean Water Partnership Loans (MPCA)
- Environment and Natural Resources Trust Fund (Legislative-Citizen Commission on Minnesota Resources)
- Environmental Assistance Grants Program (MPCA)
- Phosphorus Reduction Grant Program (Minnesota Public Facilities Authority)
- Clean Water Act Section 319 Grant Program (MPCA)
- Small Community Wastewater Treatment Construction Loans & Grants (Minnesota Public Facilities Authority)
- Source Water Protection Grant Program (MDH)
- Surface Water Assessment Grants (SWAG; MPCA)
- Wastewater and Stormwater Financial Assistance Programs (MPCA)
- Conservation Partners Legacy Grant Program (DNR)
- Environmental Quality Incentives Program (NRCS)
- Conservation Reserve Program (USDA)
- Clean Water State Revolving Fund (EPA)

Watershed Priorities

The tools, models, subwatershed analyses, Watershed Characterization Report, and county water plans have been integral in identifying and organizing information around watershed priorities that are taking place throughout the Redwood River Watershed. In lieu of completing a formal ranked prioritization exercise during the development of this report, efforts were concentrated on comparing tool and model output with existing priorities outlined in county water plans and local professional judgement. Discussions with the LWG consisting of partners from a variety of different groups and affiliations helped to refine the scope of priorities discussed in this WRAPS report. Partners participating in the Redwood River Watershed LWG included staff from county environmental services/planning and zoning departments, SWCDs, RCRCA, MPCA, DNR, BWSR, MDA, MDH, and other interested and affected citizens, LGUs, and agencies. Implementation of restoration and protection projects at the project level are very likely to directly involve these partners, so the local knowledge and expertise of the LWG weighed heavily in the creation of strategy tables in this report.

Some of the top priorities that were identified by the LWG during the Redwood River WRAPS process include:

- Implementing grade stabilization structures and practices (e.g., water and sediment control basins (638) and grassed waterways (412) in higher sloped areas of the watershed that experience significant erosion and soil loss
- Continue educating and working with landowners to manage the health of their soils to promote infiltration/filtration, minimize soil loss, and protect surface and groundwater quantity and quality (e.g., cover crops, no-till/reduced till, manure and fertilizer management)
- Restore and/or protect lakes and stream reaches with high recreational use and value
    - Lake Benton and upstream contributing areas (Norwegian Creek)
    - Redwood River in Camden State Park (trout stream)
    - Lower Ramsey Creek upstream of Ramsey Falls (trout stream)
- Restore and/or protect lakes and stream reaches that are nearly impaired or barely impaired (i.e., within 30% of water quality standards):
    - Three Mile Creek Reach 564/565/566 (impaired by TSS, within 27% of standard)
    - Clear Creek Reach 567/568 (impaired by TSS, within 13% of standard)
    - School Grove Lake (impaired, within 14% of standard)
    - East Twin Lake (not impaired, within 8% of standard)
    - Sanderson Lake (not impaired, within 9% of standard)
- Protect vulnerable and sensitive groundwater areas throughout the watershed, particularly WHPAs and DWSMAs with higher vulnerability:
    - City of Marshall
    - Lincoln Pipestone Rural Water

Redwood River Watershed Restoration and Protection Strategies Tables

This section provides detailed tables identifying restoration and protection strategies watershed-wide, and for individual lakes and streams in each HUC-10 subwatershed. The watershed-wide implementation strategy table (further discussion below) outlines strategies and actions to address some of the major watershed-wide restoration and protection initiatives such as altered hydrology, groundwater protection, and improving biological communities. The individual HUC-10 tables address specific reaches within each major subwatershed and were developed by reviewing results of the TMDL studies, the Redwood River Watershed Characterization Report, HSPF and other modeling tools and conditions affecting each subwatershed or impairment, and input and feedback from the Redwood River Watershed LWG and local citizen groups. Within these tables, 12 different strategy types were identified as key strategies in achieving short and long term TMDL reduction goals and protection of water bodies currently meeting state water quality standards. Eight of these strategy types (i.e., BMPs) are available within the Redwood River Watershed HSPF-SAM application tool (see Section 3.1 for description) and therefore adoption of these BMPs can be evaluated using this tool. The Redwood River Watershed HSPF-SAM tool contains a database for each BMP type that contains the following information included in the HUC-10 subwatershed tables. For the Strategies Tables shown below, the MPCA's Watershed Pollutant Load Reduction Calculator was used to estimate BMP adoption rates to achieve the 10-year targets and water quality goals. The BMP adoption rates represent one path to restoration and protection and are not intended to be prescriptive. Local resource managers are in the best position to make decisions on practices that are most likely to be adopted and successful.

BMP Suitable Acres for Subwatershed

"BMP Suitable Acres for Subwatershed" represents the total land area within each HUC-10 subwatershed that is practical to implement that particular BMP based on land characteristics such as soil, slope, etc. depending on the type of BMP (Table 13). For example, the available land fraction for implementing cover crops for corn and soybean rotations is the total acres of corn and beans within the subwatershed. A combination of stakeholder input and literature review were completed to determine the default suitable acres for each BMP that is included in HSPF-SAM. The MPCA compiled estimates of the number of suitable acres for all BMPs included in HSPF-SAM for each HUC-12 subwatershed throughout the state. The Redwood River HUC-12 suitable acre numbers were selected from the statewide database and aggregated for each HUC-10 for incorporation into the WRAPS tables below.

Current BMP Adoption Level

HSPF-SAM also provides the fraction of the suitable land areas where a BMP has already been implemented. These numbers represent practices implemented between 2004 through 2015 and were provided by request from the NRCS Resource Economics Analysis and Policy Division Strategic Information Team. Practices implemented before 2004 were assumed to be past their useful life and considered no longer in place. Using both "BMP Suitable Acres" and "Current Strategy Adoption Level" together, the user can identify the fraction of land area currently available for a BMP to be implemented.

Table 16. Methodology employed to determine suitable and current adoption level for BMPs within the HSPF-SAM application (MPCA 2017).

SAM BMP	Suitable Acres Methodology	Current Adoption Level (Acres) Methodology
Riparian buffers, 50 ft wide (replacing row crops)	50 ft buffers either side of all streams and ditches adjacent to cropland	Acres implemented by NRCS Practice 391 and 472
Riparian buffers, 50 ft wide (pasture)	50 ft buffers either side of all streams and ditches adjacent to pasture	Acres implemented by NRCS Practice 391 and 472
Reduced tillage (30% + residue cover)	Total cropland acres >2% slope	Acres implemented by NRCS Practice 329, 345, and 346
Reduced tillage (no-till)	Total cropland acres >2% slope	Acres implemented by NRCS Practice 329, 345, and 346
Corn & soybeans with cover crop	Total corn & soybean acres	Acres implemented by NRCS Practice 340
Restore tiled wetlands	Minnesota Restorable Wetland Inventory	2012 NLCD Wetland Acres
Controlled tile drainage	Total Drained Cropland – found by: (1) cropland planted to corn, beans, wheat, or sugarbeets; (2) in proximity (1/4 mile) to artificial drainages, canal ditches, or streams; (3) SSURGO Hydrologic Soil Group C or D (4) 0–1% slopes	Acres implemented by NRCS Practice 554
Water and sediment control basins (cropland)	Total cropland acres >2% slope	Acres implemented by NRCS Practice 638
Alternative tile intakes	Total Drained Cropland – found by: (1) cropland planted to corn, beans, wheat, or sugarbeets; (2) in proximity (1/4 mile) to artificial drainages, canal ditches, or streams; (3) SSURGO Hydrologic Soil Group C or D (4) 0–3% slope	N/A
Nutrient management + manure incorporation	Total cropland acres	Acres implemented by NRCS Practice 590

Watershed-wide Strategies Table

Many of the strategies listed in the individual HUC-10 subwatershed tables (Table 17 through Table 23) that are intended to address the TSS, bacteria, and lake impairments will also help address the watershed's biological impairments; however, some additional strategies may be needed. The Redwood River Watershed SID Report identifies major stressors contributing to the watershed's biological impairments, but does not necessarily provide specific strategies to address each individual impairment. Thus, the watershed-wide strategy table (Table 17) presented below includes a suite of strategies, grouped by primary stressor, that can be considered on a reach-by-reach basis as more information is gathered and diagnostic work is done. The strategies presented in Tables 17 through 24 represent one path to achieving the reductions needed to restore and protect water resources in the Redwood River Watershed. They are not prescriptive, as other social, economic, and climactic factors could lead local implementers to pursue different suites of BMPs in local planning and implementation efforts.

Watershed-wide strategies were selected from the MPCA's WRAPS template if they addressed one or more of the stressors identified in the SID report (altered hydrology, loss of connectivity, loss of physical habitat, low dissolved oxygen concentrations, eutrophication, suspended solids, nitrate concentrations, and chloride/conductivity toxicity). Watershed-wide strategies were also incorporated from the DNR's Watershed Characterization Report (DNR 2020). The strategies could be implemented, where appropriate, in conjunction with the HUC-10 subwatershed strategies to help address multiple impairments.

Table 17. Watershed-wide strategies and actions proposed for the Redwood River Watershed.

HUC-10 Subwatershed	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
									Estimated Adoption Rate				
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	Biological Stressor(s) addressed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
All	All Redwood River Watershed biotic impaired reaches	Lincoln, Pipestone, Murray, Lyon, Redwood, and Yellow Medicine	All Redwood River Watershed MIBI & FIBI Impairments; Stressors: Altered hydrology, Connectivity, Habitat, Dissolved Oxygen, Eutrophication, TSS, NO3, Conductivity/Chloride	See Tables 18 - 24 corresponding to individual HUC-10 Subwatersheds	See Tables 18 - 24 corresponding to individual HUC-10 Subwatersheds	Habitat and stream connectivity management	Restore streams to their stable forms using Natural Channel Design principles	Altered hydrology, Habitat, Connectivity, TSS	Unknown	Assess and prioritize projects on a reach-by-reach basis	Assess and prioritize projects on a reach-by-reach basis	Completed Projects	35 - 50
							Properly size and replace road crossings to prevent fish barriers and restore floodplain connectivity	Connectivity, Altered hydrology	Unknown				
							Create or restore wetlands for habitat (657, 658)	Habitat, Altered hydrology, Nitrate	See individual HUC-10 strategy tables 18 - 24				
							Restore floodplains and reconnect with channel using two-stage ditches or by limiting ditch maintenance so floodplain benches form	Habitat, Altered hydrology, Connectivity, TSS	Unknown				
							Riparian tree planting to improve shading (390, 612)	Dissolved oxygen, Habitat, Eutrophication	Unknown				
							Riparian plantings to reduce nuisance waterfowl levels (390, 612)	Eutrophication, Habitat	Unknown				
							Restoration and management of declining habitats (643)	Habitat	Unknown				
						Protect/restore stream banks, bluffs, and ravines	Re-meander channelized stream reaches (584)	Altered hydrology, Habitat, TSS	Unknown				
							Ravine stabilization (410)	TSS	Unknown				
							Riparian bluffs stabilized or restored (580)	TSS	Unknown				
							Restore riffle substrate	Habitat, Dissolved oxygen	Unknown				
							Protect toe of banks with natural materials and install grade control structures like	TSS, Habitat, Altered hydrology	Unknown				

HUC-10 Subwatershed	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
									Estimated Adoption Rate				
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	Biological Stressor(s) addressed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
							constructed riffles and cross-vanes						
							Stream habitat improvement and management [395]	Habitat	Unknown				
							Establish, maintain, and/or protect deep-rooted, native perennial vegetation in the riparian corridor	Habitat, TSS	Unknown				
						Wastewater point-source management	Wastewater nutrient (NO3 and TP) reductions	Nitrate, Eutrophication, Dissolved Oxygen	See individual HUC-10 strategy tables 18 - 24				
						Upland water storage/retention	Create or restore wetlands for water storage (656, 810M) and other multipurpose drainage management practices	Altered hydrology, TSS, Habitat, Nitrate	See individual HUC-10 strategy tables 18 - 24				
						Nitrate reduction	see Groundwater Protection strategies and Ramsey Creek HUC-10 Subwatershed table	Nitrate, Eutrophication	See individual HUC-10 strategy tables 18 - 24				
	All Redwood River Watershed Groundwater and Drinking Water Resources	Lincoln, Pipestone, Murray, Lyon, Redwood, and Yellow Medicine	Groundwater Quality	See Tables 18 - 24 corresponding to individual HUC-10 Subwatersheds	See Tables 18 - 24 corresponding to individual HUC-10 Subwatersheds	Protect groundwater quality, particularly vulnerable areas	Implement Minnesota's Groundwater Protection Rule to restrict fall application of nitrogen fertilizer in areas vulnerable to contamination	NA	Unknown	Assess and prioritize projects	Assess and prioritize projects	Assess and prioritize projects	
							Expand monitoring to further identify and target vulnerable and sensitive groundwater areas	NA	NA				
							Education and outreach to farmers and feedlot operators regarding nutrient management in vulnerable and sensitive areas	NA	Unknown				50

HUC-10 Subwatershed	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
									Estimated Adoption Rate				
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	Biological Stressor(s) addressed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
							Plant vegetative buffers, increase living cover, and improve soil health through cover crops and reduced tillage, prioritize in or near vulnerable groundwater and water supply management areas	NA	See individual HUC-10 strategy tables 18 - 24				
							Install alternative tile intakes (606, 170M, 172M, 173M)	NA	See individual HUC-10 strategy tables 18 - 24				
							Seal abandoned wells	NA	Unknown				
							Promote SSTS compliance through education, maintenance, and inspection	NA	See individual HUC-10 strategy tables 18 - 24				

HUC-10 Subwatershed Strategies

Upper Redwood River HUC-10 Subwatershed

The Upper Redwood River HUC-10 Subwatershed is the southern-most subwatershed and is the headwaters of the Redwood River (Figure 27). Predominately consisting of the Redwood River flowing northeast, the subwatershed encompasses approximately 83,000 acres. Counties that make up the subwatershed include Pipestone, Murray, Lincoln, and Lyon. With the exception of two limited resource value water stream reaches, all of the stream reaches are considered warmwater. Primary stream reaches include the Redwood River, Judicial Ditch 12 (Tyler Creek), as well as County Ditch 14 and County Ditch 7. HUC-12 subwatersheds include Redwood River Headwaters, Judicial Ditch No. 12, and Judicial Ditch No. 31.

Land use within the subwatershed is predominately cropland (72%), followed by rangeland (17%). Developed land use comprises 6% of the watershed, with the towns of Ruthton (population 284), Tyler (population 1,218), and Florence (population 61) present within the subwatershed. Wetlands comprise 3%, while forest makes up less than 1% of the watershed area. Open water accounts for 1% of subwatershed area and includes East Twin Lake (356 acres.), West Twin Lake (220 acres), Section Thirty-Three Lake (98 acres), Sanderson Lake (92 acres), North Swan Lake (103 acres), and South Swan Lake (109 acres).

Stream restoration and protection strategies in the Upper Redwood HUC-10 subwatershed (Table 18) focus on reducing TSS, bacteria, and nutrient loading through land management (residue, cover crops, nutrient and pasture management, etc.), and structural practices (buffers, side inlets, urban stormwater management, etc.). Lake restoration and protection strategies focus on reducing nutrient and TSS loading to lakes through land management (tillage, nutrient management, etc.), structural practices (buffers, lake level management), and internal load controls (rough fish management). Groundwater protection strategies focus on land management (nutrient management, etc.), structural practices (well sealing, buffers, alternative tile intakes, etc.), and outreach (SSTS compliance, nutrient management, etc.). Areas for consideration in the Upper Redwood River HUC -10 include:

- Restore and/or protect lakes and stream reaches that are nearly impaired or barely impaired (i.e., within 30% of water quality standards):
    - East Twin Lake (not impaired, within 8% of standard)
    - Sanderson Lake (not impaired, within 9% of standard)
- Protect vulnerable and sensitive groundwater areas throughout the watershed, particularly WHPAs and DWSMAs with higher vulnerability:
    - Lincoln Pipestone Rural Water

Figure 25. Upper Redwood River HUC-10 Subwatershed.

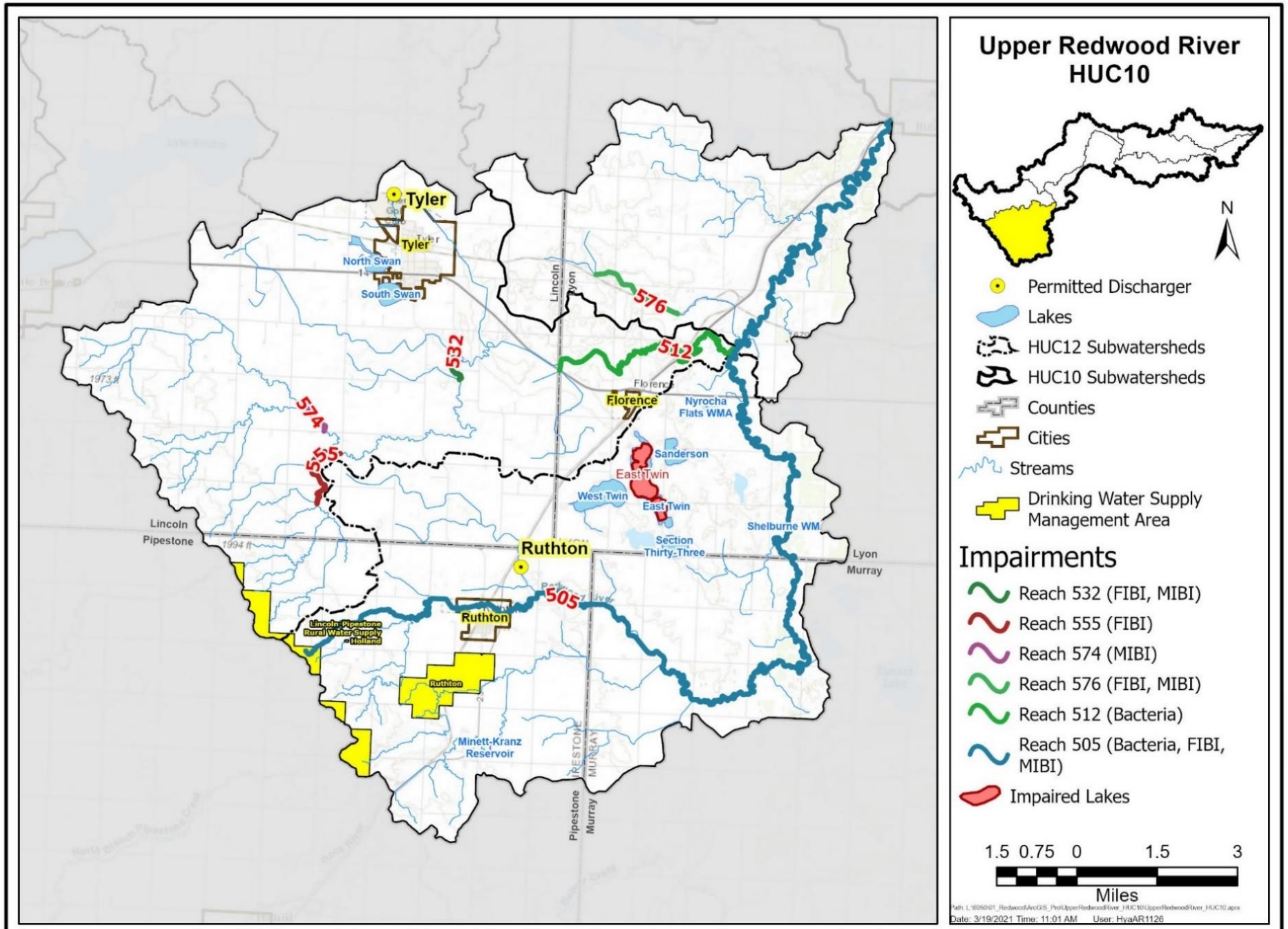


Table 18. Strategies and actions proposed for the Upper Redwood River HUC-10 Subwatershed.

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
HUC-10 Subwatershed: Upper Redwood River; HUC-12 Subwatersheds: Redwood River Headwaters, Judicial Ditch No. 12, Judicial Ditch No. 31	Redwood River (07020006-510) Note: this is a downstream impairment located in the Middle Redwood River HUC-10 Subwatershed	Location = Lyon; Upstream = Lincoln, Pipestone, Murray	TSS	90th percentile TSS concentration = 103 mg/L	Maximum 90th percentile TSS concentration = 65 mg/L; 37% reduction	Buffers - field edge	50-ft buffers on streams adjacent to cropland/pasture (390, 391, 327)	cropland: 10,930; pasture: 390	cropland: 3%; pasture: 17%	cropland: 5%; pasture: 20%	cropland: 15%; pasture: 20%	% of suitable acres	50
						Tillage/residue management	Adopt reduced tillage (30% + residue cover) and no-till (329, 345, 346)	reduced till: 22,340; no-till: 22,340	reduced till: 25%; no-till: 25%	reduced till: 30%; no-till: 30%	reduced till: 25%; no-till: 25%	% of suitable acres	
						Add cover crops for living cover in fall/spring	Implement cover crops with corn and soybeans (340)	50,000	7%	10%	15%	% of suitable acres	
						Upland water storage/retention	Restore tiled wetlands in marginal areas and as opportunities arise (656, 810M)	8,000	<1%	2%	5%	% of suitable acres	
							Implement controlled tile drainage water management (554)	4,410	<1%	2%	5%	% of suitable acres	
						Conservation practice installation	Construct water and sediment control basins (638) and grassed waterways (412)	WASCOBs and GWs: 23,360	WASCOBs: 1%; GWs: <1%	WASCOBs: 2%; GWs: 5%	WASCOBs: 10%; GWs: 10%	% of suitable acres	
						Open tile inlet and side inlet improvements	Install alternative tile intakes (606, 170M, 172M, 173M)	4,370	1%	3%	8%	% of suitable acres	
							Identify and implement side inlet improvements (410)	NA	Unknown	Implement necessary improvements and upland treatment	Implement necessary improvements	Improvements	
						Urban stormwater runoff control	ID and implement stormwater BMPs to store water and treat sediment loading from Cities of Tyler, Ruthton, and Florence	NA	Unknown	Complete assessment and feasibility	Implement identified projects and education	Completed assessments and projects	
	Redwood River (07020006-505)	Location = Lyon, Murray, Pipestone; Upstream = Lincoln	Fecal coliform	959 cfu/100 mL maximum monthly geomean	Maximum monthly geomean <200 cfu/100 mL; 79% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
						Nutrient management (cropland)	Fertilizer and manure management and incorporation (590)	53,400	10%	20%	75%	% of suitable acres	
						Pasture management	Implement exclusion fencing, grazing rotations in shoreland and high priority areas	NA	Unknown	Work with producers to identify and implement priority projects	Implement priority projects	Completed projects	
						Feedlot runoff controls	Implement feedlot runoff reduction/treatment (635, 784) where needed	NA	Unknown	Work with producers to identify and	Implement projects	Completed projects	

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location: Water Body (ID)	Water Body and Location: Location and Upstream Influence Counties	Parameter (incl. nonpollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets: Specific Implementation Strategy	Estimated Adoption Rate: HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested adoption to meet TMDL and protection goals	Estimated Adoption Rate: Units	Estimated Years to Achieve Water Quality Target
										implement projects			
	Tyler Creek (07020006-512)	Location = Lyon; Upstream = Lincoln	Fecal coliform	1,424 cfu/100 mL maximum monthly geomean	Maximum monthly geomean <200 cfu/100 mL; 86% reduction	Septic system improvements	Provide education and maintenance materials for SSTS parcels. Work through current ordinances with landowners to upgrade failing and noncompliant SSTS	NA	Point of sale inspections	Work with landowners to identify and upgrade SSTSs	Upgrade all failing and noncompliant SSTSs	SSTS upgrades	
						Urban stormwater runoff control	ID and implement stormwater BMPs to treat and reduce bacteria loading from Cities of Tyler, Ruthton, and Florence	NA	Unknown	Complete assessment and feasibility	Implement targeted projects	Completed study and projects	
	Redwood River (07020006-505)	Location = Lyon, Murray, Pipestone; Upstream = Lincoln	FIBI and MIBI; Stressors: - Altered hydrology, Habitat, DO, Eutrophication, TSS	FIBI = 37; MIBI = 14, 28, 17, 30	FIBI >50; MIBI > 37	Implement TSS and bacteria reduction strategies outlined above; see watershed-wide Table 17 for additional strategies to address stream biological impairments							50
	Unnamed Creek (07020006-532)	Location = Lincoln; Upstream = none	FIBI and MIBI; Stressors: Altered hydrology, Habitat, NO3	FIBI = 25; MIBI = 34	FIBI >42; MIBI > 41								
	Unnamed Ditch (07020006-555)	Location = Lincoln; Upstream = Pipestone	FIBI; Stressors: Altered hydrology, TSS	FIBI = 42	FIBI >55								
	Unnamed Creek (07020006-574)	Location = Lincoln; Upstream = none	MIBI; Stressor: Altered hydrology, Connectivity, Eutrophication, NO3	MIBI = 2	MIBI > 22								
	County Ditch 31 (07020006-576)	Location = Lyon; Upstream = Lincoln	FIBI and MIBI; Stressors: Altered hydrology, DO, Eutrophication, NO3	FIBI = 32; MIBI = 16	FIBI >33; MIBI > 22								
	East Twin Lake (42007000)	Lyon	FIBI; Stressors: Eutrophication	FIBI = 13, 14	FIBI > 36	Reduce sediment loads	Implement TSS reduction strategies outlined above						
						Reduce phosphorus loading	Implement eutrophication reduction strategies outlined above in watershed-wide Table 17						
						Shoreline restoration and protection	Promote and maintain riparian areas with use of shoreline buffers	NA	NA	ID projects/areas	Implement priority improvements	Improvements	

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
						Monitoring	Continue water quality monitoring to track trends	NA	NA	Develop and implement monitoring plan	Routine monitoring	Monitor water quality	
						Lake internal load management	Assess common carp and other rough fish to determine impact on water quality and native vegetation; develop management strategies	n-	Survey approximately every 5 years	Continue current schedule	Manage as necessary	Completed surveys	
										-	-		
	East and West Twin Lake (42007400)	Lyon	Phosphorus (TP)	42 ppb TP summer avg.	TP Reduction: 20 lbs/yr	Implement TSS and bacteria strategies outlined above; implement eutrophication strategies outlined above in watershed-wide table							50
						Lake level management	Complete feasibility and implement recommended actions to restore water levels (Twin)	NA	Feasibility completed	Implement recommendations	Restore water levels	Completed project	
	Sanderson Lake (42007100)	Lyon	Phosphorus (TP)	82 ppb TP summer avg.	TP Reduction: 5 lbs/yr	Monitoring	Monitor water quality to support future assessments	NA	N/A	Develop and implement monitoring plan	Routine monitoring	Monitor water quality	
							Continue monitoring fish community (Twin)						
							Update fish survey according to DNR methods and protocols (Sanderson)	NA	Last survey conducted in 2006	Complete survey	Use survey results to track changes and evaluate if fisheries mgt. is needed	Completed survey	
	Unnamed Creek (07020006-580)	Lyon	High watershed and riparian risk (MPCA tool)	Low protection	Increase protection of stream reaches	Implement TSS and bacteria strategies outlined above; see watershed-wide Table 17 for strategies to protect stream biota							
	County Ditch 7 (07020006-556)	Lyon	High watershed and riparian risk (MPCA tool)	Med/low protection									
	Lincoln Pipestone Rural Water–Holland DWSMA/WHPA	Pipestone	GW Quality	Several areas of very high vulnerability	Protect GW quality, particularly vulnerable areas	See watershed-wide Table 17 for strategies to protect groundwater; implement TSS and bacteria strategies outlined above							
	Ruthton DWSMA/WHPA	Pipestone	GW Quality	Low vulnerability									
	Groundwater - general	Lyon, Lincoln, Pipestone	GW Quality	Vulnerable GW areas = 2,669 acres									

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	

Color Key:

(pink)	Restoration
(green)	Protection

Coon Creek HUC-10 Subwatershed

Coon Creek (0702000602-01) HUC-10 Subwatershed is the second largest tributary to the Redwood River and the westernmost subwatershed within the Redwood River Watershed (Figure 28). The drainage area encompasses 97 sq. mi. (62,000 acres) of Lincoln and Lyon counties. Coon Creek is the primary stream reach within the subwatershed, as well as its tributary Judicial Ditch 30. Norwegian Creek is a significant tributary to Lake Benton. HUC-12 subwatersheds include: Norwegian Creek, Lake Benton, Upper Coon Creek, and Lower Coon Creek. All the streams are considered warmwater. Natural stream reaches account for 44% of the reach lengths, while altered channels account for 41% of reach lengths.

