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West Indian Creek Section 319 Small Watersheds Nine Key Element Plan

MINNESOTA POLLUTION CONTROL AGENCY

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Contents

Executive summary

The West Indian Creek Nine Key Element Plan (Plan) was developed to fulfill the requirements set forth by the U.S. Environmental Protection Agency (EPA) for recipients of grants appropriated by Congress under Section 319 of the Clean Water Act (EPA 2013). The requirements emphasize the use of watershed-based plans that contain the nine minimum elements documented in the guidelines and EPA's *Handbook for Developing Watershed Plans to Restore and protect our Waters* (EPA 2008).

This Plan builds on the foundation of many levels of planning efforts, water quality conditions, implementation goals and activities, and an evaluation approach for the watershed. With the EPA approval of the Plan, the Plan will set the stage to further the previous and current restoration activities and continue efforts to achieve the water quality goals in the watershed.

West Indian Creek (070400040510) has been identified as a priority area by many organizations and individuals over the years. This is primarily due to the presence of areas of outstanding biodiversity significance, high conservation value forests, and one of the state's largest maze caves which all help to support 15 state-listed rare plant species, two state-listed rare bird species, threatened bat populations, and an important trout community. Even with these exceptional resources, West Indian Creek is not immune to water quality issues. It can be found on the Minnesota's 303(d) List of Impaired Waters with excessive *Escherichia coli* (*E. coli).* Additionally, there are high concentrations of total suspended solids (TSS) and a significant rising trend in nitrate concentrations. Although West Indian Creek does not have nitrogen, phosphorus, or total suspended solids impairments, the Zumbro River Watershed Restoration and Protection Strategy (WRAPS) report does have measureable goals for these pollutants in the Lower Zumbro Hydrologic Unit Code (HUC) 10 watershed. These goals, which are consistent with Minnesota's Nutrient Reduction Strategy, include 20% nitrogen and 12% phosphorus by 2025. Additionally, there is a 40% nitrogen load reduction goal for 2040.

As the only permitted entities in the watershed are feedlots and small quarries, the solution to addressing water quality issues is in the nonpoint sources. These are chiefly cultivated lands as the primary land use and aging septic systems likely as the secondary source. In addition to its unique biology, West Indian Creek is also unique because it exists in southeast Minnesota's karst landscape, where groundwater is a very important factor. Stream flow is primarily the result of groundwater emerging to the surface through natural springs. Because of this, the contributing area to West Indian Creek cannot be restricted to the surficial watershed if true improvements are to be made in the water quality. The larger, groundwater contributing area must be carefully considered as well.

The primary strategies for addressing water quality issues in West Indian Creek are both social and technical. Relationships, trust, and knowledge will continue to be built and resource concerns will be addressed with various best management practices (BMPs). Key BMPs include feedlot and septic improvements, vegetative filter strips, nutrient management including source control (rate and timing) and conservation crop rotation and cover. Critical areas to be prioritized include uplands and headwaters of the watershed along with agricultural fields in continuous or near continuous corn production.

Introduction

Document overview

The intent of this document is to concisely address the nine elements identified in EPA's *Handbook for Developing Watershed Plans to Restore and Protect our Waters* (EPA 2008) that are critical to preparing effective watershed plans to address nonpoint source pollution. The EPA emphasizes the use of watershed-based plans containing the nine elements in Section 319 watershed projects in its guidelines for the Clean Water Act Section 319 program and grants (EPA 2013).

This Plan's foundation is the data collection, analysis, and development of plans from multiple sources and scales. Most of the monitoring and planning efforts sponsored by the state (Intensive Watershed Monitoring (IWM), Assessments, total maximum daily loads (TMDL), Watershed Restoration and Protection Strategy (WRAPS), One Watershed One Plan (1W1P), etc.) are conducted and report on as Hydrologic Unit Code - eight (HUC-8) watersheds. These foundational efforts provide the support and understanding to develop the very targeted and detailed Focus Grant Workplans for small watersheds. Instead of broad strategies, this Focus Grant Workplan will delve into specific and targeted actions to achieve water quality goals in the West Indian Creek Watershed.

This nine element plan is intended to be a living document. It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. The response of the streams will be monitored and subsequently evaluated as management practices are implemented. The management approach to achieving the goals should be adapted as new monitoring data is collected and evaluated. This approach is commonly called the "adaptive management approach" Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in is watershed. Management activities will be changed or refined to efficiently meet the goals of this plan. This is only one of many steps along the path to water quality goals in the West Indian Creek Watershed.

The intent of the nine elements and the EPA watershed planning guidelines is to provide direction in developing a sufficiently detailed plan at an appropriate scale so that problems and solutions are targeted effectively. The nine elements are listed in Table 1 along with the section of this report in which nine element can be found.

Table 1. Nine elements references

Section 319 Nine Element	Applicable Report Section
Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan	Section 5
An estimate of the load reductions expected from management measures	Section 7.1 & 9.2
A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in element b, and a description of the critical areas in which those measures will be needed to implement this Plan.	Section 9.1
An estimate of the amount of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this Plan.	Section 9.1
An information and education component used to enhance public understanding of the project and encourage the public's	Section 2.2.2 & Section 9.1

Section 319 Nine Element	Applicable Report Section
early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.	
Schedule for implementing the nonpoint source management measures identified in this Plan that is reasonably expeditious.	Section 9.1
A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.	Section 9.1
A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards	Section 9.1
A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item h immediately above.	Section 9.1 & 9.3

Public participation approach

West Indian Creek was identified as a priority in Wabasha County by the Zumbro River Watershed Partnership in the early 2000s and staff at the Wabasha Soil and Water Conservation District (SWCD) have sought funding to support work in this small watershed for several years. Efforts in 2006 included West Indian Creek watershed landowner contact via mailing and telephone communication as well as informational meetings. Another outreach effort was initiated in 2018 in preparation for a number of grant applications. This included another round of landowner contact via mailing and telephone communication as well as some door-to-door contact. The outreach that began in 2018 included over 400 staff hours.

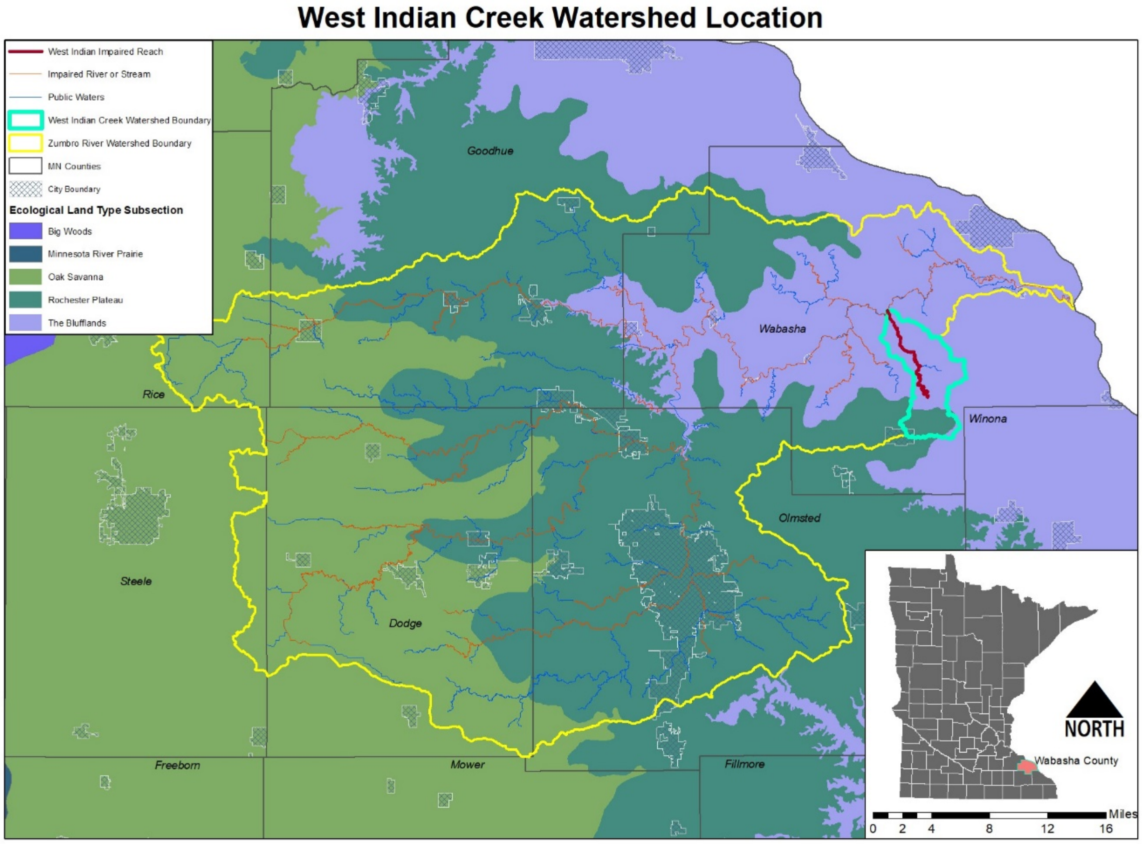
Watershed description

Physical and natural features

Watershed boundaries

West Indian Creek Watershed is part of the Zumbro River Watershed located in Southeastern Minnesota (Figure 1). All of the land in this part of Minnesota was surrendered by the Dakota people by the treaty made with the upper bands, signed at Traverse de Sioux, July 22, 1851, and with the lower bands signed at Mendota, August 5, 1851. The watershed is in and to the northeast of the city of Plainview, Minnesota and is entirely contained in Wabasha County. The watershed is a HUC12, 070400040510, in the Lower Zumbro River subwatershed and is approximately 27 square miles (17,187 acres). The creek is approximately 10.13 miles long with more than 10 small, protected tributaries. The creek empties into the Zumbro River near the town of Theilman, Minnesota. From Theilman, the Zumbro River travels 23.93 miles and drains to the Mississippi River near Kellogg, Minnesota. West Indian Creek is one of 18 designated trout streams in Wabasha County. Roughly one quarter, or 3,843 acres of the uppermost section of the watershed is located within the Rochester/Paleozoic Plateau Upland Ecological Classification System Subsection, whereas the remaining 13,344 acres of the watershed is in the Blufflands and Coulees Subsection. Here at the boundary of the Rochester Plateau and the Blufflands is an area of transition between a level to rolling plateau and dissected landscapes. In the Rochester Plateau, the depth of drift over bedrock can be between 10-100 feet, whereas in the Blufflands it varies between 0-50 feet. In both subsections, loess (wind-blown silt) soils can be 30 feet thick on broad ridge tops to less than one foot on valley walls. Moving north or downstream in West Indian Creek, cutting into the valley, depth to bedrock decreases, sedimentary rocks are often exposed in valley walls, and springs of groundwater are more widespread.

Figure 1. West Indian Creek Watershed location

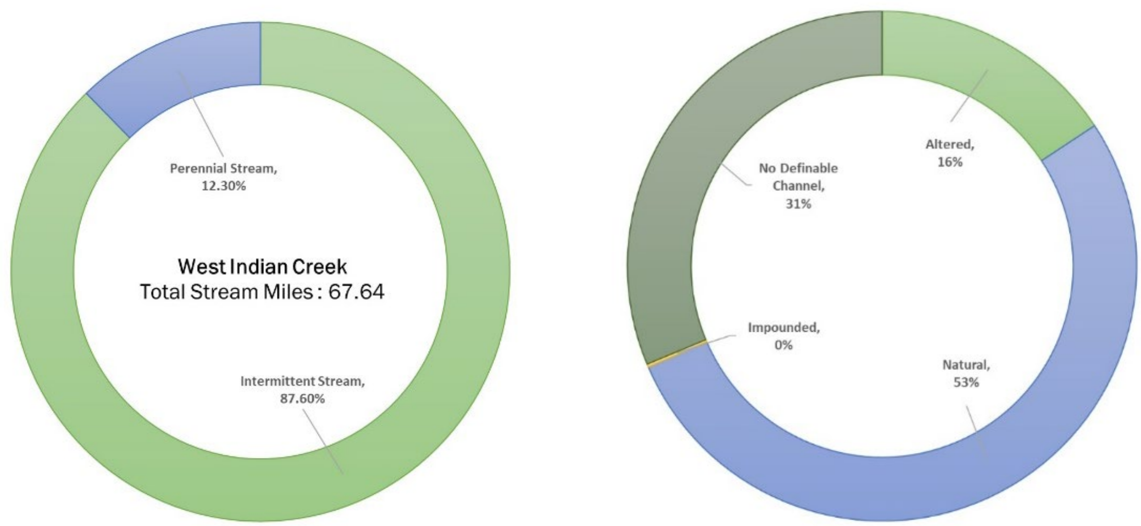


General hydrology

West Indian Creek has nearly 68 mapped intermittent and perennial stream miles, of this, 12.3% are classified has perennial and 87.6% are classified as intermittent. According to the Minnesota Statewide Altered Watercourse Project, West Indian Creek has 53% natural stream channels, 16% altered channels, and 0% impounded. 31% are classified as ‘no definable channel’ as shown in Figure 2. Situations where a water course would be classified as “non definable channel” are:

- Water courses crossed by row crops or other tillage,
- Water courses that are indistinct or do not exist on light detection and ranging (LiDAR) imagery in non-wetland areas,
- A flowline that does not have an associated Digital Raster Graphic, water course is either a new, likely altered watercourse or a mistake,
- Flowlines designated as pipelines,
- The surrounding terrain was recently urbanized, mined, or otherwise developed,
- Wetland area with indistinct/indefinite watercourse, or
- Watercourse channel is dry in most years and frequently grassy; wide and shallow in LiDAR.

