Zumbro River Watershed Restoration and Protection Strategies Report

November 2017

MINNESOTA POLLUTION CONTROL AGENCY

Protect Clean Enjoy ZUMBRO WATERSHED PARTNERSHIP

LimnoTech Water Environment | Scientists Engineers

CLEAN WATER LAND & LEGACY AMENDMENT

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Project Partners

Authors

Paul Wotzka, Zumbro Watershed Partnership (ZWP)

Justin Watkins, Minnesota Pollution Control Agency (MPCA)

Contributors / acknowledgements

Sarah Duke Middleton, ZWP

Dodge County Soil and Water Conservation District (SWCD)

Goodhue County SWCD

Olmsted County SWCD

Rice County SWCD

Steele County SWCD

Wabasha County SWCD

Minnesota Agricultural Water Resource Center (MAWRC)

Jeff Weis, Nick Proulx, Paul Radomski, Kristin Carlson, Minnesota Department of Natural Resources (DNR)

Jane de Lambert, Pat Baily, Minnesota Department of Health (MDH)

Erin Andrews, Marco Graziani, Ashley Ignatius, Greg Johnson, Kim Laing, Joe Magee, Ben Roush, Tiffany Schauls, MPCA

Nick Grewe, Dendy Lofton Ph.D., Hans Holmberg, Derek Schlea, Amanda Flynn, Todd Redder, LimnoTech, Inc.

Editing and Graphic Design

Administrative staff:

Jinny Fricke, MPCA

Cover Photo

Cold Creek; Paul Wotzka, ZWP

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Key Terms

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

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to aquatic life 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 if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus, chlorophyll-a, or Secchi disc depth standards are not met.

Hydrologic Unit Code (HUC): A Hydrologic Unit Code (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 Pomme de Terre River Watershed is assigned a HUC-8 of 07020002.

Impairment: Water bodies are listed as impaired if water quality standards are not met for designated uses including aquatic life, aquatic recreation, 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 waterbody. 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 waterbodies.

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 waterbodies.

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 non-pollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

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 Zumbro River Watershed (ZRW) encompasses a diverse landscape that supports productive farms and growing urban centers, including one of Minnesota's biggest cities: Rochester. The watershed includes rivers and streams of varying water quality and groundwater that is sensitive to pollution. Land use is a variable mix of agriculture, forest, and developed land. Agricultural cropland, pasture and forage acreage account for approximately 75% of the watershed. Cropland is used predominantly for growing corn and soybeans.

The condition monitoring, trend analysis and field investigations that comprise a foundation of this document are detailed in subsequent Chapters 1 and 2. The general summary of this work is that some waters are of good quality and need protection, and many waters are impaired and need restoration:

- Approximately 40% of the assessed stream and river reaches are fully supporting aquatic life use (i.e. good "fish and bugs") and nearly 90% of the sites sampled for fish showed good populations.
- Monitoring data at the South Fork Zumbro Milestone site (S000-268) indicate decreases in runoff-driven pollutant (e.g. phosphorus and sediment) concentrations over time. This decrease generally agrees with Minnesota's Nutrient Reduction Strategy (NRS) that estimates a 33% improvement in the phosphorus load leaving the state since the mid-1990s.
- Discharge monitoring data have documented significant decreases in point source loads of phosphorus from the wastewater treatment facilities (WWTFs) in the watershed, including the city of Rochester's.
- Stream habitat has been degraded at most of the sites sampled for aquatic macroinvertebrates such that the populations have been negatively impacted.
- Minnesota's NRS estimates little, if any, reduction in the nitrogen load to streams in the state since the mid-1990s, and the data and modeling in the ZRW show many instances of high nitrogen loading and some increasing concentration trends in streams and springs.

The purpose of the Watershed Restoration and Protection Strategy (WRAPS) is to use this foundation of technical information as a starting point from which to develop tools that will help local governments, land owners, and interest groups determine (1) the best strategies for making improvements to degraded waters and protecting resources that are already in good condition, and (2) focus those strategies in the best places to do work.

Chapter 3 is the primary section of this report for local partner use in planning or project conception. It includes details and products that came from a year-long engagement with watershed stakeholders and local government units aimed at prioritizing and implementing restoration and protection strategies. A general summary is as follows:

- Cultivated land is the source for the vast majority of the nitrogen load in the ZRW. Less than 10% of the nitrogen load leaving those land areas is via runoff; the dominant transport mechanism is leaching loss to tiles or groundwater and management should be applied accordingly. The nitrogen load can be reduced by improving nutrient use efficiency and control, treatment of excess nitrogen via drainage management and adding living cover such as perennials and cover crops.

- Stakeholders identified Lake Zumbro as a priority. A continued long-term effort to reduce phosphorus and sediment loading in the Lake Zumbro Watershed is needed to make further improvement in water quality and reduce in-filling of the upper segment of the reservoir.

- Point source phosphorus loads are important during low flow years. The draft 2016 impaired waters list includes four phosphorus listings in the ZRW (Table 1). The MPCA is considering site specific standards for Lake Zumbro (55-0004) and the South Fork Zumbro River (07040004-507). As such, the watershed TMDLs report does not include phosphorus TMDLs for those assessment units. Once the water quality goals are finalized, an assessment and if necessary a subsequent comprehensive analysis of impairments (including South Branch Middle Fork Zumbro River (07040004-978)) and sources in the Lake Zumbro Watershed will be completed. This may include TMDLs and WLAs for point sources that are protective of downstream river and reservoir water quality.

- Habitat issues in streams require further examination. Degraded and/or insufficient stream habitat is a prevalent stressor of biota (i.e. "fish and bugs") in southeast Minnesota and in the ZRW. Sediment loading to these systems is a main driver for degraded habitat quality. Sundermann et al. (2013) found that:

  > "Sediment load is another local factor altering habitat quality, as a high sediment load might lead to streambed colmation (Brunke 1999). This would particularly impair burrowing species and may reduce habitat availability, especially if hard substrates, such as gravel, cobbles or boulders, are covered by a thin layer of fine sediments."

  Planning efforts should consider the best strategies for addressing habitat issues in various settings and at various scales. State monies are supporting natural channel design projects and trout habitat improvement projects; some Soil and Water Conservation Districts (SWCDs) are implementing low-cost projects that change channel geometry and seed banks with perennial vegetation. All are viable strategies; a thoughtful and technically supported approach to optimally applying these various habitat improvement methods would allow best use of time and resources.

- Nearly all of the designated trout waters in the Lower Zumbro Watershed meet the criteria for the southeast Minnesota coldwater fish Index of Biotic Integrity (IBI). While there are restoration considerations in this lobe, a focus of protection work should be preserving the baseflow of streams via focused monitoring and careful consideration of future water appropriations.

- More living cover on the land reduces pollutant loads and provides wildlife habitat. This is a multiple-benefits "parent" strategy from which various specific strategies could be shaped. Examples that are referenced and discussed in this WRAPS document include:

  - Keep existing pastures and rangeland; look for opportunities to convert marginal row crop acres. Pasture is a working-lands best management practice (BMP) that is an integral part of local economies;

- Encourage re-enrollment of expiring Conservation Reserve Program (CRP) contracts;
- Manage forest acres with stewardship planning;

Chapter 3 concludes with a summary of restoration and protection strategies for the ZRW. Regarding phosphorus and sediment, the strategies are focused on proven agricultural conservation practices that are the hallmark of SWCDs. For nitrogen, they center on source control and vegetation changes.

Taken as a whole, the strategies state that to meet the nutrient reduction goals in the ZRW, partners should work to:

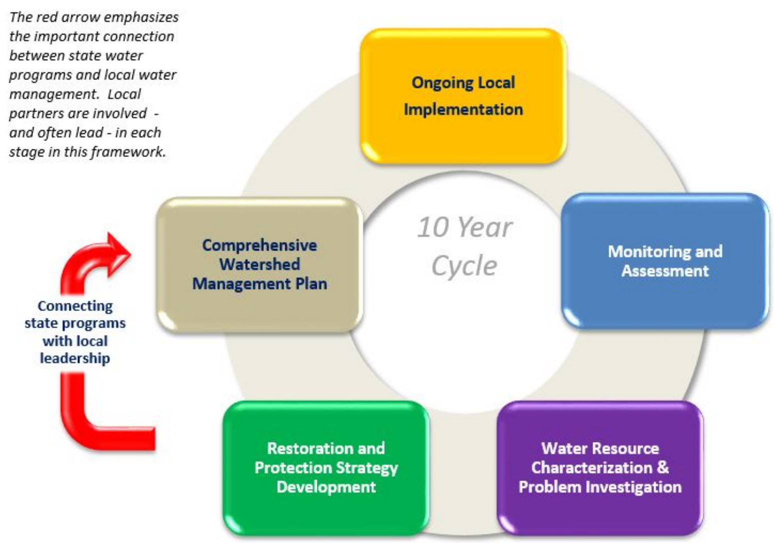
- Fully implement the buffer rule;
- Change marginal cropland (not suited to annual crops) to perennial cover;
- Expand application of cover crops in particular on short season annual cropland;
- Improve source control of nitrogen fertilizer.

Chapter 3 provides more discussion and detail, including stakeholder-derived examples of estimated scales of adoption of these BMPs that will result in goal attainment. It also tabulates a number of watershed diagnostic tool outputs that can be used to focus these strategies.

Progress and improvement in the ZRW will be marked by implementation of these strategies. On-going measurement and condition monitoring will examine the fish and macroinvertebrate populations in streams, algae blooms in lakes, and the pollutant loads leaving the watershed.

The value of the Zumbro WRAPS going forward is in its summarization and listing of (1) various technical works and tools that were developed via significant time, resources and stakeholder input, and (2) examples of BMP combinations that can attain pollutant reduction goals. These tools and examples do not amount to a plan or prescription, but rather serve to inform future planning and support local partner efforts to acquire funds to do conservation work in the watershed.

What is the WRAPS Report?



The state of Minnesota has adopted a "watershed approach" to address the state's 80 "major" watersheds (denoted by 8-digit hydrologic unit code or HUC). This watershed approach incorporates **water quality assessment, watershed analysis, civic engagement, planning**, **implementation**, and **measurement of results** into a 10-year cycle that addresses both restoration and protection.

As part of the watershed approach, waters not meeting state standards are still listed as impaired and Total Maximum Daily Load (TMDL) studies are performed, as they have been in the past, but in addition the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies and actions for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This report also serves as a watershed plan addressing U.S. Environmental Protection Agency's (EPA's) Nine Minimum Elements to qualify applicants for eligibility for Section 319 implementation funds.

Purpose	• Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning
	• Summarize Watershed Approach work done to date including the following reports:
	  • *Zumbro Watershed Monitoring and Assessment (https://www.pca.state.mn.us/sites/default/files/wq-ws3-07040004b.pdf)*
	  • *Zumbro Watershed Biotic Stressor Identification (https://www.pca.state.mn.us/sites/default/files/wq-ws5-07040004a.pdf)*
	  • *Zumbro Watershed Total Maximum Daily Load - DRAFT (https://www.pca.state.mn.us/sites/default/files/wq-iw7-45b.pdf)*
	  • *Zumbro River Interim Watershed Management Plan (http://www.zumbrowatershed.org/Resources/Documents/ZWP_InterimWatershedPlan042013.pdf)*
	  • *Zumbro River Watershed HSPF Modeling Documents*

Scope	• Impacts to aquatic recreation and impacts to aquatic life in streams • Impacts to aquatic recreation in lakes
Audience	• Local working groups (local governments, SWCDs, watershed management groups, etc.) • State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed Background & Description

The ZRW lies in southeastern Minnesota, nestled between the Cannon River, Mississippi River Winona (Whitewater River) and Root River Watersheds. The Zumbro River is comprised of three major branches bearing their watershed's name sake, distinguished by their geographic location within the watershed: South Fork Zumbro River, Middle Fork Zumbro River and North Fork Zumbro River, all originating in the agrarian plains in the western reaches of the watershed and all flowing roughly east and joining to form the mainstem near Mazeppa (Waters 1977). From their confluence, the Zumbro River travels nearly 65 miles flowing in a northeasterly direction through a deep gorge joining the Mississippi River near Kellogg. The watershed spans 1,422 mi^2, stretching from the far eastern boundaries of Rice and Steele counties and across the southern third of Goodhue County and a majority of Dodge, Olmsted, and Wabasha counties (Figure 1).

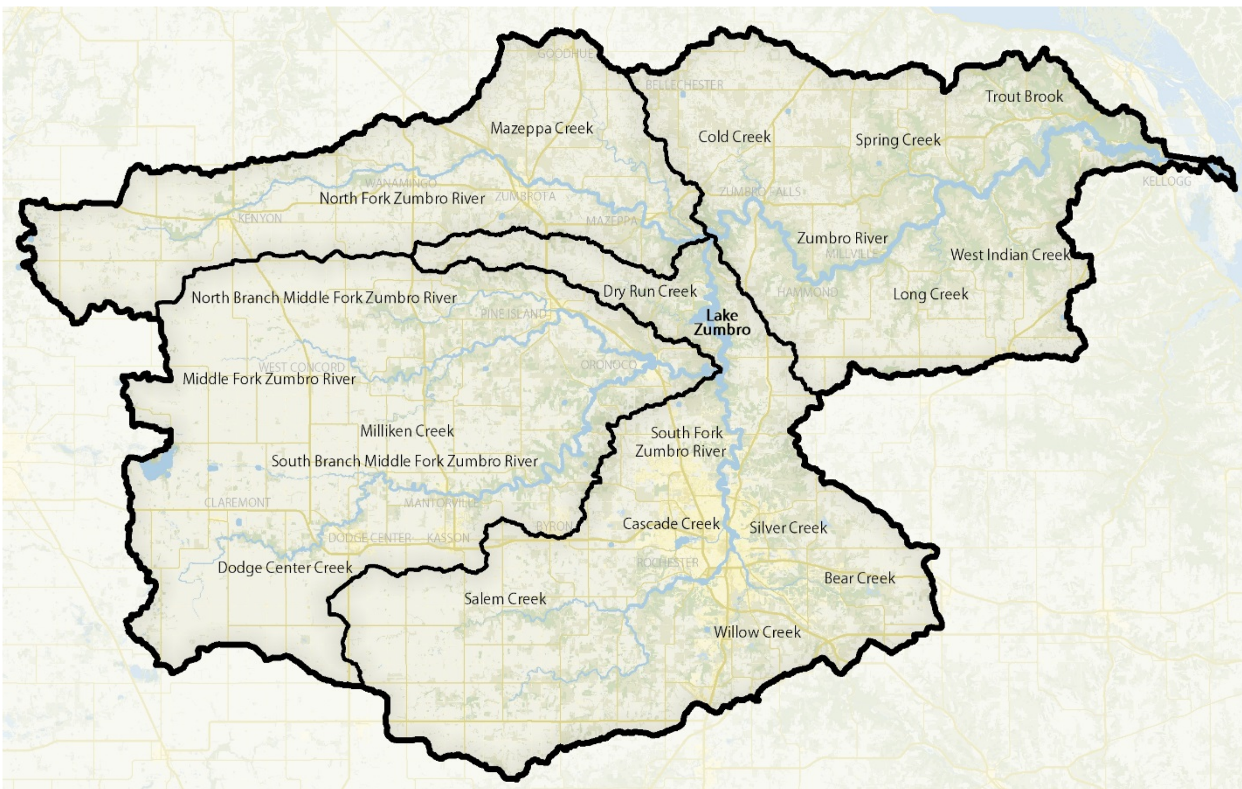


Figure 1. ZRW lobes, major cities and river reaches.

The ZRW's streams are primarily classified as warmwater. Gently rolling plains in the western and central regions of the watershed transition moving east into rolling hills and dramatic blufflands characteristic of southeastern Minnesota; this topographical shift, in addition to underlying geology, gives rise to an abundance of springs, supplying cold water to the watershed's eastern coldwater tributaries including: Mazeppa Creek, Cold Creek, Spring Creek, and Trout Brook. Significant portions of these streams are classified as wild (naturally reproducing) or semi-wild trout waters, making the region popular among anglers. The Zumbro system is also an important resource for recreation, its swift current and an abundance of snags attribute to its French namesake: "Riviere des Embarras" meaning river of difficulties, offering a challenge to canoeists and kayakers on this designated State Water Trail (Minnesota Department of Natural Resources (DNR)). Like other watersheds in southeastern Minnesota, the ZRW has few natural lakes, but several reservoirs. The most prominent in the watershed, Zumbro

Lake, was constructed in 1919 and spans 600 acres. The hydroelectric dam provides power to the city of Rochester upstream (Rochester 2013).

Much of the modern landscape of ZRW has been modified by agriculture and human development. Remaining natural prairies are limited to the steep slopes of the blufflands. Traditional pine forests have transitioned to deciduous hardwood forests and have grown in size due to fire suppression. In 1961, the Richard J Dorer Memorial Hardwood State Forest, which includes the Zumbro Bottoms State Forest, was created to promote conservation and responsible land use and restore a landscape damaged by flooding, a result of the land's overuse. A significant acreage of the forest lies within the watershed's eastern boundaries and serves as a valuable resource for wildlife and recreation in southeastern Minnesota (DNR).

The western third of ZRW marks a transition from the Western Cornbelt Plains ecoregion to the Driftless Area ecoregion. Rich organic glacial prairie soils provide a rich medium for cultivation in the western agricultural hub of the watershed, comprised of Central Iowa and Minnesota Till Prairie. Soils transition moving east into Eastern Iowa and Minnesota Till Prairie, ultimately shifting towards the karst region and Northern Mississippi Valley Loess Hills. Karst features coincide with increasing slopes and more dramatic topography. As slopes increase, the land's lack of utility as cropland transitions to a growing abundance of pasture lands. Within the wide valleys of the eastern blufflands, there is a more even mixture of grain and rangeland operations and increasing amounts of forested, wetland and natural areas. This rugged terrain falls within the driftless ecoregion.

The driftless area, or Paleozoic plateau, is a region of the northern United States, including southeastern Minnesota, southwestern Wisconsin, northeastern Iowa and extreme northwestern Illinois, that were not covered by glaciers during the Wisconsin glaciation. Bedrock forming the plateau dates back to the Paleozoic Era containing sedimentary formations from ancient seas of the Ordovician and Devonian periods; it is comprised of limestone, dolomite, sandstone and shale. During the last glaciation, the plateau stood above the surrounding plains covered by the Superior and Des Moines glacial lobes. "The driftless area is a geologic relic—affected by surrounding glaciers, but not covered with their remains" (Waters 1977). The region is largely characterized by underground caverns, sinkholes and disappearing streams. Figure 2 shows the two ecoregions in the ZRW.

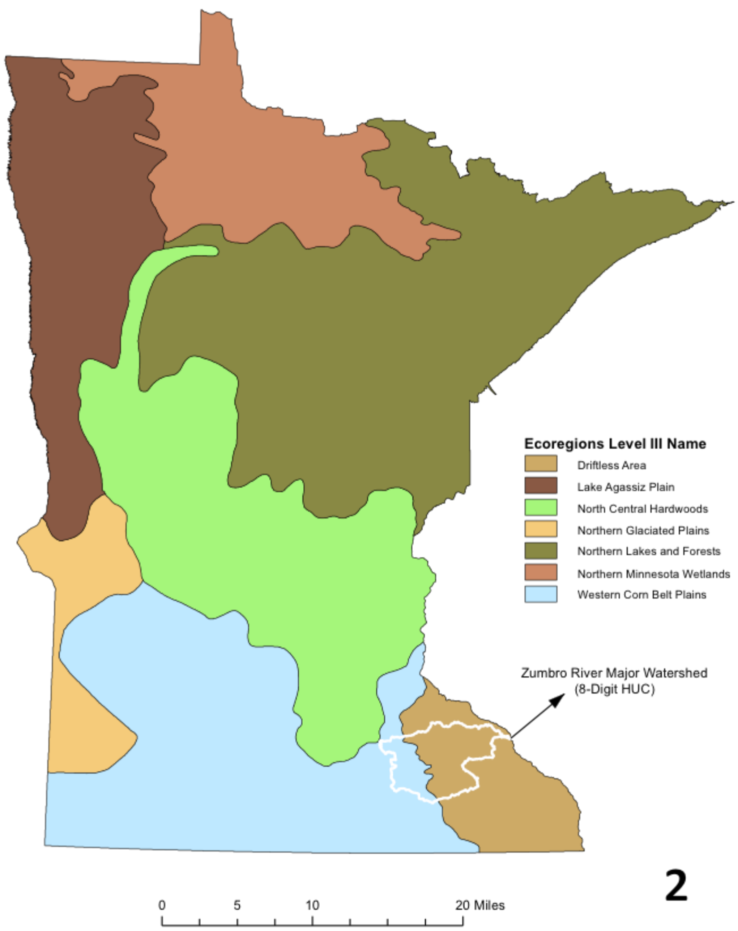


Figure 2. The Zumbro River Watershed within the Western Corn Belt Plains and Driftless Area ecoregion of Southeastern Minnesota.

Land Use Summary

Today, the ZRW's land use can be characterized as cropland (56.0%), rangeland (grassland and pasture, 23.3%), forest/shrub (9.7%), developed (9.0%), wetland (1.5%), open water (0.5%) and barren land (less than 0.1%) (Figure 3). Nearly all of the watershed's land is privately owned - roughly 98% (NRCS 2016).

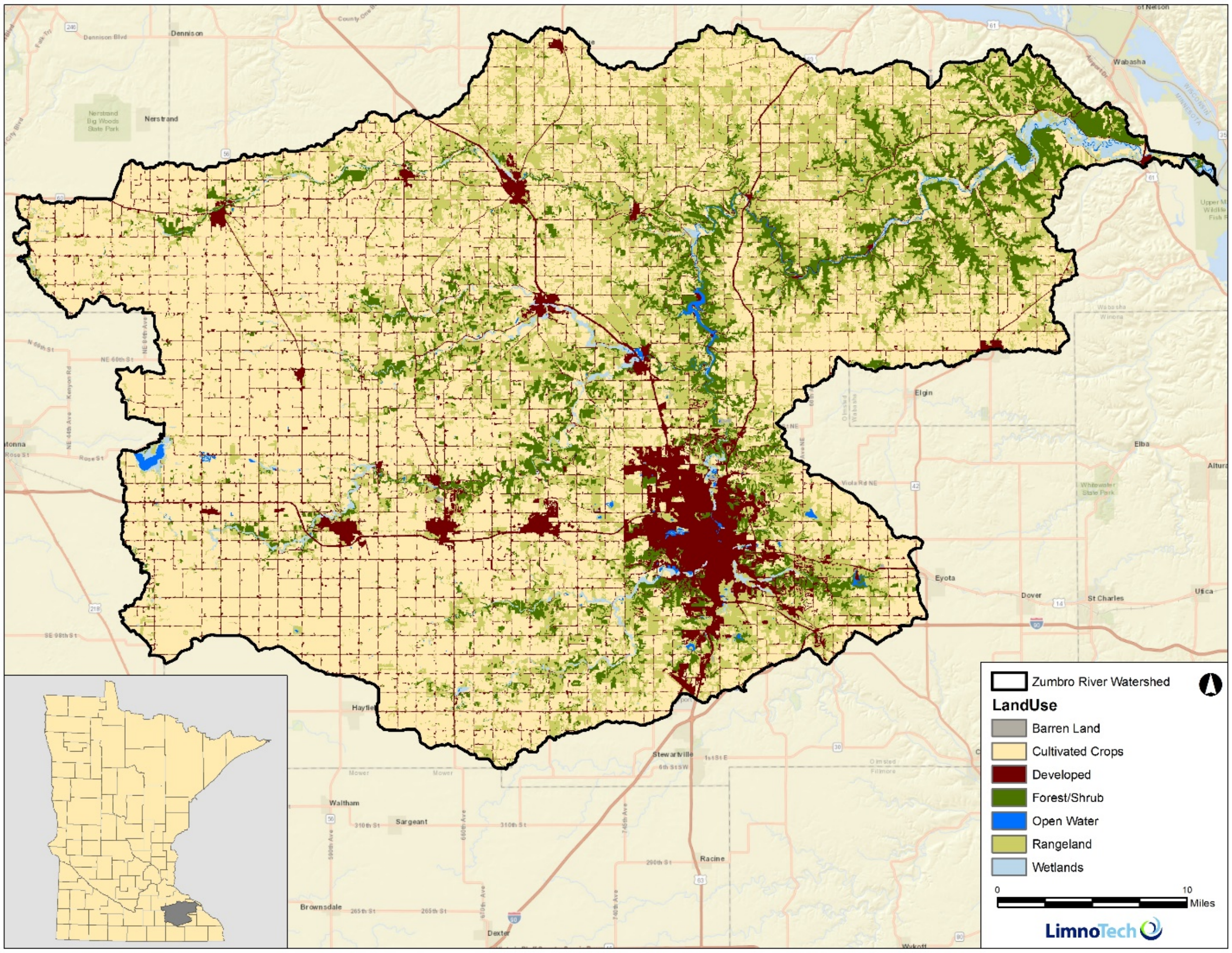


Figure 3. National Land Cover Dataset land use coverage in the ZRW (from NLCD 2011 dataset).

The northern, southern and western regions of the watershed are dominated by row crop agriculture with scattered livestock operations. The Natural Resources Conservation Service (NRCS) estimates that there are 2,730 farms in the watershed; 8% are greater than 1000 acres, 42% are less than 180 acres, and 50% are of medium size 180 to 1000 acres (NRCS 2016). Cropland is predominately planted in corn, forage for livestock and soybeans (MDA 2009 and 2010). There are currently 1,068 registered Animal Feedlot Operations (AFO) in the watershed. Animal livestock units in the watershed are divided as follows: 36% swine, 34% dairy, 26% cattle, 4% poultry, and 1% other (based on total animal units (AUs)). Wabasha County ranks as the state's fifth leading dairy producer, followed by Goodhue County. Goodhue County ranks as the state's eighth leading cattle producer (MDA 2013b and 2013d).

Moving east in the watershed, rangeland and forested uses increase. Rangeland typically surrounds heavily forested blufflands, as its steep terrain limits utility for crop production. Forested land use is greatest on the watershed's eastern boundaries.

While the watershed is predominately rural, it also encompasses Rochester, Minnesota's third largest city (population: 111,402). As such, Olmsted County has the state's eighth largest population (MDA 2013). Rural population centers in the watershed include smaller towns (Kasson: 6,074, Byron: 5,191, Zumbrota: 3,349, Dodge Center: 2,691, Pine Island: 2,590, Kenyon: 1,817, Mantorville: 1,206 and Wanamingo: 1,084) and rural communities (Mazeppa: 829, West Concord: 799, Viola: 596, Claremont: 540, Kellogg: 439, Zumbro Falls: 244, Millville: 179 and Hammond: 135) (U.S. Census Bureau).

Development in the greater Rochester area is expected to continue to grow, population estimates by the Minnesota Legislature estimate the region's population to increase in the range of 35% to 103% between the years 2000 and 2030 (MPSDC 2002).

Surface water hydrology

The Zumbro River's headwaters lie within its three major branches: the South Fork Zumbro River, Middle Fork Zumbro River and North Fork Zumbro River, all traveling roughly fifty miles before joining to form the Zumbro River. The South Fork Zumbro River flows north, serving as the upstream watershed for Rochester's urban center, flowing north and joining Zumbro Lake from the south. The Middle Fork Zumbro River begins at the outlet of Rice Lake and flows east into Zumbro Lake. The North Fork Zumbro River begins a few miles East of Faribault and flows east, converging with Mazeppa Creek before draining to the Zumbro River. The Zumbro River begins at the outlet of Zumbro Lake, an impoundment of the convergence of the South and Middle branches of the Zumbro River, gaining the flow from its North Fork a few miles downstream. From Zumbro Lake, the Zumbro River travels 65 miles in a northeasterly direction, passing near the communities of Zumbro Falls, Hammond and Millville, ultimately joining the Mississippi River near Kellogg. In 1974, a federal flood control project built levees and straightened the river from Kellogg downstream. The Zumbro River drops approximately 600 feet from its headwaters to its mouth (Waters 1977).

Despite an abundance of agricultural and urban land use within the watershed, the Zumbro River's riparian zones remain intact on many stretches of the Zumbro River and its tributaries. Fifty-six percent of the watershed's streams remain natural while 43% have been altered by channelization, according to the Minnesota Statewide Altered Watercourse Project (Figure 4). Less than 2% of the watershed's streams are impounded; however, historical records indicate that this number was once far greater. Figure 5 shows the percent of modified streams for all HUC-8 watersheds in Minnesota.

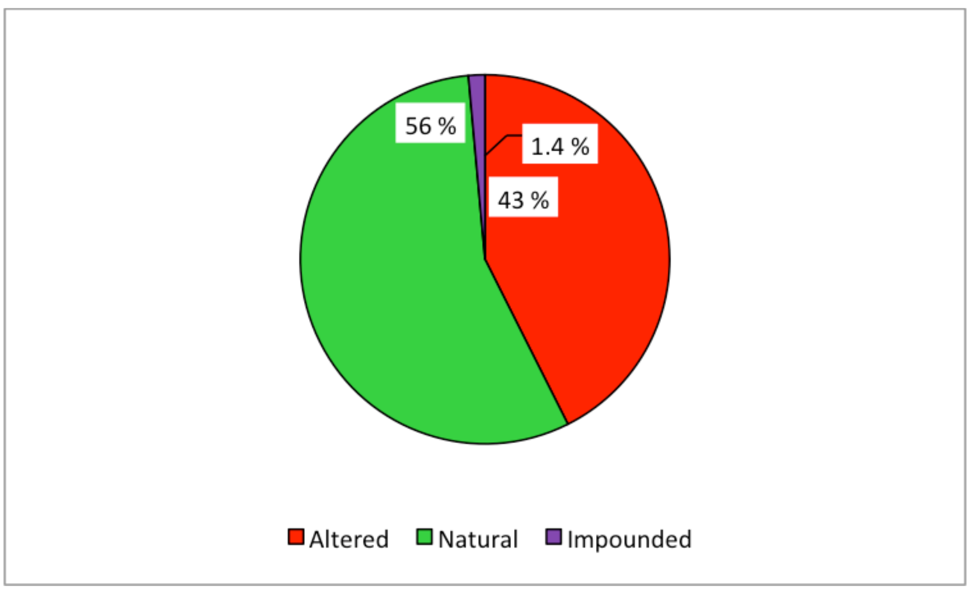


Figure 4. Comparison of natural to altered streams in the ZRW.

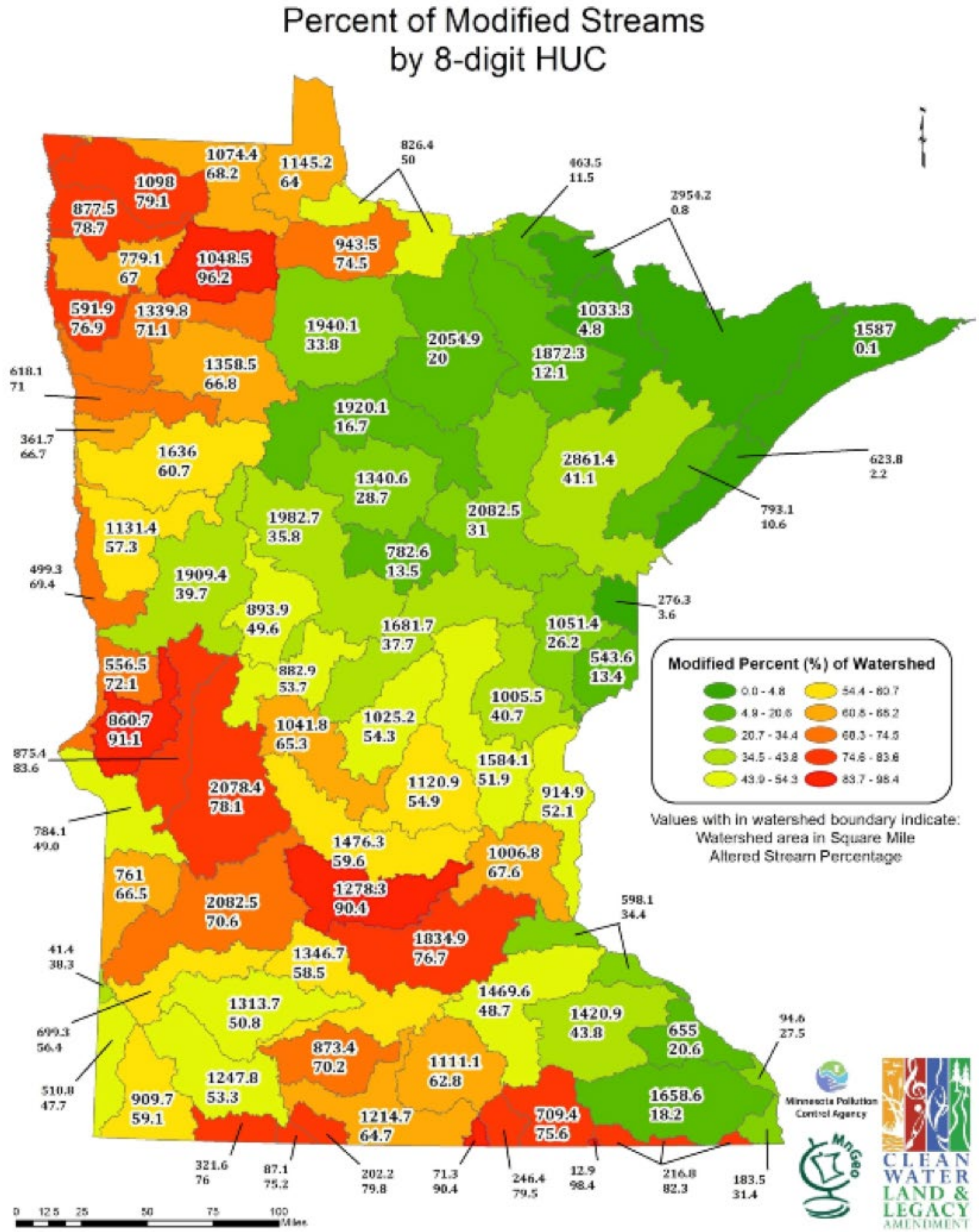


Figure 5. Map of Percent Modified Streams by Major Watershed (HUC-8), the ZRW's percentage is low compared to other regions of the state.

The powerful flows of the Zumbro River gave rise to the construction of several impoundments. Dams in the watershed were historically built for power generation for flour and timber milling, and were constructed not long after the region was settled in the 1850s. In 1919, a hydroelectric dam was built on the Zumbro River, creating present day Zumbro Lake, to supply power to the growing population of Rochester. Overtime many of the watersheds dams were not maintained and dismantled after their utility had run its course, including the once prominent dam that held Shady Lake in the city of Oronoco. Impoundments constructed more recently within and upstream of Rochester's city limits were built to provide flood control to the region. Natural lakes are not a prominent feature of the ZRW; only 17 lakes or ponds greater than 10 acres in size exist within the watershed, and many are not true lakes but rather man-made reservoirs of riverine systems.

Wetlands

There are approximately 22,000 acres of wetlands in the ZRW, roughly equivalent to 2% of its total area. Primarily concentrated within the riparian corridors of the watershed's rivers and streams, forested and emergent vegetation wetlands are the most predominant wetland types in the watershed (Figure 6). Furthermore, an extensive corridor of floodplain wetlands occurs along the lower reaches of the Zumbro River near the Mississippi River, accounting for a large percentage of the watershed's wetland area. It should be noted that these estimates represent a snapshot of the location, type, and extent of wetlands occurring in the early 1980s when aerial imagery was acquired to develop National Wetlands Inventory (NWI) maps in this part of the state. Updated NWI maps are currently available for the northern region of the watershed (i.e., Rice and Goodhue County).

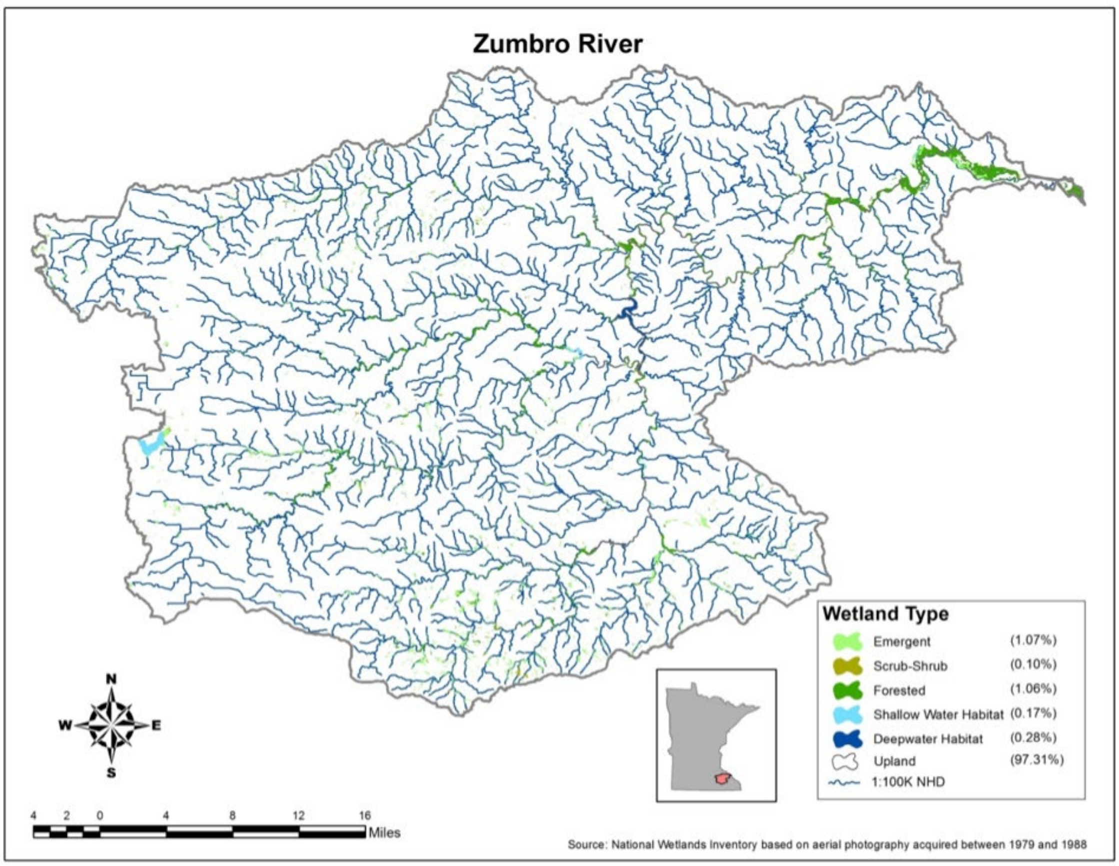


Figure 6. Wetland types and their distribution across the ZRW.

Soil data can be used to estimate the extent of historic or pre-settlement wetlands and serve as a baseline for comparing current wetland acreage. The NRCS Soil Survey Geographic (SSURGO) database, based on map units classified as "poorly drained" or "very poorly drained", provides an estimate of 168,000 acres of wetlands (~19% of watershed area) existed in the ZRW prior to European settlement (Soil Survey Staff, NRCS 2013). A comparison of these two time periods (i.e., pre-settlement vs. early 1980s) yields an estimate of 87% wetland loss for the ZRW. Wetland loss is not uniformly distributed across the watershed with the greatest rates of loss occurring in the headwaters and middle portions of the watershed (Figure 7). Floodplain wetlands were disconnected in 1974 by a federal flood control project, which built levees and straightened the river from Kellogg downstream. Former wetlands on the north and south sides of these levees are now in agricultural production.

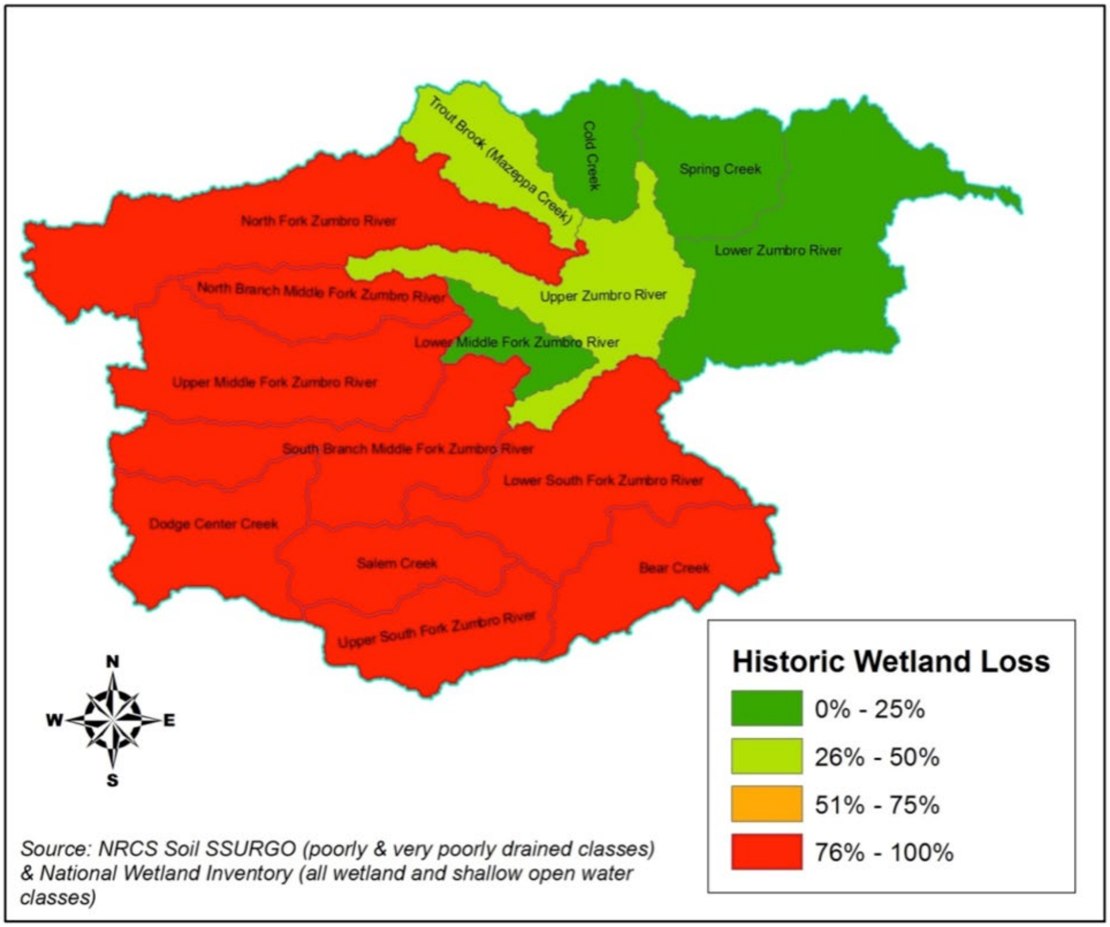


Figure 7. Estimated historic wetland loss in each subwatershed based on a comparison of "poorly drained" and "very poorly drained" soil types (SSURGO database) to wetland extent in the early 1980s (NWI).

Hydrogeology and groundwater quality

The ZRW falls within the Lower Mississippi River Basin. The watershed is found in the eastern area of the Southeast hydrogeologic region (Figure 8) and is dominated by glacial landforms and till. Due to the Paleozoic bedrock geology of the area, it is primarily limestone, dolomite and sandstone. The main aquifers include the Maquoketa-Spillville, Galena, St. Peter Sandstone, Prairie du Chien Group, Jordan Sandstone, Upper Tunnel City, Wonewoc, and the Mt. Simon (MPCA 1999; Runkel et al, 2003; Mossler, 2008).

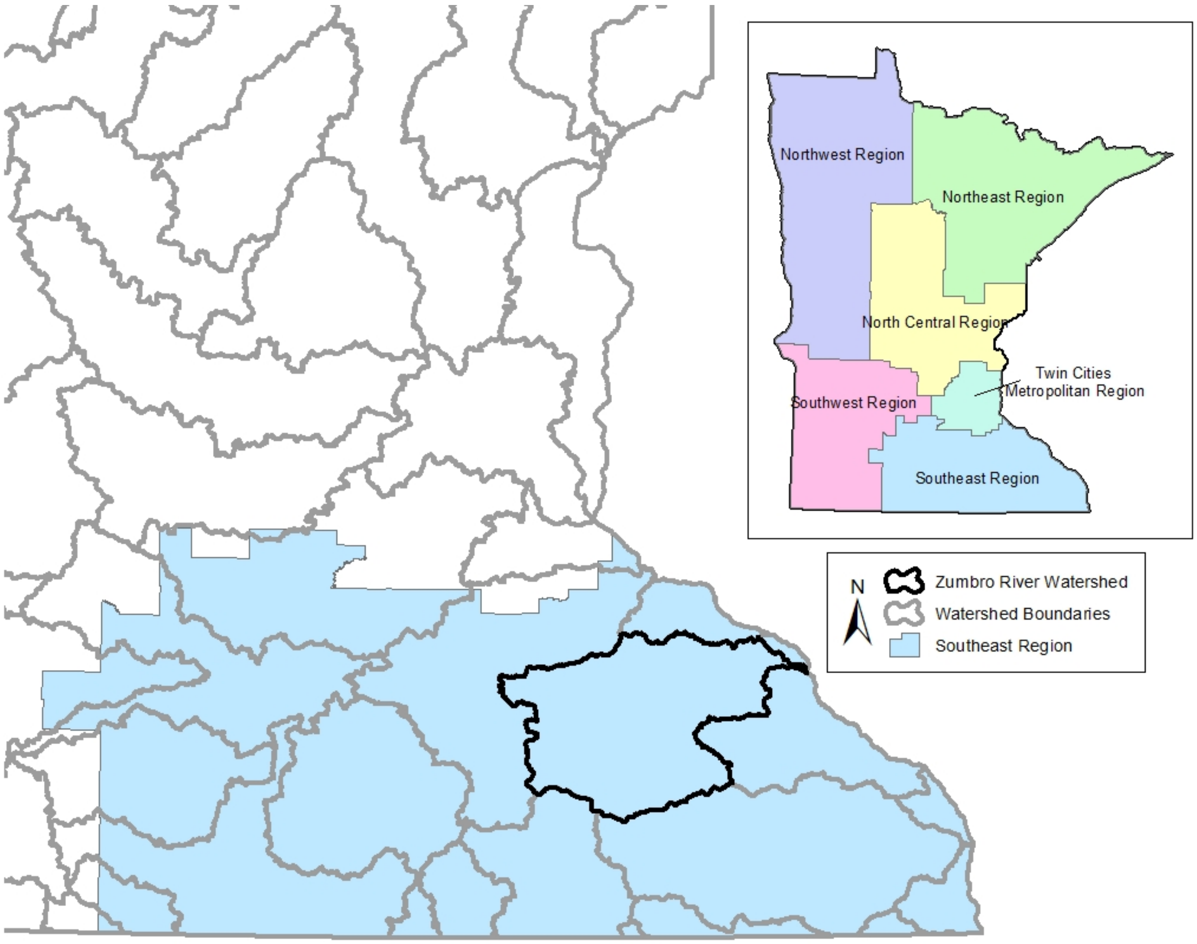


Figure 8. ZRW within the Southeast Hydrogeologic Region (Region 5).

Geology in Southeast Minnesota and the ZRW is characterized by karst features (Figure 9). These geologic features occur where limestone is slowly dissolved by infiltrating rainwater over the course of millions of years, sometimes forming hidden, rapid pathways from pollution release points to drinking water wells or back to surface water. Surface water and groundwater are so closely connected in karst areas that the distinction between the two is difficult to determine. Groundwater may emerge as a spring, flow a short distance above ground, only to vanish in a disappearing stream, returning to groundwater conduits and perhaps re-emerge farther downstream again as surface water. It has been argued that the two classical components of the hydrological cycle – “groundwater” and “surface water” -- should be referred to as “water resources” and treated as a single unique system in southeastern Minnesota.

Karst aquifers, like those commonly used in the ZRW, are very difficult to protect from activities at the ground surface because pollutants can be quickly transported to drinking water wells or surface water. Because of this, the best strategy to protect groundwater in this watershed is pollution prevention from common sources like row-crop agriculture, septic systems, abandoned wells, and AFOs.

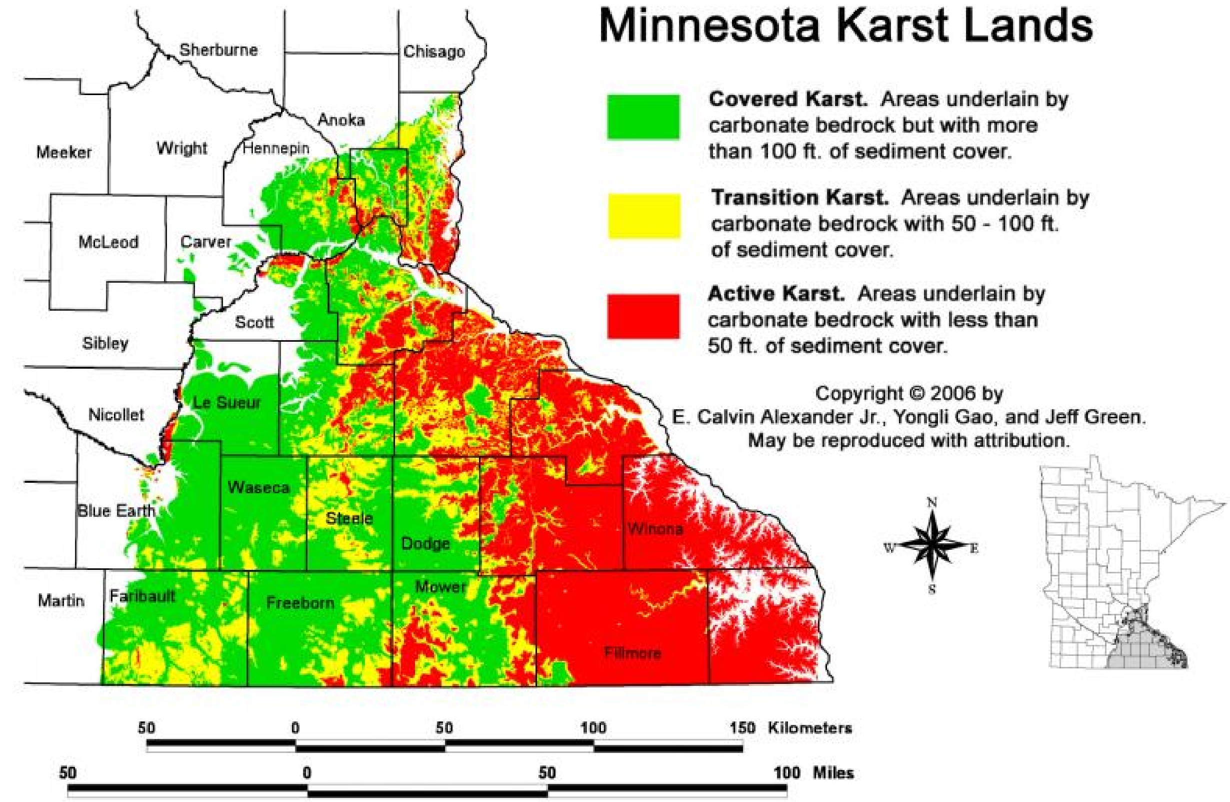


Figure 9. Locations of karst features in southeast Minnesota (source: Alexander, Gao, & Green 2007).

The ZRW falls within two of Minnesota's six Ground Water Provinces: the Southeastern and South-Central Provinces. The majority of the watershed lies within the Southeastern Province, which is characterized by "thin (less than 100 feet) clayey glacial drift overlying Paleozoic sandstone, limestone, and dolostone aquifers. Karst characteristics are common in limestone and dolostone bedrock" (DNR 2001). The western region of the watershed is located within the South-Central Province, which is characterized by "thick clayey glacial drift with limited extent sand aquifers overlying Paleozoic sandstone, limestone, and dolostone aquifers" (DNR 2001).

Recharge of these aquifers is important and limited to areas located at topographic highs, those with surficial sand and gravel deposits, and those along the bedrock/surficial deposit interface. Typically, recharge rates in unconfined aquifers are estimated at 20% to 25% of precipitation received, but can be less than 10% of precipitation where glacial clays or till are present (USGS 2007). For the ZRW, the primary average annual recharge rate to surficial materials is 6 to 8 inches per year with some regions ranging from 4 to 6 and 8 to 10 inches per year (Figure 10). Deeper confined bedrock aquifers may be recharged at least in part from outside the ZRW (Runkel et al. 2014).

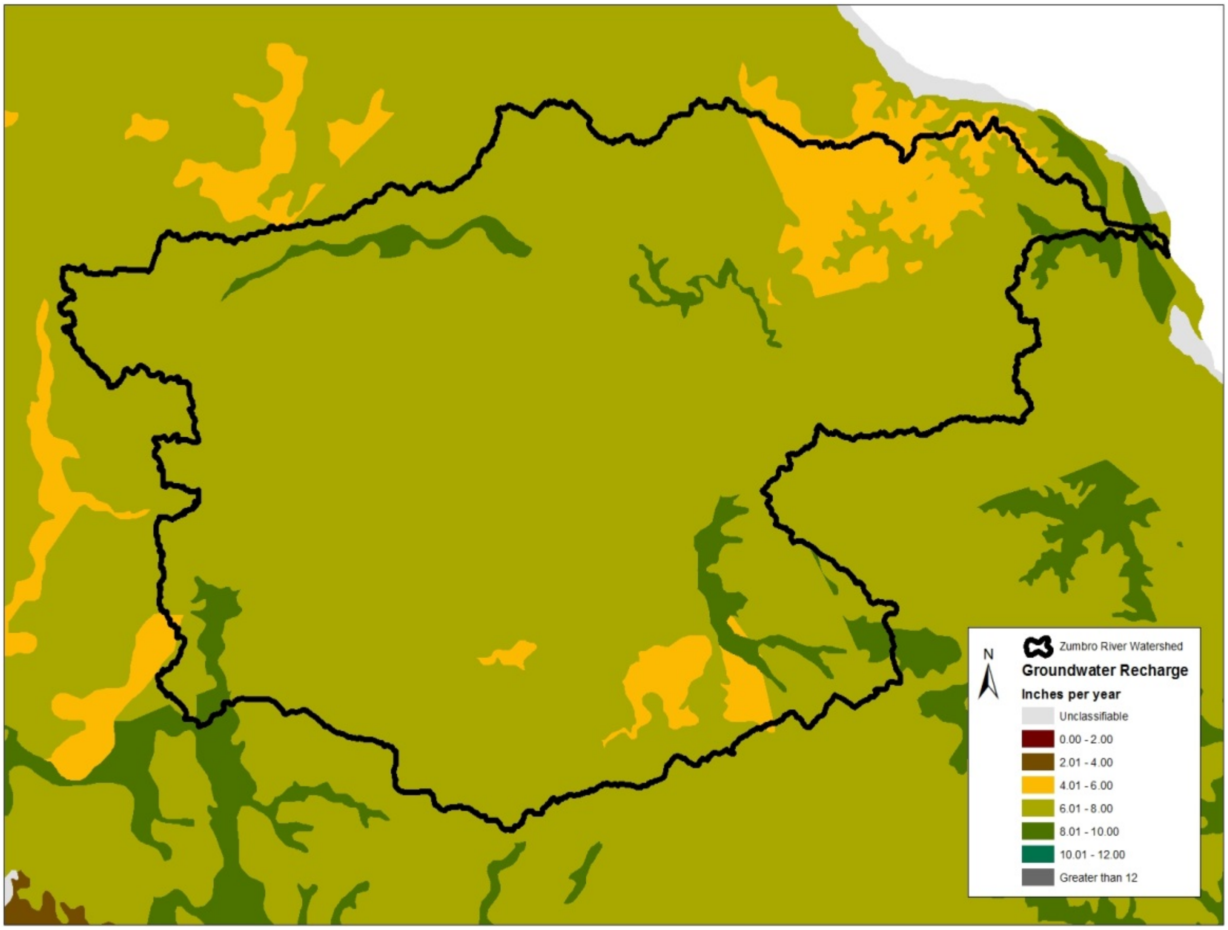


Figure 10. Average annual recharge rate to surficial materials in the ZRW (1971 – 2000).

Additional Zumbro River Watershed Resources

The ZRW has a rich history of monitoring, study and planning. As a core WRAPS task, ZWP compiled many works and have provided them on the World Wide Web via their website: *http://www.zumbrowatershed.org/page-1182261*

The Zumbro Watershed Partnership compiled a library of information to support WRAPS development: http://zumbrowatershed.org/page-1818169

USDA Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the ZRW: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/mn/technical/dma/rwa/?cid=nrcs142p2_023616

DNR Watershed Assessment Mapbook for the ZRW: http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/wsmb41.pdf and WHAF Tool: http://www.dnr.state.mn.us/whaf/index.html

2. Watershed Conditions

Stream water sampling

Eighty-two stream reaches in the ZRW were assessed against current water quality standards for water chemistry, biological indicators or both. Based on these assessments, a support status for aquatic life and/or aquatic recreational uses was assigned to each, which indicate fully supporting, not supporting or insufficient information for the assessed uses. Surface Water Assessment Grants (SWAGs) were awarded to the Zumbro Watershed Partnership (ZWP), and Goodhue SWCD to collect water chemistry samples at 13 subwatershed outlet stations (among others) to supplement MPCA assessment data. Dodge and Olmstead SWCDs assisted in collecting data as well. Those 13 chemistry stations were sampled by grantees and partners from May through September in 2012, and again June through August of 2013 to provide sufficient water chemistry data to assess all components of the aquatic life and recreation use standards. Following the Intensive Watershed Monitoring (IWM) design, water chemistry stations were placed at, or near, the outlet of each major subwatershed that was greater than 40 square miles in area (Figure 11). Additionally, citizen volunteers enrolled in the Citizen Stream Monitoring Program (CSMP) observed physical water characteristics at 33 stream stations and submitted data to MPCA in 2014, which aided in the assessment process. For more information on stream chemistry monitoring sites and stream chemistry analytes, see the ZRW Monitoring and Assessment Report (MPCA 2016a). Sampling methods were consistent among monitoring parties and are described in the document entitled "Standard Operating Procedures (SOP): Intensive Watershed Monitoring – Stream Water Quality Component" found at http://www.pca.state.mn.us/index.php/view-document.html?gid=16141. Chemistry data submitted by wastewater treatment plants as part of permitted discharges were also reviewed during the assessment process.

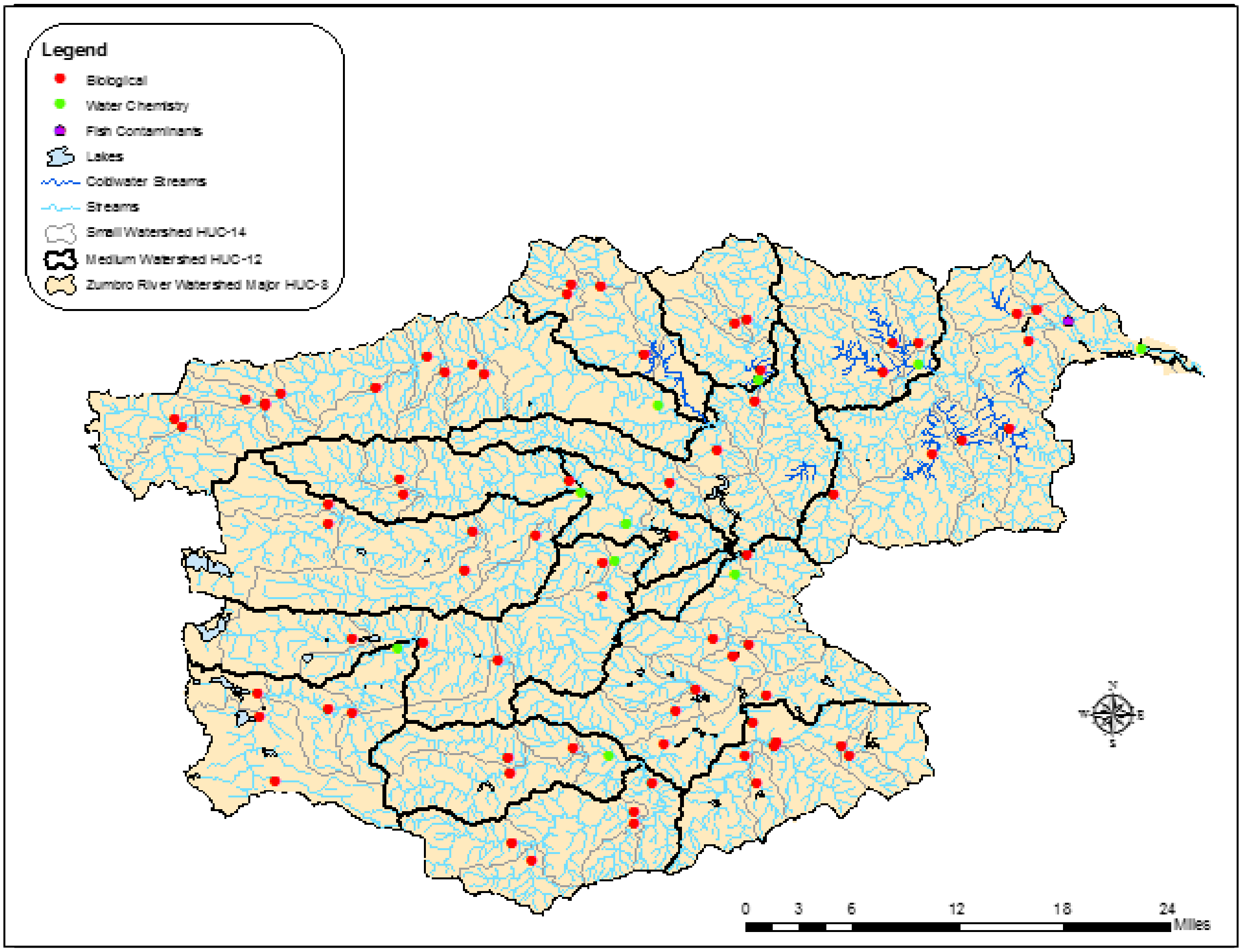


Figure 11. Locations of water quality monitoring sites managed by MPCA, CSMP, and Local Partners.

Stream flow methodology

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

Stream biological sampling

The biological monitoring component of the IWM in the ZRW was completed during the summer of 2012. A total of 65 sites were newly established across the watershed and sampled. These sites were located near the outlets of most minor HUC-14 watersheds. In addition, five existing biological monitoring stations within the watershed were revisited in 2012. These monitoring stations were initially established as either DNR monitoring stations in 2002, as part of a random Lower Mississippi River Basin wide survey in 2004, as part of a 2007 survey that investigated the quality of channelized streams with intact riparian zones, or as part of a statewide random survey to assess general quality of Minnesota streams in 2010. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2015 assessment was collected in 2012. Water body assessments to determine aquatic life use support were conducted for seventy Assessment Unit Identifier (AUIDs) (including five AUIDs that were assessed only using chemical parameters and not biological indicators). Biological information that was not used in the assessment process will be crucial to the stressor identification (SID) process and will be used as a basis for long-term trend results in subsequent reporting cycles.