Land use within the watershed is mostly cropland (66%) and rangeland (19%). Developed areas account for 5% of the subwatershed area, including the town of Lake Benton (population 703). Only a small portion of the watershed is wetland (2%), and even less is forested (<1%). Lake Benton (2,699 acres) is the largest lake found within the subwatershed, along with Dead Coon Lake (547 acres). Open water comprises 7% of the watershed area.

Stream restoration and protection strategies in the Coon Creek HUC-10 subwatershed (Table 19) focus on reducing TSS, bacteria, and nutrient loading through land management (residue, cover crops, nutrient and pasture management, etc.), and structural practices (buffers, side inlets, urban stormwater management, etc.). Lake restoration and protection strategies focus on reducing nutrient and TSS loading to lakes through land management (tillage, nutrient management, etc.), structural practices (modify/replace fish passage barriers, buffers, etc.), and internal load controls (rough fish management). Groundwater protection strategies focus on land management (nutrient management, etc.), structural practices (well sealing, buffers, alternative tile intakes, etc.), and outreach (SSTS compliance, nutrient management, etc.).

Areas for consideration in the Coon Creek HUC -10 include:

- Restore and/or protect lakes and stream reaches with high recreational use and value
  - Lake Benton and upstream contributing areas (Norwegian Creek)
- Protect vulnerable and sensitive groundwater areas throughout the watershed, particularly WHPAs and DWSMAs with higher vulnerability:
  - Lincoln Pipestone Rural Water

Figure 26. Coon Creek HUC-10 Subwatershed.

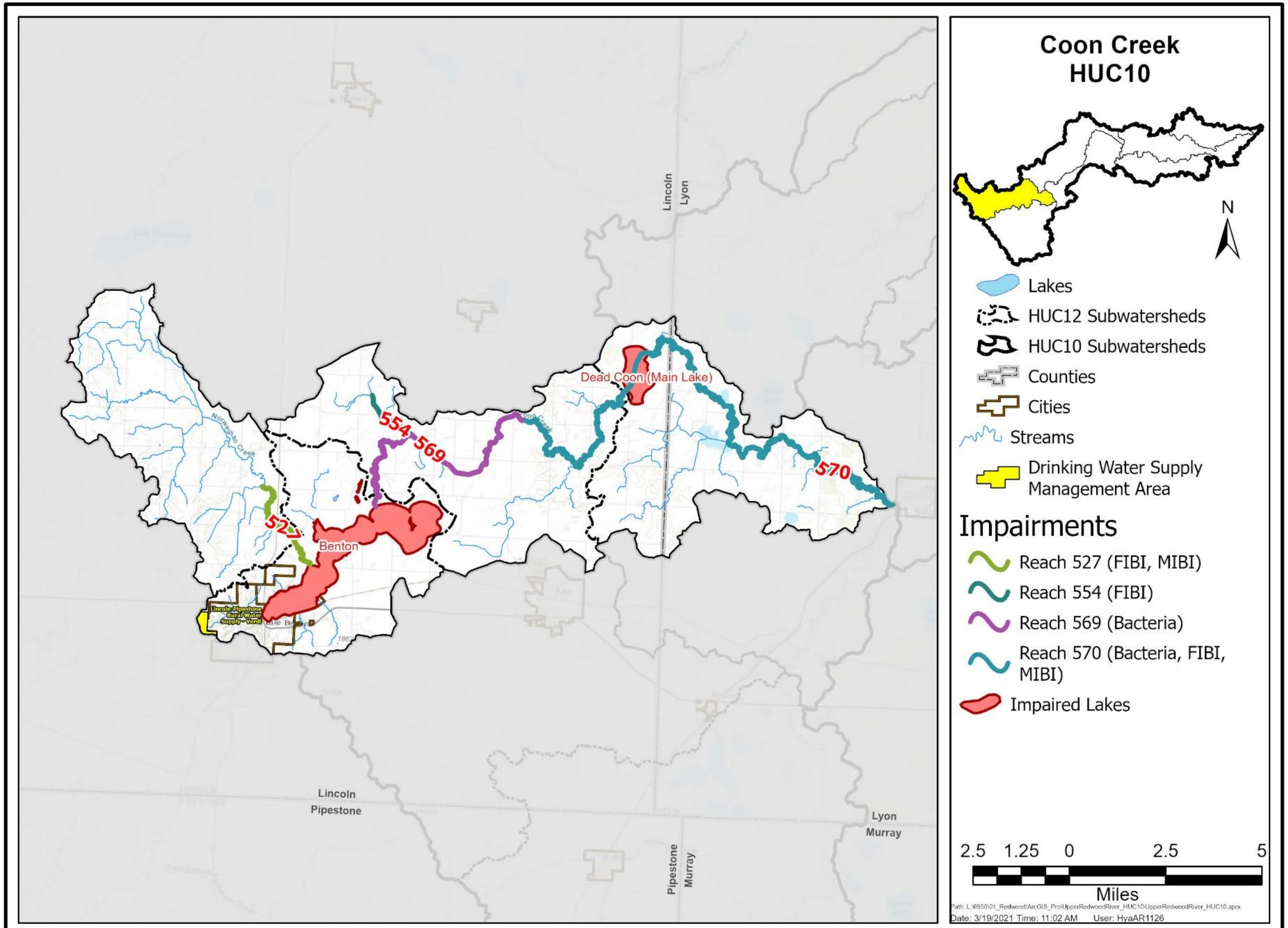


Table 19. Strategies and actions proposed for the Coon Creek HUC-10 Subwatershed.

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location: Water Body (ID)	Water Body and Location: Location and Upstream Influence Counties	Parameter (incl. nonpollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategy type (see key below)	Specific Implementation Strategy	Estimated Adoption Rate: HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested adoption to meet TMDL and protection goals	Estimated Adoption Rate: Units	Estimated Years to Achieve Water Quality Target
HUC-10 Subwatershed: Coon Creek; HUC-12 Subwatersheds: Norwegian Creek, Lake Benton, Upper Coon Creek, Lower Coon Creek	Redwood River (07020006-510) Note: this is a downstream impairment located in the Middle Redwood River HUC-10 Subwatershed	Location = Lyon; Upstream = Lincoln	TSS	90th percentile TSS concentration = 103 mg/L	Maximum 90th percentile TSS concentration = 65 mg/L; 37% reduction	Buffers - field edge	50-ft buffers on streams adjacent to cropland/pasture (390, 391, 327)	cropland: 6,970; pasture: 460	cropland: 19%; pasture: 4%	cropland: 20%; pasture: 8%	cropland: 25%; pasture: 25%	% of suitable acres	50
						Tillage/residue management	Adopt reduced tillage (30% + residue cover) and no-till (329, 345, 346)	reduced till: 17,170; no-till: 17,170	reduced till: 16%; no-till: 16%	reduced till: 30%; no-till: 20%	reduced till: 50%; no-till: 30%	% of suitable acres	
						Add cover crops for living cover in fall/spring	Implement cover crops with corn and soybeans (340)	35,590	6%	10%	20%	% of suitable acres	
						Upland water storage/retention	Restore tiled wetlands in marginal areas and as opportunities arise (656, 810M)	4,890	<1%	2%	5%	% of suitable acres	
							Implement controlled tile drainage water management (554)	1,900	<1%	1%	4%	% of suitable acres	
						Conservation practice installation	Construct water and sediment control basins (638) and grassed waterways (412)	WASCOBs and GWs: 17,950	WASCOBs: <1%; GWs: <1%	WASCOBs: 2%; GWs: 5%	WASCOBs: 15%; GWs: 15%	% of suitable acres	
						Open tile inlet and side inlet improvements	Install alternative tile intakes (606, 170M, 172M, 173M)	3,580	3%	5%	25%	% of suitable acres	
							Identify and implement side inlet improvements (410)	NA	Unknown	Implement necessary improvements and upland treatment	Implement necessary improvements	Improvements	
						Urban stormwater runoff control	ID and implement stormwater BMPs to store water and treat sediment loading from city of Lake Benton	NA	Unknown	Complete assessment and feasibility	Implement identified projects and education	Completed assessments and projects	
	Coon Creek (07020006-569 and 570)	Lincoln, Lyon	Fecal coliform	925 cfu/100 mL maximum monthly geomean	Maximum monthly geomean <200 cfu/100 mL; 78% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
						Nutrient management (cropland)	Fertilizer and manure management and incorporation (590)	36,142	14%	25%	75%	% of suitable acres	
						Pasture management	Implement exclusion fencing, grazing rotations in shoreland and high priority areas	NA	Unknown	Work with producers to identify implement priority projects	Implement priority projects	Completed projects	
						Feedlot runoff controls	Implement feedlot runoff reduction/treatment (635, 784) where needed	NA	Unknown	Work with producers to identify and	Implement projects	Completed projects	

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
										implement projects			
						Septic system improvements	Provide education and maintenance materials for SSTS parcels. Work through current ordinances with landowners to upgrade failing and noncompliant SSTS	NA	Point of sale inspections	Work with landowners to identify and upgrade SSTSs	Upgrade all failing and noncompliant SSTSs	SSTS upgrades	
						Urban stormwater runoff control	ID and implement stormwater BMPs to treat and reduce bacteria loading from Cities of Tyler, Ruthton, and Florence	NA	Unknown	Complete assessment and feasibility	Implement identified projects and education	Completed assessments and projects	
	Norwegian Creek (07020006-527)	Lincoln	FIBI and MIBI; Stressors: Altered hydrology, Connectivity, Habitat, Eutrophication	FIBI = 26; MIBI = 18	FIBI >55; MIBI > 41	Implement TSS and bacteria reduction strategies outlined above; see watershed-wide Table 17 for additional strategies to address stream biological impairments							50
	Judicial Ditch 30 (07020006-554)	Lincoln	FIBI; Stressors: Altered hydrology, Connectivity, Habitat, Eutrophication, NO3	FIBI = 29	FIBI >33								
	Coon Creek (07020006-570)	Lincoln, Lyon	FIBI and MIBI; Stressors: Altered hydrology, Connectivity, Habitat, DO, Eutrophication, TSS	FIBI = 0, 37; MIBI = 22, 21, 19	FIBI >50; MIBI >37								
										-	-		
	Lake Benton (41004300)	Lincoln	Phosphorus (TP); FIBI	18,903 lb TP/yr; 129 ppb TP summer avg.; FIBI = 15, 12	10,768 lb TP/yr; <90 ppb TP summer avg.; 43% reduction; FIBI >36	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
						Reduce phosphorus loading	Implement eutrophication reduction strategies outlined above in watershed-wide Table 17						
						Modify/replace dams culverts & fish passage barriers	Evaluate downstream crossings as potential barriers to fish passage	NA	NA	NA	Restore barriers to fish passage	# of barriers removed	
	Dead Coon - Main Lake (41002100)	Lincoln	Phosphorus (TP); FIBI	14,212 lb TP/yr; 170 ppb TP	6,584 lb TP/yr; <90 ppb TP summer avg.;	Shoreline restoration and protection	Promote and maintain riparian areas with use of shoreline buffers	NA	NA	ID projects/areas	Implement priority improvements	Improvements	

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location: Water Body (ID)	Water Body and Location: Location and Upstream Influence Counties	Parameter (incl. nonpollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets: Specific Implementation Strategy	Estimated Adoption Rate: HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested adoption to meet TMDL and protection goals	Estimated Adoption Rate: Units	Estimated Years to Achieve Water Quality Target
				summer avg.; FIBI = 5, 5	54% reduction; FIBI >36	Monitoring	Continue monitoring fish community and rough fish populations (i.e., black bullhead)	NA	Surveyed every 5 years	Continue current schedule	Manage as necessary	Completed surveys	
						Lake internal load management	Assess common carp and other rough fish to determine impact on water quality and native vegetation; develop management strategies	NA	Sediment cores collected during TMDL study	Assess fish and develop mgt. plan	Manage as necessary	Assessments and mgt. actions	
										-	-		
	Slough Lake	Lincoln	Phosphorus (TP)	156 ppb TP summer avg	TP Reduction: 9 lbs/yr	Implement TSS and bacteria strategies outlined above; implement eutrophication strategies outlined above in watershed-wide Table 17							50
						Consider expanding water quality monitoring program to track trends, fill data gaps, and support future assessments	NA	NA	Develop and implement monitoring plan	Routine monitoring	Monitor water quality		
						Update fish survey according to DNR methods	NA	Last survey conducted in 2014	Complete survey	Use survey results to track changes and evaluate if fisheries mgt. is needed	Completed survey		
	Lincoln Pipestone Rural Water–Verdi DWSMA/WHPA	Lincoln	GW Quality	High vulnerability	Protect GW quality, particularly vulnerable areas	See watershed-wide Table 17 for strategies to protect groundwater; implement TSS and bacteria strategies outlined above							
	Groundwater - general	Lincoln, Lyon	GW Quality	Vulnerable GW areas = 1,588 acres									

Color Key:

(pink)	Restoration
(green)	Protection

Middle Redwood River HUC-10 Subwatershed

The Middle Redwood River (0702000603-01) HUC-10 is a subwatershed on the mainstem Redwood River totaling 81 square miles (52,000 acres), all within Lyon County (Figure 29). The primary stream reach is the Redwood River, which predominately flows northeast, but also includes some tributaries, most notably County Ditch 60. HUC-12 subwatersheds include: city of Marshall – Redwood River, County Ditch No. 19 – Redwood River, and County Ditch No. 60. All of the stream reaches are considered warmwater, with a 7-mile 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.

Marshall (population 12,735), the largest city within the major watershed, is found within this subwatershed, as well as the towns of Russell and Lynd. Developed land use accounts for 14% of the land use, while cropland is most prominent at 68% of the subwatershed. Rangeland comprises 10% of the subwatershed area, while forest (3%), wetland (4%), and open water (1%) comprise the rest. Lakes within the subwatershed include Clear Lake (63 acres) and Brawner Lake (27 acres).

Stream restoration and protection strategies in the Middle Redwood River HUC-10 subwatershed (Table 20) focus on reducing TSS, bacteria, nutrient, and chloride loading through land management (residue, cover crops, nutrient and pasture management, smart road salting, etc.) and structural practices (buffers, side inlets, urban stormwater management, soda ash lime softening, etc.). Lake restoration and protection strategies focus on reducing nutrient and TSS loading to lakes through land management (tillage, nutrient management, etc.), structural practices (buffers, etc.), and internal load controls (rough fish management, monitoring). Groundwater protection strategies focus on land management (nutrient management, etc.), structural practices (well sealing, buffers, alternative tile intakes, etc.), and outreach (SSTS compliance, nutrient management, etc.).

Areas for consideration in the Middle Redwood River HUC-10 include:

- Restore and/or protect lakes and stream reaches with high recreational use and value
  - Redwood River in Camden State Park (trout stream)
- Protect vulnerable and sensitive groundwater areas throughout the watershed, particularly WHPAs and DWSMAs with higher vulnerability:
  - City of Marshall

Figure 27. Middle Redwood River HUC-10 Subwatershed.

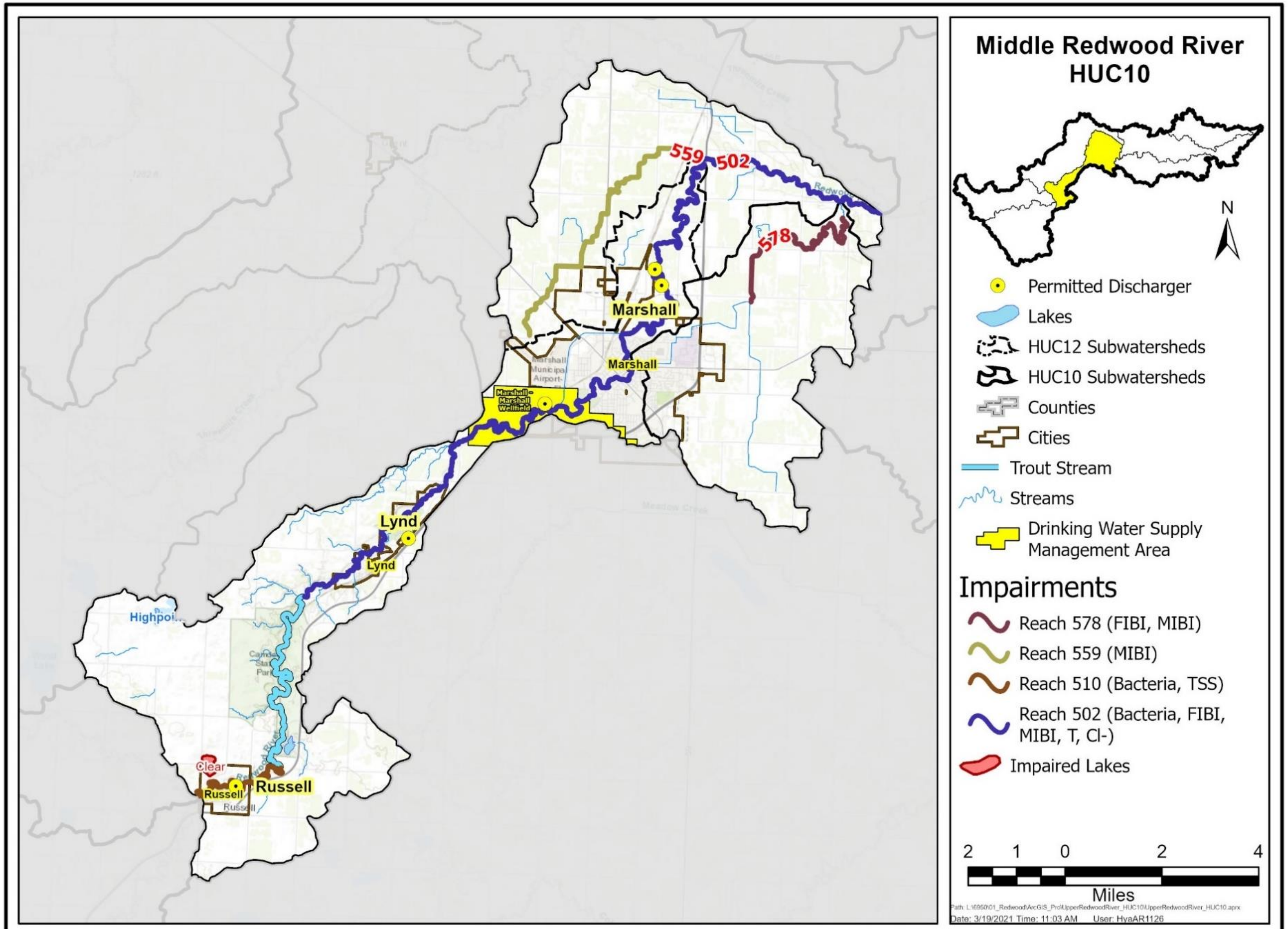


Table 20. Strategies and actions proposed for the Middle Redwood River HUC-10 Subwatershed.

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	Estimated Adoption Rate					
								HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
HUC-10 Subwatershed: Middle Redwood River; HUC-12 Subwatersheds: City of Marshall - Redwood River, County Ditch No. 19 - Redwood River, County Ditch No. 60	Redwood River (07020006-502)	Location = Lyon; Upstream = Lincoln, Pipestone, Murray	TSS	90th percentile TSS concentration = 145 mg/L	Maximum 90th percentile TSS concentration = 65 mg/L; 55% reduction	Buffers - field edge	50-ft buffers on streams adjacent to cropland/pasture (390, 391, 327)	cropland: 4,900; pasture: 620	cropland: 1%; pasture: 4%	cropland: 15%; pasture:15%	cropland: 25%; pasture: 25%	% of suitable acres	50
						Tillage/residue management	Adopt reduced tillage (30% + residue cover) and no-till (329, 345, 346)	reduced till: 7,850; no-till: 7,850	reduced till: 6%; no-till: 6%	reduced till: 20%; no-till:20%	reduced till: 35%; no-till: 35%	% of suitable acres	
						Add cover crops for living cover in fall/spring	Implement cover crops with corn and soybeans (340)	33,210	3%	10%	20%	% of suitable acres	
						Upland water storage/retention	Restore tiled wetlands in marginal areas and as opportunities arise (656, 810M)	7,690	<1%	2%	5%	% of suitable acres	
	Redwood River (07020006-510)	Location = Lyon; Upstream = Lincoln, Pipestone, Murray	TSS	90th percentile TSS concentration = 103 mg/L	Maximum 90th percentile TSS concentration = 65 mg/L; 37% reduction		Implement controlled tile drainage water management (554)	5,620	<1%	2%	4%	% of suitable acres	
						Conservation practice installation	Construct water and sediment control basins (638) and grassed waterways (412)	WASCOBs and GWs: 7,850	WASCOBs: <1%; GWs: <1%	WASCOBs: 2%; GWs: 5%	WASCOBs: 10%; GWs: 10%	% of suitable acres	
						Open tile inlet and side inlet improvements	Install alternative tile intakes (606, 170M, 172M, 173M)	6,860	2%	10%	25%	% of suitable acres	
							Identify and implement side inlet improvements (410)	NA	Unknown	Implement necessary improvements and upland treatment	Implement necessary improvements	Improvements	
						Urban stormwater runoff control	ID and implement stormwater BMPs to store water and treat sediment loading from city of Lake Benton	NA	Unknown	Complete assessment and feasibility	Implement identified projects and education	Completed assessments and projects	
	Redwood River (07020006-502)	Location = Lyon; Upstream = Lincoln, Pipestone, Murray	Fecal coliform	659 cfu/100 mL maximum monthly geomean	Maximum monthly geomean <200 cfu/100 mL; 70% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
						Nutrient management (cropland)	Fertilizer and manure management and incorporation (590)	33,040	15%	25%	75%	% cropland in subwatershed	
						Pasture management	Implement exclusion fencing, grazing rotations in shoreland and high priority areas	NA	Unknown	Work with producers to identify and implement priority projects	Implement priority projects	Completed projects	
						Feedlot runoff controls	Implement feedlot runoff reduction/treatment (635, 784) where needed	NA	Unknown	Work with producers to identify and	Implement projects	Completed projects	

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
										implement projects			
	Redwood River (07020006-510)	Location = Lyon; Upstream = Lincoln, Pipestone, Murray	*E. coli*	475 org./100 mL maximum monthly geomean	Maximum monthly geomean <126 org./100 mL; 73% reduction	Septic system improvements	Provide education and maintenance materials for SSTS parcels. Work through current ordinances with landowners to upgrade failing and noncompliant SSTS	NA	Point of sale inspections	Work with landowners to identify and upgrade SSTSs	Upgrade all failing and non-compliant SSTSs	SSTS upgrades	
	Redwood River (07020006-502)	Location = Lyon; Upstream = Lincoln, Pipestone, Murray	Chloride	463 mg/L maximum 4-day average concentration	Maximum 4-day average concentration <230 mg/L; 50% reduction	Wastewater point source management	Continue implementing soda ash lime softening process to residential, commercial, and light industrial water supply	NA	30%	50%	88%	% Reduction in water hardness	50
						Urban stormwater runoff control	Smart road salting practices to reduce chloride loads from City of Marshall	NA	Unknown	Develop implementation and outreach plan	Implement plan	Completed plan and implementation	
	Clear Lake (42005500)	Lyon	Phosphorus (TP)	502 lb TP/yr; 125 ppb TP summer avg.	305 lb TP/yr; <90 ppb TP summer avg.; 39% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
						Reduce phosphorus loads	Implement eutrophication reduction strategies outlined above in watershed-wide Table 17						
						Lake internal load management	Continue monitoring fish community and rough fish populations (i.e., black bullhead)	NA	Surveyed every 5 years	Continue current schedule	Manage as necessary	Completed surveys	
							Consider collecting sediment cores to evaluate phosphorus release from sediment and compare to TMDL modeling	NA	None	Complete sediment core analysis	Use coring results to update model and inform and prioritize projects	Completed analyses	
	Redwood River (07020006-502)	Location = Lyon; Upstream = Lincoln, Pipestone, Murray	FIBI and MIBI; Stressors: Habitat, Eutrophication, TSS, NO3	FIBI = 49, 54; MIBI = 34, 42	FIBI >50; MIBI > 41	Implement TSS and bacteria reduction strategies outlined above; see watershed-wide Table 17 for additional strategies to address stream biological impairments							50
	County Ditch 19 (07020006-559)	Lyon	FIBI; Stressors: Altered hydrology, Connectivity, Habitat, DO, Eutrophication	FIBI = 0	FIBI >33								

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
	County Ditch 60 (07020006-578)	Lyon	FIBI and MIBI; Stressors: Altered hydrology, Connectivity, Habitat, Eutrophication, NO3	FIBI = 14, 59; MIBI = 21	FIBI >33; MIBI > 24								
										-	-		
	Brawner Lake (42005400)	Lyon (Camden State Park)	Phosphorus (TP)	32 ppb TP summer avg.	Restore permanent water levels and then track/maintain good water quality conditions	Monitoring	Consider expanding water quality monitoring program to track trends, fill data gaps, and support future assessments	NA	N/A	Develop and implement monitoring plan	Routine monitoring	Monitor water quality	50
							Update fish survey according to DNR methods	NA	Last survey conducted in 2006	Complete survey	Use survey results to track changes and evaluate if fisheries mgt. is needed	Completed survey	
	Highpoint Lake (42008900)	Lyon	Phosphorus (TP)	Unknown	N/A	Monitoring	Complete fish survey according to DNR methods	NA	No surveys on record	Complete survey	Use survey to establish baseline conditions for lake	Completed survey	
							Monitor water quality to support future assessments	NA	N/A	Develop and implement monitoring plan	Routine monitoring	Monitor water quality	
	Redwood River (07020006-513; designated trout stream)	Lyon	High watershed and riparian risk (MPCA Tool)	Med protection	Increase protection of stream reach	Implement TSS and bacteria strategies outlined above; see watershed-wide Table 17 for strategies to protect stream biota							
	Marshall DWSMA/WHPA	Lyon	GW Quality	High vulnerability	Protect GW quality, particularly vulnerable areas	See watershed-wide Table 17 for strategies to protect groundwater; implement TSS and bacteria strategies outlined above							
	Groundwater - general	Lyon	GW Quality	Vulnerable GW areas = 6,369 acres									

Color Key:

(pink)	Restoration
(green)	Protection

Three Mile Creek HUC-10 Subwatershed

The Three Mile Creek (0702000604-01) HUC-10 is the largest subwatershed tributary to the Redwood River and is located in the northwest portion of the Redwood River Watershed (Figure 30). Consisting mostly of Three Mile Creek, and several unnamed tributaries, this subwatershed totals 117 square miles (75,000 acres). This subwatershed is mostly within Lyon County, with a small portion in Lincoln County. Three Mile Creek predominantly flows northeast before joining the Redwood River several miles downstream of Marshall. All of the streams in this subwatershed are considered warmwater with 50% of the stream reach lengths considered altered, and 39% natural channels. HUC-12 subwatersheds include Upper Three Mile Creek, Runholt-Mellenthin Dam, County Ditch No. 63, and Lower Three Mile Creek.

Agriculture dominates land use with 81% of the subwatershed area used for crops. Developed areas make up 5%, while barren/mining account for less than 1% of land use. The only town within the subwatershed is Ghent (population 315). Rangeland comprises 9% of the subwatershed area, with forest 1%, wetland 3%, and open water 1% making up the rest. Lakes within the subwatershed include Wood Lake (323 acres), Island Lake (164 acres), and Goose Lake (145 acres).

Stream restoration and protection strategies in the Three Mile Creek HUC-10 subwatershed (Table 21) focus on reducing TSS, bacteria, and nutrient loading through land management (residue, cover crops, nutrient and pasture management, etc.), and structural practices (buffers, side inlets, urban stormwater management, etc.). Lake restoration and protection strategies focus on reducing nutrient and TSS loading to lakes through land management (tillage, nutrient management, etc.), structural practices (buffers, etc.), and internal load controls (rough fish management). Groundwater protection strategies focus on land management (nutrient management, etc.), structural practices (well sealing, buffers, alternative tile intakes, etc.), and outreach (SSTS compliance, nutrient management, etc.).