Figure 2. Description of total stream miles in West Indian Creek Watershed

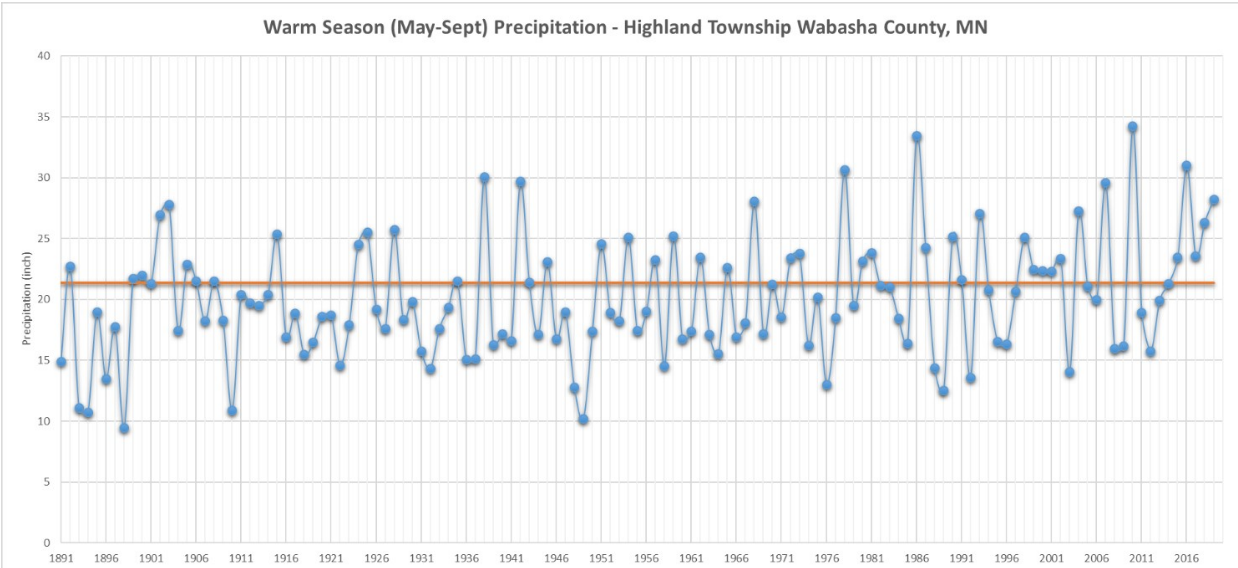


Climate and precipitation

West Indian Creek Watershed is located between two climate zones, moist subtropical mid-latitude climates and moist continental mid-latitude climates. These zones are characterized by warm and humid summers and cold winters. Average annual temperatures over the period of record (1895-2019) has ranged from 38.65 to 48.91 degrees Fahrenheit.

According to the Minnesota State Climatology Office Gridded precipitation database, the 1891 to 2010 normal warm season (May-September) precipitation for the West Indian Creek Watershed is 21.38 inches. The precipitation departure from historic average, or recent average annual precipitation (1989-2018) compared to the average for the entire climate record (1895-2018) shows that all of S.E. Minnesota has received three to four more inches of rain annually. Figure 3 shows the warm season precipitation totals for 1891 through 2019 in Highland Township, Wabasha County, Minnesota. The orange line in this figure is the warm season 'normal' precipitation total. Figure 3 shows that Highland Township, where the West Indian Creek Watershed is located, has consistently received higher than normal precipitation for the last five years. 1998 through 2002 is the only other five year period with consistent above normal warm season precipitation for the entire climate dataset, dating back to 1891.

Figure 3. Warm season precipitation 1891-2016



Wetlands data

The U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) has identified 359 acres of various types of wetlands in the West Indian Creek Watershed. The various types and areas are expanded on in Table 2 below; the primary type is hardwood wetland, which comprises 231.6 acres or 64.5% of the wetland area.

Table 2. NWI inventory in West Indian Creek Watershed

National Wetlands Inventory Type	Acres in West Indian Creek Watershed
Hardwood Wetland	231.6
Non-Vegetated Aquatic Community	59.2
Seasonally Flooded/Saturated Emergent Wetland	48.9
Shallow Marsh	13.3
Shallow Open Water Community	4.47
Artificially Flooded Shallow Marsh	0.81
Artificially Flooded Non-Vegetated Aquatic Community	0.51
Shrub Wetland	0.15

Surface water

As is discussed in subsequent sections (Geology, Groundwater Resources) 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 (MPCA, 2017b).

Department of Natural Resources (DNR) stream survey notes from 1954 state that the source of West Indian Creek is a spring in the stream channel (Image 1), and that springs are numerous along the entire stream.

Image 1. Spring flowing into West Indian Creek in the DNR/TU habitat improvement project being completed 2020-2021

Topography/elevation data

The topography of the West Indian Creek Watershed includes rolling hills, hollows, caves, sinkholes, and dramatic bluffs and valleys (Image 2).

Image 2. Outcropping of bedrock in West Indian Creek Watershed

The lowest point in the watershed is 725 feet above mean sea level and the highest point in the watershed is 1,214 feet above mean sea level. (Figure 4). An example of the rolling hills in the West Indian Creek Watershed is shown in Image 3.

Figure 4. One meter digital elevation model of West Indian Creek Watershed

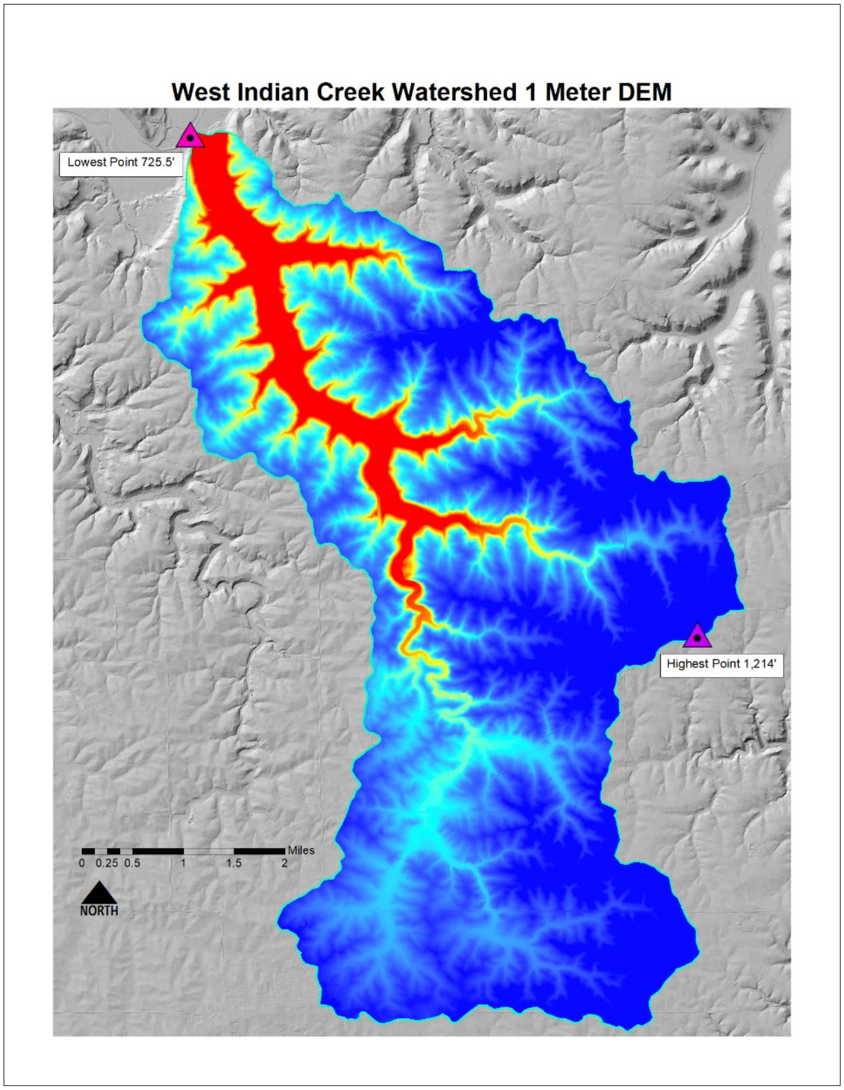


Image 3. Example of rolling fields in the headwaters/uplands of West Indian Creek Watershed

Geology

While most of Minnesota was once covered with glaciers that left behind deposits of rock, sand, and soil known as drift, southeast Minnesota was untouched by those processes. 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 is characterized by one of the highest concentrations of limestone spring creeks in the world. The groundwater that feeds the streams in southeast Minnesota helps maintain stable habitat conditions favored by trout and the insects they feed on.

These habitat conditions include:

- Cool water in summer.
- Water that's warmer than air temperatures during the winter.
- Relatively stable stream flows.

These unique conditions allow trout to continue to grow throughout the year, including through the winter, and provide consistent, ideal conditions for adult trout and for developing eggs in the streambed. The spring water emerging from limestone bedrock 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. (MPCA, 2017b, DNR).

Geology in Southeast Minnesota and the Zumbro River Watershed is characterized by karst features (Figure 5). 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-emerging 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 (MPCA, 2017b).

Figure 5. Karst lands in Minnesota (source: Alexander, Gao, & Green 2007)

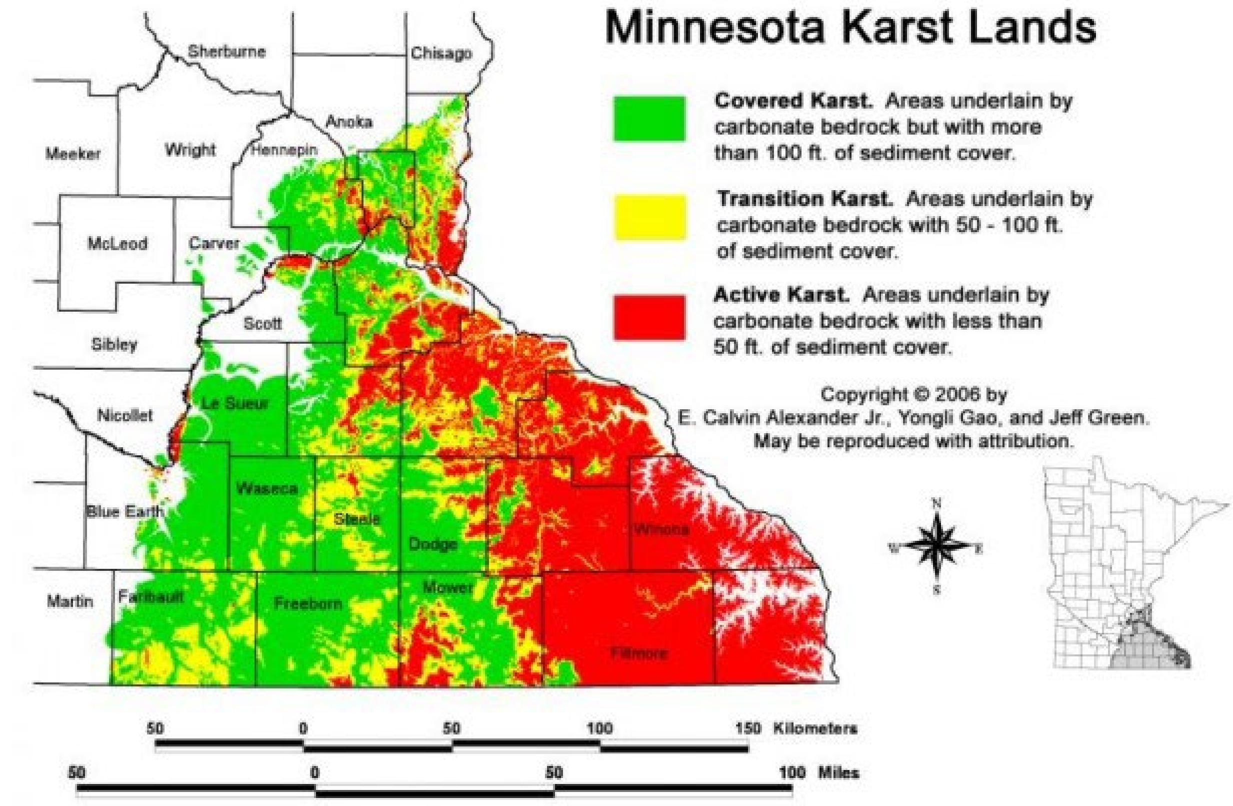


Figure 6. Kruger’s Cave, Wabasha County

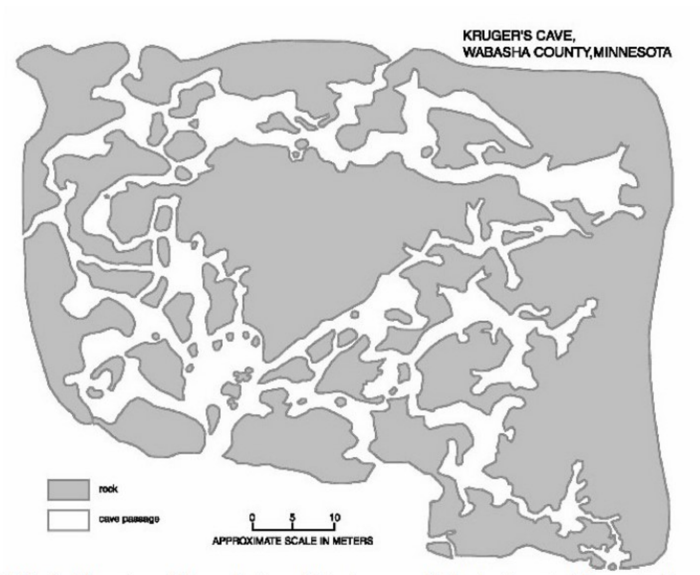


FIG. 5. Plan view of Kruger’s Cave, Plainview area, Wabasha County, Minnesota (from a drawing by David Gerboth, Minnesota Speleological Survey; Runkel *et al.*, 2007a).

Kruger Cave, one of the largest maze caves in the state, is another significant natural feature that occurs within the boundaries of state forest land in the West Indian Creek Watershed (Figure 6).

Soils

The soils in the West Indian Creek Watershed primarily consist of the Downs series in the uplands, Barremills series on the slopes, and Frontenac-Minneiska-and other series in the valleys (Figure 7). The Downs series is made up of deep, well drained soils formed in loess. Most areas in the watershed where the Downs series is present are considered either prime farmland or farmland of statewide importance. Areas with the Downs soil series and higher slopes (>9) are not considered prime farmland, these areas are often utilized for pasture or are wooded or have a combination of both. The 1965 Wabasha County Soil Survey notes that some Downs series soils with 2 - 6% slopes had been moderately eroded, 2-4 inches of the surface layer had been lost to erosion. Additionally, the soil survey notes that some areas had lost 5- 9 and even 10 inches of the surface layer where slopes are 6-12 or 12-18%. The Barremills series is described as very deep, moderately well drained soils on hills. These are soils that formed in a thin layer of slope alluvium over loess. Although the Natural Resources Conservation Services (NRCS) soil series description states that the Barremills soils are used for cropland, with common crops of corn, small grains, and hay; most areas where this series is present in the West Indian Creek watershed are not considered prime farmland because the slopes are often too high.

According to the NRCS Soils Survey information, roughly 71% of the soils are optimal for farming (

Figure 8), however these soils still require good management practices, as outlined in the Natural Resources Conservation Service Field Office Technical Guide (FOTG) for Minnesota. For example, soil capability Class IIe are soils that are subject to moderate erosion if not protected, 92% of the Class IIe capability soils are considered prime farmland. Additionally, 99% of the soils in the farmland of statewide importance category in West Indian Creek watershed are of the Class IIIe Capability group. These soils are subject to severe erosion if they are cultivated and not protected.