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

Fish contaminants

Mercury was analyzed in fish tissue samples collected from the Zumbro River and four lakes, including Lake Zumbro created by the dam above the main Zumbro River. Polychlorinated biphenyls (PCBs) were measured in fish from the river and 10 lakes. The MPCA biomonitoring staff collected the fish from the river in 2012. DNR fisheries staff collected all other fish.

In addition, fish from Zumbro River and lake were tested for perfluorochemicals (PFCs) between 2007 and 2010. PFCs became a contaminant of emerging concern in 2004 when high concentrations were measured in fish from the Mississippi River. Extensive statewide monitoring of lakes and rivers for PFCs in fish was continued through 2010. After 2010, more focused monitoring for PFCs continued in known contaminated waters, such as the Mississippi River, several lakes in the Twin Cities Metropolitan Area, and some reservoirs in the Duluth area.

The Impaired Waters List is submitted every even year to the EPA for the agency's approval. The MPCA has included waters impaired by contaminants in fish on the Impaired Waters List since 1998. Impairment assessment for PCBs and PFOS in fish tissue is based on the fish consumption advisories prepared by the Minnesota Department of Health (MDH). If the consumption advice is to restrict consumption of a particular fish species to less than a meal per week because of PCBs or PFOS, the MPCA considers the lake or river impaired. The threshold concentration for impairment (consumption advice of one meal per month) is an average fillet concentration of 0.22 mg/kg for PCBs and 0.200 mg/kg (200 ppb) for PFOS.

Before 2006, mercury in fish tissue was assessed for water quality impairment based on MDH's fish consumption advisory. An advisory more restrictive than a meal per week was classified as impaired by mercury in fish tissue. Since 2006, a water body has been classified as impaired by mercury in fish tissue if 10% of the fish samples (measured as the 90th percentile) exceed 0.2 mg/kg of mercury, which is one of Minnesota's water quality standards for mercury. At least five fish samples per species are required to make this assessment and only the last 10 years of data are used for statistical analysis. The MPCA's Impaired Waters List includes waterways that were assessed as impaired prior to 2006 as well as more recent impairments.

PCBs in fish were intensively monitored in the 1970s and 1980s, showing high concentrations of PCBs were only a concern downstream of large urban areas in large rivers, such as the Mississippi River and in Lake Superior. Therefore, continued widespread frequent monitoring of smaller river systems was not necessary. The current watershed monitoring approach includes screening for PCBs in representative predator and forage fish collected at the pour point stations in each major watershed.

Lake water sampling

The ZRW has 17 lakes at least 10 acres in size (all but one – Rice Lake – are reservoirs and most of those were created as part of a flood control project). Citizens enrolled in the Citizen Lake Monitoring Program (CLMP) in partnership with MPCA during 2014 monitored two lakes (Zumbro and Silver) for water clarity. Only two lakes (Zumbro and Rice) had sufficient water chemistry data to assess against regional lake eutrophication standards. Monitoring methods were consistent among monitoring groups and are described in the document entitled "MPCA Standard Operating Procedure for Lake Water Quality found at http://www.pca.state.mn.us/publications/wq-s1-16.pdf. The lake water quality assessment standard requires eight observations/samples within a 10-year period for phosphorus, chlorophyll-a and Secchi depth (clarity).

Ground water monitoring

The MPCA's Ambient Groundwater Monitoring Program has sampled 6 domestic wells and 10 monitoring wells within the ZRW. Figure 12 displays the locations of the MPCA's Ambient Groundwater Monitoring wells in and around the ZRW. Data from these wells are summarized in the most recent groundwater condition report (Kroening 2013). The MDA annually monitors pesticides in groundwater through a network of monitoring wells statewide. Southeast Minnesota, including the ZRW, is one of two areas MDA monitors more intensively due to the vulnerable geology.

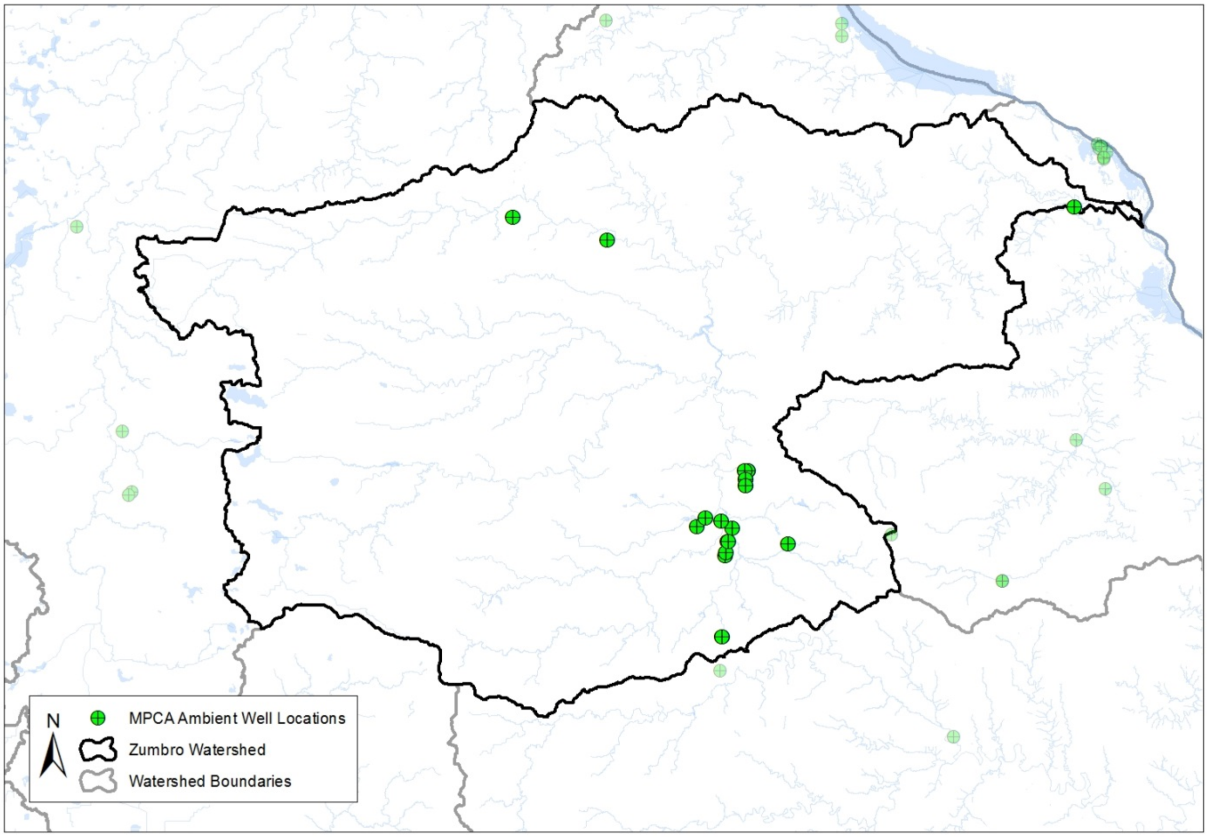


Figure 12. MPCA ambient groundwater monitoring well locations within and around the ZRW.

Wetland monitoring

The MPCA began developing biological monitoring methods for wetlands in the early 1990s, focusing on wetlands with emergent vegetation (i.e., marshes) in a depressional geomorphic setting. This work has resulted in the development of plant and macroinvertebrate (aquatic bugs, snails, leeches, and crustaceans) IBIs for the Temperate Prairies (TP), Mixed Wood Plains (MWP) and the Mixed Wood Shield (MWS) level II ecoregions in Minnesota. These IBIs are suitable for evaluating the ecological condition or health of depressional wetland habitats. All of the wetland IBIs are scored on a 0 to 100 scale with higher scores indicating better condition. Wetland sampling protocols can be viewed at:

http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/wetlands/wetland-monitoring-and-assessment.html.

Today, these indicators are used in a statewide survey of wetland condition where results can be summarized statewide and for each of Minnesota's three level II ecoregions (MPCA 2012a).

Figure 13 depicts impaired waters in the ZRW. Note that aquatic life use impairments are indicated by indirect measures (turbidity) and direct integrative measures (macroinvertebrate bioassessments (MBA) and fish bioassessments (FBA)). The streams impaired based solely or in part on MBA and/or FBA were the focus of SID (described in subsequent chapters).

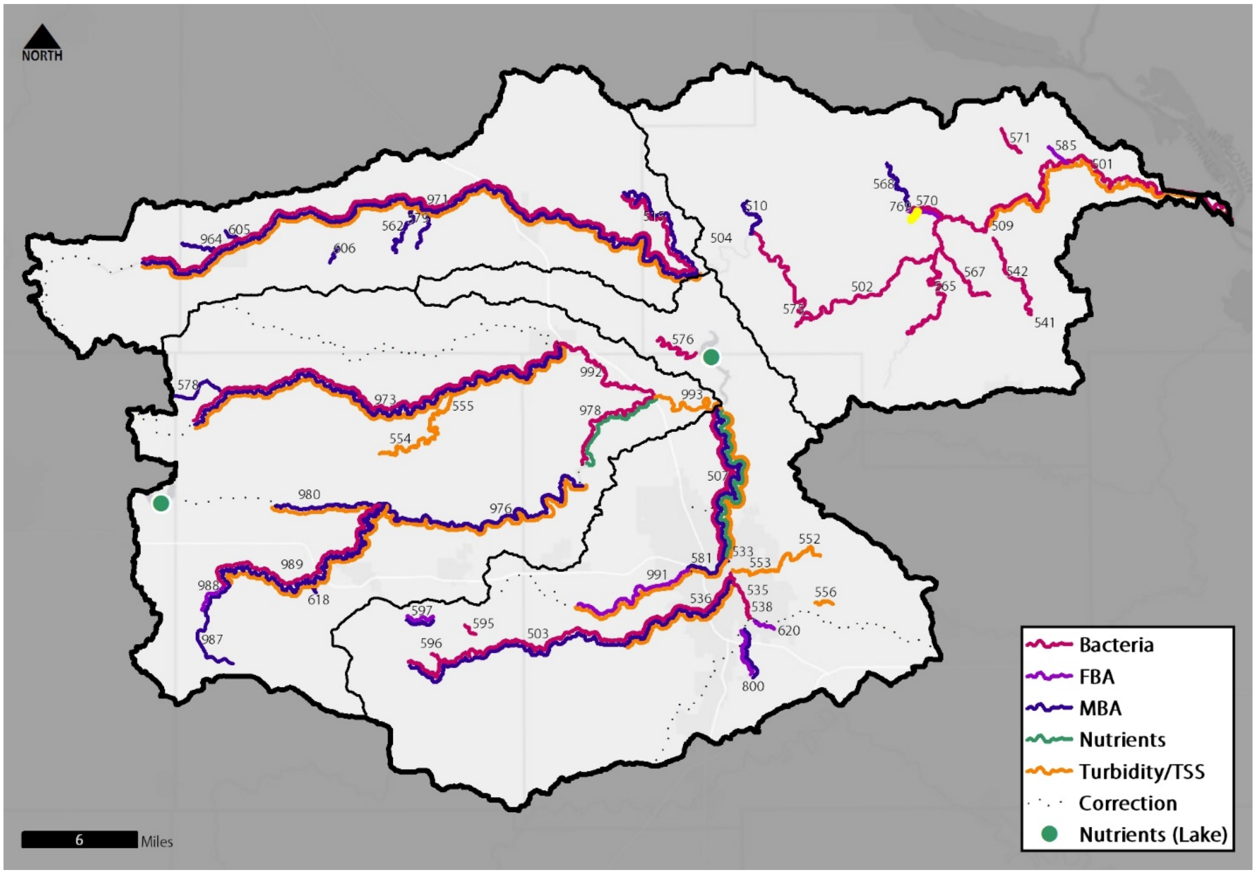


Figure 13. Impaired waters map.

2.1 Condition Status

Mercury

Some of the waterbodies in the ZRW are impaired by mercury; however, this report does not cover toxic pollutants. For more information on mercury impairments see the statewide mercury TMDL at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

Streams

Eighty-two of the 474 stream Assessment Unit Identifications (AUIDs) were assessed (Table 1) for aquatic life use, aquatic recreational use or both. Of the assessed streams, only 34 stream segments were considered to be fully supporting of aquatic life and no stream segments were fully supporting of aquatic recreation. Two AUIDs were not assessed due to their classification as limited resource waters.

Throughout the watersheds, 54 AUIDs are non-supporting of aquatic life and/or recreation. Of those AUIDs, 37 are non-supporting of aquatic life and 17 are non-supporting of aquatic recreation. Thirteen AUIDs had insufficient information to assess for aquatic life and/or recreational uses.

Six AUIDs previously listed as impaired for aquatic life use due to excessive turbidity are proposed for removal from the 303(d) Impaired Waters List in 2016 based on more recent assessments applying more lines of evidence and the current water quality standards.

Table 1: Assessment summary for stream water quality in the ZRW.

				Supporting		Non-supporting			
Watershed	**Area (acres)**	**# Total AUIDs**	**# Assessed AUIDs**	**# Aquatic Life**	**# Aquatic Recreation**	**# Aquatic Life**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
HUC-8 07040004	**909,440**	**474**	**82**	**34**	**0**	**37**	**17**	**14**	**6**
Lower South Fork Zumbro River	84,860	28	9	1	0	5	1	3	2
Bear Creek	52,064	25	8	4	0	3	1	1	3
Upper South Fork Zumbro River	49,382	6	4	4	0	0	0	0	0
Salem Creek	39,782	12	4	2	0	2	1	0	0
South Branch Middle Fork Zumbro River	80,507	17	7	3	0	2	1	1	0
Dodge Center Creek	57,806	17	6	1	0	4	1	1	0
Lower Middle Fork Zumbro River	19,652	3	3	1	0	2	1	0	0
Upper Middle Fork Zumbro River	82,535	23	7	4	0	3	1	0	0
North Branch Middle Fork Zumbro River	37,460	12	2	2	0	0	0	1	1
North Fork Zumbro River	117,876	50	12	5	0	7	1	0	0
Mazeppa Creek	35,661	16	1	0	0	1	1	0	0
Lower Zumbro River	114,868	156	7	2	0	4	4	2	0
Spring Creek	40,922	49	5	1	0	3	2	1	0
Upper Zumbro River	66,647	42	6	4	0	0	2	3	0
Cold Creek	29,337	18	1	0	0	1	0	1	0

Lakes

There are only 17 lakes/ponds/reservoirs greater than 10 acres in size in the ZRW (Table 2). Of those 17, two had sufficient data to assess for aquatic recreational standards (Rice Lake 74-0001-00; and Zumbro Reservoir 55-0004-00). Both lakes exceeded the eutrophication standards (total phosphorus, chlorophyll-a and Secchi data are used in the assessment) for the WCBP ecoregion and do not fully support aquatic recreation use. Note that while this indicates that these lakes are not currently meeting water quality goals, it does not mean that they are generally unfit for recreation. Site-specific water quality goals are being developed for Lake Zumbro (see TMDLs Report).

Table 2. Assessment summary for lake water chemistry in the ZRW.

			Supporting		Non-supporting			
Watershed	**Area (acres)**	**Lakes >10 Acres**	**# Aquatic Life**	**# Aquatic Recreation**	**# Aquatic Life**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
HUC-8: 0704004	**909,440**	**17**	**0**	**0**	**0**	**2**	**0**	**0**
Lower South Fork Zumbro River	84,860	9	0	0	0	0	0	0
Bear Creek	52,064	3	0	0	0	0	0	0
Upper South Fork Zumbro River	49,382	1	0	0	0	0	0	0
South Branch Middle Fork Zumbro River	80,507	1	0	0	0	1 – Rice Lake	0	0
Lower Zumbro River	114,868	2	0	0	0	0	0	0
Upper Zumbro River	66,647	1	0	0	0	1 – Lake Zumbro	0	0

See the ZRW Monitoring and Assessment Report for more detail regarding assessment and condition status: https://www.pca.state.mn.us/sites/default/files/wq-ws3-07040004b.pdf.

Regional Context for Aquatic Life Use Support

In the ZRW and in southeast Minnesota regionally, IWM has documented many fish IBI (index of biological integrity, which uses various metrics to "score" biotic communities) values that are high/good relative to their corresponding macroinvertebrate IBI values. The following figures describe this phenomenon (Figure 14 and Figure 15). Note that greater than 90% of the fish IBI values in the Zumbro are good or fair/good, while only ~55% of the invertebrate IBI values are good or fair/good. This is better than most watersheds in southeast Minnesota. Both IBI values (when available) were used as lines of evidence in aquatic life use support decisions. In general, if one of the values is below the threshold or "goal" the stream is categorized as not supporting.

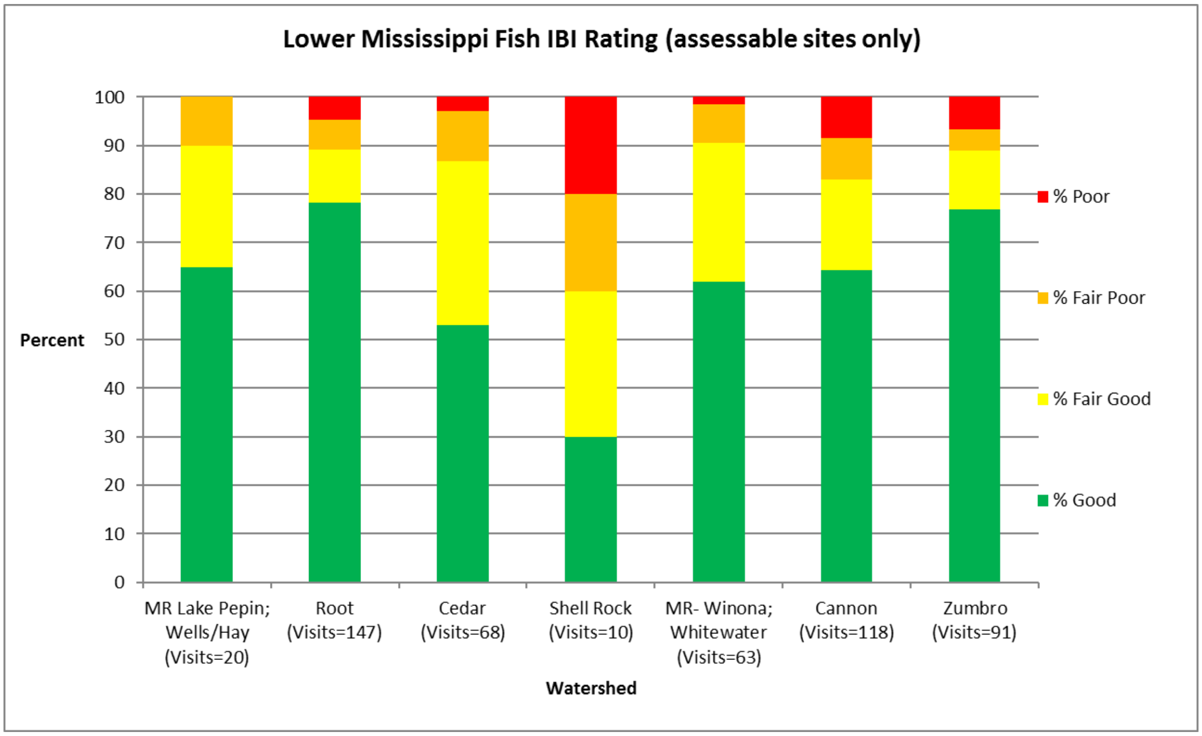


Figure 14. Lower Mississippi fish IBI values.

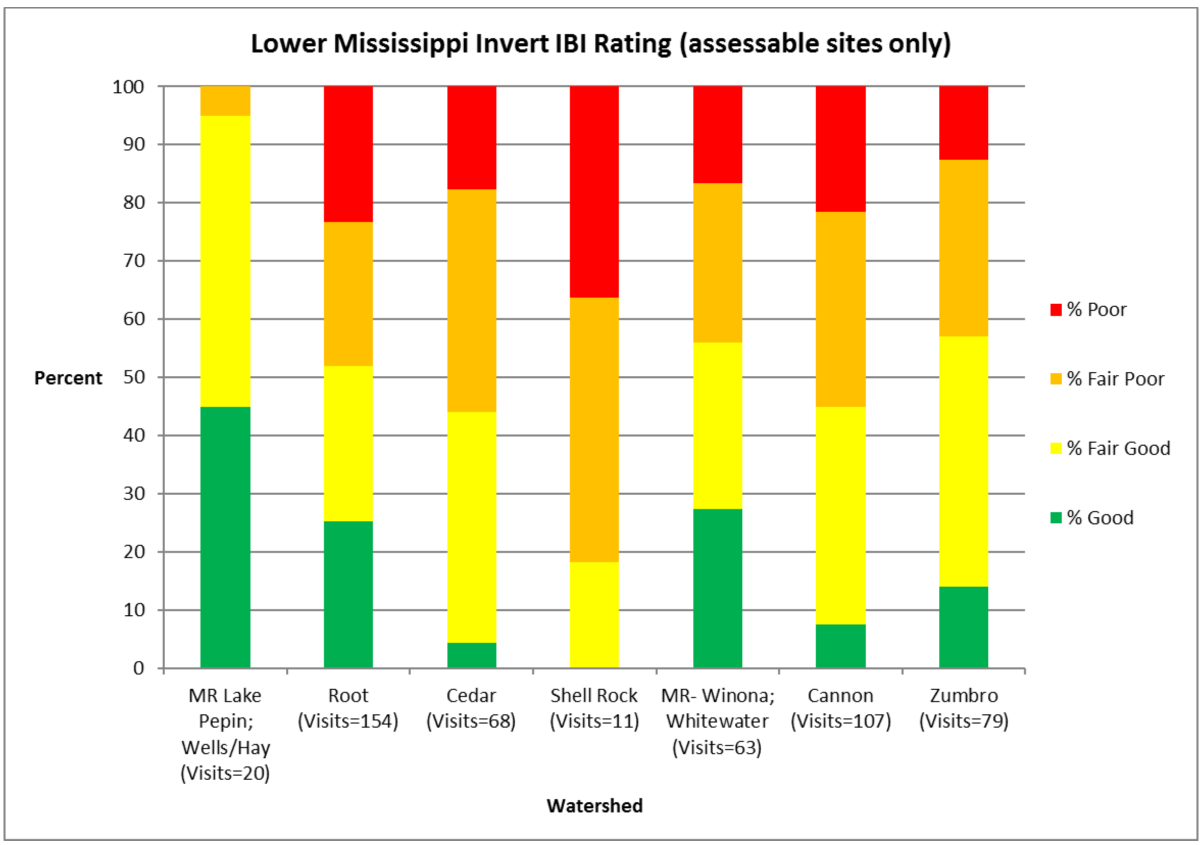


Figure 15. Lower Mississippi invertebrate IBI values.

2.2 Water Quality Trends

2.2.1 River and Stream Data

Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites notes that sites across Minnesota, including the South Fork Zumbro River, show significant reductions over the period of record for TSS, phosphorus, ammonia and biochemical oxygen demand (MPCA 2014a). The NRS documented a 33% reduction of the phosphorus load leaving the state via the Mississippi River from the pre-2000 baseline to current. These reports and others listed below generally agree that while further reductions are needed, municipal and industrial phosphorus loads as well as loads of runoff-driven pollutants (i.e. TSS and total phosphorus (TP)) are decreasing; a conclusion that lends assurance that the ZRW WRAPS phosphorus goals and strategies are reasonable.

Regarding nitrite/nitrate nitrogen, the longest period of record (Milestone data in Table 3 below) suggests an increasing trend at the South Fork Zumbro site (75th Street).

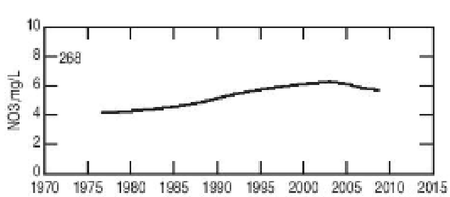
A more detailed examination of nitrogen trends in the watershed show different trends over specific periods of time likely related to climate and precipitation variability; see Table 4 and Nitrogen in Minnesota Surface Waters, page C1-20. The NRS indicates little if any progress regarding reductions of the nitrogen load leaving our state: approximately 0% change since the pre-2000 baseline.

Table 3. Water quality trends summary from *Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites* (MPCA 2014a).

Zumbro River at CSAH-14, 3 Mi N of Rochester (S000-268)(ZSF-5.7) (period of record 1973 - 2008)	Total Suspended Solids	Total Phosphorus	Nitrite/ Nitrate	Ammonia	Biochemical Oxygen Demand	Chloride
overall trend	decrease	decrease	increase	decrease	decrease	increase
average annual change	-2.9%	-7.1%	2.3%	-10.0%	-4.6%	3.0%
total change	-64%	-92%	120%	-97%	-81%	186%
1995 - 2008 trend	decrease	no trend	no trend	no trend	no trend	little data
average annual change	-6.7%					
total change	-42%					
median concentrations first 10 years	45	0.9	3	0.50	5	36
median concentrations most recent 10 years	16	0.2	7	<0.05	2	54

Table 4. . Trends in flow-adjusted nitrate concentrations at the South Fork Zumbro milestone site (S000-268) based on 241 observations (MPCA 2013).

Zumbro River - Rochester	
Overall change 1976-2008	+38%
1976-2002	+51%
2003-2008	-9%



2.2.2 Citizen Monitoring Data

Citizen Monitoring Programs for both lakes and streams provide long-term records of water clarity for many of the waters in the ZRW. A recent examination of CLMP data for Lake Zumbro (through 2015) found that the median transparency from 1976 to 2016 increased by 0.7 feet per decade (Figure 16). Given the variability over these years, there is no evidence of a long term trend. A plausible range for the long term trend is between an increase of 0.38 and an increase of 1.03 feet per decade.

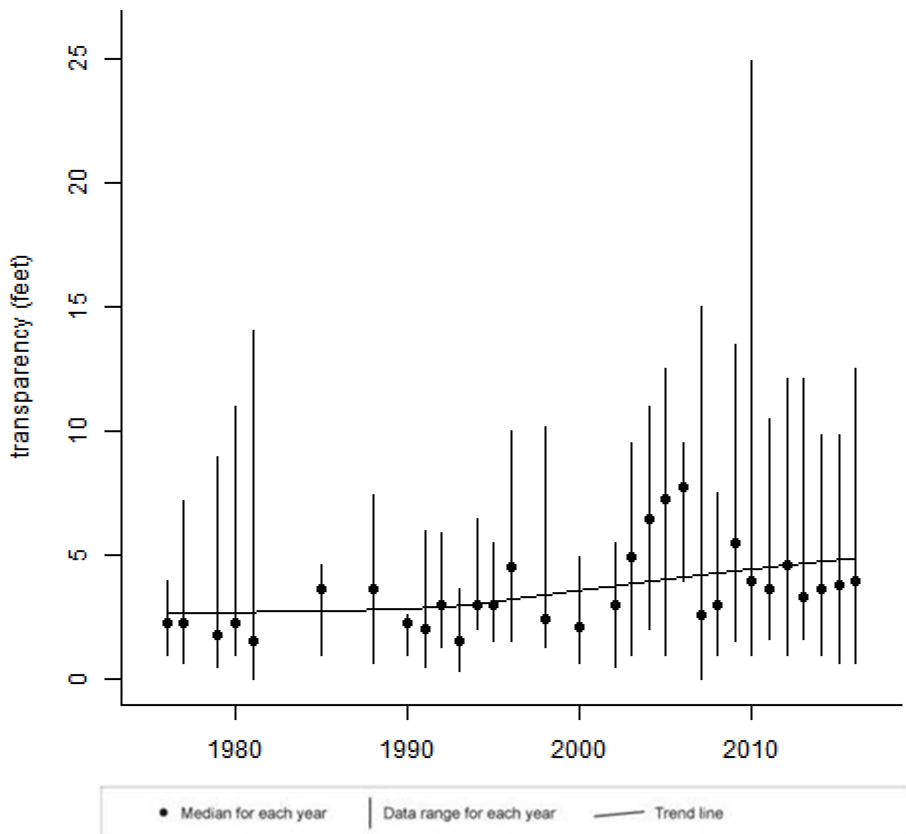


Figure 16. Lake Zumbro (55-0004) water quality trend.

2.2.3 Nitrates in trout streams and springs

The MPCA has collected baseflow and stormflow samples at West Indian Creek since 2007. Statistical analysis of 104 water samples collected in 2007 through 2015 indicates a statistically significant (α = 0.05) increasing trend in nitrate concentrations (Figure 17).

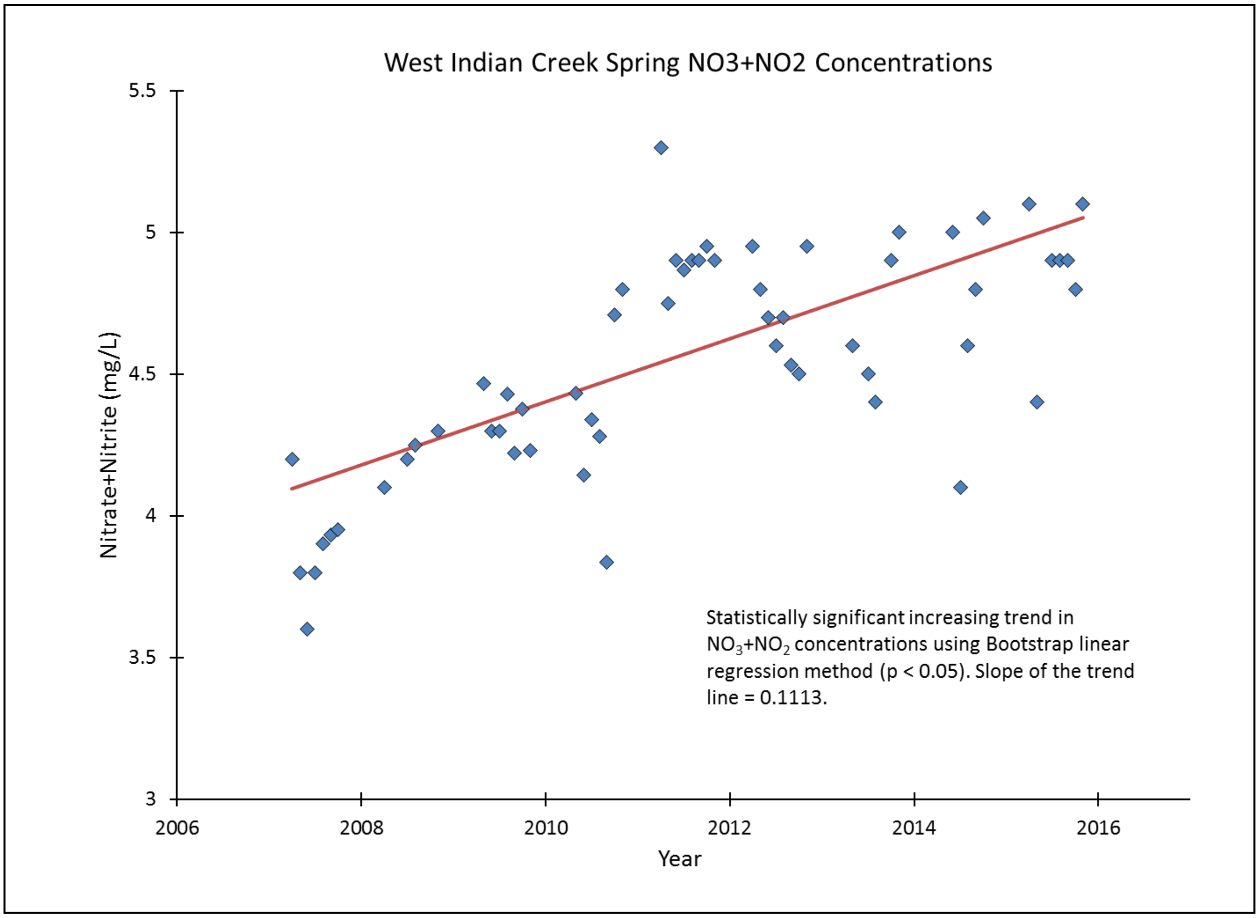


Figure 17. West Indian Creek nitrate data over time.

The MDA collects pesticide and nitrate-nitrogen water quality samples from approximately 13 springs in southeast Minnesota. Samples are collected twice per year, and are intended to target baseflow (groundwater) periods instead of stormflow (rain event) periods. In addition, the MDA monitors approximately 12 domestic wells in the fall to supplement regional spring monitoring. The MDA publishes an annual work plan that provides specific information for the upcoming year and an annual report with monitoring results available at www.mda.state.mn.us/monitoring. Nitrate samples collected from a spring on Cold Spring Brook (Wabasha County) are included in Figure 18 below. These data indicate an apparent trend, but it is only statistically significant if two values are excluded from the analysis as outliers. The two lower nitrate concentrations (3.81 mg/l collected 5/25/2011 and 4.07 mg/l collected on May 29, 2013) may be the result of a local contribution of more "recent" water that is relatively low in nitrate, mixed in with the deeper, more regionally sourced water that is otherwise showing a steady increase in concentration (Tony Runkel, personal communication 2017). Both samples were collected during relatively "wet" periods according to the flow record at the South Fork Zumbro USGS gauge (05372995); late May 2011 flows were approximately double the 35-year median values and late May 2013 flows were approximately four times the 35-year median values. Note that lower *concentrations* during wet periods (May 2013 was one of the wettest months in recent years) do not necessarily mean decreased nitrate *loads* from the spring; flows likely increased leading up to those sample collections (flows are not measured at the spring).

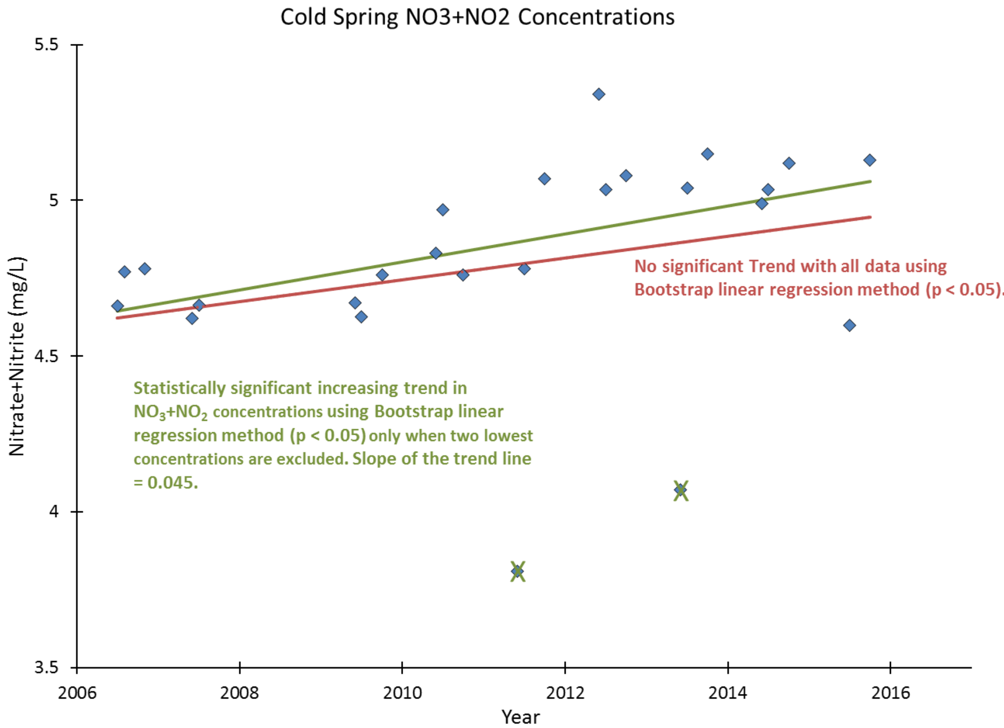


Figure 18. Cold Creek spring data (MPCA trend analysis).

Zumbro River Watershed Trend Analysis

Nitrogen in Minnesota Surface Waters (MPCA)
https://www.pca.state.mn.us/sites/default/files/wq-s6-26c1.pdf

Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites (MPCA)
https://www.pca.state.mn.us/sites/default/files/wq-s1-71.pdf

2.3 Stressors and Sources

2.3.1 Stressors of Aquatic Life

The MPCA has increased the use of biological monitoring and assessment as a means to determine and report the condition of the state's rivers and streams. This approach centers on examination of fish and aquatic macroinvertebrate communities and related habitat conditions at multiple sites throughout a major watershed. From these data, an IBI score can be developed, which provides a measure of overall community health. In cases of aquatic life use impairment, stressors to the aquatic community must be identified in order to translate the problem from an integrative measure(s) to causal factors. This is accomplished by further examining streams (via both field work and desktop work) that show low IBI values for fish and bugs, with a focus on linking the biotic communities to probable stressors. For example, if a macroinvertebrate community sampled in a given stream reach is composed primarily of nitrate-tolerant species and the stream shows high nitrate values in baseflow, a likely conclusion is that nitrate is a stressor to the invertebrate biota. In the ZRW, 28 AUIDs are currently impaired with a poor biological assemblage (Table 5).

Table 5. Biologically impaired AUIDs in the ZRW and corresponding water quality impairments.

		Impairments	
Stream Name	**AUID #**	**Biological**	**Water Quality**
Spring Creek	07040004-568	Macroinvertebrates	---
Spring Creek	07040004-570	Fish	*E. coli*
Cold Creek (Cold Spring Brook)	07040004-510	Macroinvertebrates	---
Trout Brook (Mazeppa Creek)	07040004-515	Macroinvertebrates	*E. coli*
Trout Brook	07040004-585	Fish	---
Unnamed creek	07040004-964	Macroinvertebrates	---
Unnamed creek (Spring Creek Tributary)	07040004-605	Macroinvertebrates	---
Silver Creek/Spring Creek	07040004-606	Macroinvertebrates	---
Shingle Creek	07040004-562	Macroinvertebrates	---
Unnamed Creek	07040004-579	Macroinvertebrates	---
North Fork Zumbro	07040004-971	Macroinvertebrates	Turbidity, *E. coli*
Unnamed Creek	07040004-578	Macroinvertebrates	---
Middle Fork Zumbro	07040004-973	Macroinvertebrates	Turbidity, *E. coli*
Dodge Center Creek	07040004-989	Macroinvertebrates	Turbidity, *E. coli*
Henslin Creek	07040004-618	Macroinvertebrates	---

		Impairments	
Stream Name	**AUID #**	**Biological**	**Water Quality**
Judicial Ditch 1	07040004-987	Macroinvertebrates	---
Judicial Ditch 1	07040004-988	Fish and Macroinvertebrates	---
South Branch Middle Fork	07040004-980	Macroinvertebrates	Turbidity
South Branch Middle Fork	07040004-976	Macroinvertebrates	Turbidity
Salem Creek	07040004-503	Macroinvertebrates	Fecal Coliform
Salem Creek Trib	07040004-597	Fish and Macroinvertebrates	---
Unnamed Creek (Trib to Willow)	07040004-800	Fish and Macroinvertebrates	---
Badger Run	07040004-620	Fish	---
Unnamed Creek	07040004-621	Fish	---
South Fork Zumbro	07040004-507	Macroinvertebrates	Turbidity, Fecal Coliform
South Fork Zumbro	07040004-536	Macroinvertebrates	Turbidity, Fecal Coliform
Cascade Creek	07040004-581	Macroinvertebrates	Turbidity
Cascade Creek	07040004-991	Fish	---

After examining many candidate causes for the biological impairments, the following were identified as probable stressors of aquatic life:

Table 6. Stressors of aquatic life.

Pollutant Stressors	**Non-pollutant Stressors**	**Stressors with Potential Links to Pollutants**
Nitrate (11), TSS (8)	Flow Alteration & Connectivity (11)	Degraded Habitat (22), Low Dissolved Oxygen (2), Temperature (1)

Pollutant stressors are addressed via TMDLs (see Chapter 2.4). Non-pollutant stressors are not subject to load quantification and therefore do not require TMDLs. If a non-pollutant stressor is linked to a pollutant (e.g. habitat issues driven by TSS or low DO caused by excess phosphorus) a TMDL is required. However, in many cases habitat stressors are not linked to pollutants. With respect to the two DO stressors in the ZRW, there are insufficient data and means for conclusively linking the condition to a pollutant cause. See Table 12 for a summary of TMDL computations in the watershed, including those that were computed according to SID results. See Appendix F for a tabular summary of stressors for each AUID. Streams stressed by degraded habitat are not addressed by TMDLs but are still priorities for restoration; see Appendix B for a list of AUIDs with identified habitat stressors. The Zumbro Watershed

SID Report provides more detailed discussion of each biological impairment examined: https://www.pca.state.mn.us/sites/default/files/wq-ws5-07040004a.pdf.

Pollutant sources

The following paragraphs provide an overview of point and nonpoint sources of pollution in the ZRW. Further, the impairments in the ZRW that are linked to a conventional pollutant are addressed in the ZRW TMDL (see Chapter 2.4 and full document). A good resource for examining nonpoint source pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions (statute language) are the Hydrological Simulation Program –FORTAN (HSPF) model output maps (some of which are included in Chapter 3).

Point Sources

Permitted point sources are included in Table 7 below. Given that the ZRW is a predominately rural landscape, point sources account for a relatively small component of pollutant loads. However, at lower flows, point sources can play a significant role in pollutant loading and water quality conditions. Point sources of phosphorus can be further examined using the MPCA's interactive tool regarding phosphorus in wastewater: https://www.pca.state.mn.us/water/phosphorus-wastewater.

Table 7. Point Sources in the ZRW (Point sources with consistent flow). Major point sources are shown in bold.

Facility Name	Point Source Type	Permit No.
Al-Corn Clean Fuel	Minor	MN0063002
AMPI Rochester	Minor	MNG255051
Bellechester WWTP	Minor	MN0022764
Byron WWTP	Minor	MN0049239
Camp Victory WWTP	Minor	MN0067032
Claremont WWTP	Minor	MN0022187
Dodge Center WWTP	Minor	MN0031016
Franklin Heating Station	Minor	MN0041271
Goodhue WWTP	Minor	MN0020958
Hallmark Terrace Incorporated	Minor	MN0030368
Hammond WWTP	Minor	MN0066940
Hayfield WWTP	Minor	MN0023612
Kasson WWTP	Minor	MN0050725
Kellogg WWTP	Minor	MNG580027
Kemps Milk Plant	Minor	MN0059803
Kenyon WWTP	Minor	MN0021628
Mantorville WWTP	Minor	MN0021059
Mazeppa WWTP	Minor	MN0046752
Milestone Materials Goldberg Quarry	Minor	MN0062227
Pine Island WWTP	Minor	MN0024511
Rochester Athletic Club	Minor	MN0062537
Rochester WWTP	**Major**	**MN0024619**
RPU Sliver Lake	Minor	MN0001139
Seneca Food Corporation	Minor	MN0000477
Wanamingo WWTP	Minor	MN0022209
West Concord WWTP	Minor	MN0025241
Zumbro Falls WWTP	Minor	MN0051004
Zumbro Ridge Estates MHP	Minor	MN0038661
Zumbrota WWTP	**Major**	**MN0025330**

In addition to the above list of permitted point sources, there are many non-surface water discharge wastewater activities within the ZRW. While these facilities are not point sources, they are significant wastewater management systems and include land application and pre-treatment practices. A comprehensive list of non-surface water discharging facilities is included as Appendix I.

Nonpoint Sources

The state of Minnesota has invested significant time and resources into major investigations of key pollutants of concern in the ZRW. Nonpoint pollutant sources are summarized below (via major study conclusions and tables). For further information and detail, refer to the respective source documents. The Zumbro River HSPF (ZRWHSPF) modeling documentation addresses nonpoint pollutant sources, including apportionment of sediment loads.

Overview of Sediment & Phosphorus Sources

Several investigations related to sediment source apportionment have been conducted within the past 5 to 15 years for watershed areas in southeast Minnesota and for Lake Pepin. These studies have generally involved sediment "fingerprinting" through the geochemical analysis of sediments, and the representation of distinct sediment sources within HSPF models developed for the MPCA (LimnoTech 2013). Because phosphorus, given the nature of the ZRW watershed, often shares many general sources and pathways with those of sediment, these investigations are useful in considering both pollutants. In a literature review conducted in 2013, LimnoTech examined the following:

- Sediment fingerprinting for Lake Pepin and its tributary systems (Kelly and Nater 2000, Schottler et. al. 2010);
- Minnesota River HSPF model development and calibration (TetraTech 2009);
- Sediment fingerprinting for the Le Sueur Watershed (Belmont 2012), located west of the ZRW;
- Sediment fingerprinting for source and transport pathways in the Root River (Belmont 2011, Stout 2012), located south of the ZRW; and
- Root River HSPF model development and calibration (TetraTech 2013).

A summary of general findings of the literature review:

- Overall sediment delivery from tributaries to the Upper Mississippi River in southeast Minnesota has increased substantially since European settlement and the onset of agricultural activities in the tributary watersheds;
- The relative contributions of "non-field" sources of sediment to the overall watershed sediment yield appears to be increasing over time, with a likely link to the "flashier" hydrology (i.e. rapidly increasing and decreasing flow volumes) resulting from agricultural land use and associated drainage and urban development (LimnoTech 2013).

These conclusions comport with the Minnesota NRS summary findings pertaining to phosphorus, underscoring the shared nonpoint sources of these erosion/runoff driven pollutants:

- The primary sources of phosphorus transported to surface waters are cropland runoff, atmospheric deposition, permitted wastewater, and streambank erosion. These four sources combined are 71%, 76%, and 83% of the statewide phosphorus load under dry, average, and wet years, respectively.

- During dry conditions, National Pollutant Discharge Elimination System (NPDES) permitted wastewater discharges and atmospheric deposition become more prominent sources of phosphorus. Under wet conditions, streambank erosion becomes the most significant source of phosphorus in the state.
- The most significant phosphorus sources by major basin during an average precipitation year include cropland runoff, wastewater point sources, and streambank erosion in the Mississippi River Major Basin (MPCA 2014b).

Other resources useful in examining sediment and phosphorus sources in the ZRW include the Lower Mississippi River Basin Regional Sediment Data Evaluation Project (Barr Engineering 2004, http://www.pca.state.mn.us/index.php/view-document.html?gid=5983), Detailed Assessments of Phosphorus Sources to Minnesota Watersheds (Barr Engineering 2004 and 2007, https://www.pca.state.mn.us/water/detailed-assessments-phosphorus-sources-minnesota-watersheds) and Minnesota's NRS (https://www.pca.state.mn.us/water/nutrient-reduction-strategy).

Internal Phosphorus Loads in Lakes

Internal cycling of phosphorus can be an important driver of phytoplankton growth. The phosphorus loads to the lakes and reservoirs in the ZRW include both watershed and internal components. Approximating both is important in understanding how watershed work to reduce phosphorus loads may (or may not) impact water quality for a given lake. For example, in 2004 Chesapeake Biogeochemical Associates examined sediment release of phosphorus at four stations in the Byllesby Reservoir, just northwest of the ZRW. They estimated that, on average, internal recycling accounts for approximately 7% of the TP loading and 16% of the soluble reactive phosphorus loading to the reservoir.

Internal phosphorus loading is also important to understand in the context of "unaccounted for" loads. With Rice Lake, as was the case for several lakes in the Cannon River Watershed TMDL, predicted model results of in lake phosphorus were still not meeting water quality standards even when tributary loads were set to zero. Heiskary and Martin found that in these cases, the "unaccounted for" portion can be assigned to internal loading (Heiskary and Martin 2015).

Internal phosphorus loading in lakes typically occurs through wind-driven sediment resuspension, bioturbation (e.g. sediment disturbance by benthic-dwelling fish), macrophyte senescence (e.g. curly-leaf pondweed) and/or diffusive sediment flux under anoxic conditions (Sondergaard et al. 2003). Rice Lake is a relatively shallow lake that does not typically stratify for prolonged periods. Its fish community is dominated by a few species that are tolerant of hypoxia and warm water temperatures. Aquatic plants are naturally abundant in the lake (DNR 2016). The internal load of phosphorus in Rice Lake is a key driver of water quality: carp gained access to Rice Lake in 1952 and have had a profound impact on internal cycling of nutrients via destruction of aquatic plant and invertebrate populations and aggravating lake sediments. Management strategies that focus on internal nutrient cycling have been successful in the past and will be useful going forward (DNR 2016).

Sediment Source Apportionment from ZRW HSPF Model Development

The calibrated ZRWHSPF model simulates that upland sources contribute 42% of the sediment load for the entire watershed, which is the highest simulated sediment source. This is consistent with the observation that a larger upland source percentage may be appropriate for the Zumbro River given the predominance of type "C" or highly erodible/unstable soils. The next highest simulated sediment source is bed and bank erosion at 39% and the third-largest contributor is gully and ravine erosion at 18%. Point sources, tile drainage, and groundwater outflow pathways each contribute less than 1% to the overall sediment delivery. A breakdown of the sediment sources is shown in Table 8 and Figure 19.

Table 8. Breakdown of sediment sources by major drainage area and for the entire ZRWHSPF model (1996-2009).

Drainage Area	Gully/Ravine	Upland	Tile Drains	Point Sources	Bed/Bank Erosion
South Fork	21%	52%	0.3%	0.4%	27%
Middle Fork	19%	42%	0.8%	0.0%	38%
North Fork	17%	50%	0.2%	0.1%	33%
Mainstem	14%	31%	0.0%	0.0%	55%
Entire Watershed	18%	42%	0.4%	0.1%	39%

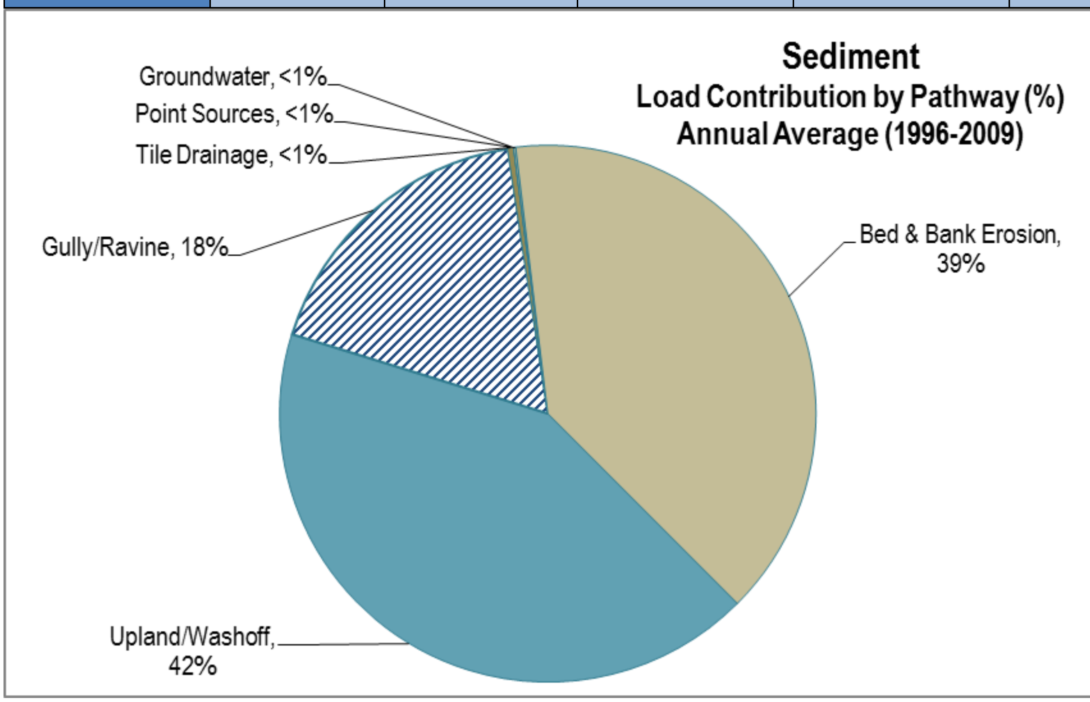


Figure 19. Breakdown of sediment sources for the ZRWHSPF model (1996 – 2009).

The ZRWHSPF model also summarizes Unit Area Loading (UAL) values for a number of pollutants. A summary of the phosphorus UALs is included in the following figure.

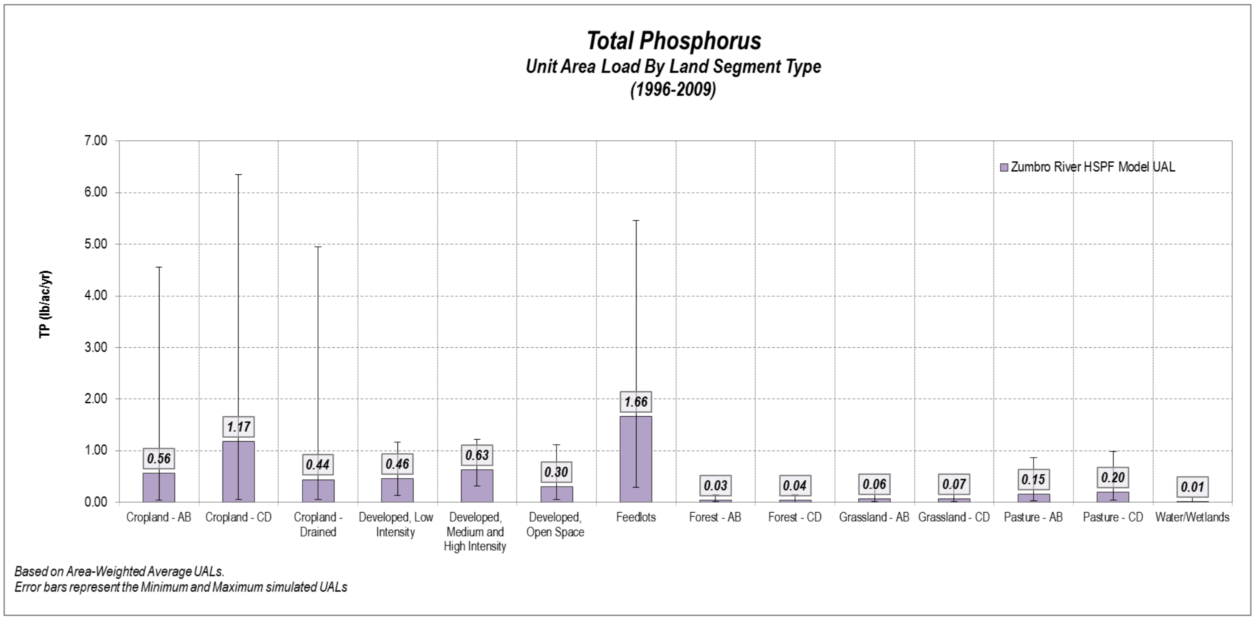


Figure 20. Total phosphorus unit area loads by land segment type for the 1996 – 2009 simulation period.

Nitrogen Sources Overview

Minnesota's NRS, as called for in the 2008 Gulf of Mexico Hypoxia Action Plan, was completed in 2014 (https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf). Minnesota is the state that contributes the sixth highest Nitrogen (N) load to the Gulf and is 1 of 12 member states serving on the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. The cumulative N and phosphorus (P) contributions from several states are largely the cause of a hypoxic (low oxygen) zone in the Gulf of Mexico. This hypoxic zone affects commercial and recreational fishing and the overall health of the Gulf, since fish and other aquatic life cannot survive with low oxygen levels. Minnesota developed a strategy that examines nitrogen loads, sources, trends in surface waters and identifies how further progress can be made to reduce N and P entering both in-state and downstream waters (MPCA 2014b). The National Oceanic and Atmospheric Administration measured the largest annual hypoxic zone ever recorded in the Gulf of Mexico in summer of 2017.

The scientific foundation of information for the nitrogen component of the NRS is represented in the 2013 report, *Nitrogen in Minnesota Surface Waters* ("Nitrogen Study" MPCA 2013, http://www.pca.state.mn.us/index.php/view-document.html?gid=19622). This document will be useful as the MPCA and other state and federal organizations further their nitrogen-related work, and also as local governments consider how high N levels might be reduced in their watersheds.

The Nitrogen Study and the NRS state that cropland nitrogen losses through agricultural tile drainage and agricultural groundwater (leaching loss from cropland to local groundwater) make up the majority of nitrogen sources in Minnesota, contributing 51%, 68%, and 73% of the nitrogen load under dry, average, and wet years, respectively. In the Lower Mississippi River Basin, agricultural groundwater is the greatest source of nitrogen to surface waters at 57%, followed by agricultural drainage 23%, and crop runoff at 9% (MPCA 2014b). The remaining 11% is split between point sources (5%), atmospheric (2%), forest (2%) and "other" nonpoint sources (2%) (Figure 21). The finding that runoff is a very minor source of nitrogen is important when considering tools for targeting and strategies for addressing nitrogen (in contrast to those applied when addressing non-dissolved phosphorus). The two nutrient pollutants are transported to surface waters via distinctly different pathways.

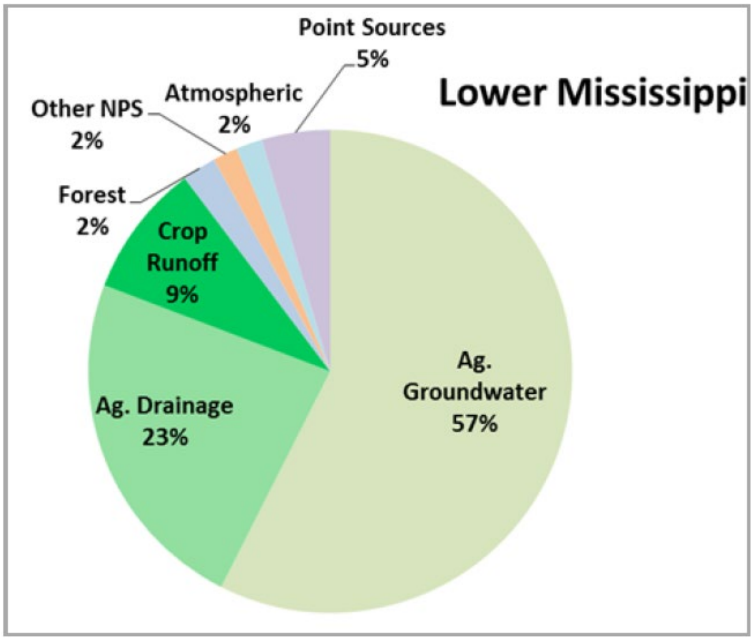


Figure 21. Estimated nitrogen sources to surface waters from the Minnesota contributing areas of the Lower Mississippi River Basin (average precipitation year). From MPCA 2013.

Cropland Nitrogen: Main Source in ZRW

In the case of nitrate-nitrogen, various research has established a correlation between the dominant land use – row crop agriculture – and concentrations in the receiving water. At the largest scale, Goolsby et al. (1999) examined nitrogen sources in 42 "small basin sites" in the Mississippi-Atchafalaya River Basin. These 42 basins range in size but in general would be viewed as "big rivers" (for example: Raccoon River in Iowa, Upper Mississippi River at Twin Cities metro area). A correlation of watershed row crop land use and nitrate concentration at the 42 river sites found that *"…high nitrate concentrations are associated with basins having either a high percentage of land in row crops (corn, soybeans, or sorghum) or a high population density (people per km²), or both*." (Goolsby et al. 1999). More locally, Schilling & Libra published in 2000 *The Relationship of Nitrate Concentrations in Streams to Row Crop Land Use in Iowa*. This study correlated long-term mean nitrate concentrations with row crop land use for 15 watersheds (387 to 1,071 square miles) across the state of Iowa. The primary conclusion was that "*In Iowa, nitrate concentrations in surface water show a strong linear relationship to watershed row crop intensity.*"

Stream baseflow is the critical condition with respect to nitrate concentration and loading in heavily karsted watersheds (which contain most of southeast Minnesota's trout streams). In such settings, unlike sediment and phosphorus, baseflow conducts the majority of the nitrate load, as nutrients readily move vertically from land surface to underlying aquifers. Masarik et al found that baseflow NO_3 alone account[s] for 80% of the annual N loss in the Fever River, which drains an agriculturally dominated watershed in the Northern Mississippi Valley Loess Hills region (Masarik, K.C., G.J. Kraft, D.J. Mechenich, and B.A. Browne, 2007). Jordan, Correll & Weller documented a strong relationship between nitrate concentration and row crop density for 27 study sites in the Chesapeake Bay Watershed and noted that

"…annual flow-weighted mean NO_3 concentrations increase as the proportion of cropland in the watershed increases, but in the Piedmont [containing the baseflow dominated streams] *the rate of increase is much greater. At any given percentage of cropland, NO_3 concentrations for Piedmont watersheds were generally more than double those for Coastal Plain watersheds* (Jordan, Correll & Weller 1997). Schilling and Libra noted that, regarding the Driftless Area watersheds in their study area *"…the three next least-intensively row-cropped watersheds fall above the overall relationship. These are the Upper Iowa, Volga, and Maquoketa, all located in the high-relief, shallow fractured- bedrock terrain of northeast Iowa. This geologic setting allows for the relatively efficient leaching of nitrate-N from the soil, and for the rapid transport of groundwater and nitrate to these "high baseflow" rivers…"*

An analysis of the relationship between base flow nitrate concentrations in southeast Minnesota trout streams and percentage of row crop land in the watersheds of these streams produced a statistically significantly regression. The 100 trout stream sites examined included nine in the ZRW (see Figure 22). Specific conclusions of this work include:

- Potential Source Linkage: Nitrate concentrations in Southeast Minnesota's trout streams show a strong linear relationship to row crop land use. A linear regression showed a slope of 0.16, suggesting that the average base flow nitrate concentration in the trout stream watersheds of Southeast Minnesota can be approximated by multiplying a watershed's row crop percentage by 0.16. This regression analysis indicates that a watershed of approximately 60% corn and soybean acres corresponds to exceedances of Minnesota's drinking water nitrate-nitrogen standard of 10 mg/L at the point of sample in the stream (trout streams in Minnesota are protected as drinking water sources). This conclusion is supported by the findings of Nitrogen in Minnesota Surface Waters, which describe similar relationships between nitrogen in surface waters and "leaky soils below row crops," which include areas of shallow depth to bedrock such as the trout stream region of Southeast Minnesota (MPCA 2013).
- Potential Natural Background: The natural background level of nitrate in streams appears to be very low given that the base flow concentrations of streams with undisturbed (very little row crop land use and little or no other human impact) watersheds were less than 1 mg/L. Statistical analysis also suggested that in the absence of human disturbance in a watershed, the base flow nitrate concentration at the point of sample in the stream could approach 0 mg/L. This is in general agreement with recent work by the USGS that concluded human impacts are the primary reason for elevated nitrogen in United States surface waters; background concentrations of nitrate were 0.24 mg/L in watersheds dominated by non-urban and non-agricultural land uses (Dubrovsky et al. 2010) (Watkins, Rasmussen, Streitz et al. 2013).