Areas for consideration in the Three Mile Creek HUC -10 include:

- Restore and/or protect lakes and stream reaches that are nearly impaired or barely impaired (i.e., within 30% of water quality standards):
    - Three Mile Creek Reach 564/565/566 (impaired by TSS, within 27% of standard)
- Protect vulnerable and sensitive groundwater areas throughout the watershed, particularly WHPAs and DWSMAs with higher vulnerability:
    - City of Marshall

Figure 28. Three Mile Creek HUC-10 Subwatershed.

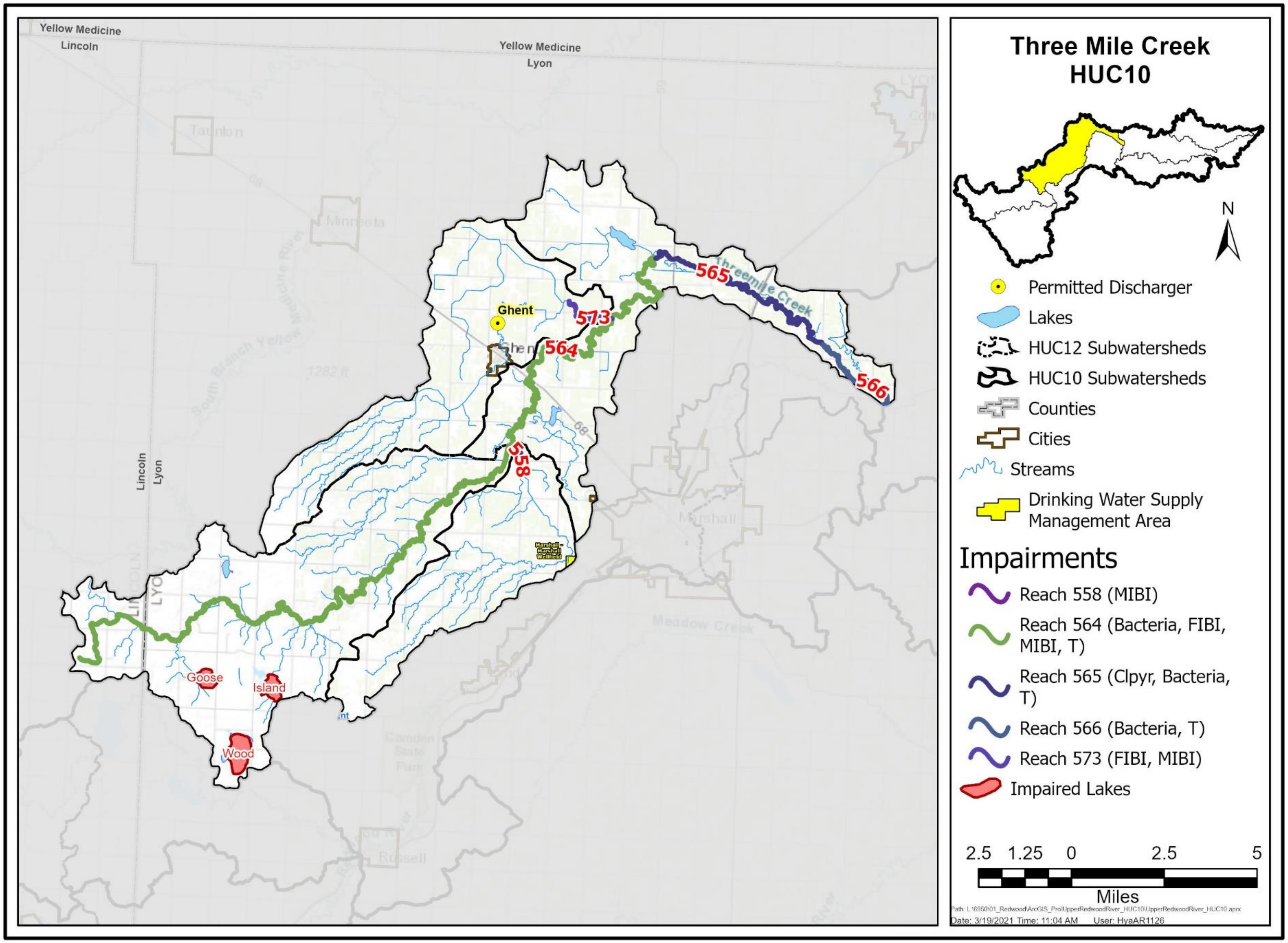


Table 21. Strategies and actions proposed for the Three Mile Creek HUC-10 Subwatershed.

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
							Specific Implementation Strategy	Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
HUC-10 Subwatershed: Three Mile Creek; HUC-12 Subwatersheds: Upper Three Mile Creek, Runholt-Mellenthin Dam, County Ditch No. 63, Lower Three Mile Creek	Three Mile Creek (07020006-564, 565, and 566)	Location = Lyon; Upstream = Lincoln	TSS	90th percentile TSS concentration = 83 mg/L	Maximum 90th percentile TSS concentration = 65 mg/L; 22% reduction	Buffers - field edge	50-ft buffers on streams adjacent to cropland/pasture (390, 391, 327)	cropland: 14,540; pasture: 1,170	cropland: 4%, pasture: 10%	cropland: 10%; pasture: 15%	cropland: 20%; pasture: 25%	% of suitable acres	40
						Tillage/residue management	Adopt reduced tillage (30% + residue cover) and no-till (329, 345, 346)	reduced till: 17,560; no-till: 17,560	reduced till: 11%; no-till: 11%	reduced till: 15%; no-till: 15%	reduced till: 20%; no-till: 20%	% of suitable acres	
						Add cover crops for living cover in fall/spring	Implement cover crops with corn and soybeans (340)	56,370	3%	10%	20%	% of suitable acres	
						Upland water storage/retention	Restore tiled wetlands in marginal areas and as opportunities arise (656, 810M)	8,170	<1%	2%	5%	% of suitable acres	
							Implement controlled tile drainage water management (554)	7,660	<1%	2%	5%	% of suitable acres	
						Conservation practice installation	Construct water and sediment control basins (638) and grassed waterways (412)	WASCOBs and GWs: 18,640	WASCOBs: <1%; GWs: <1%	WASCOBs: 2%; GWs: 5%	WASCOBs: 15%; GWs: 15%	% of suitable acres	
						Open tile inlet and side inlet improvements	Install alternative tile intakes (606, 170M, 172M, 173M)	10,910	2%	10%	25%	% of suitable acres	
							Identify and implement side inlet improvements (410)	NA	Unknown	ID projects/areas	Implement necessary improvements	Improvements	
						Urban Stormwater Runoff Control	ID and implement stormwater BMPs to store water and treat sediment loading from City of Marshall	NA	Unknown	Complete assessment and feasibility	Implement identified projects and education	Completed study and projects	
	Three Mile Creek (07020006-564, 565, and 566)	Location = Lyon; Upstream = Lincoln	Fecal coliform	1,263 cfu/100 mL maximum monthly geomean	Maximum monthly geomean <200 cfu/100 mL; 84% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
						Nutrient management (cropland)	Fertilizer and manure management and incorporation (590)	56,660	20%	50%	96%	% of suitable acres	
						Pasture management	Implement exclusion fencing, grazing rotations in shoreland and high priority areas	NA	Unknown	Work with producers to identify and implement priority projects	Implement priority projects	Completed projects	
						Feedlot runoff controls	Implement feedlot runoff reduction/treatment (635, 784) where needed	NA	Unknown	Work with producers to identify and	Implement projects	Completed projects	

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
										implement projects			
						Septic system improvements	Provide education and maintenance materials for SSTS parcels. Work through current ordinances with landowners to upgrade failing and noncompliant SSTS	NA	Point of sale inspections	Work with landowners to identify and upgrade SSTSs	Upgrade all failing and noncompliant SSTSs	SSTS upgrades	
						Urban stormwater runoff control	ID and implement stormwater BMPs to treat bacteria loading from City of Ghent	NA	Unknown	Complete assessment and feasibility	Implement identified projects and education	Completed assessments and projects	
	Goose Lake (42009300)	Lyon	Phosphorus (TP)	1,667 lb TP/yr; 133 ppb TP summer avg.	967 lb TP/yr; <90 ppb TP summer avg.; 42% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
						Reduce bacteria loads	Implement bacteria reduction strategies outlined above						
						Monitoring	Continue monitoring fish community and rough fish populations (i.e., black bullhead)	NA	Surveyed every 5 years	Continue current schedule	Manage as necessary	Completed surveys	
	Island Lake (42009600)	Lyon	Phosphorus (TP); FIBI	673 lb TP/yr; 119 ppb TP summer avg.; FIBI = 13	408 lb TP/yr; <90 ppb TP summer avg.; 33% reduction	Lake internal load management	Assess sediment, common carp, and other rough fish to determine impact on water quality and native vegetation; develop management strategies	NA	None	Assess fish and development mgt. plan	Manage as necessary	Assessments and mgt. actions	
	Unnamed Tributary (07020006-558)	Lyon	MIBI; Stressors: Altered hydrology, Connectivity, Habitat	MIBI = 19	MIBI > 22	Implement TSS and bacteria reduction strategies outlined above; see watershed-wide Table 17 for additional strategies to address stream biological impairments							50
	Three Mile Creek (07020006-564)	Lyon	FIBI and MIBI; Stressors: Habitat, DO, Eutrophication, TSS	FIBI = 32; Invert IBI = 31	FIBI >55; Invert IBI > 41								
	Unnamed Creek (07020006-573)	Lyon	FIBI and Invert IBI; Stressors: Altered hydrology, Eutrophication, NO3	FIBI = 44; Invert IBI = 19	FIBI >55; Invert IBI > 37								

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
	Wood Lake (42007800)	Lyon	FIBI	FIBI = 16, 4	FIBI >36	Reduce sediment loads	Implement TSS reduction strategies outlined above						
						Reduce phosphorus loading	Implement eutrophication reduction strategies outlined above in watershed-wide Table 17						
						Shoreline restoration and protection	Promote and maintain riparian areas with use of shoreline buffers	NA	NA	ID projects/areas	Implement priority improvements	Improvements	
						Monitoring	Consider expanding water quality monitoring program to track trends, fill data gaps, and support future assessments	NA	NA	Continue current schedule	Manage as necessary	Completed surveys	
							Continue monitoring fish community and rough fish populations (i.e., common carp, black bullhead)	NA	Surveyed every 1-4 years	Assess fish and development mgt. plan	Manage as necessary	Assessments and mgt. actions	
						Lake internal load management	Assess common carp, and other rough fish to determine impact on water quality and native vegetation; develop management strategies	NA	None	Assess fish and development mgt. plan	Manage as necessary	Assessments and mgt. actions	
										-	-		
	Unnamed Creek (07020006-572)	Lyon	High watershed and riparian risk (MPCA Tool)	Low protection	Increase protection of stream reach	Implement TSS and bacteria strategies outlined above; see watershed-wide Table 17 for strategies to protect stream biota							50
	Marshall WHPA	Lyon	GW Quality	High vulnerability	Protect GW quality, particularly vulnerable areas	See watershed-wide Table 17 for strategies to protect groundwater; implement TSS and bacteria strategies outlined above							
	Groundwater - general	Lyon	GW Quality	Vulnerable GW areas = 2,917 acres									

Color Key:

- Restoration
- Protection

Clear Creek HUC-10 Subwatershed

Clear Creek (0702000605-01) HUC-10 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 (Figure 31). Most of the subwatershed is in Redwood County, with a small portion in Lyon County. This subwatershed consists of Clear Creek and several unnamed tributaries that flow to Clear Creek. All the stream reaches are warmwater and channelization is prevalent with 81% of the stream reach lengths altered, and only 6% natural channels. HUC-12 subwatersheds include Upper Judicial Ditch No. 31, Judicial Ditch No. 14 and 15, and Lower Judicial Ditch No. 31.

The dominant land use in this subwatershed is cropland (91%), which is the second highest percentage of the subwatersheds in the Redwood River Watershed. Developed areas account for 5% of the 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. Towns present in the subwatershed include Milroy (population 271) and Seaforth (population 77).

Stream restoration and protection strategies in the Clear Creek HUC-10 subwatershed (Table 22) focus on reducing TSS, bacteria, and nutrient loading through land management (residue, cover crops, nutrient and pasture management, etc.), and structural practices (buffers, side inlets, urban stormwater management, etc.). Groundwater protection strategies focus on land management (nutrient management, etc.), structural practices (well sealing, buffers, alternative tile intakes, etc.), and outreach (SSTS compliance, nutrient management, etc.).

Areas for consideration in the Clear Creek HUC-10 include:

- Restore and/or protect lakes and stream reaches that are nearly impaired or barely impaired (i.e., within 30% of water quality standards):
    - Clear Creek Reach 567/568 (impaired by TSS, within 13% of standard)
- Protect vulnerable and sensitive groundwater areas throughout the watershed, particularly WHPAs and DWSMAs with higher vulnerability:
    - City of Marshall

Figure 29. Clear Creek HUC-10 Subwatershed.

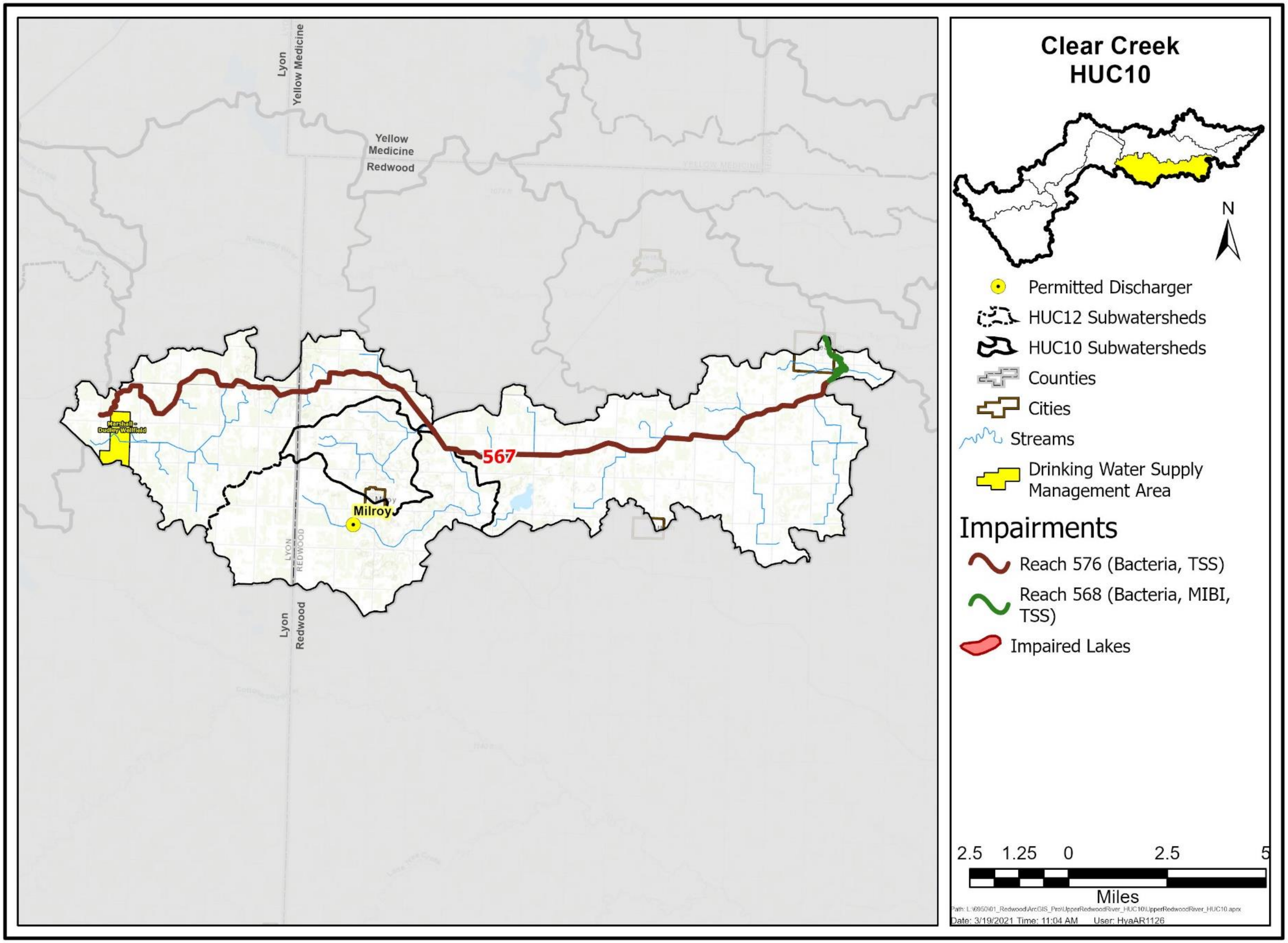


Table 22. Strategies and actions proposed for the Clear Creek HUC-10 Subwatershed.

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location: Water Body (ID)	Water Body and Location: Location and Upstream Influence Counties	Parameter (incl. nonpollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goals / Targets and Estimated % Reduction	Strategy type (see key below)	Specific Implementation Strategy	Estimated Adoption Rate: HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested adoption to meet TMDL and protection goals	Estimated Adoption Rate: Units	Estimated Years to Achieve Water Quality Target
HUC-10 Subwatershed: Clear Creek; HUC-12 Subwatersheds: Upper JD No. 31, JD No. 14 and 15, Lower JD No. 31	Clear Creek (07020006-567 and 568)	Lyon, Redwood	TSS	90th percentile TSS concentration = 65 mg/L	Maximum 90th percentile TSS concentration = 65 mg/L; 5% reduction recommended to ensure the TSS standard is met	Buffers - field edge	50-ft buffers on streams adjacent to cropland/pasture (390, 391, 327)	cropland: 6,080; pasture:7	cropland: <1%; pasture: 2%	cropland: 5%; pasture: 10%	cropland: 25%; pasture: 25%	% of suitable acres	35
						Tillage/residue management	Adopt reduced tillage (30% + residue cover) and no-till (329, 345, 346)	reduced till: 8,760; no-till: 8,760	reduced till: 3%; no-till: 3%	reduced till: 8%; no-till: 5%	reduced till: 20%; no-till: 20%	% of suitable acres	
						Add cover crops for living cover in fall/spring	Implement cover crops with corn and soybeans (340)	47,380	2%	5%	12%	% of suitable acres	
						Upland water storage/retention	Restore tiled wetlands in marginal areas and as opportunities arise (656, 810M)	11,000	<1%	2%	5%	% of suitable acres	
							Implement controlled tile drainage water management (554)	14,020	<1%	2%	5%	% of suitable acres	
						Conservation practice installation	Construct water and sediment control basins (638) and grassed waterways (412)	WASCOBs and GWs: 9,080	WASCOBs: <1%; GWs: <1%	WASCOBs: 2%; GWs: 5%	WASCOBs: 15%; GWs: 15%	% of suitable acres	
						Open tile inlet and side inlet improvements	Install alternative tile intakes (606, 170M, 172M, 173M)	19,960	4%	10%	20%	% of suitable acres	
							Identify and implement side inlet improvements (410)	NA	Unknown	Implement necessary improvements and upland treatment	Implement necessary improvements	Improvements	
						Urban stormwater runoff control	ID and implement stormwater BMPs to store water and treat sediment loading from Cities of Milroy, Lucan, and Seaforth	NA	Unknown	Complete assessment and feasibility	Implement identified projects and education	Completed assessments and projects	
	Clear Creek (07020006-567 and 568)	Lyon, Redwood	Fecal coliform	935 cfu/100 mL maximum monthly geomean	Maximum monthly geomean <200 cfu/100 mL; 79% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
						Nutrient management (cropland)	Fertilizer and manure management and incorporation (590)	47,380	12%	50%	98%	% of suitable acres	
						Feedlot runoff controls	Implement feedlot runoff reduction/treatment (635, 784) where needed	NA	Unknown	Work with producers to identify and implement projects	Implement projects	Completed projects	

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
						Septic system improvements	Provide education and maintenance materials for SSTS parcels. Work through current ordinances with landowners to upgrade failing and noncompliant SSTS	NA	Point of sale inspections	Work with landowners to identify and upgrade SSTSs	Upgrade all failing and noncompliant SSTSs	SSTS upgrades	
	Clear Creek (07020006-568)	Location = Redwood; Upstream = Lyon	MIBI; Stressors: Eutrophication, TSS, NO3	MIBI = 11	MIBI > 37	Implement TSS and bacteria reduction strategies outlined above; see watershed-wide Table 17 for additional strategies to address stream biological impairments							50
										-	-		
	Unnamed Creek (07020006-562)	Redwood	Med/high riparian risk and high watershed risk (MPCA Tool)	Low protection	Increase protection of stream reaches	Implement TSS and bacteria strategies outlined above; see watershed-wide Table 17 for strategies to protect stream biota							50
	Judicial Ditch 14 and 15 (07020006-517)	Redwood	High riparian and watershed risk (MPCA Tool)	Low protection									
	Marshall Dudley DWSMA/WHPA	Lyon	GW Quality	High vulnerability	Protect GW Quality, particularly vulnerable areas	See watershed-wide Table 17 for strategies to protect groundwater; implement TSS and bacteria strategies outlined above							
	Groundwater - general	Lyon	GW Quality	Vulnerable GW areas = 3,090 acres									

Color Key:

- Restoration
- Protection

Ramsey Creek HUC-10 Subwatershed

Ramsey Creek (0702000606-01) HUC-10 is a northeastern subwatershed that outlets to the Redwood River near Redwood Falls (Figure 32). This is the downstream-most subwatershed in the Redwood River Watershed before its confluence with the Minnesota River. This subwatershed encompasses 67 square miles (43,000 acres) of Redwood County, and a smaller portion of Yellow Medicine County. All the stream reaches are considered warmwater, with 88% of the stream reaches channelized. The last four miles of Ramsey Creek, just upstream of Ramsey Falls and the creek's confluence with the Redwood River, is natural and managed as a put and take trout fishery by the DNR. HUC-12 subwatersheds include Judicial Ditch No. 33, Judicial Ditch No. 32, and Ramsey Creek.

Most of the subwatershed is agricultural with 92% cropland. Wetlands comprise 1%, forest 1%, rangeland 1%, and open water less than 1% of the watershed area. Less than 1% of the watershed area is barren/mining.

Stream restoration and protection strategies in the Ramsey Creek HUC-10 subwatershed (Table 23) focus on reducing TSS, bacteria, and nutrient loading through land management (residue, cover crops, nutrient and pasture management, etc.), and structural practices (buffers, tile drainage water treatment, side inlets, urban stormwater management, etc.). Groundwater protection strategies focus on land management (nutrient management, etc.), structural practices (well sealing, buffers, alternative tile intakes, etc.), and outreach (SSTS compliance, nutrient management, etc.).

Areas for consideration in the Ramsey Creek HUC-10 include:

- Restore and/or protect lakes and stream reaches with high recreational use and value
  - Lower Ramsey Creek upstream of Ramsey Falls (trout stream)

Figure 30. Ramsey Creek HUC-10 Subwatershed.

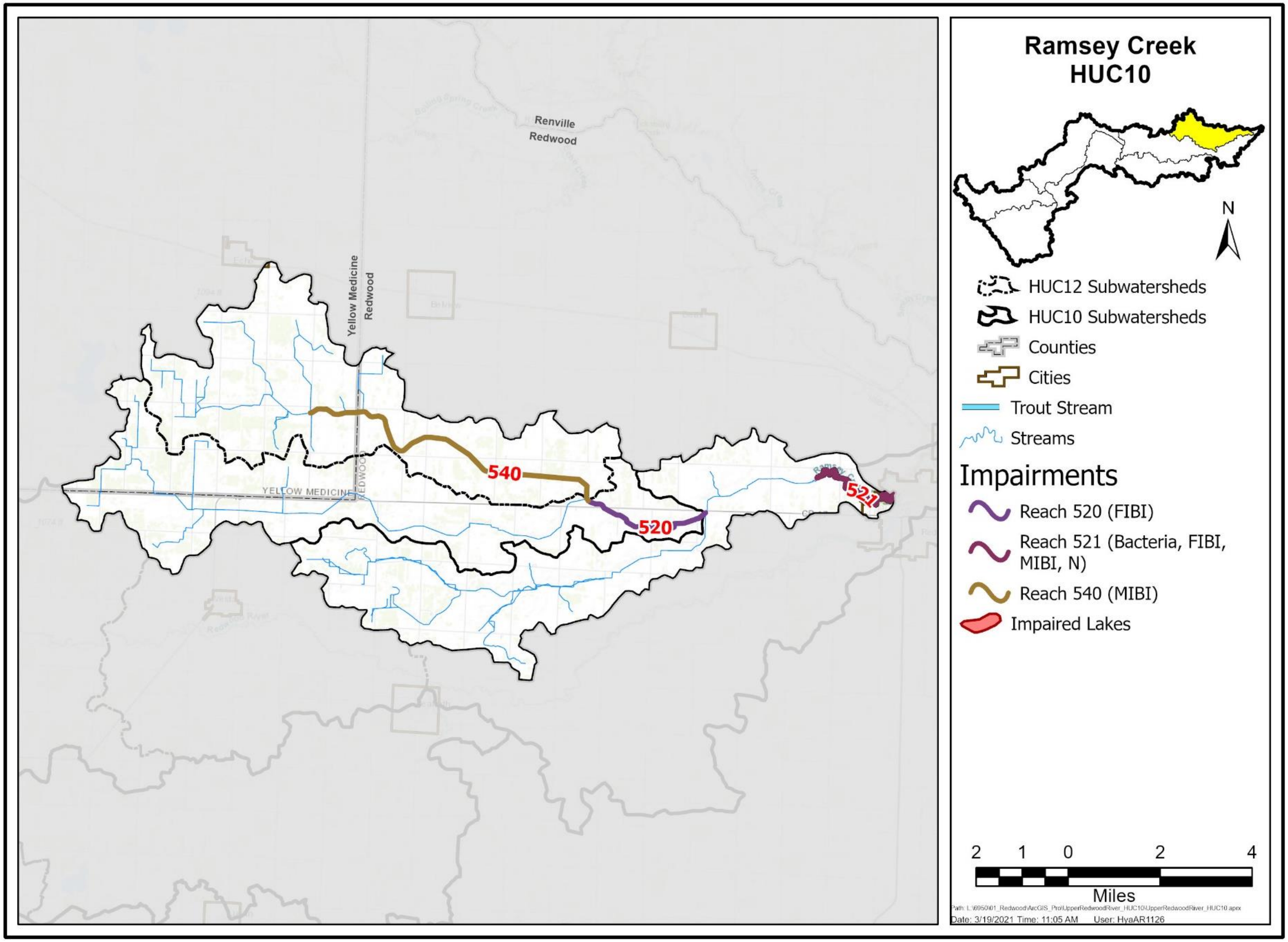


Table 23. Strategies and actions proposed for the Ramsey Creek HUC-10 Subwatershed.