Figure 7. Soil types in the West Indian Creek Watershed

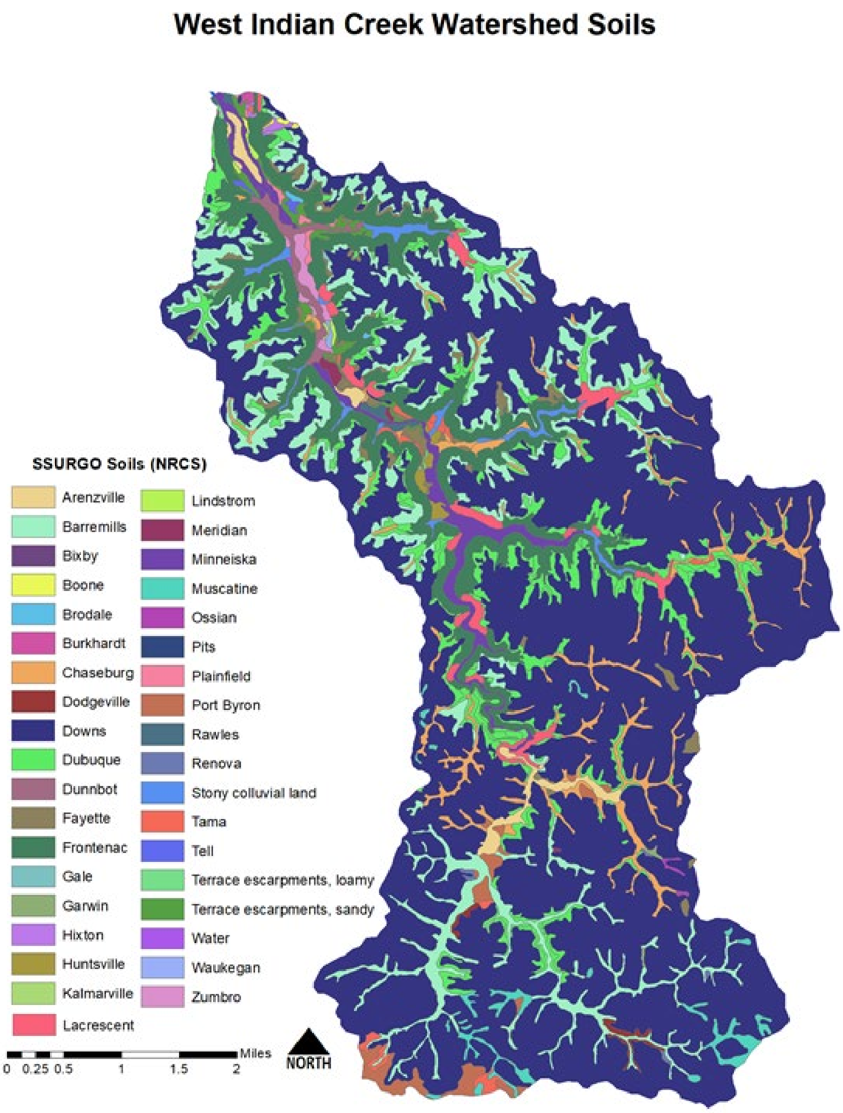
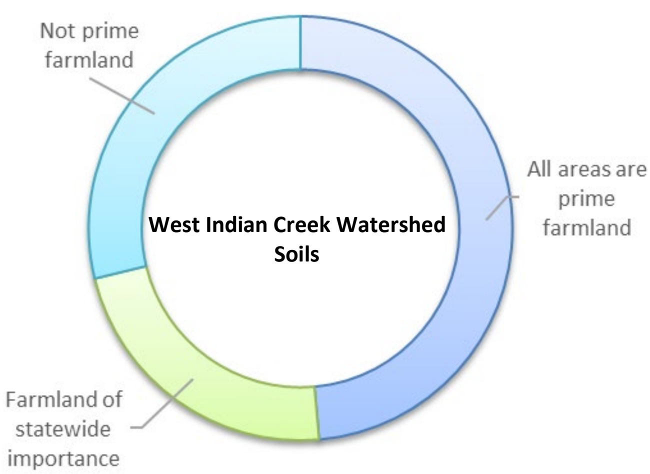


Figure 8. West Indian Creek Watershed farmland ranked soils

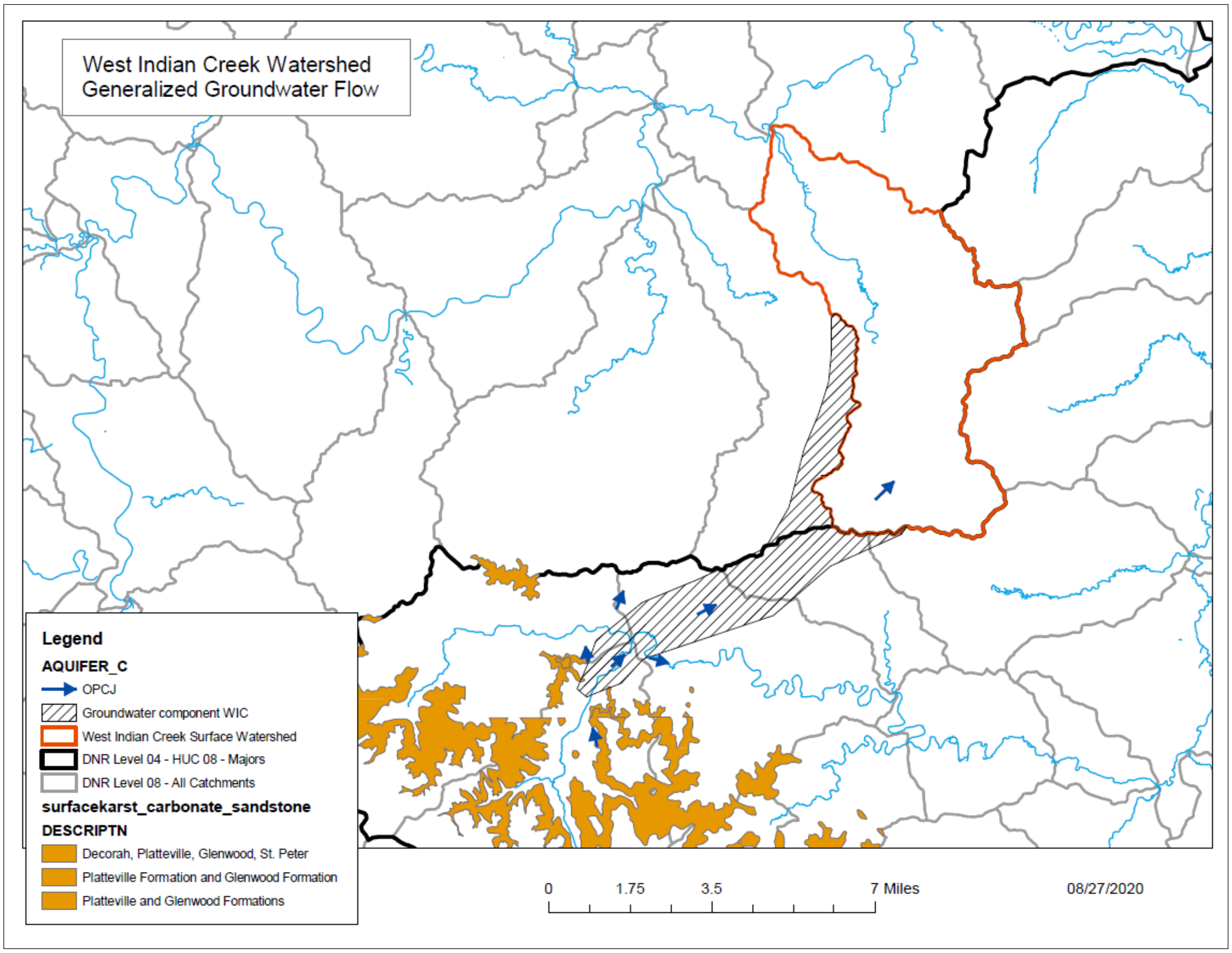


Groundwater resources

Karst aquifers, like those commonly used for drinking water supplies in the Zumbro River Watershed, are very difficult to protect from activities at the ground surface because pollutants can be quickly transported to drinking water wells or surface water. The Karst features and regions are illustrated in Figure 10. Because of The rapid transport of pollutants to drinking water, the best strategy to protect groundwater in this watershed is pollution prevention from common sources like row-crop agriculture, septic systems, abandoned wells, and Animal Feedlot Operations (MPCA, 2017b).

The Drinking Water Supply Management Area for the City of Plainview is located at the headwaters of the West Indian Creek Watershed. This area is a source of regional groundwater recharge and is considered vulnerable to surface contamination. Water chemistry results from the two public wells show that they are impacted by nitrate and have other markers of surface water influence. Groundwater flow paths in the Jordan aquifer move from the Plainview area toward West Indian Creek, a local discharge point. (J. Ronnenberg, personal communication, 2019)

Figure 9. Groundwater flow paths in the West Indian Creek Watershed (provided by the MDH, 2020)



In addition to Plainview, there are at least two other public water supply wells in the watershed. These are non-community wells, and as such, lack the resources available to municipalities to control land use in the areas outside of their own properties. These systems would benefit from the assistance of BMP promotion and implementation that reduces contaminant leaching, such as nitrate and bacteria (J. Ronnenberg, personal communication, 2019).

Figure 10. Karst regions and features in the West Indian Creek Watershed (Minnesota DNR, 2020)

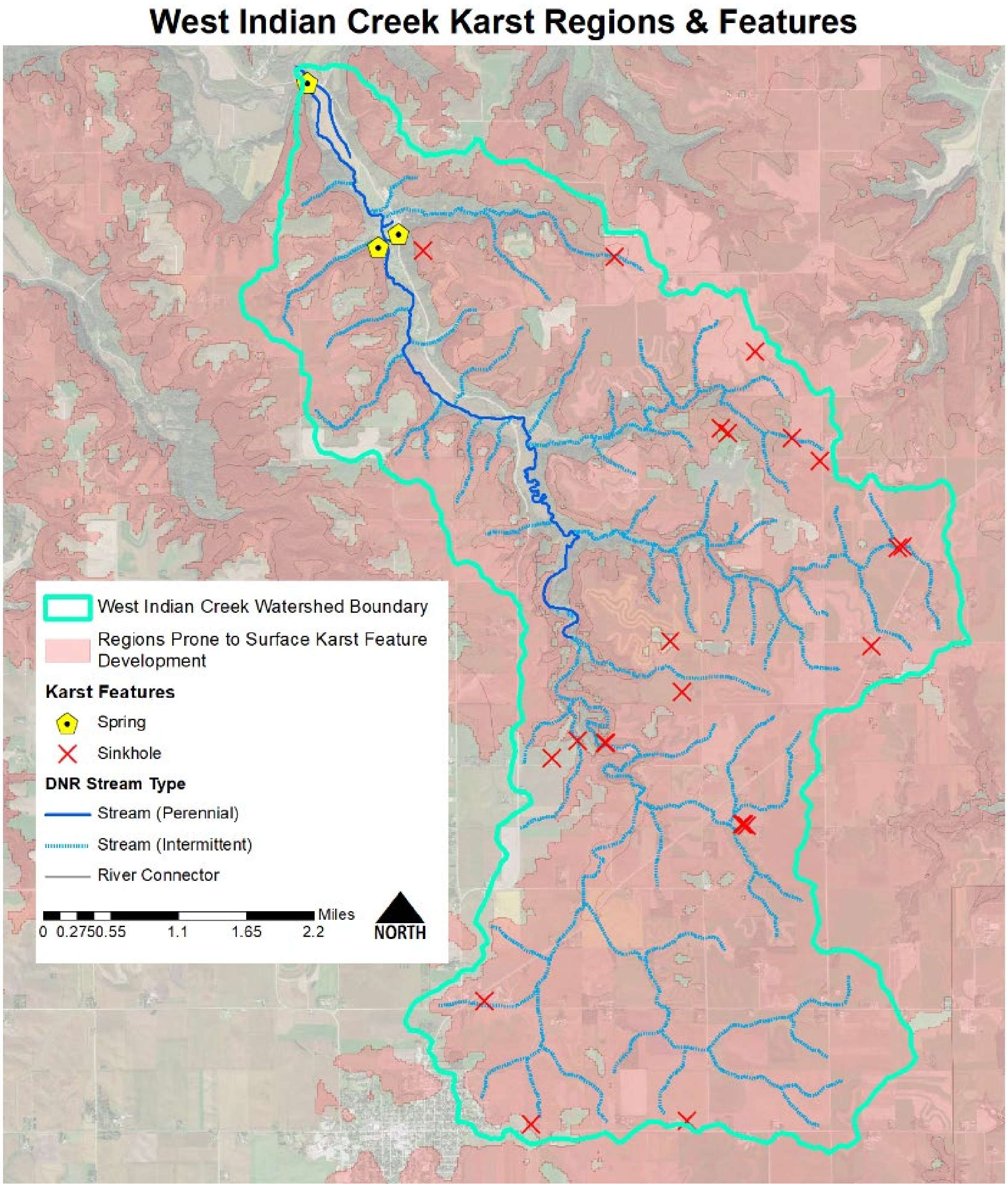


Image 4. Newly mapped spring in the West Indian Creek Watershed

There are three mapped springs in the West Indian Creek Watershed; however, this is likely not a comprehensive representation given these springs are located far downstream on West Indian Creek. While walking two small sections of West Indian Creek (around two stream miles) on September 30, 2020, staff discovered, mapped, and sampled nine additional springs (Image 4). There are 23 mapped sinkholes in the watershed, again this is likely not a comprehensive representation. A verified sinkhole is direct evidence that karst processes are active both on the surface and in a karst aquifer in the subsurface. The absences of sinkholes on the land surface, however, does not imply the absence of active karst processes on the surface or of a karst aquifer in the subsurface.