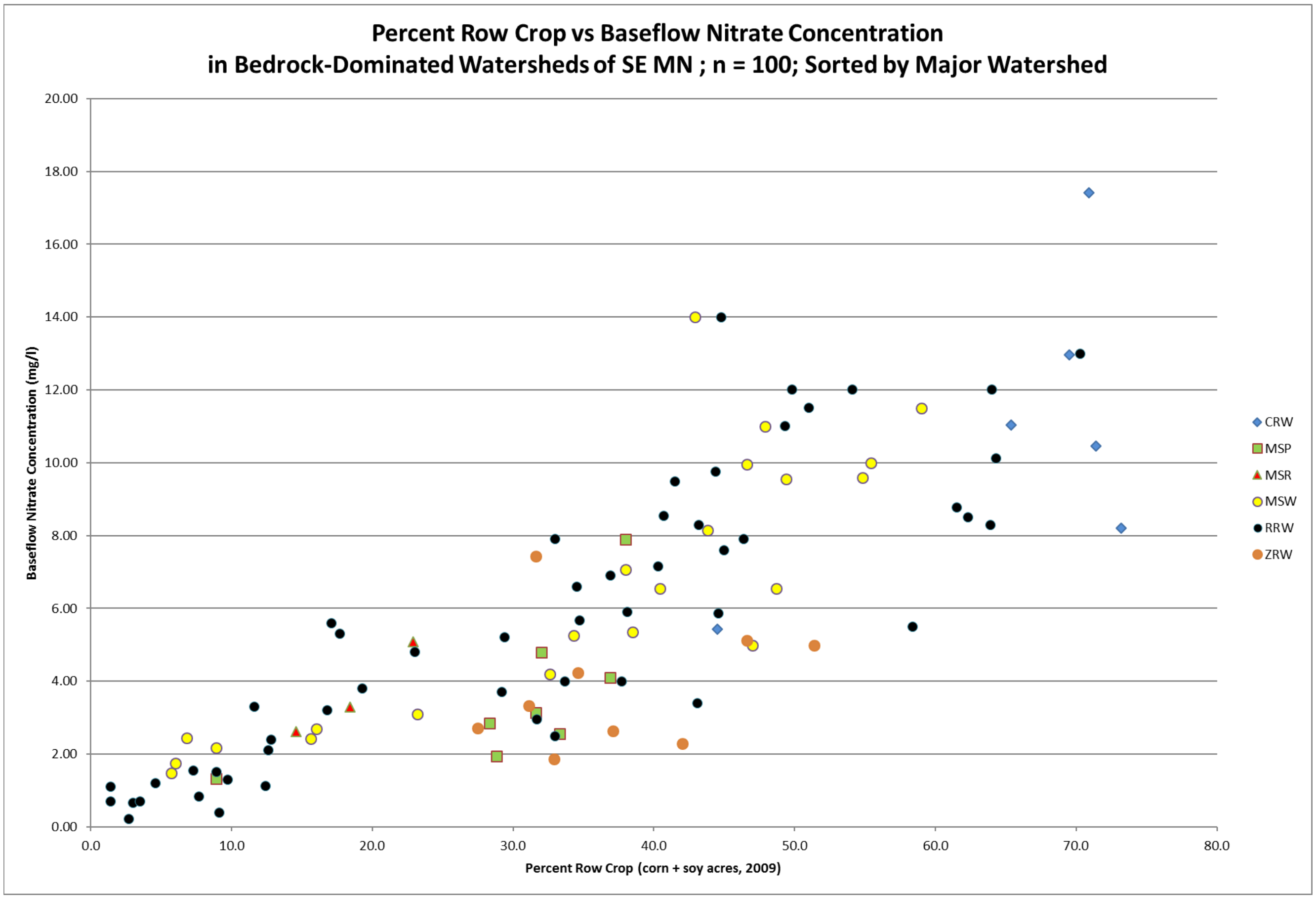


Figure 22. Baseflow nitrate and row crop acres regression (Watkins, Rasmussen, Streitz et al 2013).

Variable leaching loss across different land uses and within the Cropland N Source

Field and plot-scale work by the University of Minnesota has documented nitrate-nitrogen loading rates (measured via sampling of subsurface tiles) for various cropping systems and other land covers. Over the course of four years of monitoring, continuous corn showed the highest loading rate and perennial cover (CRP) showed the lowest loading rate – approximately 50 times less than that of continuous corn (Figure 23).

Effect of CROPPING SYSTEM on drainage volume, NO_3-N concentration, and N loss in subsurface tile drainage during a 4-yr period (1990-93) in MN.

Cropping System	Total discharge	Nitrate-N Conc.	Nitrate-N Loss
	Inches	ppm	lb/A
Continuous corn	30.4	28	194
Corn – soybean	35.5	23	182
Soybean – corn	35.4	22	180
Alfalfa	16.4	1.6	6
CRP	25.2	0.7	4

University of Minnesota
Driven to Discover

Figure 23. Effect of cropping system on nitrogen loss (from U of MN).

Regarding nitrogen leaching from cultivated lands, there is no desktop method for discerning relative loss from field to field within the bound of the watershed's row crop acres; the agronomic variables are too many and they are not captured in available geographic data. Rather, areas of greatest leaching loss should be determined by the local government units (mainly the SWCDs and NRCS) and interested landowners, using the best available local nutrient management data and professional judgment.

In 2010, a nitrate consortium that met in Rochester, Minnesota concluded that monitoring nitrate concentrations in soil water would provide significant support to such efforts to understand and manage nitrogen leaching loss from various land uses and crop management settings in southeast Minnesota. Randall et al noted "Nitrate-N concentrations in the soil water at five feet (below the root zone) provide a good basis upon which to compare the environmental risks associated with various N management systems (Randall).

In 2011, a soil-water monitoring network was implemented in southeast Minnesota with the main purpose of identifying the range of nitrate-nitrogen concentrations leaching from various land cover and management types under various climatic conditions. From 2011 through 2015, nearly 60 lysimeters on 21 sites covering 10 different types of land use were sampled. Nitrate concentrations were measured using suction-cup lysimeters. In the bar chart below, over 2,500 samples are summarized and average nitrate concentrations are displayed above each land cover type. Row crop averages ranged from 7.3 to 26.0 mg/l while non-row crop averages ranged from less than 1.0 to 11.3 mg/L. Maximum observed values are also displayed below the chart (Figure 24).

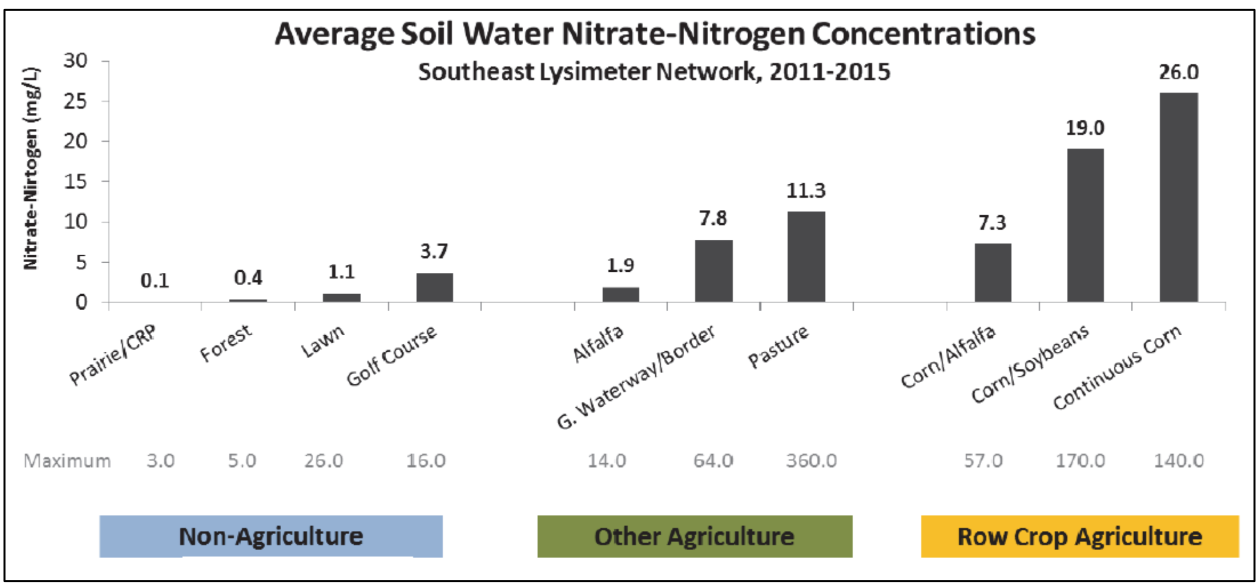


Figure 24. Soil water nitrate-nitrogen concentration data summary by land use and crop rotation.

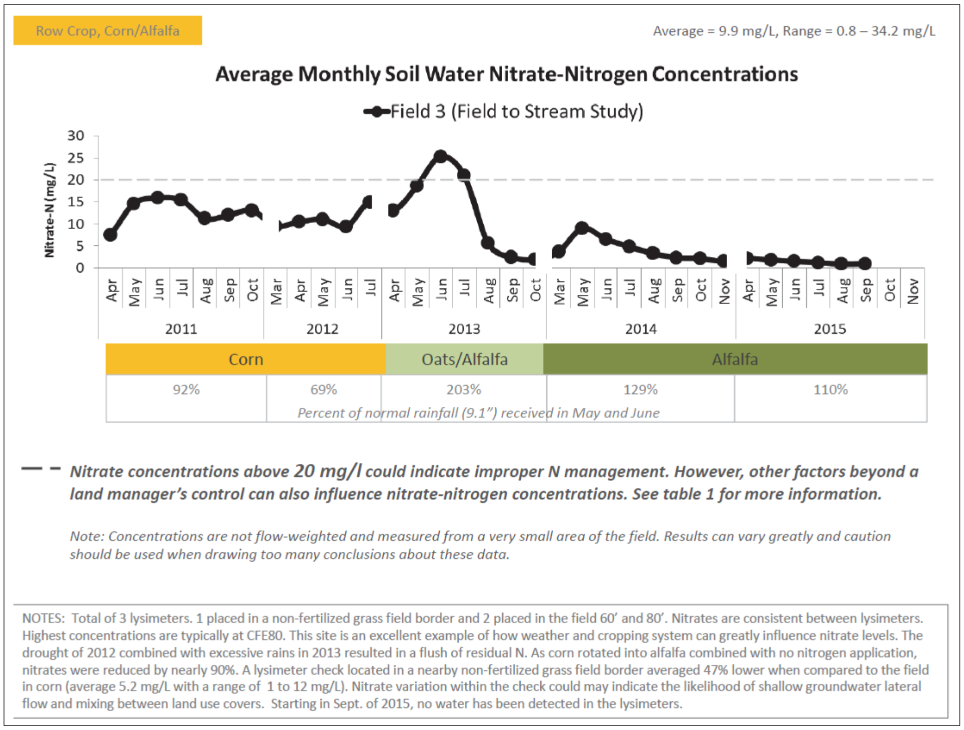


Figure 25. Example soil-water data at Field 3.

Note that concentrations are not flow-weighted and measured from a very small area of the field. As such, the general conclusions regarding land use and management system differences are robust, but can vary significantly by individual results.

Row Crop, Corn/Alfalfa

Site Field 3

Nitrogen Management

Year	Crop	Prev. Crop	Main N Source	Timing	Method	Total N Rate[1]	Notes
2011	Corn	Soybeans	urea	spring	broadcast/inc.	117	
2012	Corn	Corn	urea	pre-plant	broadcast/inc.	192	dry
2013	Oats/Alfalfa	Corn				No N applied	very wet
2014	Alfalfa	Oats/Alfalfa				No N applied	
2015	Alfalfa	Alfalfa				No N applied	

[1]Total N rate includes credits from starter, AMS, MAP/DAP and first or second year manure and/or alfalfa

Figure 26. Nitrogen Fertilizer and Crop Rotation information for Field 3.

Case Study: What Happens when the Main Nitrogen Source is Eliminated?

In a study designed to examine the nitrate-nitrogen reduction in a wetland along the Decorah Edge in Rochester, Minnesota, Jones et al. evaluated the effects of changing land use at a small scale. In the course of developing a land area for residential housing, row cropping ceased thereby marking a point of dramatic change in the local land use and management. The study installed a well nest that allowed for monitoring of nitrates in the groundwater of various stratigraphic units beneath the study area. The work confirmed that the effects of crop fertilization are present in groundwater well after cessation of the practice, but continued monitoring of the well in the uppermost unconfined limestone bedrock has documented a steady decline in nitrate concentration over time. See Figure 27 and Figure 28 below.

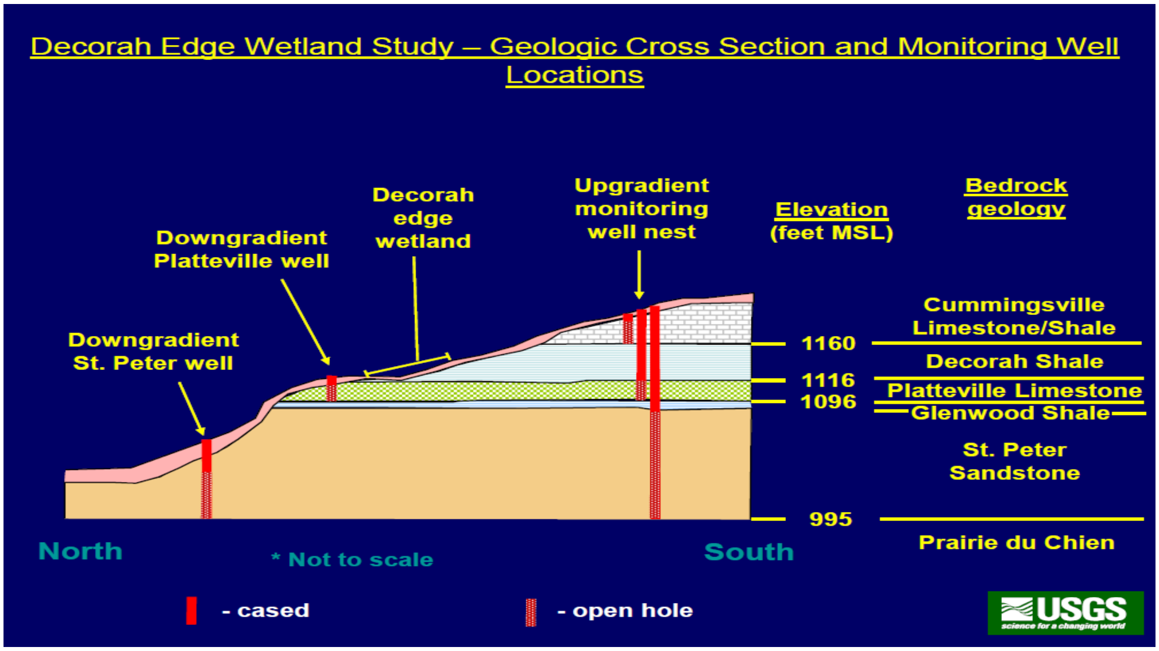


Figure 27. Decorah Edge study wells. The data in this figure are from the shallow wells with the open hole interval in the Cummingsville Limestone. Figure from Jones et al.

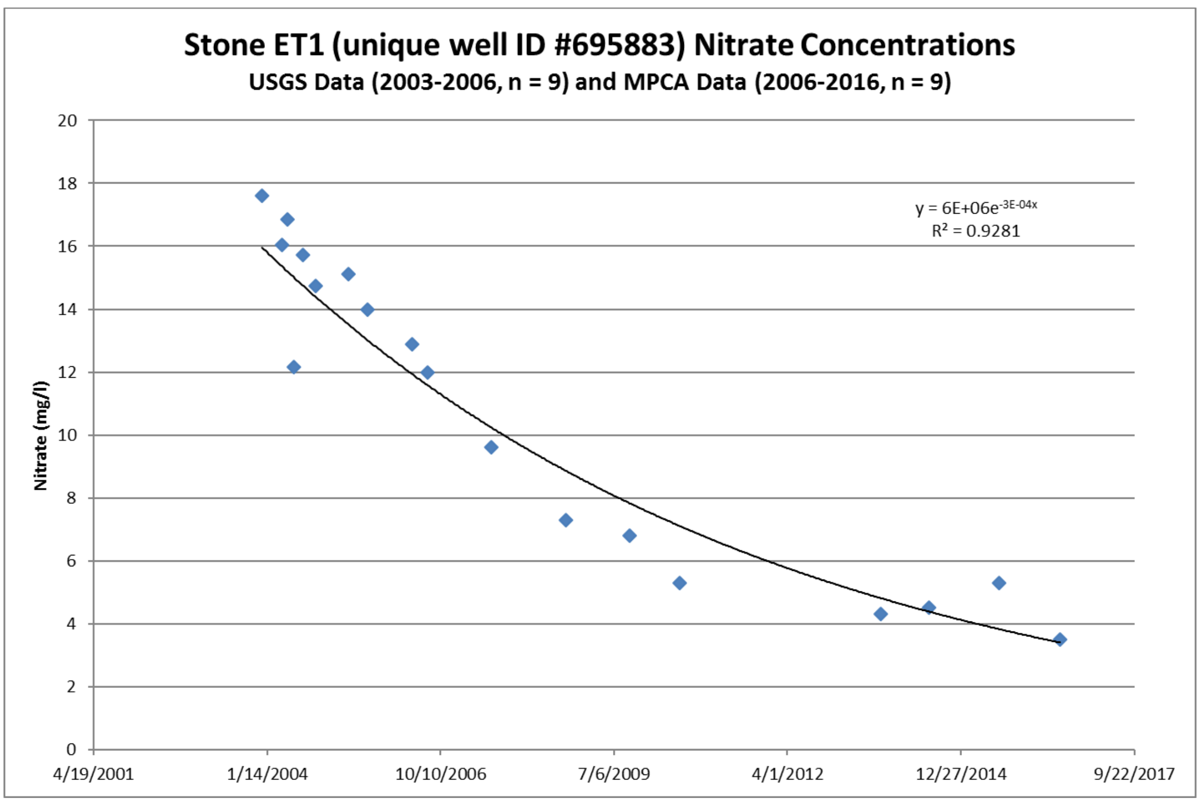


Figure 28. Stone ET1 well nitrate data.

The MPCA Ambient Groundwater Monitoring Program continues to monitor the site Stone ET1; the dataset stands as unique and valuable in documenting the effects of land use changes on local groundwater quality.

Given that the primary transport mechanisms for loading nitrate to the surface waters of the ZRW watershed are tile drainage and "ag groundwater," it follows that the response time of nitrate concentrations in wells, springs, streams and rivers to changes in land use practices will likely vary in different hydrogeological settings (Runkel et al. 2014). In the case of the Stone ET1 well, groundwater nitrate concentrations dropped below 10 mg/l after approximately four years of cessation of row cropping. Other settings (e.g. tiled stream systems) may respond more quickly, while others (e.g. trout streams with deeper ("older") source water) may take longer to show water quality changes. As such, water quality changes in receiving waters cannot be the only measure of attainment of nitrogen reduction goals. Interim measures (e.g. successfully implementing the combinations of BMPs described in subsequent chapters of this document) should be considered. Nitrate concentrations of soil water, shallow wells or springs in the upper bedrock units may allow for monitoring of "middle points" between land use practices and surface water monitoring locations. Studies outside of southeastern Minnesota have concluded that some hydrogeological systems function in a manner whereby changes in base flow nitrate concentrations lag changes in land use practices by decades (e.g. Tesoriero et. al. 2013). The most significantly lagged response in southeastern Minnesota should be expected in the deep valleys incised into the Prairie du Chien Plateau, where significant baseflow is derived from deep, siliciclastic-dominated bedrock sources with one or more overlying aquitards (Runkel et al. 2014).

Other resources useful in examining nitrogen sources in the ZRW include:

- Nitrogen in Minnesota Surface Waters (MPCA https://www.pca.state.mn.us/sites/default/files/wq-s6-26a.pdf),
- Minnesota's NRS (https://www.pca.state.mn.us/water/nutrient-reduction-strategy), and
- Geologic controls on groundwater and surface water flow in southeastern Minnesota and its impact on nitrate concentrations in streams (MGS http://conservancy.umn.edu/handle/11299/162612).
- Minnesota's Nitrogen Fertilizer Management Plan (MDA, http://www.mda.state.mn.us/~/media/Files/chemicals/nfmp/nfmp2015.pdf)

Pathogen Sources

The following text, which provides an overview of nonpoint sources of fecal coliform and *E. coli* bacteria and associated pathogens, is excerpted and adapted from *the Revised Regional TMDL Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota* (MPCA 2006). Additional research conducted by Chandrasekaran et al. (2015) is also noted. At the time the MPCA 2006 study was conducted, Minnesota's water quality standard was described in terms of fecal coliform colonies as indicators of fecal pathogens; it has since changed to make use of *E. coli* counts (the water quality standard used in these TMDLs) for the same purpose.

The relationship between land use and fecal coliform concentrations found in streams is complex, involving both pollutant transport and rate of survival in different types of aquatic environments. Intensive sampling at numerous sites in southeastern Minnesota shows a strong positive correlation between stream flow, precipitation, and fecal coliform bacteria concentrations. In the Vermillion River Watershed, storm-event samples often showed concentrations in the thousands of organisms per 100 mL, far above non-storm-event samples. A study of the Straight River Watershed divided sources into continuous (failing individual sewage treatment systems, unsewered communities, industrial and institutional sources, WWTFs) and weather-driven (feedlot runoff, manured fields, urban stormwater) categories. The study hypothesized that when precipitation and stream flows are high, the influence of continuous sources is overshadowed by weather-driven sources, which generate extremely high fecal coliform concentrations. However, during drought, low-flow conditions continuous sources can generate high concentrations of fecal coliform, the study indicated. Besides precipitation and flow, factors such as temperature, livestock management practices, wildlife activity, fecal deposit age, and channel and bank storage also affect bacterial concentrations in runoff (Baxter-Potter and Gilliland 1988). Fine sediment particles in the streambed can serve as a substrate harboring fecal coliform bacteria. “Extended survival of fecal bacteria in sediment can obscure the source and extent of fecal contamination in agricultural settings,” (Howell et al. 1996). Sadowsky et. al. studied reproduction and survival of *E. coli* in ditch sediments and water in the Seven Mile Creek Watershed; their work concluded that while cattle are likely major contributors to fecal pollution in the sediments of Seven Mile Creek, it is also likely that some *E. coli* strains reproduce in the sediments and thus some sites probably contain a mixture of newly acquired and resident strains (Sadowsky et al. 2010). A study published in 2015 by Chandrasekaran et al. (Sadowsky being a co-author), continued research in the Seven Mile Creek Watershed. Results from this study concluded that populations of *E. coli* can exist in ditch sediments as temporal sinks and be a source of bacteria to streams. The authors highlight the issue with using only livestock manure operations as an indicator of source impacts to water quality.

Hydrogeological features in southeastern Minnesota may favor the survival of fecal coliform bacteria. Cold groundwater, shaded streams, and sinkholes may protect fecal coliform from light, heat, drying, and predation (MPCA 1999). Sampling in the South Branch of the Root River Watershed showed concentrations of up to 2,000 organisms/100 mL coming from springs, pointing to a strong connection between surface water and ground water (Fillmore County 1999 and 2000). The presence of fecal coliform bacteria has been detected in private well water in southeastern Minnesota. However, many detections have been traced to problems of well construction, wellhead management, or flooding, not from widespread contamination of the deeper aquifers used for drinking water. Finally, fecal coliform survival appears to be shortened through exposure to sunlight. This is purported to be the reason why, at several sampling sites downstream of reservoirs, fecal coliform concentrations were markedly lower than at monitoring sites upstream of the reservoirs. This has been demonstrated at Lake Byllesby on the Cannon River just northwest of the ZRW, and the Silver Lake Reservoir on the South Fork of the Zumbro River in Rochester. Despite the complexity of the relationship between sources and in-stream concentrations of fecal coliform, the following can be considered major source categories:

Urban and Rural Stormwater

Untreated stormwater from cities, small towns, and rural residential or commercial areas can be a source for many pollutants, including fecal coliform bacteria and associated pathogens. Fecal coliform concentrations in urban runoff can be as great as or greater than those found in cropland runoff, and feedlot runoff (EPA 2001). Sources of fecal coliform in urban and residential stormwater include pet and wildlife waste that can be directly conveyed to streams and rivers via impervious surfaces and storm sewer systems. Newer urban development often includes stormwater treatment in the form of such practices as sedimentation basins, infiltration areas, and vegetated filter strips. Smaller communities or even rural residences not covered by MS4 Permits may be sources of stormwater and associated pollutants.

Livestock Facilities and Manure Application

The MPCA currently uses the federal definition of a Concentrated Animal Feeding Operation (CAFO) in its regulation of animal feedlots. In Minnesota, the following types of livestock facilities are issued, and must operate under, a NPDES Permit or a State Disposal System (SDS) Permit (Permit): a) all federally defined (CAFOs), some of which are under 1000 AUs in size, which have or had a discharge; and b) all CAFOs and non-CAFOs, which have 1000 or more AUs.

The vast majority of livestock facilities in the Lower Mississippi River Basin in Minnesota are not CAFOs subject to NPDES Permit requirements. Nevertheless, they are subject to state feedlot rules, which include provisions for registration, manure management, inspection, permitting, and upgrading. Much of this work is accomplished through delegation of authority from the state to county government.

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 ZRW, the counties of Goodhue, Rice and Steele counties are delegated the feedlot regulatory authority. Of the approximately 1,068 feedlots in the ZRW, there are 38 active NPDES permitted CAFOs (Figure 29). 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. The number of AUs by animal type registered with the MPCA feedlot database are summarized in Table 9.

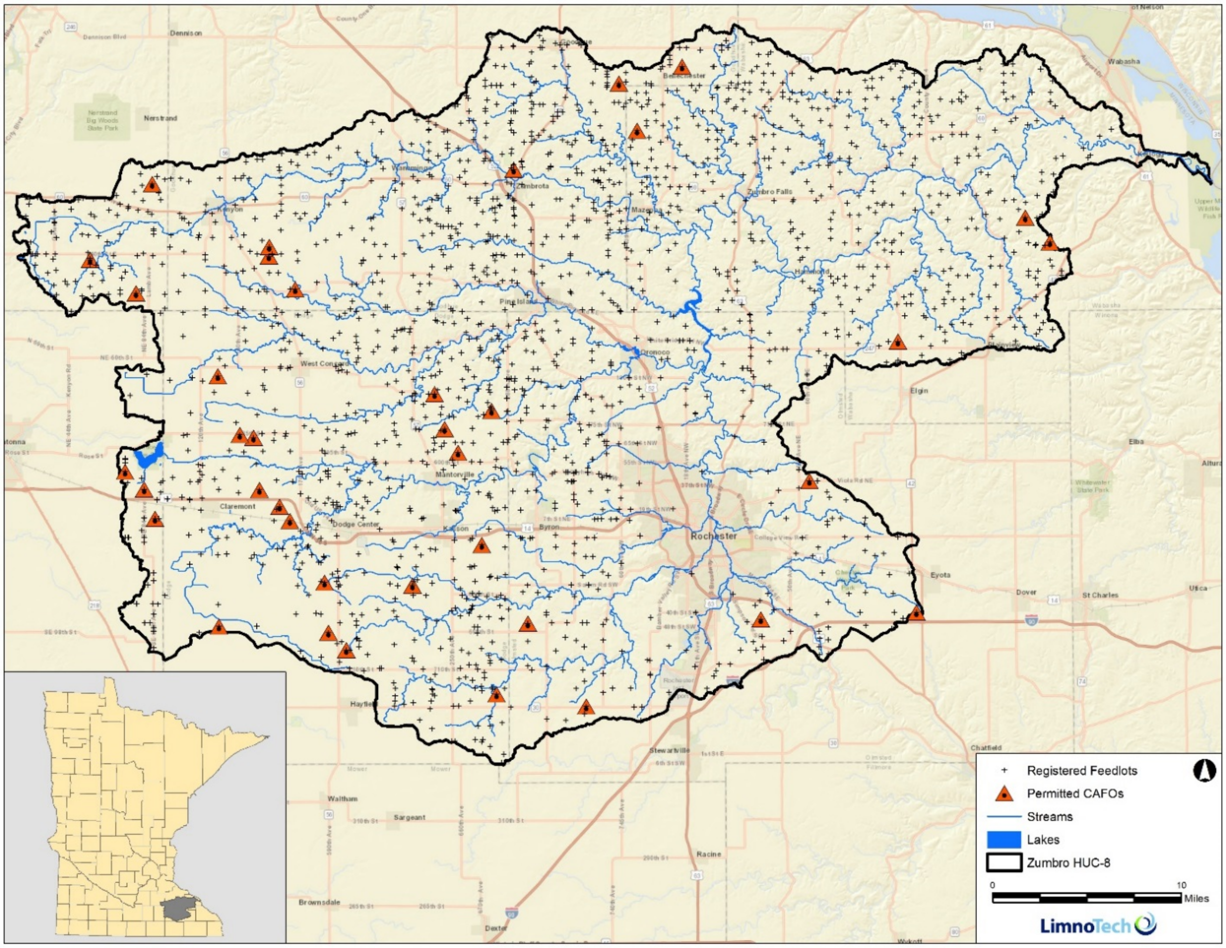


Figure 29. Location of all feedlots within the ZRW. Feedlots with an NPDES permit are identified in orange.

Table 9. The number of AUs registered in the MPCA feedlot database for permitted CAFOs.

Facility Name	NPDES Permit No	Livestock Type	AUs
BC Calf Farm	MNG441289	Cows	980
Belvidere Group Partner - Merle	MNG440031	Swine	1260
Brian Edgar Farm - Sec 18	MNG440449	Swine	1200
Brian Herbst Farm Sec 2	MNG441115	Swine	1022
Central Livestock Assn. - Zumbrota Market	MNG441119	Cows, Horse, Sheep, & Swine	1530
Craig & Carly Benedix Farm - Craig 3000	MNG440445	Swine	900
Craig & Caryl Benedix Farm - Ridge	MNG440445	Swine	900
Daley Brothers LLC	MN0067911	Cows	1428
David C Johnson Farm Sec - 20	MNG440260	Swine	1124.4
David Gosch Farm	MNG441180	Cows & Swine	972
Donley Farm Inc	MNG441101	Cows & Swine	1382.4

Facility Name	NPDES Permit No	Livestock Type	AUs
Durst Bros Dairy - Site I	MNG440646	Cows	2240
Ellingsberg Farm	MNG441030	Swine	864
Eric Dressel	MNG441214	Swine	1470
Fieseler Farms	MNG440787	Swine	1200
Grandview Hogs of Dodge Center LLP - Sow	MNG440054	Swine	912.6
Grant T Erler Farm	MNG441240	Swine	895
Jason Tebay Farm	MNG441032	Swine	1320
Jennie-O Turkey Store - Claremont Farm	MNG440039	Poultry	1839
Kevin Hoebing Farm	MNG441192	Swine	1459.5
Knott Farms	MNG440030	Swine	1200
Luke Scherger	MNG441008	Swine	2250
Manco of FMT Inc	MNG440042	Swine	1500
Mathew & Daniel Arendt Farm	MNG440942	Swine	1020
McNallan Dairy	MNG440504	Cows	1196
Minnesota Family Farms - Sow Site 1	MNG440044	Swine	1096
Nicholas Hanson Farm	MNG440765	Swine	1500
Richard Wolf Farm	MNG440963	Cows, Goats, & Swine	946.5
Schoenfelder Farms LLP - Main Farm	MN0063517	Cows, Horse, & Swine	4317
Schumacher Farms of Elgin Inc	MN0070025	Cows	2417
Shane Wagner Farm South	MNG440575	Swine	900
Shane Wagner Farm West	MNG440575	Swine	1320
Toquam Hogs	MNG440043	Swine	1176
VanZuilen Enterprises	MNG440323	Swine	1200
VZ Hogs LLP - North Finishers	MNG440265	Swine	1200
VZ Hogs LLP - Sow Site 1	MNG440265	Swine	1032
Wayne Evers Farm	MNG441278	Cows	2523
William Schmidt Farm 1	MNG440451	Swine	900

Individual Sewer Treatment Systems

Nonconforming septic systems are an important source of fecal coliform bacteria, particularly during periods of low precipitation and runoff when this continuous source may dominate fecal coliform loads. Unsewered or under sewered communities include older individual systems that are generally failing, and/or collection systems that discharge directly to surface water. This may result in locally high concentrations of wastewater contaminants in surface water, including fecal coliform bacteria, in locations close to population centers where risk of exposure is relatively high. The Subsurface Sewage Treatment Systems (SSTS) program at the MPCA keeps records of estimated non-compliant systems and imminent public health threats (IPHT); a sample of these data is provided below in Table 10 (note that the numbers pertain to counties and not watersheds).

Table 10. Subsurface sewage treatment system estimates by county.

County	Total SSTS	Non-Compliant SSTS	Imminent Public Health Threats
Dodge	2867	917	287
Goodhue	5200	1040	1456
Olmsted	3480	661	278
Rice	7151	1345	1345
Steele	3051	793	305
Wabasha	4259	681	256

2.4 TMDL Summary

The ZRW TMDLs report includes seven TSS TMDLs, 17 pathogen TMDLs and one phosphorus TMDL for Rice Lake. Note that in the ZRW 17 TSS TMDLs (https://www.pca.state.mn.us/sites/default/files/wq-iw9-13e.pdf) and five pathogen (fecal coliform) TMDLs (https://www.pca.state.mn.us/sites/default/files/wq-iw9-03b.pdf) have already been approved by the EPA.

In the case of the stream aquatic life impairments, many of the use support decisions drew heavily on biota data, which require further examination (SID, see Chapter 2.3) to determine whether pollutants are causing the impairments. Pollutant stressors are addressed via TMDLs. Non-pollutant stressors are not subject to load quantification and therefore do not require TMDLs. If a non-pollutant stressor is linked to a pollutant (e.g. habitat issues driven by TSS or low DO caused by excess phosphorus) a TMDL is required. However, in many cases habitat stressors are not linked to pollutants. With respect to the two identified dissolved oxygen (DO) stressors in the ZRW, there are insufficient means for conclusively linking the condition to a pollutant cause.

Note that all aquatic life use impairments – not just those with associated TMDLs - are addressed in this WRAPS Report. Many streams that are stressed by degraded habitat do not require TMDLs but may still be a focus in future planning or restoration work in the ZRW. For example, Cascade Creek 07040004-991 was assessed as non-supporting of aquatic life use, drawing largely on biota data. SID indicated lack of habitat and flow alteration as stressors; neither of which is a pollutant and as such there is no TMDL required for the reach. However, local government units and the DNR have initiated a stream restoration on that AUID that aims to provide floodplain reconnection and improve habitat and channel stability (Figure 30).

Figure 30. Cascade Creek stream restoration project photo.

Table 11 below and Appendix A in the TMDLs document summarize in detail the rationales for addressing (or not) each impaired water via TMDL. Table 12 summarizes ZRW impairments addressed by TMDLs: 18 AUIDs that do not support aquatic recreation use and seven AUIDs that do not support aquatic life use.

For more information, see the ZRW TMDL Report:
https://www.pca.state.mn.us/water/watersheds/zumbro-river

Table 11. List of 303(d) reaches in the ZRW that are impaired for aquatic life use.

Listed Waterbody Name	Location Description	Reach (AUID)	Basis for Aquatic Listing			Addressed in TMDL Report
			MIBI	FIBI	Turbidity	
Unnamed Creek	Unnamed cr to unnamed cr	07040004-597	x	x		No
Unnamed Creek	Unnamed cr to unnamed cr	07040004-503	x			No
Unnamed Creek	Unnamed cr to unnamed cr	07040004-621		x		No
Badger Run	Unnamed cr to Bear Cr	07040004-620		x		No
Unnamed Creek	Unnamed cr to Willow Cr	07040004-800	x	x		No
Silver Creek	Unnamed cr to unnamed cr	07040004-552			x	No*
Zumbro River, South Fork	Salem Cr to Bear Cr	07040004-536	x		x	No*
Cascade Creek	Unnamed cr to unnamed cr	07040004-991		x		No
Cascade Creek	Unnamed cr to S Fk Zumbro R	07040004-581	x			No
Zumbro River, South Fork	Cascade Cr to Zumbro Lk	07040004-507	x		x	No*

Listed Waterbody Name	Location Description	Reach (AUID)	Basis for Aquatic Listing			Addressed in TMDL Report
			MIBI	FIBI	Turbidity	
Judicial Ditch 1	T106 R18W S28, east line to Unnamed cr	07040004-987	x			No
Dodge Center Creek	Unnamed cr to -92.99 44.0212	07040004-988	x	x		No
Dodge Center Creek	-92.99 44.0212 to S Vr M Fk Zumbro R	07040004-989	x		x	Yes
Henslin Creek	Unnamed cr to Dodge Center Creek	07040004-618	x			No
Zumbro River, Middle Fork, South Branch	Unnamed cr to Dodge Center Cr	07040004-980	x			No
Zumbro River, Middle Fork, South Branch	Dodge Center Cr to Unnamed cr	07040004-976	x		x	No
Zumbro River, Middle Fork	T108 R18W S20, west line to N Br M Fk Zumbro R	07040004-973	x		x	Yes - as Aquatic Rec only
Unnamed Creek	Headwaters to M Fk Zumbro R	07040004-578	x			No
Milliken Creek	Unnamed cr to M Fk Zumbro R	07040004-555			x	Yes
Zumbro River, Middle Fork (Shady Lake)	S Br M Fk Zumbro R to Zumbro Lk	07040004-993			x	Yes
Trout Brook	T110 R15W S24, west line to N Fk Zumbro R	07040004-515	x			Yes - as Aquatic Rec only
Zumbro River, North Fork	T109 R19W S11, west line to Trout Bk	07040004-971	x			Yes
Unnamed Creek	Unnamed cr to N Fk Zumbro R	07040004-964	x			No
Unnamed Creek	Unnamed cr to N Fk Zumbro R	07040004-605	x			No
Spring Creek	Unnamed cr to unnamed cr	07040004-606	x			No
Shingle Creek	Unnamed cr to N Fk Zumbro R	07040004-562	x			No
Unnamed Creek	Headwaters to N Fk Zumbro R	07040004-579	x			No
Cold Creek	T110 R14W S25, north line to Zumbro R	07040004-510	x			No
Spring Creek	Unnamed cr to Unnamed cr	07040004-568	x			Yes

Listed Waterbody Name	Location Description	Reach (AUID)	Basis for Aquatic Listing			Addressed in TMDL Report
			MIBI	FIBI	Turbidity	
Spring Creek	Unnamed cr to Zumbro R	07040004-570		x		Yes
Spring Creek Tributary	T110 R12W S28, south line to Spring Cr	07040004-769			x (Secchi Tube)	Yes
Trout Brook	Hope Coulee to Zumbro R	07040004-585	x	x		No

*TSS TMDLs have been approved as part of the 2012 Zumbro Turbidity TMDL study.

Table 12. New TMDL Computations.

HUC-10 Watershed	TSS	Pathogens	Phosphorus
North Fork Zumbro River	1	2	
Middle Fork Zumbro River	2	2	
South Branch Middle Fork Zumbro River	1	2	Rice Lake
South Fork Zumbro River		3	
Zumbro River	3	8	

TSS and pathogen TMDLs typically do not have significant impacts for municipal and industrial wastewater dischargers in Minnesota, because in nearly every case the discharge permits include TSS and *E. coli* limits that are equal to or less than the respective water quality standards for the impaired waters. Because there are already approved TSS and *E. coli* TMDLs downstream of all the watershed Municipal Separate Storm Sewer Systems (MS4s), their permits/Stormwater Pollution Prevention Plans (SWPPPs) already reflect BMPs to address these pollutants. As such, the new MS4 WLAs noted in Table 13 will require consideration and will be added to existing lists of downstream WLAs for TSS and *E. coli*.

Table 13. MS4 wasteload allocation summary.

<table>
<tr><th>Water Body Name</th><th>Reach (AUID)</th><th>Watershed Area (ac)</th><th>MS4 Area (ac)</th><th>% MS4 Area</th><th colspan="2">List of MS4 Communities</th><th>Parameter</th></tr>
<tr><td>Zumbro River</td><td>07040004-978</td><td>140,453</td><td>739</td><td>0.53%</td><td colspan="2">Oronoco Township (FUTURE)</td><td>E. coli</td></tr>
<tr><td>Zumbro River</td><td>07040004-993</td><td>275,942</td><td>5,685</td><td>2.06%</td><td colspan="2">Oronoco Township (FUTURE)</td><td>TSS</td></tr>
<tr><td rowspan="8">Bear Creek</td><td rowspan="8">07040004-538</td><td rowspan="8">51,812</td><td rowspan="8">10,882</td><td rowspan="8">21.00%</td><td>Federal Medical Center</td><td>17 ac.</td><td rowspan="8">E. coli</td></tr>
<tr><td>Haverhill Township</td><td>2 ac.</td></tr>
<tr><td>Marion Township</td><td>2,017 ac</td></tr>
<tr><td>MnDOT Outstate</td><td>855 ac.</td></tr>
<tr><td>Olmsted County</td><td>214 ac.</td></tr>
<tr><td>Rochester City</td><td>6,753 ac.</td></tr>
<tr><td>Rochester Comm & Tech College</td><td>101 ac.</td></tr>
<tr><td>Rochester Township</td><td>923 ac.</td></tr>
<tr><td>Dry Run Creek</td><td>07040004-576</td><td>19,236</td><td>1,566</td><td>8.14%</td><td colspan="2">Oronoco Township (FUTURE)</td><td>E. coli</td></tr>
</table>

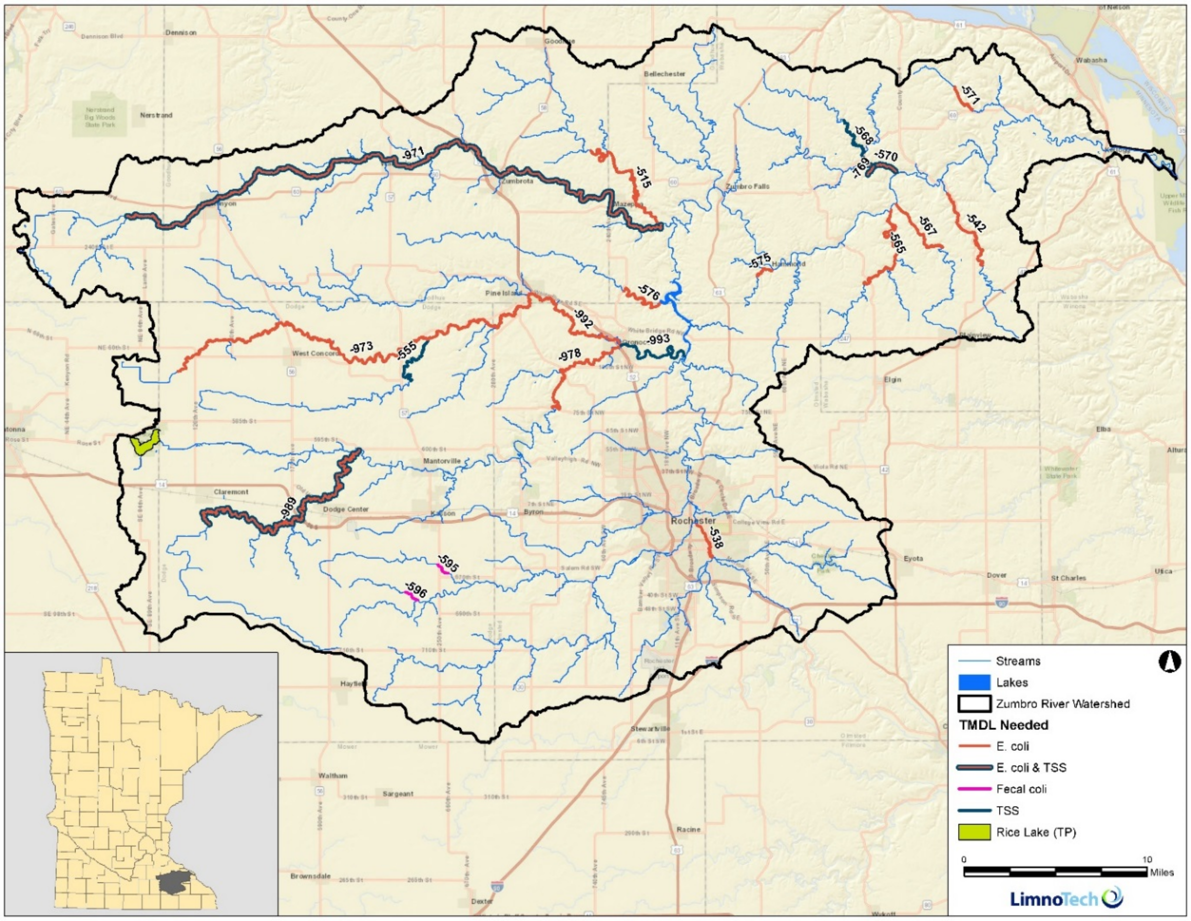


Figure 31. New TSS and pathogen (*E. coli* and fecal coliform) TMDLs.

Future TMDLs for Phosphorus

The draft 2016 impaired waters list includes four phosphorus listings in the ZRW (Table 1). The MPCA is considering site specific standards for Lake Zumbro (55-0004) and the South Fork Zumbro River (07040004-507). As such, the watershed TMDLs report does not include phosphorus TMDLs for those assessment units. Once the water quality goals are finalized, an assessment and if necessary a subsequent comprehensive analysis of impairments (including South Branch Middle Fork Zumbro River (07040004-978)) and sources in the Lake Zumbro Watershed will be completed. This may include TMDLs and WLAs for point sources that are protective of downstream river and reservoir water quality.

Table 14. Phosphorus impairments in the Zumbro River Watershed.

HUC-10 Watershed	Listed Waterbody Name	Location Description	Reach (AUID)	Listing Year
South Branch Middle Fork Zumbro River	Rice Lake	Lake or Reservoir	74-0001-00	2016
Zumbro River	Zumbro Lake	Lake or Reservoir	55-0004-00	2002
South Branch Middle Fork Zumbro River	Zumbro River, Middle Fork, South Branch	75th St NW to M Fk Zumbro R	07040004-978	2016
South Fork Zumbro River	Zumbro River, South Fork	Cascade Cr to Zumbro Lk	07040004-507	2016

2.5 Protection Considerations

Protection of Existing Use Support

Use support is one consideration in examining protection needs in the ZRW. However, in southeast Minnesota use support should be considered in a greater context; in some cases it alone should not call for prescription of a unique set of strategies that purport to address "protection" but not "restoration." Strategies to reduce pollutant loading, maintain or increase perennial vegetation, improve habitat, etc. apply well to nearly all watersheds in the region. As such, in many instances fully supporting waters may indicate priorities for work while not meriting unique strategies (and therefore not requiring individual rows in Table 20 to Table 24).

Despite the many documented impaired uses, the ZRW Monitoring and Assessment Report details well the fully supporting waters in the ZRW. One example in Figure 32 below shows waters that fully support aquatic life use in the ZRW.

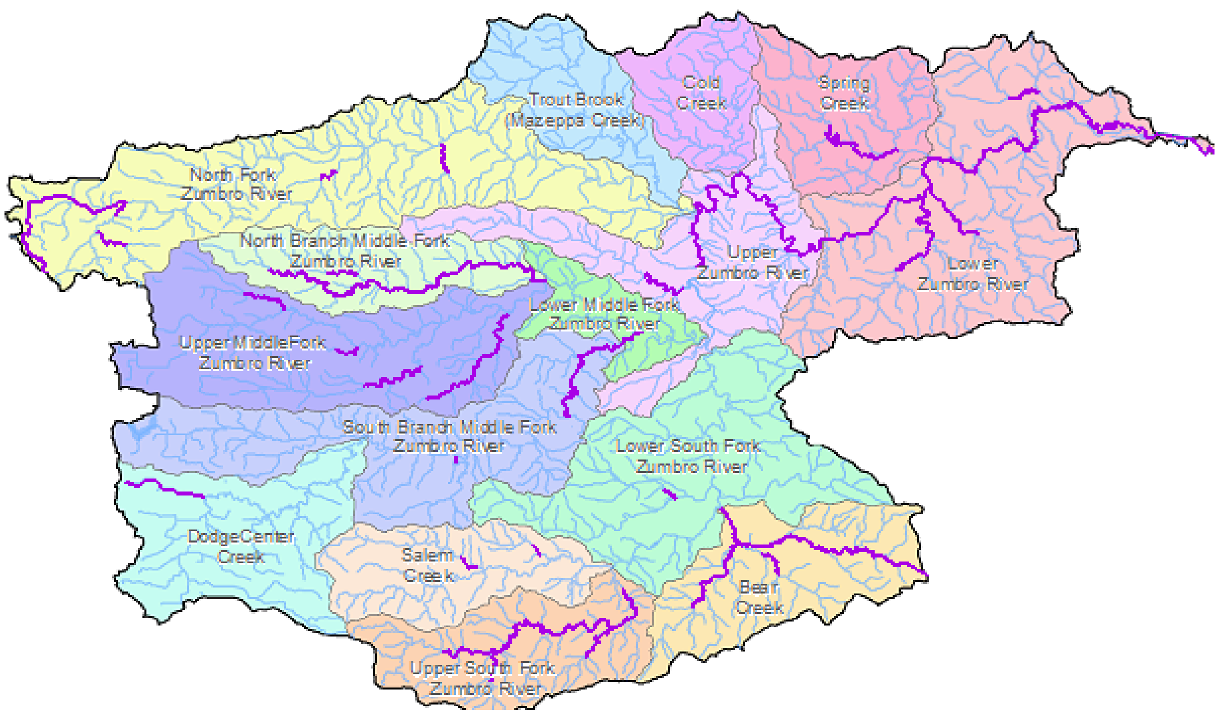


Figure 32. Fully supporting waters in the ZRW for aquatic life. Purple lines indicate stream and river reaches fully supporting aquatic life use.

The waters depicted above should be key protection considerations going forward. Increased pollutant loading or habitat degradation could significantly impact these waters. More information (e.g. smaller scale examination and consultation with local stakeholders) would help to discern more specific strategies that would constitute protection (such that it would be distinct from a "restoration strategy"). However, their full support status identifies them as priorities for conservation work in general.

Protection of Outstanding Resource Areas

In addition to consideration of existing use support, protection planning is focused on outstanding value natural resources in the ZRW. These land and water areas are best examined via tools and plans maintained by The Nature Conservancy (TNC) and DNR, both partners in conservation planning. Figure 33 depicts an example of protection priority watersheds (HUC-12 scale) according to analysis by TNC that examined overlap between aquatic and terrestrial protection targets, subbasin health (based on a subset of the WHAF dataset), and both agricultural land conversion and development risk. See Appendix E for TNC methodology used to derive Figure 33 below.

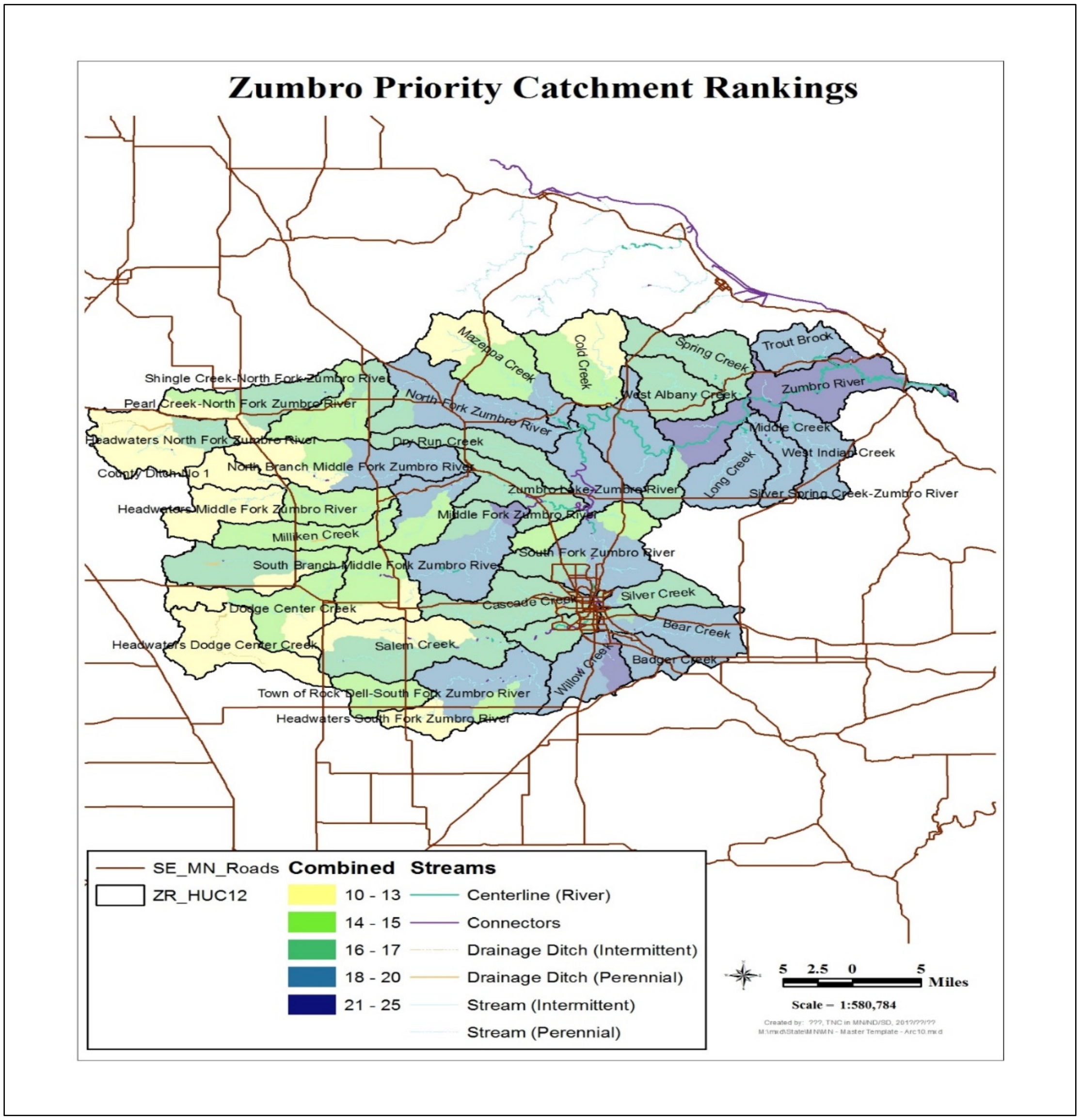


Figure 33. Protection analysis from The Nature Conservancy. Darker colors are higher priorities for protection.

These land areas can be paired with output from other planning efforts that focus on protection to derive priorities for acquisition, easement and technical assistance that would maintain and manage perennial cover (e.g. forest stewardship planning) on private lands. For example, priorities described in DNR's Wildlife Action Network (WAN) for the Lower Zumbro lobe overlap well with those of TNC (e.g.

main river corridor and the trout streams). Further discussion of the WAN (see below) and other protection prioritization and strategies follows in Chapter 3.1.

Protection of Groundwater

The following groundwater sensitivity rankings and accompanying maps were developed by the MDH as part of their Groundwater Restoration and Protection Strategies (GRAPS) for Minnesota. The MDH is responsible for protecting sources of drinking water, which is groundwater for 75% of Minnesotans. These rankings and maps translate ongoing groundwater and drinking water data and programs to the watershed scale for integration into watershed management plans.

Figure 34 is the pollution sensitivity of uppermost aquifers in the ZRW. It is based on the DNR's "pollution sensitivity of near-surface materials" dataset. The sensitivity rating (developed by DNR) applies to non-karst areas only. Note that "Karst" and "bedrock at or near surface" are interpreted as highly sensitive areas.

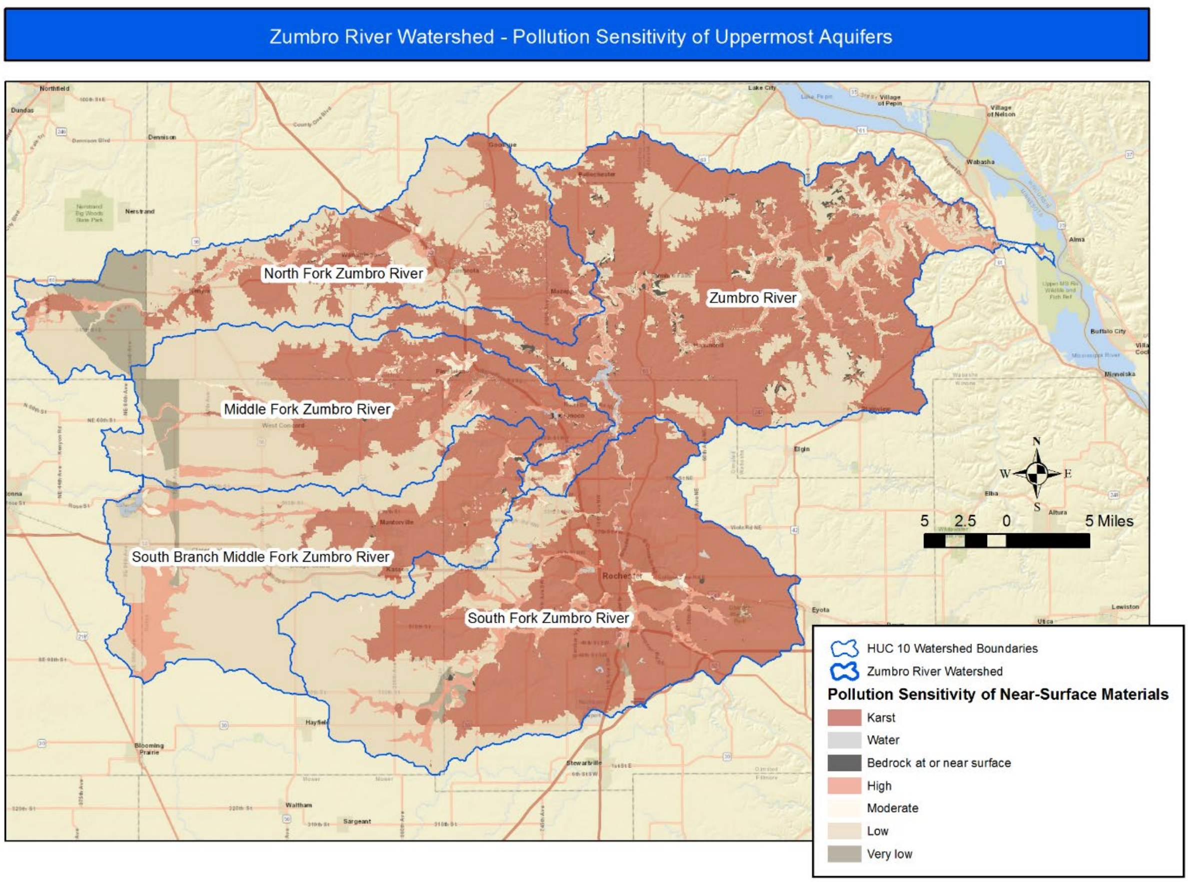


Figure 34. ZRW Pollution sensitivity of uppermost aquifers.

Figure 35 depicts a gradient of the geologic sensitivity of wells across the watershed. The geologic sensitivity was determined by characteristics recorded at the time of well drilling, such as the thickness and type of material overlying the aquifer. For example, a thick clay layer above the aquifer better protects it from contamination than a layer of sand, since it is more difficult for contaminants to penetrate a layer with low permeability. For unconfined aquifers, the depth of the water table also plays a role in calculating geologic sensitivity. The static water level measurement in the well reflects the approximate elevation of the water table in the aquifer. Wells with a relatively deep static water level are less likely to be contaminated than those with a higher static water level. This is because the time it takes for water and contaminants to infiltrate to the water table increases with depth.

Based on these characteristics, each well in the watershed was classified as having either “Low”, “Moderate”, or “High” geologic sensitivity to contamination. These values were then converted to a raster dataset using the natural neighbor technique in ArcMap, which allows for the interpolation between points to create a smooth gradient over the watershed. More details on the geologic sensitivity calculations are described in a flowchart, available per request from MDH (Jane de Lambert, MDH, personal communication September 27, 2017).

In comparison to the “Pollution Sensitivity of Near-Surface Materials” figure, which shows the vulnerability of the uppermost aquifers based on the top 10 feet of surficial geomorphology, this figure reflects vulnerability of aquifers based on the subsurface. These figures can be used in tandem to assess the total susceptibility of groundwater to contamination in each area, by combining both surficial and subsurface data sources

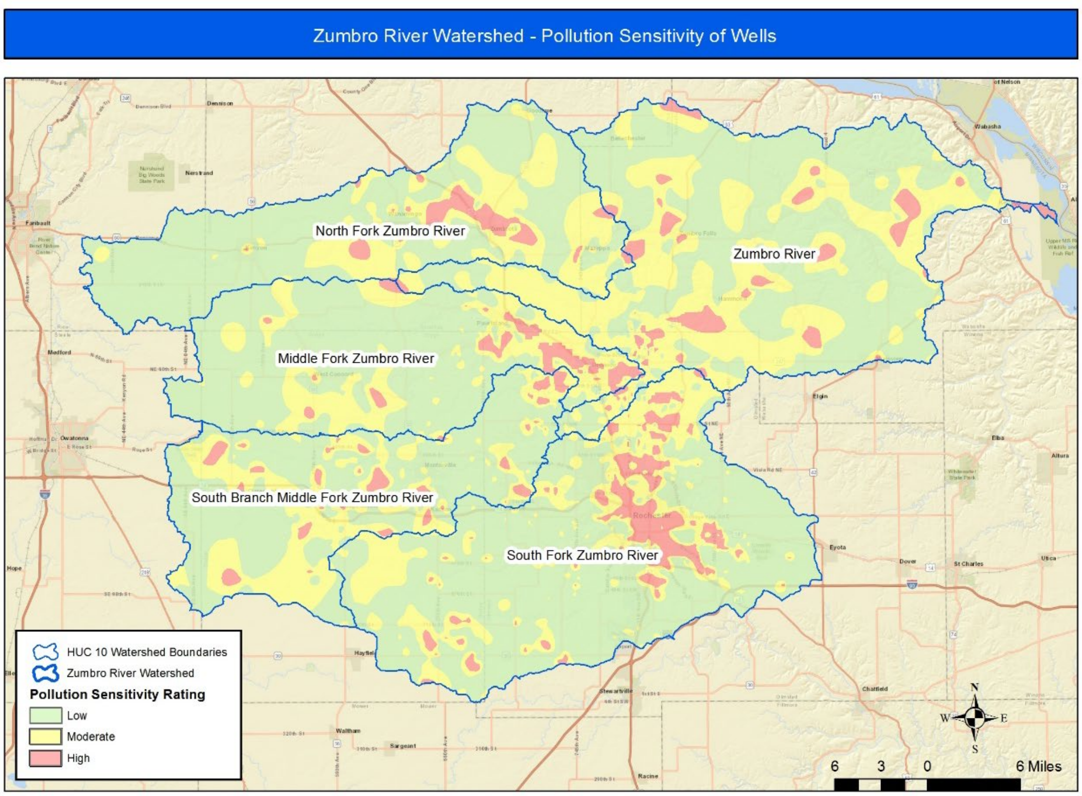


Figure 35. ZRW pollution sensitivity of wells.