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
HUC-10 Subwatershed: Ramsey Creek; HUC-12 Subwatersheds: JD No. 32, JD No. 33, Ramsey Creek	Ramsey Creek (07020006-521)	Location = Redwood; Upstream = Yellow Medicine	Nitrate	Maximum Nitrate concentration = 18.8 mg/L	Maximum nitrate concentration = 10 mg/L; 47% reduction	Buffers - field edge	50-ft buffers on streams adjacent to cropland/pasture (390, 391, 327)	cropland: 6,465; pasture: 10	cropland: <1%; pasture: 2%	cropland: 5%; pasture: 5%	cropland: 15%; pasture: 15%	% of suitable acres	50
						Nutrient management (cropland)	Fertilizer and manure management and incorporation (590)	38,920	11%	50%	75%	% of suitable acres	
						Tillage/residue management	Adopt reduced tillage (30% + residue cover) and no-till (329, 345, 346)	reduced till: 12,180; no-till: 12,180	reduced till: <1%; no-till: <1%	reduced till: 5%; no-till: 5%	reduced till: 20%; no-till: 20%	% of suitable acres	
						Add cover crops for living cover in fall/spring	Implement cover crops with corn and soybeans (340)	37,010	5%	12%	15%	% of suitable acres	
						Agricultural tile drainage water treatment	Install tile line bioreactors (747)	NA	Unknown	5%	8%	% of suitable acres	
							Restore and/or construct wetlands for storage and treatment (656, 810M)	8,670	<1%	2%	5%	% of suitable acres	
							Implement controlled tile drainage water management (554)	7,510	<1%	2%	5%	% of suitable acres	
							Implement saturated buffers (604)	NA	Unknown	ID potential sites	Construct priority buffers	Completed projects	
						Open tile inlet and side inlet improvements	Install alternative tile intakes (606, 170M, 172M, 173M)	11,500	4%	10%	20%	% of suitable acres	
							Identify and implement side inlet improvements (410)	NA	Unknown	Implement necessary improvements and upland treatment	Implement necessary improvements	Improvements	
	Ramsey Creek (07020006-521)	Location = Redwood; Upstream = Yellow Medicine	*E. coli*	277 org./100 mL maximum monthly geomean	Maximum monthly geomean <126 org./100 mL; 55% reduction	Reduce nutrient loads	Implement nitrate reduction strategies outlined above						50
						Feedlot runoff controls	Implement feedlot runoff reduction/treatment (635, 784) where needed	NA	Unknown	Work with producers to identify and implement projects	Implement projects	Completed projects	
						Septic system improvements	Provide education and maintenance materials for SSTS parcels. Work through current ordinances with landowners to	NA	Point of sale inspections	Work with landowners to identify and upgrade SSTSs	Upgrade all failing and noncompliant SSTSs	SSTS upgrades	

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
							upgrade failing and noncompliant SSTS						
	Judicial Ditch 33 (07020006-520)	Location = Redwood; Upstream = Yellow Medicine	FIBI; Stressors: Connectivity, Habitat, Eutrophication, NO3	FIBI = <1	FIBI > 35	Implement TSS and bacteria reduction strategies outlined above; see watershed-wide Table 17 for additional strategies to address stream biological impairments							50
	Ramsey Creek (07020006-521)	Location = Redwood; Upstream = Yellow Medicine	FIBI and MIBI; Stressors: Connectivity, TSS, NO3	FIBI = 20; MIBI = 14	FIBI > 50; MIBI > 37								
	Judicial Ditch 32 (07020006-540)	Yellow Medicine, Redwood	MIBI; Stressors: Altered hydrology, Connectivity, Habitat, Eutrophication, TSS, NO3	MIBI = 18	MIBI > 22								
										-	-		
	Unnamed Creek (07020006-561)	Lyon, Redwood	Med/high riparian risk and high watershed risk (MPCA Tool)	Med/low protection	Increase protection of stream reach	Implement TSS, bacteria, and watershed-wide strategies Table 17 to increase protection							50
	Groundwater - general	Lyon	GW Quality	Vulnerable GW areas = 5,093 acres	Protect GW Quality, particularly vulnerable areas	See watershed-wide Table 17 for strategies to protect groundwater; implement Nitrate and bacteria strategies outlined above							

Color Key:

(pink)	Restoration
(green)	Protection

Lower Redwood River HUC-10 Subwatershed

The Lower Redwood River (0702000607-01) HUC-10 is the largest subwatershed within the Redwood River Watershed (Figure 33). This subwatershed covers approximately 123 square miles (79,000 acres) 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 several tributaries to the mainstem such as Judicial Ditch 3, County Ditch 92, and County Ditch 33. HUC-12 subwatersheds include County Ditch No. 3 – Redwood River, County Ditch No. 80 – Redwood River, County Ditch No. 33 – Redwood River, and Redwood River. All 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. A prominent natural feature on the Redwood River is Lake Redwood and the 45-foot waterfall present within Cansa'yapi Oyate (formerly Alexander Ramsey Park) in Redwood Falls.

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, which includes the town of Vesta (population 339) and portions of Redwood Falls (population 5,459), which is the second largest town in the watershed. Wetlands account for 2%, while open water comprises 1% of the subwatershed area. Lakes found within the subwatershed include School Grove (337 acres), and Lake Redwood (54 acres). Forest, rangeland, and barren/mining make up less than 1% of subwatershed area. Stream restoration and protection strategies in the Lower Redwood River HUC-10 subwatershed (Table 24) focus on reducing TSS, bacteria, and nutrient loading through land management (residue, cover crops, nutrient and pasture management, etc.) and structural practices (buffers, side inlets, urban stormwater management, etc.). Lake restoration and protection strategies focus on reducing nutrient and TSS loading to lakes through land management (tillage, nutrient management, etc.), structural practices (buffers, etc.), and internal load controls (rough fish management). Groundwater protection strategies focus on land management (nutrient management, etc.), structural practices (well sealing, buffers, alternative tile intakes, etc.), and outreach (SSTS compliance, nutrient management, etc.).

Areas for consideration in the Lower Redwood River HUC-10 include:

- Restore and/or protect lakes and stream reaches that are nearly impaired or barely impaired (i.e., within 30% of water quality standards):
    - School Grove Lake (impaired, within 14% of standard)
- Protect vulnerable and sensitive groundwater areas throughout the watershed, particularly WHPAs and DWSMAs with higher vulnerability:
    - Redwood Falls WHPA

Figure 31. Lower Redwood River HUC-10 Subwatershed.

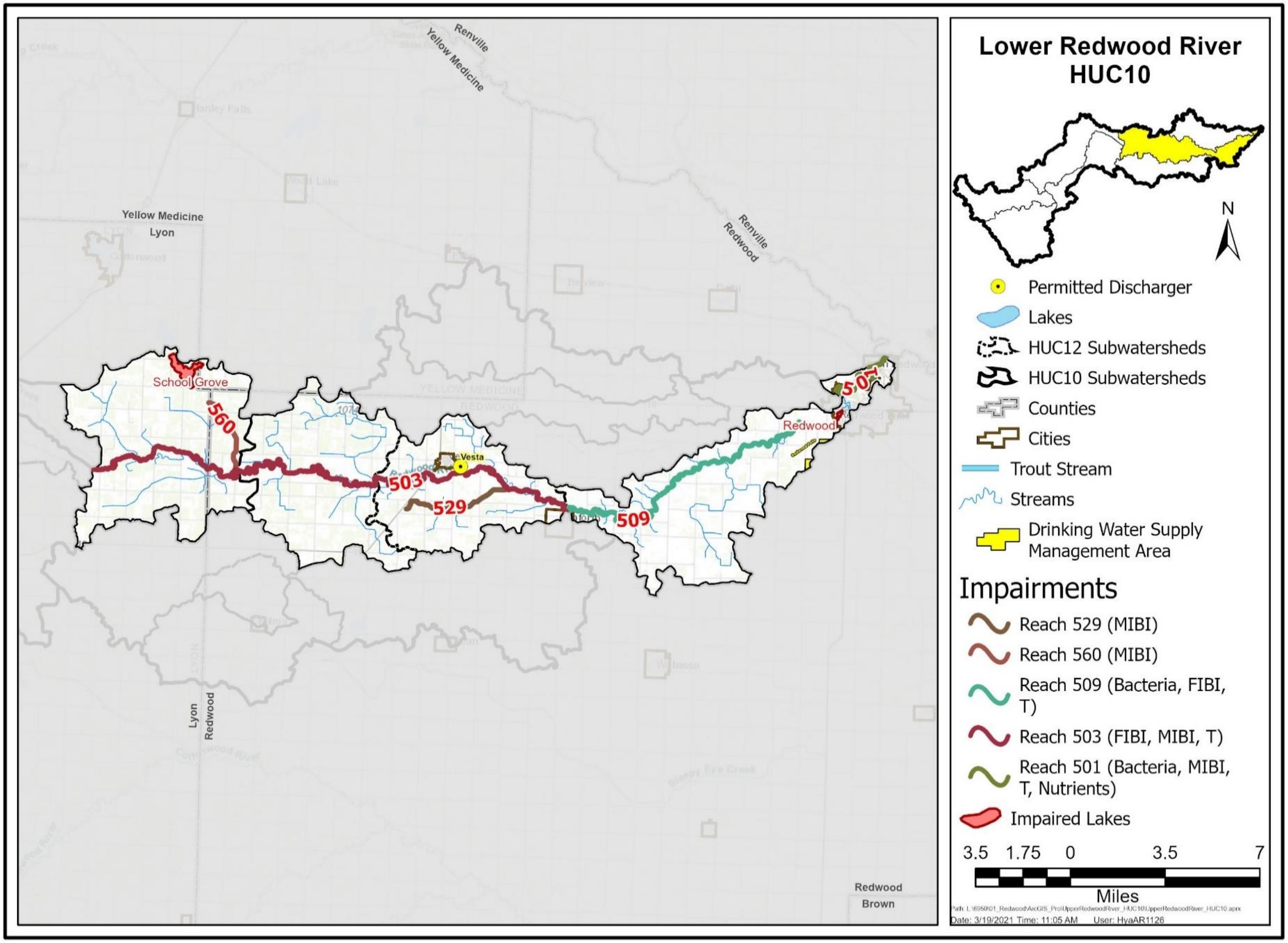


Table 24. Strategies and actions proposed for the Lower Redwood River HUC-10 Subwatershed.

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
HUC-10 Subwatershed: Lower Redwood River; HUC-12 Subwatersheds: County Ditch No. 3, County Ditch No. 80, County Ditch No. 33, Redwood River	Redwood River (07020006-501)	Location = Redwood; Upstream = Lincoln, Pipestone, Murray, Lyon, Yellow Medicine	TSS	90th percentile TSS concentration = 76 mg/L	Maximum 90th percentile TSS concentration = 65 mg/L; 14% reduction	Buffers - field edge	50-ft buffers on streams adjacent to cropland/pasture (390, 391, 327)	cropland: 10,240; pasture: 195	cropland: 61%; pasture: 68%	cropland: 70%; pasture: 70%	cropland: 70%; pasture: 70%	% of suitable acres	35 - 50
						Tillage/residue management	Adopt reduced tillage practices (conservation tillage and no-till; 329, 345, 346)	reduced till: 17,000; no-till: 17,000	reduced till: 14%; no-till: 14%	reduced till: 20%; no-till: 20%	reduced till: 30%; no-till: 30%	% of suitable acres	
						Add cover crops for living cover in fall/spring	Implement cover crops with corn and soybeans (340)	62,440	5%	8%	15%	% of suitable acres	
						Upland water storage/retention	Restore tiled wetlands in marginal areas and as opportunities arise (656, 810M)	14,010	<1%	2%	5%	% of suitable acres	
	Redwood River (07020006-509)	Location = Redwood; Upstream = Lincoln, Pipestone, Murray, Lyon, Yellow Medicine	TSS	90th percentile TSS concentration = 150 mg/L	Maximum 90th percentile TSS concentration = 65 mg/L; 57% reduction		Implement controlled tile drainage water management (554)	9,860	<1%	2%	5%	% of suitable acres	
						Conservation practice installation	Construct water and sediment control basins (638) and grassed waterways (412)	WASCOBs and GWs: 17,325	WASCOBs: 1%; GWs: 0.01%	WASCOBs: 2%; GWs: 5%	WASCOBs: 15%; GWs: 15%	% of suitable acres	
						Open tile inlet and side inlet improvements	Install alternative tile intakes (606, 170M, 172M, 173M)	12,835	8%	15%	25%	% of suitable acres	
							Identify and implement side inlet improvements (410)	NA	Unknown	ID projects/areas	Implement necessary improvements	Improvements	
						Urban stormwater runoff control	ID and implement stormwater BMPs to store water and treat sediment loading from Cities of Vesta, Seaforth, and Redwood Falls	NA	Unknown	Complete assessment and feasibility	Implement identified projects and education	Completed assessments and projects	
	Redwood River (07020006-501)	Location = Redwood; Upstream = Lincoln, Pipestone, Murray, Lyon, Yellow Medicine	Fecal coliform	222 cfu/100 mL maximum monthly geomean	Maximum monthly geomean <200 cfu/100 mL; 10% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined in other HUC-10 Tables 18 - 24						50
						Nutrient management (cropland)	Fertilizer and manure management and incorporation (590)	63,100	17%	50%	75%	% of suitable acres	
						Feedlot runoff controls	Implement feedlot runoff reduction/treatment (635, 784) where needed	NA	Unknown	Work with producers to identify and implement projects	Implement projects	Completed projects	
	Redwood River (07020006-509)	Location = Redwood; Upstream = Lincoln,	Fecal coliform	354 cfu/100 mL maximum monthly geomean	Maximum monthly geomean <200	Septic system improvements	Provide education and maintenance materials for SSTS parcels. Work through current ordinances with landowners to	NA	Point of sale inspections	Work with landowners to identify and upgrade SSTSs	Upgrade all failing and noncompliant SSTSs	SSTS upgrades	

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
		Pipestone, Murray, Lyon, Yellow Medicine			cfu/100 mL; 44% reduction		upgrade failing and noncompliant SSTS						
						Urban stormwater runoff control	ID and implement stormwater BMPs to treat bacteria loading from Cities of Vesta, Seaforth, and Redwood Falls	NA	Unknown	Complete assessment and feasibility	Implement identified projects and education	Completed assessments and projects	
	Redwood River (07020006-501)	Location = Redwood; Upstream = Lincoln, Pipestone, Murray, Lyon, Yellow Medicine	Phosphorus (TP)	303 ppb TP summer avg.	<150 ppb TP summer avg.; 50% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined in other HUC-10 Tables 18 - 24						50
						Reduce phosphorus loads	Implement eutrophication reduction strategies outlined above in watershed-wide Table 17						
						Wastewater point source management	Will be addressed following the completion of the Redwood River RES TMDL for reach 501						
						Dredging	Complete Lake Redwood Reclamation and Enhancement Project to remove 650,000 cubic yards of sediment	NA	Project started in 2020	Complete project	Complete project	Completed project	
	School Grove Lake (42000200)	Lyon, Yellow Medicine	Phosphorus (TP)	1,638 lb TP/yr; 99 ppb TP summer avg.	1,401 lb TP/yr; <90 ppb TP summer avg.; 14% reduction	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
						Reduce phosphorus Loads	Implement eutrophication reduction strategies outlined above in watershed-wide Table 17						
						Monitoring	Continue monitoring fish community and rough fish populations	NA	Surveyed every 5 years	Continue current schedule	Manage as necessary	Completed surveys	
						Lake Internal load management	Develop lake management plan to address internal sources of phosphorus (sediment and carp)	NA	Sediment cores and carp assessment completed during TMDL study	Development mgt. plan	Manage as necessary	Management plan and actions	
	Redwood River (07020006-501)	Location = Redwood; Upstream = Lincoln, Pipestone, Murray, Lyon, Yellow Medicine	MIBI; Stressors: TSS, NO3	MIBI = 25	MIBI > 31	Implement TSS and bacteria reduction strategies outlined above; see watershed-wide Table 17 for additional strategies to address stream biological impairments							50

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	
	Redwood River (07020006-503)	Location = Redwood; Upstream = Lincoln, Pipestone, Murray, Lyon, Yellow Medicine	FIBI and MIBI; Stressors Altered hydrology, Habitat, Eutrophication, TSS, NO3	FIBI = 29, 41; MIBI = 33	FIBI > 49; MIBI > 41								
	Redwood River (07020006-509)	Location = Redwood; Upstream = Lincoln, Pipestone, Murray, Lyon, Yellow Medicine	FIBI; Stressors: Connectivity, Eutrophication, TSS, NO3	FIBI = 29	FIBI > 49								
	County Ditch 33 (07020006-529)	Redwood	MIBI; Stressors: Altered hydrology, Connectivity, Habitat, DO, NO3	MIBI = 20	MIBI > 22								
	Judicial Ditch 3 (07020006-560)	Location = Redwood, Lyon; Upstream = Yellow Medicine	MIBI; Stressors: Altered hydrology, Connectivity, Habitat, DO, Eutrophication, NO3	MIBI = 17	MIBI > 22								
										-	-		
	Lake Redwood (07020006)	Location = Redwood; Upstream = Lincoln, Pipestone, Murray, Lyon, Yellow Medicine	Phosphorus (TP)	379 ppb TP summer avg.	Track and improve water quality conditions	Reduce sediment loads	Implement TSS reduction strategies outlined above						50
	Lake Redwood (07020006)					Reduce nutrient loads	Implement eutrophication reduction strategies outlined above in watershed-wide Table 17						50
	Lake Redwood (07020006)					Monitoring	Consider expanding water quality monitoring program to track trends as future improvements are made and to support future assessments	NA	NA	Develop and implement monitoring plan	Routine monitoring	Monitor water quality	50
	Lake Redwood (07020006)					Monitoring	Monitor fish community	NA	Last surveyed in 2006	Monitor approx. every 5 years	Manage as necessary	Completed surveys	50
	Redwood Falls WHPA	Redwood	GW Quality	Moderate vulnerability	Protect GW Quality, particularly vulnerable areas	See watershed-wide Table 17 for strategies to protect groundwater; implement TSS and bacteria strategies outlined above							50
	Groundwater - general	Lyon	GW Quality	Vulnerable GW areas = 11,916 acres	Protect GW Quality, particularly vulnerable areas	See watershed-wide Table 17 for strategies to protect groundwater; implement TSS and bacteria strategies outlined above							50

HUC-10 Subwatershed; HUC-12 Subwatersheds	Water Body and Location		Parameter (incl. nonpollutant stressors)	Water Quality		Strategy type (see key below)	Strategy scenario showing estimated scale of adoption to meet 10 yr. milestone and final water quality targets						Estimated Years to Achieve Water Quality Target
								Estimated Adoption Rate					
	Water Body (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Specific Implementation Strategy	HSPF-SAM Strategy/BMP Suitable Acres for Subwatershed	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested adoption to meet TMDL and protection goals	Units	

Color Key:

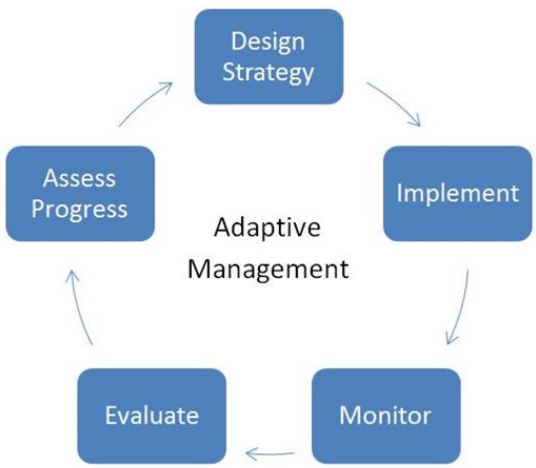
(pink)	Restoration
(green)	Protection

4. Monitoring Plan

Ongoing monitoring of both land management and water resources is needed to inform and calibrate watershed models and evaluate progress towards defined goals, and desired outcomes. Section 7 of the concurrently developed Redwood River Watershed TMDL Report includes more information on monitoring.

It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. The response of the lakes and streams will be monitored and subsequently evaluated as management practices are implemented. The management approach to achieve the goals should be adapted as new monitoring data are collected and evaluated (i.e., adaptive management approach, Figure 33). Continued monitoring and “course corrections” responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in these watersheds. Management activities will be changed or refined to efficiently meet the TMDLs and lay the groundwork for de-listing the impaired water bodies.

Figure 32. Adaptive management framework.



If the restoration and protection strategies are fully adopted, it is expected that on average, water quality pollutant concentrations could decline each year equivalent to approximately 2.3% of the starting (i.e., long-term) pollutant load reduction for the TSS impairments, 3.3% for the *E. coli* impairments, 2.5% for the chloride impairment, 2.5% for the river eutrophication (TP) impairment, and 0.9% for the lake TP impairments.

This is a general guideline. Factors that may mean slower progress include limits in funding or landowner acceptance, challenging fixes (e.g., invasive species, lake internal load management) and unfavorable climatic factors. Conversely, there may be faster progress for some impaired waters, especially where high-impact fixes are slated to occur.

Data from numerous monitoring programs will continue to be collected and analyzed throughout the Redwood River Watershed. Monitoring is conducted by local, state, and federal entities, and also special projects as described below.

Intensive Watershed Monitoring

Through the State of Minnesota's Watershed Approach, the MPCA collects water quality and biological data for two years every 10 years at established stream and lake monitoring stations within every major watershed in the state. The first round of IWM for the Redwood River Watershed was completed in 2017 and 2018. In addition to the chemistry and biological monitoring completed by the MPCA, water chemistry monitoring for two lakes and eight streams was completed through a Surface Water Assessment Grant (SWAG) with RCRCA. Lake samples were collected from May through September for both years. 2017 stream samples were collected May through September, while 2018 samples were collected from June through August. RCRCA staff collected the samples, transported samples to the laboratory, verified results entered in the EQuIS database, and administered the grant. These efforts are summarized in the Redwood River Watershed Monitoring and Assessment Report (MPCA 2020a).

The second cycle of monitoring and assessment will start in 2027. The MPCA, with assistance from LGUs, will re-visit and re-assess some of the cycle 1 monitoring stations, as well as consider monitoring new sites with demonstrated local or state importance. It is expected that funding for monitoring and analysis will be available through the MPCA.

Watershed Pollutant Load Monitoring Network

The WPLMN, which includes state and federal agencies, Metropolitan Council Environmental Services, state universities, and local partners, collects data on water quality and flow in Minnesota to calculate pollutant loads in rivers and streams. Data are collected at 199 sites around the state. Each year, approximately 25 to 35 water quality samples are collected at each monitoring site, either year-round or seasonally depending on the site. Water quality samples are collected near flow gaging stations, and typically analyzed for TSS, TP, nitrate-nitrogen, Total Kjeldahl nitrogen (TKN), and dissolved orthophosphate (PO4). Samples are collected more frequently when water flow is moderate and high, when pollutant levels are typically elevated and most changeable. Pollutant concentrations are generally more stable when water flows are low, and fewer samples are taken in those conditions. This staggered approach generally results in samples collected over the entire range of flows.

Data collected through WPLMN are used to assist in watershed modeling, determine pollutant source contributions, evaluate trends, develop reports, and measure water quality restoration efforts. There are three WPLMN sites within the Redwood River Watershed, all on the Redwood River at: Russell (CR15), Marshall (300th St), and Redwood Falls (see Section 2.2).

Volunteer Water Monitoring Program

The MPCA's Volunteer Water Monitoring Program relies on a network of volunteers who take stream and lake measurements regularly, with the data reported annually. Data collected through these efforts can provide a continuous record of water body transparency throughout much of the state. There is currently a limited number of volunteers performing monitoring within the Redwood River Watershed. The MPCA and local units of government have sought and will continue to seek more volunteers to monitor water quality and transparency for surface waters within the watershed.

RCRCA

RCRCA has a long history of water quality monitoring in the Redwood River Watershed with a special focus on sediment and nutrient contributions from tributaries of the Redwood River. Water quality monitoring efforts have been based on a three-tier system. Primary, secondary, and tertiary monitoring stations have been developed to assess areas of the watershed delivering the greatest amount of sediment and nutrients to the Redwood River. RCRCA monitoring in the Redwood River Watershed includes snowmelt, storm event, and baseflow monitoring with analysis for TSS, TKN, nitrate-nitrogen, PO4 and TP. This information has been used to select priority management areas and measure progress toward watershed goals.

Discovery Farms Monitoring

Discovery Farms Minnesota is a farmer-led effort to gather field scale water quality information from different types of farming systems, in landscapes across Minnesota. The mission of the Discovery Farms program is to gather water quality information under real-world conditions. The goal is to provide practical, credible, site-specific information to enable better farm management.

The program is designed to collect accurate measurements of sediment, nitrogen, and phosphorus movement over the soil surface and through subsurface drainage tiles. This work leads to a better understanding of the relationship between agricultural management and water quality. Discovery Farms are currently located at several sites across Minnesota. The network is expected to grow, over time, to include farms that represent the diversity of agricultural operations in Minnesota.

Discovery Farms Minnesota is coordinated by the Minnesota Agricultural Water Resources Center (MAWRC), in partnership with the MDA, and the University of Minnesota Extension. Much of the sampling and data collection is done by staff from local County, SWCD, and/or watershed management organizations.

There are currently two Discovery Farms monitoring locations in the Redwood River Watershed – Redwood North and Redwood South, which are both located in Redwood County north of Wabasso (Figure 26). The Redwood North site drains approximately 12.5 acres of corn-soybean crop rotation through both surface runoff and subsurface tile; similarly, the Redwood South site drains approximately 10.2 acres of corn-soybean rotation. These sites are designed to provide information that will lead to a better understanding of how farm nutrient management practices can impact sediment and nutrient movement to surface waters. Monitoring for these sites began in 2016 with monitoring and sample collection performed by RCRCA staff. Chemistry samples are analyzed for TSS, TP, PO4, TKN, ammonia nitrogen, and nitrate-nitrogen. Total runoff volume from overland and tile drainage are also measured which allows for the estimate of total pollutant load coming off the plots.

Pesticide Monitoring

The purpose of the MDA's pesticide monitoring program is to determine the presence and concentration of pesticides in Minnesota waters, and present long-term trend analysis based on information collected over the past 30 years. Trend analysis requires long-term investments in monitoring within MDA's established networks. The MDA releases an annual water quality monitoring report that includes all pesticide water quality data and long-term trends available on MDA's website. The MDA will continue to conduct statewide pesticide monitoring in the future and will provide additional information related to the occurrence of pesticides in Minnesota waters.

MDA completed 14 pesticide water quality sample collection events from 7 lakes within the Cottonwood and Redwood River watersheds from 2012 through 2019. None of the lakes sampled in the Redwood River Watershed were above the applicable pesticide water quality reference values.

The MDA completed 517 pesticide and/or nutrient water quality sample collection events from 10 river and stream locations within the Cottonwood and Redwood River watersheds from 1992 through 2019. Samples are analyzed for dozens of pesticides. To date, no river and stream pesticide impairments have been identified in the Redwood River Watershed. The MDA will continue to monitor these locations into the future to allow for analysis of pesticide detections over time.

Finally, the MDA completed 10 pesticide water quality sample collection events from 5 wetlands within the Cottonwood and Redwood River Watersheds in 2014. No pesticide detections in the wetlands in either watershed were above the applicable water quality reference values.

Southwest Minnesota State University Monitoring

Through a grant obtained in 2004, Southwest Minnesota State University (SMSU) developed the Redwood River Mentoring and Monitoring Project that focused on the Redwood River in Marshall. The project was focused on active learning, civic engagement, and collaboration with local secondary educators (Holly Knudson, Marshall High School and Carrie Sueker, Marshall Middle School). The project was able to expand and include broader outreach in 2016 to include students studying agriculture through funding provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR). The project ended spring 2020, after 16 years of data collection, when Dr. Emily Deaver, the Principal Investigator on the project, retired from SMSU. A total of 3,945 students (college, high school, and 7th grade) were mentored over the course of the project (Figure 33).

Figure 33. Data collection by 7th grade, high school, and SMSU college students on the Redwood River at Wayside Rest near Highway 23 south of Marshall.

Each semester, SMSU students learned details about river water quality and methods to analyze a variety of parameters (i.e., DO, temperature, pH, nitrate, phosphate, turbidity and flow rate). The college students then mentored local high school students to teach them the same information. The high school students in turn taught groups of 7th grade students, and then all three sets of students traveled together to three monitoring sites on the Redwood River to measure the water quality. Data collection happened once in October and once in April of each year at three sites in and around the city of Marshall: the Pre-Marshall, the Mid-Marshall Site and the Post-Marshall Site.