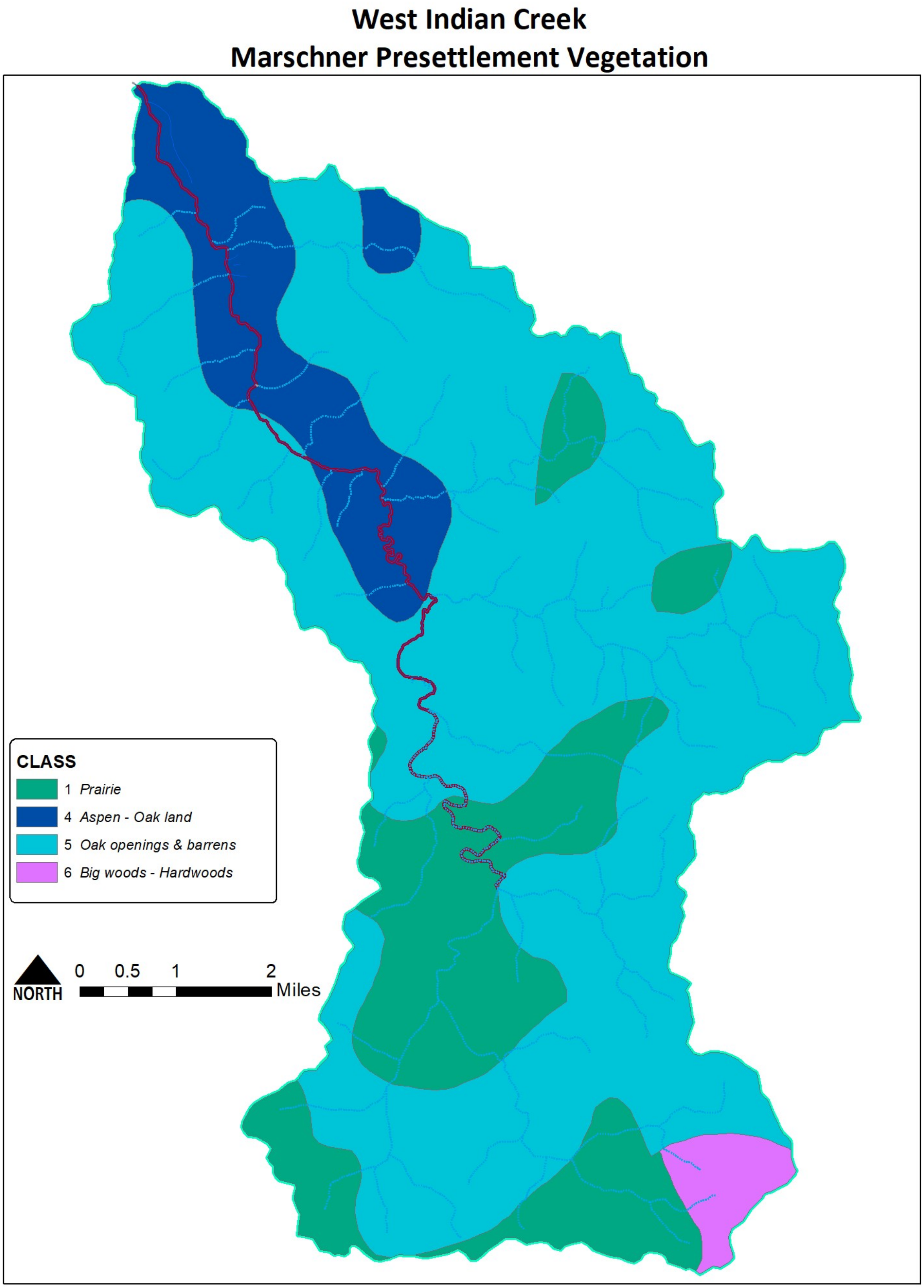
DNR stream survey notes from 1954 state that small springs are numerous along the whole of West Indian Creek and that the source of the entire stream is a spring in the stream channel.

Vegetation

Pre-settlement vegetation in the West Indian Creek Watershed consisted of primarily (65%) oak openings and barrens. The lower West Indian Creek valley, extending from the confluence with the Zumbro River to where MPCA's long term monitoring site is now located, was Aspen-Oak land. The uplands of the small watershed were prairie, comprising nearly 20% of the watershed. A small corner (2%) of the far headwaters area was classified as Big Woods-Hardwoods, made up of oak, maple, basswood, and hickory trees.

Vegetation changed significantly with agricultural settlement of Wabasha County in the 1850s. At that time, a 200 acre farm was considered large and the primary crops included wheat, barley, rye, corn, and oats. Farmers generally had a more diverse array of crops and in the early 1900s, strip and contour farming were promoted. More recently, farms and individual fields have increased in size and focused on corn and soybean production. Table 13 provides the current percentages crops in the watershed and Figure 12 provides current land cover.

Figure 11. West Indian Creek Marschner pre-settlement vegetation map



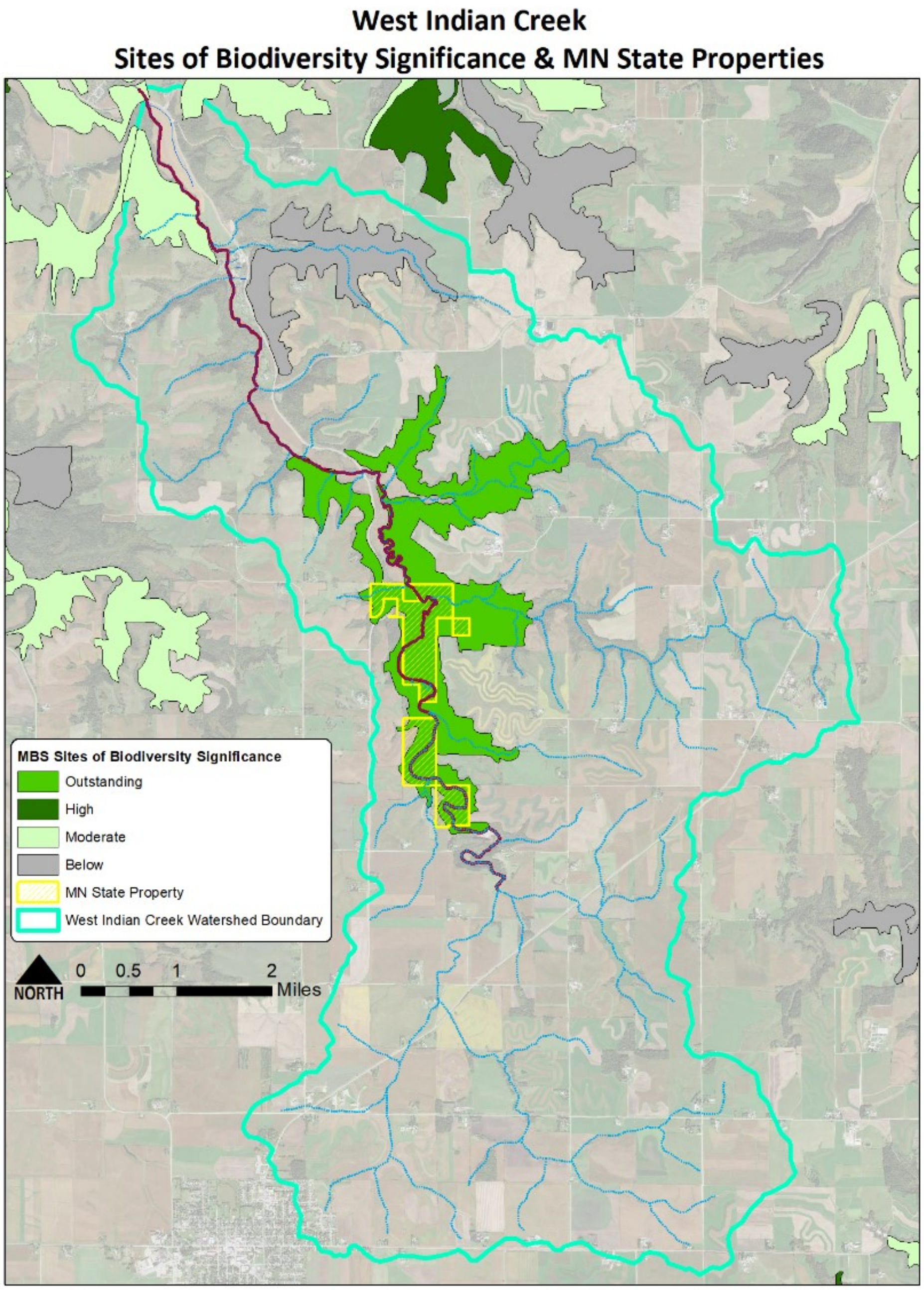
Exotic and invasive species

The introduction and establishment of non-native invasive insect, disease, and plant species is a concern for natural resource managers. Invasion of forest ecosystems by non-native invasive species can cause significant economic losses and expenditures for control because they destroy or displace native plants and animals, degrade native species habitat, reduce productivity, and disrupt forest ecosystem processes such as hydrological patterns, soil chemistry, moisture holding capability, and susceptibility to erosion (DNR, 2013) Examples of non-native invasive species with known adverse effects on Minnesota forest resources include: white pine blister rust, gypsy moth, and European buckthorn. There is potential for significant adverse impacts from other species present, such as: emerald ash borer, garlic mustard, reed canary grass, multiflora rose, exotic honeysuckle, spotted knapweed, wild parsnip, and oriental bittersweet. Many of these invasive species are known to be found in the West Indian Creek watershed as well as the surrounding area. In addition to those already listed, poison hemlock and Canada thistle have also been identified in the watershed.

Sensitive areas and endangered species

West Indian Creek Watershed contains 293 acres of designated High Conservation Value Forest part of the Richard J. Doerer Memorial Hardwood State Forest. 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 native plant communities. Additional features that contribute to the site's designation include the presences of cave bat hibernacula and an abundance of rare plant and wildlife species.

Figure 12. Sites of biodiversity significance and Minnesota state properties



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. 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. These forests typically contain trees older than 120 years, standing and fallen dead trees, and have experienced minimal levels of human disturbance. Three designated old-growth forest stands remain in the Zumbro River Watershed, occurring adjacent to one another within the West Indian Creek HCVF. These include a 32 acres stand dominated by black ash, a 31 acres stand composed largely of sugar maple, and a 53 acre stand consisting mostly of red oak. (MPCA, 2017b).

The Upper West Indian Creek Valley area is one of the most biologically significant forested areas in Wabasha County and, among similar valleys in Southeast Minnesota, is of outstanding biological significance (Figure 12). Within the watershed is 1,276.69 acres of outstanding biodiversity significance, this area is located along the upper reaches of West Indian Creek. The site supports a high quality and diverse array of forest communities including lowland hardwood forest, maple-basswood forest, mesic oak forest, white pine-hardwood forest, oak woodland, mixed hardwood seepage swamp, and algific talus slope. The area contains important geologic features including moist and dry cliffs and several caves. At least one of the caves present on the site was used by hibernating bats. Small bluff prairies occur atop several of the dry cliffs. The creek is a state-designated trout stream fed by springs and seeps that emerge in the area. There are also 185.88 acres of moderate biodiversity significance, and 372.81 acres of negative/below biodiversity significance. The 372.81 acres and remaining 15,351.62 acres of the watershed are lands where native plant communities have been seriously altered or destroyed by human activities such as farming, recent logging, draining, and development according to the Minnesota Biological Survey (MBS).

The area supports multiple populations of fifteen state-listed plants and two state-listed bird species. The Upper West Indian Creek valley is of statewide significance due to its large contiguous acreage of native plant communities, the quality of these communities, the presence of rare specialized habitats, and the large concentration of rare plants and animals, occurring in a large, intact natural landscape (DNR, 2013).

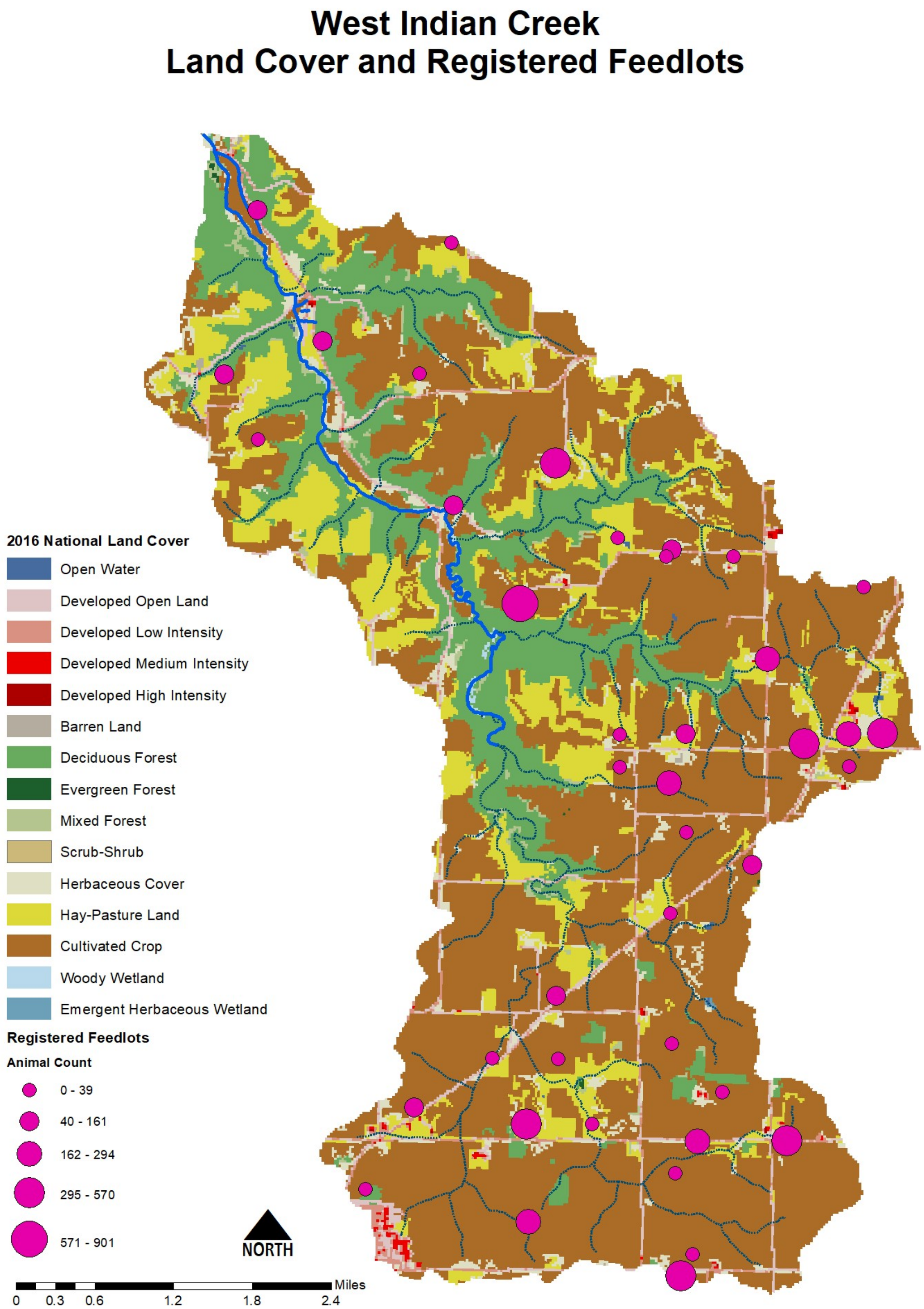
In 1978 the DNR acquired some land in the Upper West Indian Creek Valley. At that time there was a known population of Snow Trillium, a state special concern species, present. For that reason, the site was designated a Natural Heritage Registry Site shortly after its acquisition (DNR, 2013).

At this time, the state of Minnesota owns 308.73 acres of primarily outstanding biodiversity significant land within the West Indian Creek Watershed (Figure 12).