Protection of Baseflow in Lower Zumbro Trout Streams

The Driftless Area is a geographic region covering parts of southwest Wisconsin, southeast Minnesota, northeast Iowa, and a small part of northwest Illinois. The distinctive landscape of the Driftless Area is characterized by craggy limestone, sandstone valleys, and steep hillsides. This ancient terrain, which was bypassed by the glaciers, is characterized by one of the highest concentrations of limestone spring creeks in the world. The spring water emerging from limestone bedrock provides a near constant flow of cold water. The limestone enriches the water with essential minerals for aquatic insects and other creatures, which contributes to prime conditions for healthy populations of trout and other coldwater dependent species. More than 600 spring creeks (exceeding 4,000 river miles) cross this 24,000 square-mile landscape. Trout anglers produce an economic benefit to the Driftless Area in excess of $1.1 billion every year (Driftless Area Restoration Effort 2008).

All but one of the designated trout waters in the Lower Zumbro Watershed lobe meet the criteria for the southeast Minnesota coldwater fish IBI (see Figure 36). The IBIs describe fish or bug quality, and higher scores are better. Different thresholds (i.e. goals for IBIs) are set for different stream types and sizes. In Figure 36, the IBI goal of 50 is highlighted in red; values at or above 50 mean that the fish in the stream indicate a healthy community of trout and other coldwater species. While there are restoration considerations in this lobe (e.g. elevated nitrates in the trout streams and poor macroinvertebrate IBIs in Cold Spring Brook), a focus of protection work should be preserving the baseflow of streams via focused monitoring and application of water appropriation analysis.

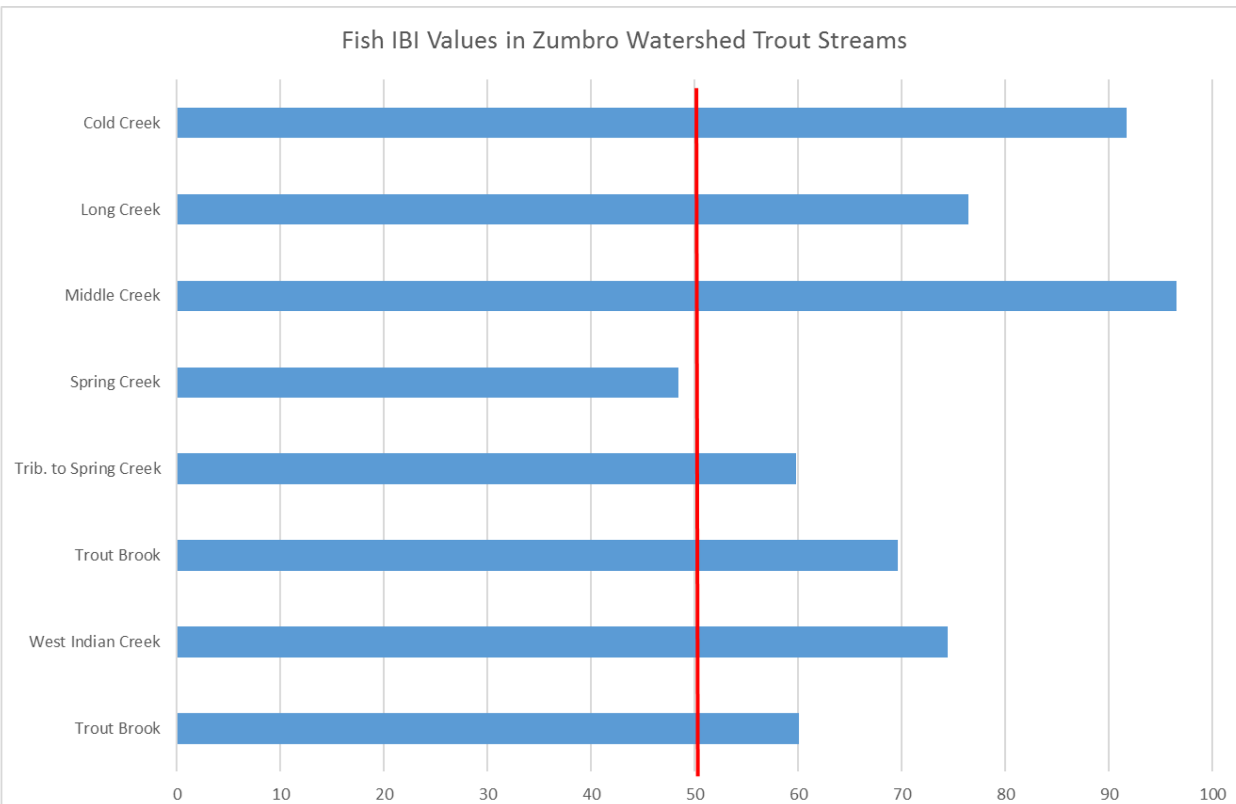


Figure 36. Trout stream fish IBI values.

3. Prioritizing and Implementing Restoration and Protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize priority areas for targeting actions to improve water quality, identify point sources, and identify nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, the CWLA requires including an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources.

This section of the report provides the results of such prioritization and strategy development. Because much 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 best management practices. Thus, effective ongoing civic engagement is fully a part of the overall plan for moving forward.

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, thus, should be considered approximate. Furthermore, many strategies are predicated on needed funding being secured. 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

Critical Areas

The CWLA states that WRAPS should "*summarize … priority areas for targeting actions to improve water quality" and "identify nonpoint sources of pollution … with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions."* This language comports with the EPA's directive to identify critical areas for pollution reduction for application of Section 319 nonpoint source funds. In the ZRW, the best tool for identifying these critical areas is the HSPF model, which operates on subwatersheds that are approximately scaled to typical HUC-12 polygons. Model outputs identify relatively small areas that according to the best available information load the most nutrients and sediment to surface waters. These models are discussed further in subsequent text and summarized in Appendix D, and example maps of model output can be reviewed in Figure 38, Figure 39, and Figure 40. Critical areas may describe contiguous geography (e.g. a HUC-12 watershed) or a condition or landscape feature present across a broader area (e.g. riparian zones or ephemeral gullies). Within the modeled polygons further delineation of critical areas can be achieved via Geographic Information System (GIS) work where available (e.g. terrain analysis) and professional judgment and experience of local government units and stakeholders.

Beyond critical areas for pollutant reduction, restoration and protection work can be prioritized according to other condition examinations (e.g. "layering" multiple impairments and stressors together), high level directives, (e.g. Nonpoint Source Funding Plan), and/or stakeholder input (e.g. Zonation results). The following text overviews a number of directives, works and tools that can be used to prioritize work in the ZRW, some of which may be best applied in the segue from ZRW WRAPS to subsequent planning steps or project concepts.

Waters at or Near Thresholds

In 2013, the Minnesota Legislature added "accountability" language to the CWLA. This new language aimed to increase accountability for the public funds used to clean up our water. The Act now defines WRAPS and requires the Board of Water and Soil Resources (BWSR) to prepare a Nonpoint Priority Funding Plan (NPFP).

The NPFP is a criteria-based process to prioritize Clean Water Fund investments. It provides state agencies with a coordinated, transparent and adaptive method to ensure that Clean Water Fund implementation allocations are targeted to cost-effective actions with measurable water quality results. The process may also help agencies identify gaps in programming to accelerate progress toward meeting water management goals. The plan can be reviewed here: http://www.bwsr.state.mn.us/planning/npfp/2016_NPFP_Final.pdf. The plan excerpt below indicates high-level priorities for spending.

Leadership from the state agencies that are tasked with protection and restoration of Minnesota's water resources came together and agreed on a set of high-level state priorities that align their programs and activities, working to reduce nonpoint source pollution as follows (Minnesota Board of Water and Soil Resources 2016):

- *Restore those impaired waters that are closest to meeting state water quality standards.*
- *Protect those high-quality unimpaired waters at greatest risk of becoming impaired.*
- *Restore and protect water resources for public use and public health, including drinking water.*

Figure 37 below is an example summary of waters at or near thresholds: it depicts fish and macroinvertebrate IBIs that are within five points of their respective impairment thresholds. These data are useful in considering the NPFP directive to *Protect those high-quality unimpaired waters at greatest risk of becoming impaired*. In this context, Dodge Center Creek is highlighted given the multiple biological monitoring locations that indicate use support, but IBI values that are very near the threshold for impairment. Biological monitoring results can be similarly plotted to examne stations that are impaired but very near the threshold. The ZRW Monitoring and Assessment Report provides information regarding assessment units that are above or below IBI thresholds but within the respective CIs; these data can be summarized or plotted by users going forward to provide examination of streams that are currently close to aquatic life use support goals. Indirect measures may also be considered, such as percent exceedance of a TSS goal (e.g. 65 mg/l water quality standard) or TSS load reductions described in the TMDLs document.

In Figure 37, note that the large circles (both pink and red) indicate fish IBI values five points or less above the threshold, the small circles (both pink and red) denote macroinvertebrate IBI values five points or less above the threshold. As discussed in Section 2.5 and in the Monitoring and Assessment Report, IBIs describe fish or bug quality, and higher scores are better. Different thresholds (i.e. goals for IBIs) are set for different stream types and sizes.

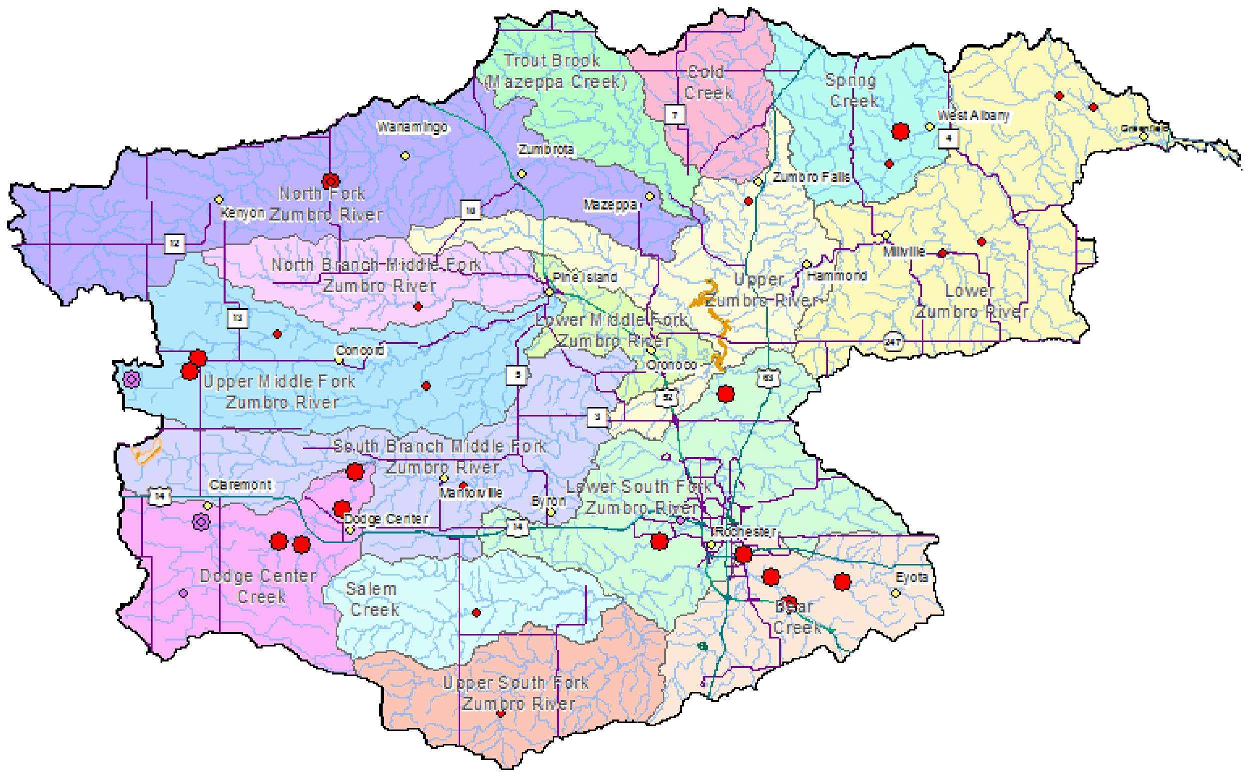


Figure 37. IBI values near threshold.

Lake Zumbro, Rice Lake and the South Fork Zumbro River (AUID -507) are all close to eutrophication thresholds described by TP and associated response variables. Site specific standards are being developed for Lake Zumbro and the South Fork Zumbro River (AUID -507). Rice Lake is "near" a water quality goal in the sense that management practices have in recent years resulted in goal attainment (followed by a return to an impaired state).

Targeting Areas for Pollutant Load Reduction Using Hydrologic Simulation Program –FORTRAN

A hydrologic water quality simulation model was developed to support decision-making for sediment and nutrient reduction strategies in the ZRW. The MPCA chose the HSPF Model for this purpose and enlisted LimnoTech Inc. consultants for model calibration and application. Full documentation of the HSPF Model calibration can be found at https://www.pca.state.mn.us/water/watersheds/zumbro-river and a summary of the effort in Appendix D.

In the ZRWHSPF model, the watershed was divided into subwatersheds that have a single, representative reach. A total of 109 such subwatersheds made the divisions, ranging in size from 17 acres to 37,565 acres with an average subwatershed area equal to 678 acres. LimnoTech utilized water quality data collected between 1996 through 2009 to calibrate and successfully validate the model for hydrology and water quality (LimnoTech 2015). Base condition or baseline simulations, constructed on the collected water quality and quantity data, were developed for the major nutrients, phosphorus (P) and nitrogen (N), and sediment. Examples for total nitrogen (TN), total phosphorus (TP), and sediment (TSS) base conditions maps are shown in Figure 38, Figure 39, and Figure 40 below.

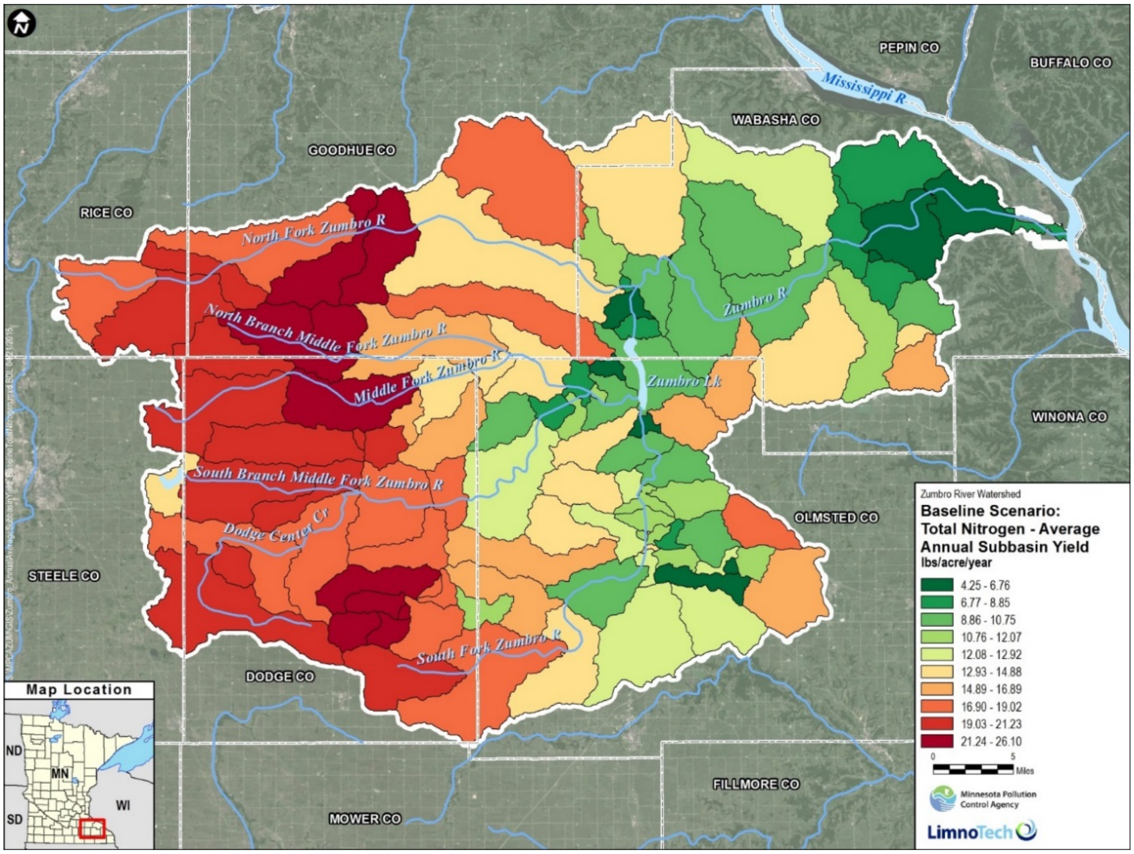


Figure 38. HSPFZRW model baseline simulation for TN.

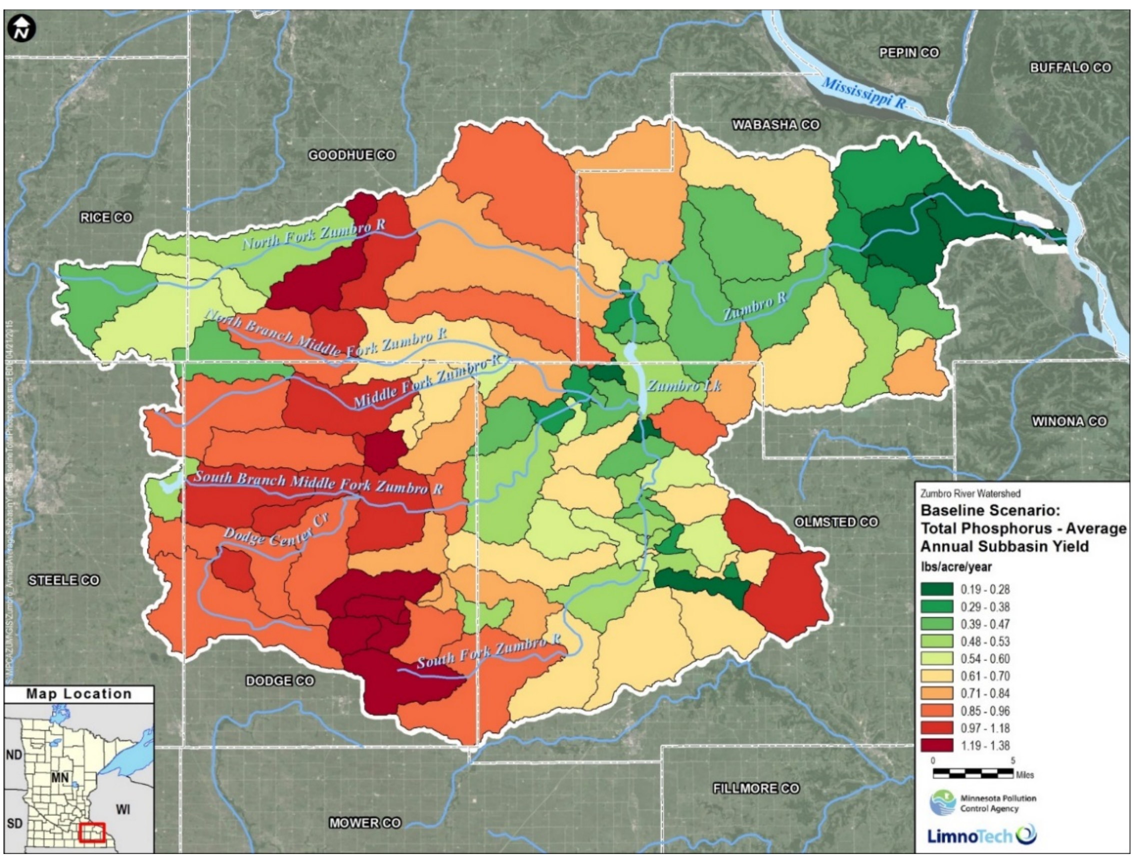


Figure 39. HSPFZRW model baseline simulation for TP.

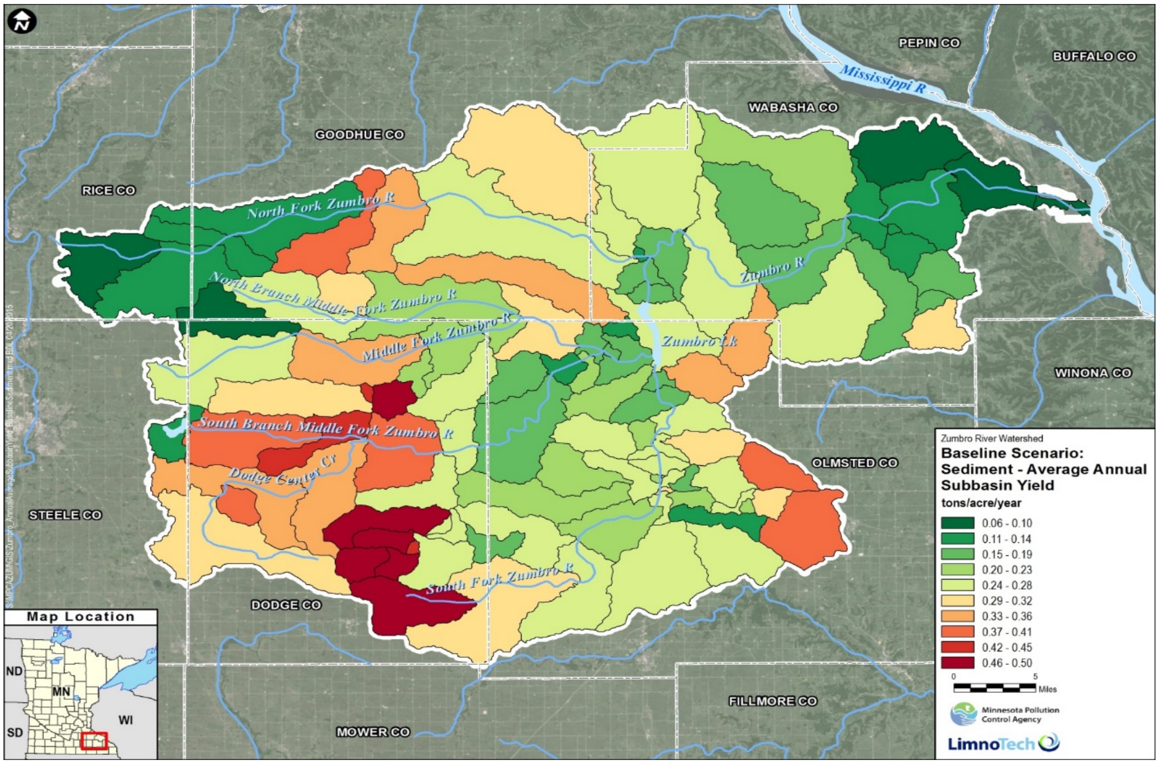


Figure 40. HSPFZRW model baseline simulation for TSS.

In addition to modeling baseline conditions, the ZRWHSPF model was applied to evaluate various management scenarios. This helped provide information on how effective specific pollutant reduction practices may be for decreasing sediment and nutrient loading and improving water quality. Load reductions at the outlet of the ZRW. The pollutant load reductions are from base line conditions.

Specifically, 10 different management scenarios were developed in consultation with watersheds partners. The scenarios developed consisted of point and nonpoint practices. Input from local units of government, based on their experience with implementing conservation practices in the ZRW, was critical to determine which practices to model. Table 15 describes five of these management scenarios and tabulates the estimated sediment and nutrient pollutant load reductions at the outlet of the ZRW. The pollutant load reductions are from base line conditions.

Table 15. Nonpoint and Nonpoint + Point management scenarios and percent reductions for TN, TP, and TSS.

Management Scenario	Description	% Reduction from Baseline for Total Nitrogen (TN)	% Reduction from Baseline for Total Phosphorus (TP)	% Reduction from Baseline for Sediment (TSS)
D Nonpoint	**Conservation tillage** management practices applied to 30% of the cropland acres with the highest sediment yields from model baseline landscape predictions.	-4%	-13%	-14%
H Nonpoint	**Cover crop** of cereal rye applied in the Fall to 30% of cropland acres where: 1) High sediment and phosphorus yielding cropland based on model baseline predictions 2) Sensitive groundwater areas 3) Location of tiled lands	-8%	-11%	-12%
I Nonpoint	**Sedimentation Ponds:** Location based baseline landscape predictions in conjunction with critical source areas identified in previous study; represented as "dry ponds" designed to capture 10 year 24 hour rain event.	-0.40%	-6%	-8%
H Point & Nonpoint	**Combined Management:** - Point source effluent set at 70% of average wet weather design flow (scenario C) - Cover crops applied to 30% of cropland acres (scenario H) - Retention basins capturing runoff from 30% of cropland acres (scenario I)	-8%	-14%	-17%
A Point	**Point Sources at Permitted Limits,** This scenario provides an upper bound on the impacts of point sources on in stream water quality.	6%	5%	1%

To illustrate which geographical areas of the ZRW would have the greatest load reduction potential for a particular management scenario, maps were developed depicting the range of reductions by subwatershed for a specific scenario. For example, in the map in Figure 41, the cover crop management scenario H, show an 8% overall TN reduction would occur in the ZRW. Most of those load reductions would occur in the heavily shaded subwatersheds in the upper Middle Fork, South Branch of the Middle

Fork, and South Fork Subwatersheds. These subwatersheds would represent critical areas where the greatest reductions of TN would take place for this management scenario.

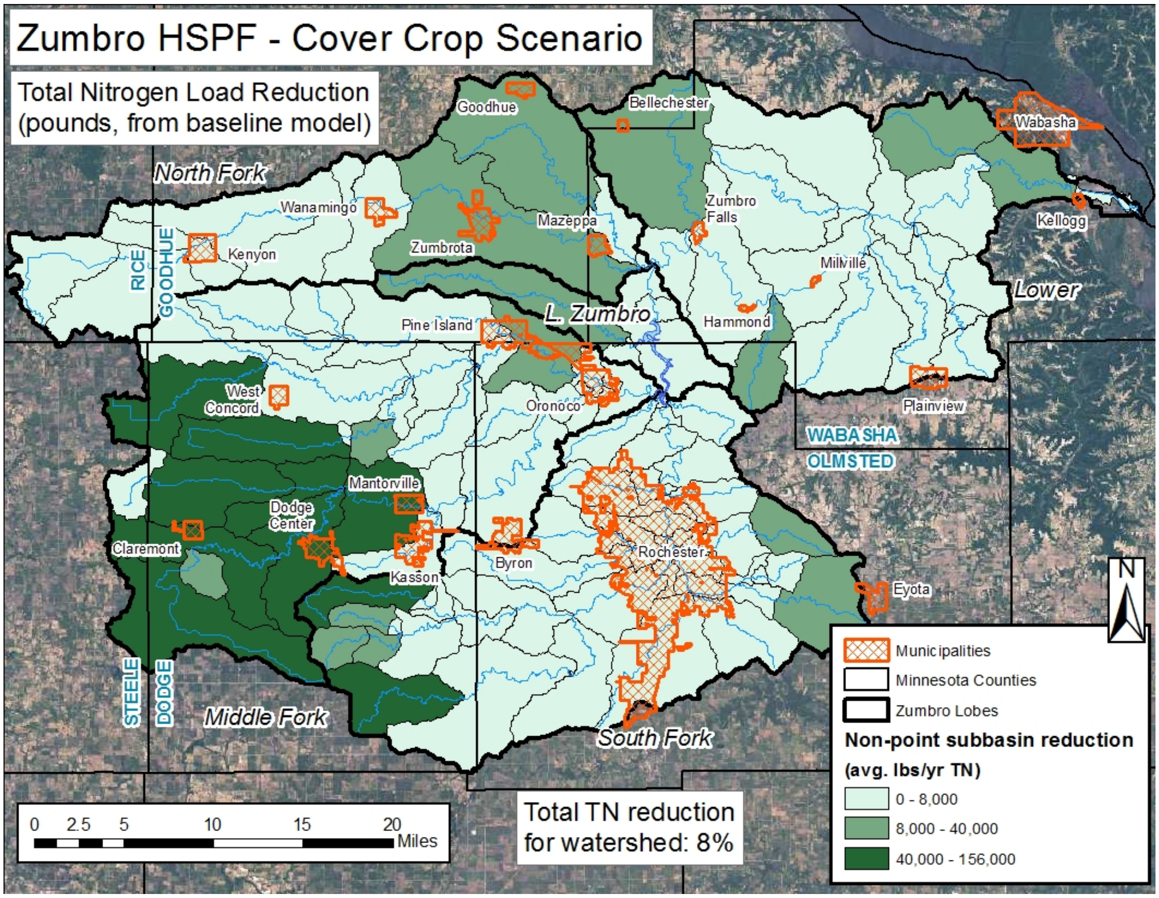


Figure 41. ZRW TN load reduction for Cover Crop Management Scenario.

Similarly, Figure 42 represents a TSS load reduction map for HSPF basins for the conservation tillage management scenario (Scenario D from Table 15). The map shows basins that can achieve the greatest TSS load reductions with the implementation of this scenario. The overall sediment reduction at the outlet would be 14% from baseline conditions. The map indicates that subwatersheds in the upper South Fork including Bear Creek, upper South Branch of the Middle Fork, upper Middle Fork, and North Fork subwatersheds would achieve the greatest reduction of TSS if conservation tillage practices were applied to the crop acres with the highest sediment yield in the ZRW. The darkly highlighted basins would be considered critical areas for TSS reduction under this management scenario.

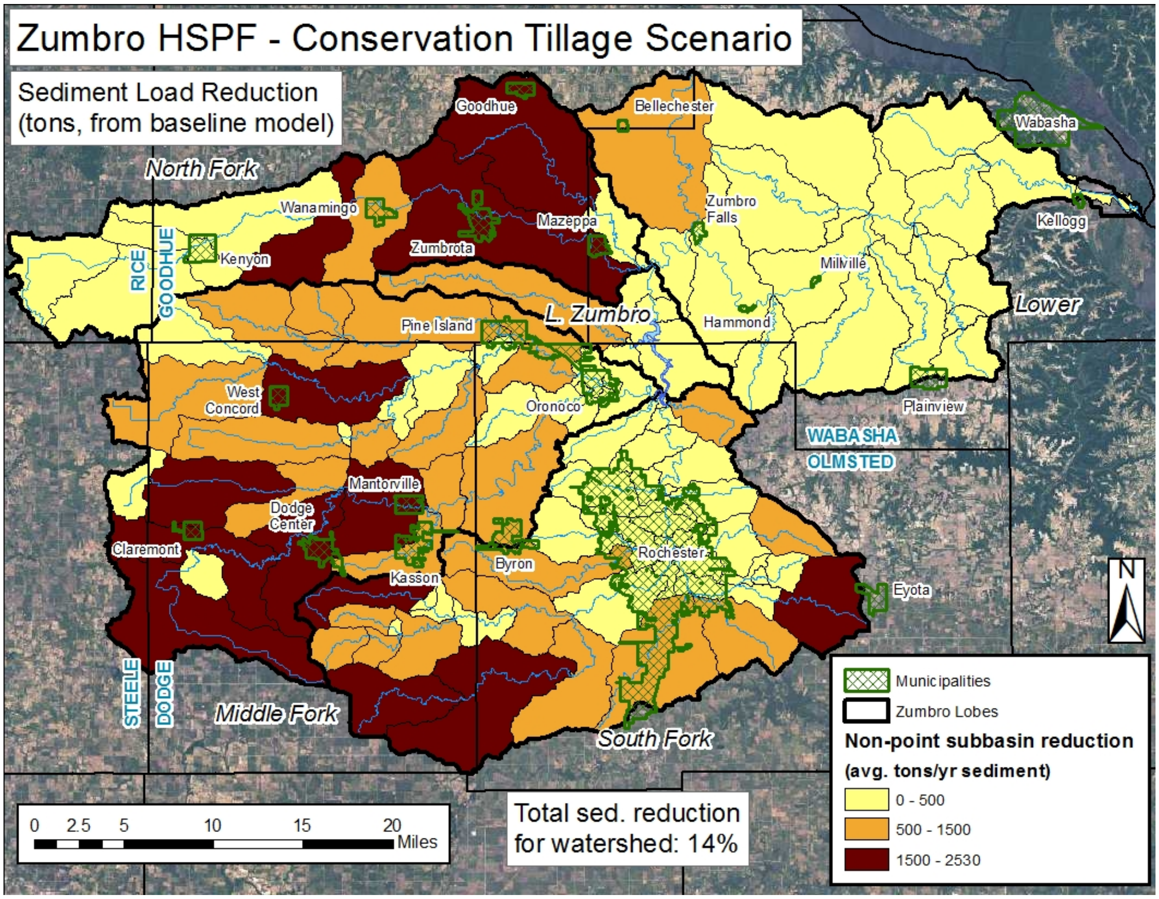


Figure 42. ZRW TSS load reduction for Conservation Tillage Management Scenario.

For TP reduction, scenario J yielded the highest overall reduction of 17% at the watershed outlet. Scenario J is a combination of point and nonpoint practices (Figure 43). It is scenario H (cover crops applied to 30% of cropland acres), plus scenario I (retention basins capturing runoff from 30% of cropland acres), and scenario C (point source effluent is limited to 70% of average wet weather design flow and reduced phosphorus discharge limits for some facilities). From this scenario, it can be seen that a number of subwatersheds across the ZRW would have the greatest TP reductions.

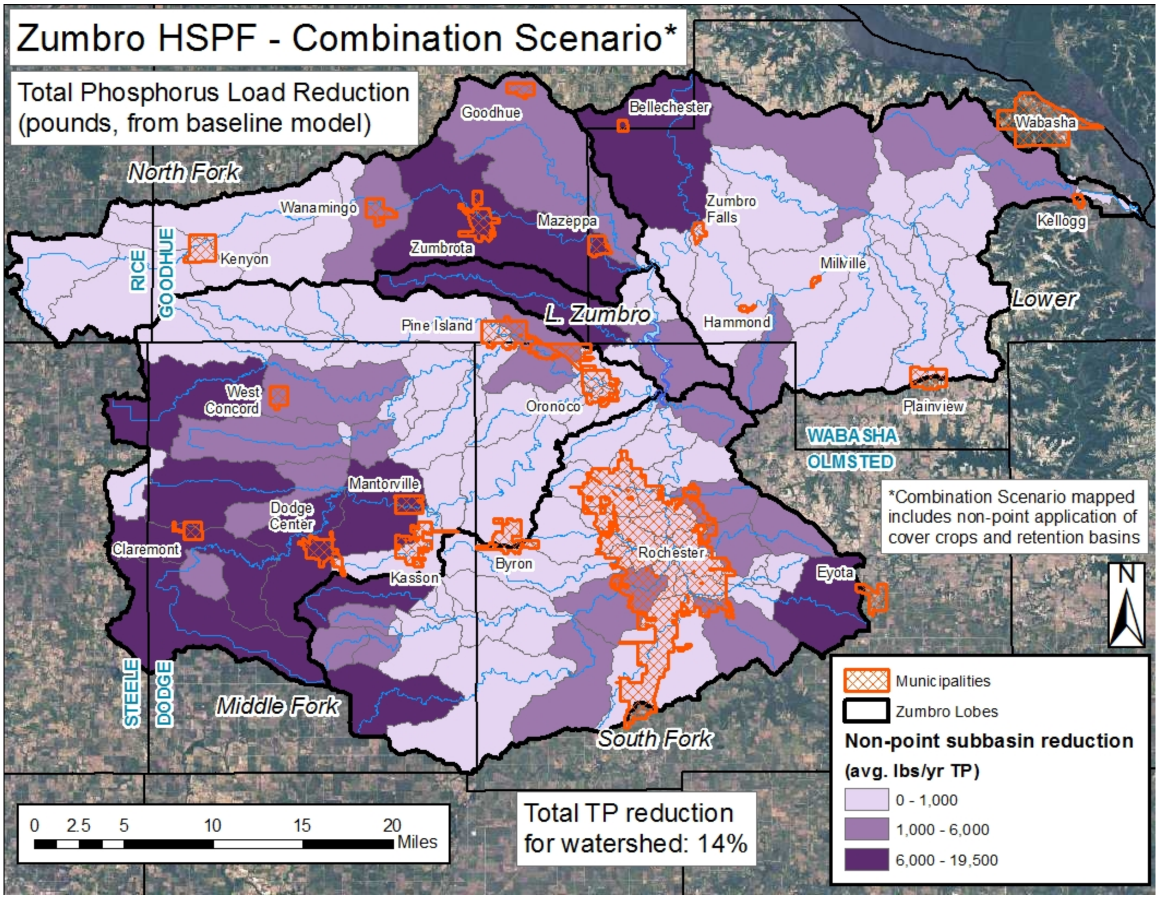


Figure 43. ZRW TP load reduction for Combination Point and Nonpoint Source Management Scenario.

The purpose in describing these examples is to show how the HSPF model is capable of taking common conservation management practices and applying them to baseline conditions in order to see where in the ZRW the most nutrient and sediment loading reduction would take place. These critical areas, as stated in the introduction to this section, could then be the focus of more detailed (e.g. field scale) GIS based examinations, to determine targeted implementation of these practices. Local government units can further examine implementation of various scenarios using the HSPF Scenario Application Manager (SAM).

Targeting and Prioritization of Geographic Areas with Zonation

Zonation, a values-based model, was used to prioritize areas for restoration and protection. This model was based on fundamental conservation principles, including biodiversity and connectivity. The model uses the DNR's five-component healthy watershed conceptual framework to facilitate an organized process to assess and review watershed problems and solutions. The five components for a healthy watershed are: biology, hydrology, water quality, geomorphology, and connectivity. This approach recognizes that attempts to solve our clean water needs are not separate from our other conservation needs; each conservation activity should provide multiple benefits. The Zonation values-based model helps achieve this multiple benefits goal by identifying areas that optimize benefits by incorporating data valued by the community. For the ZRW, goals were to obtain both clean water benefits and other conservation benefits. The model used a compilation of individual and aggregated criteria of valuable landscape features, with the objective of providing data and maps that prioritize places on the landscape for restoration or protection.

The conservation priority map from the Zonation analysis identified four general areas for consideration as priority areas (see Figure 44). These areas are shaded dark green in the map. First, high rankings were evident in the Lower Zumbro Watershed associated with trout stream riparian areas and in areas with high-channelized flow erosive potential. High priority areas were also identified around Rice Lake on the western edge of the watershed. In addition, the lands surrounding and downstream of Lake Zumbro were generally high priority. Finally, lands overlaying the groundwater resources critical to the city of Rochester located in the Bear and Silver Creek Subwatersheds were identified as high-priorities. Participants in the various WRAPS meetings supported these four priority areas for inclusion into the plan with the suggestion to focus restoration and protection activities over the next 10 years within these areas.

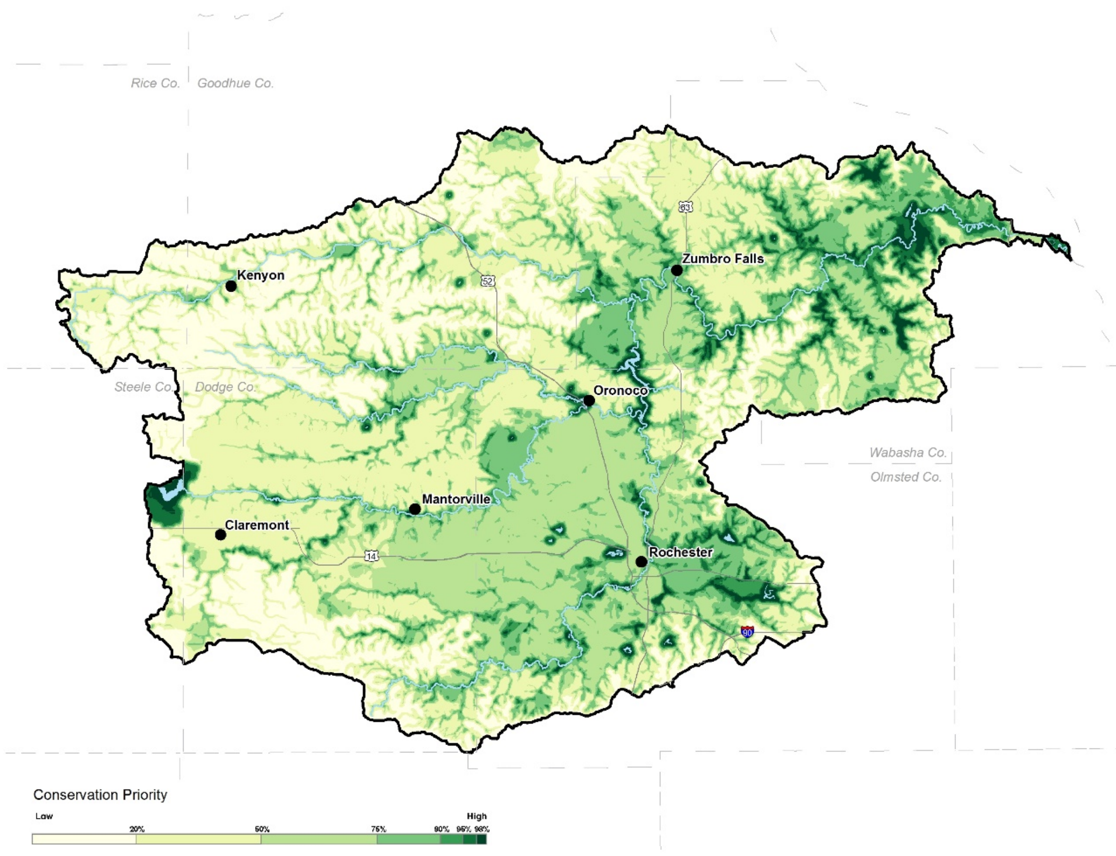


Figure 44. Conservation Priority Areas in the ZRW from Zonation.

For the final step of the Zonation modeling process, participants were asked to fine-tune the priority output maps. County staff from the four main counties in the ZRW made the following adjustments (Figure 45):

- Wabasha County added West Indian Creek Watershed as an additional polygon. This watershed is a designated trout stream with significant public land within its boundaries. County staff felt that an important nutrient/sediment reduction strategy in this subwatershed should be to implement cover crops in the headwaters on acres growing short season crops such as sweet corn and peas.
- Dodge County added the stream corridor of the South Branch of the Middle Fork Zumbro River

from two miles west of Mantorville to its confluence with the head of Lake Zumbro. This stream includes numerous areas of high conservation priority including the Lake Shady restoration project that will be a waterways park and recreational area.

- Goodhue County added the North Fork of the Zumbro River corridor from the headwaters near Kenyon to the confluence with the main stem of the Zumbro east of Mazeppa. This fork of the Zumbro River has historically been impacted by excessive sedimentation but is in the process of recovering and has the potential for many additional recreational opportunities.
- In addition to the Silver Creek Drinking Water Supply Management Area (DWSMA) and Bear Creek, Olmsted County added Chester Woods Park to the existing polygon of Bear Creek Subwatershed east of Rochester. The Park is an important recreational area for the County.

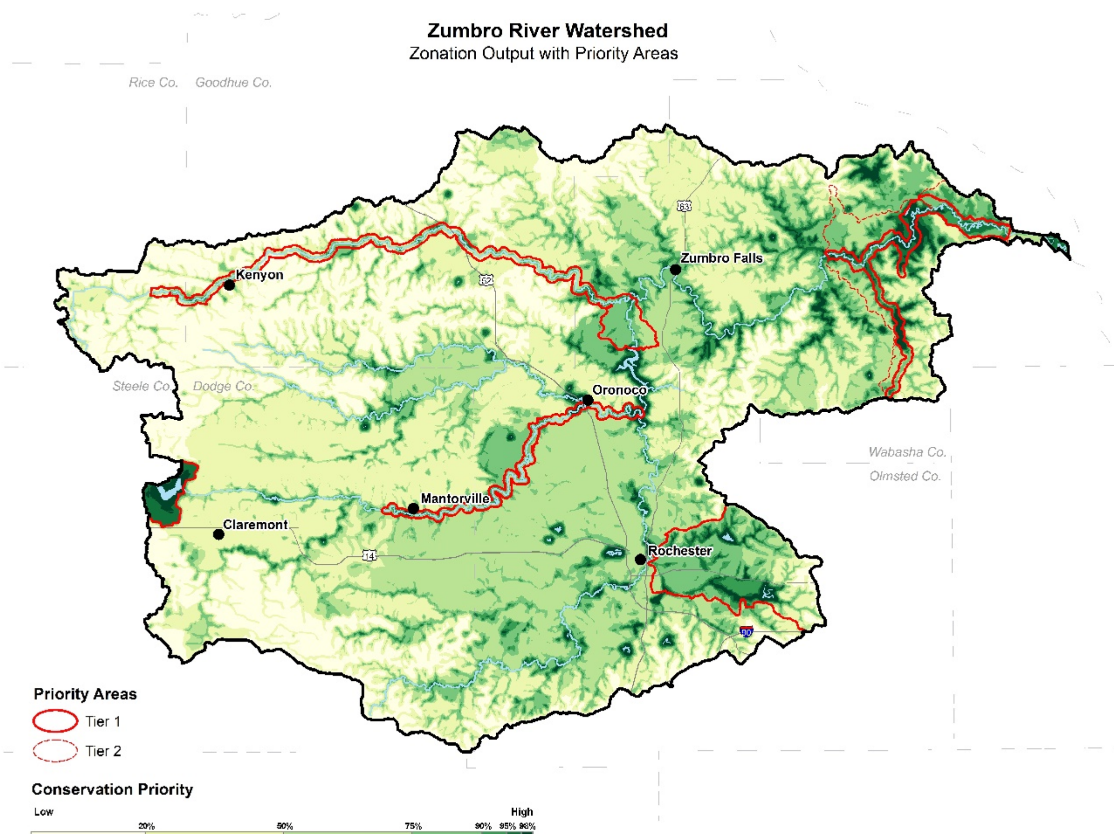


Figure 45. Priority Areas Based Refined by Local Input. Base Map is Conservation Priority Areas from Zonation Modeling.

Dodge County also added highly sensitive groundwater areas to the map in Figure 46. This area was designated a high priority because it is highly correlated with high nitrate concentrations of private drinking water wells.

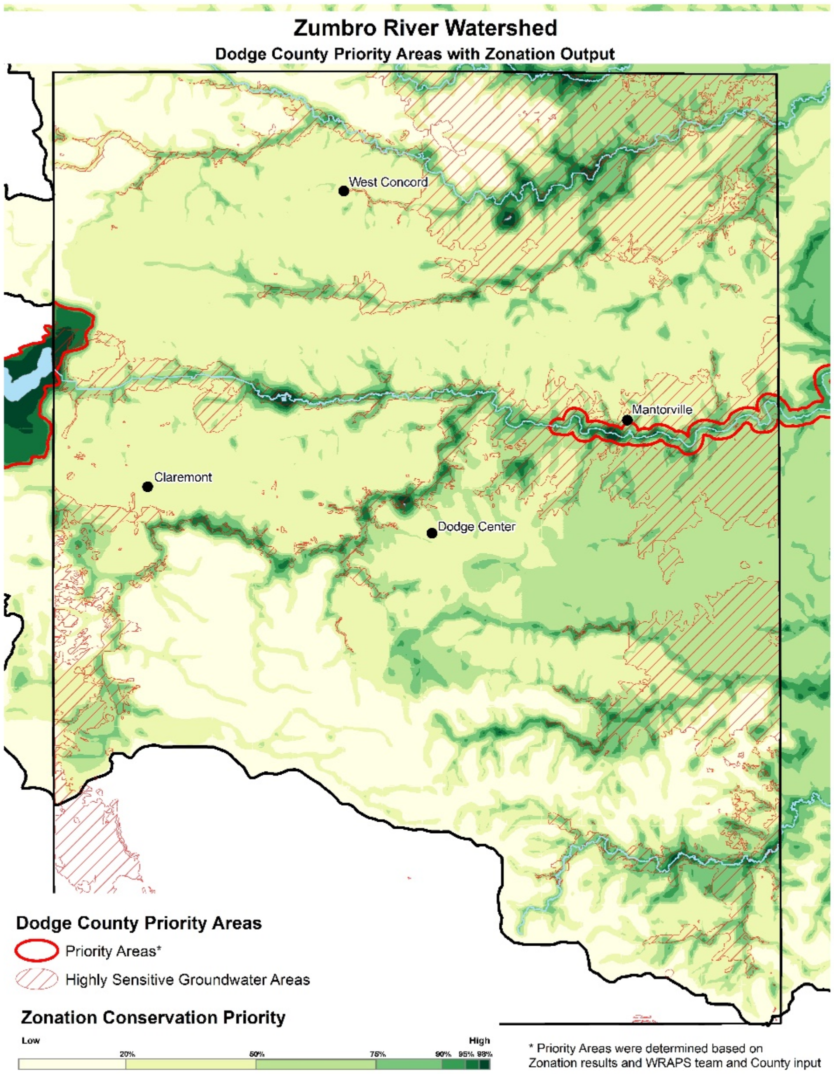


Figure 46. Dodge County Priority Areas with Zonation output.

Department of Natural Resources Priority Areas for Protection and Restoration in the ZRW

This material was prepared by efforts led by the DNR Division of Ecological and Water Resources (EWR). Region 3 staff members from five DNR divisions (Fisheries, Wildlife, Forestry, Parks and Trails, and EWR) were engaged in several meetings to develop watershed priorities for the ZRW. The meetings focused on gathering input from staff based upon professional judgment from their combined experience and local knowledge from working in the watershed. The information gathered is presented below in a series of lists and maps organized on the 10-digit HUC number. It also reflects different priorities based on each DNR Division's respective mission. Priorities identified during this process include protection, restoration, and technical guidance types of strategies and are presented in no particular order.

Minnesota's Wildlife Action Plan (2015 to 2025) was recently updated by the DNR and focuses on conservation and protection for rare, declining, or vulnerable to decline nongame wildlife species, including certain birds, mammals, reptiles, amphibians, fish, 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 WAN component of the plan focuses on 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, will result in projects and practices with multiple environmental benefits (i.e. protecting and restoring perennial vegetation for habitat enhancement and for clean water). Each HUC-10 map below indicates the WAN boundaries and scores.

Additional information on the Minnesota Wildlife Action Plan can be found on the following webpage: http://www.dnr.state.mn.us/mnwap/index.html

Supporting information regarding DNR priorities for protection and restoration in the ZRW can be found in Appendix H and on the ZRW website: https://www.pca.state.mn.us/water/watersheds/zumbro-river.

Color-coding for strategies listed below and on maps:

Strategy Categories
Protection
Restoration
Technical Guidance

Strategies for North Fork Zumbro River Watershed HUC 0704000404

1. **North Fork Zumbro River-Mazeppa Creek**- Protect two surface water sinks south of the city of Goodhue through local zoning and surface water runoff management
2. **North Fork Zumbro River-Mazeppa Creek**- Implement a channel and habitat restoration within the Tiedemann Wildlife Management Area (WMA) to reduce sediment loading from bank erosion and improve aquatic and riparian habitat.
3. **North Fork Zumbro River**- Rehabilitate the channel upstream from the former Mazeppa dam and one mile downstream to eliminate bank erosion and improve fish habitat.
4. **North Fork Zumbro River**- Implement a channel and habitat restoration within the Woodbury WMA to reduce sediment loading from bank erosion and improve aquatic and riparian habitat

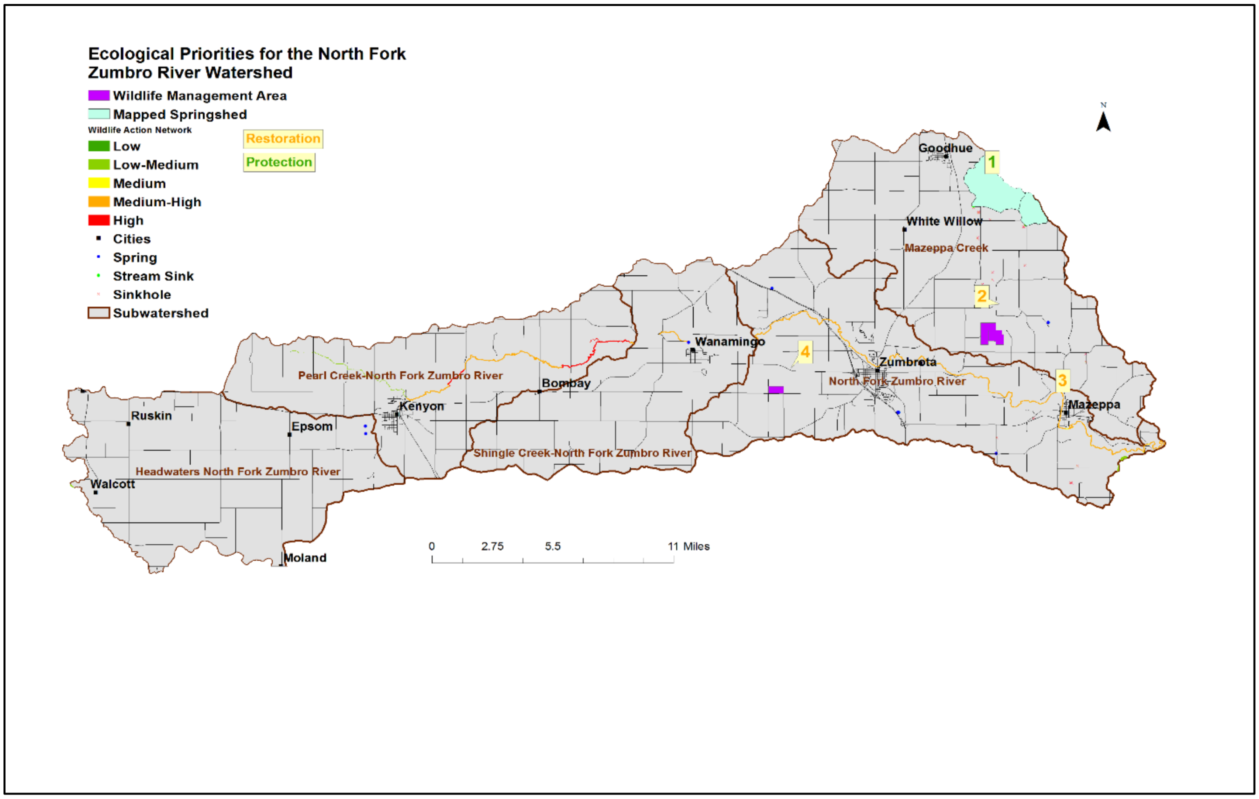


Figure 47. Ecological Priorities for the North Fork ZRW.

Strategies for Middle Fork Zumbro River Watershed HUC 0704000403

5. **Middle Fork Zumbro River-City of Concord Subwatershed**- Conduct springshed mapping in the eastern third of the subwatershed due to high prevalence of karst features.
6. **Middle Fork Zumbro River-City of Concord Subwatershed**- Protect habitat diversity and restore riparian lands in the eastern half of the subwatershed where biodiversity is outstanding.
7. **Middle Fork Zumbro River-Harcom Creek Subwatershed**- Conduct springshed mapping in the northwest section of the subwatershed.
8. **Middle Fork Zumbro River-Harcom Creek Subwatershed**- Protect habitat diversity and restore riparian lands in the northern half of the subwatershed where biodiversity is high.
9. **North Branch Middle Fork Zumbro River**- Implement a channel and habitat restoration within the Roscoe WMA to reduce sediment loading from bank erosion and improve aquatic and riparian habitat.
10. **North Branch Middle Fork Zumbro River**- Conduct springshed mapping from State Highway 57 downstream to the Roscoe WMA due to high prevalence of karst features.
11. **North Branch Middle Fork Zumbro River**- Protect habitat diversity and restore riparian lands in the southeast section of the subwatershed where biodiversity is high.

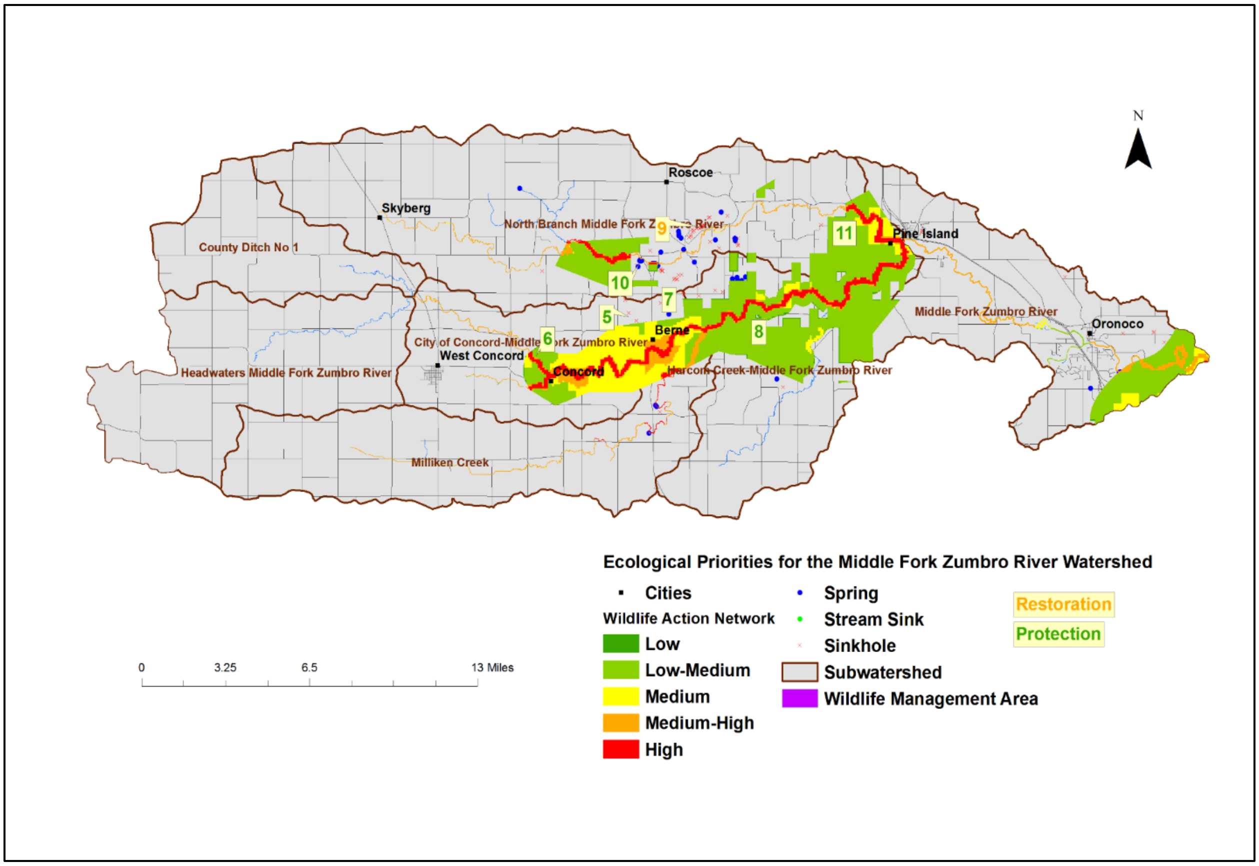


Figure 48. Ecological Priorities for the Middle Fork ZRW.

Strategies for South Branch Middle Fork Zumbro River Watershed HUC 0704000402

12. South Branch Middle Fork Zumbro River-Rice Lake- Improve the carp barriers at the lake outlets to prevent reinvasion of common carp and maintain water clarity.
13. South Branch Middle Fork Zumbro River-Masten Creek Subwatershed- Implement a channel and habitat restoration in the Pheasants Forever WMA to reduce sediment loading from bank erosion and improve aquatic and riparian habitat.
14. South Branch Middle Fork Zumbro River- Implement a channel and habitat restoration in the Naylor WMA to reduce bank erosion and improve aquatic and riparian habitat.
15. South Branch Middle Fork Zumbro River- Implement a channel and habitat restoration in the McMartin WMA to reduce sedimentation from bank erosion and improve aquatic and riparian habitat.

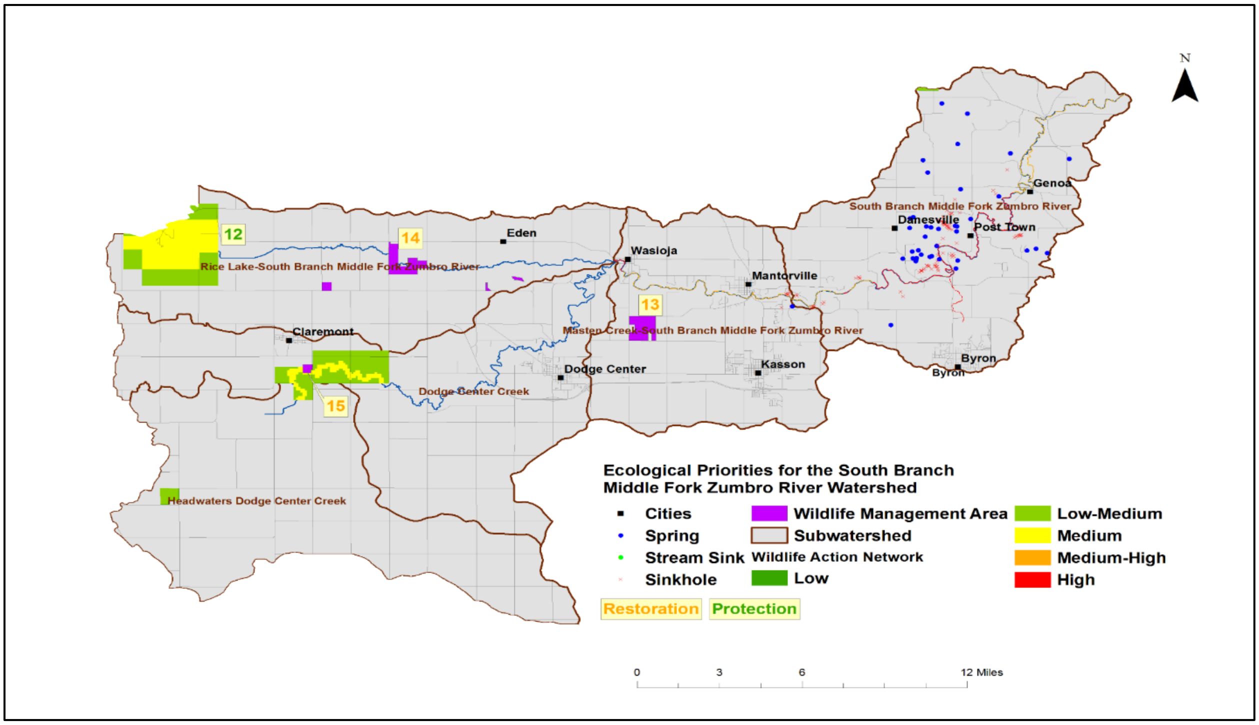


Figure 49. Ecological Priorities for the South Branch Middle Fork ZRW.