Diagnostic and Targeted Monitoring

The Redwood River Watershed SID report, TMDL allocations, and source assessment exercises were developed using available monitoring data, surveys, assessments, and models. For some of the impairments or protection waters, additional targeted data and information collection might be warranted prior to investing significant money and resources into restoring or protecting these water bodies. Collecting additional diagnostic and targeted monitoring data could help calibrate and/or validate modeling results, refine the TMDL source assessments, pinpoint geographic locations of problem areas, and provide baseline data prior to project implementation. It is not feasible or necessary for each impairment to have detailed, costly, field-derived source assessments. In many cases, information gained from enhanced source assessment for one impairment can be extrapolated to other impairments in the watershed or even region. The MPCA is currently developing guidance on when it is appropriate to consider funding for enhanced phosphorus source assessment for lakes and microbial source tracking for streams. This guidance is intended to inform MPCA's decisions on dedicating state funding or staff time to enhanced source assessment activities. Several potential targeted monitoring activities were identified in the Redwood River Watershed SID and TMDL reports. Many of these have been incorporated into the individual strategies tables in this WRAPS as activities that could be further considered:

- Microbial source tracking in select bacteria impaired streams to identify sources of fecal contamination.
- Longitudinal (upstream to downstream) *E. coli* monitoring surveys in certain bacteria-impaired stream reaches to further refine and evaluate potential locations of elevated bacteria loading.
- Collect flow and water quality (e.g., TP) in major tributaries and wetlands flowing to impaired lakes. Compare monitoring results to HSPF and lake response models for validation and/or re-calibration.
- Collect sediment cores to evaluate phosphorus release from sediments within selected lakes and compare to model predictions.
- Conduct/update fish and/or vegetation surveys according to DNR methodology for lakes that have never been surveyed or have limited or outdated survey data.

In summary, state and local monitoring efforts have resulted in a wealth of water quality information in the Redwood River Watershed. This information has been used to assess water quality in streams, rivers, and lakes in the watershed and to help understand the factors contributing to pollutant loading. To further develop that understanding, and document change over time, the following monitoring efforts should be considered in the Redwood River Watershed:

1. IWM every 10 years – snapshots of AqL use and AqR support.
2. WPLMN monitoring at watershed and sub-watershed scale – evaluates progress toward pollutant load reduction goals.
3. MDA pesticide monitoring – robust data set allows for trend analysis and identification of emerging pesticide concerns.
4. Local organization efforts – continued monitoring from groups such as RCRCA to collect data at multiple watershed scales.
5. Volunteer lake and stream monitoring – greatly expands geographical scope of potential monitoring.
6. Discovery Farms for field scale monitoring – collects useful data for on-field management.

7. Special studies/investigations as needed – consider special studies to clearly define pollutant sources when circumstances warrant (e.g., inform implementation efforts).

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Appendix A: Lake and Stream 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

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

Appendix B: Stream and Lake TMDL Summaries

Figure B-1. Redwood River Reach 502 TSS load duration curve and monitored loads and exceedances.

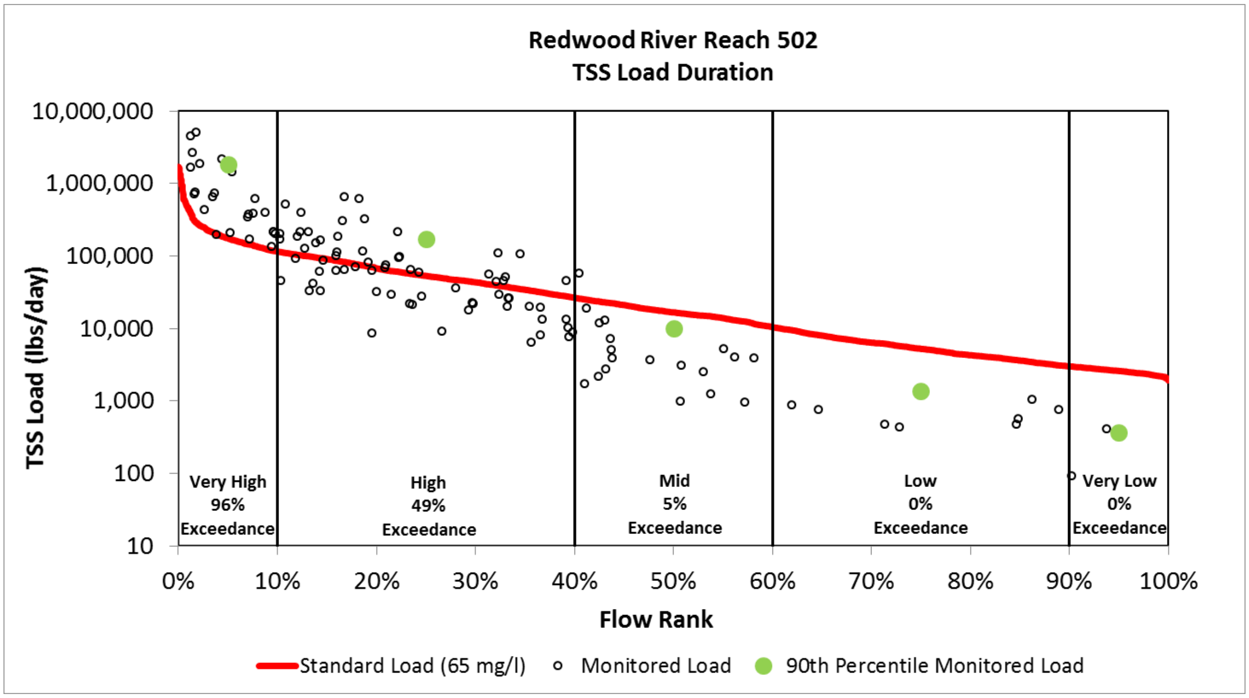


Table B-1. TSS TMDL summary for Redwood River Reach 502.

Total Suspended Solids		Flow zones*				
		Very high	High	Mid-range	Low	Very low
Sources		TSS load (lbs/day)				
Wasteload	ADM Corn Processing – Marshall (MN0057037)	661	661	661	661	***
	Lynd WWTP (MNG585030)	128	128	128	128	***
	Marshall WWTP (MN0022179)	1,126	1,126	1,126	1,126	***
	Russell WWTP (MNG585062)	220	220	220	220	***
	Magellan Pipeline Co LP – Marshall (MN0059838)	180	180	180	180	***
	Ruthton WWTP (MNG585105)	142	142	142	142	***
	Tyler WWTP (MNG585116)	409	409	409	409	***
	City of Marshall MS4 (MS400241)**	5,173	1,579	495	155	***
	Construction/Industrial SW	538	164	52	16	***
	Total WLA	**8,577**	**4,609**	**3,413**	**3,037**	***
Load	**Total LA**	**156,895**	**45,909**	**12,434**	**1,933**	***
MOS		**8,709**	**2,659**	**834**	**262**	**130**
Total load		**174,181**	**53,177**	**16,681**	**5,232**	**2,591**
Existing 90th percentile concentration (mg/L)******		**145**				
Overall estimated percent reduction******		**55%**				

* Model simulated flow for HSPF reach 290 (2008-2017) was used to develop the flow zones and LCs for this reach.

** The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (65 mg/L or NPDES permit concentration) x (conversion factors).
*** Water quality monitoring station(s) used to estimate reductions: S001-199, S001-203, S003-702, S009-023.

Figure B-2. Redwood River Reach 503 TSS load duration curve and HSPF simulated TSS loads and exceedances.

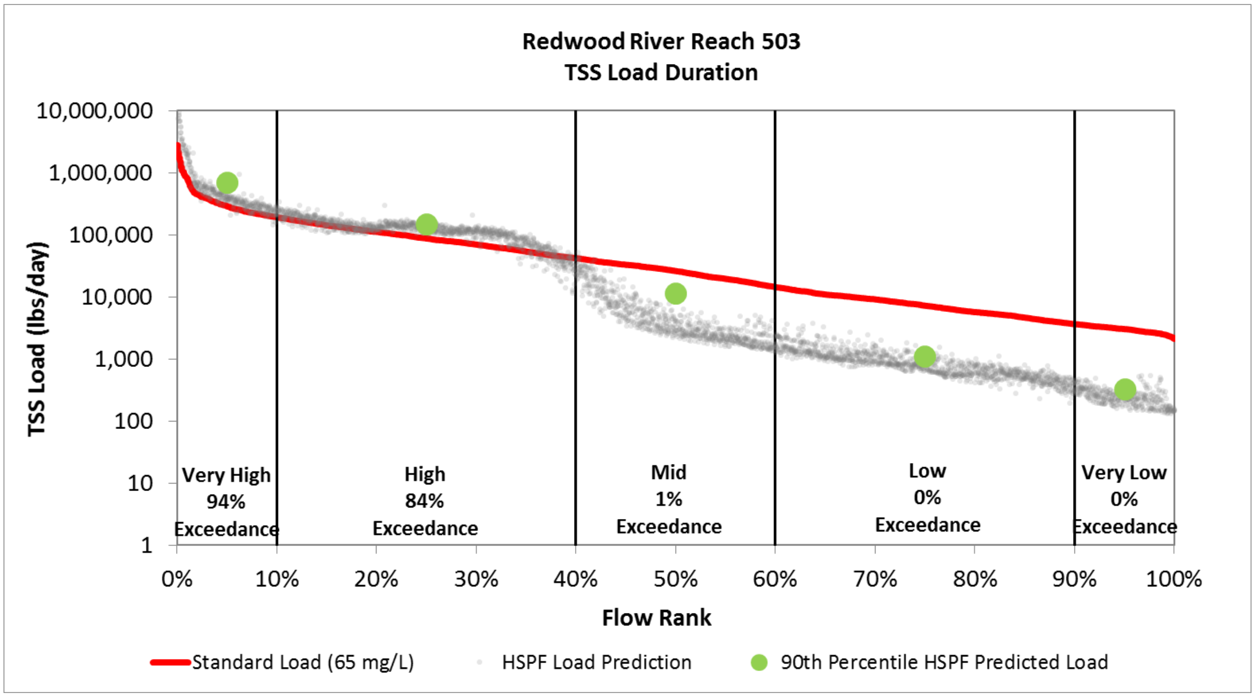


Table B-2. TSS TMDL summary for Redwood River Reach 503.

Total Suspended Solids		Flow zones*				
		Very high	High	Mid-range	Low	Very low
Sources		TSS load (lbs/day)				
Wasteload	ADM Corn Processing – Marshall (MN0057037)	661	661	661	661	***
	Ghent WWTP (MNG585121)	97	97	97	97	***
	Lynd WWTP (MNG585030)	128	128	128	128	***
	Marshall WWTP (MN0022179)	1,126	1,126	1,126	1,126	***
	Russell WWTP (MNG585062)	220	220	220	220	***
	Vesta WWTP (MNG585043)	97	97	97	97	***
	Magellan Pipeline Co LP – Marshall (MN0059838)	180	180	180	180	***
	Ruthton WWTP (MNG585105)	142	142	142	142	***
	Tyler WWTP (MNG585116)	409	409	409	409	***
	City of Marshall MS4 (MS400241)**	5,173	1,579	495	155	***
	Construction/Industrial SW	892	270	81	22	***
	Total WLA	**9,125**	**4,909**	**3,636**	**3,237**	***
Load	**Total LA**	**265,001**	**78,147**	**21,199**	**3,632**	***
MOS		**14,428**	**4,371**	**1,307**	**362**	**152**
Total load		**288,554**	**87,427**	**26,142**	**7,231**	**3,038**
Existing 90th percentile concentration (mg/L)****		****				
Overall estimated percent reduction****		**56%**				

* Model simulated flow for HSPF reach 430 (2008-2017) was used to develop the flow zones and LCs for this reach.
** The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (65 mg/L or NPDES permit concentration) x (conversion factors).

*** The impairment listing for this reach is based on Secchi Tube data (see Table 7) as no TSS data have been collected for this reach. Therefore, reductions are based on HSPF simulated TSS loads/concentrations.

Figure B-3. Redwood River Reach 509 TSS load duration curve and monitored loads and exceedances.

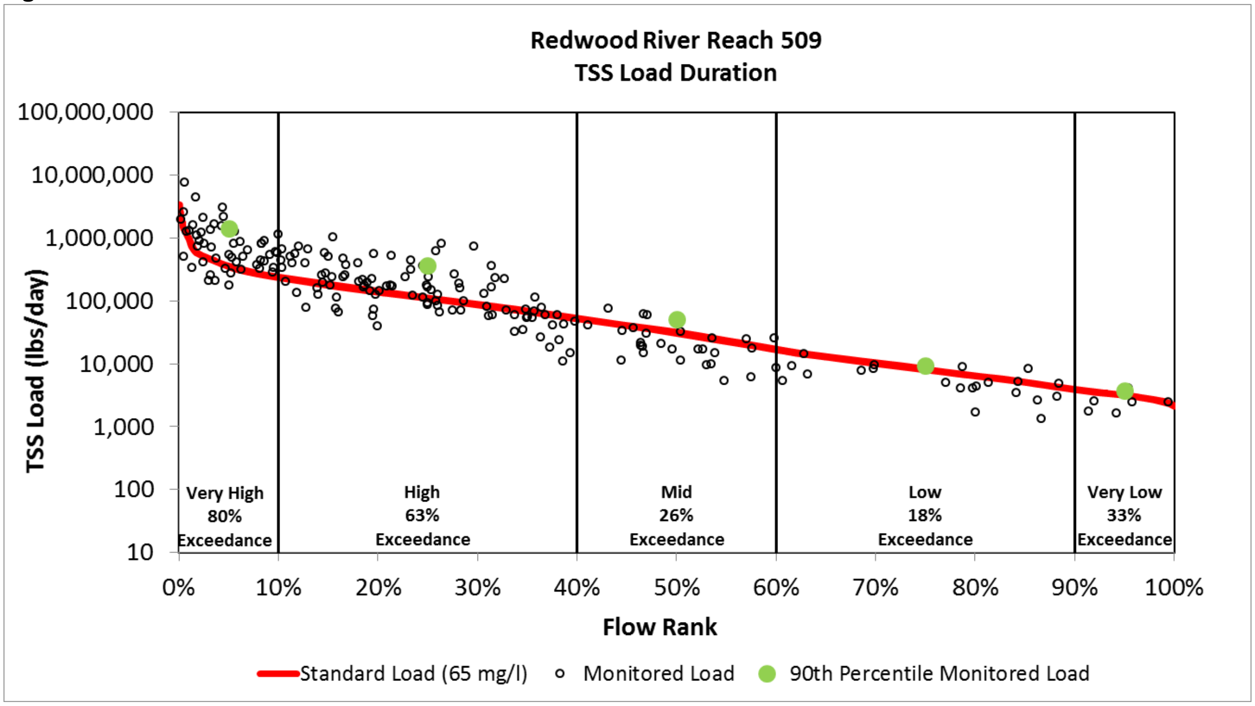


Table B-3. TSS TMDL summary for Redwood River Reach 509.

Total Suspended Solids		Flow zones*				
		Very high	High	Mid-range	Low	Very low
Sources		TSS load (lbs/day)				
Wasteload	ADM Corn Processing – Marshall (MN0057037)	661	661	661	661	***
	Ghent WWTP (MNG585121)	97	97	97	97	***
	Lynd WWTP (MNG585030)	128	128	128	128	***
	Marshall WWTP (MN0022179)	1,126	1,126	1,126	1,126	***
	Russell WWTP (MNG585062)	220	220	220	220	***
	Milroy WWTP (MNG585124)	93	93	93	93	***
	Vesta WWTP (MNG585043)	97	97	97	97	***
	Magellan Pipeline Co LP – Marshall (MN0059838)	180	180	180	180	***
	Ruthton WWTP (MNG585105)	142	142	142	142	***
	Tyler WWTP (MNG585116)	409	409	409	409	***
	City of Marshall MS4 (MS400241)**	5,173	1,579	495	155	***
	Construction/Industrial SW	1,081	340	99	25	***
	Total WLA	**9,407**	**5,072**	**3,747**	**3,333**	***
Load	**Total LA**	**322,834**	**99,609**	**26,670**	**4,402**	***
MOS		**17,486**	**5,510**	**1,601**	**407**	**157**
Total load		**349,727**	**110,191**	**32,018**	**8,142**	**3,149**
Existing 90th percentile concentration (mg/L)******		**150**				
Overall estimated percent reduction******		**57%**				

* Model simulated flow for HSPF reach 470 (2008-2017) was used to develop the flow zones and LCs for this reach.
** The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (65 mg/L or NPDES permit concentration) x (conversion factors).
*** Water quality monitoring station(s) used to estimate reductions: S001-679.

Figure B-4. Redwood River Reach 510 TSS load duration curve and monitored loads and exceedances.

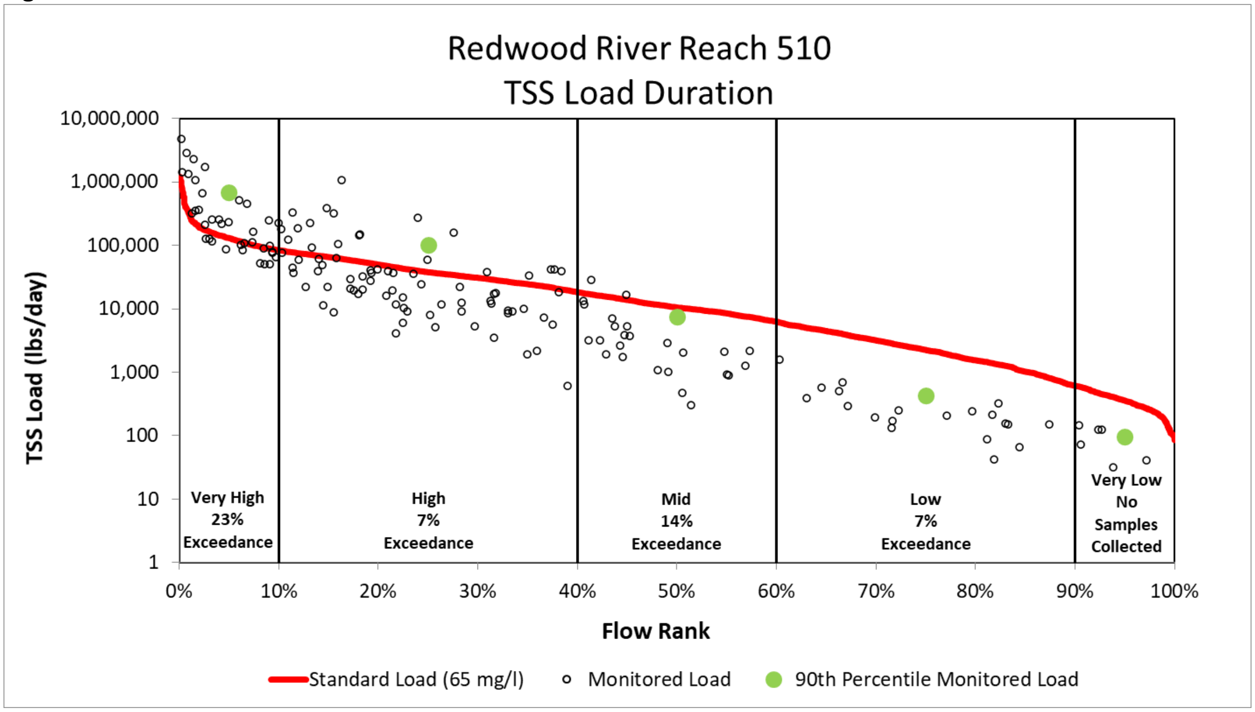


Table B-4. TSS TMDL summary for Redwood River Reach 510.

Total Suspended Solids		Flow zones*				
		Very high	High	Mid-range	Low	Very low
Sources		TSS load (lbs/day)				
Wasteload	Ruthton WWTP (MNG585105)	142	142	142	142	**
	Tyler WWTP (MNG585116)	409	409	409	409	**
	Construction/Industrial SW	23	7	2	0.4	**
	Total WLA	**574**	**558**	**553**	**551**	**
Load	**Total LA**	**33,440**	**10,396**	**2,078**	**69**	**
MOS		**1,790**	**577**	**138**	**33**	**8**
Total load		**35,804**	**11,531**	**2,769**	**653**	**169**
Existing 90th percentile concentration (mg/L)* **		**103**				
Overall estimated percent reduction* **		**37%**				

* Model simulated flow for HSPF reach 495 (2008-2017) was used to develop the flow zones and LCs for this reach.
** Water quality monitoring station(s) used to estimate reductions: S000-696.

Figure B-5. Three Mile Creek Reaches 564/565 TSS load duration curve and monitored loads and exceedances.

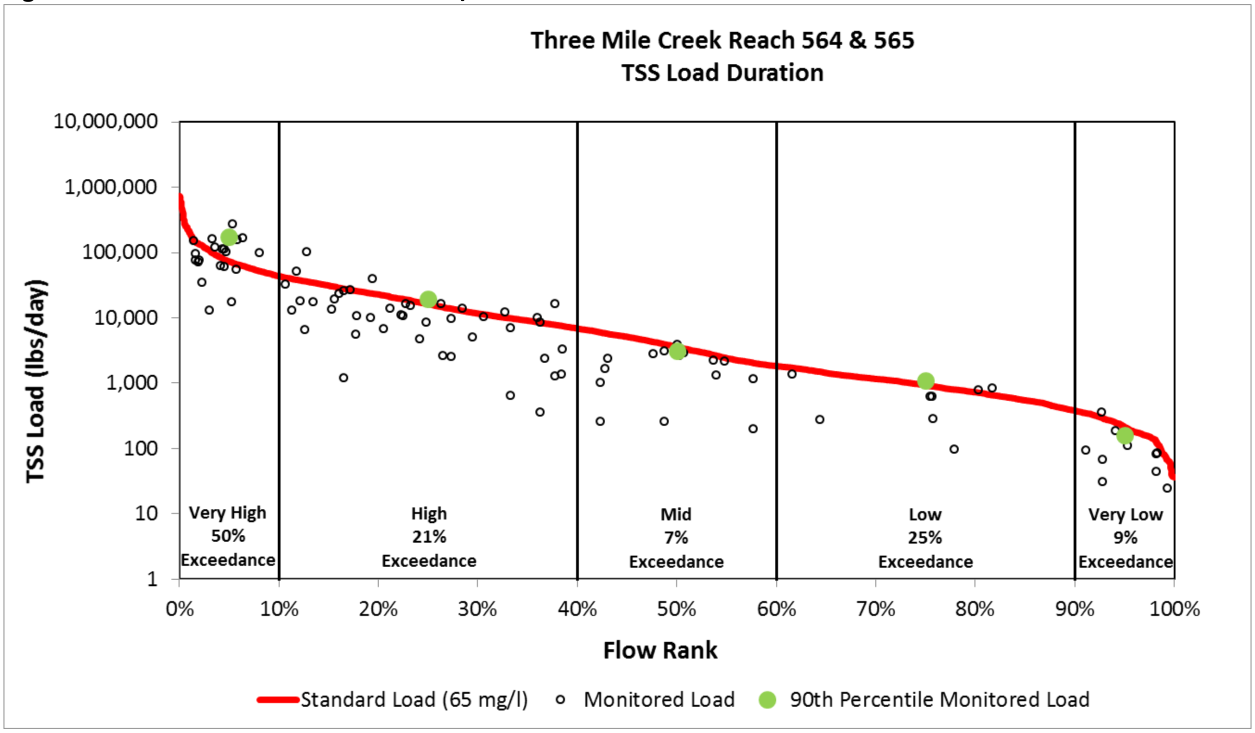


Table B-5. TSS TMDL summary for Three Mile Creek Reaches 564/565.

Total Suspended Solids		Flow zones*				
		Very high	High	Mid-range	Low	Very low
Sources		TSS load (lbs/day)				
Wasteload	Ghent WWTP (MNG585121)	97	97	97	97	97
	Construction/Industrial SW	230	51	11	3	0.7
	Total WLA	**327**	**148**	**108**	**100**	**98**
Load	**Total LA**	**70,404**	**15,591**	**3,380**	**805**	**108**
MOS		**3,723**	**828**	**184**	**48**	**11**
Total load		**74,454**	**16,567**	**3,672**	**953**	**217**
Existing 90th percentile concentration (mg/L)**		**83**				
Overall estimated percent reduction**		**22%**				

* Model simulated flow for HSPF reach 315 (2008-2017) was used to develop the flow zones and LCs for this reach.

** Water quality monitoring station(s) used to estimate reductions: S002-313.

Figure B-6. Clear Creek Reach 568 TSS load duration curve and monitored loads and exceedances.

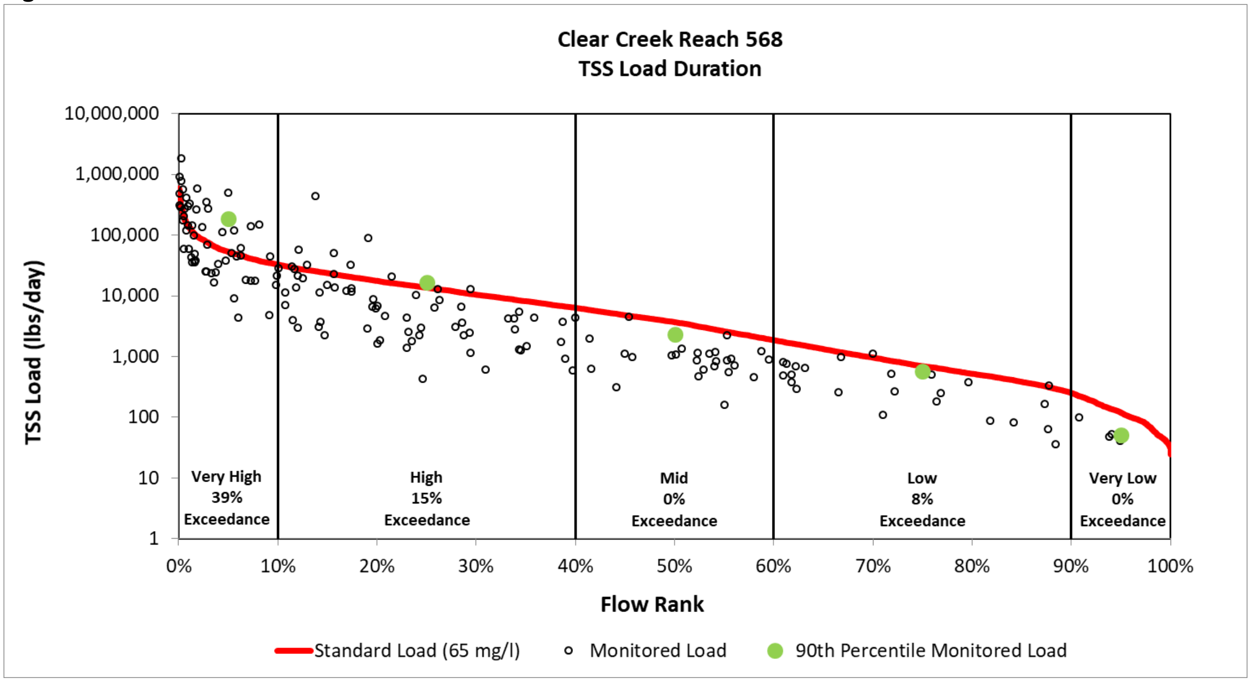


Table B-6. TSS TMDL summary for Clear Creek Reach 567 and 568.

Total Suspended Solids		Flow zones*				
		Very high	High	Mid-range	Low	Very low
Sources		TSS load (lbs/day)				
Wasteload	Milroy WWTP (MNG585124)	93	93	93	93	**
	Construction/Industrial SW	35	10	2	0.4	**
	Total WLA	**128**	**102**	**95**	**93**	**
Load	**Total LA**	**51,753**	**14,023**	**3,138**	**444**	**
MOS		**2,731**	**743**	**170**	**28**	**5**
Total load		**54,611**	**14,868**	**3,403**	**565**	**92**
Existing 90th percentile concentration (mg/L)* **		****				
Overall estimated percent reduction* **		**5%**				

* Model simulated flow for HSPF reach 443 (2008-2017) was used to develop the flow zones and LCs for this reach.
** The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (65 mg/L or NPDES permit concentration) x (conversion factors).
*** Water quality monitoring station(s) used to estimate reductions: S002-311.

Figure B-7. Redwood River Reach 510 *E. coli* load duration curve and monitored loads and exceedances.