Land use and land cover

According to the 2016 National Land Cover Database, the primary land use in the West Indian Creek Watershed is cultivated cropland, which makes up around 59% of the land area. Another 14% of the land use is attributed to hay and pasture lands for a total of around 73% of the watershed being utilized for agriculture. There are 22 registered animal feedlots within the watershed. The next largest land cover category is deciduous forest at 16.8% of the watershed area. Less than 5% of the watershed area is developed. The land use and registered feedlots are displayed in Figure 13.

Figure 13. Land cover and registered feedlots in the West Indian Creek Watershed



Agricultural practices

West Indian Creek Watershed has been subject to extensive row crop agriculture for the last century and beyond, as can be seen in the first aerial image taken of the area in 1949 (Image 5). According to the USDA's ACPF six-year land use summary table, the watershed's agricultural land is 29% corn/soybean rotation, 29% pasture/grass/hay, 18% corn/perennial rotation, and 14% continuous corn. The remaining 10% is in various forms of corn rotation. With the large number of dairies and other animal operations, field application of manure is common throughout the watershed.

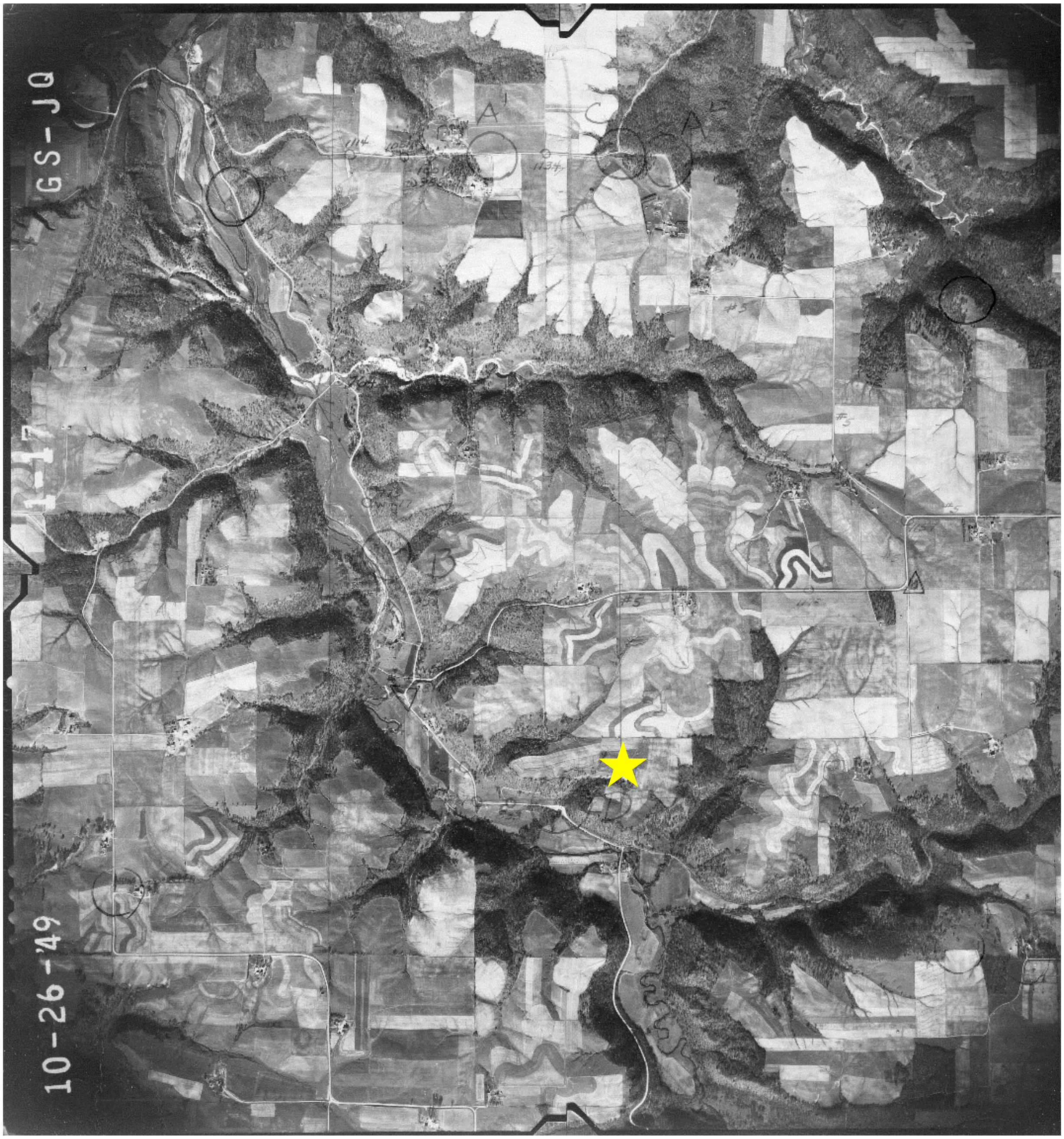
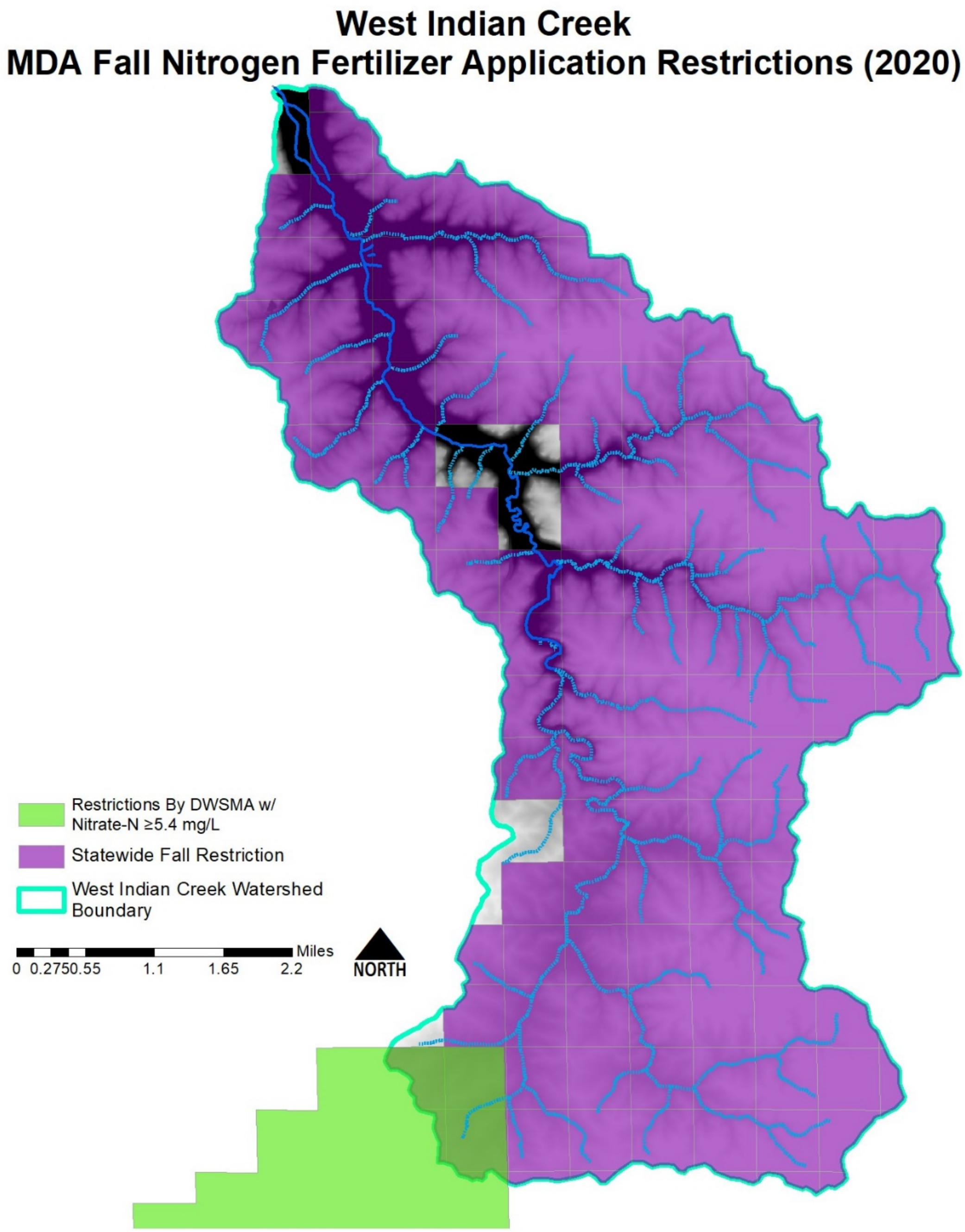


Image 5. First aerial image of much of West Indian Creek Watershed, 1949, with MPCA's long-term monitoring site marked.

Farming began here in the 1850s and has played a major role in the area's economy. Agricultural practices have changed over the years, primarily by increasing in size and uniformity. Much of the landscape is use for two crops, corn and soybeans. Machinery used for production has also increased in size, making strip cropping less practical. Dairy, poultry, swine, and beef cattle farms have been present in the area since the late 1800s and similarly, have increased in size, especially dairy farms in this area.

Effective in September 2020, is Minnesota's Groundwater Protection rule (Minn. R. ch. 1573) which focuses on restrictions to fall application of nitrogen fertilizer in areas with vulnerable groundwater or protected areas around a public well known as a drinking water supply management area (DWSMA) with nitrate-nitrogen concentrations at or in excess of 5.4 mg/L. The vast majority of the West Indian Creek watershed has been included in the vulnerable groundwater area where fall application of nitrogen fertilizer is restricted, shown in purple in Figure 14. Additional restrictions are applicable to the area shown in green, the Drinking Water Supply Management Area of Plainview, Minnesota.

Figure 14. Minnesota Department of Agriculture nitrogen fertilizer application restrictions (2020)



Mining activities

There are three quarries within the watershed boundaries. Two have been permitted for several years, and one is currently initiating the permitting process. All permitted sites are permitted for construction sand and gravel mining. At these sites, there is no dewatering and stormwater is contained on site and allowed to infiltrate.

Fisheries

Much of West Indian Creek is designated by DNR as a trout stream with protected tributaries and by MPCA as a Class 2Ag water (Image 6). Class 2Ag waters are protected for general cold water aquatic life and habitat. These are waters capable of supporting and maintaining a balanced, integrated, adaptive community of cold water aquatic organisms having a species composition, diversity, and functional organization comparable to the median of biological condition gradient level 4. West Indian Creek supports naturally reproducing populations of both brown and brook trout as well as slimy sculpin. The trout fishery of West Indian Creek is highly valued by DNR and fishing organizations. The two habitat improvement and stream restoration projects within the watershed are a clear indication of the value of its fishery.

Image 6. Section of habitat improvement project completed by Trout Unlimited and DNR on West Indian Creek

Developed areas

The boundaries of the city of Plainview extend into the West Indian Creek watershed, comprising about 1.05% of the watershed area. Additionally, the Whippoorwill Campground occupies around 71 acres in the watershed with around 100 RV sites and a restaurant and banquet hall.

According to the 2019 Cropland Data Layer, only 5% of the watershed is developed. Two percent of the developed land is low intensity and the remaining three percent is considered open space. Less than 0.3% of the watershed is considered medium and high intensity development.

Relevant authorities

There are various agencies and local organizations involved in the restoration of the West Indian Creek Watershed. Table 3 describes the different agencies and authorities potentially involved in West Indian Creek.

Table 3. Relevant authorities in the West Indian Creek Watershed

Level of Government	Agency	Authorities
Federal	U.S. Environmental Protection Agency	Clean Water Act National Pollutant Discharge Elimination System(NPDES) Safe Drinking Water Act Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
	U.S. Army Corps of Engineers	Rivers & Harbors Act, Sec. 10 Clean Water Act Section 404 Permits
State	Minnesota Pollution Control Agency	Water Quality Certification, Sec. 401 of Clean Water Act Surface Water Standards Water Quality Monitoring & Assessment Impaired Waters List NPDES permits Feedlot Regulation Subsurface Sewage Treatment Systems (above 10,000 gal/day)
	Department of Natural Resources	Public Waters Work Permits Surface Water Appropriation Permits Surface Water Hydrology Programs Preliminary Well Assessment Shoreland Management
	Board of Water & Soil Resources	Comprehensive Watershed Management Plans Groundwater Protection Plans Soil & Water Conservation District Oversight MN Wetland Conservation Act
	Minnesota Department of Agriculture	Monitoring of agricultural chemicals, Groundwater Protection Rule
	Minnesota Department of Health	Well Management Program Wellhead Protection Safe Drinking Water Act Health Risk Limits Source Water Assessments
County	Wabasha County Soil & Water Conservation District	Wetland Conservation Act Rules & Administration MN Buffer Rule compliance Local zoning ordinances
	Wabasha County	Local ordinances Subsurface Sewage Treatment Systems (under 10,000 gal/day)

Demographic characteristics

Population

There are nearly 350 land owners in the West Indian Creek Watershed and 389 address points, 58% of these address points occur in the city of Plainview which occupies 181 acres or 1.05% of the watershed. The remaining 98.9% of the watershed includes 163 address points.

The median age of individuals living in Highland Township was estimated to be 47 according to the Unites States Census Bureau. Additional age breakdown is presented in Table 4.

Table 4. Percentage of population by age group in the West Indian Creek Watershed

Age Group	% of Township Population
Under 5 years	4.1%
5 to 17 years	17.3%
18 to 24 years	9.7%
25 to 44 years	18.5%
45 to 54 years	17.1%
55 to 64 years	23.3%
65 to 74 years	3.9%
75 years and over	6.2%

The population of the area is predominantly white and English speaking, with less than 1% being non-white or speaking another language. Estimates of individuals in Highland township who were born in Minnesota are between 90% and 95%.

There is no significant growth anticipated for the area over the next 10 years.

Economics

Median individual income in Highland Township was estimated by the United States Census Bureau at $35,238 in 2018. The percentage of individuals for whom poverty status is determined to be at or above 150% of the poverty level in Highland Township was estimated at 88.2% in 2018.

Watershed conditions

Water quality standards

The federal Clean Water Act requires states to designate beneficial uses for all waters and develop water quality standards to protect each use. Water quality standards consist of several parts:

- Beneficial uses – identify how people, aquatic communities, and wildlife use our waters.
- Numeric criteria – amounts of specific pollutants allowed in a body of water and still protects it for the beneficial uses.
- Narrative criteria – statements of unacceptable conditions in and on the water.
- Antidegradation protections – extra protection for high-quality or unique waters and existing uses.

Together, the beneficial uses, numeric, narrative criteria, and antidegradation protections provide the framework for achieving Clean Water Act goals.

Minnesota's water quality standards are provided in Minn. R. ch. 7050. All current state water rules administered by the MPCA are available on the Minnesota water rules page (https://www.pca.state.mn.us/water/water-quality-rules).