Strategies for South Fork Zumbro River Watershed HUC 0704000401

16. **South Fork Zumbro River-City of Rochester Subwatershed**- Improve aquatic habitat within the city of Rochester flood control project area.
17. **South Fork Zumbro River-City of Rochester Subwatershed**- Conduct springshed mapping upstream from Maywood Lake due to the high prevalence of karst features.
18. **South Fork Zumbro River-Salem Creek Subwatershed**- Implement a stream channel and habitat restoration within the Bud Jensen WMA to reduce sediment loading from bank erosion and improve aquatic and riparian habitat.
19. **South Fork Zumbro River**- Implement a channel and habitat restoration in the Keller WMA to reduce sediment loading from bank erosion and improve aquatic and riparian habitat.
20. **South Fork Zumbro River**- Implement a channel and habitat restoration in the Suess, High Forest, and Marion Marshal WMAs to reduce sediment loading from bank erosion and improve aquatic and riparian habitat.
21. **South Fork Zumbro River-Town of Rock Dell Subwatershed**- Protect surface water sinks through local zoning and acquisition.
22. **South Fork Zumbro River-Town of Rock Dell Subwatershed**- Implement a channel and habitat restoration in the Rock Dell WMA to reduce sediment loading from bank erosion and improve aquatic and riparian habitat.

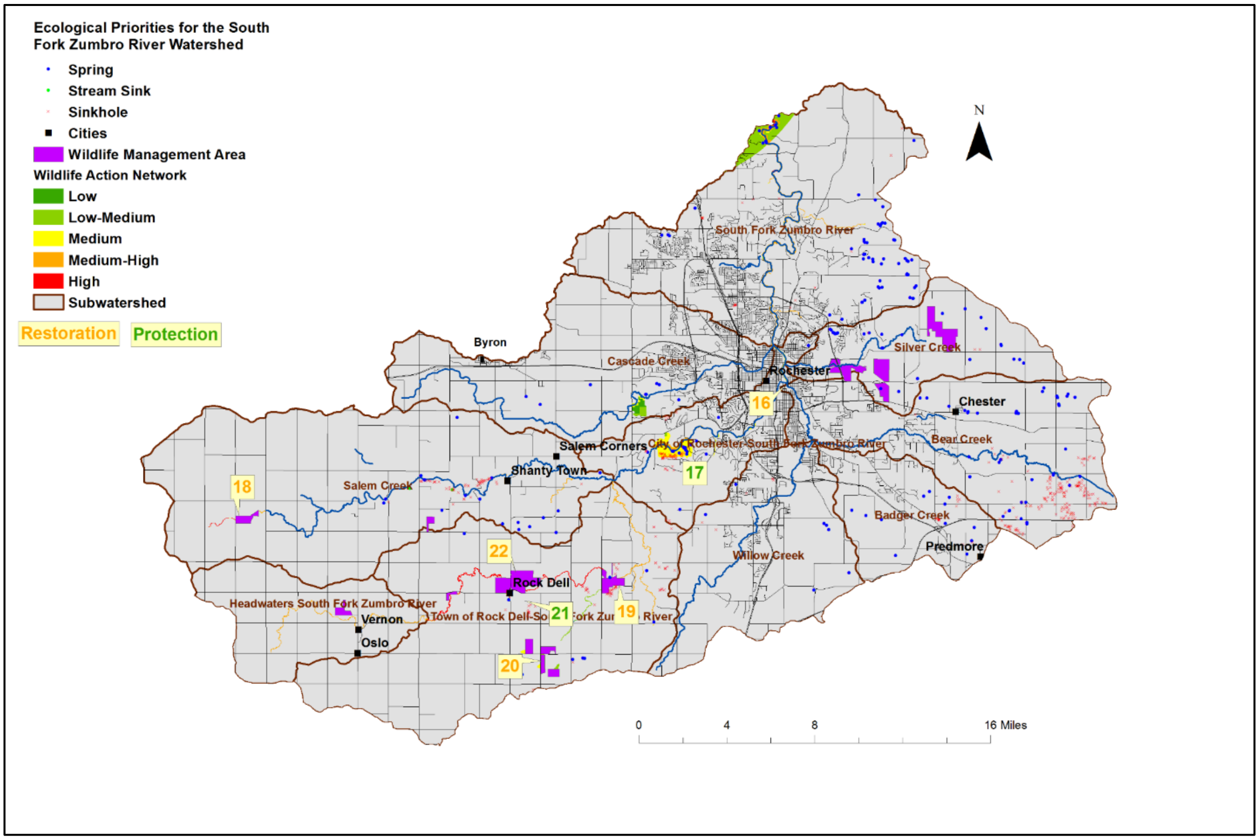


Figure 50. Ecological Priorities for South Fork ZRW.

Strategies for Lower Zumbro River Watershed HUC 0704000405

23. **Lower Zumbro River-City of Zumbro Falls Subwatershed**- Improve forest quality and maintain riparian connectivity through active forest management and acquisition.
24. **Lower Zumbro River-Cold Spring Brook Subwatershed**- Implement a channel restoration project following results of the Watershed Assessment of River Stability and Sediment Supply (WARSSS) assessment to reduce sediment loading and improve aquatic habitat for trout and invertebrates.
25. **Lower Zumbro River-Dry Run Creek Subwatershed**- Protect habitat diversity and restore riparian and shoreland habitat through acquisition and private lands management.
26. **Lower Zumbro River-Long Creek Subwatershed**- Improve forest quality and maintain riparian connectivity through active forest management and acquisition.
27. **Lower Zumbro River-Spring Creek Subwatershed**- Conduct a WARSSS assessment to identify sediment sources and causes for altered hydrology.
28. **Lower Zumbro River-Spring Creek Subwatershed**- Improve forest quality and maintain riparian connectivity through active forest management and acquisition.
29. **Lower Zumbro River-West Albany Creek Subwatershed**- Protect the surface water sink five miles east of Zumbro Falls through local zoning and surface runoff management.

30. **Lower Zumbro River-West Indian Creek Subwatershed**- Implement a channel and habitat restoration in a two mile-long reach under angling easement to improve aquatic and riparian habitat.

31. **Lower Zumbro River-Zumbro Lake Subwatershed**- Protect the surface water sink in the southwestern section of the subwatershed through local zoning and surface runoff management.

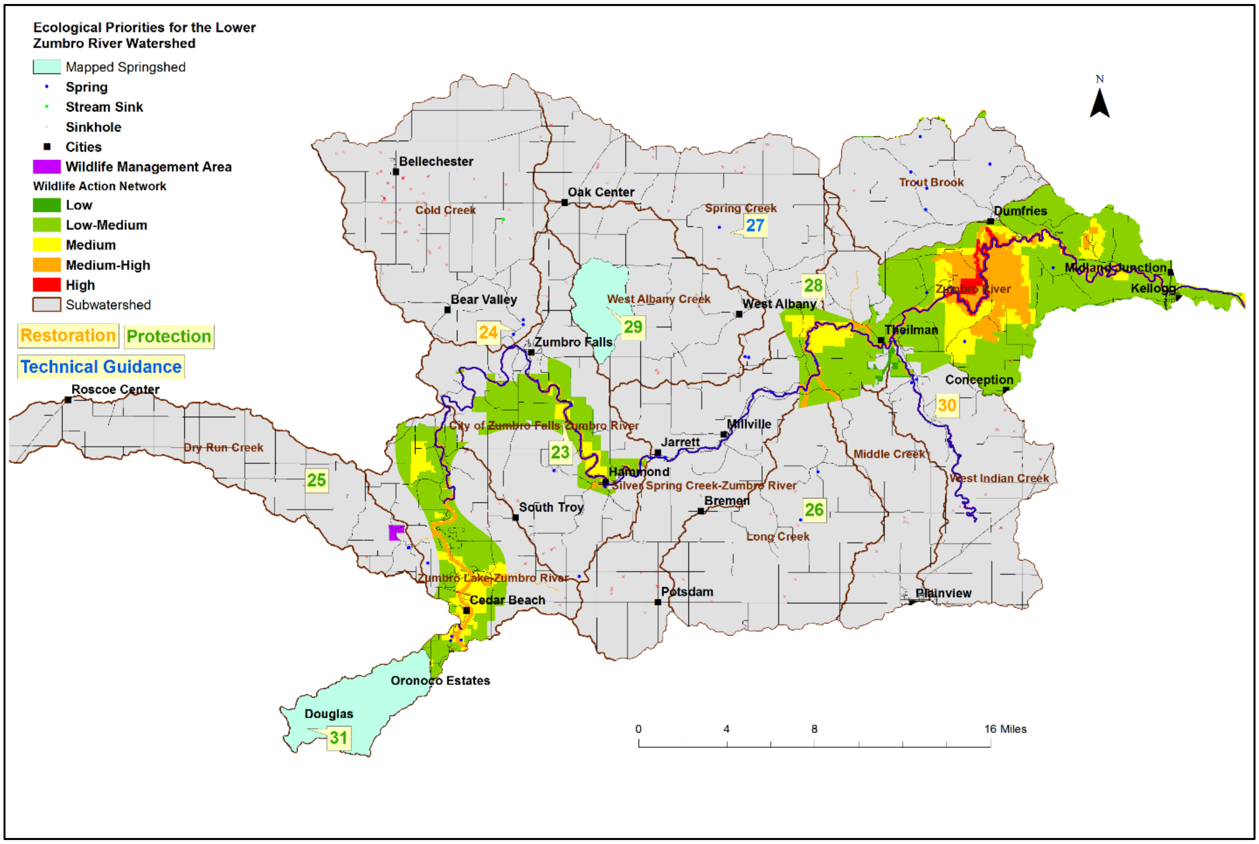


Figure 51. Ecological Priorities for the Lower ZRW.

Structural BMP Inventory

The SWCDs in the ZRW have mapped structural BMPs and delineated the drainage areas treated by each. This planning tool serves to confirm the work completed to date and provide guidance regarding focus areas for new BMPs as well as potential BMP maintenance/cleanout needs (Figure 52). Figure 53 shows percentage of each ZRWHSPF catchment that is treated by structures.

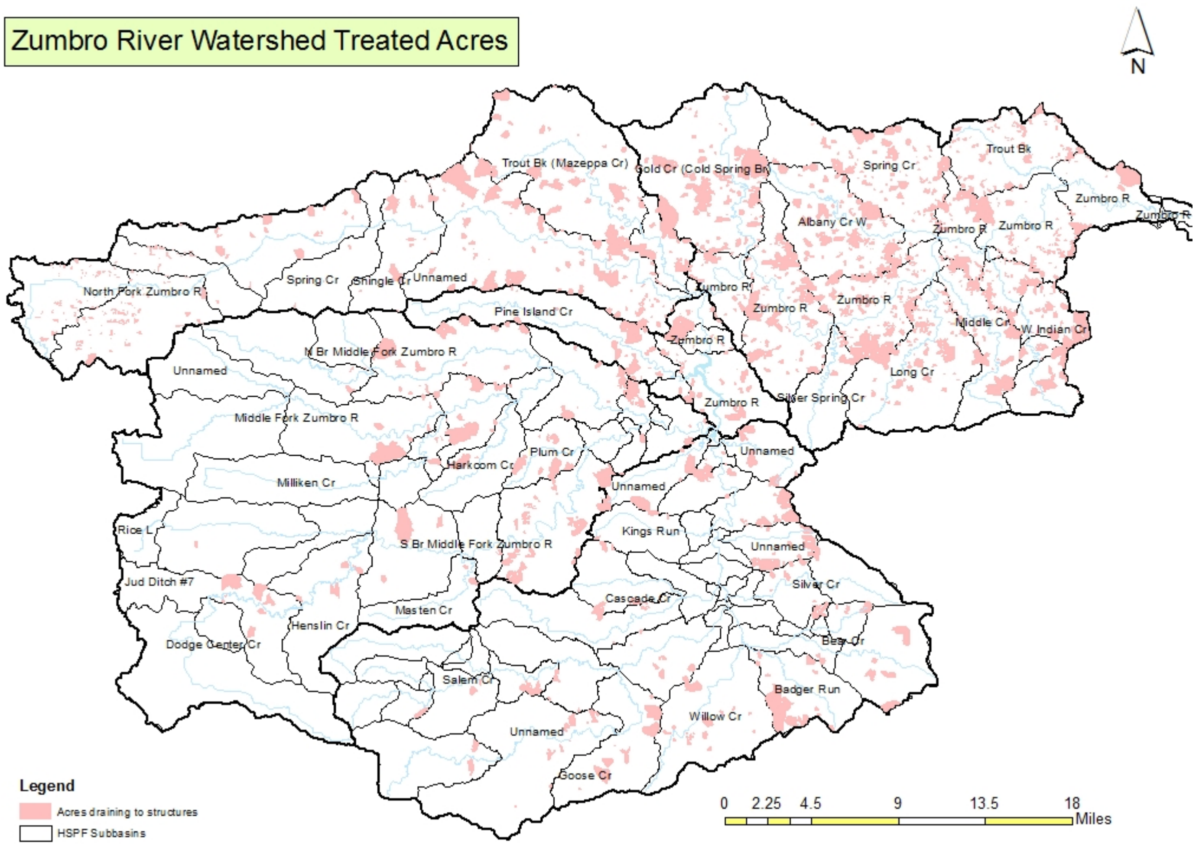


Figure 52. ZRW structural BMP inventory.

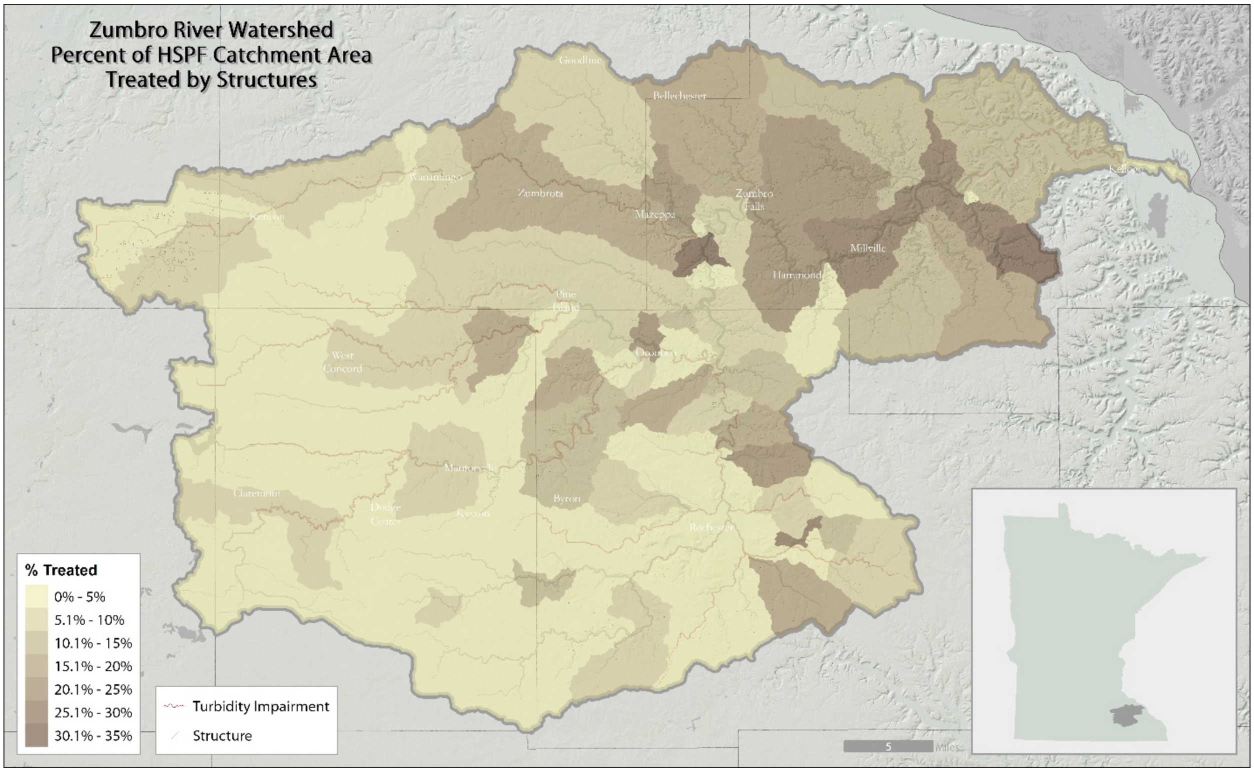
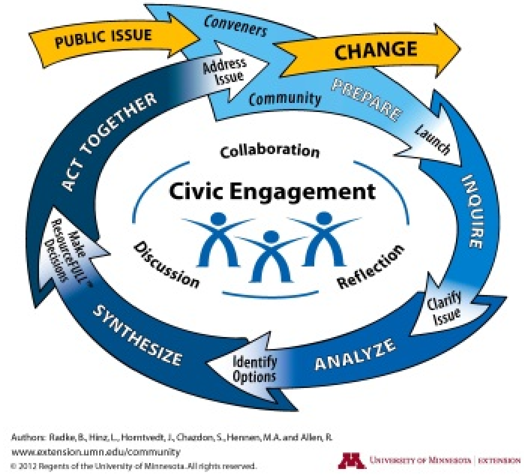


Figure 53. Map showing the percentage of each ZRWHSPF catchment that is treated by structures (also see Figure 52).

3.2 Civic Engagement



A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement. This is distinguished from the broader term 'public participation' in that civic engagement encompasses a higher, more interactive level of involvement. Specifically, the University of Minnesota Extension's definition of civic engagement is "Making 'resourceFULL' decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration." A resourceFULL decision is one based on diverse sources of information and supported with buy-in, resources (including human), and competence. Further information on civic engagement is available at: http://www1.extension.umn.edu/community/civic-engagement/.

Introduction

The ZRW includes a 501(c) 3 nonprofit organization, the ZWP, which is focused on improving water quality on a watershed-scale. It is a member-driven organization, which works with citizens and LGUs to restore the natural and social benefits of a healthy watershed through education and collaborative projects. ZWP was founded in 2004, and is composed of citizens and elected officials. The ZWP board structure includes representatives from all six counties within the ZRW (Dodge, Goodhue, Olmsted, Rice, Steele, and Wabasha). Those representatives include 6 County Commissioners, 6 SWCD Supervisors, and 13 citizen members elected by the membership.

Rooted in strong partnerships, ZWP has promoted and facilitated collaboration among entities throughout the watershed for over a decade. This momentum generated the *Zumbro River Watershed Management Plan (20072012)*, the *Zumbro Watershed Management Plan: Sediment Reduction Component (2012)*, and the *Interim Zumbro Watershed Management Plan (2013)*. A notable working knowledge of the watershed and its residents, coupled with existing ZWP initiatives to promote the watershed approach, generated an effective environment for WRAPS stakeholder engagement.

The ZWP was elected to serve as the convening and facilitating entity throughout the WRAPS process. This afforded LGUs the ability to participate and contribute substance, without the need to allot FTE hours for coordination and document assembly.

WRAPS Planning & Process Design

Encompassing nearly 1 million acres, the ZRW is a landscape with much diversity. Such variances include geography, hydrology, land use, and socioeconomic influences. To facilitate more in-depth discussions and capture these unique influences, the WRAPS meetings were held in three "lobes" across the watershed: the Lower Zumbro River lobe, Middle and North Forks Zumbro River lobe, and the South Fork Zumbro River and Lake Zumbro lobe.

The ZRW WRAPS began with a 'kick off' meeting in March 2016, followed by three lobe meetings in June, August, and November 2016. The lobe meetings functioned as an update for the new watershed science that consisted of water quality impairments and modeling, geographically targeted sources of nutrient loading, and discussions of restoration and protection priorities and strategies. Guest speakers also made presentation at the lobe meetings on the status of Lake Zumbro, Rochester's storm water and wastewater facilities, and Discovery Farms' water quality monitoring. A finale meeting was held on January of 2017, where a draft section of the ZRW WRAPS was presented to attendees, followed by discussion and feedback on the document. All meeting agendas and presentation can be found on the ZWP web site under the WRAPS tab.

In 2013, prior to the WRAPS process, the consulting firm The Research Edge LLC., was hired by the ZWP to assess the current knowledge and attitudes of ZRW residents. Participants of the survey resided within the watershed and were contacted via phone. The 'Information Sources' component of the survey revealed that watershed residents rely heavily on traditional media, with online or public forums as the strongest alternative to newspapers or magazines for local water quality and flooding issues. The stakeholder outreach conducted in the ZRW WRAPS reflects this preference.

Before commencing the ZRW WRAPS, several stakeholders within the ZRW assisted with the Cannon River Watershed WRAPS pilot. At the Cannon finale meeting, stakeholders completed a short survey on the WRAPS process. That feedback has been heavily incorporated into the ZRW WRAPS, specifically the depth of involvement with SWCDs, county staff, and agricultural industry representatives.

Implementation

The engagement of stakeholders and watershed residents during the ZRW WRAPS had two distinct components. Those parties heavily involved in the process on a professional level (SWCDs, county staff, govt. agencies, commodity group representatives, etc.) were greatly engaged via the three tools: HSPF modeling, the synthesis step of the Zonation values-based model, and the nitrogen and phosphorus best management practices spreadsheets (N and P BMP tools), as well as the lobe meetings. In contrast, watershed residents as a whole were engaged in the WRAPS progression through lobe meeting attendance, the Zonation survey and ZWP platforms (*Waterways Speaker Series*, published literature, and the ZWP website and Facebook page).

Zonation Modeling and Civic Engagement

The Zonation values-based model was used in a civic engagement process that commenced at the ZRW WRAPS Kickoff Meeting and at a Water Ways Speaker Series Meeting. As part of this process, meeting participants decided what landscape features were valued, and the rankings of those valued features within the model, by filling out a survey. The survey was completed by attendees of the Zumbro WRAPS Kick-off Meeting (N=26) in March, attendees of the April Waterways *Speaker Series* Meeting (N=27), and members of the interested public during Earth Day activities (N=35). Figure 54 below summarizes the rankings of those landscape features (See Appendix G for details on the approach and methods). The protection and restoration priority maps from the Zonation output are contained in Section 3.1 of this report.

The survey comprised of pairwise comparisons was used to solicit the preferences of individuals. Features used in the comparison were based loosely on the DNR's five-component healthy watershed approach, with the addition of alternative land uses or economic features representing a social component. The pairwise survey was structured to gather value preferences for an overall conservation strategy. Each individual taking the survey used his or her judgment about the relative importance of all elements at each level of the hierarchy. The relative importance values included "equal," "prefer," and "strongly prefer." The use of abbreviated pairwise importance values helped reduce the cognitive burdens associated with a large number of pairwise comparisons. Individual responses were aggregated with a geometric mean, and the pairwise comparison matrix was constructed to compute the feature-specific weights consistent with the analytic hierarchy process (AHP).

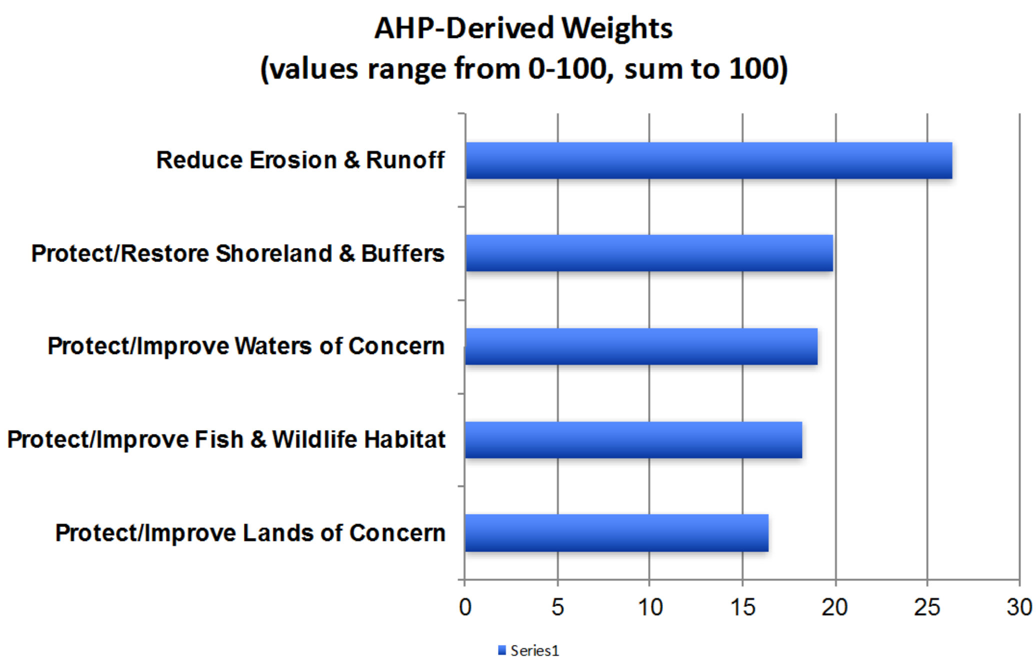


Figure 54. Broad-scale weights used in the Zonation model from a survey using the analytic hierarchy process (AHP); weights sum to 100.

Stakeholder Outreach

The watershed approach and WRAPS have been frequently discussed in the ZRW. This has been done through a variety of mediums, both before and throughout the ZRW WRAPS process.

The ZWP hosts and promotes the free monthly *Waterways Speaker Series* in Rochester, Minnesota. This platform affords the public an opportunity to engage with scientists, managers, and commodity groups. Presenters discuss the watershed approach, innovative projects, and grass roots efforts within our region that promote cleaner water and reduce flooding.

Recent *Waterways Speaker Series* topics include:

- November 2016: *Mapping Our Way to Cleaner Water* presented by Bill Huber, DNR Buffer Mapping Hydrologist
- October 2016: *Farmer-led Solutions for Water Quality Improvement* presented by Jeremy Geske, Minnesota Agricultural Water Resource Center (MAWRC)
- November 2015: *Solutions to Stormwater Pollution* presented by Megan Moeller, Rochester Stormwater Educator

- February 2015: *How Farmers Are Protecting Water and Soil Resources* presented by Ryan Buck, Farm and President of the Minnesota Corn Growers
- December 2014: *A "Watershed Approach" to Restoring and Protecting the Zumbro* presented by Justin Watkins, MPCA
- February 2014: *Using Civic Engagement to Mobilize Clean Water Projects* presented by Barb Radke, University of Minnesota Extension

To best reach target audiences and stakeholders on watershed issues, monthly newspaper articles and the quarterly newsletter *The Zumbro River News* are published. Written by Kevin Strauss, ZWP Education Coordinator, these pieces highlight the watershed approach, provide updates on the ZRW WRAPS process and innovative water quality projects, and are a source for news on water and river issues. Both formats are distributed throughout the watershed. The monthly newspaper articles are published in community newspapers, whereas the quarterly newsletter is distributed to ZWP members and community hubs (libraries, community centers, etc.), and posted on the ZWP website.

The ZWP website serves as a repository for the ZRW WRAPS information, including meeting announcements, contact information, and a WRAPS Library. The *Zumbro River Watershed Management Plan (2007-2012)* and *Zumbro River Watershed Interim Watershed Management Plan (2013)* can also be found at this site, along with related publications and reports, data and mapping, news articles, and web links.

Meetings

The ZWP served as both host and facilitator for meetings held throughout the WRAPS process (see Table 16). This convening of stakeholders offered valuable feedback and input from entities across the watershed. These meetings also functioned as a platform to voice concerns, values, and priorities, which then manifested into strategies that vary among each region of the ZRW.

The meetings highlighted in Table 16 were directly associated with building the WRAPS. Numerous watershed-wide meetings and initiatives preceded the ZRW's participation in, and also greatly informed, the WRAPS process. These include, but are not limited to:

- March 2015: Minnesota Buffer Summit in Mazeppa, Minnesota
- 2012 through 2015: PAC (Project Advisory Committee) Meetings. Updates on watershed approach, modeling scenarios determined, etc.
- June 2012 through July 2014: *Slow the Flow* Educational Campaign (ZWP). This educational initiative was designed with short and long-term strategies to engage residents, LGUs, landowners, and businesses to take action to slow down and reduce the amount of water running into the Zumbro River. Part of this campaign resulted in the installation of 126 bridge signs, and 12 education signs throughout the watershed; the idea being, once you know the name of a creek, you can then begin to develop a relationship with it/foster stewardship.
- February 2015 MPCA Professional Judgment Group Meeting for Monitoring and Assessment, and Biological SID in the ZRW
- 2012 and 2013: TMDL meetings and ZRW 1st and 2nd Colloquiums that manifested into the *Zumbro Watershed Management Plan: Sediment Reduction Component (2012)*, and the *Interim Zumbro Watershed Management Plan (2013)*

Lobe Meetings

Throughout the summer and fall of 2016, three lobe meetings were held. Subsequent follow-up consultations took place during that time with county, city, and SWCD staff, and crop consultants (see Table 16 below). This engagement was the primary source for stakeholder input for the ZRW WRAPS. Upon receiving an overview of the WRAPS tools (HSPF modeling, N and P BMP spreadsheets, and zonation), key end users collaborated to apply lobe-specific knowledge of resources to generate example combinations of BMPs that would result in attainment of nitrogen and phosphorus reduction goals.

Table 16. ZRW WRAPS and TMDL meeting summaries.

Date	Title/Topic	Attendees
November 20, 2014	ZWP Professional Advisory Group. Watershed stakeholders discussed several potential management or BMP scenarios that could be set-up and run with the ZRWHSPF model with LimnoTech consultants. A total of 10 scenarios were developed to estimate the effect of potential management practices on sediment and nutrient transport and delivery to local tributaries, Lake Zumbro, and the watershed outlet.	County, city, & SWCD staff; state agency staff; ZWP Board members and staff.
March 19, 2016	Zumbro WRAPS Kick Off Meeting. WRAPS and TMDL process overview. Lake Zumbro phosphorus impairment and BATHTUB modeling. HSPF model development and results. Overview of other tools and example WRAPS in Cannon.	County, city, & SWCD staff; elected officials; state agency staff; urban & rural residents; landowners; lakeshore residents; farmers; ZWP Board members; commodity group representatives; TNC
April 14th, 2016	ZWP Water Ways Speaker Series: *Choices, Choices: Deciding What's Important in the Zumbro Watershed* presented by Paul Wotzka, ZWP. What landscape features and conservations measures are most valued in the ZRW? Attendees filled out a questionnaire and ranked their priorities as part of the Zonation values-based modeling for ZRW WRAPS.	Urban and rural residents; farmers; academics; ZWP members and staff; county, city, and SWCD staff; elected officials; lakeshore residents
June 7th & 8th, 2016	1st Round Lobe Meetings: An overview of the Zumbro Watershed Management Plan (2013); lobe characteristics and impairments/stressors; Discovery Farms water quality research and programming; 1st round of HSPF modeling	County, city, & SWCD staff; elected officials; state agency staff; urban & rural residents; landowners; lakeshore residents; farmers; ZWP Board members; commodity group representatives; TNC

	scenarios; Lake Zumbro BATHTUB modeling; results from Zonation survey/systematic conservation; Rochester WWTF history and overview; Lake Zumbro restoration approach.	
June 9th, 2016	ZWP Water Ways Speaker Series: *SimZumbro: High Tech Tools for Cleaner Water* presented by Ben Roush, MPCA. An overview of water quality models (HSPF), how they can incorporate changes in land use and BMPs, and management scenarios developed to realize these changes.	Urban and rural residents; farmers; academics; ZWP members and staff; county, city, and SWCD staff; elected officials; lakeshore residents
July 19, 2016	BMP Tool Meeting with Crop Consultants: An overview of the N/P BMP Tool & applications in the ZRW; discussion of U of MN approach (BMP Tool) versus IA & IL, and are the BMP Tool assumptions made realistic	Crop consultants from the ZRW
August 9th & 10th, 2016	2nd Round Lobe Meetings: Review of sources & pathways of sediment & nutrients in ZRW; soil organic matter – importance & how it is gained/lost; nutrient & sediment reduction goals; application of N/P BMP Tool; review of HSPF & 2nd wave of scenarios	County, city, & SWCD staff; elected officials; state agency staff; urban & rural residents; landowners; lakeshore residents; farmers; ZWP Board members; commodity group representatives; TNC
August 24, 2016	Cover Crop & Strip Till Demo Day: ZRW farmer-led tour of effective agricultural conservation practices and challenges. The ZWP had an informational ZWR WRAPS booth at this event.	Farmers; landowners; urban and rural residents; county & SWCD staff; commodity group representatives
September 7th, 2016	Applications of the N/P BMP Tool Meeting – Wabasha County	ZWP and MPCA staff met with SWCD & county staff
September 8th, 2016	Applications of the N/P BMP Tool Meeting – Dodge County	ZWP and MPCA staff met with SWCD & county staff
September 14, 2016	Applications of the N/P BMP Tool Meeting – Goodhue County	ZWP and MPCA staff met with SWCD & county staff
September 15, 2016	Applications of the N/P BMP Tool Meeting – Olmsted County	ZWP and MPCA staff met with SWCD & county staff

November 15th & 16th, 2016	3rd Round Lobe Meeting: Protection strategies – fully supporting waters, drinking water, DNR protection efforts; Review of N/P BMP Tool summary tables and revised Zonation Priority Area Maps from meetings with counties; summary and update on watershed TMDLs	County, city, & SWCD staff; elected officials; state agency staff; urban & rural residents; landowners; lakeshore residents; farmers; ZWP Board members; commodity group representatives; TNC
December 14th, 2016	Meeting with City of Rochester (MS4): Discussion of WRAPS applications to an MS4, Zonation, and BMP Tools.	City of Rochester stormwater staff & MPCA staff
January 28th, 2017	ZRW WRAPS Finale Meeting: A review and discussion of draft sections of the ZRW WRAPS document and solicited feedback on the entire process. Detailed presentation of watershed TMDLs and discussion of site specific standard development for South Fork Zumbro River and Lake Zumbro.	County, city, & SWCD staff; elected officials; state agency staff; urban & rural residents; landowners; lakeshore residents; farmers; ZWP Board members; commodity group representatives; TNC
February 9, 2017	ZWP's Water Ways Speaker Series: BWSR 1W1P coordinator, Julie Westerlund, spoke about the 1W1P planning efforts and how it relates to the WRAPS.	Urban and rural residents; farmers; academics; ZWP members and staff; county, city, and SWCD staff; elected officials; lakeshore residents

Findings from Outreach & Engagement Efforts

While ZRW WRAPS outreach and engagement occurred in various forums, the lobe and subsequent county meetings provided the most feedback. Participants offered both verbal and written input and perspectives that greatly informed this document. Contributors critiqued the effectiveness of strategies, tools, and modeling presented at lobe meetings. The high level of participation provided important substance for the ZRW WRAPS document.

A period of public comment on the draft WRAPS report was offered from August 21, 2017, to September 20, 2017. Public notice of the comment period was published in the State Register.

3.3 Restoration & Protection Strategies

The management strategies for the ZRW are focused on protecting and improving local water and land resources, and addressing a "fair share" obligation to reduce pollutant loading in pursuit of downstream goals (i.e. Gulf Hypoxia). The following text provides explanation regarding the structure and content of Tables 20 to 24. Tools for examining priorities for both restoration and protection are discussed previously in Section 3.1.

Table Structure

Tables 20 through 24 describe watershed restoration and protection strategies and are divided by approximate HUC-10 with a map preceding each: All Watershed, South Fork and Lake Zumbro Table, Middle and South Branch Middle Fork Table, North Fork Table, and Lower Zumbro Table. This format is consistent with planning and engagement efforts in the ZRW to date, and serves to break up the table thereby allowing for a more manageable examination of the rows and columns. Further, for strategies that apply generally and do not have attachment to specific impaired, supporting or priority waters, the All Watershed table provides a useful summary (and reduces redundant entry of rows in the four lobe tables).

Goals

Pollutant reduction goals for nitrogen (45% by 2040 with interim goal of 20% by 2025) and phosphorus (12% by 2025) were taken from Minnesota's NRS (MPCA 2014b). The Rice Lake the nutrient reduction goals is listed individually. Some HUC-10 watersheds do not include local nutrient-caused impairments, but example goal attainment scenarios are included because each watershed must pursue reductions per NRS goals. Example estimated scales of adoption of BMP combinations were carefully constructed with stakeholders to attain the interim goal of 20% nitrogen reduction and the final goal of 12% phosphorus reduction for one or more HUC-10 watershed each watershed lobe.

For nitrate-stressed streams, the 20% reduction goal would mark a significant improvement (nitrate toxicity standards are in development and as such there is at this time no defined numeric goal for warmwater streams). For the two phosphorus impaired lakes, a 12% reduction in phosphorus may not attain all local water resource goals (e.g. Rice Lake and Lake Zumbro). Rice Lake is largely driven by internal loading of phosphorus. The point and nonpoint source reductions of phosphorus required to meet a Lake Zumbro phosphorus goal are to be determined. For these reasons, stakeholders agreed that pursuit of the 12% reduction described in the NRS is an appropriate HUC-10 goal for 2025 (a year that closely coincides with the next Zumbro WRAPS iteration, which will allow for re-examination of conditions and goals).

While TSS and pathogen goals are described in the table, in most cases the strategies for addressing these pollutants are shared with those for non-dissolved phosphorus. This is consistent with other WRAPS in southeast Minnesota (e.g. the approved Mississippi River Lake Pepin and Cannon River WRAPS grouped *Strategies for addressing volume, sediment, phosphorus and pathogens*) in that the BMPs address runoff-driven pollutant loads. Further, there is no available tool to estimate scales of adoption specific to TSS or pathogen goal attainment at small scales (e.g. HUC-10).

Core Strategies for Restoration

Restoration strategies are largely focused on nonpoint source nutrient reduction because (1) many ZRW impairments are driven by nonpoint nutrient loads, and (2) the best tools for examining estimated scales of adoption to achieve reduction goals are centered on nitrogen and phosphorus. The strategies included in Table 21 to Table 24 are founded on core combinations of best management practices that were examined closely by technical practitioners and vetted with local stakeholders in both meeting and work session environments. The nutrient BMP spreadsheets for both nitrogen and phosphorus (developed by University of Minnesota) were used to iteratively examine the combinations of practices and the resultant load reductions. The spreadsheets represent the best available tools for engaging stakeholders in this context. The HSPF model scenario simulations show general agreement with the reduction estimates provided by the spreadsheets (see Chapter 3.1 for summary table depicting HSPF scenarios and respective load reduction estimates).

To achieve the 2025 nitrogen reduction goal, stakeholders made use of the following core strategies as starting points for constructing combinations of BMPs that together resulted in goal attainment. See Table 18 for more details:

- **Source reduction**: Between 75% to 90% of corn acres receive target N rate (University of Minnesota Maximum Return to Nitrate fertilization rate) – This strategy did not include N-inhibitors or timing shifts.
- **Vegetative changes:**
    - Between 50% to 80% of short season crop acres (including corn silage) are planted to a rye cover crop.
    - Between 20% to 25% of corn and soybean acres are planted to cereal rye cover crop.
    - Between 5% to 50% of marginal corn and soybean acres are planted to perennial vegetation or crops.

To achieve the 2025 phosphorus reduction goal, the base combination of BMPs includes the nitrogen-focused practices above, plus gains in reduced tillage on greater than 30% of row crop acres and full implementation of the buffer rule. The selected BMPs and estimated scales of adoption for both nitrogen and phosphorus were developed by local stakeholders and have been supported as attainable watershed goals. In the five watershed scale examples below, the combinations of BMPs that attain the goals vary somewhat but are founded on these core strategies, which summarize *what needs to happen* with regard to nutrient reduction in the ZRW.

Permits will describe the means for pursuing pollutant reductions from point sources (MS4s) and municipal and industrial wastewater). In the case of MS4s, it is important to note that loading reduced via some implementation actions is creditable to the load allocation (LA) and some to the WLA. Examples of non-WLA-creditable projects include strategies aimed at reducing in-lake loading (e.g. in-lake management). For clarification on a particular project, proposers should contact the MPCA Stormwater Program.

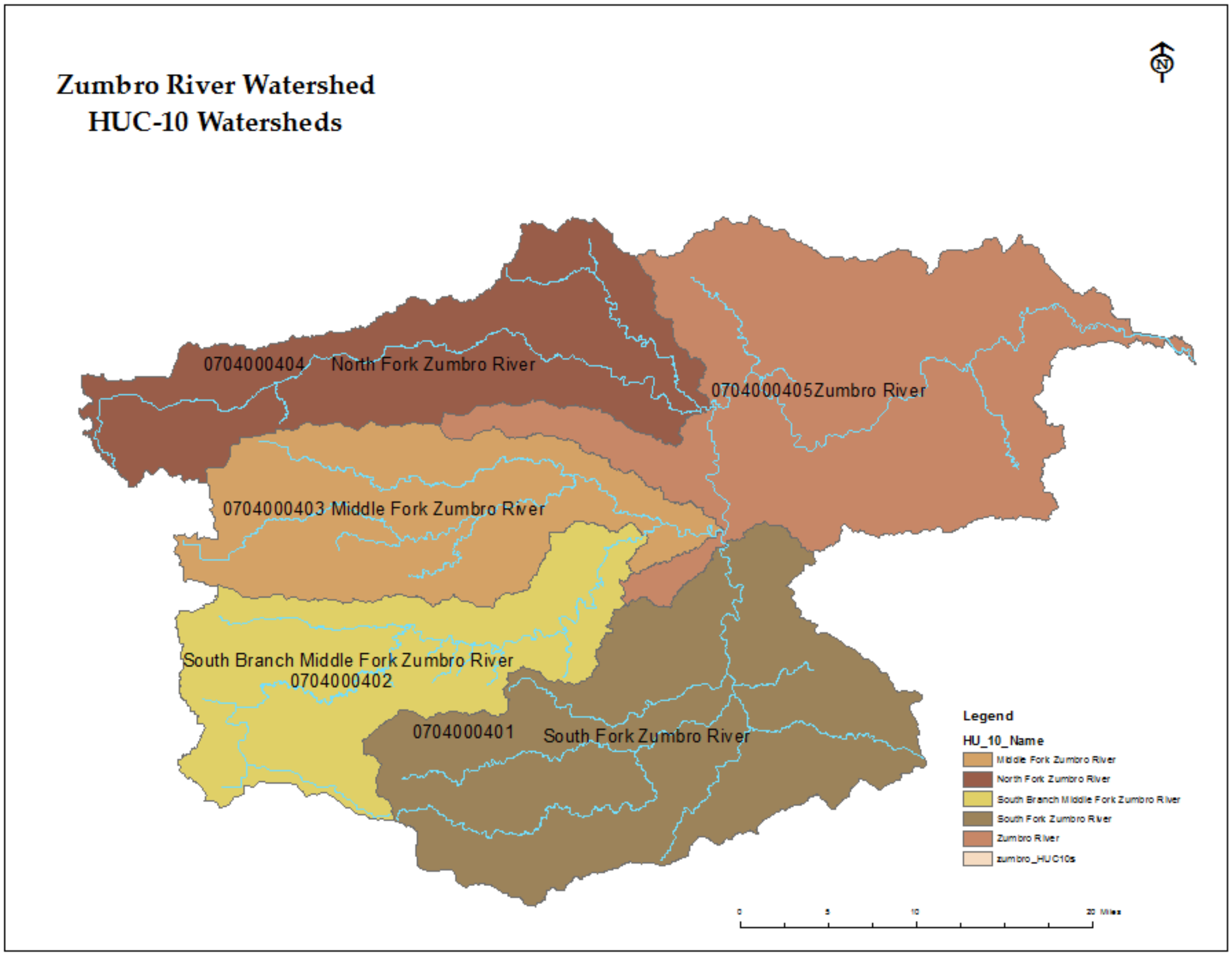


Figure 55. HUC-10s for ZRW.

Core Strategies for Protection

- Maintain and preserve perennial lands.
  - Keep existing pastures and rangeland; look for opportunities to convert marginal row crop acres to pasture or other perennial cover. Pasture is a working-lands BMP that is an integral part of local economies.
  - Encourage re-enrollment of expiring CRP contracts.
  - Manage forest acres with stewardship planning.
- Protect high quality water and land resources via easements and fee title acquisition.
- Pursue DNR Fisheries management easements on streams as a means of focusing habitat improvement money.
- Enforce the Wetlands Conservation Act and work toward no net loss of wetlands in the watershed.
- DNR has provided 16 protection priorities; some with strategy recommendations (see 3.1).

Strategy for Improving Soil Health

A specific strategy within ZRW Sediment Reduction TMDL Implementation Plan was to increase soil infiltration and water holding capacity. This strategy was proposed watershed-wide and could be applied to every cultivated agricultural acre and pervious urban acre. Two action items are listed in the Plan for this strategy: 1) increase the adoption of cover crops, and 2) track increase soil organic matter (SOM) and water holding capacity. The ZRW WRAPS Report will build on this work to propose a soil health strategy that will include tracking and increasing SOM plus another soil test, for bulk density, as soil measurements to indicate soil health.

Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. This definition speaks to the importance of managing soils so they are sustainable for future generations. Soil health's importance for watershed restoration and protection goes to the capacity of soils to capture and retain precipitation where it falls, thereby decreasing runoff and soil erosion, as well as nutrient (nitrogen and phosphorus) losses, from cultivated parts of the landscape. By decreasing runoff and leaching, soils have an innate capacity for improving water quality. Below are enumerated the two proposed soil measurements and their role in retaining and absorbing precipitation.

A measureable component of soil health is SOM. SOM is defined as any soil material that comes from the tissues of organisms (plants, animals, or microorganisms) that are currently or were once living. SOM is increased by leaving plant residues on the soil surface, rotating crops with pasture or perennials, incorporating cover crops into the cropping rotation, or by adding organic residues such animal manure, litter, or sewage sludge. There are many benefits to maintaining or increasing SOM levels: reduced bulk density, enhanced fertility, reduced nutrient leaching, resistance to soil erosion, and reduction of greenhouse gases by soil carbon sequestration. Most importantly for water quality benefits is the ability of SOM to increase the available water holding capacity (AWHC) of the soil. The United States Department of Agriculture (USDA) estimates that a 1% increase SOM results in nearly an inch adsorption and retention of rainfall per acre. All three soil types in the chart below show large increases in available water holding capacity by increasing SOM (Figure 56). A 1% increase in SOM can increase AWHC nearly three-fold. This strategy to increase SOM and benefit soil health would build resilience into the agricultural landscape of the ZRW by minimizing the impacts of intense rainfall and prolonged drought while at the same time benefiting soil fertility.

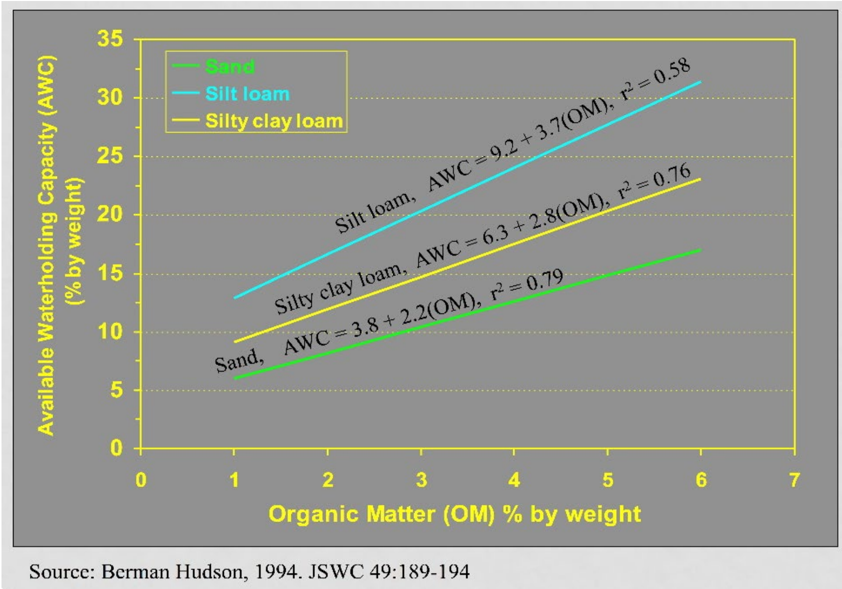


Figure 56. Soil types and their respective adsorption capacity as a function of SOM.

Another component of soil health is soil bulk density. Bulk density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its soil volume. Bulk density is changed by crop and land management practices that affect soil cover, organic matter, soil structure, and/or porosity. High bulk density is an indicator of low soil porosity and soil compaction. Table 17 describes the general relationship of bulk density to root growth based on soil texture and lists bulk density values for ideal and restricted root growth:

Table 17. Soil bulk density for ideal and restrictive plant root growth.

Soil Texture	Ideal Bulk Densities for plant growth (g/cm^3)	Bulk Densities that restrict root growth (g/cm^3)
Sandy	<1.60	>1.80
Silty	<1.40	>1.65
Clayey	<1.10	>1.47

On cropland, long-term solutions to bulk density and soil compaction problems revolve around decreasing soil disturbance and increasing SOM. Cultivation destroys SOM and weakens the natural stability of soil aggregates, making them susceptible to erosion caused by water and wind. By reducing water infiltration into the soil, compaction can lead to increased runoff and erosion from sloping land or waterlogged soils in flatter areas (from NRCS publication on soil quality indicators on the Bulk Density of Soils). The chart below (Figure 57) indicates that infiltration rates will increase 10-fold on soils that are not compacted:

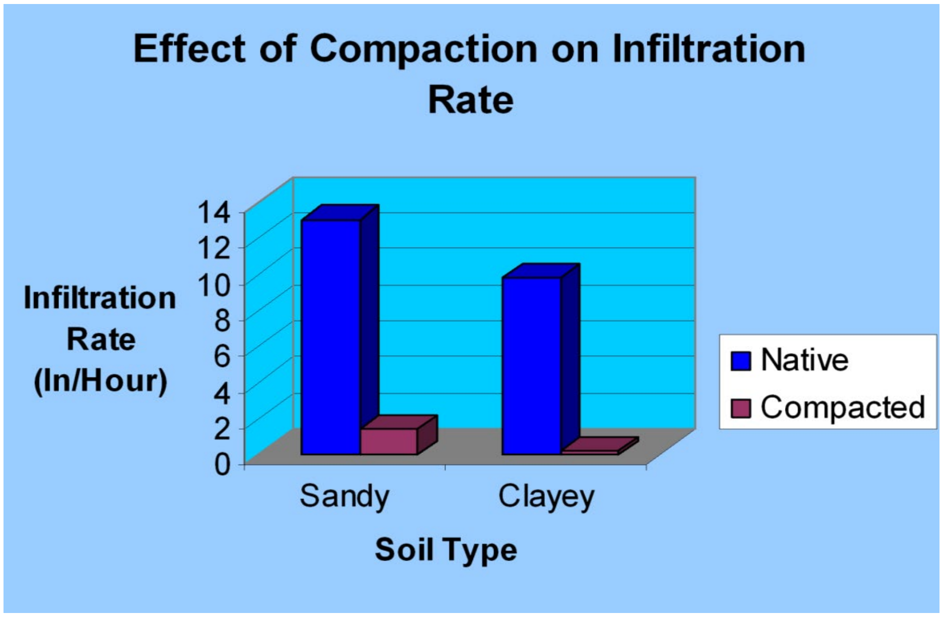


Figure 57. Infiltration rates by soil type and level of compaction. (Source: Minnesota Stormwater Manual)

Increasing SOM and decreasing bulk density are two long-term goals that farmers in the ZRW can use to measure the soil health of their fields, and thereby increase the fertility of their soils and benefit water quality by decreasing runoff and nutrient losses at the same time. These two soil measurements are objective, quantifiable, and inexpensive. By tracking these measurements in the ZRW, farmers can help to attain water quality goals for reducing sediment, nitrogen, and phosphorus into the water resources of the watershed.

Estimated Scales of Adoption needed to Meet Goals

A summary of the BMP Tool spreadsheet work is included in the following pages.

Table 18. BPM Tool spreadsheet output for Nitrogen reduction.

Nitrogen (N) BMPs	S. Fk. Zumbro HUC-10 (01), % Adoption or Acres Treated	South Br. Middle Fk. HUC-10 (02), % Adoption or Acres Treated	North Fk. Zumbro HUC-10 (04), % Adoption or Acres Treated	Lower Zumbro HUC-10 (05), % Adoption or Acres Treated	Zumbro HUC-8, % Adoption or Acres Treated
Acres of Cropland	125,000	99,000	113,000	137,000	578,000
Corn acres receiving target N rate, no inhibitor/shift	80% or 44,370	80% or 28,930	75% or 41,640	90% or 66,010	90% or 234,190
Fall N target rate acres receiving N inhibitor	75% or 7,310	80% or 12,830	100% or 23,030*		90% or 42,500
Fall N applications switched to Spring		20% or 640		100% or 4,360	50% or 2,360
Fall N switch to Spring/side dressing	25% or 610	40% or 1,280			
Restored Wetlands		5% or 480			
Tile line bioreactors	5% or 320	5% or 530	5% or 140		20% or 5,600
Controlled drainage		5% or 530			
Saturated Buffers	2% or 130	10% or 1,060	5% or 140		20% or 5,600
Riparian Buffers, 100/2= 50ft wide [model adjustment]	100% or 2,700	100% or 1,880	100% or 2,710	96% or 3,670	96% or 12,600
Rye cover crop on corn/soybean acres	10% or 6,200	20% or 16,910	10% or 9,120	10% or 7,150	25% or 22,670
Short season crops planted to a rye cover	80% or 4,170	50% or 2,500	60% or 2,990	80% or 5,240	80% or 21,000
Perennial crop % of marginal corn bean acres	50% or 3,270	5% or 350		50% or 4,440	20% or 6,960
Cropland N load reduction % with these Adoption Rates or Acres Treated	19.70%	19.80%	23.40%	24.00%	19.40%
Treatment Cost/yr.	$1,440,000	$1,700,000	$1,360,000	$1,870,000	$5,960,000
N fertilizer cost savings from reduced inputs	$670,000	$290,000	$760,000	$1,110,000	$3,620,000
Net BMP Treatment Cost	$770,000	$1,400,000	$600,000	$760,000	$2,340,000

*Suitable acres for Fall N target rate acres receiving N inhibitor in the North Fork Zumbro HUC-10 were estimated by LGUs to be approximately four times the original estimate in the NBMP spreadsheet. Subsequent tables will read “100% or 23,030 acres” but will not include this footnote.

Table 19. BPM Tool spreadsheet output for Phosphorus reduction.

Phosphorus (P) BMPs	S. Fk. Zumbro HUC-10 (01), % Adoption or Acres Treated	South Br. Middle Fk. HUC-10 (02), % Adoption or Acres Treated	North Fk. Zumbro HUC-10 (04), % Adoption or Acres Treated	Lower Zumbro HUC-10 (05), % Adoption or Acres Treated	Zumbro HUC-8, % Adoption or Acres Treated
Acres of Cropland	125,000	99,000	113,000	137,000	578,000
Target P205 rate	80% or 90,420	80% or 73,480	70% or 69,260	80% or 90,940	80% or 412,000
Fall corn fertilization to pre-plant/starter		25% or 830		50% or 1,950	50% or 9,000
Use reduced tillage on corn, soy, and small grains >2%	10% or 4,190	25% or 8,480	50% or 19,040	80% or 32,890	80% or 154,000
Riparian Buffers, 50 ft. wide, 100 ft. treated	100% or 6,770	95% or 4,240	100% or 7,230	95% or 10,340	95% or 32,000
Perennial crop % of marginal corn and soybean land	50% or 3,170	5% or 340		50% or 4,250	20% or 7,000
Rye cover crop on corn/soybean acres	6% or 6,460	20% or 17,400	10% or 9,390	7% or 7,470	10% or 34,000
Short season crops planted to a rye cover crop	80% or 4,310	50% or 2,530	60% or 3,060	80% or 5,550	80% or 22,000
Controlled Drainage		5% or 530			20% or 6,000
Alternative Tile Intakes	3% or 580				20% or 15,000
Inject/incorporate manure	50% or 5,050	90% or 5,830	30% or 2,990	50% or 7,450	50% or 24,000
Cropland P load reduction % with these Adoption Rates	15.70%	15.70%	15.00%	16.20%	17.20%
Treatment Cost/yr.	$1,390,000	$1,390,000	$1,010,000	$1,500,000	$4,150,000
P fertilizer cost savings from reduced inputs	$1,430,000	$690,000	$1,115,000	$1,330,000	$3,160,000
Net BMP Treatment Cost (black text = + net)	$40,000	$700,000	$105,000	$170,000	$990,000

The Task for the Group Meetings

Minn. Stat. 114D.26 states that WRAPS are required to provide estimated scales of adoption of BMPs that would result in attainment of water quality goals. A core engagement component of the Zumbro WRAPS process was to meet with each county in the ZRW to discuss and formulate examples of how to best meet statewide nutrient reduction goals for phosphorus and nitrogen for specific HUC-10 subwatersheds within their counties. The MAWRC and crop consultants in the ZRW were also engaged in the same task, only at a HUC-8 or entire watershed scale. Table 18 and Table 19 above summarize example combinations of practices that were developed by SWCD and county personnel, the MAWRC, and crop consultants using the N/P BMP Tool to meet a 20% reduction goal for nitrogen and 12% reduction goal for phosphorus. These scenarios recommend practices that would work in those specific watersheds by estimating percent adoption rates and acres treated for those practices that they thought would be achievable.

The Tool also translates "percent adoption rates" for specific BMPs into numbers of "acres treated" based on the number of acres suitable for the practice. For example, if a specific BMP could be implemented on 10,000 suitable acres, an adoption rate of 20% would mean that 2,000 acres would be "treated" and receive the practice. The county's conservation personnel could then use those 2,000 acres as a measurable goal to achieve during the 10-year window of the WRAPS and One Watershed One Plan (1W1P) plan. Counties could utilize these acre and adoption goals for grants and other incentives for landowners to implement these practices.

Lessons Learned Working with the BMP Tool

During the course of the group work sessions, attendees asked how many "acres treated" a specific adoption rate percentage would represent. Both the N and P-BMP tools make that conversion. Based on recommendations from attendees, both the adoption rate percentages and the acres treated are listed in the Summary Table.

An additional recommendation from attendees included listing "existing acres" for each BMP. However, the Tool does not consistently give estimates of existing acres; nor does there exist, in every case, the information required to accurately estimate "existing acres" treated by a BMP. The P-BMP Tool has estimates for "existing acres" for specific BMPs; the N-BMP Tool does not. The point was also raised that the number of acres in any given year that receive BMPs can fluctuate based on weather conditions and available conservation funds from federal and states government programs. Given the difficulty in utilizing these numbers in a piecemeal fashion, "existing acres" are not listed in the Summary Tables. The combinations of BMPs represent examples of goal attainment; they are estimates and should not be discussed in a context that would weigh them against great detail and specificity.

The rye cover crop following corn and soybeans BMP also ran into difficulties with respect to "suitable acres." The default setting in the Tool for suitable acres for this practice is 100%, meaning all corn and soybean acres are suitable for a rye cover crop in the fall. In most cases, meeting attendees would apply an approximate 10% adoption rate to these suitable acres to arrive at the total acres of cover crops to be implemented. A notable exception occurred with the crop consultant and MAWRC attendees: based on their experience with the difficulty of planting cereal rye in the late fall after harvest, they recommended that suitable acres for rye cover should be adjusted downward to 25% of acres after soybeans going into corn grain, and 10% of corn grain acres going into soybeans. The group then applied a higher rate of adoption of the cover crop practice to this lower number of suitable acres.

Finally, the N-BMP and P-BMP "acres treated" for the 50-foot riparian buffer do not match because the P-BMP reflects acres *treated* by the practice, while N-BMP acres would be acres *taken out of production* for this practice. The P-BMP Tool uses a formula to come up with treated acres that extend beyond the buffer 50-foot corridor. This approach accounts for the fact that much phosphorus is transported in a particle form and the buffer would be treating a number of upstream acres, for example, surrounding cultivated fields where the phosphorus movement originates. The opposite is true for nitrogen, which is primarily transported in a dissolved form in groundwater (see 2.3). Dissolved nitrogen is often not treated by riparian buffers as it moves vertically to groundwater or into tiles. The acres treated by buffers in the N-BMP tool, therefore, would represent only those acres that would be converted within the 50-foot riparian corridor from cultivated to perennial cover.

Questions concerning assumptions, calculations, and applications of the BMP Tool should be directed to Dave Wall at the MPCA (david.wall@state.mn.us).

Summaries of the Tables

The Counties in the ZRW applied the N/P BMP tools to formulate varying example approaches to meeting nutrient reduction goals with the N/P BMP Tool.

To meet the >20% reduction goal for Nitrogen in the next 10 years:

- All counties proposed significant adoption rates – 75% to 90% - for corn acres receiving target N rate with no inhibitors or timing shift of N applications. This BMP alone could meet one-half to three-quarters of the 20% nitrogen reduction goal. In addition, the adoption of this BMP could save farmers in the ZRW between $3,000,000 to $4,000,000 in N-fertilizer costs. Other source reduction N BMPs were utilized by counties but proposed widely different adoption rates. For example, Goodhue and Wabasha Counties did not utilize the BMP of switching Fall N applications to spring, but Dodge County proposed a 40% adoption rate.
- All structural BMPs for meeting the N reduction goal (restored wetlands, tile line bioreactors, controlled drainage, and saturated buffers) were not proposed as widely adopted solutions for reducing N. These BMPs are more expensive to implement and maintain, have high initial costs, and most of the watershed's geography is not appropriate for implementation.
- The 50-foot stream riparian buffers will be adopted on all of the suitable acres in the ZRW according to the Stream Bank Buffer Laws passed in 2015 and 2016. Stream bank buffers will work to attain approximately one-tenth of the overall N-reduction goal. Riparian buffers work much better at P-reduction than N-reduction.
- Short season crops planted to a rye cover crop was proposed at 50% to 80% adoption rate of suitable acres. Although proposed for a small number of acres, this BMP accounts for one-tenth of the N-reduction goal.

To meet the >12% reduction goal for Phosphorus in the next 10 years:

- All scenarios had high adoption rates for targeting a P_2O_5 rate that would reduce P fertilizer inputs, and consequently save farmers money. Overall, source reduction of phosphorus fertilizer accounted for slightly more than one-fourth of the phosphorus reductions.
- Counties varied widely on the BMP of using reduced tillage on row crop acres with greater than 2% slopes – from 10% to 80% adoption rates. For example, in the Lower Zumbro, Wabasha County estimated an 80% adoption rate for this BMP to be applied on 32,890 acres, while Olmsted County estimated a 10% adoption rate for the South Fork Zumbro HUC 10 to be applied on 4,190 acres.
- The 50-foot stream riparian buffers will be adopted on all of the suitable acres in the ZRW according to the Stream Bank Buffer Laws passed in 2015 to 2016. Stream bank buffers will work to attain one-third to one-half of the overall P-reduction goal.
- Counties also had widely varying adoption rates converting marginal row crop acres to perennial crops. Adoption rates varied from 5% in Dodge County to 50% in Olmsted and Wabasha Counties.
- Rye cover crop adoption rates on short season crops were fairly consistent - in the range of 50% to 80%. The rye cover cropping BMP of short season crops, although covering few acres (3,000 to 6,000 in each of the HUC10s), resulted in an estimated one-twelfth of the needed P-reduction goal.

Broad Watershed Strategies

There are no tools (like those available for phosphorus and nitrogen) for estimating scales of adoption required for habitat work, pathogen reduction or protection strategies. The WRAPS engagement process was focused on estimating scales of adoption needed to achieve nutrient reduction goals; those details are included in subsequent watershed lobe tables. It should be noted that many strategies to address nutrient reduction would likely have positive impacts in terms of both *E. coli* load reductions and habitat improvements.