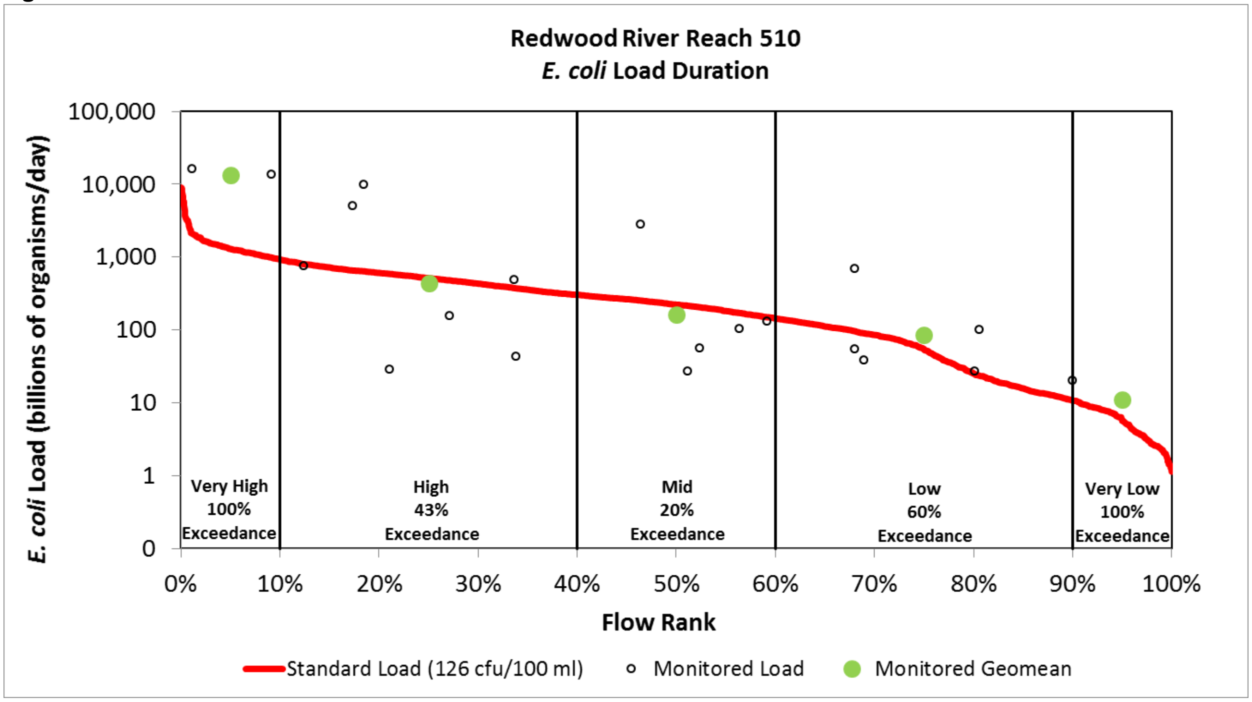


Table B-7. *E. coli* TMDL summary for Redwood River Reach 510.

E. coli		Flow zones*				
		Very high	High	Mid-range	Low	Very low
Sources		*E. coli* load (billions of organisms/day)				
Wasteload	Russell WWTP (MNG580062)	3	3	3	3	**
	Ruthton WWTP (MNG580105)	2	2	2	2	**
	Tyler WWTP (MNG580116)	5	5	5	5	**
	Total WLA	**10**	**10**	**10**	**10**	**
Load	**Total LA**	**1,897**	**750**	**318**	**69**	**
MOS		**100**	**40**	**17**	**4**	**0.4**
Total load		**2,007**	**800**	**345**	**83**	**9**
Existing Concentration, Apr-Oct (org/100 mL)***		**159**				
Maximum Monthly Geometric Mean (org/100mL)***		**475**				
Overall Estimated Percent Reduction***		**73%**				

* Model simulated flow for HSPF reach 190 from April-October (2008-2017) was used to develop the flow zones and LCs for this reach.

** The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (126 org per 100 mL) x conversion factors.

*** Water quality monitoring station(s) used to estimate reductions: S000-696.

Figure B-8. Ramsey Creek Reach 521 *E. coli* load duration curve and monitored loads and exceedances.

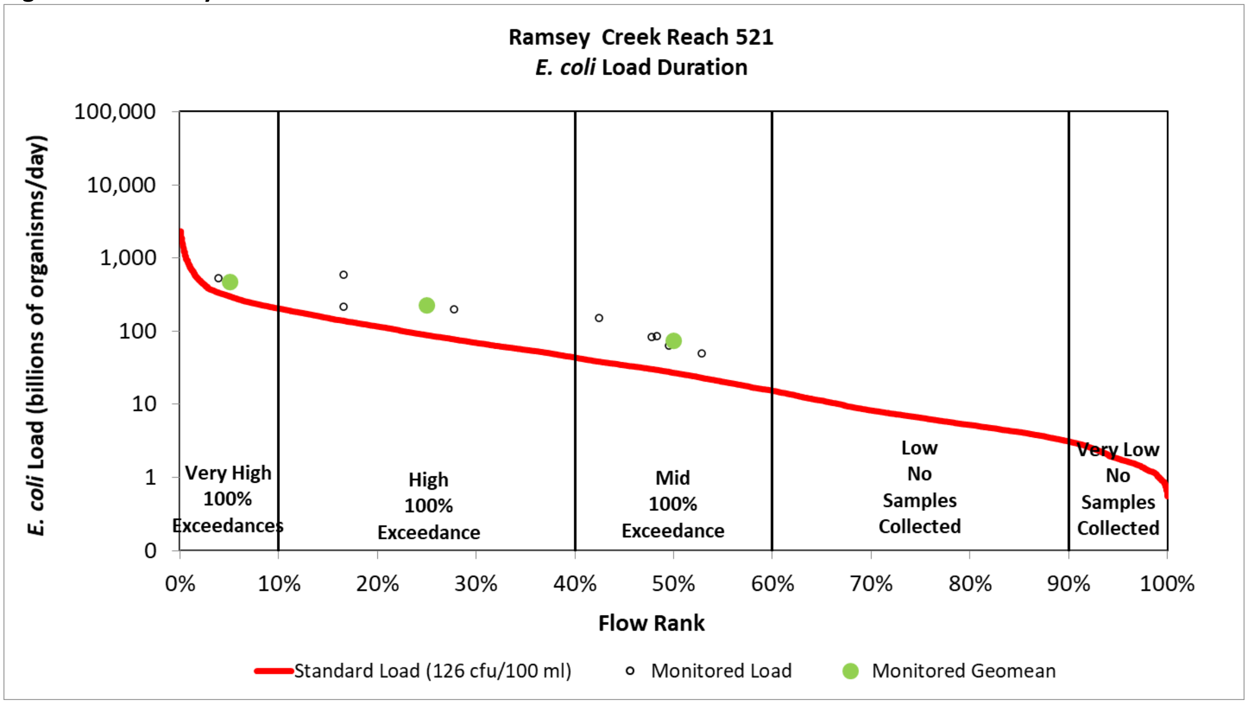


Table B-8. *E. coli* TMDL summary for Ramsey Creek Reach 521.

E. coli		Flow zones*				
		Very high	High	Mid-range	Low	Very low
Sources		*E. coli* load (billions of organisms/day)				
Wasteload	City of Redwood Falls MS4 (MS400236)	1	0.4	0.1	0.02	0.006
	Total WLA	**1**	**0.4**	**0.1**	**0.02**	**0.006**
Load	**Total LA**	**298**	**96**	**23**	**5**	**1**
MOS		**16**	**5**	**1**	**0.3**	**0.07**
Total load		**315**	**101**	**24**	**5**	**1**
Existing Concentration, Apr-Oct (org/100 mL)**		**317**				
Maximum Monthly Geometric Mean (org/100mL)**		**277**				
Overall Estimated Percent Reduction**		**55%**				

* Model simulated flow for HSPF reach 495 from April-October (2008-2017) was used to develop the flow zones and LCs for this reach.

** Water quality monitoring station(s) used to estimate reductions: S004-387.

Figure B-9. Redwood River Reach 502 chloride load duration curve and monitored loads and exceedances.

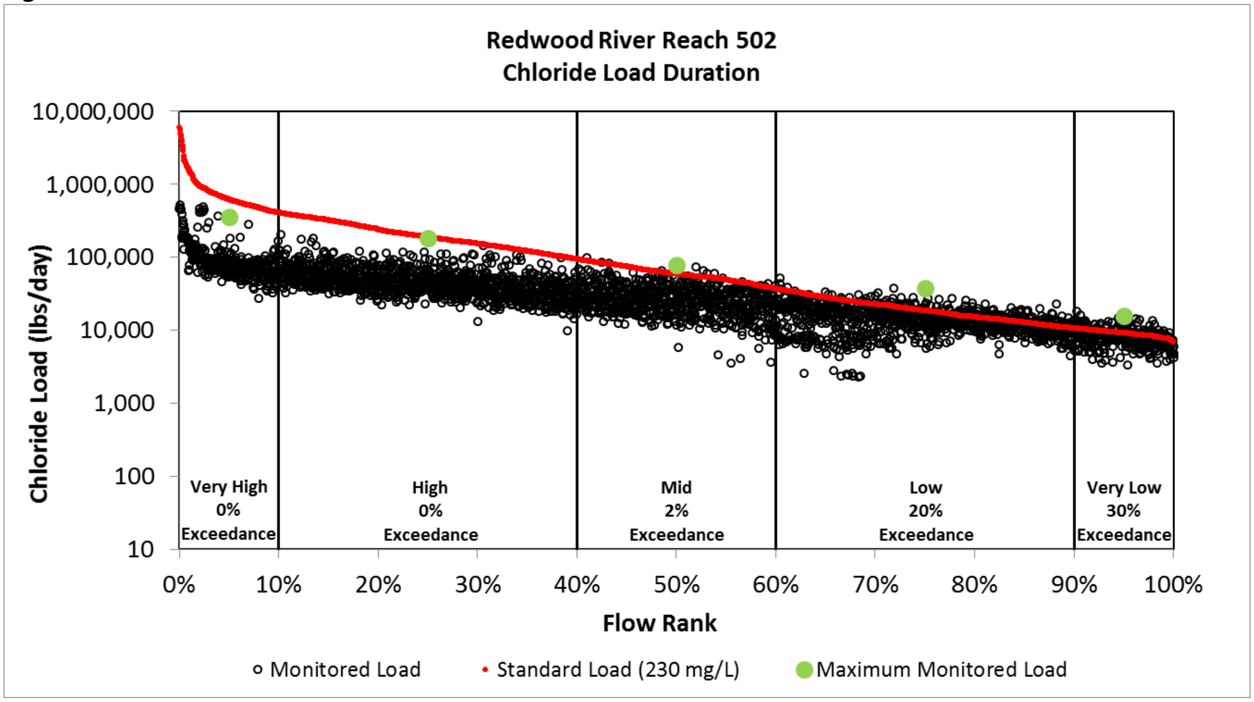


Table B-9. Chloride TMDL summary for Redwood River Reach 502.

Chloride		Flow zones*				
		Very high	High	Mid-range	Low	Very low
Sources		Chloride load (lbs/day)				
Wasteload	ADM Corn Processing – Marshall (MN0057037)	5,064	5,064	5,064	**	**
	Lynd WWTP (MNG580030)	656	656	656	**	**
	Marshall WWTP (MN0022179)	8,632	8,632	8,632	**	**
	Russell WWTP (MNG580062)	1,125	1,125	1,125	**	**
	Magellan Pipeline Co LP – Marshall (MN0059838)	1,381	1,381	1,381	**	**
	Ruthton WWTP (MNG580105)	725	725	725	**	**
	Tyler WWTP (MNG580116)	2,092	2,092	2,092	**	**
	City of Marshall MS4 (MS400241)	27,514	8,400	2,635	**	**
	Total WLA	47,189	28,075	22,310	**	**
Load	**Total LA**	538,328	150,682	33,764	**	**
MOS		30,817	9,408	2,951	926	458
Total load		616,334	188,165	59,025	18,514	9,169
Existing maximum concentration (mg/L)* **		**463**				
Overall estimated percent reduction* **		**50%**				

* Model simulated flow for HSPF reach 290 from 2008-2017 (all months) was used to develop the flow zones and loading capacities for this reach.

** The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (230 mg/L) x conversion factors.

*** Water quality monitoring station used to estimate reductions: S001-203.

Table B-10. Lake Benton (41-0043-00) phosphorus TMDL.

Phosphorus Sources		Existing TP load*		Allowable TP load		Estimated load reduction	
		lbs/year	lbs/day	lbs/year	lbs/day	lbs/year**	%
Wasteload	Construction/Industrial SW	18	0.05	18	0.05	0	0%
	Total WLA	**18**	**0.05**	**18**	**0.05**	**0**	**0%**
Load	Non-MS4 runoff	5,903	16.16	3,941	10.79	1,962	33%
	SSTS	407	1.11	184	0.50	223	55%
	Atmospheric deposition	633	1.73	633	1.73	0	0%
	Internal load	11,942	32.70	4,915	13.46	7,027	59%
	Total LA	**18,885**	**51.70**	**9,673**	**26.48**	**9,212**	**49%**
MOS				**1,077**	**2.95**		
Total load		**18,903**	**51.75**	**10,768**	**29.48**	**9,212**	**43%**

* Model calibration year(s): 2002 & 2017.

** Net reduction from current load to TMDL is 8,135 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 8,135 + 1,077 = 9,212 lbs/yr.

Figure B-10. Lake Benton phosphorus source reductions to meet TMDL.

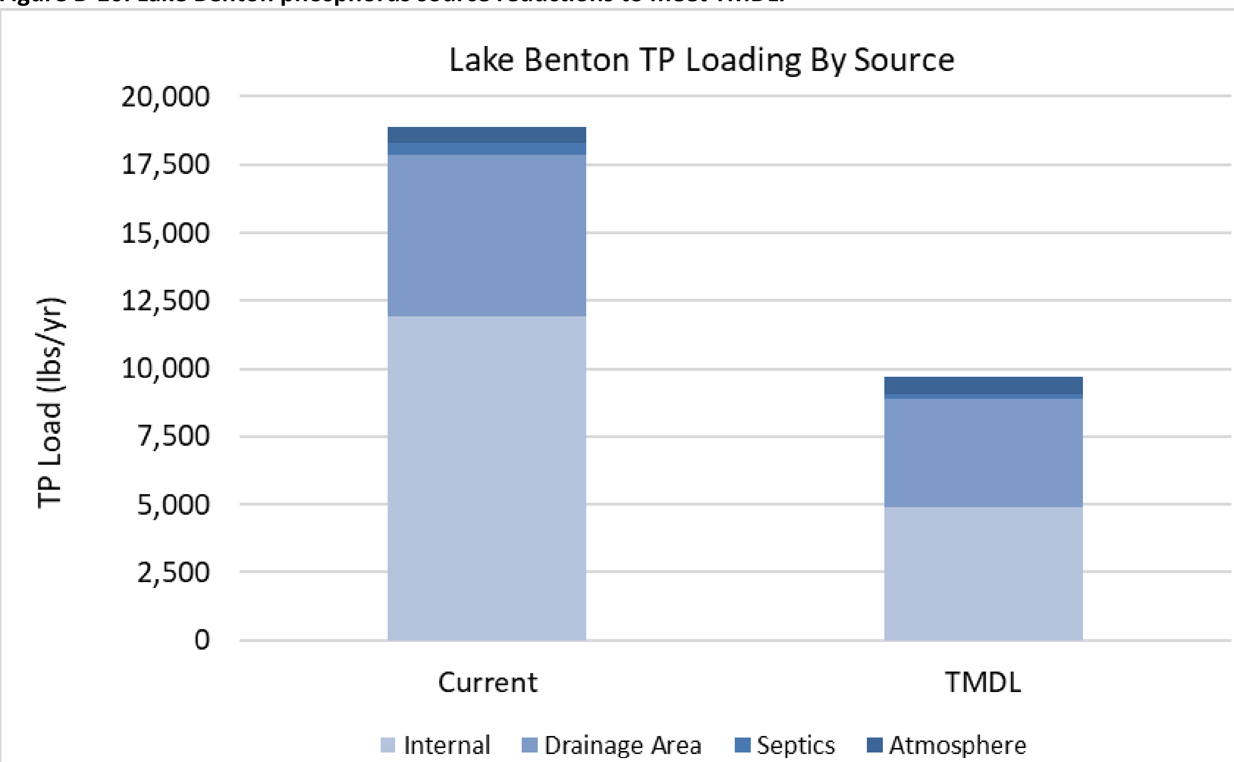


Table B-11. Dead Coon Lake (Main Lake) (41-0021-01) phosphorus TMDL.

Phosphorus Sources		Existing TP load*		Allowable TP load		Estimated load reduction	
		lbs/year	lbs/day	lbs/year	lbs/day	lbs/year**	%
Wasteload	Construction/Industrial SW	12	0.03	12	0.03	0	0%
	Total WLA	**12**	**0.03**	**12**	**0.03**	**0**	**0%**
Load	Non-MS4 runoff	3,930	10.76	3,166	8.67	764	19%
	SSTS	538	1.47	206	0.56	332	62%
	Upstream lakes (Benton)	3,213	8.80	2,083	5.70	1,130	35%
	Atmospheric deposition	131	0.36	131	0.36	0	0%
	Internal load	6,388	17.49	328	0.90	6,060	95%
	Total LA	**14,200**	**38.88**	**5,914**	**16.19**	**8,286**	**58%**
MOS				**658**	**1.80**		
Total load		**14,212**	**38.91**	**6,584**	**18.02**	**8,286**	**54%**

* Model calibration year(s): 2002, 2007 and 2017.

** Net reduction from current load to TMDL is 7,628 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 7,628 + 658 = 8,286 lbs/yr.

Figure B-11. Dead Coon Lake (Main Lake) phosphorus source reductions to meet TMDL.

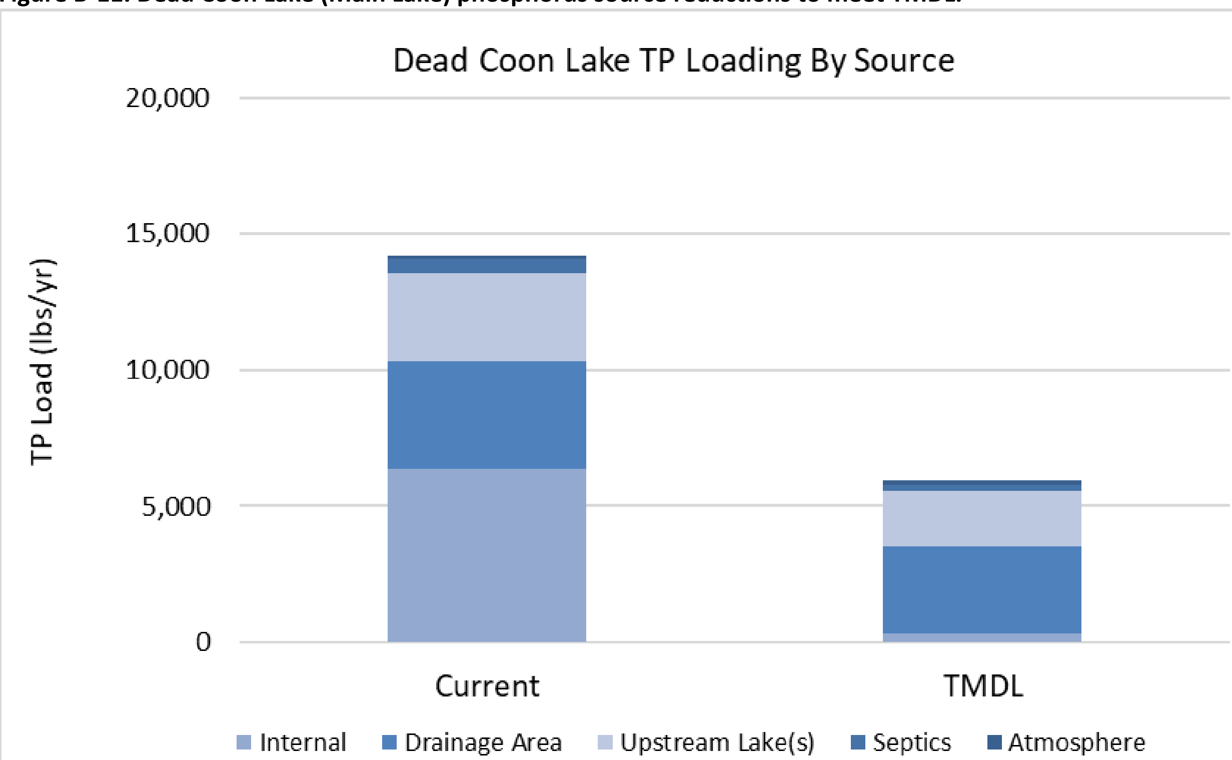


Table B-12. Goose Lake (42-0093-00) phosphorus TMDL.

Phosphorus Sources		Existing TP load*		Allowable TP load		Estimated load reduction	
		lbs/year	lbs/day	lbs/year	lbs/day	lbs/year**	%
Wasteload	Construction/Industrial SW	3	0.01	3	0.01	0	0%
	Total WLA	**3**	**0.01**	**3**	**0.01**	**0**	**0%**
Load	Non-MS4 runoff	961	2.63	576	1.58	385	40%
	SSTS	7	0.02	4	0.01	3	39%
	Atmospheric deposition	36	0.10	36	0.10	0	0%
	Internal load	670	1.83	251	0.69	419	63%
	Total LA	**1,674**	**4.58**	**867**	**2.38**	**807**	**48%**
MOS				**97**	**0.26**		
Total load		**1,677**	**4.59**	**967**	**2.65**	**807**	**42%**

* Model calibration year(s): 2002, 2007 and 2017.
** Net reduction from current load to TMDL is 710 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 710 + 97 = 807 lbs/yr.

Figure B-12. Goose Lake phosphorus source reduction to meet TMDL.

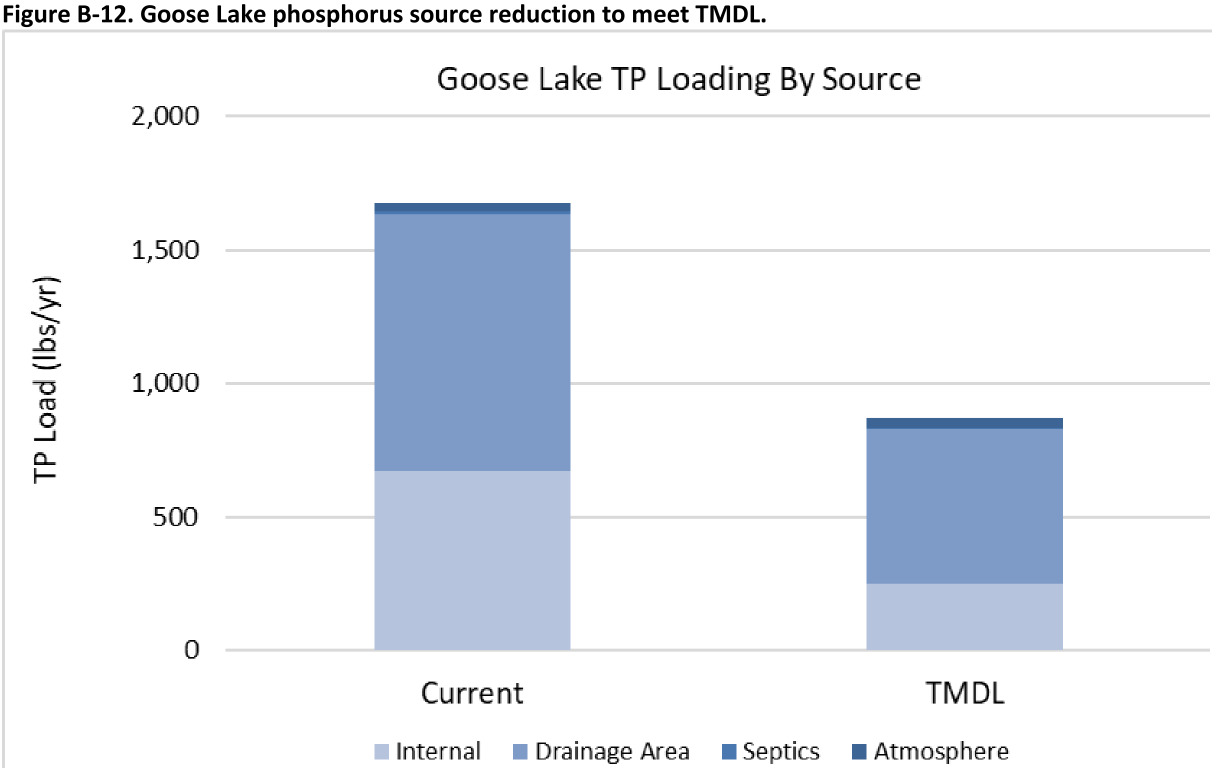


Table B-13. Clear Lake - Lyon County (42-0055-00) phosphorus TMDL.

Phosphorus Sources		Existing TP load*		Allowable TP load		Estimated load reduction	
		lbs/year	lbs/day	lbs/year	lbs/day	lbs/year**	%
Wasteload	Construction/Industrial SW	0.7	0.002	0.7	0.002	0.0	0%
	Total WLA	**0.7**	**0.002**	**0.7**	**0.002**	**0.0**	**0%**
Load	Non-MS4 runoff	221.3	0.606	127.4	0.349	93.9	42%
	SSTS	9.5	0.026	6.8	0.019	2.7	28%
	Atmospheric deposition	15.7	0.043	15.7	0.043	0.0	0%
	Internal load	255.0	0.698	124.3	0.340	130.7	51%
	Total LA	**501.5**	**1.373**	**274.2**	**0.751**	**227.3**	**45%**
MOS				**30.5**	**0.084**		
Total load		**502.2**	**1.375**	**305.4**	**0.837**	**227.3**	**39%**

* Model calibration year(s): 2017 and 2018.

** Net reduction from current load to TMDL is 196.8 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 196.8+ 30.5 = 227.3 lbs/yr.

Figure B-13. Clear Lake - Lyon County phosphorus source reductions to meet TMDL.

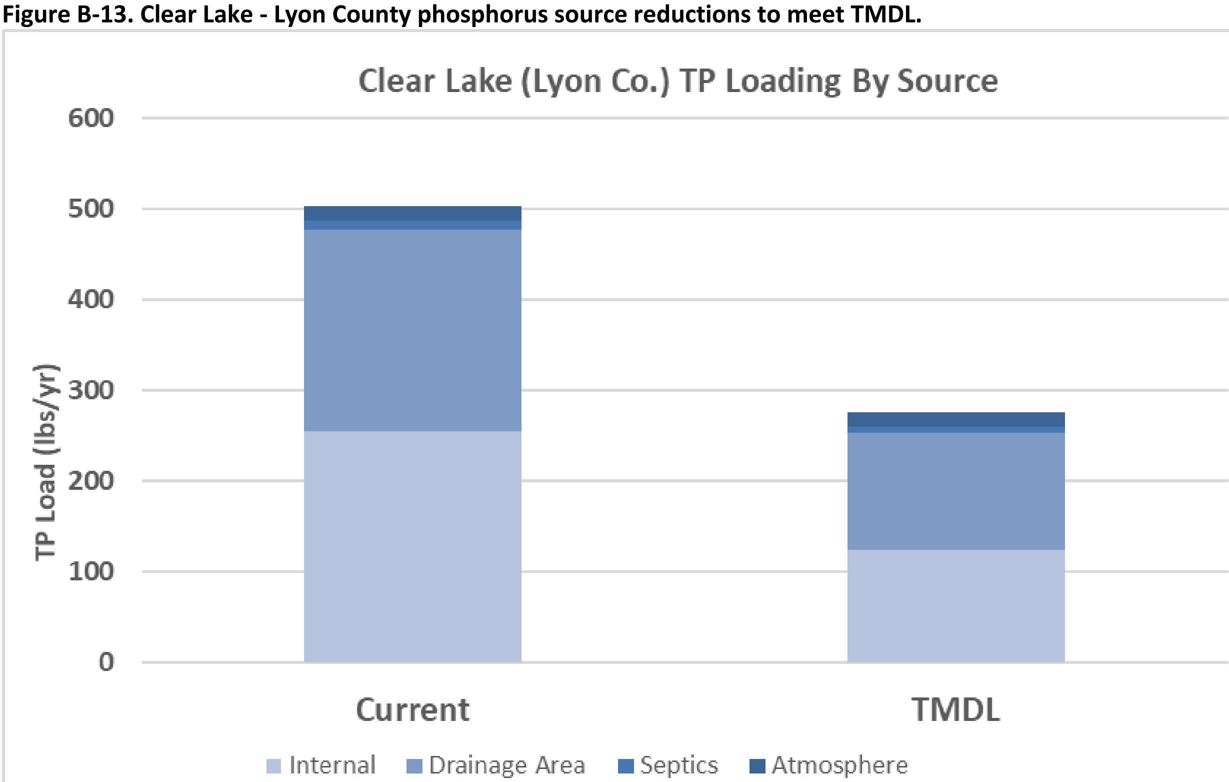


Table B-14. School Grove Lake (42-0002-00) phosphorus TMDL.