Designated beneficial uses

The beneficial uses for public waters in Minnesota are grouped into one or more classes as defined in Minn. R. ch. 7050.0140. The classes and beneficial uses are:

- Class 1 – domestic consumption.
- Class 2 – aquatic life and recreation.
- Class 3 – industrial consumption.
- Class 4 – agriculture and wildlife.
- Class 5 – aesthetic enjoyment and navigation.
- Class 6 – other uses and protection of border waters.
- Class 7 – limited resource value waters.

The aquatic life use class now includes a tiered aquatic life uses (TALU) framework for rivers and streams. The framework contains three tiers-exceptional, general, and modified uses.

All surface waters are protected for multiple beneficial uses.

Numeric criteria/ State standards

Narrative and numeric water quality criteria for all uses are listed for three common categories of surface waters in Minn. R. ch. 7050.0220. The four categories are:

- Cold water aquatic life and habitat, also protected for drinking water: classes 1B, 2A, 2Ae, or 2Ag; 3A or 3B; 4A and 4B; and 5.
- Cool and warm water aquatic life and habitat and wetlands: classes 2B, 2Be, 2Bg, 2Bm, or 2D; 3A, 3B, 3C, or 3D; 4A and 4B or 4C; and 5.
- Limited resource value waters: classes 3C; 4A and 4B; 5; and 7.

The narrative and numeric water quality criteria for the individual use classes are listed in Minn. R. ch. 7050.0221 through 7050.0227. The procedures for evaluating the narrative criteria are presented in Minn. R. ch. 7050.0150.

The MPCA assesses individual waterbodies for impairment for class 2 uses – aquatic life and recreation. Class 2A waters are protected for the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life and their habitats. Class 2A waters are also assessed against the drinking water standard for nitrate. Class 2B waters are protected for the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish, and associated aquatic life and their habitats. Both class 2A and 2B waters are also protected for aquatic recreation activities including bathing and swimming.

Protection for aquatic recreation entails the maintenance of conditions safe and suitable for swimming and other forms of water recreation. In streams, aquatic recreation is assessed by measuring the concentration of *Escherichia coli (E. coli)* in the water, which is used as an indicator species of potential waterborne pathogens.

Protection of aquatic life entails the maintenance of a healthy aquatic community as measured by fish and macroinvertebrate indices of biological integrity (IBIs). Fish and invertebrate IBI scores are evaluated against criteria established for individual monitoring sites by waterbody type and use subclass (exceptional, general, and modified).

General use waters harbor “good” assemblages of fish and macroinvertebrates that can be characterized as having and overall balanced distribution of the assemblages and with the ecosystem functions largely maintained through redundant attributes. Modified use waters have been extensively altered through legacy physical modifications, which limit the ability of the biological communities to attain the general use. Currently the modified use is only applied to streams with channels that have been directly altered by humans (e.g., maintained for drainage, riprapped).

The ecoregion standard for aquatic recreation protects lake users from nuisance algal bloom conditions fueled by elevated phosphorus concentrations that degrade recreational use potential.

Antidegradation policies/procedures

The purpose of the antidegradation provisions in Minn. R. ch. 7050.0250 through 7050.0335 is to achieve and maintain the highest possible quality in surface waters of the state. To accomplish this purpose:

1. Existing uses and the level of water quality necessary to protect existing uses shall be maintained and protected.
2. Degradation of high water quality shall be minimized and allowed only to the extent necessary to accommodate important economic or social development.
3. Water quality necessary to preserve the exceptional characteristics of outstanding resource value waters shall be maintained and protected.
4. Proposed activities with the potential for water quality impairments associated with thermal discharges shall be consistent with section 316 of the Clean Water Act, United States Code, Title 33, Section 1326.

West Indian Creek standards and criteria

Most of the waters with designated beneficial uses in the West Indian Creek watershed are classified as 2Ag, general cold water use. There are just over 3.5 miles of the upper and lower portions of West

Indian Creek that are classified as 2Bg, general cool or warm water use. The water quality standards and criteria used in assessing these streams include the parameters provided in Table 5.

Table 5. Parameter and class standards and criteria in West Indian Creek Watershed

Parameter	Class 2Ag Standards & Criteria	Class 2B Standards & Criteria
E. coli	Not to exceed 126 organisms per 100 mL as a geometric mean of not less than 5 samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1260 organisms per 100 mL. Applies April 1-Oct 31	
Nitrogen, Nitrate	10 mg/L	N/A
Dissolved oxygen	Daily minimum of 7.0 mg/L	Daily minimum of 5.0 mg/L
pH	To be between 6.5 and 8.5 pH units	To be between 6.5 and 9 pH units
Total suspended solids (TSS)	10 mg/L, not to be exceeded more than 10% of the time between April 1-Sept 30	65 mg/L, not to be exceeded more than 10% of the time between April 1-Sept 30
Chloride	Chronic: 230 mg/L Maximum standard: 860 mg/L Final Acute Value: 1720 mg/L	
Stream eutrophication	Based on summer average concentrations for the South River Nutrient Region: TP ≤150 µg/L Chlorophyll-*a* ≤35 µg/L Diel DO flux ≤4.5 mg/L Five-day BOD ≤3.0 mg/L If TP criterion is exceeded and no other variable is exceeded, the eutrophication standard is met	Based on summer average concentrations for the South River Nutrient Region: TP ≤150 µg/L Chlorophyll-*a* ≤40 µg/L Diel DO flux ≤5.0 mg/L Five-day BOD ≤3.5 mg/L If TP criterion is exceeded and no other variable is exceeded, the eutrophication standard is met
Biological indicators	Southern cold water streams Fish IBI numeric threshold: 50 Macroinvertebrates IBI numeric threshold: 43	Southern streams Fish IBI numeric threshold: 50 Low-gradient southern forest streams Macroinvertebrate IBI numeric threshold: 43

Available monitoring and resource data

West Indian Creek is part of the DNR southeast Minnesota long term monitoring program. Biologic sampling began here in 1981 with annual samples being collected since 1999. The DNR also has notes and water quality data from stream surveys completed in 1954 and 1975. The Minnesota Pollution Control Agency (MPCA) also has a long term monitoring site on West Indian Creek (Image 7), where water chemistry samples have been collected since 2007. MPCA's dataset includes the parameters and corresponding number of measurements in Table 6.

Table 6. Parameter and the number of measurements since 2007 in West Indian Creek Watershed

Parameter	Number of measurements
Dissolved oxygen	78
E. coli	38
Inorganic nitrogen	211
pH	77
Phosphorus	156
Specific Conductance	77
Total Suspended Solids	176
Volatile Suspended Solids	176
Transparency (Secchi)	247
Temperature	102
Turbidity	158
Discharge (continuous)	221,820
Temperature (continuous)	128,484
Turbidity (continuous)	228,527

Image 7. MPCA long-term monitoring site on West Indian Creek

Water quality data (impairments and threats)

The Clean Water Act, Section 303(d) requires TMDLs to be developed for surface waters that do not meet applicable water quality standards necessary to support their designated uses. A TMDL determines the maximum amount of a pollutant a receiving water body can assimilate while still achieving water quality standards and allocates allowable pollutant loads to various sources needed to meet water quality standards. Currently, there are only two listed impairments in the West Indian Creek watershed (Table 7). The impairments affect aquatic consumption and aquatic recreation based on mercury in fish tissue and *E. coli* bacteria concentrations. More information regarding the *E. coli* impairment and other threats to the West Indian Creek watershed are described in the following pages.

Table 7. Listed impairments in the West Indian Creek Watershed

Resource of Concern	Description	Waterbody Identification (WID)	Use Class	Year Added to List	Impairment	TMDL Status
West Indian Creek	T109 R11W S21, south line to T109 R11W S6, north line	07040004-542	1B, 2Ag, 3B	2016 2008	Aquatic recreation: *E. coli* Aquatic consumption: Mercury in fish tissue	Approved

E. coli

Table 8 presents *E. coli* sample data collected from 2009-2011, this data is the basis for the only 303(d) listed impairment for West Indian Creek. These values are within the average of the streams having *E. coli* impairments in the Zumbro River watershed and neighboring Cannon River and Root River watersheds.

Table 8. *E. coli* monitoring data 2009-2011

Listed Waterbody Name	Reach AUID	WQ Station ID	No. Samples above 126 MPN/100mL	E. coli Geomean (MPN/100 mL)	Sample Date
West Indian Creek	07040004-542	S004-452	14/18	344.9	2009-2011
		S005-733	15/18	285.4	2009-2011

The presence of fecal pathogens in surface water is a regional problem in southeast Minnesota. Minnesota's 2020 303(d) List of Impaired Waters includes 154 stream reaches impaired by fecal pathogens in the Cedar River and Lower Mississippi River Basins in Minnesota. Water quality monitoring over several decades has shown widespread exceedances of state and federal water quality standards for fecal coliform bacteria throughout the basin.

E. coli is proposed to have two primary habitats, the first being the intestinal tracts of mammals and birds, and the second being the nonhost environment (water/sediment) (Zhi, S et.al., 2016 Evidence of Naturalized Stress-Tolerant Strains of *E. coli* in municipal waste water treatment plants). *E. coli* and other fecal indicator bacteria (FIB) were thought to survive poorly in the nonhost environment. Because of this, elevated levels of FIB in surface waters are often blamed on run off from feedlots and manure amended agricultural land, septic system leakage, untreated sewage from sewer overflows, human recreation, wildlife, and urban runoff. (Booth et al., 2003, Chalmers et al., 1997, Cox et al., 2005, Coye and Goldoft, 1989, Dufour, 1984a, Haile et al., 1999, Novotny et al., 1985, Wells et al., 1991) In recent years though, more and more studies have reported the growth and persistence of *E. coli* in various natural environments. (Byappanahalli et al., 2003, Carrillo et al., 1985, Whitman and Nevers, 2003) Byappanahalli et al. reported the persistence and growth of E. coli in soils and riparian sediments of Indiana and also in coastal forest soils from the Great Lakes watershed (Byappanahalli et al., 2003, Byappanahalli et al., 2006). Similarly, Ishii and coworkers provided evidence supporting the long-term survival and growth of E. coli in Lake Superior watersheds of Minnesota (Ishii et al., 2006a, Ishii et al., 2007). In addition to soils and water, *E. coli* can be found to associate with the filamentous macroalga Cladophora (Ishii et al., 2006b, Whitman et al., 2003) and periphyton communities (Ksoll et al., 2007) also harbor large concentrations of *E. coli* in the Great Lakes.

Hydrogeologic features in southeast Minnesota have the potential to favor the survival of fecal coliform bacteria. Cold water, shaded streams, and sinkholes may protect fecal coliform from light, heat, drying, and predation (MPCA, 1999).

Data from MPCA's IWM conducted in 2009-2010 show chronically elevated bacteria levels. Two of the 36 samples collected and analyzed exceed the individual sample standard of 1260 cfu/100 mL, with three additional samples having greater than 1000 cfu/100 mL. June through August all exceed the monthly geometric mean standard of 126 cfu/100 mL. In the Zumbro River Watershed, all cold water streams, where sufficient data was available for assessment, did not meet aquatic recreation standards due to bacteria issues (MPCA, 2016). A TMDL study for West Indian Creek was completed and approved by EPA in February 2018. Based on the load duration curve, Figure 15, the loading capacities and allocations in Table 9 were developed. There are no permitted wastewater facilities or MS4 communities within the drainage area, therefore there is no Waste Load Allocation.

Figure 15. *E. coli* load duration curve from the West Indian Creek Watershed *E. coli* TMDL Report

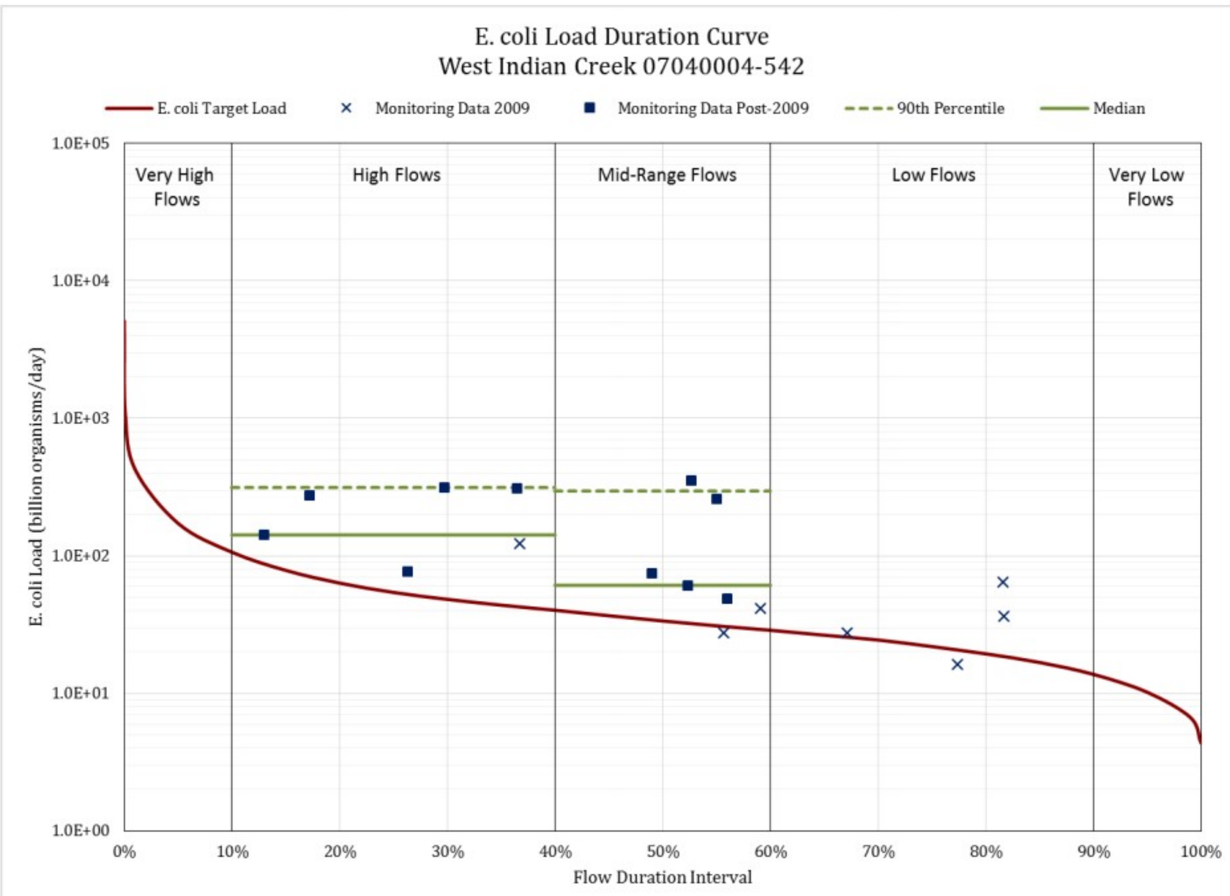


Table 9. West Indian Creek *E. coli* TMDL

West Indian Creek 07040004-542 TMDL Summary	Flow Regime				
	VHigh	**High**	**Mid**	**Low**	**VLow**
	Billions of Organisms/day				
***E.coli* Loading Capacity (TMDL)**	172.67	54.29	33.67	21.92	10.19
Wasteload Allocation (WLA)	NA	NA	NA	NA	NA
Load Allocation	155.40	48.86	30.30	19.73	9.17
10% Margin of Safety	17.27	5.43	3.37	2.19	1.02