The presence of fecal pathogens in surface water is a regional problem in southeast Minnesota. The issue was well described in a stakeholder-driven process that culminated in approval of 39 approved fecal coliform TMDLs for streams and rivers in the region. The *Revised Regional TMDL Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota*, approved in 2006, can be reviewed at the MPCA web site: http://www.pca.state.mn.us/index.php/view-document.html?gid=8006. Subsequent to TMDL approval, stakeholders completed an implementation plan: http://www.pca.state.mn.us/index.php/view-document.html?gid=8013. Following the findings and strategies summarized in these documents, numerous projects have been executed in efforts to reduce pathogen loading to the region's surface waters. Feedlot runoff, unsewered and under-sewered communities and over-grazed pastures (among others) have all been addressed via grant funding. Given the existing focus on *E. coli* impairments (an important issue in southeast Minnesota), the WRAPS engagement process in the ZRW did not describe new strategies for *E. coli* reduction. Given the regional nature of the impairment there are insufficient means to specify priority stream reaches for *E. coli* reduction (and as such there is not a need to include individual table rows for each impairment). Rather, the additional *E. coli* TMDLs in the ZRW (see Appendix A) are considered (for planning purposes) an addendum to the Regional TMDL work.

Degraded habitat as a stressor of aquatic life (fish and “bugs”) is pervasive in the ZRW (and in southeast Minnesota). Strategies and prioritization for habitat improvement at various scales are managed by the DNR. The ZRW Monitoring and Assessment Report includes IBI values for stream reaches that have confirmed aquatic life impairments and associated habitat stressors; they provide some ability to measure progress going forward as habitat improvement efforts continue.

Table 20. Broad strategies for the entire ZRW.

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions (load or concentration)	Water Quality: Goal	Strategies (see key below)	Strategy Type
All	All	All	Parameters cited in permit	-	-	Municipal & Industrial Wastewater	Compliance with NPDES ermits which will reflect WLAs.
			Parameters cited in permit	-	-	Urban Stormwater	Compliance with NPDES permits which will reflect WLAs. http://stormwater.pca.state.mn.us/index.php/Main_Page
			Parameters cited in permit	-	-	Construction and Industrial Stormwater permittees -- compliance with general permits	Compliance with NPDES permits
	See ZRW Monitoring and Assessment Report that lists all streams stressed by habitat impacts (22 AUIDs)	All	**Habitat**	See ZRW Monitoring and Assessment Report for fish and macroinvertebrate IBI values	IBI values at or above thresholds	**Address Physical Habitat and Channel Geometry following Natural Channel Design Principals**	Stream habitat improvements when needed to address local stressor or cause of impairment
							Stream Restorations
							Bank shaping and Floodplain Reconnection for incised channels
						Improve Connectivity	Address road crossing structures causing connectivity issues to biological movement, sediment transport and/or alter local hydrology
						Protect recovering ditch systems	Avoid or minimize ditch clean-out
						Vegetation Changes	Implement buffer rule
	All	All	**All conventional parameters**	–	Improve Soil Health by Maintaining and Increasing Soil Organic Matter and Decreasing Soil Bulk Density Levels	**Increase Adsorption and Retention of Rainfall and thereby Reduce Runoff and Excess Nutrients Losses**	Improve Soil Health
					Restore and protect native vegetation on blufftop field "shoulders" sloping down to forested bluffsides	**Reduce and prevent runoff and erosion**	Vegetative changes.
	See Appendix A for list of *E. coli* impairments	All	***E. coli***	See Appendix A for *E. coli* geomeans	Geomeans <126 org/100ml	**Regional Strategies for Pathogen Reduction**	SE Fecal TMDL - 2007 SEMN Bacteria Implementation Plan https://www.pca.state.mn.us/sites/default/files/wq-iw9-02c.pdf

HUC-10 Subwatershed	Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Strategy Type
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goal		
						Inspect Feedlots	Focus on shoreland feedlots with Open Lot Agreements in place
	All	All	**All conventional parameters**	-	IBI values at or above thresholds	**Maintain and Preserve Perennial Lands**	No net loss of pasture and rangeland
							Forest Stewardship Plans for wooded acres
							Land Covenants e.g. Sustainable Forestry Incentive Act
							Agricultural and Land Management Leases
							Property Tax credits and reductions e.g. Managed Forest Land 2c and Native Prairie Tax Exemption
							Encourage re-enrollment of expiring CRP contracts
						Protect unique land and water features	Easement and acquisition
						Shoreland and Floodplain Management	EnforceMinn. R. 6120: Shoreland and Floodplain Management
			Flow	-	Diversion limit of no more than 10% of the August median base flow will preserve the seasonal variability of the natural hydrology under all but the most extreme drought conditions.	**Protect baseflow of trout streams**	Focused monitoring and application of water appropriation analysis
				-	-	**Keep existing water storage**	No net loss of wetlands; keep wetland banking transactions within ZRW

(pink)	Restoration
(green)	Protection
(blue)	Strategies to address downstream impairments
(white)	Point Sources

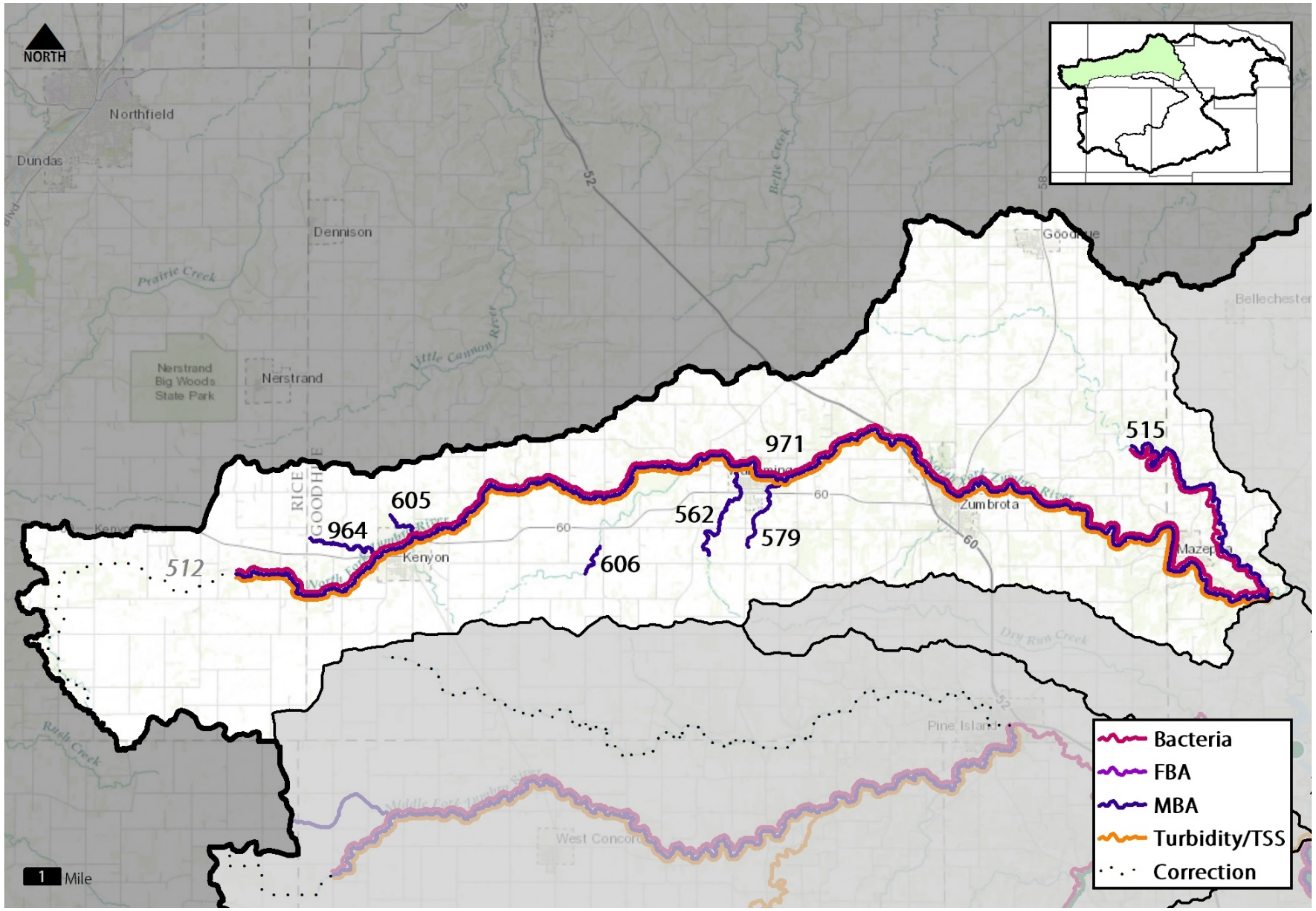


Figure 58. Map of the North Fork Watershed and macroinvertebrate impairments.

Table 21. Strategies and actions proposed for the North Fork Watershed.

HUC-10 Subwatershed	Waterbody and Location		Parameter	Water Quality		Strategies (see key below)	Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.				Governmental Units with Primary Responsibility										Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate													
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions	Goal		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal Units are Percent Adoption of Suitable Acres and [lbs removed]	DNR	SWCD	MPCA	NRCS	Wabasha County	Rice County	Goodhue County	MS4s	BWSR	MDA	
North Fork 0704000404	All	Rice, Goodhue, and Wabasha Counties	Nitrogen (TN) or Nitrate	See Appendix C for TN Loading information which will be tracked indefinitely at four sites in the ZRW	45% load reduction per Nutrient Reduction Strategy; 20% reduction is interim milestone and working goal for lobe	The NBMP tool was applied to examine 20% nitrogen load reduction goal attainment. . The primary strategies examined are included as rows below, and one example scenario is depicted in the adoption rate columns. . Note that these adoption rates vary relatively and there are many combinations that would result in goal attainment. . See Table 18 for more details.															
						Reduced Fertilizer Inputs	Use the U of MN nitrogen fertilizer BMPs relevant for the area and specific crop rotation, including crediting of all legumes and manure	NA	20% load reduction by 2025 per NRS	75% or 41,640 [313,000]		•		•					•	•	2040 per NRS
						Fall N applications	Fall Target Rate Acres Receiving N Inhibitors	NA		100% or 23,030 [145,000]		•		•					•	•	
						Increase vegetative cover/root duration [to reduce nitrate leaching]	Short season crops (corn silage, small grains, peas, sweet corn, , dry edible beans) planted to a cereal rye cover crop	NA		60% or 2,990 [38,000]		•		•					•	•	
							Cover crops on corn/soybean acres	NA		10% or 9,120 [56,000]		•		•					•	•	
							Convert riparian lands to perennials per buffer rule	NA		100% or 2,710 [54,000]		•		•	•	•	•		•		
							Convert marginal row crop farmland to perennial cover (marginal lands as determined by <60 on Crop Productivity Index)	NA				•		•					•		
						Structural Changes	Tile Line Bioreactors	NA		5% or 140 [170]	•	•		•					•		
							Saturated Buffers	NA		5% or 140 [1,000]	•	•		•					•		
	All	Rice, Dakota and Goodhue Counties	Phosphorus	See Appendix C for TP Loading information which will be tracked indefinitely at	12% load reduction per Nutrient Reduction Strategy	The PBMP tool was applied to examine 12% phosphorus load reduction goal attainment. . The primary strategies examined are included as rows below, and one example scenario is depicted in the adoption rate columns. . Note that these adoption rates vary relatively and there are many combinations that would result in goal attainment. . See Table 19 for more details.															
						Reduced Inputs	Target BMP P2O5 Rate using soil testing and U of MN fertilizer guidelines	NA	12% phosphorus load	70% or 69,260 [2,660]		•		•						•	2025 per NRS

HUC-10 Subwatershed	Waterbody and Location		Parameter	Water Quality		Strategies (see key below)	Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.				Governmental Units with Primary Responsibility										Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions	Goal		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal Units are Percent Adoption of Suitable Acres and [lbs removed]	DNR	SWCD	MPCA	NRCS	Wabasha County	Rice County	Goodhue County	MS4s	BWSR	MDA	
				four sites in the ZRW					reduction by 2025 per NRS												
						Vegetation Changes	Convert riparian lands to perennials per buffer rule	11%		100% or 7,230 [3,350]		•		•	•	•	•		•		
							Convert marginal row crop farmland to perennial cover (marginal lands as determined by <60 on Crop Productivity Index)					•		•					•		
	North Fork - 971	Rice, Goodhue, and Wabasha Counties	TSS (<10% exceedance of standard applies April - September)	10% exceedance of 65 mg/l	<10% exceedance of 65 mg/l		Cover crops on corn/soybean acres			10% or 9,390 [230]		•		•					•	•	
							Short season crops planted to a cereal rye cover crop			60% or 3,060 [500]		•		•					•	•	
						Structural Changes	Use reduced tillage on corn, soybeans and small grains > 2% slope	30%		50% or19,040 [2,150]		•		•					•		
							Inject/incorporate manure	10%		30% or 2,990 [410]		•		•					•		
							Structural impoundment BMP			30% of cropland acres	•	•	•	•					•		
						Urban Stormwater	Compliance with NPDES permits which will reflect WLAs. http://stormwater.pca.state.mn.us/index.php/Main_Page						•					•			
	North Fork - 970	RiceCounty	All	IBI values at or above thresholds: see monitoring and assessment report	IBI values at or above thresholds	Vegetation Maintenance	Maintain or increase perennial vegetation in watersheds				•	•	•	•		•					
							Protect or restore native riparian vegetation				•	•	•	•		•					
						Policy & Ordinance	Avoid or mitigate for future proposed agricultural drainage improvement projects				•	•	•	•		•					
							Require land in the shore impact zone to be established, maintained, or restored in native/perennial				•	•	•	•		•					

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter	Water Quality: Current Conditions	Water Quality: Goal	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal Units are Percent Adoption of Suitable Acres and [lbs removed]	DNR	SWCD	MPCA	NRCS	Wabasha County	Rice County	Goodhue County	MS4s	BWSR	MDA	Estimated Year to Achieve Water Quality Target
							riparian buffer at the time of development or at the time of permit issuance														
	Unnamed Stream -963	Goodhue County					Adhere/increase shoreland setbacks.				•	•	•	•		•			•		

Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.

Governmental Units with Primary Responsibility

(pink)	Restoration
(green)	Protection
(blue)	Strategies to address downstream impairments
(white)	Point Sources

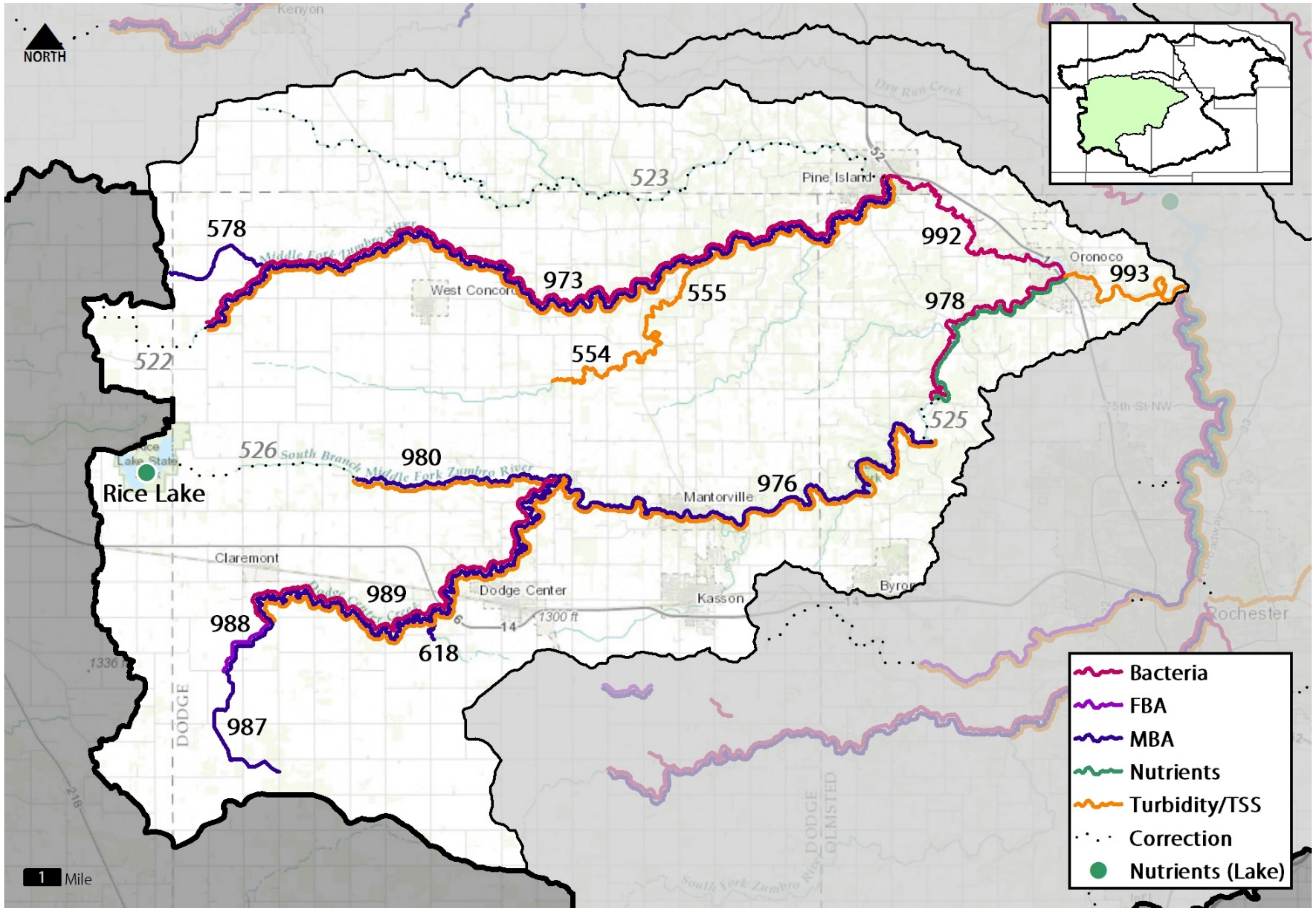


Figure 59. Map of the Middle Fork Watershed and macroinvertebrate impairments.

Table 22. Strategies and actions proposed for the Middle Fork Watershed.

HUC-10 Subwatershed	Waterbody and Location		Parameter	Water Quality		Strategies (see key below)	Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.				Governmental Units with Primary Responsibility											Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate														
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions	Goal		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal Units are Percent Adoption of Suitable Acres or Acres Treated, and [lbs removed]	DNR	SWCD	MPCA	NRCS	Olmsted County	Dodge County	Goodhue County	Steele County	MS4s	BWSR	MDA	
South Branch Middle Fork 0704000402 and Middle Fork 0704000403	All	Dodge, Steele, Goodhue, and Olmsted Counties	Nitrogen (TN) or Nitrate	See Appendix C for TN Loading information which will be tracked indefinitely at four sites in the ZRW	45% load reduction per Nutrient Reduction Strategy; 20% reduction is interim milestone and working goal for lobe	The **N-BMP Tool** was applied to examine 20% nitrogen load reduction goal attainment. . The primary strategies examined are included as rows below, and one example scenario is depicted in the adoption rate columns. . Note that these adoption rates vary by HUC 10. There are many combinations that would result in goal attainment. . See Table 18 for more details.																2040 per NRS
						Reduced Fertilizer Inputs	Use the U of MN nitrogen fertilizer BMPs relevant for the area and specific crop rotation, including crediting of all legumes and manure	NA	20% load reduction by 2025 per NRS	80% or 28,930 [215,000]		•		•							•	
						Fall N applications	Switch to spring	NA		20% or 640 [20,000]		•		•							•	
							Receive N inhibitor	NA		80% or 12,830 [49,000]												
							Switch to split spring/sidedressing	NA		40% or 1,280 [43,000]		•		•							•	
						Increase vegetative cover/root duration [to reduce nitrate leaching]	Short season crops (corn silage, small grains, peas, sweet corn, dry edible beans) planted to a cereal rye cover crop	NA		50% or 2,500 [23,000]		•		•						•	•	
							Cover crops on corn/soybean acres	NA		20% or 16,910 [89,000]		•		•						•	•	
							Convert riparian lands to perennials per buffer rule	NA		100% or 1,880 [29,000]		•		•	•	•	•	•		•		
							Convert marginal row crop farmland to perennial cover (marginal lands as determined by <60 on Crop Productivity Index)	NA		5% or 350 [66,000]		•		•						•		
						Structural Changes	Restored Wetlands	NA		5% or 480 [4,000]	•	•		•						•		
							Tile Line Bioreactors	NA		5% or 530 [1,000]		•		•						•		
							Controlled Drainage	NA		5% or 530 [2,000]		•		•						•	•	
							Saturated Buffers	NA		10% or 1,060 [7,000]		•		•						•		
	All	Rice, Goodhue, Steeele, Dodge and Olmsted Counties	Phosphorus	See Appendix C for TP Loading information which will be	12% load reduction per Nutrient	The PBMP tool was applied to attain a 12% phosphorus load reduction goal. The primary strategies examined are included as rows below. . One example scenario is depicted in the adoption rate or acres treated columns. . Note that these adoption rates or acres treated vary by HUC 10. There are many combinations that would result in achieving the reduction goal. . See Table 19 for more details.																

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter	Water Quality: Current Conditions	Water Quality: Goal	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal Units are Percent Adoption of Suitable Acres or Acres Treated, and [lbs removed]	DNR	SWCD	MPCA	NRCS	Omlsted County	Dodge County	Goodhue County	Steele County	MS4s	BWSR	MDA	Estimated Year to Achieve Water Quality Target
				tracked indefinitely at four sites in the ZRW	Reduction Strategy	Reduced Inputs	Target BMP P2O5 Rate using soil testing and U of MN fertilizer guidelines	NA	12% phosphorus load reduction by 2025 per NRS	80% or 73,480 [1,400]		•		•							•	2025 per NRS
						Reduced Inputs	Fall corn fertilization to pre-plant/starter	32%		25% or 830 [20]		•		•							•	
						Vegetation Changes	Convert riparian lands to perennials per buffer rule	8%		95% or 4,240 [4,530]		•		•	•	•	•	•		•		
	Middle Fork -522	Dodge and Steele Counties	TSS (<10% exceedance of standard applies April - September)	7% exceedance of 71 mg/l	<10% exceedance of 71 mg/l	Vegetation Changes	Convert marginal row crop farmland to perennial cover (marginal lands as determined by <60 on Crop Productivity Index)			5% or 340 [90]		•		•								
	SB Middle Fork -525 (now -978)	Steele, Dodge and Olmsted Counties		11.28% exceedance of 70 mg/l	<10% exceedance of 70 mg/l	Vegetation Changes	Cover crops on corn/soybean acres			20% or 17,400 [360]		•		•							•	
	SB Middle Fork -526 (now -980)	Steele, Dodge and Olmsted Counties		8% exceedance of 70 mg/l	<10% exceedance of 70 mg/l	Vegetation Changes	Short season crops planted to a cereal rye cover crop			50% or 2,530 [380]		•		•							•	
	Milliken Creek -554	Dodge and Steele Counties		8% exceedance of 48 mg/l	<10% exceedance of 48 mg/l																	
	Milliken Creek -555	Dodge and Steele Counties		8% exceedance of 65 mg/l	<10% exceedance of 65 mg/l	Structural Changes	Use reduced tillage on corn, soybeans and small grains > 2% slope	25%		25% or 8,480 [780]		•		•								
	Dodge Center Creek -592 (now -989)	Dodge and Steele Counties		9% exceedance of 70 mg/l	<10% exceedance of 70 mg/l	Structural Changes	Controlled Drainage			5% or 530 [90]		•		•							•	
	Middle Fork -993	Olmsted, Goodhue, and Dodge Counties		14% exceedance of 65 mg/l	<10% exceedance of 65 mg/l	Structural Changes	Inject/incorporate manure	8%		90% or 5,830 [940]		•		•								
						Urban Stormwater	Structural impoundment BMP			30% of cropland acres		•		•						•		

Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter	Water Quality: Current Conditions	Water Quality: Goal	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal Units are Percent Adoption of Suitable Acres or Acres Treated, and [lbs removed]	DNR	SWCD	MPCA	NRCS	Omlsted County	Dodge County	Goodhue County	Steele County	MS4s	BWSR	MDA	Estimated Year to Achieve Water Quality Target
							Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.															
							Compliance with NPDES permits which will reflect WLAs. http://stormwater.pca.state.mn.us/index.php/Main_Page						•						•	•		
	Rice Lake (LAKE ID)	Steele	Phosphorus	5062 kg/yr	565 kg/yr	**Drawdown strategies to control internal nutrient cycling**	Annual Temporary Summer Control of 6 to 12 inches below the normal runout between April 1 and July 31.				•											
							Occasional Winter Drawdown to increase probability of winterkill when rough fish have deleterious influence on aquatic habitats.				•											
							Major Growing Season Drawdown to regenerate aquatic plants, especially emergent varieties.				•											
	North Branch of Middle Fork -975	Goodhue and Dodge Counties	All	IBI values at or above thresholds: see monitoring and assessment report	IBI values at or above thresholds	**Vegetation Maintenance**	Maintain or increase perennial vegetation in watersheds				•	•	•	•		•	•					
	Middle Fork South Br -977	Dodge and Olmsted Counties					Protect or restore native riparian vegetation															
	Harkcom Creek-563 (Upper Middle Fork)	Dodge County				**Policy & Ordinance**					•	•	•	•		•	•					
							Avoid or mitigate for future proposed agricultural drainage improvement projects				•	•	•	•		•	•					
							Require land in the shore impact zone to be established, maintained, or restored in native/perennial riparian buffer at the time of development or at the time of permit issuance				•	•	•	•		•	•					
											•	•	•	•		•	•			•		

HUC-10 Subwatershed	Waterbody and Location		Parameter	Water Quality		Strategies (see key below)	Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.				Governmental Units with Primary Responsibility											Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate														
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions	Goal		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal Units are Percent Adoption of Suitable Acres or Acres Treated, and [lbs removed]	DNR	SWCD	MPCA	NRCS	Omlsted County	Dodge County	Goodhue County	Steele County	MS4s	BWSR	MDA	
	Dodge Center Creek -966						Adhere/increase shoreland setbacks.															

(pink)	Restoration
(green)	Protection
(blue)	Strategies to address downstream impairments
(white)	Point Sources

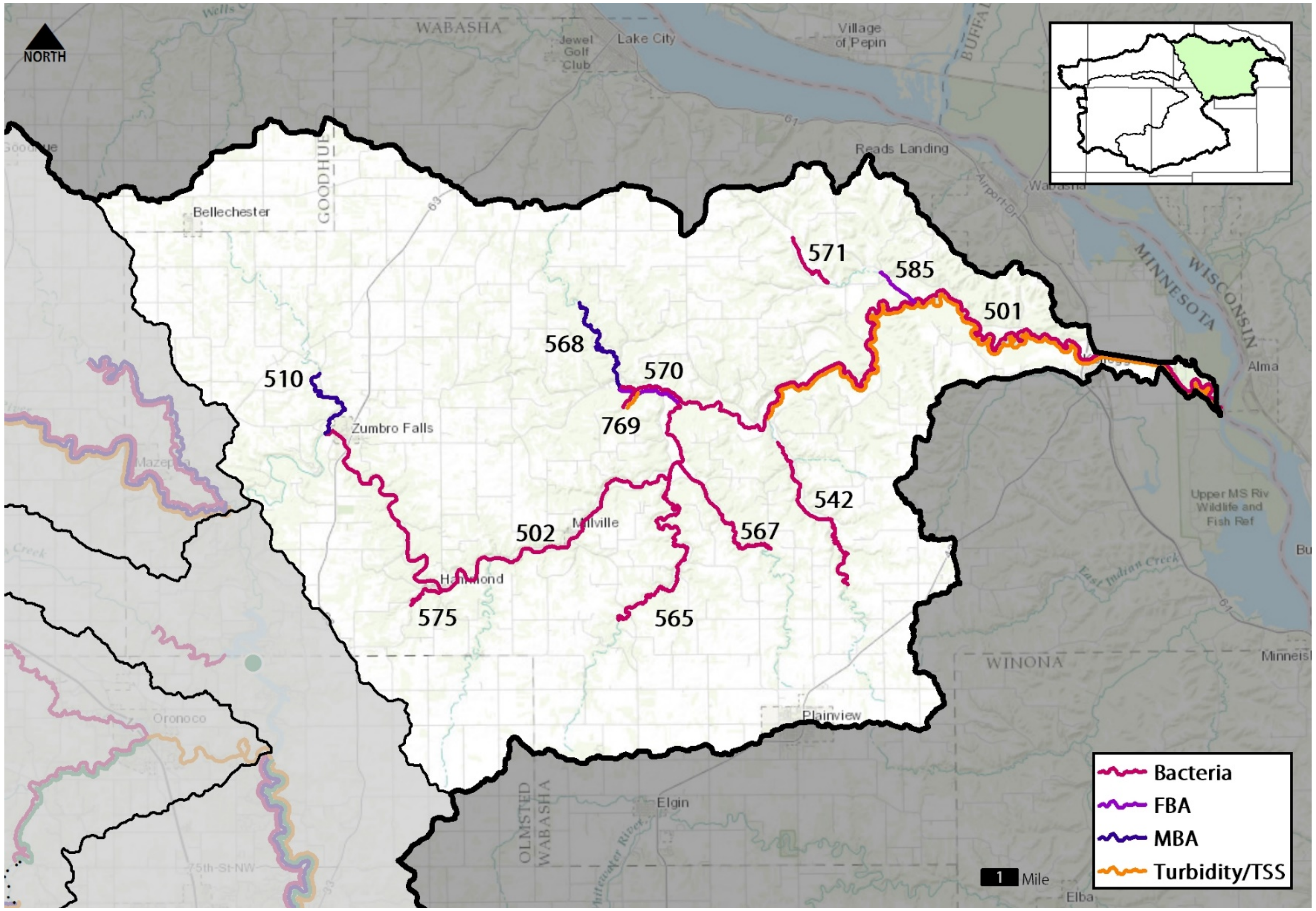


Figure 60. Map of the Lower Zumbro Watershed and macroinvertebrate impairments.

Table 23. Strategies and actions proposed for the Lower Zumbro Watershed.

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter	Water Quality: Current Conditions	Water Quality: Goal	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal Units are Percent Adoption of Suitable Acres and [lbs removed]	DNR	SWCD	MPCA	NRCS	Goodhue County	Olmsted County	Wabasha Cnty	BWSR	MDA	Estimated Year to Achieve Water Quality Target
						Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.					Governmental Units with Primary Responsibility									
Lower Zumbro River 0704000405	All	Goodhue, Olmsted, and Wabasha Counties	Nitrogen (TN) or Nitrate	See Appendix C for TN Loading information which will be tracked indefinitely at four sites in the ZRW	45% load reduction per Nutrient Reduction Strategy; 20% reduction is interim milestone and working goal for lobe	The NBMP tool was applied to examine 20% nitrogen load reduction goal attainment. . The primary strategies examined are included as rows below, and one example scenario is depicted in the adoption rate columns. . Note that these adoption rates vary relatively and there are many combinations that would result in goal attainment. . See Table 18 for more details.														
						Reduced Fertilizer Inputs	Use the U of MN nitrogen fertilizer BMPs relevant for the area and specific crop rotation, including crediting of all legumes and manure	NA	20% load reduction by 2025 per NRS	90% or 66,010 [547,000]		•		•					•	2040 per NRS
						Shift fall N applications	Switch to spring	NA		100% or 4,360 [35,000]		•		•					•	
						Increase vegetative cover/root duration [to reduce nitrate leaching]	Short season crops (corn silage, small grains, peas, sweet corn, dry edible beans) planted to a cereal rye cover crop	NA		80% or 5,240 [78,000]		•		•				•	•	
					<10 mg/l baseflow nitrate concentration		Cover crops on corn/soybean acres	NA		10% or 7,150 [73,000]		•		•				•	•	
							Convert marginal row crop farmland to perennial cover (marginal lands as determined by <60 on Crop Productivity Index)	NA		50% or 4,440 [101,000]		•		•				•		
							Convert riparian lands to perennials per buffer rule	NA		96% or 3,670 [81,000]		•		•	•	•	•	•		
	All	Goodhue, Olmsted, and Wabasha Counties	Phosphorus	See Appendix C for TP Loading information which will be	Lobe Goal of 12% load reduction per Nutrient	The PBMP tool was applied to examine 12% phosphorus load reduction goal attainment. The primary strategies examined are included as rows below, and one example scenario is depicted in the adoption rate columns. Note that these adoption rates vary relatively and there are many combinations that would result in goal attainment. These strategies address sediment in addition to phosphorus, although local TSS goals are expressed in terms of percent exceedance of water quality standard. See Table 19 for more details.														

HUC-10 Subwatershed	Waterbody and Location		Parameter	Water Quality		Strategies (see key below)	Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.				Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions	Goal		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal Units are Percent Adoption of Suitable Acres and [lbs removed]	DNR	SWCD	MPCA	NRCS	Goodhue County	Olmsted County	Wabasha Cnty	BWSR	MDA	
				tracked indefinitely at four sites in the ZRW	Reduction Strategy	Reduced Inputs	Target BMP P2O5 Rate using soil testing and U of MN fertilizer guidelines	NA	12% phosphorus load reduction by 2025 per NRS	80% or 90,940 [2,500]		•		•					•	2025 per NRS
	Zumbro River -501	Wabasha County	TSS (<10% exceedance of standard applies April - September)	24% exceedance of 92 mg/l	<10% exceedance of 92 mg/l	Vegetation Changes	Convert riparian lands to perennials per buffer rule	14%		95% or 10,340 [2,500]		•		•	•	•	•	•		
	Spring Creek -568	Wabasha County		17% exceedance of 10 mg/l at -570	<10% exceedance of 10 mg/l at -570		Convert marginal row crop farmland to perennial cover (marginal lands as determined by <60 on Crop Productivity Index)			50% or 4,250 [1280]		•		•				•		
							Cover crops on corn/soybean acres			7% or 7,470 [200]		•		•				•	•	
	Spring Creek -570						Short season crops planted to a cereal rye cover crop			80% or 5,550 [930]		•		•				•	•	
						Structural Changes	Use reduced tillage on corn, soybeans and small grains > 2% slope	30%		80% or 32,890 [4,280]		•		•				•		
	Spring Creek trib -769						Inject/incorporate manure	11%		50% or 7,450 [900]		•		•				•		
							Structual impoundment BMP			30% of cropland acres		•		•				•		
	All	All	All	NA	NA	Protect Trout Streams	Easements to protect/improve habitat and WQ; protect baseflow via monitoring and application of water appropriation analysis				•	•		•	•	•	•			
	Zumbro River -502	Wabasha County	All	IBI values at or above thresholds: see	IBI values at or above thresholds	Vegetation Maintenance	Maintain or increase perennial vegetation in watersheds				•	•	•	•	•	•	•			

HUC-10 Subwatershed	Waterbody and Location		Parameter	Water Quality		Strategies (see key below)	Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.				Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
								Estimated Adoption Rate												
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions	Goal		Strategy Type	Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal Units are Percent Adoption of Suitable Acres and [lbs removed]	DNR	SWCD	MPCA	NRCS	Goodhue County	Olmsted County	Wabasha Cnty	BWSR	MDA	
				monitoring and assessment report			Protect or restore native riparian vegetation				•	•	•	•	•	•	•			
						Policy & Ordinance	Avoid or mitigate for future proposed agricultural drainage improvement projects				•	•	•	•	•	•	•			
	West Indian Creek -542						Require land in the shore impact zone to be established, maintained, or restored in native/perennial riparian buffer at the time of development or at the time of permit issuance				•	•	•	•	•	•	•			
							Adhere/increase shoreland setbacks.				•	•	•	•	•	•	•	•		

(pink)	Restoration
(green)	Protection
(blue)	Downstream impairments
(white)	Point Sources

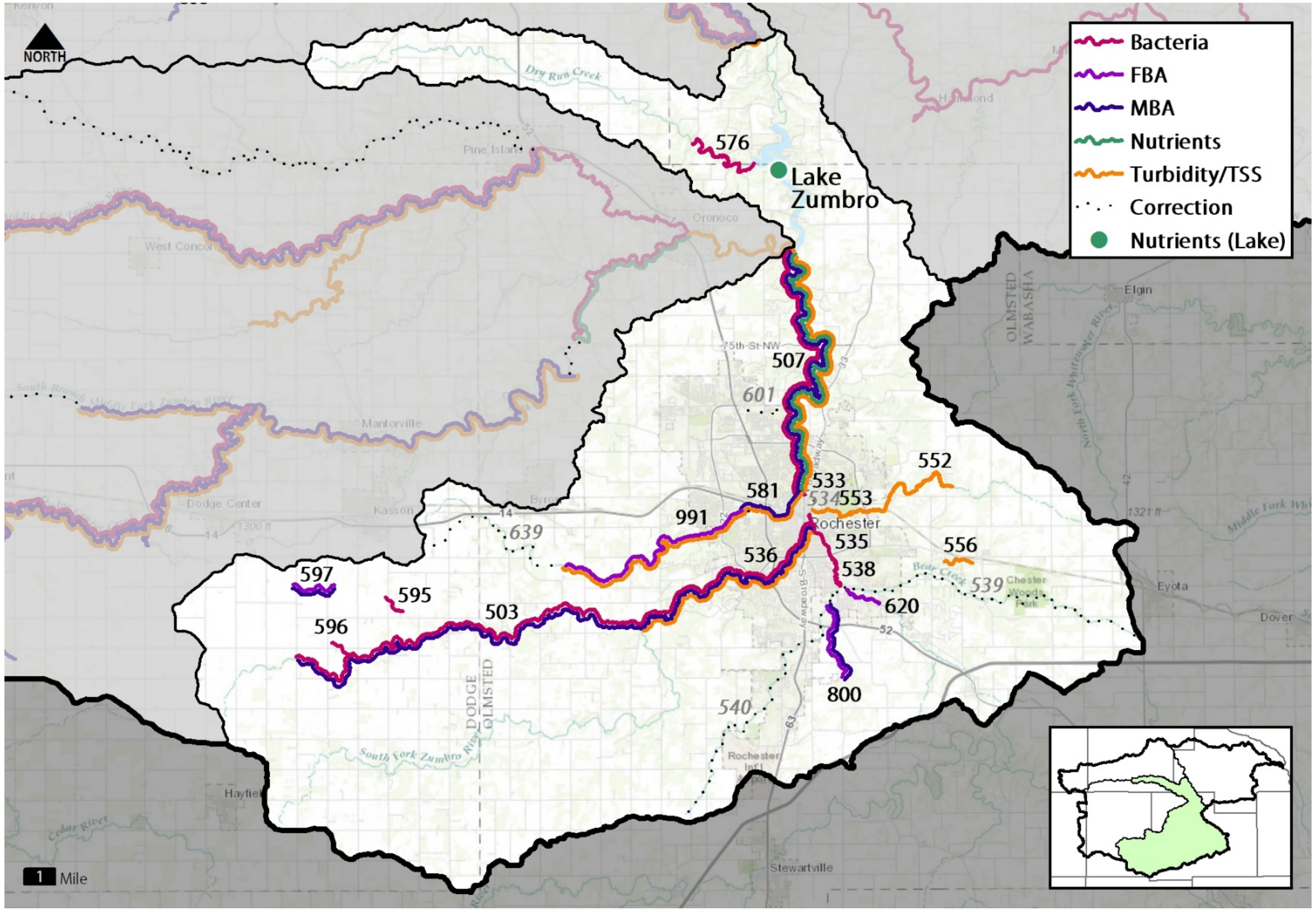


Figure 61. Map of the South Fork Watershed and Lake Zumbro.

Table 24. Strategies and actions proposed for the South Fork Watershed and Lake Zumbro.

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter	Water Quality: Current Conditions	Water Quality: Goal	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal Units are Percent Adoption of Suitable Acres or Acres Treated, and [lbs removed]	DNR	SWCD	MPCA	NRCS	Olmsted County	Dodge County	MS4s	BWSR	MDA	Estimated Year to Achieve Water Quality Target
						Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.					Governmental Units with Primary Responsibility									
South Fork Zumbro 0704000401 and Lake Zumbro	All	Dodge and Olmsted Counties	Nitrogen (TN) or Nitrate	See Appendix C for TN Loading information which will be tracked indefinitely at four sites in the ZRW	45% load reduction per Nutrient Reduction Strategy; 20% reduction is interim milestone and working goal for lobe	The NBMP tool was applied to examine 20% nitrogen load reduction goal attainment. The primary strategies examined are included as rows below, and one example scenario is depicted in the adoption rate columns. Note that these adoption rates vary by HUC 10. There are many combinations that would result in goal attainment. . See Table 18 for more details.														
						Reduced Fertilizer Inputs	Use the U of MN nitrogen fertilizer BMPs relevant for the area and specific crop rotation, including crediting of all legumes and manure	NA	20% load reduction by 2025 as per NRS	80% or 44,370 [340,000]		●		●					●	2040 per NRS
						Fall N applications	Receive N inhibitor	NA		75% or 7,310 [32,000]		●		●					●	
							Switch to split spring/sidedressing	NA		25% or 610 [17,000]		●		●					●	
						Structural Changes	Tile Line Bioreactors	NA		5% or 320 [<1,000]		●		●				●		
							Saturated Buffers	NA		2% or 130 [1,000]		●		●				●		
						Increase vegetative cover/root duration [to reduce nitrate leaching]	Short season crops (corn silage, small grains, peas, sweet corn, dry edible beans) planted to a cereal rye cover crop	NA		80% or 4,170 [50,000]		●		●				●	●	
							Cover crops on corn/soybean acres	NA		10% or 6,200 [49,000]		●		●					●	
							Convert riparian lands to perennials per buffer rule	NA		100% or 2,700 [51,000]		●		●	●	●		●		
							Convert marginal row crop farmland to perennial cover (marginal lands as determined by <60 on Crop Productivity Index)	NA		50% or 3,270 [64,000]		●		●				●		
	All	Dodge and Olmsted Counties	Total Phosphorus (TP)	See Appendix C for TP Loading information which will be tracked indefinitely at four sites in the ZRW	12% load reduction per Nutrient Reduction Strategy	The PBMP tool was applied to attain a 12% phosphorus load reduction goal. The primary strategies examined are included as rows below. One example scenario is depicted in the adoption rate or acres treated columns. Note that these adoption rates or acres treated vary by HUC 10. There are many combinations that would result in achieving the reduction goal. See Table 19 for more details.														
						Reduced Inputs	Target BMP P2O5 Rate using soil testing and U of MN fertilizer guidelines	NA	12% phosphorus load reduction by	80% or 90,420 [3,210]		●		●				●	●	2025 per NRS
						Vegetation Changes	Convert riparian lands to perennials per buffer rule	9%		100% or 6,770 [4,740]		●		●	●	●		●		

HUC-10 Subwatershed	Waterbody and Location: Waterbody (ID)	Waterbody and Location: Location and Upstream Influence Counties	Parameter	Water Quality: Current Conditions	Water Quality: Goal	Strategies (see key below)	Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Estimated Adoption Rate: Interim 10-year Milestone	Estimated Adoption Rate: Suggested Goal Units are Percent Adoption of Suitable Acres or Acres Treated, and [lbs removed]	DNR	SWCD	MPCA	NRCS	Olmsted County	Dodge County	MS4s	BWSR	MDA	Estimated Year to Achieve Water Quality Target
							Convert marginal lands to perennial cover (marginal lands as determined by <60 on Crop Productivity Index)		2025 per NRS	50% or 3,170 [920]		•		•				•		
							Cover crops on corn/soybean acres			6% or 6,460 [140]		•		•				•	•	
							Short season crops planted to a cereal rye cover crop			80% or 4,310 [680]		•		•				•	•	
	Lake Zumbro 55-0004-00	Wabasha and Olmsted Counties	Phosphorus	TBD; Site Specific Standard in development		Structural Changes	Use reduced tillage on corn, soybeans and small grains > 2% slope	29%		10% or 4,190 [400]		•		•				•		
	Zumbro River, South Fork -507	Olmsted County	TSS	13% exceedance of 69 mg/l	<10% exceedance of 69 mg/l		Alternative Tile Intakes	3%		3% or 580 [70]		•		•				•		
							Inject/incorporate manure	9%		50% or 5,050 [740]		•		•				•		
	Zumbro River, South Fork -536	Olmsted County		10% exceedance of 70 mg/l	<10% exceedance of 70 mg/l		Structural impoundment BMP			30% of cropland acres		•		•				•		
	Bear Creek - 538	Olmsted County		11% exceedance of 72 mg/l	<10% exceedance of 72 mg/l							•		•				•		
	Bear Creek - 539	Olmsted County		11% exceedance of 71 mg/l	<10% exceedance of 71 mg/l							•		•				•		
	Silver Creek - 552	Olmsted County		13% exceedance of 67 mg/l	<10% exceedance of 67 mg/l							•		•				•		
	Silver Creek - 553	Olmsted County		15% exceedance of 67 mg/l	<10% exceedance of 67 mg/l							•		•				•		
	King's Run - 601	Olmsted County		17% exceedance of 69 mg/l	<10% exceedance of 69 mg/l							•		•				•		
	Bear Creek trib (unnamed) - 556	Olmsted County		7% exceedance of 71 mg/l	<10% exceedance of 71 mg/l	Urban Stormwater	Compliance with NPDES permits which will reflect WLAs. http://stormwater.pca.state.mn.us/index.php/Main_Page						•				•	•		

Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.

HUC-10 Subwatershed	Waterbody and Location		Parameter	Water Quality		Strategies (see key below)	Scenarios and adoption levels are example combinations that result in estimated goal attainment. They are not prescriptive. Local planning will confirm best strategy combinations and scales of adoption to pursue.				Governmental Units with Primary Responsibility									Estimated Year to Achieve Water Quality Target
	Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions	Goal		Strategy Type	Estimated Adoption Rate: Current strategy adoption level, if known	Interim 10-year Milestone	Suggested Goal Units are Percent Adoption of Suitable Acres or Acres Treated, and [lbs removed]	DNR	SWCD	MPCA	NRCS	Olmsted County	Dodge County	MS4s	BWSR	MDA	
	Cascade Creek -581	Olmsted County		16% exceedance of 62 mg/l	<10% exceedance of 62 mg/l															
	Cascade Creek -639	Olmsted and Dodge Counties		12% exceedance of 62 mg/l	<10% exceedance of 62 mg/l															
	Willow Creek -540	Olmsted and Dodge Counties		9% exceedance of 71 mg/l	<10 exceedance of 71 mg/l															
	Upper South Fork 982, 969, 968, and 983	Omlsted and Dodge Counties	All	IBI values at or above thresholds: see monitoring and assessment report	IBI values at or above thresholds	**Vegetation Maintenance**	Maintain or increase perennial vegetation in watersheds				•	•	•	•	•	•	•			
						Vegetation Maintenance	Protect or restore native riparian vegetation				•	•	•	•	•	•	•			
						Policy & Ordinance	Avoid or mitigate for future proposed agricultural drainage improvement projects				•	•	•	•	•	•	•			
						Policy & Ordinance	Require land in the shore impact zone to be established, maintained, or restored in native/perennial riparian buffer at the time of development or at the time of permit issuance				•	•	•	•	•	•	•			
	Badger Run - 619	Olmsted County				**Policy & Ordinance**	Adhere/increase shoreland setbacks.				•	•	•	•	•	•	•	•		
	Bear Creek - 539, 986	Olmsted County																		

(pink)	Restoration
(green)	Protection
(blue)	Strategies to address downstream impairments
(white)	Point Sources

Table 25. Key for Strategies Column.

Strategy	Description
Nonpoint Source	
Nitrogen Reduction Strategies	Manage marginal lands in perennials, optimize nutrient management planning, timing and implementation, expand the use of cover crops, encourage managed grazing throughout the watershed
These strategies are taken directly from the NBMP spreadsheet (see the tool for further examination).	NRCS Job Codes; Nutrient Management (590), Prescribed Grazing (528), Cover Crop (340), Filter Strip (393), Waste Storage Facility (313)
Phosphorus Reduction Strategies	Reduce sediment transport from row croplands and promote sound residue management practices. Impoundments, contour farming, no-till farming, grassed buffer strips, etc. are all BMPs used to reduce soil erosion.
These strategies are taken directly from the PBMP spreadsheet (see the tool for further examination).	NRCS Job Codes Cover Crop (340), Residue and Tillage Management (345 & 329), Filter Strip (393), Contour Farming (330), Contour Buffer Strips (332)
SE MN Bacteria Implementation Plan (2007)	http://www.pca.state.mn.us/index.php/view-document.html?gid=8013
Structural Impoundment BMP	Water impoundment structures that reduce peak flows of rain events. These impoundments are located within row crop fields as well as edge of fields and in managed pastures. Using the information gathered from the Little Cannon River SWAT Model, as well as professional observations of stream conditions in MRLP subwatersheds, BMP treatment of 40% of land surface is the goal for this strategy.
	These practices include but are not limited to Water and Sediment Control Basins (638), Grade Control Structures (410), Terraces (600) and Diversions (632) (as a component)
Address Physical Habitat and Channel Geometry following Natural Channel Design Principals	Provide habitat improvement practices in an effort to reach a stream's full potential of sustaining game and non-game species. Incorporating natural design concepts to restoration projects as well as working with a streams' evolution should be a priority in the well-treated watersheds.
	Stabilize/restore channels within the headwater/upper parts of a given watershed first
	Target channels that are either stuck within the middle of stream channel succession scenarios (see attached) and are far from recovery.
	Practices referenced: All practices listed in the Nongame Wildlife Habitat Guide (TU), Toewood design concept and cedar tree revetments. Also referenced NRCS Job Code; Stream Habitat Improvement and Management (395)
Point Source	
NPDES point source compliance	All NPDES-permitted sources shall comply with conditions of their permits, which are written to be consistent with any assigned WLAs. It is recommended that NPDES permitted sources evaluate Total Nitrogen and optimize facility performance.
Stormwater Manual	http://stormwater.pca.state.mn.us/index.php/Main_Page

4. Monitoring Plan

Future monitoring in the ZRW will be according to the watershed approach framework. The IWM strategy utilizes a nested watershed design allowing the aggregation of watersheds from a coarse to a fine scale. The foundation of this comprehensive approach is the 80 major watersheds within Minnesota. IWM occurs in each major watershed once every 10 years (MPCA 2012b). The ZRW Monitoring and Assessment Report provides detailed discussion of IWM and how it will be applied going forward - it will be repeated in ZRW in 2022.

Pollutant load monitoring at State Highway 61 at Kellogg (S004-384) and at the pour points of each fork is on-going and will be used to track reductions in pollutant loads in the ZRW; these sites are instrumented and gauged to track flow volumes, and are intensively monitored by the MPCA staff and partners. Site locations and loading data can be viewed at the MPCA web site: https://www.pca.state.mn.us/water/watershed-pollutant-load-monitoring-network

Further, the *Revised Regional TMDL Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota* includes a monitoring section that describes activities and responsibilities pertaining to the greater regional examination of pathogens in surface water, of which ZRW is a part.

The Lake Zumbro Improvement Association monitors water clarity in the reservoir (i.e. Citizen Lake Monitoring and Citizen Stream Monitoring Programs), and the DNR monitors water clarity in Rice Lake; these are important on-going efforts useful in trend analysis (see Section 2.2).

Focused Monitoring & Research Needs

In addition to monitoring for both assessment and effectiveness purposes, there are research needs to better understand pollutant loads and dynamics in the ZRW. Streamflow monitoring, GW level monitoring, and aquifer tests in the trout stream watersheds may further form the basis for protection strategies for these waters. Regarding pathogens, the *Revised Regional TMDL Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota Implementation Plan* notes that research needs include, but are not limited to:

- Study of sources of pathogens in cities and urban areas;
- Better understanding of load reduction capabilities for applicable structural and non-structural BMPs;
- Models to evaluate loading sources and track load reductions;
- Methods to evaluate pollutant migration pathways and delivery mechanisms from pathogen sources to surface waters, both generally and in karsted landscapes; DNA "fingerprinting" to identify pathogen sources.

The Sediment Reduction Component of the Zumbro Watershed Comprehensive Management Plan includes substantial discussion regarding research needs (https://www.pca.state.mn.us/sites/default/files/wq-iw9-13c.pdf).

Zumbro River Watershed Monitoring Plan Summary	
	• Aquatic life use support: IMW every 10 years. • Aquatic recreation use support: IWM provides milestone check-points, other monitoring focused on research needs and better understanding. • Nitrogen in groundwater: monitoring wells (e.g. volunteer network) and springs (e.g. at Cold Spring Brook). • Tracking goals in pollutant load reductions: pollutant load monitoring sites, on-going. • BMP tracking: SWCD inventories, BWSR eLink, NRCS reporting at watershed scale . • Citizen Lake and Stream Monitoring.

Zumbro River Watershed Reports

Many of the ZRW reports referenced in this watershed report are available at the ZRW webpage: https://www.pca.state.mn.us/water/watersheds/zumbro-river

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Appendices

A. *E. coli* geometric means

B. Streams stressed by habitat

C. Watershed load monitoring data

D. HSPF Summary Report

E. Methodology for TNC protection prioritization

F. Summary of stressors

G. Description of Prioritization Approach and Methods

H. Zumbro River Watershed – An Ecological Inventory

I. Non-surface water discharge wastewater facility summary

Appendix A: *E. coli* geometric means

HUC-10 Watershed	Listed Waterbody Name	Reach (AUID)	WQ Station ID	# Samples Above 126 MPN/100 mL	*E. Coli* Geomean (MPN/100 mL)	Sample Date
Middle Fork Zumbro River	Zumbro River	07040004-973	S004-382	3/4	291.7	2008
			S006-065	15/15	436.5	2012 - 2013
Middle Fork Zumbro River	Zumbro River	07040004-992	S007-126	12/19	220.1	2008; 2012 - 2013
North Fork Zumbro River	Trout Brook	07040004-515	S005-551	33/43	225.2	2009 - 2010; 2012 - 2013
			S005-739	17/17	601.1	2009 - 2011
North Fork Zumbro River	Zumbro River	07040004-971	S000-033	17/20	347.2	2009 - 2010
			S005-741	29/32	436.2	2009 - 2013
			S005-742	14/18	302.8	2009 - 2011
South Branch Middle Fork Zumbro River	Zumbro River	07040004-978	S001-982	14/15	292.6	2012 - 2013
South Branch Middle Fork Zumbro River	Dodge Center Creek	07040004-989	S001-485	14/14	447.00	2012 - 2013
South Fork Zumbro River	Bear Creek	07040004-538	S000-800	3/4	180.1	2008
			S001-324	15/15	708.4	2012 - 2013
South Fork Zumbro River	Unnamed Creek	07040004-595	S003-711	11/14	388.8 - *E. coli* equivalent	2004
South Fork Zumbro River	Unnamed Creek	07040004-596	S003-712	45/60	286.9 - *E. coli* equivalent	2002 - 2003
Zumbro River	West Indian Creek	07040004-542	S004-452	14/18	344.9	2009 - 2011
			S005-733	15/18	285.4	2009 - 2011
Zumbro River	Long Creek	07040004-565	S005-737	10/18	205.0	2009 - 2011
			S005-738	14/18	218.7	2009 - 2011
Zumbro River	Middle Creek	07040004-567	S005-740	15/19	250.4	2009 - 2011
Zumbro River	Spring Creek	07040004-570	S006-082	15/15	724.7	2012 - 2013
Zumbro River	Trout Brook	07040004-571	S005-746	11/18	269.7	2009 - 2011
Zumbro River	Hammond Creek	07040004-575	S005-735	16/18	398.5	2009 - 2011
Zumbro River	Dry Run Creek	07040004-576	S005-550	20/26	423.3	2009 - 2010
Zumbro River	Spring Creek Tributary	07040004-769	S005-745	18/18	758.4	2009 - 2011

Appendix B: Streams stressed by degraded habitat

Stream Name	AUID
Salem Creek	**07040004-503**
Zumbro River, South Fork	**07040004-507**
Cold Creek/Cold Spring	**07040004-510**
Trout Brook (Mazeppa Creek)	**07040004-515**
Zumbro River, South Fork	**07040004-536**
Spring Creek	**07040004-570**
Unnamed Creek	**07040004-578**
Unnamed Creek	**07040004-579**
Cascade Creek	**07040004-581**
Trout Brook (Dumfries)	**07040004-585**
Dodge Center Creek	**07040004-989**
Salem Creek Trib	**07040004-597**
Silver Creek/Spring Creek	**07040004-606**
Badger Run	**07040004-620**
Unnamed Creek	**07040004-621**
Unnamed Creek (Trib to Willow)	**07040004-800**
Unnamed creek	**07040004-964**
Zumbro River, North Fork	**07040004-971**
SBMF Zumbro (DS rice lake)	**07040004-980**
Judicial Ditch 1	**07040004-987**
JD 1	**07040004-988**
Cascade Creek	**07040004-991**

Appendix C: Watershed load monitoring data

Name	Hydstra ID	Site Type	Parameter	Year	# samples	FWMC (mg/L)	Mass (kg)	Vol (acre ft)	Equis ID
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Dissolved orthophosphate	2013	25	0.15	22,354	120609	S007-111
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Dissolved orthophosphate	2014	22	0.125	17,484	113378	S007-111
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Inorganic nitrogen	2013	25	10	1,484,217	120609	S007-111
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Inorganic nitrogen	2014	22	10	1,473,230	113378	S007-111
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Total Kjeldahl nitrogen	2013	25	1.42	210,714	120609	S007-111
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Total Kjeldahl nitrogen	2014	22	1.58	220,287	113378	S007-111
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Total phosphorus	2013	25	0.312	46,349	120609	S007-111
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Total phosphorus	2014	22	0.342	47,806	113378	S007-111
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Total suspended solids	2013	25	98	14,639,080	120609	S007-111
North Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071003	Subwatershed	Total suspended solids	2014	22	159	22,182,300	113378	S007-111
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Dissolved orthophosphate	2013	25	0.231	40,850	143086	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Dissolved orthophosphate	2014	22	0.222	33,517	122454	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Inorganic nitrogen	2013	25	6.7	1,179,463	143086	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Inorganic nitrogen	2014	22	7.8	1,178,424	122454	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Inorganic nitrogen	2015	21	6.4	482,842	61164	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Total Kjeldahl nitrogen	2013	25	1.96	346,453	143086	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Total Kjeldahl nitrogen	2014	22	1.83	276,513	122454	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Total phosphorus	2013	25	0.492	86,777	143086	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Total phosphorus	2014	22	0.47	70,974	122454	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Total suspended solids	2013	25	210	37,137,740	143086	S007-141
North Fork Zumbro River nr Mazeppa, CSAH7	H41006001	Subwatershed	Total suspended solids	2014	22	178	26,953,316	122454	S007-141
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Dissolved orthophosphate	2013	25	0.141	24,104	138845	S007-112
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Dissolved orthophosphate	2014	21	0.159	27,781	141773	S007-112
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Inorganic nitrogen	2013	25	8.5	1,450,381	138845	S007-112
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Inorganic nitrogen	2014	21	8.6	1,508,869	141773	S007-112
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Total Kjeldahl nitrogen	2013	25	1.78	305,611	138845	S007-112
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Total Kjeldahl nitrogen	2014	21	2.02	353,450	141773	S007-112
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Total phosphorus	2013	25	0.399	68,336	138845	S007-112
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Total phosphorus	2014	21	0.461	80,697	141773	S007-112
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Total suspended solids	2013	25	178	30,453,430	138845	S007-112
South Branch Middle Fork Zumbro River nr Oronoco,5th St	H41071002	Subwatershed	Total suspended solids	2014	21	297	51,955,400	141773	S007-112
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Dissolved orthophosphate	2013	27	0.145	45,565	254352	S003-802
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Dissolved orthophosphate	2014	22	0.146	33,008	183272	S003-802
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Inorganic nitrogen	2013	27	6.3	1,971,262	254352	S003-802
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Inorganic nitrogen	2014	23	6.5	1,463,411	183272	S003-802
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Total Kjeldahl nitrogen	2013	27	1.31	410,752	254352	S003-802
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Total Kjeldahl nitrogen	2014	22	1.25	282,046	183272	S003-802
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Total phosphorus	2013	27	0.294	92,256	254352	S003-802
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Total phosphorus	2014	22	0.307	69,487	183272	S003-802
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Total suspended solids	2013	27	73	23,002,310	254352	S003-802
South Fork Zumbro River nr Oronoco, CR121	H41049001	Subwatershed	Total suspended solids	2014	22	87	19,570,870	183272	S003-802
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Dissolved orthophosphate	2010	38	0.197	239,013	982870	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Dissolved orthophosphate	2011	37	0.114	148,915	1063570	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Dissolved orthophosphate	2012	27	0.168	106,550	514939	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Dissolved orthophosphate	2013	40	0.157	196,872	1013550	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Dissolved orthophosphate	2014		0	0	0	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Dissolved orthophosphate	2014	34	0.126	128,481	823581	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Inorganic nitrogen	2010	38	5	6,019,943	982870	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Inorganic nitrogen	2011	37	6.5	8,480,399	1063570	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Inorganic nitrogen	2012	28	5.2	3,284,162	514939	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Inorganic nitrogen	2013	40	6.5	8,119,731	1013550	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Inorganic nitrogen	2014	34	5.9	5,964,023	823581	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total Kjeldahl nitrogen	2010	38	1.4	1,699,108	982870	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total Kjeldahl nitrogen	2011	37	1.02	1,336,914	1063570	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total Kjeldahl nitrogen	2012	28	1.26	798,456	514939	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total Kjeldahl nitrogen	2013	40	1.41	1,767,772	1013550	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total Kjeldahl nitrogen	2014	33	1.02	1,037,424	823581	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total phosphorus	2010	38	0.348	421,578	982870	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total phosphorus	2011	37	0.207	271,839	1063570	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total phosphorus	2014	34	0.245	248,942	823581	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total suspended solids	2010	43	163	197,895,500	982870	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total suspended solids	2011	39	122	159,582,600	1063570	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total suspended solids	2012	35	218	138,716,400	514939	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total suspended solids	2013	49	168	210,601,400	1013550	S004-384
Zumbro River at Kellogg, US61	H41043001	Major Watershed	Total suspended solids	2014	41	185	187,479,800	823581	S004-384

Load monitoring data can be interactively viewed and retrieved using the data viewer

Appendix D: HSPF summary report

Minnesota Pollution Control Agency

1/30/17

Zumbro HPSF Model Summary

The hydrologic model HSPF (Hydrological Simulation Program – FORTRAN) was used to support decision-making for potential sediment and nutrient reduction strategies in the Zumbro River Basin. This document describes the development of the Zumbro HSPF as well as some of the modeled data output. For information regarding these models or for any data/reports relating to them, please contact Dr. Charles Regan (chuck.regan@state.mn.us) at the MPCA.

HSPF Development

HSPF models allow for advanced hydrologic simulation of a basin through multiple sources of spatial and temporal observed data. The model was developed and continues to be supported by the EPA and has been consistently used in peer-reviewed watershed studies. More on HSPF can be found at http://www.pca.state.mn.us/index.php/view-document.html?gid=21398. This model was completed by the engineering firm LimnoTech in 2015 and all data is part of the public domain.