Phosphorus Sources		Existing TP load*		Allowable TP load		Estimated load reduction	
		lbs/year	lbs/day	lbs/year	lbs/day	lbs/year**	%
Wasteload	Construction/Industrial SW	4	0.01	4	0.01	0	0%
	Total WLA	**4**	**0.01**	**4**	**0.01**	**0**	**0%**
Load	Non-MS4 runoff	1,142	3.13	803	2.20	339	30%
	SSTS	7	0.02	5	0.01	2	28%
	Atmospheric deposition	83	0.23	83	0.23	0	0%
	Internal load	402	1.10	366	1.00	36	9%
	Total LA	**1,634**	**4.48**	**1,257**	**3.44**	**377**	**23%**
MOS				**140**	**0.38**		
Total load		**1,638**	**4.49**	**1,401**	**3.83**	**377**	**14%**

* Model calibration year(s): 2002, 2007 and 2017.

** Net reduction from current load to TMDL is 237 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 237 + 140 = 377 lbs/yr.

Figure B-14. School Grove Lake phosphorus source reductions to meet TMDL.

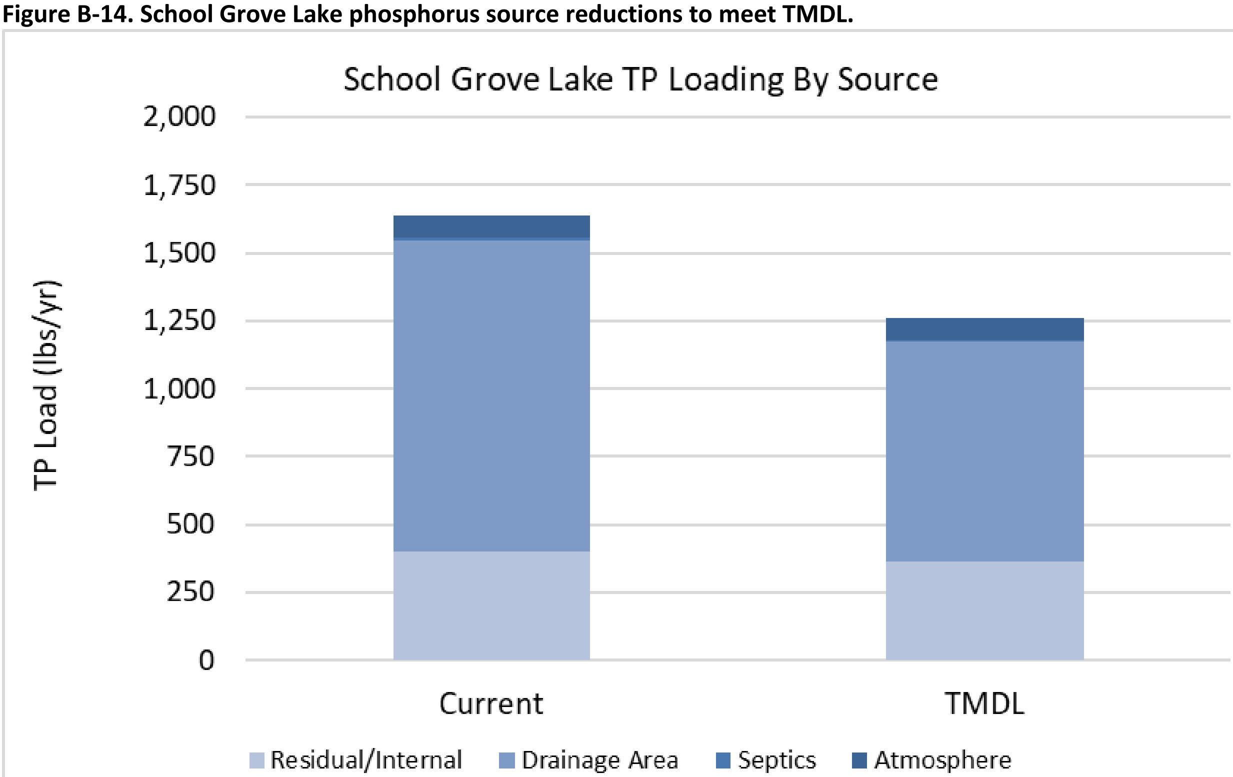


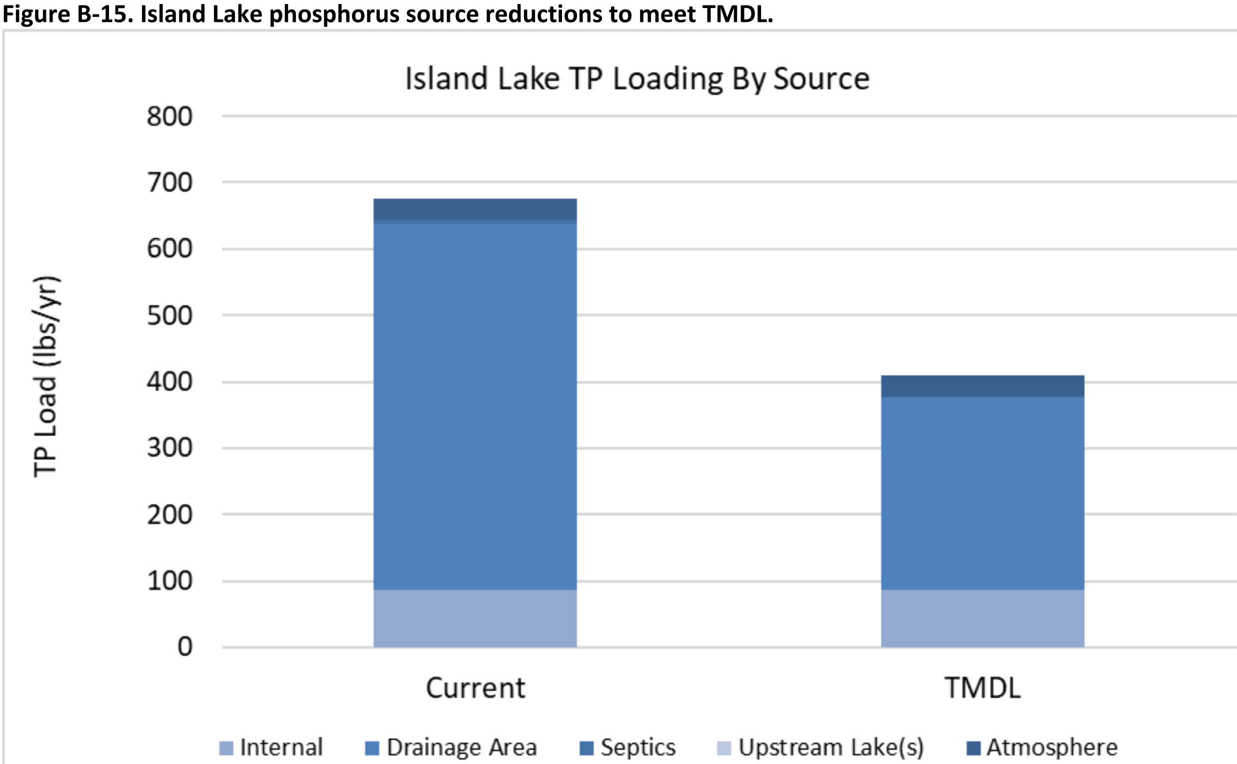
Table B-15. Island Lake (42-0002-00) phosphorus TMDL.

Phosphorus Sources		Existing TP load*		Allowable TP load		Estimated load reduction	
		lbs/year	lbs/day	lbs/year	lbs/day	lbs/year**	%
Wasteload	Construction/Industrial SW	2	0.005	2	0.005	0	0%
	Total WLA	**2**	**0.005**	**2**	**0.005**	**0**	**0%**
Load	Non-MS4 runoff	550	1.507	287	0.785	263	48%
	SSTS	5	0.012	3	0.009	2	28%
	Atmospheric deposition	32	0.087	32	0.087	0	0%
	Internal load	86	0.237	86	0.237	0	0%
	Total LA	**673**	**1.843**	**408**	**1.118**	**265**	**39%**
MOS				**45**	**0.123**		
Total load		**675**	**1.848**	**455**	**1.246**	**265**	**33%**

* Model calibration year(s): 2017 and 2018.

** Net reduction from current load to TMDL is 220 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 220 + 45 = 265 lbs/yr.

Figure B-15. Island Lake phosphorus source reductions to meet TMDL.



Appendix C: Precipitation Data

Figure C-1. Annual precipitation at the Redwood Falls Municipal Airport.

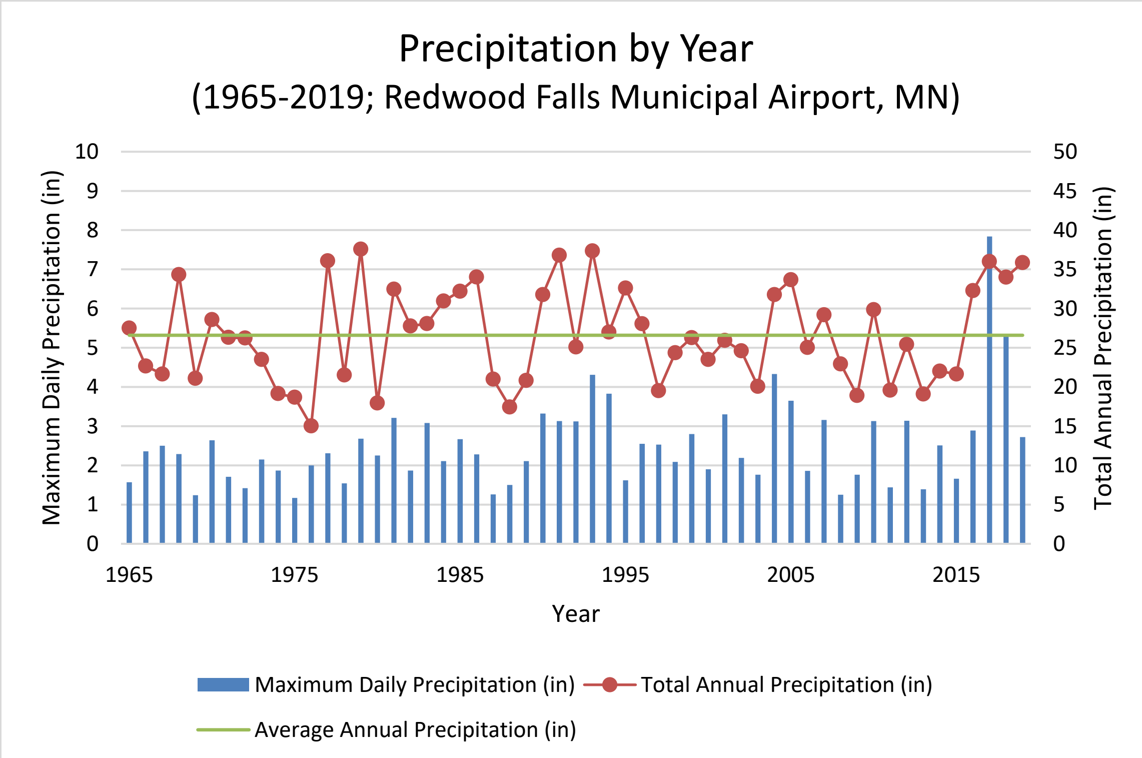


Figure C-2. Monthly precipitation at the Redwood Falls Municipal Airport.

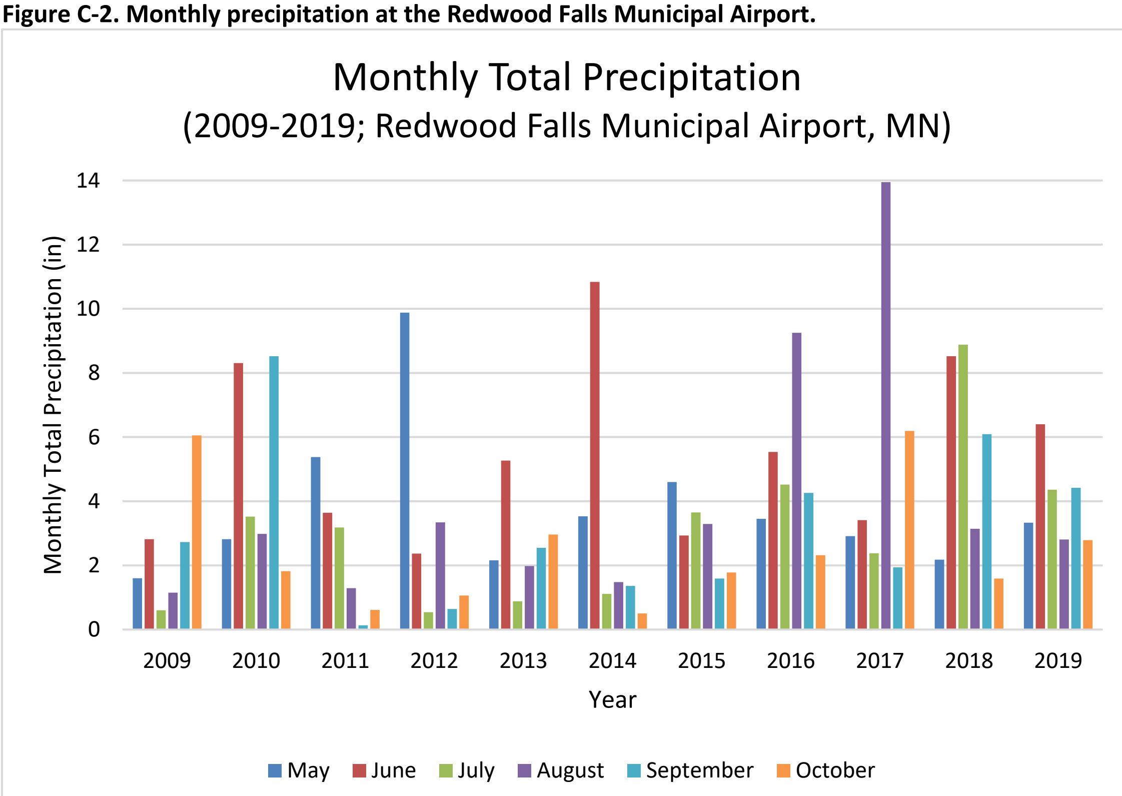


Figure C-3. Annual precipitation at the Marshall station (USC00215204).

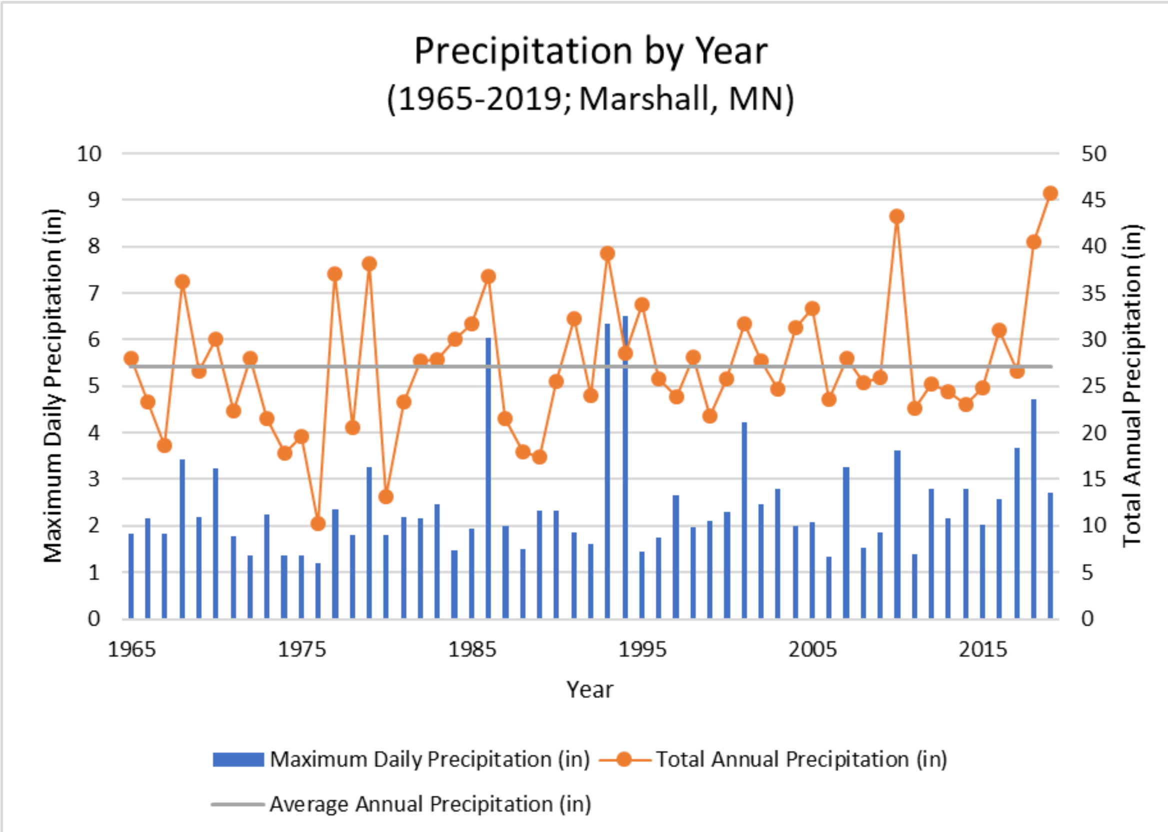


Figure C-4. Monthly precipitation at the Marshall station (USC00215204).

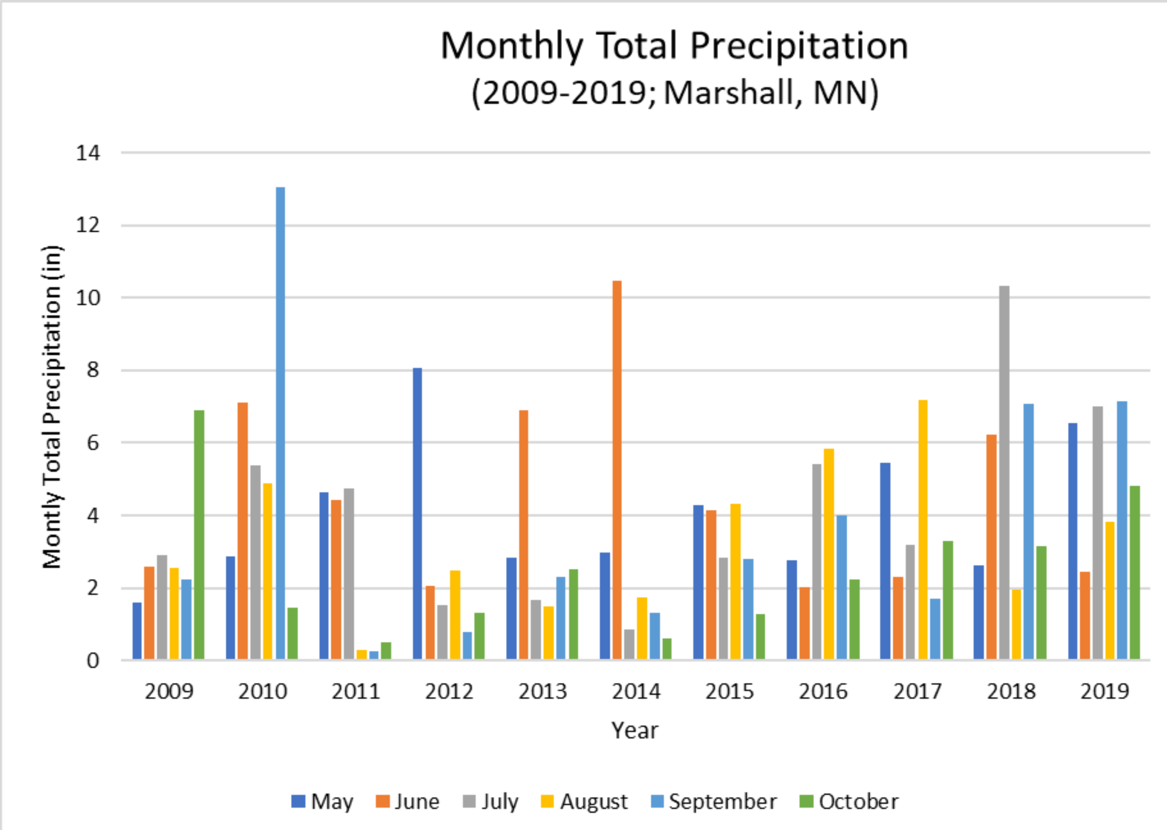
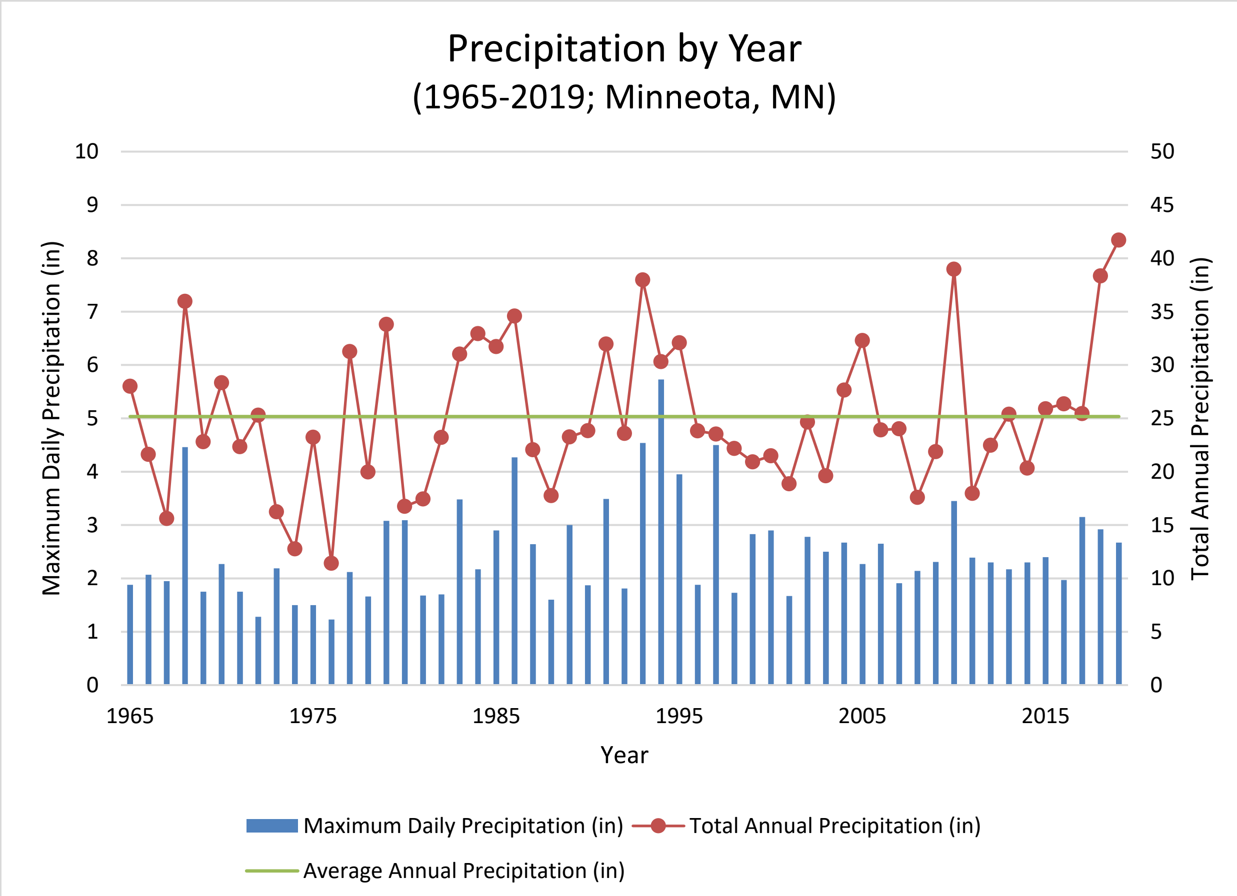


Figure C-5. Monthly precipitation at the Minneota station (USC00215482).



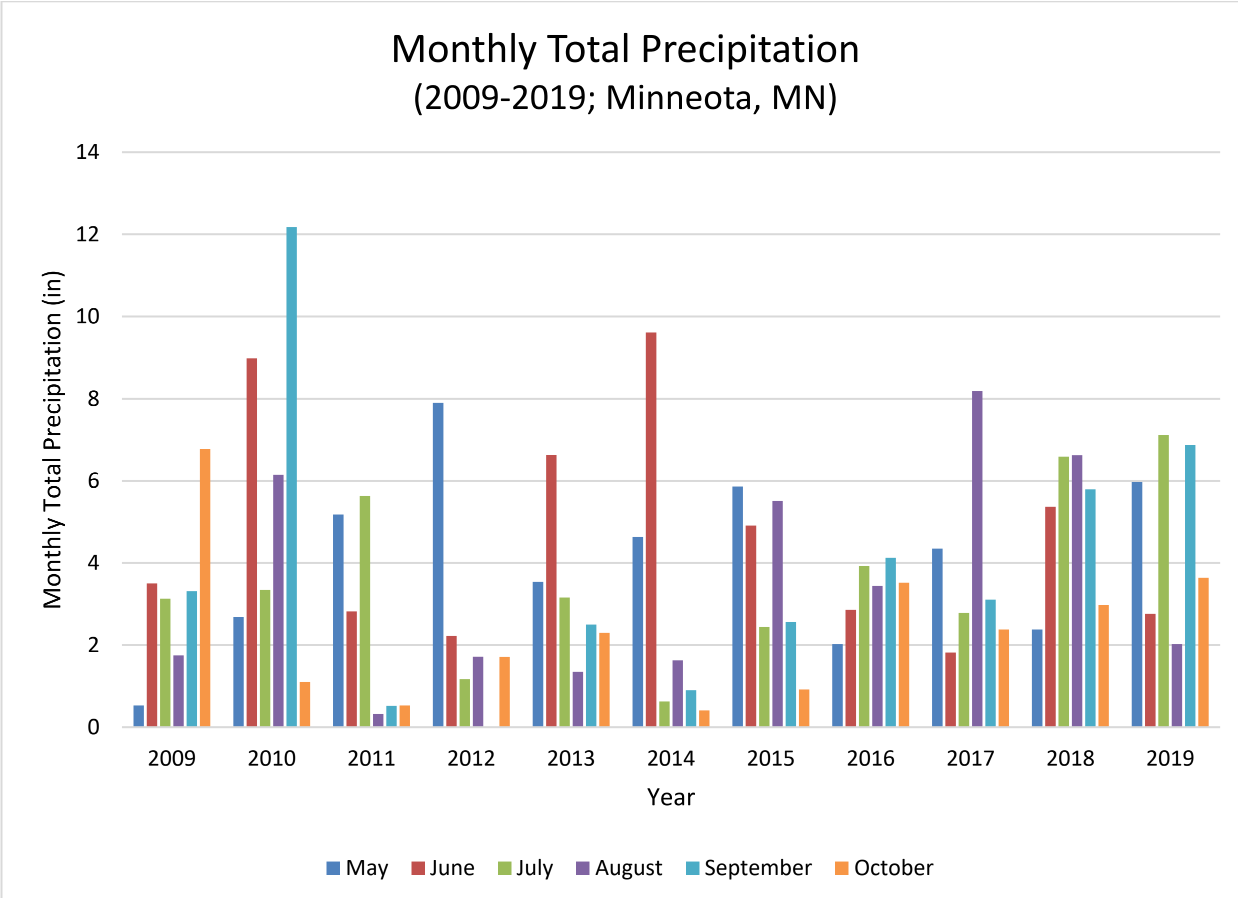


Figure C-6. Monthly precipitation at the Minneota station (USC00215482).

Figure C-7. Yearly precipitation at the University of Minnesota Southwest Research and Outreach Center at Lamberton, MN station (USC00214546).