Total suspended solids and turbidity

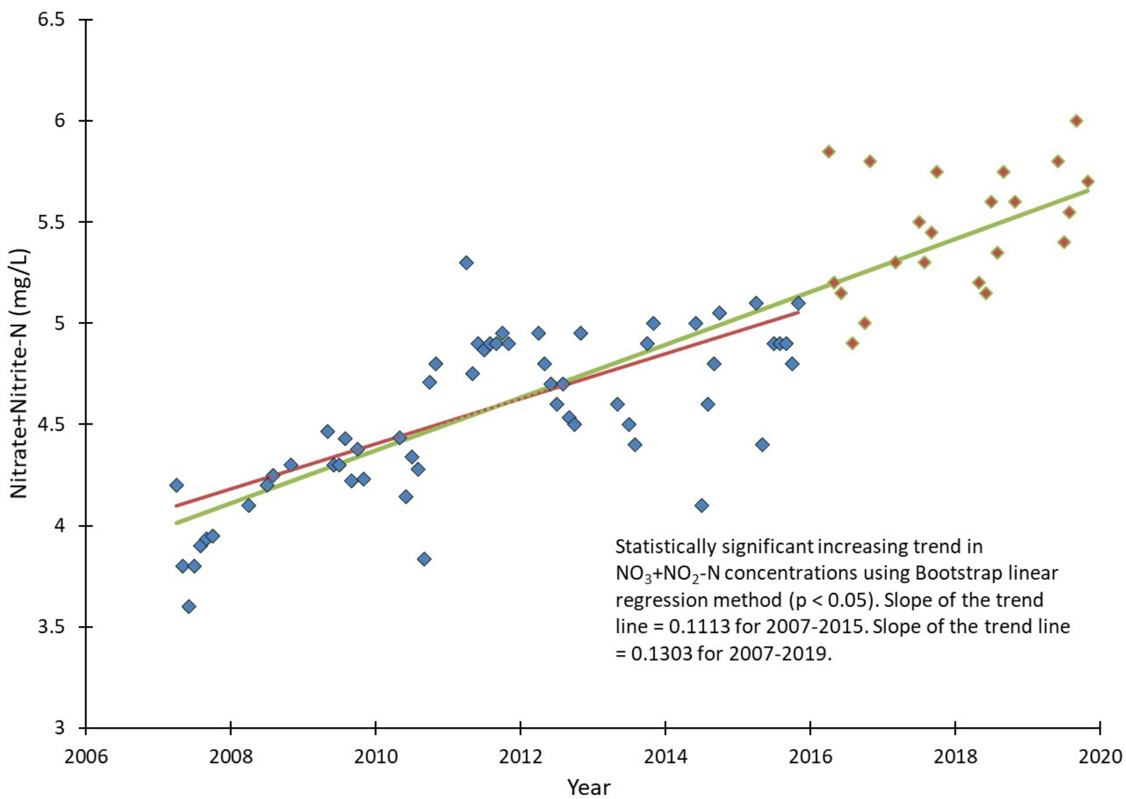
Total Suspended Solids (TSS) data collected in West Indian creek indicate that the stream could be listed as impaired, however aquatic life measurements were good enough to prevent the listing at the time of the most recent assessment. TSS standards are set to protect aquatic life, as such if excess TSS were an issue in West Indian Creek one would expect the aquatic life itself to respond. MPCA assessment policy is to conclude 'inconclusive' in situations where the parameter indicates impairment; however the aquatic life data is not congruent. This 'inconclusive' conclusion is reported to the EPA as 'insufficient information'. Protection is warranted to prevent further degradation and impairment. West Indian Creek could be heading towards impairment without further action to prevent it.

Nitrogen

Nitrate is one of the most common contaminants of groundwater in Minnesota and is a public health concern when found in groundwater used for drinking water. The Safe Drinking Water Act standard for nitrate in drinking water is 10 mg/L. The U.S. Geological Survey found that concentrations over 1 mg/L nitrate indicate human influence (USGS, 2010)

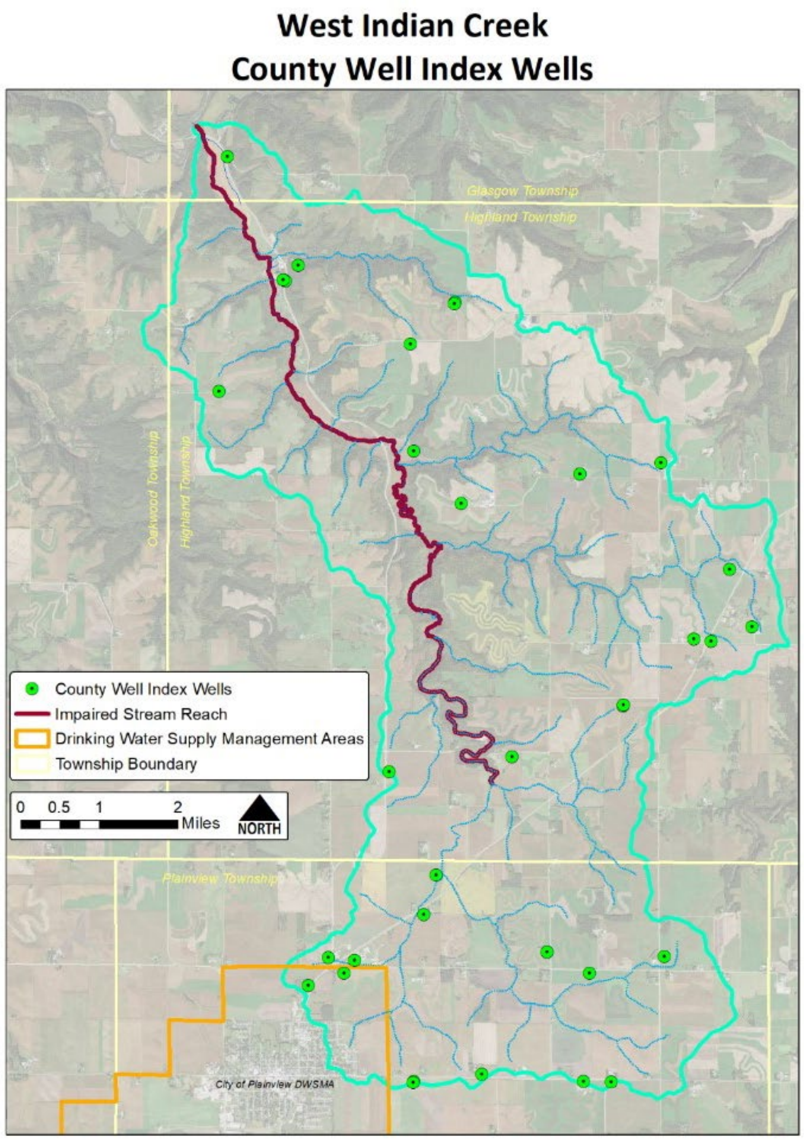
MPCA's Zumbro River WRAPS report showed a concerning statistically significant rising nitrate trend through 2016 (Figure 16). Recent data confirms that nitrate concentrations in West Indian Creek have continued to rise since. Figure 16 presents the previous analysis through 2015 and the updated analysis through 2019. The dataset shows a statistically significant increasing trend in nitrate concentration in West Indian Creek. Additionally, the updated analysis suggests that the rate of increase in nitrate concentration has also risen slightly as evidenced by the increased slope of the linear regression line. At the current rate of increase, West Indian Creek could reach or exceed the water quality standard for nitrate (10 mg/L) in 2053.

Figure 16. Baseflow concentrations of nitrate in the West Indian Creek Watershed 2006-2019



County Well Index wells are illustrated in Figure 17. Private wells tested through the MDA Township Testing Program show that ≥10% of the wells in the West Indian Creek Watershed contain ≥10 mg/L Nitrate-N (MDH, 2019). Testing also showed that 23.4% of the wells tested in Highland, 33.8% in Plainview, and 10.8% in Glasgow townships exceed the health standard for nitrate in drinking water. Karst features, including sinkholes, springs, caves, disappearing streams, and blind valleys, can be a direct link between surface and ground water. The direct link between surface and ground water makes the area's groundwater more susceptible to contamination from surface water pollution. This makes protection of surface water a high priority in this area since it can be a direct threat to human health (Wabasha County, 2015).

Figure 17. West Indian Creek County Well Index wells



All residents of Wabasha County rely on groundwater for their drinking water and 1/3 of residents are served by private wells. In the West Indian Creek watershed most of the drinking water wells are privately owned. These wells are not provided the program oversight and resources that public water supply wells receive through the Safe Drinking Water Act and Wellhead Protection Program. Access to water testing and BMP for land treatment and sanitary systems is essential in these areas. Well management and Subsurface Sewage Treatment System (SSTS) services would help individual land owners have more control over reducing their own health risks (J. Ronnenberg, personal communication, 2019) A small portion of the City of Plainview's Drinking Water Supply Management Area is contained in West Indian Creek Watershed. The City of Plainview has two community wells, both have an increasing trend in nitrate concentrations since the late 1990s.

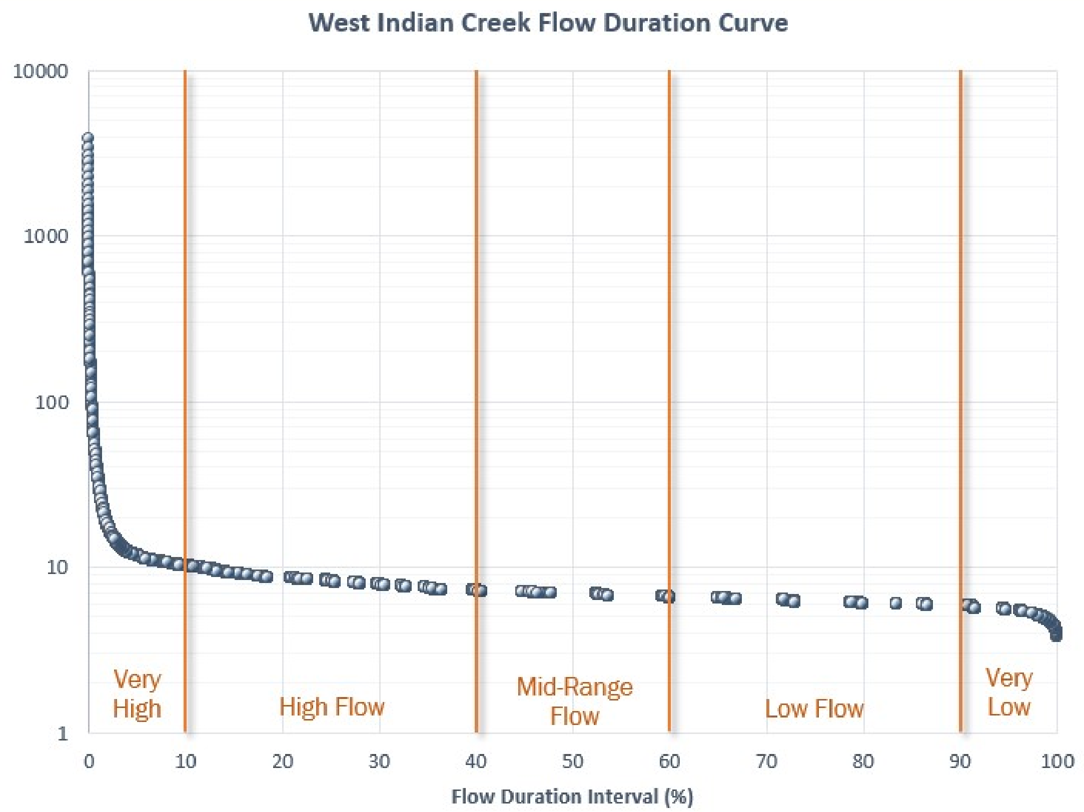
Phosphorus

Phosphorus is also frequently an issue in agricultural landscapes. The summer baseflow average total phosphorus in West Indian Creek from 2007 to 2019 is 74.4 µg/L. The summer stormflow average total phosphorus is 2,489.8 µg/L. Water quality assessments completed in 2015 indicate that river eutrophication was inconclusive due to TP exceeding the standard; however, there is no data to support assessment of the response variables.

Flow data

Average baseflow in West Indian Creek is between 6.5 and 7.2 cubic feet per second (cfs). The highest recorded flow is 3,907 cfs (08/11/2016) and the lowest recorded flow is 3.82 cfs (6/10/2015) (Figure 18).

Figure 18. West Indian Creek Flow data



The average number of events (flow >10 cfs) each year between 2007 and 2017 is 4.45 (Table 10). Between years, events vary quite a bit with regards to maximum flow; however, on average, flows peak and return to normal within one to three days.

Table 10. Warm season flow averages for West Indian Creek 2007-2017

Year	Warm Season Average Flow (cfs)
2007	11.89
2008	6.52
2009	7.12
2010	8.20
2011	8.56
2012	7.10
2013	7.83
2014	7.57
2015	5.99

Year	Warm Season Average Flow (cfs)
2016	11.70
2017	11.55
2018	10.79
2019	11.07
overall	8.91

Table 11. Flow events in West Indian Creek 2007-2019

Year	No. of Events	Max. Flow (cfs)	No. of Days w/ Flow >10 cfs	Max. No. of Consecutive Days w/ Flow >10 cfs
2007	5	1417	9	3
2008	4	99	3	2
2009	3	390	2	1
2010	7	1087	16	8
2011	4	216	11	4
2012	5	225	7	2
2013	9	50	15	5
2014	6	530	16	5
2015	6	228	8	2
2016	6	3908	14	5
2017	7	444	93	35
2018	8	695	69	19
2019	10	663	144	54

Although no formal analysis has been completed regarding this, it has been the general observation of both MPCA and DNR staff that baseflow in West Indian Creek has increased. Recent studies have found that increased precipitation combined with recent changes in land cover, land use, and artificial drainage are responsible for increased stream flows in the Midwest, Minnesota, and southeast Minnesota (Dadaser-Celik et al 2009; Lenhart and Nieber 2011, Zumbro Watershed Partnership, 2012).