Subwatershed Delineation and Land Segment Development

The watershed model is separated into subwatersheds based on hydrography data (from GIS analysis) and could also be adjusted based on specific stream concerns (such as impairments). Pervious and impervious land segments within each subwatershed divide the subwatersheds into distinct sections based on land use, soil properties, and tillage practices. This data was compiled from multiple federal, state, and local organizations and government entities. Land cover data for land segments originated from the National Land Cover Database of 2001 and 2006.

Calibration - Hydrology

Eleven flow calibration gages data used for hydrologic calibration. Two major gages were used for primary calibration (Zumbro River at Kellogg and the South Fork Zumbro at Rochester), while the remaining upstream gages helped parameterize model variables, including land segment flow values. The modeled period was between 1995 and 2009. Calibration involves first determining annual water balance, then modifying for seasonal changes in hydrology, ensuring high and low flow volumes are accurate, and finally modifying hydrograph to storm flows. Snow and snowmelt are also factored into the model based on meteorological inputs.

Calibration – Water Quality

Multiple constituents of water quality were modeled, including biochemical oxygen demand, dissolved oxygen, sediment, temperature, and various nutrients. Water quality calibration was more challenging because fewer data points exist (compared to flow data) and there is greater uncertainty in data collection. Observed water quality and flow data from 30 point sources, like waste water treatment facilities or industrial discharges (based on NPDES permits), was also incorporated into the model

Sediment

Sediment loads are divided into sand, silt, and clay for the HSPF simulation. Calibration included parametrization of land sediment loading sources, delivery rates to streams, sediment trapping in Lake Zumbro and Rice Lake, and in-stream scour and deposition rates. There were eight in-stream calibration stations throughout the Zumbro Basin, including the primary hydrologic calibration point at the Zumbro River at Kellogg.

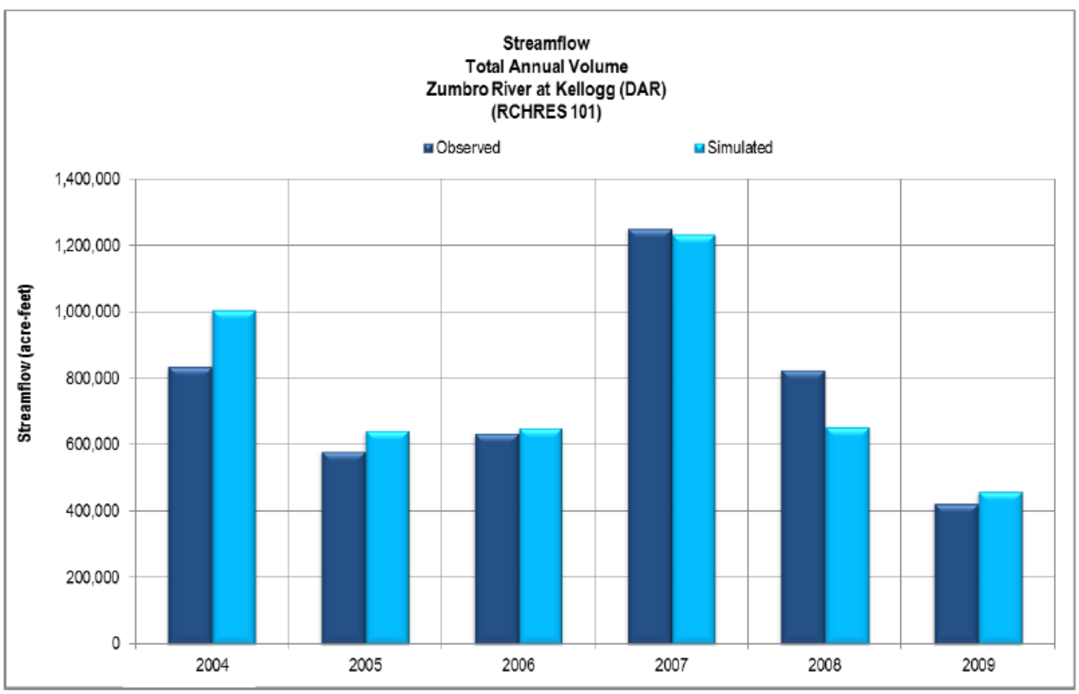
Dissolved Oxygen, Biochemical Oxygen Demand, and Nutrients

Parameterization of water quality constituents was designed to account for land use, soils, geology, and land management practices. Parameters were not adjusted purely to ensure simulated data matched observed data, but rather to accurately demonstrate observed watershed properties. Nitrate and ammonia atmospheric deposition was also included from the National Atmospheric Deposition Program and the EPA.

Calibration Results

The calibration process for HSPF modeling is the "weight of evidence" method, meaning that calibration involves a combination of statistical analysis, visual comparisons, and compatibility with existing scientific information. In general, the model was well calibrated for hydrology and water quality based on qualitative comparisons and quantitative analyses such as correlation coefficient and coefficient of determination metrics. LimnoTech determined the model was suitable for all MPCA business needs. *Figure 1* shows an example of hydrologic calibration for the Zumbro River at Kellogg. Additional calibration figures are available upon request.

Figure 1: Observed annual streamflow volume (dark blue) and HSPF simulated volume (light blue) at the outlet of the Zumbro River. (Figure produced by LimnoTech.)



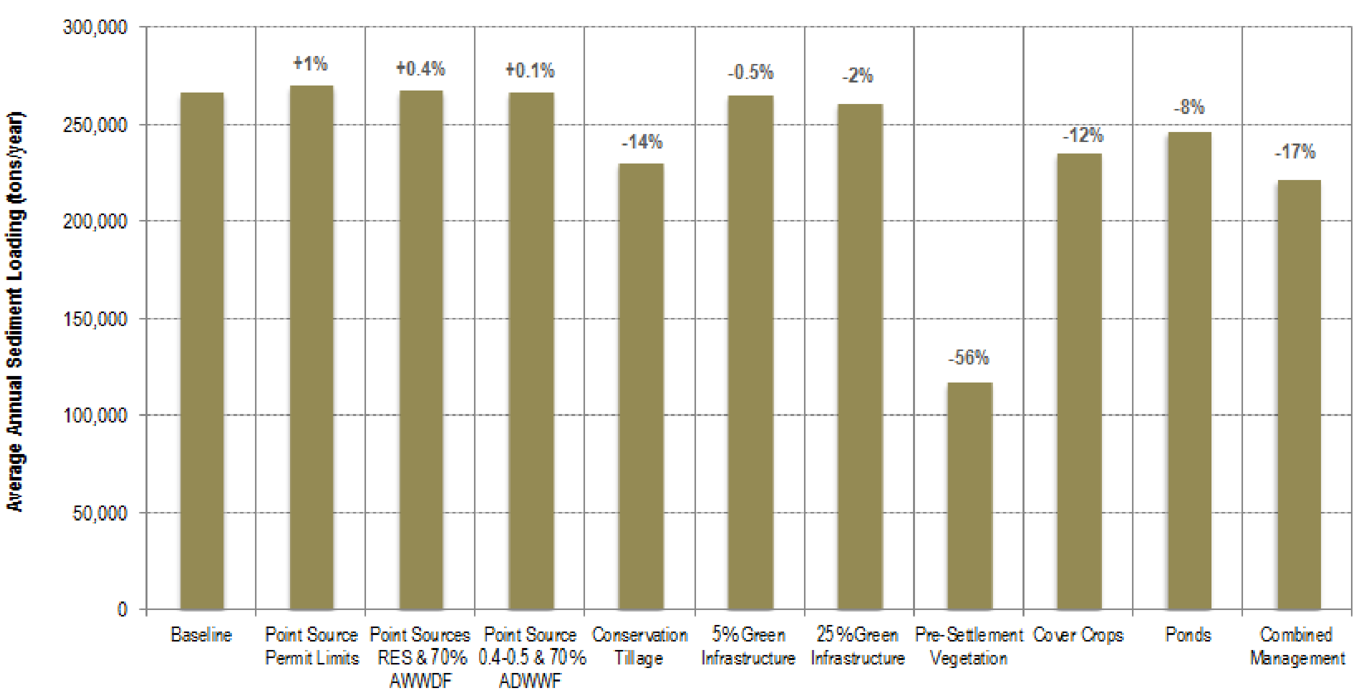
HSPF Scenarios

Along with simulation of current watershed conditions (known as the "baseline" model), HSPF can be used to simulate changes in nonpoint and point source loading. These adjusted watershed conditions are known as scenarios and can be used to guide efforts to meet water quality standards. In the Zumbro Watershed, scenarios were developed to inform nonpoint and point source nutrient and sediment management goals. Ten scenarios were initially created for these purposes. The combined scenario (J) below included point source reductions described in scenario C along with cover crops (scenario H) and sedimentation ponds (scenario I). Results of the scenarios are shown in the following tables and map.

Table 1: HSPF scenarios for the Zumbro watershed. (Figure produced by LimnoTech.)

Scenario ID	Scenario Description	Category
A	Point Sources at Permitted Limits	Point Source
B	Point Sources at RES and 70% AWWDF	Point Source
C	Point Sources at 0.40 or 0.50 mg P/L and 70% AWWDF	Point Source
D	Conservation Tillage	Nonpoint Source
E	Green Infrastructure - 5% Implementation	Nonpoint Source
F	Green Infrastructure - 25% Implementation	Nonpoint Source
G	Pre-Settlement Vegetation	Nonpoint Source
H	Cover Crops	Nonpoint Source
I	Sedimentation Ponds	Nonpoint Source
J	Combined Management Scenario	Point Source + Nonpoint Source

Table 2: Sediment load reductions for HSPF scenarios. Data correspond to averages of modeled period between 1996 and 2009. (Figure produced by LimnoTech.)



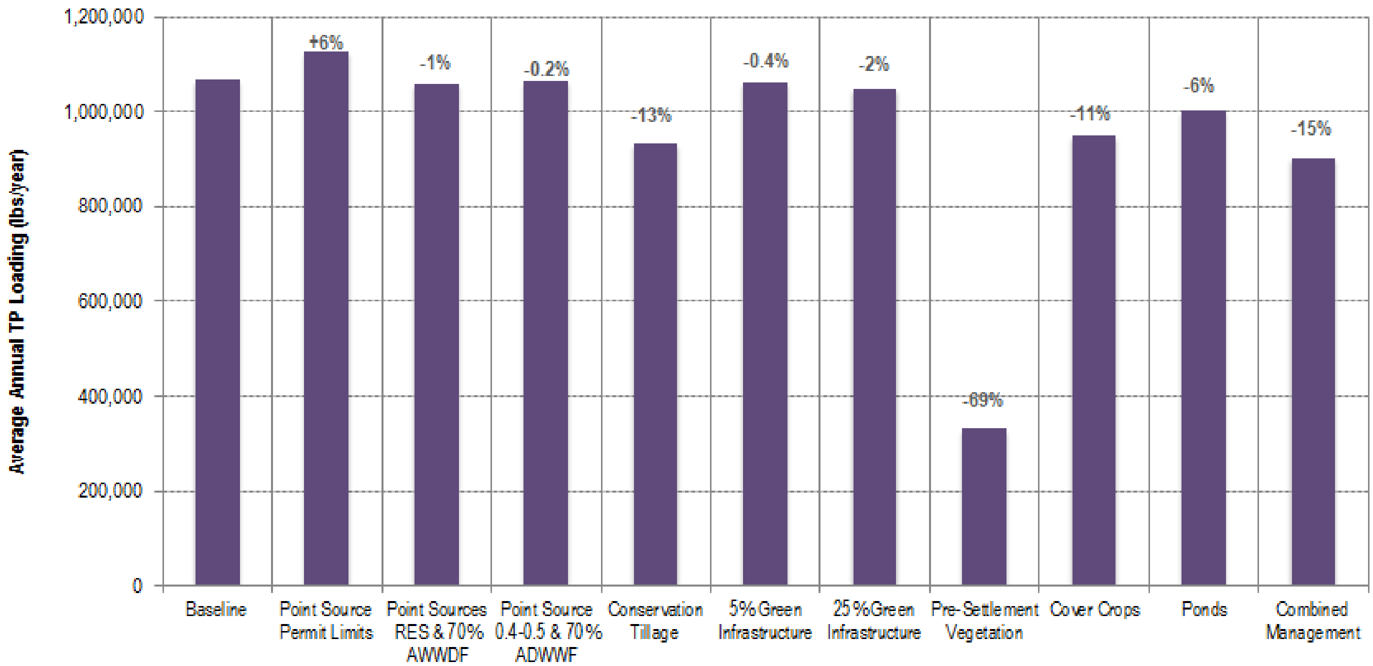
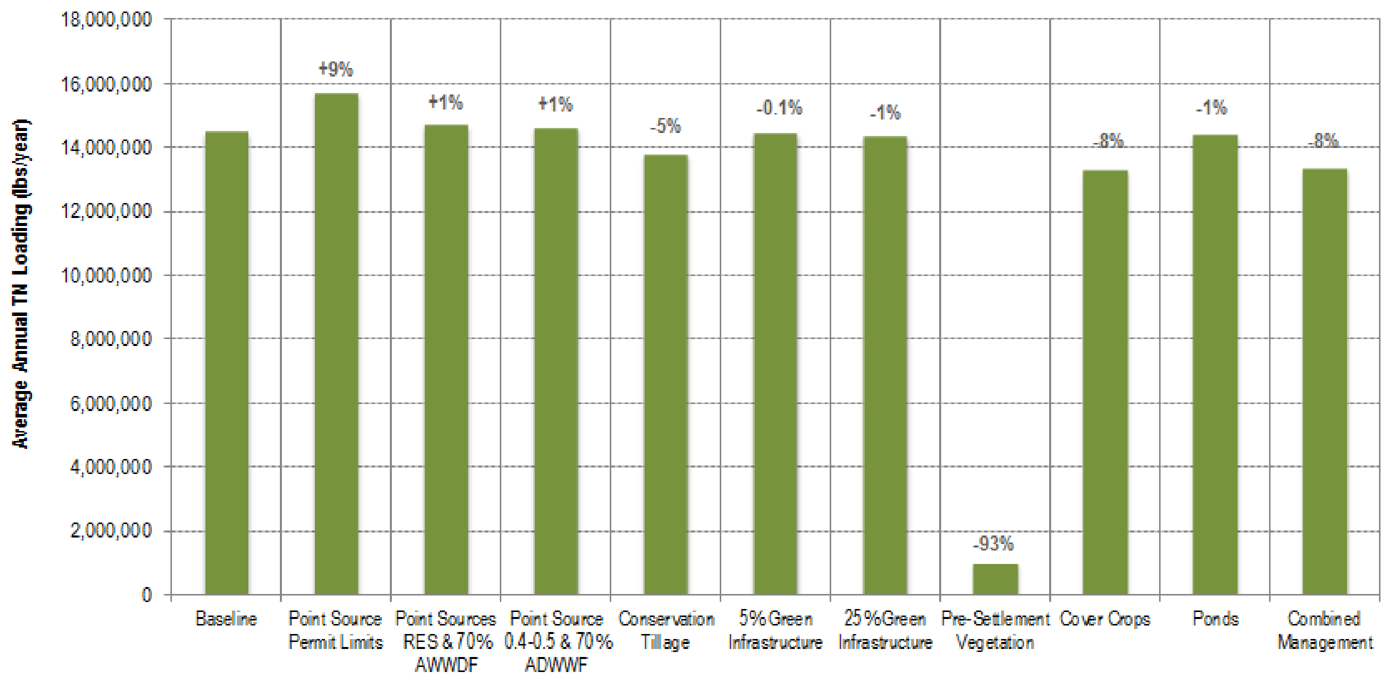


Table 4: Nitrogen load reductions for HSPF scenarios. Data correspond to averages of modeled period between 1996 and 2009. (Figure produced by LimnoTech.)



Appendix E: Methodology for TNC protection prioritization

Zumbro River Priority Mapping methodology

Kristen Blann, March 18, 2016

Habitat Quality:

These layers were selected to rate LEVEL 8 DNR subwatersheds based on the presence and abundance of features likely to be a focus of multi-benefit protection efforts.

MBS Biodiversity Significance:

- A raster was created scoring cells of "Outstanding" biodiversity significance 4 points, "High" 3 points, "moderate" 2 points, and "Below" 1 point. All "No Data" areas were 0 points. The zonal mean for each LEVEL 8 DNR subwatershed was calculated and scores were standardized to 10 points by dividing each subwatershed by the max score and multiplying by 10.

Public Ownership:

- Total area of public and conservation land in each subwatershed was calculated. Scores were standardized to 10 points as follows: Less than 1%: 0 points; 1% to 3%=2 points; 3% to 5%=4 points, 5% to 10% acres=7 points, more than 10%=10 points. [selection of these thresholds was based on rounding of quintiles]

Fish IBI Thresholds:

- Monitoring stations reporting values within the MPCA's confidence interval of relevant fish IBI impairment thresholds were given the following points:
    - Above threshold, and above CI: 8 Points
    - Above threshold, but within CI: 10 Points
    - Below threshold, and within half of the CI: 4 points
    - More than half the CI below threshold, within one CI: 2 points

Perennial Cover in Critical Areas:

- Overlapped NLCD 2011 land cover data and the EBI Water Quality layer to pick out areas scoring over 60 in the EBI data for their impact on water quality that were mapped as having perennial land cover in the NLCD data. The total area in each LEVEL 8 DNR was calculated and standardized to 10 points.

EBI Habitat Quality Layer:

- The zonal mean of each subwatershed was calculated for the EBI Habitat Quality layer. Subwatersheds were then classified into quintiles, with the top quintile receiving 10 points, the 2^{nd} highest 8 points, the third highest 6, etc. For this version, I just standardized to 10 points, so it is scored on continuous scale.

Conversion Risk:

Layers measuring the risk of conversion from perennial cover to row crops, as well as risk of more intensive development were created by Kristen Blann, aquatic ecologist with TNC. Ag conversion risk is raster data on a 1 to 100 scale. The zonal mean for each subwatershed was. For urban conversion risk, the percent of the watershed expected to be urban (new + existing urban cover) in the “future worst case” scenario is calculated and standardized to a 10 point scale.

Watershed Health Assessment Framework (WHAF):

A subset of the layers available from the WHAF was also included in the analysis (all scores standardized to 10 points for each LEVEL 8 DNR for each of the main categories below):

- Hydrology index
  - Perennial cover index (2011)
  - Impervious cover index (2011)
  - Water withdrawal, predicted vulnerability (H_I_WW_PV)
  - Loss of hydrologic storage (H_I_LHS)
    - Storage, straightened-meandering stream ratio index (altered watercourse) (H_M_LHS_AW)
    - Wetland loss (H_M_LHS_WL)
- Biology metrics
  - Aquatic invertebrate IBI
  - Fish IBI
  - Mussel score
- Geomorphology
  - Erosivity and erodibility (correlated with Fish IBI in multivariate analysis, so I decided to include it)
- Connectivity index
  - Riparian connectivity
  - Aquatic connectivity
- WQ Metric
  - Nonpoint sources: phosphorus risk
  - Point source Index
    - Wastewater treatment plants
    - Superfund sites
    - Septic systems
    - Potential contaminants
    - AUs
    - OPC

Combined Scores:

Final scores for each subwatershed were calculated by taking the sum of the average component score within each scoring category (Protection Value, Conversion Risk, and WHAF Metrics). Since each component within the categories had a max score of 10, this resulted in combined scores for each LEVEL 8 DNR having a max of 30. Each subwatershed was then ranked by percentile. The map shows those subwatersheds that scored in the top four deciles (60th percentile and above).

I did two scores: one that was a "QUALITY" score based on summing the Habitat Quality and WHAF modules, and a COMBINED score that incorporates risk.

Appendix F: Summary of stressors

Stream Name	AUID	Biological Impairment	Stressors						
			Temperature	Dissolved Oxygen and Eutrophication	Nitrate	Total Suspended Solids	Lack of Habitat	Flow Alteration/Connectivity	Chloride/Conductivity
Spring Creek	07040004-568	Inverts	●	---	o	●	---	---	---
Spring Creek	07040004-570	Fish	---	---	o	●	●	---	---
Cold Creek	07040004-510	Inverts	---	---	o	---	●	---	---
Trout Brook (Mazeppa Creek)	07040004-515	Inverts	---	---	o	---	●	o	---
Trout Brook (Dumfries)	07040004-585	Fish	---	---	---	---	●	o	---
Unnamed creek	07040004-964	Inverts	---	o	●	---	●	o	---
Unnamed creek (Spring Creek Tributary)	07040004-605	Inverts	---	---	●	o		---	---
Spring Creek	07040004-606	Inverts	---	●	●	---	●	---	---
Shingle Creek	07040004-562	Inverts	---	---	●	o		---	---
Unnamed Creek	07040004-579	Inverts	---	---	---	---	●	---	---
North Fork Zumbro	07040004-971	Inverts	---	o	o	●	●	---	---
Unnamed Creek	07040004-578	Inverts	---	---	●	o	●	●	---
Middle Fork	07040004-973	Inverts	---	---	●	o	---	---	---
Dodge Center Creek	07040004-989	Inverts	---	---	o	●	●	o	---
Henslin Creek	07040004-618	Inverts	---	---	●	o	---	---	---
Judicial Ditch 1	07040004-987	Inverts	---	●	●	o	●	●	---
Judicial Ditch 1	07040004-988	Fish and Inverts	---	o	●	o	●	●	---
South Branch Middle Fork	07040004-976	Inverts	---	---	o	●	---	---	---

Stream Name	AUID	Biological Impairment	Stressors						
			Temperature	Dissolved Oxygen and Eutrophication	Nitrate	Total Suspended Solids	Lack of Habitat	Flow Alteration/Connectivity	Chloride/Conductivity
South Branch Middle Fork	07040004-980	Inverts	---	---	o	●	●	●	---
Salem Creek	07040004-503	Inverts	---	---	●	---	●	---	---
Salem Creek Trib	07040004-597	Fish and Inverts	---	o	●	o	●	●	---
Unnamed Creek (Trib to Willow)	07040004-800	Fish and Inverts	---	---	---	---	●	●	---
Badger Run	07040004-620	Fish	---	---	---	o	●	●	---
Unnamed Creek	07040004-621	Fish	---	---	---	---	●	●	---
South Fork Zumbro	07040004-507	Inverts	---	o	o	●	●	●	o
South Fork Zumbro	07040004-536	Inverts	---	---	---	o	●	---	---
Cascade Creek	07040004-581	Inverts	---	o	---	●	●	●	---
Cascade Creek	07040004-991	Fish	---	---	o	o	●	●	---
● = stressor; o = inconclusive stressor; --- = not a stressor									

Appendix G: Description of Prioritization Approach and Zonation Methods

By Paul J. Radomski and Kristin Carlson

Prioritization Overview

As threats to Minnesota's watersheds continue to mount, it is becoming increasingly important to identify and conserve high-priority areas. There are multiple opportunities for protection or restoration in any watershed. Identifying which practices to implement and where in the landscape to implement them can help more effectively target efforts and more efficiently utilize limited resources. A number of information technology tools are available for prioritizing and targeting land for restoration and protection efforts within a watershed.

A systematic approach aimed at optimizing environmental benefits while reducing interference between competing land uses will be critical. Two of the most common approaches for conservation prioritization are system-based models and value-based models. One of the major strengths of system-based models is that they require us to think deeply about a system by writing down our mental models of how we believe the system functions. For many watersheds, this has been done using the HSPF hydrologic system model, which simulates watershed hydrology and water quality at the catchment scale. However, we often do not have system models that can accurately identify where in the watershed specific good management practices should be applied or that have the ability to simulate alternative land management actions and predict consequences at specific locations in the watershed.

Values-based models use a compilation of individual criteria of valuable landscape features (heterogeneous content) and aggregated criteria (context and connections) with an objective function to prioritize places within the landscape for conservation. Although there are some shortcomings of using value models over system models (value models only allow exploration of tradeoffs and optimization, and they do not provide guidance on what practices should be implemented where), the use of value models is an efficient method for prioritizing places for protection or restoration.

The values-based model prioritization approach we used is based on fundamental conservation principles, including content, context, heterogeneity, and connectivity. We used the DNR's five-component healthy watershed conceptual model to facilitate an organized process to assess and review watershed problems and solutions. The five components are: biology, hydrology, water quality, geomorphology, and connectivity. This approach recognizes that attempts to solve our clean water needs are not separate from our other conservation needs; each conservation activity should provide multiple benefits. Value models help achieve this multiple benefits goal by identifying areas that optimize benefits by accounting for what the community values. The use of an additive benefits objective function in the value model allows for the retention of high quality occurrences of as many conservation features as possible. Value models also can be used in a public participation process, whereby participants can decide on what features are valued and the ranking of those valued features. Addressing conservation goals effectively necessitates a collaborative approach, and value-based models provide a structure for collaborative efforts. In addition, value models and the five-component conceptual model used to structure the content in the value models are simple concepts that are easy to explain and apply at the local government scale.

Methods

The value models were developed using Zonation software (Moilanen et al. 2009). Zonation produces a nested hierarchy of conservation priorities. It begins with the full landscape and iteratively removes parcels (cells) that contribute least to conservation; therefore, the removal order is the reverse order of the priority ranking for conservation. Zonation assumes that the full watershed is available for conservation. In our models, the lakes were masked out prior to analysis. This focused the prioritization on the terrestrial parcels, in accordance with the conservation and restoration goals of our partners. Zonation's algorithms seek maximal retention of weighted normalized conservation features.

Weights are used to influence which features are valued more. Within the five-component healthy watershed framework, for example, water quality conservation features could be weighted higher than biological features. The feature-specific weights used in the value models reflect social valuation, and they were set using the analytic hierarchy process (AHP; Saaty and Peniwati 2007). A survey comprised of pairwise comparisons was used to solicit the preferences of individuals. Features used in the comparison were based loosely on the DNR's five-component healthy watershed approach, with the addition of alternative land uses or economic features representing a social component. The pairwise survey was structured to gather value preferences for an overall conservation strategy. Each individual taking the survey used his or her judgment about the relative importance of all elements at each level of the hierarchy. The relative importance values included "equal," "prefer," and "strongly prefer." The use of abbreviated pairwise importance values helped reduce the cognitive burdens associated with a large number of pairwise comparisons. Individual responses were aggregated with a geometric mean, and the pairwise comparison matrix was constructed to compute the feature-specific weights consistent with the AHP. The survey was administered to participants of the 19 March 2016 Zumbro River WRAPS Kick-off Meeting (N=26), to attendees of the 07 June 2016 Meeting (N=27), and to member of the interested public (N=35).

There are three commonly definable objective functions possible in Zonation: core area, target-based planning, and additive benefit functions. The core area objective function aims to retain high-quality occurrences of each feature. This function is most appropriate when there is a definite set of conservation features and all of them are to be conserved. The target-based planning objective function is a prescriptive approach where requirements are specified *a priori* for each feature. This function produces a minimum set coverage solution, and is most appropriate when a defined proportion of the watershed is assigned for conservation.

We used the additive benefit function variant of Zonation, which aggregates values by summation across features:

$$V(P) = \Sigma w_j N_j(P)^{z_j}$$

where the value of a parcel *V(P)* is equal to the summation of weighted *w* normalized conservation features of the parcel $N_j(P)$ to the power of *z* (set to 0.25 for all features).

The conservation features used in the analysis are found in Table 1, and each layer was on the same grid with a resolution of 30 by 30m. We used high-resolution data to maximize conservation planning realism and for greater practicality in local government conservation planning and implementation.

The additive benefit function is appropriate when tradeoffs between conservation features are allowed. Zonation allows ranking to be influenced by neighboring parcels, so that highly valued areas can be aggregated. This minimizes fragmentation of conservation within the landscape. We utilized the distribution-smoothing algorithm in Zonation, which uses an aggregation kernel a parameter. Using this algorithm assumes that fragmentation (low connectivity) generally should be avoided for all conservation features. The connectivity distance can be conservation feature-specific. Initial analyses indicate that an aggregation kernel a of 0.01, which corresponds to a connectivity distance of 200m, may be appropriate for conservation efforts targeted at the watershed scale. We found that very small connectivity distances made no difference in parcel prioritization, since the connectivity effect did not extend very far into neighboring parcels, and very large connectivity distances aggregated parcels across unrealistically large areas. We also found that across a modest range of connectivity distances the results were minor.

As a final step, meeting participants provided input on two prioritization-related efforts. First, participants reviewed and provided feedback on a suite of potential priority areas. From this feedback, a final set of priority areas was selected. Second, a survey was used to solicit the preferences of individuals about the types of watershed protection and restoration activities that they would like to see implemented. The survey was administered to participants of various meetings (N = 88).

Results

The pairwise questionnaire survey results identified the shoreland and riparian area component of the value model inputs as the highest weight, followed by the reduction of erosion and runoff component (Figure 1 and Table 2). .

A priority map was created with the Zonation value model. The map represents a priority map where lands were ranked as to their importance for application of various land best management practices (Figure 2), and this map is broken into the three lobes (Figures 3a-c).

The conservation priority map from the Zonation analysis identified at four general areas for consideration. First, high rankings were evident in the Lower Lobe associated with trout stream riparian areas and in areas with high-channelized flow erosive potential (Figure 2a & 3a). High priority areas were also identified around Rice Lake (Figure 2b & 3b). The catchment lands downstream of Lake Zumbro were generally high priority (Figure 2c & 3c), as were the lands overlaying the groundwater resources critical to the city of Rochester (Figure 2c & 3c). Participants in the various WRAPS meetings supported these four priority areas for inclusion into the plan with the suggestion to focus restoration and protection activities within these areas for the next 10 years (Figure 4).

Protecting and restoring wetlands, implementing best management practices on agricultural and developed lands, and protecting and restoring riparian vegetation were the activities that participants identified as most important for this watershed (Table 3, Figure 5). The following activities were also regarded as critical: improving technical assistance & incentive programs, and improving education, outreach and civic engagement. Activities with the lowest preference included protecting areas with acquisition or easement.

References

Moilanen, A., H. Kujala, and J. Leathwick. 2009. The Zonation framework and software for conservation prioritization. Pages 196-210 in A. Moilanen, K. A. Wilson, and H. P. Possingham, editors. Spatial conservation prioritization: quantitative methods and computational tools. Oxford University Press, Oxford, UK.

Saaty, T.L., and K. Peniwati. 2007. Group decision-making: Drawing out and reconciling differences. Pittsburgh, PA: RWS Publications.

Table 1. Variable descriptions for content used in land prioritization value models.

Objective	**Description**
Protect or Improve Waters of Concern [Water Quality]	
Focus on Groundwater contamination susceptibility	The relative susceptibility of an area to groundwater contamination (based on geologic stratigraphy, aquifer transmissivity, and recharge potential). Based on analysis from the Pollution Control Agency (PCA).
Focus on Drinking Water Supply Management Area (DWSMA) vulnerability for Municipalities	The risk associated with potential contaminant sources within a public water supply DWSMA to contaminate its drinking water supply. This risk is based on the aquifer's inherent geologic sensitivity, the assessed vulnerability of the public water supply well(s), and the composition of the groundwater. In highly vulnerable DWSMAs, there is a strong causal relationship between land use activities on the surface and groundwater quality. Information from the Minnesota Department of Health (MDH).
Focus on Groundwater at greatest risk to nitrate contamination	Areas with relatively high, moderate, and low probability of having elevated nitrate concentrations in groundwater. Nitrate probability ranking was determined based on land use and hydrogeologic sensitivity. Information from MDH.
Focus on Impaired waters	Catchments (i.e., drainage basins) upstream of aquatic life impaired lakes within the watershed. Identified as impaired by the Minnesota PCA.
Focus on Catchments with high pollution	Estimated total suspended solids, total nitrogen, and total phosphorus by catchment as determined by the HSPF hydrological model.
Reduce Erosion & Runoff	
Focus on Areas with high erosive potential	Stream Power index: This is an index of the channelized flow erosive potential. This variable is from the BWSR and UMN's Environmental Benefits Index. [or use Highly Erodible Area as determined by DNR analysis]

Protect or Restore Bluffs and steep slopes	Bluffs or steep slopes. Based on analysis from the DNR or calculated from LiDAR data.
Protect Existing wetlands	Remaining wetlands as documented by the National Wetland Inventory (NWI).
Protect or Restore Stream floodplains	Stream potential flood zones (based on location, elevation and soil type). Based on floodplain analyses from the DNR.
Reduce Soil erosion risk	Susceptibility of soils to erosion. This variable is from the BWSR and UMN's Environmental Benefits Index; it was calculated from a subset of the universal soil loss equation.

Protect or Improve Fish & Wildlife Habitat	
Protect Rare plants or animals	Locations of species currently tracked by the MDNR, including Endangered, Threatened, and Special Concern plant and animal species as well as animal aggregation sites.
Protect Sites of biodiversity significance and Native prairies	Areas with varying levels of native biodiversity that may contain high quality native plant communities, native prairies, rare plants, rare animals, and/or animal aggregations. Identified by Minnesota Biological Survey.
Protect or Restore Lakes of biological significance	Catchments of high quality lakes. MDNR list of high quality lakes based on dedicated biological sampling.
Protect High value forests	MDNR designated high conservation value forests due to plant and animals present and MDNR designed old-growth forests.
Protect or Restore Trout stream catchments	Catchments of MDNR designated trout streams.
Protect or Restore Ecological corridors	Ecological corridors between generally large, intact, native or "semi-natural" terrestrial habitat patches.

Protect or Restore Lake Shoreland and Stream Buffers	
Protect or Restore Stream buffers	Land within 50 feet of stream or river.
Protect or Restore Shoreland	Land within 1000 feet of lake shoreline.

Protect or Restore Lands of Concern	
Restore Pasture/hay	Land cover type is pasture or hay (areas used for livestock grazing or planted with perennial seed or hay crops).
Restore Cultivated croplands	Land cover type is cultivated crops (areas used for the production of annual crops or actively tilled areas).
Restore Specific Land capability class lands	This classification shows, in a general way, the suitability of soils for most kinds of field crops. Classes 4-8 have serious limitations for agriculture, and are used to identify areas for potential conservation investment in prairie or forest management (classification from NRCS).
Protect Valuable timber lands	Forest lands that have been identified by forestry managers as important.
Protect Undeveloped lands in high growth areas	Lands close to existing development may be more likely to be developed, and some of these lands that provide important ecosystem services may be of conservation value.

Table 2. Broad-scale and fine-scale weights used in the value models from a questionnaire using the analytic hierarchy process (AHP; weights sum to 100).

Broad-Scale Prioritization	AHP Derived Weight	Weight Used in Model
Protect/Improve Waters of Concern	19.1	
Reduce Erosion & Runoff	26.4	
Protect/Improve Fish & Wildlife Habitat	18.3	
Protect/Restore Shoreland & Buffers	19.9	
Protect/Improve Lands of Concern	16.4	
Fine-scale Prioritization		
Drink Water	17	3.2
Impaired waters	17	3.2
Groundwater nitrate risk	17	3.2
Groundwater Contamination Susceptibility	17	3.2
Catchments of lakes vulnerable to nutrient loading	17	3.2
Catchments with higher pollution	17	3.2
Areas with high erosive potential	20	5.3
Bluffs and steep slopes	20	5.3
Existing wetlands	20	5.3
Stream floodplains	20	5.3
Soil erosion risk	20	5.3
Rare features	17	3.0
Sites of biodiversity significance	17	3.0
Lakes of Biological Significance	17	3.0
High value forests	17	3.0
Trout stream catchments	17	3.0
Ecological corridors	17	3.0
Stream buffers	50	9.9
Lake shorelands	50	9.9
Valuable timber lands	20	3.3
Undeveloped lands in high growth areas	20	3.3
BMPs on Pasture/hay lands	20	3.3
BMPs on Cultivated croplands	20	3.3
Land capability 4-8 classes	20	3.3

Table 3. The list of activity descriptions used in a survey on individual preferences on protection and restoration activities for the Cannon River Watershed.

Activity	Description
Protect or Restore **Riparian Vegetation**	Activities include use of zoning to protect lake and stream vegetation buffers, incentive programs to promote protection and restoration of buffers, and tree and shrub plantings along shores.
Protect or Restore **Permanent Vegetation on Marginal Lands**	Activities include the protection of natural vegetation on lands that have serious limitations for agriculture, restoration of disturbed lands by planting natural vegetation, and planting of tree and shrubs where appropriate.
Protect or Restore **Wetlands**	Activities include use of wetland rules to protect existing wetlands as well as programs to restore drained wetlands.
Implement **Best Management Practices (BMPs) on Developed Lands**	Activities may include use of advanced runoff water and wastewater management techniques in urban areas. Other BMPs may also include re-establishment of native vegetation to reduce impacts of runoff on watershed hydrology.
Implement **Best Management Practices (BMPs) on Agricultural Lands**	Activities may include use of advanced runoff water and nutrient management techniques on farmed lands. Other BMPs may also include re-establishment of native vegetation to reduce impacts of runoff on watershed hydrology.
Protect **Areas with Conservation Easements**	Use of a set of restrictions a landowner voluntarily places on his or her property in order to preserve its conservation values. A conservation easement is conveyed to a government agency or nonprofit conservation organization qualified to hold and enforce easements. Most conservation easements are perpetual.
Protect **Areas by Acquisitions**	Purchase by government or nonprofit organization to protect outstanding natural resource areas for public use and protection.

Improve **Education, Outreach, & Civic Engagement**	Providing education about critical land and water conservation approaches to the public, and working collaboratively with citizens to address existing and emerging conservation issues.
Improve **Technical Assistance & Incentive Programs**	Providing technical assistance to citizens on projects and best management practices, as well as assisting in the administration of various cost share programs that protect or restore landscape health and water quality.

Figure 1. The broad-scale weights used in the value models from a questionnaire using the analytic hierarchy process (AHP; weights sum to 100).

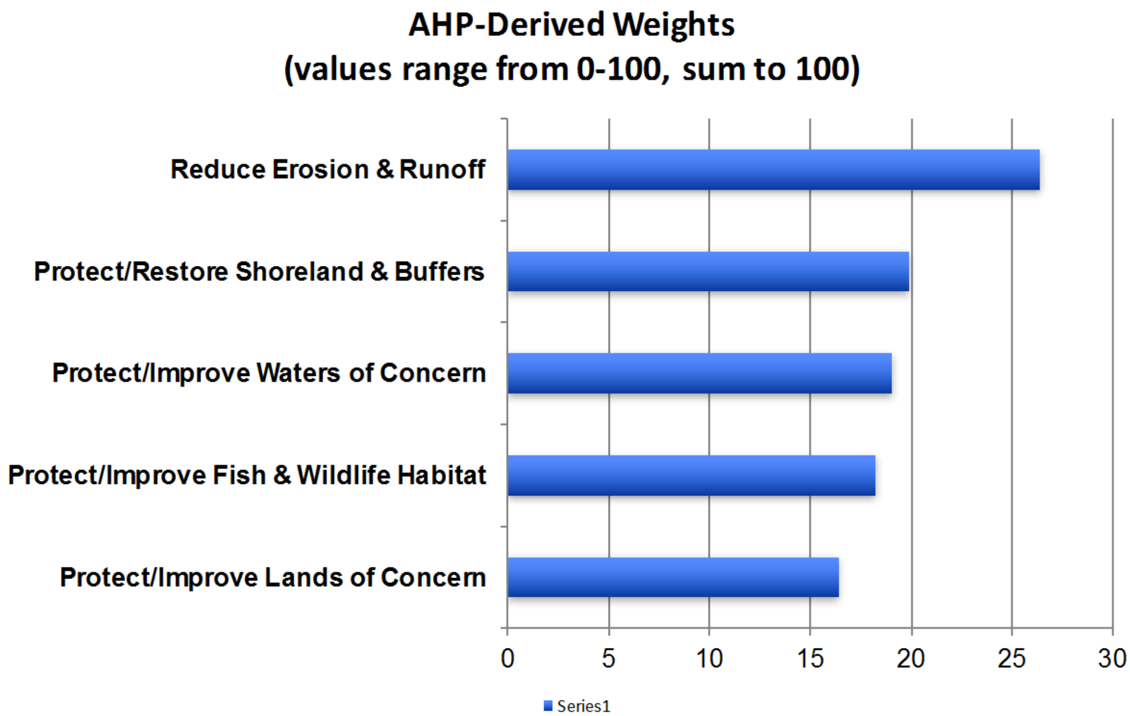


Figure 2. Priority map from Zonation analysis.

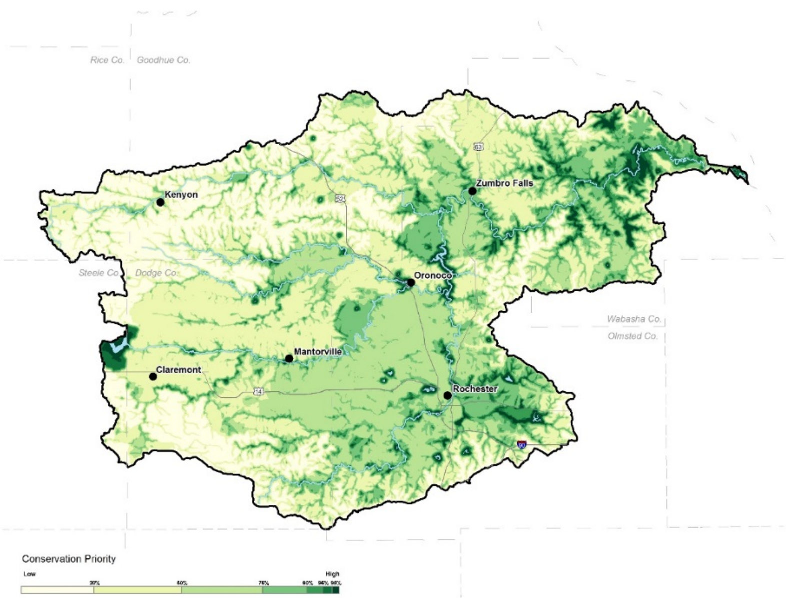


Figure 2a. Priority map from Zonation analysis – Lower Lobe.

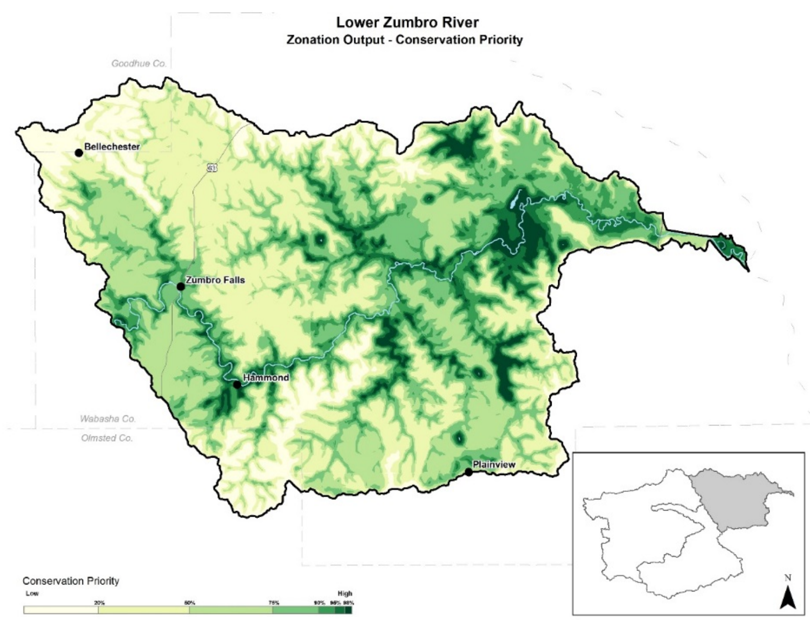


Figure 2b. Priority map from Zonation analysis – Middle Lobe.

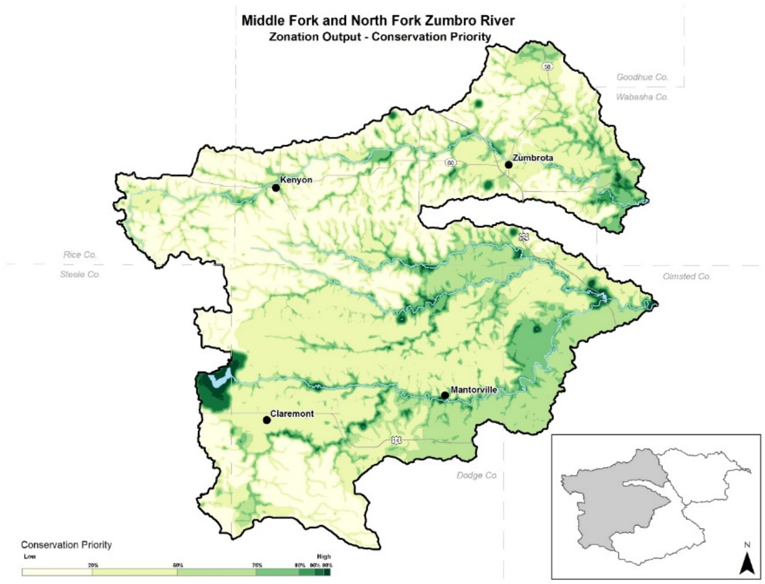


Figure 2c. Priority map from Zonation analysis – Lake Zumbro & S. Fork Lobe.

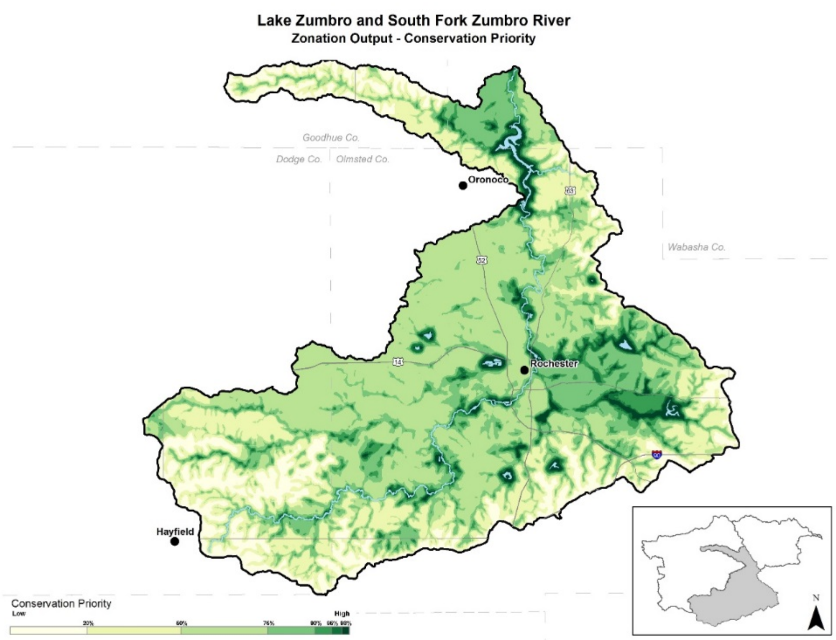


Figure 3. Priority map from Zonation analysis and land cover.

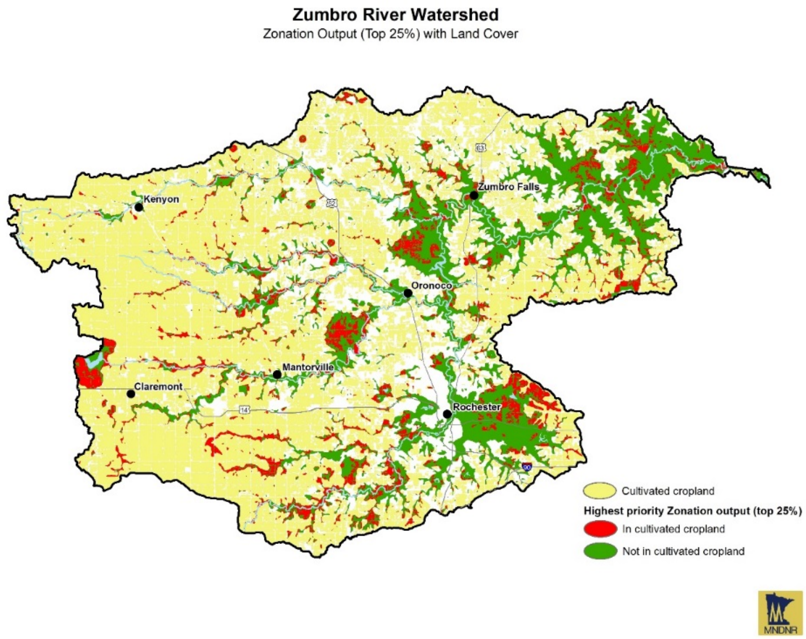


Figure 3a. Restoration priority map from Zonation and land use – Lower Lobe.

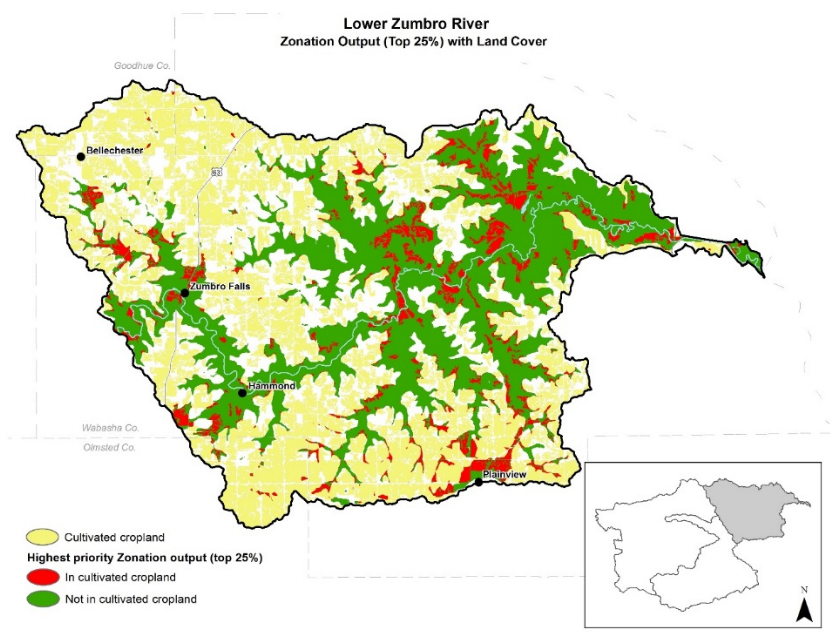


Figure 3b. Restoration priority map from Zonation and land use – Middle Lobe.

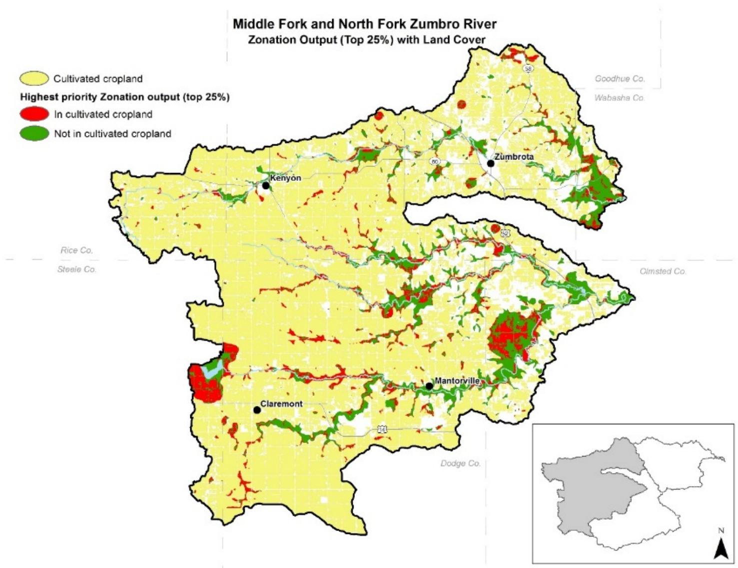


Figure 3c. Restoration priority map from Zonation and land use – Lake Zumbro and S. Fork Lobe.

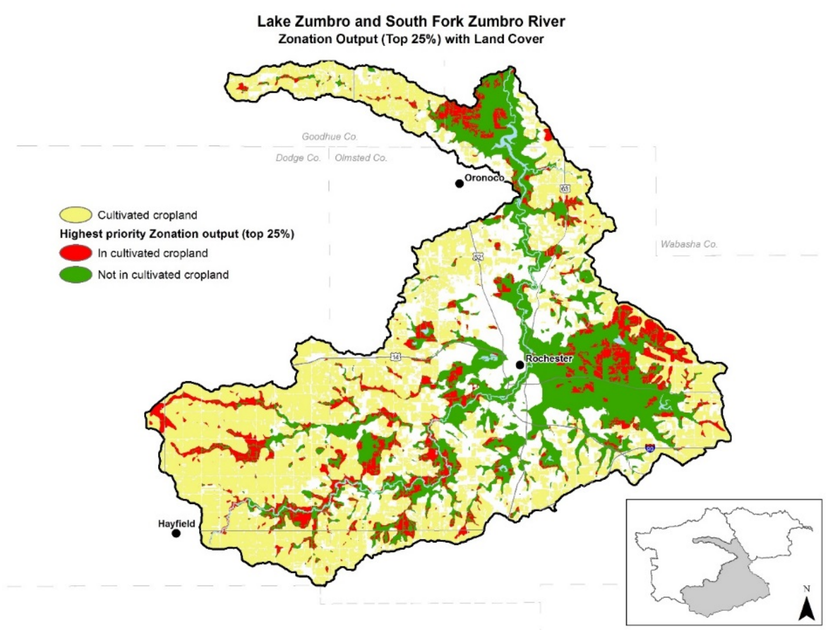


Figure 4. Priority areas identified for the Zumbro River Watershed. Red areas are priority areas. Base map is conservation priority map from Zonation analysis.

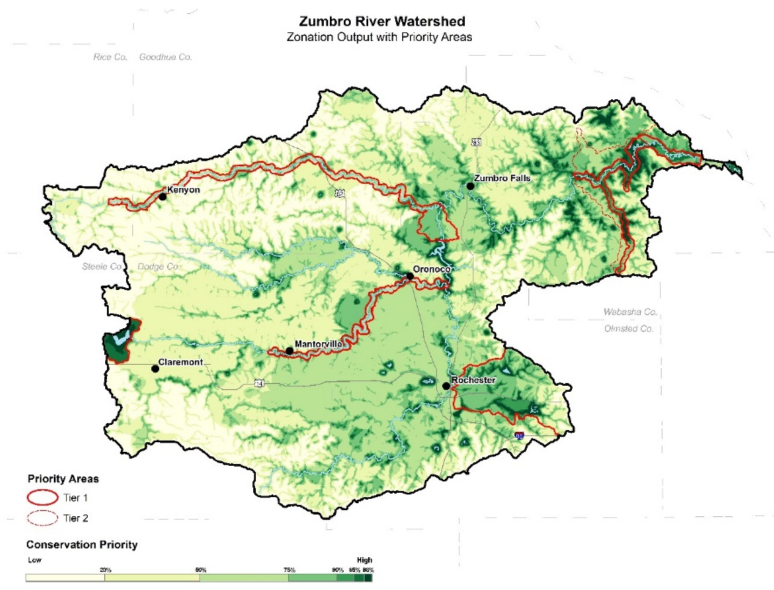


Figure 4a. Dodge County Priority Areas with Zonation Output

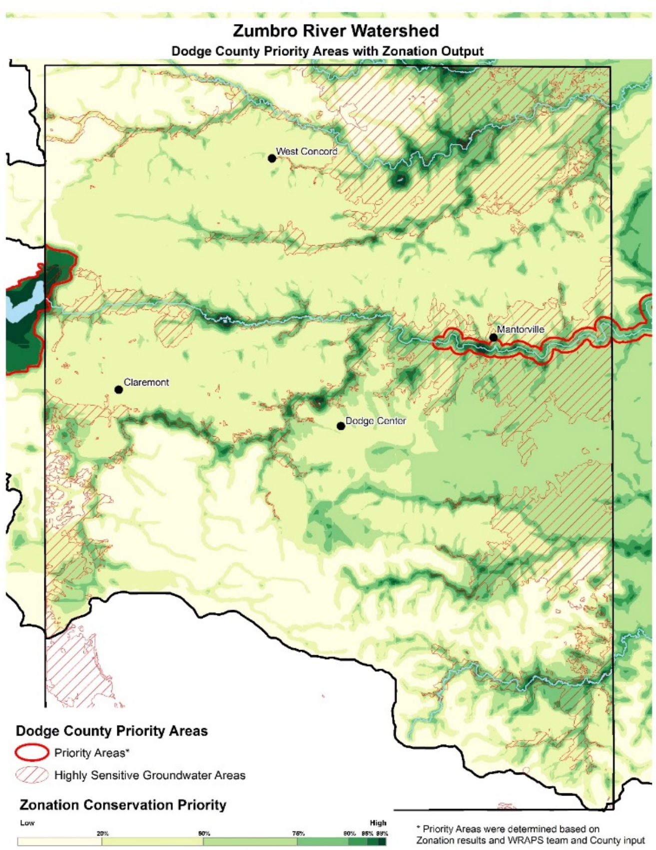
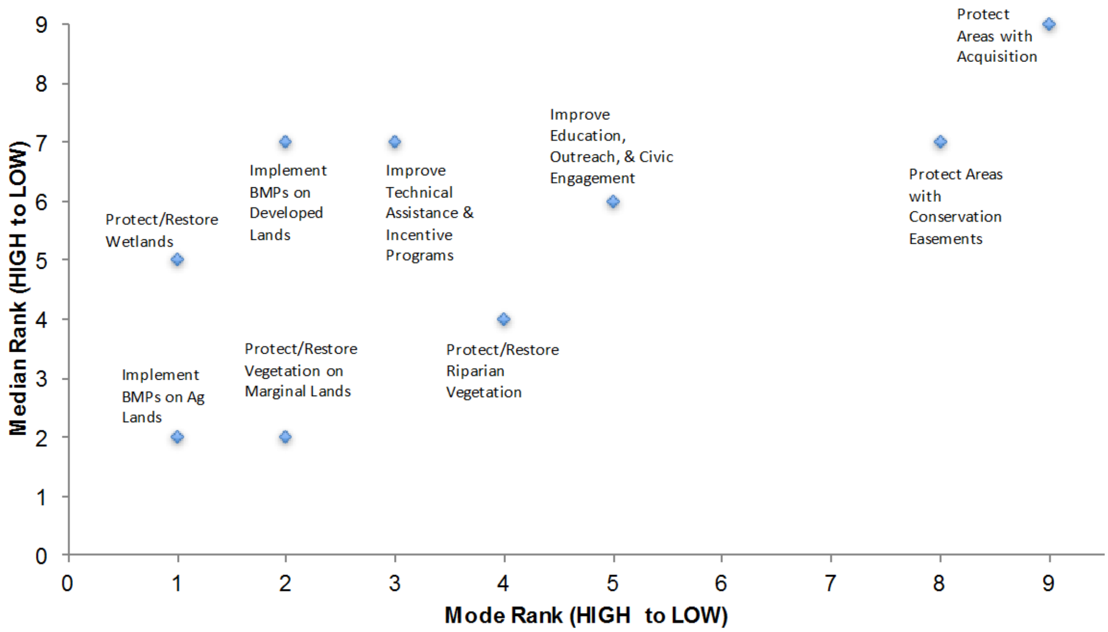


Figure 5. Survey results from the activities survey. The modes of ranks and effort are presented (N = 88 participants).



Appendix H: DNR Summary Documents

Department of Natural Resources Priority Areas for Protection and Restoration in the ZRW (supporting information for the lists and maps included in 3.1).

PROTECTON SUMMARY			
Strategy #	**Subwatershed**	**Issue**	**Action**
1	Mazeppa Creek	Groundwater protection where surface water sinks occur	Zoning; surface water runoff management
5	City of Concord	Groundwater protection	Springshed mapping by DNR groundwater hydrologist
6	North Fork	Biodiversity protection	Acquisition, easements, private lands programs
7	Harcom Creek	Groundwater protection	Springshed mapping by DNR groundwater hydrologist
8	Harcom Creek	Biodiversity protection	Acquisition, easements, private lands programs
10	North Branch Middle Fork	Groundwater protection	Springshed mapping by DNR groundwater hydrologist
11	North Branch Middle Fork	Biodiversity protection	Acquisition, easements, private lands programs
12	Rice Lake	Nutrient levels	Improve the carp barrier to prevent immigration
17	City of Rochester	Groundwater protection	Springshed mapping by DNR groundwater hydrologist
21	South Fork	Groundwater protection where surface water sinks occur	Zoning; surface water runoff management
23	City of Zumbro Falls	Forest/riparian Habitat Quality	Acquisition, easements, private lands forestry
25	Dry Run Creek	Riparian/shoreland habitat quality	Acquisition, easements, private lands programs
26	Long Creek	Forest/riparian Habitat Quality	Acquisition, easements, private lands forestry
28	Spring Creek	Forest/riparian Habitat Quality	Acquisition, easements, private lands forestry
29	West Albany Creek	Surface water sinks	Zoning; surface water runoff management
31	Lake Zumbro	Surface water sinks	Zoning; surface water runoff management

RESTORATION SUMMARY			
Strategy #	**Subwatershed**	**Issue**	**Action**
2	Mazeppa Creek	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
3	Mazeppa Creek	Poor channel stability	Purchase easements; implement channel restoration
4	North Fork	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
9	North Branch Middle Fork	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
13	Masten Creek	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
14	South Branch Middle Fork	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
15	South Branch Middle Fork	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
16	City of Rochester	Poor aquatic habitat and connectivity	Work with City of Rochester and Army Corps of Engineers to improve habitat and connectivity
18	Salem Creek	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
19	South Fork	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
20	South Fork	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
22	South Fork	High sediment loading; poor habitat quality	Restore floodplain connectivity and habitat
24	Cold Spring Brook	High bedload and channel sediment loading	Restore floodplain connectivity
30	West Indian Creek	Poor aquatic habitat; high sediment loading	Restore floodplain connectivity and habitat

TECHNICAL GUIDANCE SUMMARY			
Strategy #	**Subwatershed**	**Issue**	**Action**
27	Spring Creek	Altered hydrology; high sediment loading	DNR clean water staff conducts an assessment of channel stability and sediment supply.

Zumbro River Watershed – An Ecological Inventory

Prepared by: Kristopher Hennig, Assistant Regional Ecologist R3

Summary: The ZRW is in the Eastern Broadleaf Forest ecological province and spans three ecological subsections including Oak Savanna, the Rochester Plateau, and the Blufflands. Terrain to the west is a level to gently rolling plain of loess-mantled ridges that grades eastward into a highly variable, loess-capped plateau, deeply dissected by river valleys. Topography has played a large role in the extent and variability of historic vegetation cover by limiting or promoting the spread of fire. Tallgrass prairies and bur oak savannas dominated in the relatively level landscape of the Oak Savanna and Rochester Plateau subsection where fire more easily spread (Minnesota Department of Natural Resources 2005a, 2005b). In contrast, the heterogeneity of the landscape in the Blufflands to the east resulted in more prairie and savanna communities on ridge tops and dry upper slopes, while mixed hardwood and floodplain forests persisted on moister slopes or valleys protected from fire (Minnesota Department of Natural Resources 2005c). Land use today is mostly agricultural, particularly in the western half of the watershed.