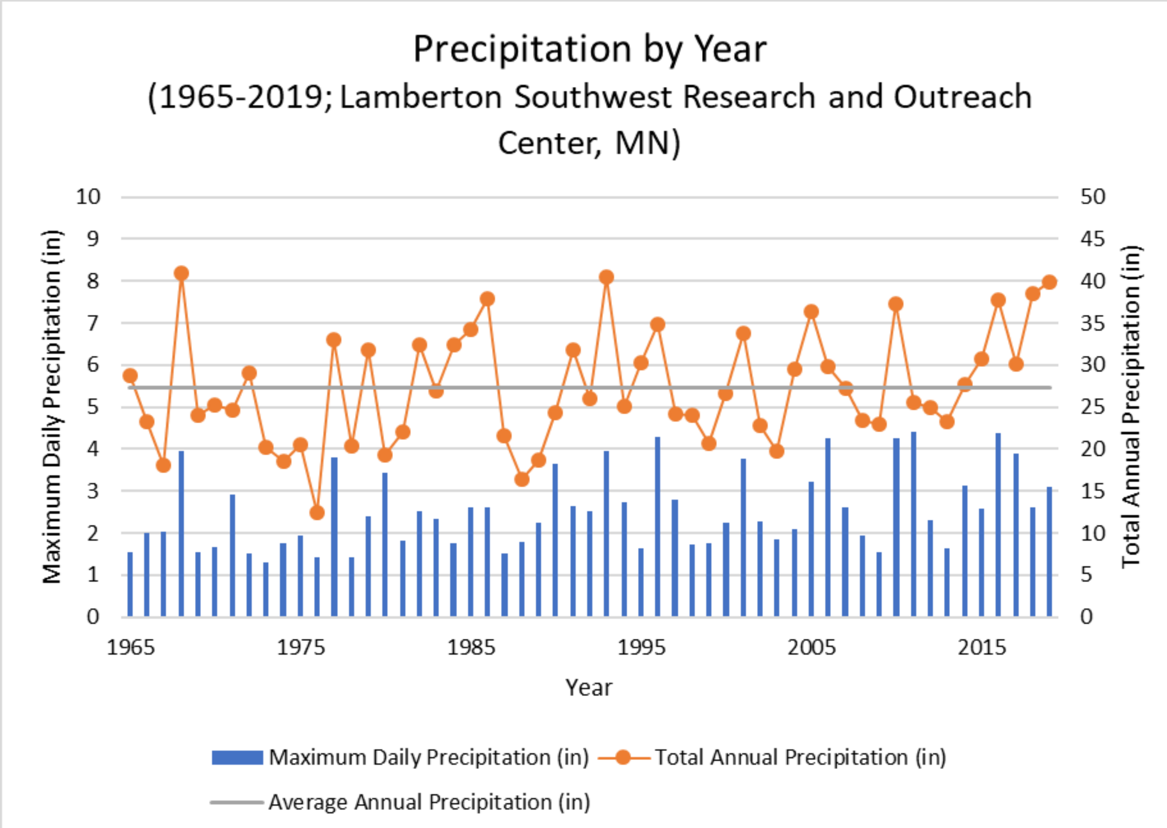


Figure C-8. Monthly precipitation at the Lamberton Southwest Research and Outreach Center station (USC00214546).

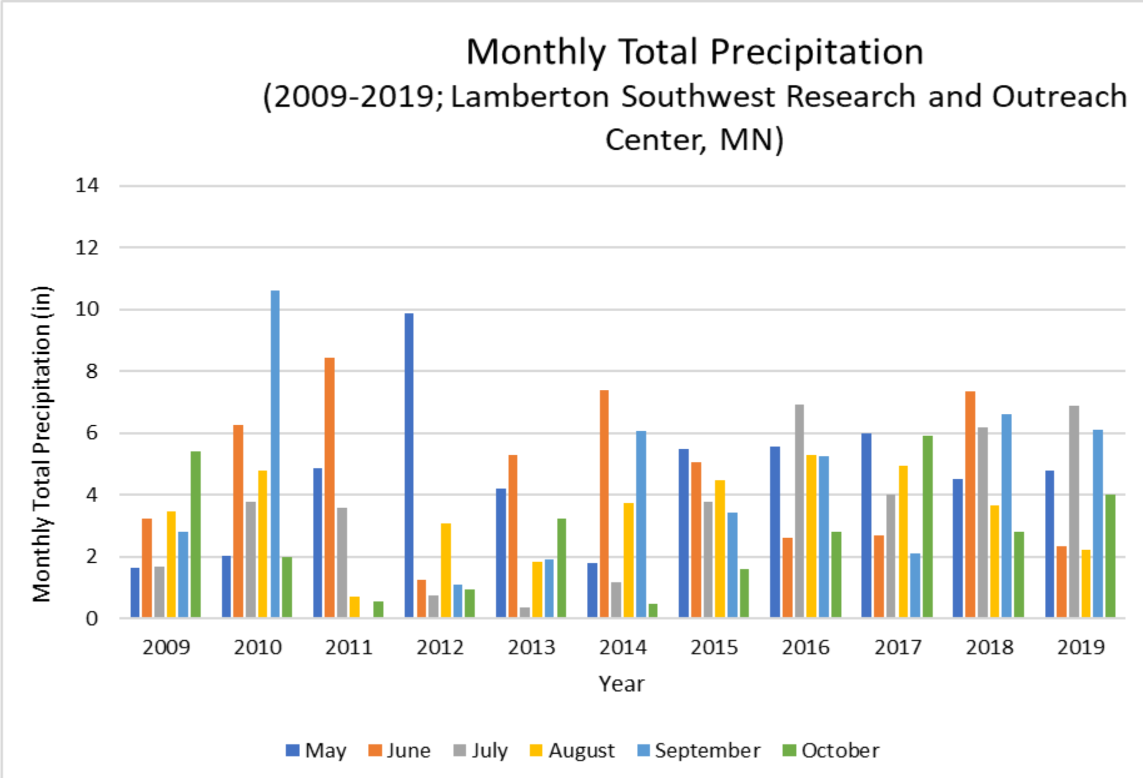


Figure C-9. Yearly precipitation at the Tracy station (USC00218323).

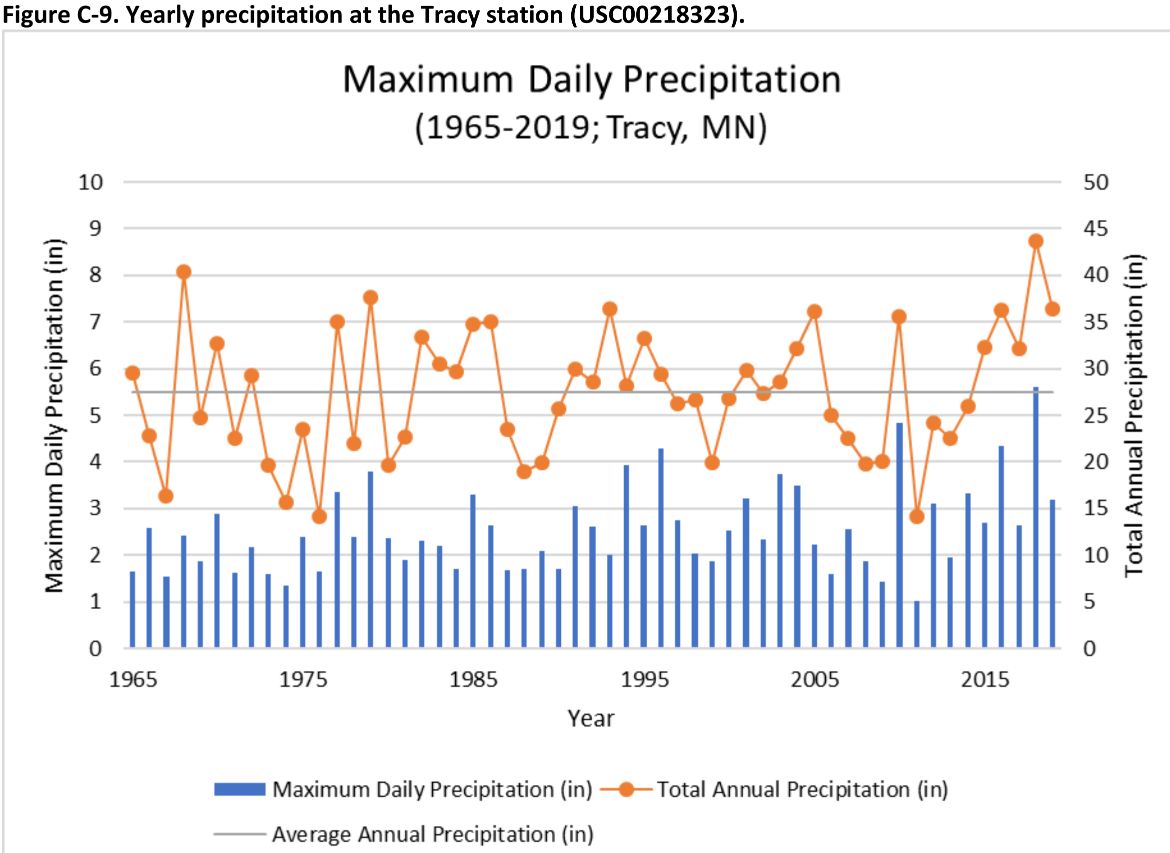


Figure C-10. Monthly precipitation at the Tracy station (USC00218323).

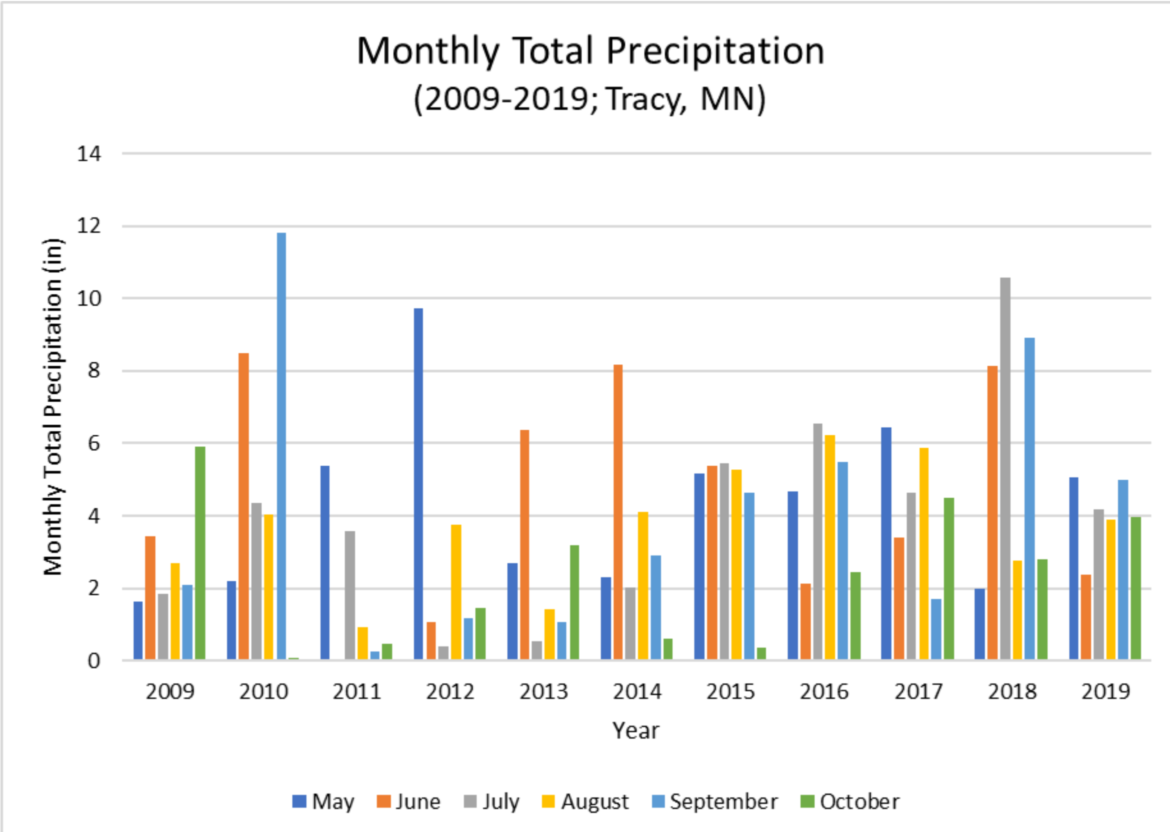
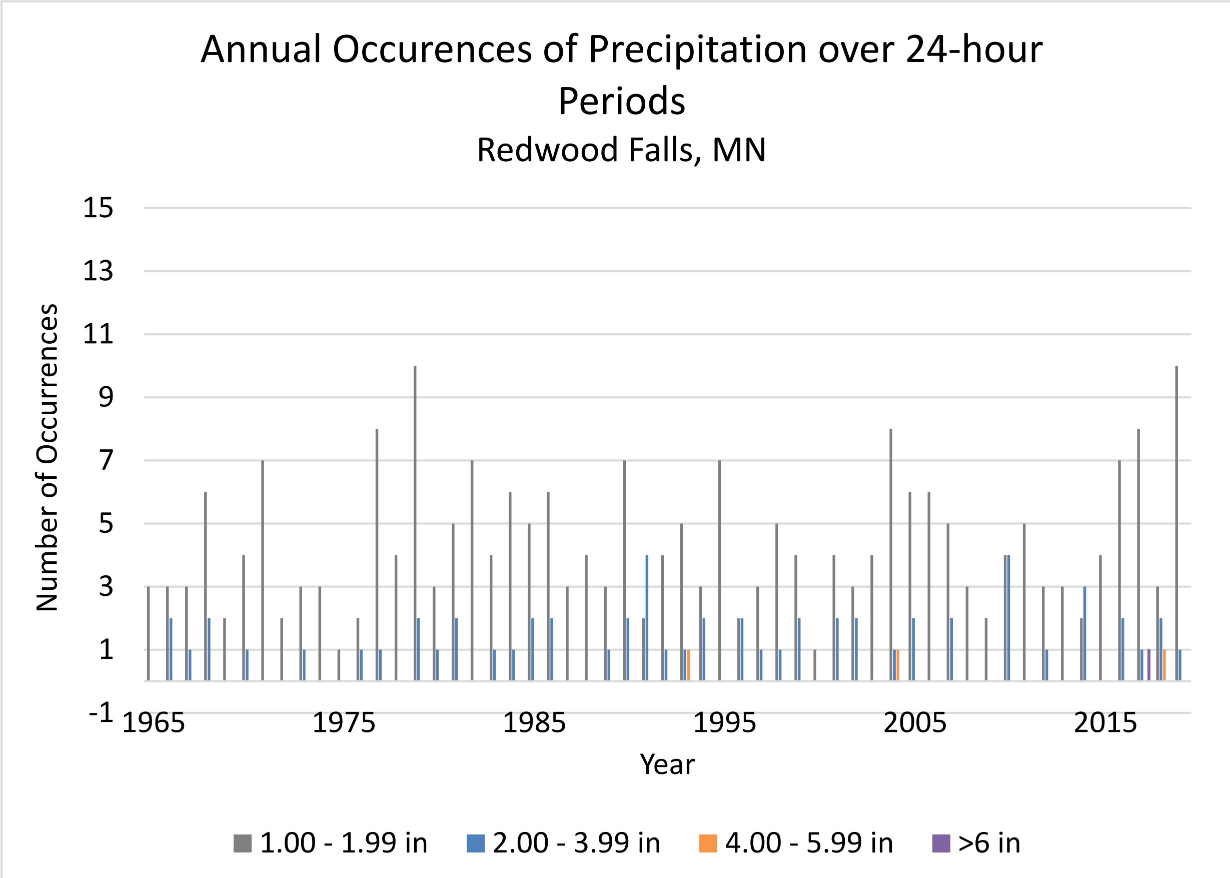


Figure C-11. 24-hour rain events at the Redwood Falls Municipal Airport.



Appendix D: Subwatershed Summaries

As described in Section 3.1, the purpose of the WRAPS subwatershed analysis was to provide a tool and framework to help local stakeholders and resource managers evaluate and compare the subwatersheds throughout the Redwood River Watershed. During the WRAPS process, a tabular database was constructed that included descriptive watershed statistics and other information for each HUC-12 subwatershed. The final product of the analysis was a two-page summary for each HUC-12 subwatershed that consists of an overview map (page one) and a descriptive summary (page two) of the subwatershed (Redwood River Webpage).

Overview Map

The overview map is intended to provide a closer, detailed look at the subwatershed. The map shows the location of the subwatershed within the greater Redwood River Watershed, the upstream contributing subwatersheds, elevation change of the subwatershed, as well as water bodies, WMAs, impairments, and townships within the subwatershed.

Descriptive Summary

The subwatershed descriptive summary (page two) contains a column for quick facts about the subwatershed including watershed area, contributing/upstream HUC-12 watersheds and their areas, elevation change within the HUC-12, and known longitudinal barriers identified in the DNR's Watershed Characterization Report. The descriptive summary also contains a list of the watershed impairments, reductions needed to meet TMDLs, and general strategies for addressing the impairments. Finally, four small maps from the DNR's Watershed Health Assessment Framework (WHAF) were included to highlight health scores for key watershed pollutant sources/stressors which can be compared to other subwatersheds throughout the Redwood River Watershed. Regardless of the variable, WHAF scores range from 0-100, with 0 representing the least healthy condition and 100 representing the healthiest condition. An overview of the WHAF tool and detailed information on how each watershed health score was calculated can be found online here. The four WHAF maps presented in the descriptive summaries are summarized below.

Altered Watercourse

The Altered Watercourse metric is the ratio of the length of altered watercourses in the catchment to the total length of watercourses. Data from the Altered Watercourse Project were used to classify all streams in the state to major classes of natural, altered, impounded, or no definable channel. The score ranges from 0-100 with low scores representing the worst condition of all streams being altered and high scores represent the best condition of all streams being natural. See here for more information on how the Altered Watercourse score was developed.

Livestock Animals

The Livestock Animals metric totals the number of AUs in registered feedlots within each catchment. The AU count is normalized for the watershed area to calculate an AU/acre. The score ranges from 0-100 with low scores indicating an AU/acre density of >0.75 and high scores indicating no registered feedlots within the catchment. See here for more information on how the Livestock Animals score was developed.

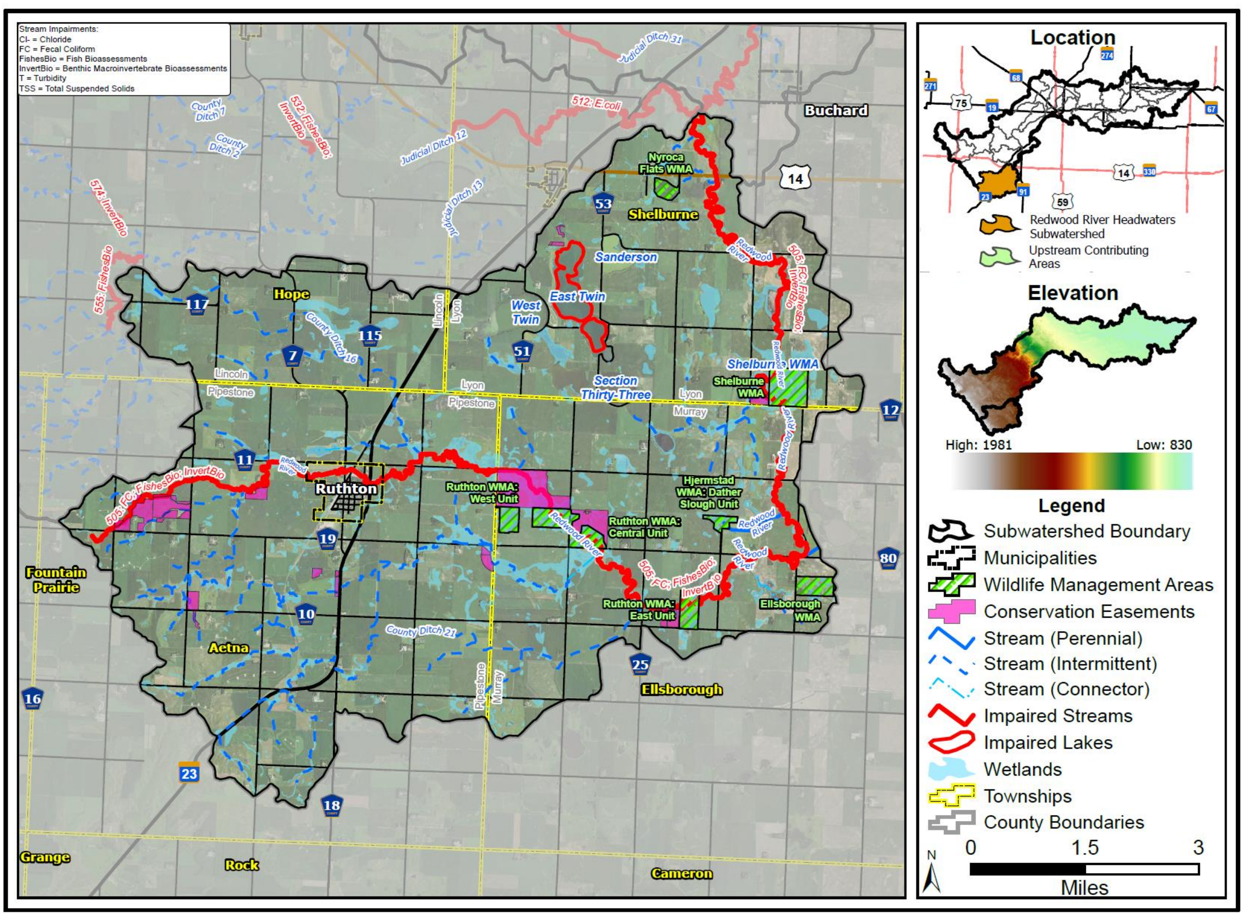
Steep Slopes Near Streams

Spatial data used to calculate the Steep Slopes Near Streams health score include the DNR Hydrography Streams with Strahler Stream Order, 30-meter buffer of streams with a Strahler Stream Order ≤3-, and 100-meter buffer and 30-meter buffer or streams with Strahler Stream Order >3. Spatial data layers were used to identify areas of steep slopes found in close proximity to streams. The score ranges from 0-100 and ranks the risk that erosion from steep slopes will impact streams. A high density of steep slopes results in a low score, whereas a low density of steep slopes results in a high score. See here for more information about how the Steep Slopes Near Streams score was developed.

Wetland Loss

The Wetland Loss metric calculates the ratio of current water storage capacity to pre-settlement water storage capacity. Pre-settlement water storage was approximated using hydric soils information from county (SSURGO) and state (STATSGO) soil surveys. Current water storage was approximated using the National Wetland Inventory (NWI). The score ranges from 0-100, with low scores indicating a high proportion of land within the catchment has been converted out of water storage and high scores indicating a high proportion of land has been preserved as water storage area. See here for more information on how the Wetland Loss score was developed.

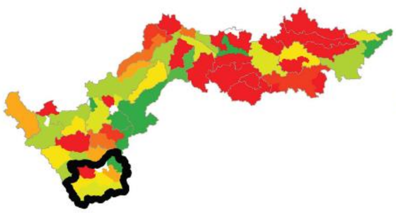
Redwood River Headwaters Subwatershed



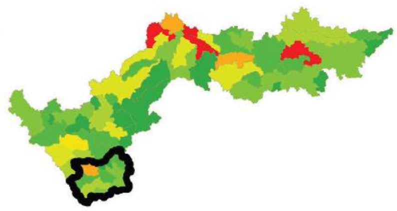
Redwood River Headwaters

HUC-12 ID 70200060101

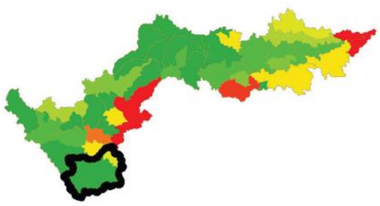
Altered Watercourses



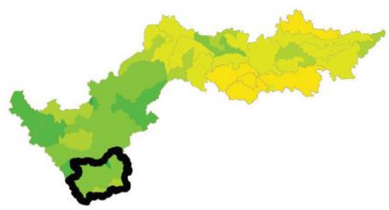
Livestock Animals



Steep Slopes Near Streams



Wetland Loss



High Score Healthiest — **Low Score** Least Healthy

Strategies:

Primary pollutant addressed by strategy type noted in italics.

Soil Health *Sediment*	**Implement cover crops, no-till, and/or low-till management techniques to improve soil health and increase water storage capacity of soils**
Manure & Septic Management *Bacteria*	**Implement appropriate combination of education, inspections, BMP construction, and upgrades with individual producers and owners**
Biotic	**Implement strategies above to address biotic stressors, including altered hydrology, habitat, eutrophication, DO, and TSS**

Quick Facts:

Subwatershed Size:
36,131 acres

Upstream Subwatersheds:
None

Counties:
41% Pipestone
27% Murray
23% Lyon
10% Lincoln

Cities:
Ruthton

Major Waterbodies:
Redwood River
East and West Twin Lakes
Sanderson Lake

Elevation Change:
Maximum Elevation: 1,981 ft
Minimum Elevation: 1,606 ft

Impairments:

Bacteria:
79% Reduction needed for Redwood River Reach 505 to meet TMDL

Biotic:
Redwood River Reach 505 is impaired for fish and macroinvertebrates. East Twin Lake is impaired for fish.

Appendix E: Additional Redwood River technical resources

Additional Redwood River Watershed resources

Hydrologic Condition and Terrain Analysis Report for the Redwood River Watershed: Redwood River Watershed Characterization Report | WRL Digital Asset Management (mnpals.net)

Lincoln County Water Management Plan: https://ae1a4a0a-c04a-4e97-aa8f-2f6377097303.filesusr.com/ugd/d35c58_c7a4f4b8da8446feb9a22ba9f819b5a7.pdf

Lyon County Comprehensive Local Water Management Plan: https://www.lyonco.org/departments/lyon-county-soil-water-conservation-district/reports-and-plans/-folder-1112#docan2403_3404_2333

Minnesota Department of Natural Resources (DNR) Climate Summary for Watersheds: Redwood River: http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/climate_summary_major_27.pdf

Minnesota Department of Natural Resources (DNR) Redwood River Watershed Characterization Report: https://wrl.mnpals.net/islandora/object/WRLrepository%3A3670

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

Minnesota Department of Natural Resources (DNR) Watershed Health and Assessment Framework (WHAF) Redwood River Watershed Report Card: http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_27.pdf

Minnesota Nutrient Planning Portal for Redwood River Watershed: https://mrbdc.mnsu.edu/mnnutrients/watersheds/redwood-river-watershed

Minnesota Pollution Control Agency (MPCA) Redwood River Watershed Monitoring and Assessment Report: https://www.pca.state.mn.us/sites/default/files/wq-ws3-07020006.pdf

Minnesota Pollution Control Agency (MPCA) Redwood River Watershed Total Maximum Daily Load (TMDL) Study for Total Suspended Solids, *E. coli*, Chloride, and Lake Nutrients: provide final link

Minnesota Pollution Control Agency (MPCA) Redwood River Fecal Coliform Total Maximum Daily Load Report: https://www.pca.state.mn.us/sites/default/files/wq-iw7-21e.pdf

Minnesota Pollution Control Agency (MPCA) Redwood River Watershed Stressor Identification Report: Redwood River Watershed Stressor Identification Report (state.mn.us)

Murray County Local Water Management Plan: Water Plan (revize.com)

Pipestone County Comprehensive Plan (Includes Water Plan): https://img1.wsimg.com/blobby/go/b84d0090-eb02-46e0-8112-ccf3eec10e72/downloads/ComprehensivePlan.pdf?ver=1587152032853

Redwood County Comprehensive Local Water Management Plan: https://c9c11c37-9889-4c8b-b0ac-4022c0d3a130.filesusr.com/ugd/4af85c_e82127e3bb994e0ca42f9dcfea6429cd.pdf

United States Department of Agriculture and National Resources Conservation Service (NRCS) Rapid Watershed Assessment Resource Profile Redwood HUC: 07020006: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022932.pdf

Yellow Medicine County Comprehensive Local Water Plan: https://www.co.ym.mn.gov/index.asp?SEC=654CAAB6-1A68-4F27-9852-B7E178D83F8E&DE=B847C405-88FC-494B-97DE-AAA53AEE84ED