Native Plant Communities: Native plant communities (NPCs) are relatively undisturbed associations of plants that tend to occur together across the landscape in response to similar soil, moisture, light, and disturbance requirements (Minnesota Department of Natural Resources 2005d). NPCs provide a variety of functions that affect humans and the environment alike including water filtration, flood attenuation, carbon storage, erosion control, and habitat for thousands wildlife and plant species (Minnesota Department of Natural Resources 2016a). NPC types and subtypes in Minnesota have been assigned a conservation status rank (S-rank) that reflects the risk of elimination of the community from the State (Minnesota Department of Natural Resources 2009).

There are 49 recognized NPC types/subtypes that are recognized as occurring within the ZRW (Table 1), over half which are considered by the MNDNR to be "Critically Imperiled" (S1), "Critically Imperiled to Imperiled" (S1S2), "Imperiled" (S2), or "Vulnerable to Extirpation" (S3) (Table 1). More common NPC types/subtypes may also be classified as "Apparently Secure; Uncommon but not Rare" (S4) or "Secure, Common, Widespread, and Abundant" (S5) (Minnesota Department of Natural Resources 2009). Of the forty-nine NPCs, seventeen are associated with wet habitats or water features.

> Calcareous Fens: Calcareous fens are one of the rarest NPCs in the United States. In Minnesota, only 219 calcareous fens have been identified, thirteen of which occur in the ZRW. Most occupy no more than a few acres in extent. They are characterized by "a substrate of non-acidic peat and dependent on a continuous supply of cold, oxygen-poor groundwater rich in calcium and magnesium bicarbonates" (Minnesota Department of Natural Resources 2015a). This calcium-rich habitat supports a community of plants dominated by calcium-loving species. Eight state-listed, rare plant species are known from calcareous fens, including four that occur in the ZRW. These communities are highly vulnerable to disturbances. For instance, reductions in the normal groundwater supply can oxidize the surface peat which may promote shrub and tall, coarse vegetation growth that displaces the fen community. Similarly, nitrogen-rich surface water may promote invasion by aggressive exotic plants and flooding will drown the community (Minnesota Department of Natural Resources 2015a). Due to their rarity and vulnerability calcareous fens are a specially protected resource in Minnesota (Minnesota Wetlands

Conservation Act, Minnesota Statutes, section 103G.222 - .2373 and Minnesota Rules, chapter 8420)(Minnesota Department of Natural Resources 2015a).

Sites of Biodiversity Significance: The Minnesota Biological Survey assigns biodiversity significance ranks that indicate the statewide importance of the sites for native biological diversity. These rankings are assigned to a site based on the presence and abundance of rare species, the size and condition of NPCs, and the size and/or intactness of a landscape (Minnesota Department of Natural Resources n.d., Minnesota County Biological Survey and Minnesota Department of Natural Resources 2009). Within the ZRW, twenty-one sites covering approximately 4,800 acres are ranked as outstanding, thirty-two sites totaling over 9,400 acres are ranked as high, and 167 sites totaling nearly 23,100 acres ranked as moderate biodiversity significance (Figure X). It is important to note that biodiversity significance rankings normally reflect the site conditions when MBS fieldwork originally took place in the region, some of which began as early as 1987.

Concord 13, a site of outstanding biodiversity significance, is one of the more sizeable, intact NPC blocks in Dodge County at 737 acres. The site consists of mesic, maple hardwood forest systems including relatively large blocks of the state Imperiled (S2) Sugar Maple – Basswood – (Bitternut Hickory) Forest (MHs39a) on the upper slopes and wet-mesic hardwood forest (MHs49a, S3) and floodplain terrace along the river (FFs59, FFs59a (S3), FFs59c (S2)) (Minnesota County Biological Survey 2010). A series of dry (CTs12b, S4) and mesic limestone, dolomite cliffs (Southern) (CTs33b, S3) can be found along the river at north, south, and west-facing aspects. Additionally, several state rare plant and animal species have been found within this site (Minnesota County Biological Survey 2010).

West Albany 35, a site of high biodiversity significance, covers >900 acres and consists of steep slopes and large expanses of floodplain along the Zumbro River. This site hosts large tracts of state Imperiled (S2) Elm – Ash – Basswood Terrace Forest (FFs59c) and Red Oak – Sugar Maple – Basswood – (Bitternut Hickory) Forest (MHs38c) which is Vulnerable to Extirpation (S3) (Minnesota County Biological Survey 1993). Several state rare plant species including Davis' sedge (*Carex davisii*) and Goldie's fern (*Dryopteris goldiana*) have been observed in this location (Minnesota County Biological Survey 1993).

Table 1. Areas attributed a Biological Significance ranking occurring within the ZRW. Area presented has been calculated in acres. "Outstanding" sites contain the very best examples or abundance/extent of rare species and native plant communities. "High" sites contain very good quality examples of rare species or native plant communities. "Moderate" sites contain some occurrences of rare species and moderately disturbed native plant communities with strong potential to recover with appropriate management. "Below" are sites that lack rare species or natural features or do not meet MBS standards to qualify as any other rank. These sites may be of local conservation value or have a high potential for restoration of native habitat.

Ecological Subsection	Subsection Area within Zumbro River Watershed	Outstanding	High	Moderate	Below
Oak Savanna	287129 acres	694	2543	1609	2339
Rochester Plateau	467086 acres	2485	1259	9646	4864
The Blufflands	155151 acres	1628	5611	11847	5251

Rare Elemental Occurrences: The DNR maintains records on Minnesota's rare plant, animals, native plant communities, and other rare features in its Natural Heritage Information System (NHIS). The purpose of this database is to foster a better understanding of abundance and distribution of these rare ecological resources. The distribution of rare elemental occurrences may be viewed in Figure 1.

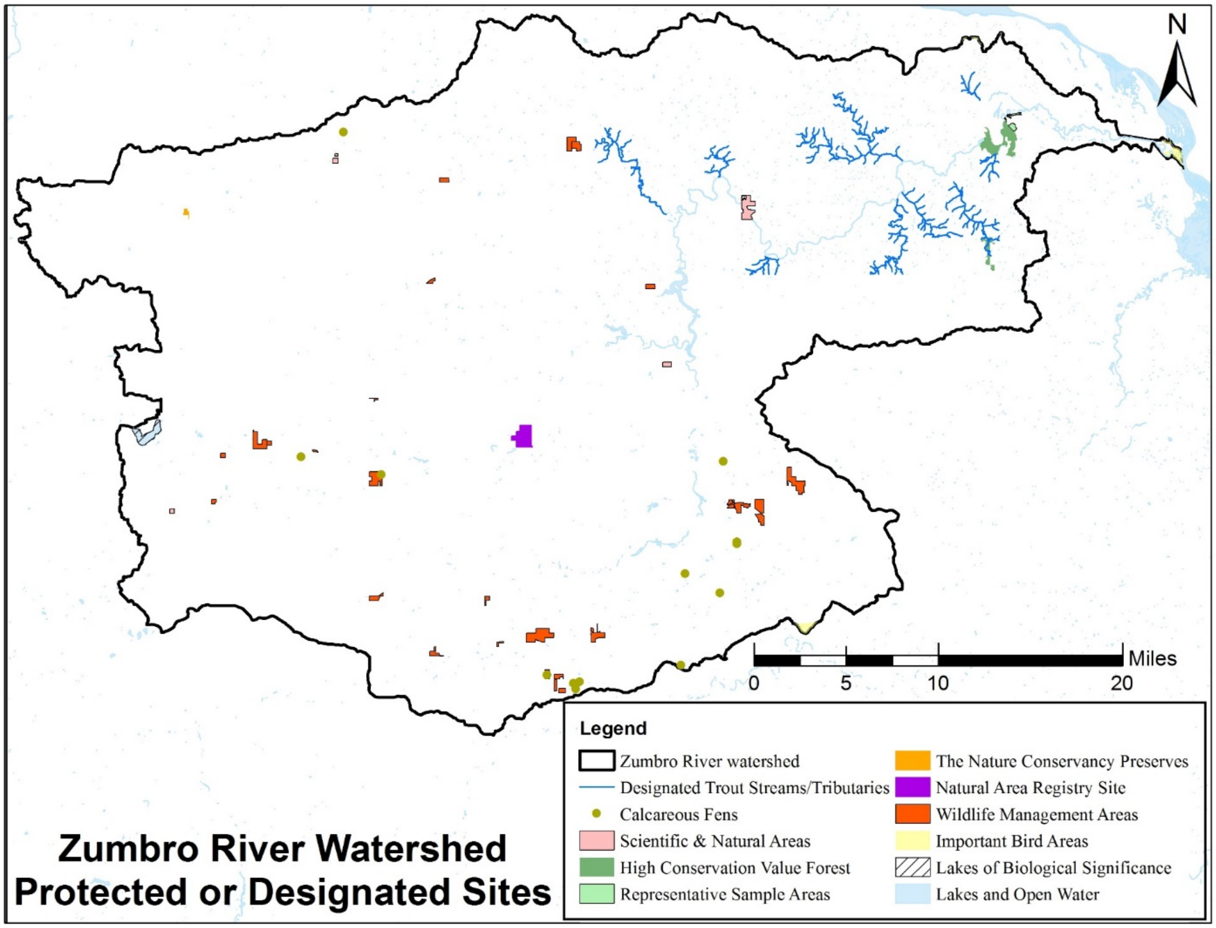
Botanical: There are 59 plant species within the ZRW that are tracked by the state including 7 endangered, 21 threatened, 27 of special concern, and four watchlist species that are tracked, but have no legal status. Of particular note are the handsome sedge (*Carex formosa*), which has just two Minnesota populations one of which occurs in the ZRW, and the dwarf trout lily (*Erythronium propullans)*, Minnesota's only federally endangered plant species and possibly one of only two or three plant species endemic to the state (Minnesota Department of Natural Resources n.d.).

Fungal: A species of firedot lichen (*Caloplaca stellata*), a species of special concern, has been identified in Wabasha County.

Zoological: There are 49 wildlife species within the ZRW tracked by the state including 4 endangered, 8 threatened, 26 special concern, and 8 watchlist species. Over half of these wildlife species are associated with wetlands or aquatic habitats (Table). Of special interest are the high number of threatened and special concern mussel species that occur in this watershed. Degradation of mussel habitat in streams is a persistent threat to this group. Dams, channelization, and dredging encourages siltation, physically alters habitat, and impedes movement of mussel fish hosts. Non-native zebra mussels (*Dreissena polymorpha*) may also invade habitat and outcompete native mussel species for resources (Minnesota Department of Natural Resources 2016b).

Animal Assemblages: There are three types of animal assemblages that have been recognized in the ZRW. These include one bat colony occurring in Wabasha County in the Blufflands ecological subsection, 3 waterbird colonies scattered through the western half of the watershed, and 12 mussel sampling sites spread throughout the watershed.

Minnesota Important Bird Areas: Important Bird Areas (IBAs) provide critical habitat for one or more breeding, wintering, and/or migrating bird species. Three pieces of three much larger IBAs are contained within the ZRW, two occurring in the eastern portion of the Blufflands ecological subsection and another in the southern portion of the Rochester Plateau ecological subsection.



Blufflands-Root River IBA: Blufflands-Root River IBA exhibits a diversity of landscape features including steep river valleys and banks, floodplain forests, and upland deciduous forests (National Audubon Society 2016a). These habitats provide increasingly important sites for breeding and migrating species in an area largely composed of agriculture. This IBA contains the greatest number of breeding Acadian Flycatchers (*Empidonax virescens*) and Cerulean Warblers (*Steophaga cerulea*) in the state and the second largest population of Louisiana Waterthrush (*Parkesia motacilla*). Approximately 250 acres of the greater 519,631 acre IBA occurs within the ZRW at the IBA's western edge.

Mississippi River - Lake Pepin IBA: The Mississippi River – Lake Pepin IBA occurs along the Mississippi River from Red Wing to Read's Landing (National Audubon Society 2016b). It provides some of the best bird habitat in the state, especially for migrant species. Twenty to 30 migrant warbler species may be observed annually. 200-300 Bald Eagles (*Haliaeetus leucocephalus*) nest, migrate, and winter in this IBA each year. Additionally, the world's largest concentration of migrating Common Mergansers (*Mergus merganser*) occurs on Lake Pepin in the month of November (>70,000). A myriad of other bird species can be found within this congregation. Sixty-four acres of the greater 28,947 acre IBA occurs within the ZRW at the IBA's southern edge.

Upper Mississippi National Wildlife Refuge IBA: The Upper Mississippi NWR IBA runs along the purchase boundaries of the Upper Mississippi River National Wildlife and Fish Refuge and includes Pools 4, 5, 5a, 6, 7, 8, and part of 9 (National Audubon Society 2016c). This site is important for migrating waterfowl including Canvasbacks (*Aythya valisineria*), Tundra Swans (*Cygnus columbianus*), nesting waterbirds, and Bald Eagles (*Haliaeetus leucocephalus*). Approximately 322 acres of the more than 38,000 acre IBA can be found in the ZRW at the IBA's upper reaches.

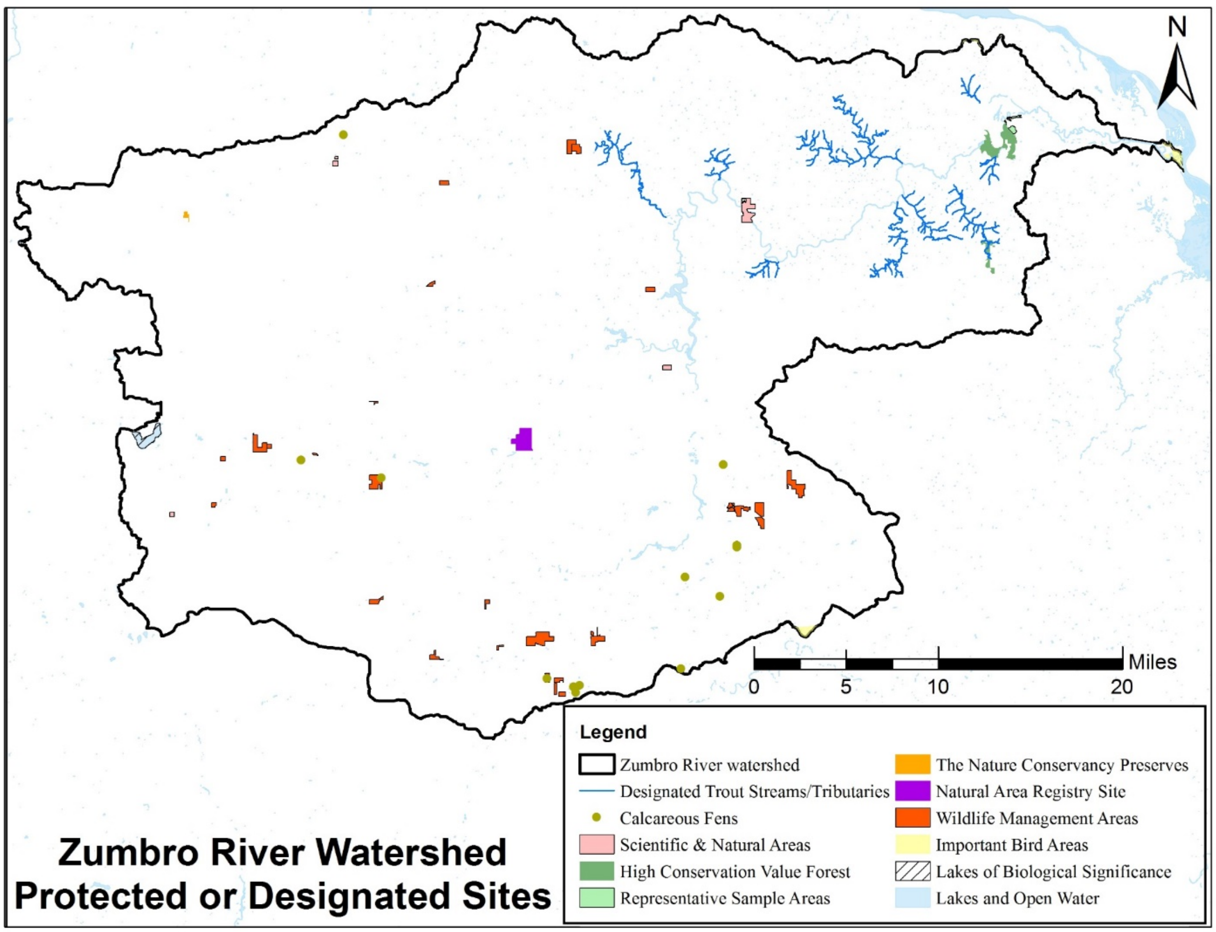
State Wildlife Management Areas: State Wildlife Management Areas (WMAs) acts as the foundation to the State of Minnesota's wildlife management effort. WMAs are managed for the protection and enhancement of a variety of habitats including prairie and grassland, wetland, and early and mid-successional forest. These sites, over 1.3 million acres of land in total, provide opportunities for hunting, fishing, trapping, and wildlife watching across the state. Nearly 3,400 acres are managed on thirty-one WMAs in the ZRW.

Scientific and Natural Areas: Scientific and Natural Areas (SNAs) are state lands that have been designated to preserve natural features of exceptional scientific and educational value. They generally contain remarkable examples of intact and/or rare NPCs, populations of rare species, and geological features of statewide importance. Four SNAs occur within the ZRW including Hythecker Prairie, North Fork Zumbro Woods, Oronoco Prairie, and Zumbro Falls Woods. Hythecker prairie, totaling almost 40 acres, has been mapped by MBS as an area of high biodiversity significance and represents an excellent example of southern wet prairie (WPs54). North Fork Zumbro Woods, at almost 430 acres, contains outstanding examples of four forest communities (FFs59c (S2), MHs38c (S3), MHs39, MHs49a (S3)) and harbors four rare plant species including populations of Minnesota's only federally endangered plant species, the dwarf trout lily (*Erythronium propullans)*. Oronoco Prairie, at nearly 78 acres, consists of oak savanna (UPs14) and dry gravel (UPs13b, S2) and dry bedrock bluff prairie (UPs13c, S3) that harbor at least seven state rare plant species including the federally threatened prairie bush clover (*Lespedeza leptostachya)*. Finally, the Zumbro Falls Woods SNA occupies over 64 acres and contains floodplain forest NPCs (FFs59a, S3) along much of the riparian corridor that provides optimum habitat for the state threatened wood turtle (*Glyptemys insculpta)*.

Natural Area Registry: The NDNR developed the Natural Area Registry (NAR) to highlight ecologically and geologically significant or unique sites that occur on public lands in Minnesota that have not been designated as SNAs. It is a voluntary agreement between the MNDNR and land manager that identifies the special ecological or geological features within the site and outlines recommended management approaches to maintain or enhance the features that are present. One NAR site occurs within the ZRW:

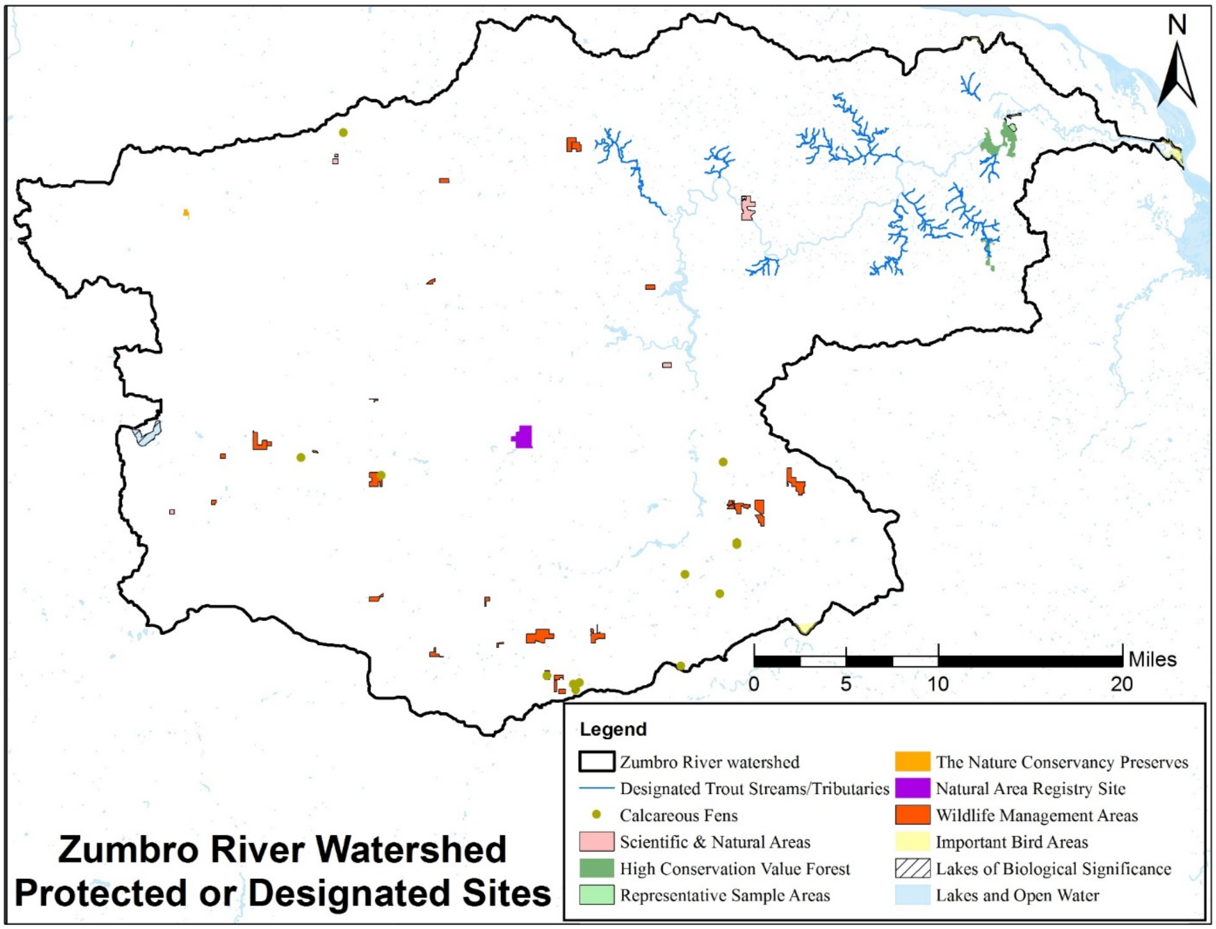
Oxbow County Park, covering 636 acres, provides examples of five NPC forest subtypes of outstanding or high biodiversity significance ranging in their conservation status from between Imperiled (S2) to Vulnerable to Extirpation (S3). These include Oak – Shagbark Hickory Woodland (FDs38a, S3), Elm – Ash – Basswood Terrace Forest (FFs59c, S2), Red Oak – White Oak Forest (MHs37a, S3), Red Oak – Sugar Maple – Basswood – (Bitternut Hickory) Forest (MHs38c, S3), and Sugar Maple – Basswood (Bitternut Hickory) Forest (MHs39a, S2). Additionally, seven state rare species occur within the park, including two endangered plant species, goldenseal (*Hydrastis canadensis*) and handsome sedge *(Carex formosa)*. Oxbow County Park contains one of only two populations of handsome sedge along with one of the fifteen occurrences of goldenseal that occur statewide. Similarly, wood turtles (*Glyptemys insculpta)*, a state threatened species, have been repeatedly observed in or near the park along the South Branch of the Middle Fork of the Zumbro River.

Representative Sample Areas: The Forest Stewardship Certification Council requires that "representative samples of existing ecosystems within the landscape be protected in their natural state (Criterion 6.4; FSC-US Board 2010)." In compliance, the MNDNR designates Representative Sample Areas (RSA) across the state that are ecologically viable, representative ecosystems in order to establish and/or maintain an ecological reference; create or maintain an under-represented ecological condition; or to serve as a set of protected areas or refugia for species, communities, and community types. Management within RSAs are restricted to low impact activities compatible with the protected RSA objectives (Barnard 2010). Within the ZRW, there is the Zumbro RSA, which is composed of five units, totaling ~126 acres, that occurs in the uplands adjacent to the Main Branch of the Zumbro River.



The site is classified by MBS as having high biodiversity significance and contains three NPCs with state conservation status ranks ranging from Critically Imperiled to Imperiled. These include White Pine – Oak Woodland (Sand) (FDs27b, S1), Dry Sand – Gravel Oak Savanna (Southern) (UPs14b, S1S2), and Dry Sand – Gravel Prairie (Southern) (UPs13b, S2).

High Conservation Value Forests: State statute requires that forests are managed for a broad spectrum of objectives and resources, including conservation of rare species, communities, and features (State of Minnesota Revisor of Statutes 2016a, 2016b). As a participant in the Forest Stewardship Council (FSC) forest certification process, the DNR is obligated to designate high conservation value forests (HCVFs) in the State. HCVFs are broadly defined as "areas of outstanding biological or cultural significance" (Minnesota Department of Natural Resources n.d.). Principle 9 of the FSC-US National Forest Management Standard states that "Management activities in high conservation value forests shall maintain or enhance the attributes which define such forests" (FSC-US Board 2010). Two HCVFs, both occurring in the RJD Memorial Hardwood State Forest, are located within the ZRW.

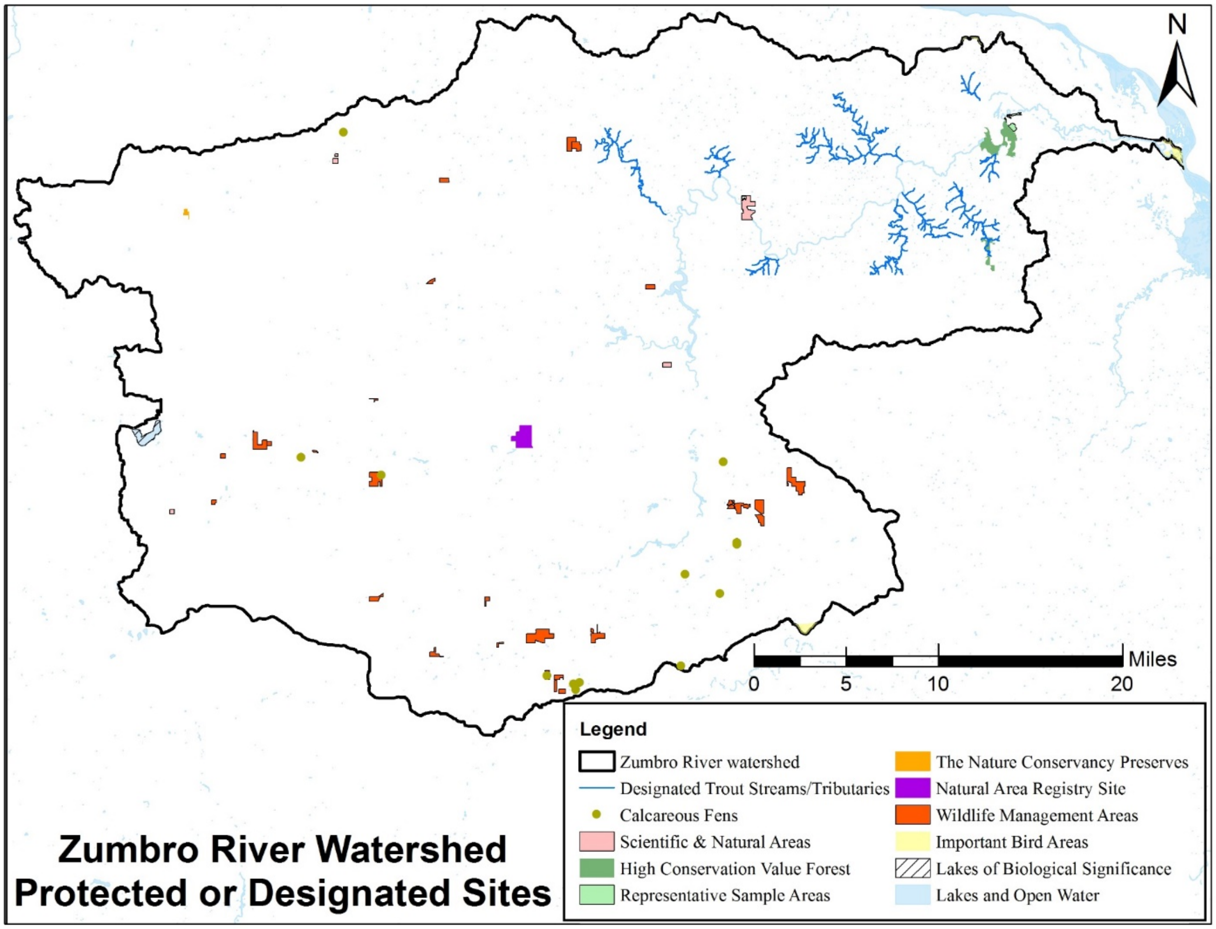


West Indian Creek is a designated HCVF in the RJD Memorial Hardwood State Forest in Wabasha County with 293 acres located in the ZRW. The HCVF comprises extensive slopes and bottomland located along three miles of West Indian Creek and contains the most diverse and intact stretch of valley in the county. The northern half of the HCVF contains over 121 acres of designated primary old-growth forest in addition to slopes with high-quality maple-basswood and oak forests, moist and dry cliffs, and critically imperiled seepage swamp NPCs. Additional features that contributed to the sites designation include the presence of cave bat hibernacula and an abundance of rare plant and wildlife species (Region 3 HCVF Team 2013a).

Old-growth forests are quite rare in Minnesota. Originally comprising slightly over half of pre-settlement forested lands, widespread clear-cut logging has resulted in a 96% decline of old-growth forests by 2000 (Minnesota Department of Natural Resources 2002). Designated old-growth forest stands are now protected from harvest to provide unique habitat for native wildlife and plants, act as genetic reservoirs for unique genetic material, understand how intensive management affects natural forest conditions, and for the enjoyment of outdoor enthusiasts (Minnesota Department of Natural Resources 1994, 2016c). These forests typically contain trees older than 120 years, standing and fallen dead trees, and have experienced minimal levels of human disturbance (Minnesota Department of Natural Resources 2002). Three designated old-growth forest stands remain in the ZRW, occurring adjacent to one another within the West Indian Creek HCVF. These include a 32 acre stand dominated by black ash, a 31 acre stand composed largely of sugar maple, and a 53 acre stand consisting mostly of red oak.

Zumbro Bottoms HCVF also occurs in the RJD Memorial Hardwood State Forest and occupies 1033 acres that has largely been ranked as moderate or high biodiversity significance. This HCVF contains steep bluffs above the Zumbro River that includes nine, small to mid-sized, bluff prairies on south to west facing slopes of the present sandstone outcrops. Dry oak forest exists on sandy terraces, oak woodland/brushland occupies steep west facing-slopes, mature mesic oak forest on east-facing slopes, and mature floodplain forest occurs along the river. A diversity of state rare wildlife and plant species have been observed in the site including timber rattlesnake (*Crotalus horridus*), wood turtle, kitten-tails (*Besseya bullii*), and cliff goldenrod (*Solidago sciaphila*). Management objectives include retention of larger patches of mature forest canopy for rare bird species and prescribed burning to maintain prairies, savanna, and dry oak woodlands (Region 3 HCVF Team 2013b).

The Nature Conservancy Preserves: TNC owns and manages over 50 preserves across the State of Minnesota, one of which falls within the ZRW. The Grace Nature Preserve occupies a 44 acre area situated along the North Fork of the Zumbro River in the Northwestern corner of the watershed.

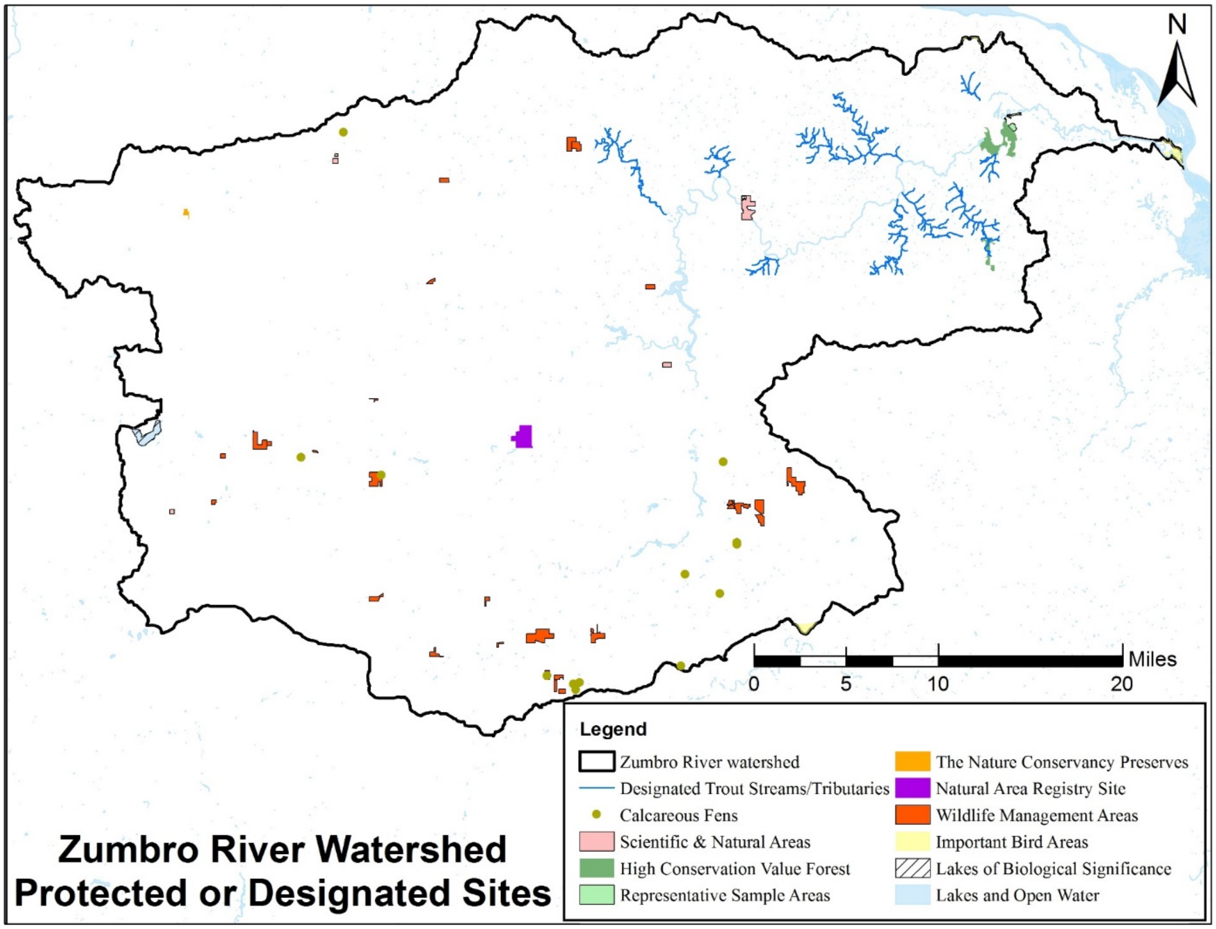


Three forested plant communities occurring within the Preserve including Red Oak – White Oak Forest (MHs37a, S3), Sugar Maple – Basswood – (Bitternut Hickory) Forest (MHs39a, S2), and Elm – Ash – Basswood Terrace Forest (FFs59c, S2). These communities are defined by the State of Minnesota as Imperiled (S2) or Vulnerable to Extirpation (S3) and classified as having outstanding biodiversity significance by MBS. A significant number of dwarf trout lily colonies (Federally Endangered) occur within the Preserve.

Lakes of Biological Significance: Lakes of Biological Significance are classified as such based upon four community types (Aquatic plants, fish, amphibians, and birds). Lakes are rated for each community and assigned as having outstanding, high, or moderate biological significance. Rice Lake, a 528 acre lake in Steele County, is the sole Lake in the ZRW to receive this designation at present and meets criteria to classify it as having an outstanding bird community. Rice Lake, as its name implies, hosts significant populations of wild rice, which in addition to providing important feed for wildlife is a culturally important plant in Minnesota. Rice Lake is the only lake in the ZRW that has been identified as a "Wild Rice Lake".

Trout Stream Designation: The state of Minnesota imposes certain restrictions on designated trout streams in order to protect and foster the propagation of trout. In these waters, taking of fish is prohibited, except during the open season and the taking of minnows is prohibited at all times (State of Minnesota Revisor of Statutes 2015). The ZRW contains twelve designated trout streams and 140 designated trout stream tributaries, all of which occur in The Blufflands ecological subsection. The streams and tributaries account for roughly 321 miles of stream.

Table 2. Native plant communities (NPCs) of the ZRW. Conservation Status is assessed at multiple scales.



S-ranks are assessed at the state scale. G-ranks are assessed at the global scale. The conservation rank of a Native Plant Community is based on a scale of one to five. 1 = Critically Imperiled, 2 = Imperiled, 3 = Vulnerable to Extirpation, 4 = Apparently Secure, and 5 = Demonstrably widespread, abundant, and secure. SNR = State not ranked. If two ranks are side-by-side (e.g., S2S3), it means the determined conservation rank is considered to be between the above listed status's.

NPC Code[1]	NPC Name	S-Rank	Watershed Acreage
CTs46a2	Algific Talus , Dolomite Subtype	S1	1.7
FDs27b	White Pine - Oak Woodland (Sand)	S1	87.9
FFs59b	Swamp White Oak Terrace Forest†	S1	4.4
OPp93c	Calcareous Fen (Southeastern)†	S1	21.7
WFs57b	Black Ash - Sugar Maple - Basswood - (Blue Beech) Seepage Swamp†	S1	3.5
WPs54a	Wet Seepage Prairie (Southern)†	S1	11.5
UPs13a	Dry Barrens Prairie (Southern)	S1S2	34.2
UPs14a2	Dry Barrens Oak Savanna (Southern), Oak Subtype	S1S2	6.3

UPs14b	Dry Sand - Gravel Oak Savanna (Southern)	S1S2	176.7
WFs57a	Black Ash - (Red Maple) Seepage Swamp†	S1S2	8.9
CTs33a	Mesic Sandstone Cliff (Southern)	S2	1.6
FDs27c	Black Oak - White Oak Woodland (Sand)	S2	180.2
FFs59c	Elm - Ash - Basswood Terrace Forest†	S2	1906.5
MHs39a	Sugar Maple - Basswood - (Bitternut Hickory) Forest	S2	1321.7
MHs49b	Elm - Basswood - Black Ash - (Blue Beech) Forest	S2	46.4
UPs13b	Dry Sand - Gravel Prairie (Southern)	S2	68.5
UPs23a	Mesic Prairie (Southern)	S2	117.1
WPs54b	Wet Prairie (Southern)†	S2	50
CTs23b	Mesic Limestone - Dolomite Talus (Southern)	S3	2.8
CTs33b	Mesic Limestone - Dolomite Cliff (Southern)	S3	95
FDs38a	Oak - Shagbark Hickory Woodland	S3	775
FFs59a	Silver Maple - Green Ash - Cottonwood Terrace Forest†	S3	1205.9
FFs68a	Silver Maple - (Virginia Creeper) Floodplain Forest†	S3	73.6
MHs37a	Red Oak - White Oak Forest	S3	2520
MHs38a	White Pine - Oak - Sugar Maple Forest	S3	56.3
MHs38c	Red Oak - Sugar Maple - Basswood - (Bitternut Hickory) Forest	S3	772.6
MHs39b	Sugar Maple - Basswood - Red Oak - (Blue Beech) Forest	S3	906.1
MHs49a	Elm - Basswood - Black Ash - (Hackberry) Forest†	S3	324.5
UPs13c	Dry Bedrock Bluff Prairie (Southern)	S3	330
WMs83a	Seepage Meadow/Carr†	S3	133.5
WMs83a1	Seepage Meadow/Carr, Tussock Sedge Subtype†	S3	207.5
FDs36a	Bur Oak - Aspen Forest	S3S4	52
CTs12b	Dry Limestone - Dolomite Cliff (Southern)	S4	15
MHs37b	Red Oak - White Oak - (Sugar Maple) Forest	S4	750.6
WMn82b	Sedge Meadow†	S4S5	178
WMn82a	Willow - Dogwood Shrub Swamp†	S5	19.5
FDs36	Southern Dry-Mesic Oak-Aspen Forest	SNR	1
FDs37	Southern Dry-Mesic Oak (Maple) Woodland	SNR	2.6
FDs38	Southern Dry-Mesic Oak-Hickory Woodland	SNR	6.8
FFs59	Southern Terrace Forest	SNR	664.9
CTs12	Southern Dry Cliff	SNR	32.5
MHs37	Southern Dry-Mesic Oak Forest	SNR	1134.6
MHs38	Southern Mesic Oak-Basswood Forest	SNR	675
MHs39	Southern Mesic Maple-Basswood Forest	SNR	1477.3
MHs49	Southern Wet-Mesic Hardwood Forest†	SNR	616.3
MRn93	Northern Bulrush-Spikerush Marsh†	SNR	16.9
OPn92	Northern Rich Fen (Basin)†	SNR	1.4
UPs23	Southern Mesic Prairie	SNR	6.3
WPs54	Southern Wet Prairie†	SNR	26.1

†Native plant communities that are associated with wet or aquatic habitats or are directly adjacent to and dependent on water features such as lakes and rivers.

[1]NPC codes reflect the dominant ecological system driving the plant community (for example, major disturbance regime or nutrient cycling), floristic region, relative soil moisture and nutrient regime, and sometimes plant community type and subtype (Minnesota Department of Natural Resources 2005d). For more information, see one of the Field Guides to the Native Plant Communities of Minnesota.*

Table 3. State and federally listed and watchlist wildlife species recorded within the ZRW. State status is in parentheses following common name: WL=watchlist, SPC=special concern; THR=threatened; END=endangered.

Category	Scientific Name	Common Name
Animal Assemblage		Bat Concentration
		Colonial Waterbird Nesting Site†
		Mussel Sampling Site†
Amphibians	*Acris blanchardi*	Blanchard's Cricket Frog
	Necturus maculosus	Mudpuppy (SPC)*†
Birds	*Empidonax virescens*	Acadian Flycatcher (SPC)*†
	Haliaeetus leucocephalus	Bald Eagle (WL)†
	Vireo bellii	Bell's Vireo (SPC)*
	Steophaga cerulean	Cerulean Warbler (SPC)*†
	Ammodramus henslowii	Henslow's Sparrow (END)*
	Chondestes grammacus	Lark Sparrow (SPC)*
	Lanius ludovicianus	Loggerhead Shrike (END)*
	Parkesia motacilla	Louisiana Waterthrush (SPC)*†
	Falco peregrinus	Peregrine Falcon (SPC)*
	Progne subis	Purple Martin (SPC)*†
	Buteo lineatus	Red-shouldered Hawk (SPC)*†
	Grus canadensis	Sandhill Crane (WL)
	Asio flammeus	Short-eared Owl (SPC)*†
	Bartramia longicauda	Upland Sandpiper (WL)
Fish	*Lethenteron appendix*	American Brook Lamprey
	Moxostoma duquesnei	Black Redhorse (SPC)*†

	Cycleptus elongatus	Blue Sucker (SPC)*†
	Crystallaria asprella	Crystal Darter (END)*†
	Acipenser fulvescens	Lake Sturgeon (SPC)*†
	Etheostoma grammacus	Least Darter (SPC)*†
	Ichthyomyzon fossor	Northern Brook Lamprey (SPC)*†
	Notropis nubilus	Ozark Minnow (SPC)*†
	Lythrurus umbratilis	Redfin Shiner (SPC)*†
	Clinostomus elongatus	Redside Dace (SPC)*†
Insects	*Cicindela lepida*	Ghost Tiger Beetle (THR)*
	Cicindela macra macra	Sandy Stream Tiger Beetle
Mammals	*Mustela nivalis*	Least Weasel (SPC)*
	Perimyotis subflavus	Tricolored Bat (SPC)*
Mussels	*Ligumia recta*	Black Sandshell (SPC)*†
	Lasmigona compressa	Creek Heelsplitter (SPC)*†
	Alasmidonta marginata	Elktoe (THR)*†
	Venustaconcha ellipsiformis	Ellipse (THR)*†
	Lasmigona costata	Fluted-shell (THR)*†
	Obovaria olivaria	Hickorynut (WL) †
	Actinonaias ligamentina	Mucket (THR)*†
Reptiles	*Emydoidea blandingii*	Blanding's Turtle (THR)*†

	Heterodon platirhinos	Eastern Hog-Nosed Snake (WL)
	Pituophis catenifer	Gophersnake (SPC)*
	Lampropeltis triangulum	Milksnake (WL)
	Coluber constrictor	North American Racer (SPC)*
	Heterodon nasicus	Plains Hog-nosed Snake (SPC)*
	Crotalus horridus	Timber Rattlesnake (THR)*
	Pantherophis ramspotti	Western Foxsnake (WL)
	Glyptemys insculpta	Wood Turtle (THR)*†

**Minnesota Species of Greatest Conservation Need (SGCN). SGCN species include those native animals whose "populations are rare, declining, or vulnerable to decline and are below levels desirable to ensure their long-term health and stability"(Minnesota Department of Natural Resources 2015b)*

† Species associated with aquatic or wetland habitats.

Table 4. State listed fungi and plant species with occurrences in the ZRW from the NHIS database. State, and federal where noted, status is indicated in parentheses following common names: SPC=special concern; THR=threatened; END=endangered.

Category	Scientific Name	Common Name
Fungus	*Caloplaca stellata*	A species of Firedot Lichen (SPC)*
Vascular Plant	*Allium cernuum*	Nodding Wild Onion (SPC)
	Arisaema dracontium	Green Dragon (SPC, FACW)†
	Aristida tuberculosa	Seaside Three-awn (THR)
	Arnoglossum plantagineum	Tuberous Indian-plantain (THR)
	Asclepias sullivantii	Sullivant's Milkweed (THR)
	Asplenium platyneuron	Ebony Spleenwort (SPC)
	Baptisia bracteata var. glabrescens	Plains Wild Indigo (SPC)
	Baptisia lactea var. lactea	White Wild Indigo (SPC)†
	Besseya bullii	Kitten-tails (THR)
	Boechera laevigata	Smooth Rock Cress (SPC)
	Botrychium campestre	Prairie Moonwort (SPC)
	Carex conjuncta	Jointed Sedge (THR, FACW)†
	Carex davisii	Davis' Sedge (THR)
	Carex formosa	Handsome Sedge (END)
	Carex grayi	Gray's Sedge (SPC,FACW)†
	Carex jamesii	James' Sedge (THR)
	Carex laevivaginata	Smooth-sheathed Sedge (THR, OBL)†
	Carex laxiculmis var. copulata	Spreading Sedge (THR)
	Carex muskingumensis	Muskingum Sedge (SPC, OBL)†
	Carex plantaginea	Plantain-leaved Sedge (END)
	Carex sterilis	Sterile Sedge (THR, OBL)†

Carex typhina	Cattail Sedge (SPC, OBL)†
Cirsium pumilum var. hillii	Hill's Thistle (SPC)
Crataegus calpodendron	Late Hawthorn (SPC)
Deparia acrostichoides	Silvery Spleenwort (SPC)
Desmodium nudiflorum	Stemless Tick Trefoil (THR)
Dicentra canadensis	Squirrel Corn (SPC)
Diplazium pycnocarpon	Narrow-leaved Spleenwort (THR)
Dodecatheon amethystinum	Jewelled Shooting Star (WL)
Dryopteris goldiana	Goldie's Fern (SPC)
Eryngium yuccifolium	Rattlesnake Master (SPC)
Erythronium propullans	Dwarf Trout Lily (END, FED. END)
Floerkea proserpinacoides	False Mermaid (THR, OBL)†
Gleditsia triacanthos	Honeylocust (WL)
Hasteola suaveolens	Sweet-smelling Indian plantain (END)†
Hydrastis canadensis	Goldenseal (END)
Jeffersonia diphylla	Twinleaf (SPC)
Juglans cinerea	Butternut (END)
Juniperus horizontalis	Creeping Juniper (SPC)
Lespedeza leptostachya	Prairie Bush Clover (THR, FED. THR)
Minuartia dawsonensis	Rock Sandwort (THR)
Napaea dioica	Glade Mallow (THR, FACW)†
Nuttallanthus canadensis	Old Field Toadflax (SPC)
Orobanche fasciculata	Clustered Broomrape (THR)
Oxypolis rigidior	Cowbane (WL, OBL)†
Panax quinquefolius	American Ginseng (SPC)
Pellaea atropurpurea	Purple Cliff Brake (SPC)
Phegopteris hexagonoptera	Broad Beech Fern (END)
Phlox maculata	Wild Sweetwilliam (SPC, FACW)†
Platanthera flava var. herbiola	Tubercled Rein Orchid (THR, FACW)†
Quercus bicolor	Swamp White Oak (SPC, FACW)†
Rhynchospora capillacea	Hair-like Beak Rush (THR, OBL)†
Sanicula trifoliata	Beaked Snakeroot (SPC)
Scleria verticillata	Whorled Nutrush (THR, OBL)†
Symphyotrichum pilosum	White Heath Aster (WL)
Taenidia integerrima	Yellow Pimpernel (SPC)
Tephrosia virginiana	Goat's Rue (SPC)
Trillium nivale	Snow Trillium (SPC)
Valeriana edulis var. ciliata	Edible Valerian (THR)
Vitis aestivalis var. bicolor	Silverleaf Grape (THR)

†Species associated with wetland habitats. Most of these species are listed as facultative wetland (FACW) or obligate wetland (OB) species on the 2016 National Wetland Plant list (Lichvar 2016, US Army Corps of Engineers 2016), otherwise they are known to be associated with wet habitats in Minnesota.

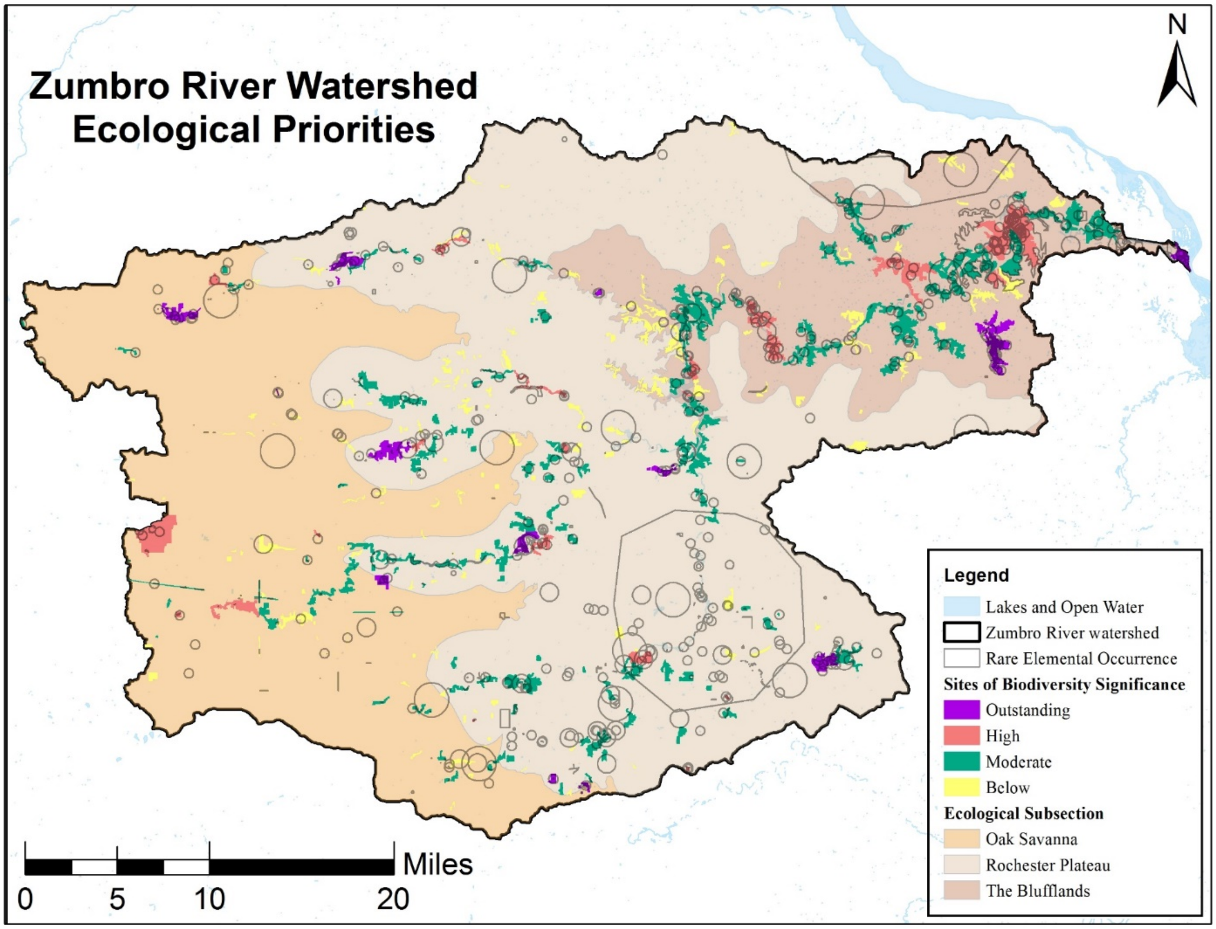


Figure 1: Rare elemental occurrences and sites of biodiversity significance within the Zumbro River Watershed.

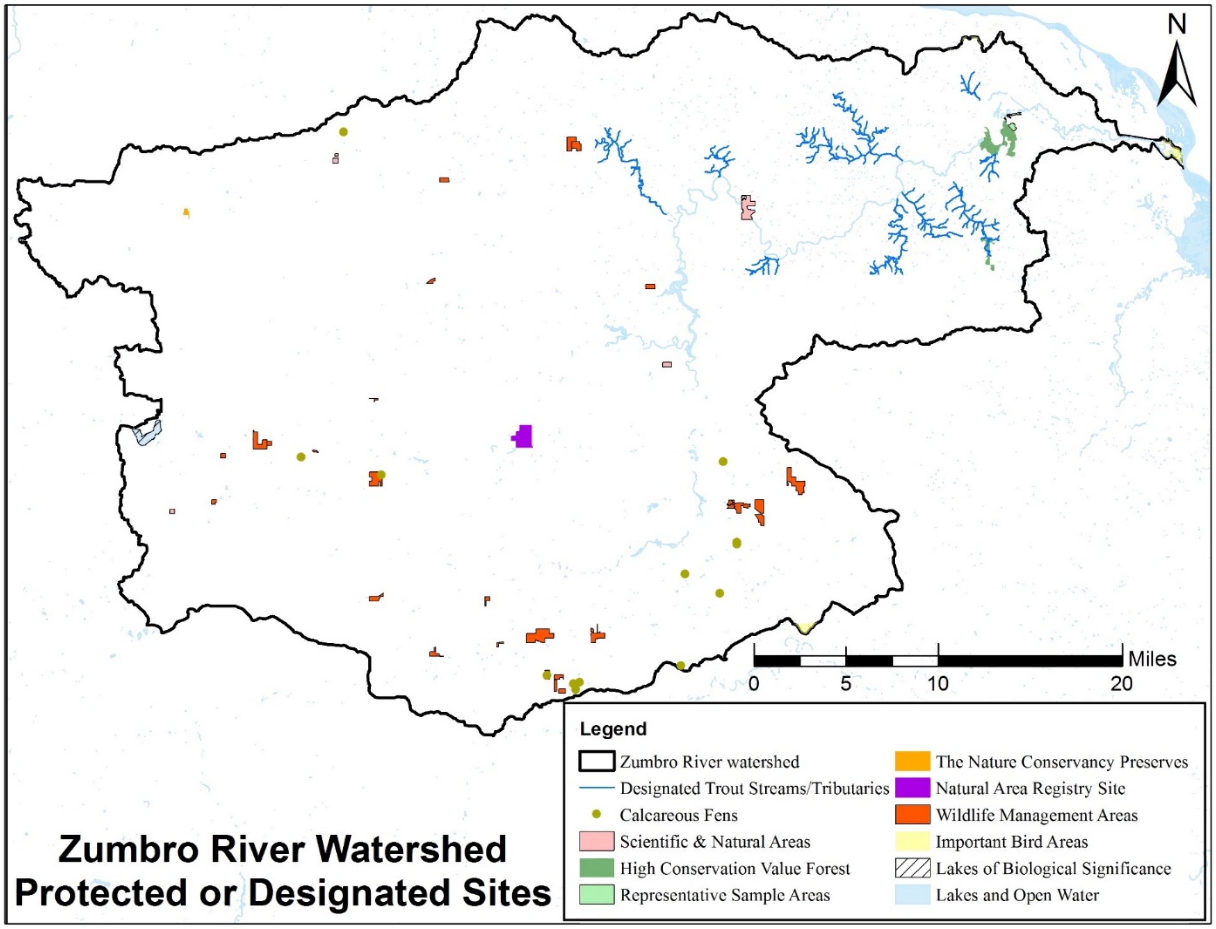


Figure 2: Protected and/or designated lands or bodies of water within the state of Minnesota

Citations

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Appendix I: Non-surface water discharge wastewater facility summary

Facility Name	Permit No	Permit Type	Waste Type	Ownership	Facility Description	Station Type	Station Description
ABA Water Systems Inc	MNP067091	SDS	Industrial	Private (Non-Government)	Business Services, NEC	Waste Stream	Intermediate: Pretreatment discharge to POTW
AMPI - Rochester	MNG960010	SDS	Industrial	Private (Non-Government)	Natural, Processed, and Imitation Cheese	Land Application	Non-biosolids WWT/Sludge Appl Site
Byron WWTP	MN0049239	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
DairiConcepts LP	MNG960069	SDS	Industrial	Private (Non-Government)	Natural, Processed, and Imitation Cheese	Land Application	Non-biosolids WWT/Sludge Appl Site
Daniel DeCook Sand & Gravel LLC	MNG490172	NPDES/SDS	Industrial	Private (Non-Government)	Construction Sand and Gravel	Land Application	MNG49 Wastewater
Dodge Center WWTP	MN0021016	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
DS Manufacturing Inc	MNG120005	SDS	Industrial	Private (Non-Government)	Electroplating, Plating, Polishing, Anodizing, and Coloring	Waste Stream	Intermediate: Pretreated wastewater discharge to POTW
Edgewood Estates Second Addition	MN0067997	SDS	Domestic	Private (Non-Government)	Operators of Dwellings Other Than Apartment Buildings	Waste Stream	Biosolids to Land Treatment/Application
Faribault WWTP	MN0030121	NPDES/SDS	Domestic	Local Government	Sewerage Systems; Refuse Systems	Land Application	Application Site, Biosolids
Goodhue WWTP	MN0020958	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
Hammond WWTP	MN0066940	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
Hayfield WWTP	MN0023612	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
Hormel Foods Corp - Austin Plant	MN0050911	NPDES/SDS	Industrial	Private (Non-Government)	Meat Packing Plants	Land Application	Non-biosolids WWT/Sludge Appl Site
IFP Inc	MN0056413	SDS	Industrial	Private (Non-Government)	Poultry Slaughtering and Processing; Dried and Dehydrated Fruits, Vegetables, and Soup Mixes; Flavoring Extracts and Flavoring Syrups, Not Elsewhere Classified	Land Application	Spray Irrigation
International Ingredient Corp	MN0053881	SDS	Industrial	Private (Non-Government)	Dry, Condensed, Evaporated Products	Land Application	Spray Irrigation
Kasson WWTP	MN0050725	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids

Facility Name	Permit No	Permit Type	Waste Type	Ownership	Facility Description	Station Type	Station Description
Kenyon WWTP	MN0021628	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
Kerry Ingredients & Flavours Inc	MNG960036	SDS	Industrial	Private (Non-Government)	Dry, Condensed, Evaporated Products	Land Application	Non-biosolids WWT/Sludge Appl Site
Lakeside Foods Inc - Plainview MN0047465	MN0047465	NPDES/SDS	Industrial	Private (Non-Government)	Canned Fruits, Vegetables, Preserves, Jams, and Jellies; Frozen Fruits, Fruit Juices, and Vegetables	Land Application	Spray Irrigation & Industrial Byproducts
Land O'Lakes Inc - Pine Island	MNG960009	SDS	Industrial	Private (Non-Government)	Natural, Processed, and Imitation Cheese; Dry, Condensed, and Evaporated Dairy Products	Land Application	Non-biosolids WWT/Sludge Appl Site
Leitzen Concrete Products Inc	MNG490280	SDS	Industrial	Private (Non-Government)	Construction Sand and Gravel	Land Application	MNG49 Wastewater
Mantorville WWTP	MN0021059	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
Mathy Construction - Aggregate	MNG490081	NPDES/SDS	Industrial	Private (Non-Government)	Construction Sand and Gravel	Land Application	MNG49 Wastewater
Oronoco Estates	MN0040967	SDS	Domestic	Private (Non-Government)	Operators of Residential Mobile Home Sites	Land Application	Spray Irrigation
Pine Island WWTP	MN0024511	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
Plainview Elgin Sanitary District	MN0055361	NPDES/SDS	Domestic	Private (Non-Government)	Sewerage Systems	Land Application	Application Site, Biosolids
River Park	MN0067920	SDS	Domestic	Private (Non-Government)	Operators of Dwellings Other Than Apartment Buildings	Land Application	Application Site, Biosolids
River Park	MN0067920	SDS	Domestic	Private (Non-Government)	Operators of Dwellings Other Than Apartment Buildings	Waste Stream	Internal Waste Stream
Riverwood Hills Septic Drainfield Site	MN0067245	SDS	Domestic	Private (Non-Government)	General Contractors-Single-Family Houses	Land Application	Application Site, Biosolids
Riverwood Hills Septic Drainfield Site	MN0067245	SDS	Domestic	Private (Non-Government)	General Contractors-Single-Family Houses	Waste Stream	Influent Waste
Rochester Asphalt Inc	MNG490311	NPDES/SDS	Industrial	Private (Non-Government)	Construction Sand and Gravel	Land Application	MNG49 Wastewater
Rochester WWTP/Water Reclamation Plant	MN0024619	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids

Facility Name	Permit No	Permit Type	Waste Type	Ownership	Facility Description	Station Type	Station Description
Schwan's Global Supply Chain Inc	MNG960016	SDS	Industrial	Private (Non-Government)	Frozen Specialties, Not Elsewhere Classified	Land Application	Non-biosolids WWT/Sludge Appl Site
Seneca Foods Corp - Rochester	MN0000477	NPDES/SDS	Industrial	Private (Non-Government)	Canned Fruits, Vegetables, Preserves, Jams, and Jellies; Frozen Fruits, Fruit Juices, and Vegetables	Land Application	Spray Irrigation & Industrial Byproducts
Stussy Construction Inc	MNG490134	NPDES/SDS	Industrial	Private (Non-Government)	Crushed and Broken Limestone	Land Application	MNG49 Wastewater
Wabasha WWTP	MN0025143	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
Wanamingo WWTP	MN0022209	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
West Concord WWTP	MN0025241	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids
Zumbrota WWTP	MN0025330	NPDES/SDS	Domestic	Local Government	Sewerage Systems	Land Application	Application Site, Biosolids