Across Minnesota there has been a 20% increase in the number of one inch rains and a 65% increase in the number of three inch rains. Since 2000 widespread rains of more than six inches are four times more frequent than in the previous three decades (DNR, 2019). According to the DNR, southeast Minnesota now receives three to four more inches of rain than the historic average. The effects of these changes can be significant in the karst region. The steep hills and shallow, fractured bedrock are conducive to rapid movement of rainfall and snowmelt from the landscape to streams. Higher stream flows exacerbate the problem of turbidity and sedimentation through increased channel erosion (Zumbro Watershed Partnership, 2012).

Biological data

Fish and macroinvertebrates

The MPCA staff sampled fish and benthic macroinvertebrates of West Indian Creek in 2012. Both fish and macroinvertebrates were found to be meeting biologic criteria and supporting aquatic life uses (MPCA, 2016). The MPCA and DNR find fish and bugs to be doing well in West Indian Creek, the heavy use of this stream by anglers would also suggest that stream biology is in good condition. Additional review of the macroinvertebrate data and comparison with the Southern Coldwater Median (for stations meeting the macroinvertebrate IBI threshold) is provided in Table 12. Overall, from a biological standpoint, the metrics do not strongly implicate nitrate as a stressor, but they also do not deny it as a possibility. The taxa percent of trichoptera and nitrate index score are very close to the median, but just slightly below. Trichoptera are included in this analysis because they have been found to be generally sensitive to increasing nitrate. Related to that, the number of nitrate intolerant taxa and percentage of nitrate tolerant taxa are slightly better than the median. (T, Schauls 2020)

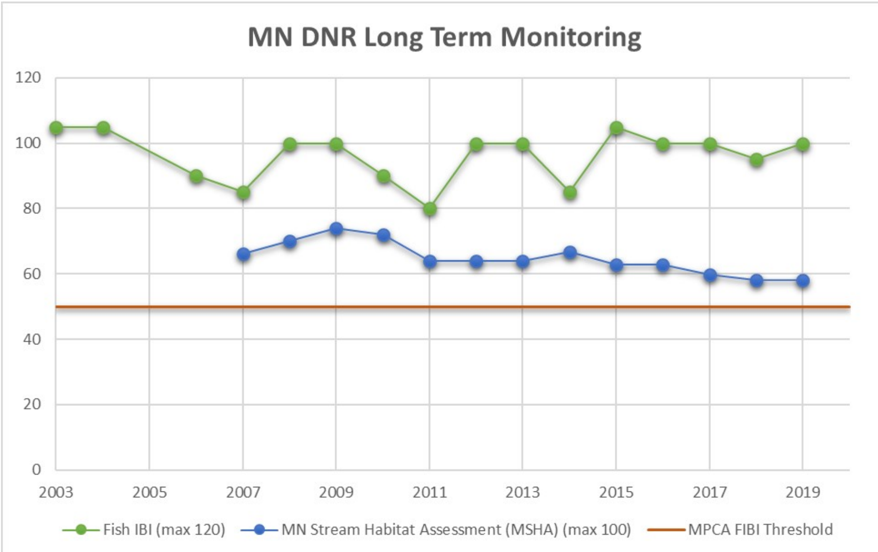
Table 12. MIBI data compared with the Southern Coldwater Median

	TrichopteraChTxPct	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
12LM014 (2012)	**16.6**	3.08	**2**	16	**48.1**
Southern Coldwater Median (for stations meeting the MIBI threshold)	*16.7*	*3.04*	*1*	*14*	*56.9*
Expected response to stress	↓	↑	↓	↑	↑

A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota shows a 75% probability that a stream with 12 mg/L or greater nitrate will have a macroinvertebrate index of biotic integrity (MIBI) score below the threshold of 46.1. It was also found that for a stream with 6 mg/L or greater nitrate, there is a 50% probability of the MIBI being below the impairment threshold. Given the nitrate concentrations in West Indian Creek are nearing 6 mg/L and continuing to increase, it is reasonable to conclude that the macroinvertebrate community is vulnerable to impairment due to increasing nitrate. (T, Schauls 2020)

West Indian Creek is part of the DNR's southeastern long-term monitoring program. Fish sampling began there in 1981, with annual samples being collected since 1999. Figure 19 shows data collected by DNR since 2003, including the index of biotic integrity for fish (FIBI) (which has a maximum achievable value of 120) and the Minnesota Stream Habitat Assessment results for each year (maximum achievable value of 100). Also included on the figure is MPCA's FIBI threshold for West Indian Creek of 50.

Figure 19. Long-term biological monitoring by DNR 2003-2019



Stream corridor data

Minnesota's Buffer Law (Minn. Stat. § 103F.48) requires perennial vegetative buffers of up to 50 feet along lakes, rivers, and streams and buffers of 16.5 feet along public drainage ditches. These buffers help filter out phosphorus, nitrogen, and sediment. The deadline for implementation of buffers on public waters was November of 2017. The Wabasha SWCD reports 100% compliance with the buffer law.

Stream habitat and corridor improvement projects have been carried out by partnerships with DNR, private land owners, and Trout Unlimited. A stream corridor improvement project, on 0.8 miles of West Indian Creek, was completed in 2012. The second began work in the spring of 2020 on 2.16 miles of West Indian Creek. Both of these projects include sloping and stabilization of stream banks, reconnecting the stream to its floodplain, installation of soil erosion blankets, and adding native plant species.

Pollutant source assessment

The primary pollutant sources in West Indian Creek watershed are nonpoint. There are a limited number of permitted point sources within the watershed.

Nonpoint source

Table 13 provides data from the Minnesota 2019 Cropland Data Layer of relative agricultural land use quantities. In total, this sums to between 73-74% of the land area of the West Indian Creek Watershed is used for agriculture.

Table 13. Percentage of agricultural land by planting in the West Indian Creek Watershed

Land use	Percentage of watershed area
Corn	40%
Grassland/pasture	14%
Soybean	10%
Alfalfa	9%
Sweet corn	1%
Total	74%

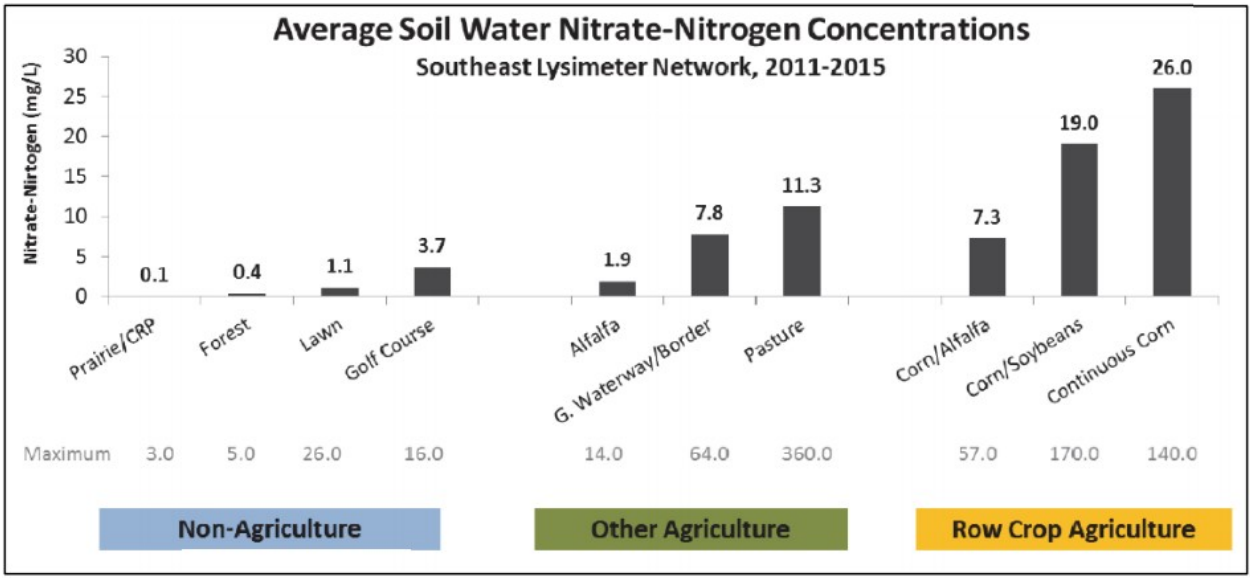
Corn is the single largest user of nitrogen fertilizer on Minnesota's landscape. Most corn in Minnesota is either continuous corn (corn following corn) or in a rotation following soybeans (UMN Extension, 2018). A literature review of a large number of worldwide drainage studies shows annual nitrate-N loss via tile lines varies from 0- 124 lbs/ac. Although, West Indian Creek watershed does not have a significant amount of tile drainage, the karst landscape provides a similar environment for pollutant leaching. A University of Minnesota (UMN) Extension study of the effect of different cropping systems on drainage discharge volume, nitrate-nitrogen concentration and loss in subsurface tile drained fields showed that continuous corn cropping systems have the highest nitrate-nitrogen loss rates, Table 14.

Table 14. Nitrogen loss by cropping systems

Cropping system	Total discharge (four-year)	Nitrate-N (four-year)	
		Concentration (ppm)	Loss (lbs/acre)
Continuous corn	30.4 inches	28	194
Corn-soybean	35.5 inches	23	182
Soybean-corn	35.4 inches	22	180
Alfalfa	16.4 inches	1.6	6
Conservation Reserve Program (CRP)	25.2 inches	0.7	4

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. In Figure 20, over 2,500 samples are summarized and average nitrate concentrations are displayed above each land cover type.

Figure 20. Average soil water nitrate-nitrogen concentrations in the West Indian Watershed, 2011-2015 (SE Lysimeter Network) (Figure 24, Zumbro WRAPS)



Additionally, 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 (Watkins et al, 2013) produced a statistically significant linear relationship. This 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. This conclusion is supported by the findings of Nitrogen in Minnesota Surface Waters, which describes 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.

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 (MPCA, 2017b). Sediment bound phosphorus is a very common source of the nutrient, especially in watersheds with little or no point sources. The primary sources of phosphorus in surface waters of West Indian Creek are cropland runoff, atmospheric deposition, and streambank erosion.

The Root River Field to Stream Partnership (RRFSP), a unique water monitoring project in southeast Minnesota, uses both edge-of-field and in-stream monitoring to characterize water quality in three study areas within the Root River Watershed. The Root River watershed is located one county to the south of West Indian Creek and contains a number of streams very similar to West Indian, including Bridge Creek. A number of key observations and recommendations from the data collected by RRFSP from 2010 to 2018 include:

- Dissolved phosphorus losses were highest in March and often occur when the ground is frozen. Incorporation of fertilizer and proper management of soil test phosphorus levels will help reduce these losses.
- Nearly 80% of the sediment loss occurred during May and June. During this critical time, fields were prepared for planting, but not at full canopy. Total phosphorus loss is closely linked to soil loss. Good soil conservation practices will help reduce these losses.
- Most nitrogen is lost through sub-surface leaching. Reducing nitrate leaching losses is challenging, but a very important task. Fine-tuning nitrogen rates, split applying nitrogen, crediting legumes and manure, growing perennials, and using cover crops are important practices.

- Over 50% of the annual nutrient and sediment losses typically occurred during one to two rain events each year.

Subsurface sewage treatment systems (SSTS)

Wabasha County's 2015 water plan estimates that 78% of SSTS (septic systems) are compliant, 18% are considered failing, and approximately 7% are believed to be imminent public health threats (IPHT). Examples of systems that would be considered IPHT are those where sewage backs up into a house, surfacing systems, 'straight pipes' (meaning they discharge to a ditch or river), or cesspools. Failing SSTS are those that could not meet the vertical separation distances in the soil and are considered to be failing to protect groundwater (Wabasha County, 2015). SSTS are inspected for compliance at point of sale or issuance of building permits.

One way to estimate the number of SSTS in the watershed is to utilize the known number of wells, however, this is not the most accurate way to estimate in Wabasha County. Another way to estimate is by the number of rural address points, of which there are 143 in the watershed. Using this estimate, approximately 25 SSTS are failing and 10 are IPHTs.

Streambank erosion

During dry conditions, atmospheric deposition is the more prominent source of phosphorus; however, under wet conditions, streambank erosion becomes the most significant source of phosphorus (MPCA, 2017b). As shown in Image 8 and Image 9, streambank erosion has been an enduring issue in the West Indian Creek Watershed even in the state forest land. The DNR has noted moderate streambank erosion for several years during their biological monitoring in West Indian Creek. Streambank erosion is also one of the most significant sources of sediment to West Indian Creek.

Image 8. Eroding stream banks in state forest land

Hydrological Simulation Program – FORTRAN (HSPF) modeling in the Zumbro River watershed show the top nonpoint sources of sediment and phosphorus are the result of upland runoff from highly erodible or unstable soils and bed and bank erosion.

Image 9. DNR Streambank erosion north of Plainview where land owner plans stream straightening Aug. 29, 1947

Atmospheric deposition

HSPF modeling for the Zumbro River watershed, the HUC-8 that contains the West Indian Creek watershed, include a pre-settlement atmospheric nitrogen deposition rate of approximately 0.50 kg-N/ha/year. This value originates from a joint National Park Service (NPS) and U.S. Fish and Wildlife Service (USFWS) effort to develop deposition analysis thresholds (FLAG 2002). The HSPF modeling also included a baseline or present-day scenario atmospheric deposition rate of approximately 20 kg-N/ha/year. This results in approximately 139,100 kg-N/year in West Indian Creek watershed.

Registered and unregistered feedlots

Animal waste containing fecal bacteria can be transported in watershed runoff to surface waters. The MPCA regulates animal feedlots in Minnesota. The primary goal of the state program for Animal Feeding Operations (AFOs) is to ensure that surface waters are not contaminated by the runoff from feeding facilities, manure storage or stockpiles, and cropland with improperly applied manure. Livestock also occur at hobby farms and small-scale farms that are not large enough to require registration, but may have small-scale feeding operations and associated manure application or stockpiles. All feedlots in Minnesota are regulated by Minn. R. ch. 7020.

The composition of the AFOs (22 registered as of May 2020) in West Indian Creek Watershed is approximately 59% dairy, 34% beef cattle, 6% swine. The largest is 468 animal units or 750 animals and the average is 193 animal units or 212 animals. In Minnesota, AFOs are required to register an animal feedlot capable of holding 50 or more animal units (AUs), or a manure storage area capable of holding the manure produced by 50 or more AUs, and an animal feedlot capable of holding 10 or more and fewer than 50 AUs, or a manure storage area capable of holding the manure produced by 10 or more and fewer than 50 AUs, that is located within shoreland. Further explanation of registration requirements can be found in Minn. R. ch. 7020.035.

Of the approximately 22 registered feedlots in the small watershed, there are no active NPDES permitted operations and none are classified as CAFOs. There are an additional 23 feedlots within a 0.5 mile radius of the West Indian Creek Watershed boundary with active registrations. This includes, 2 large operations with NPDES permits. These additional feedlots include 1,165 beef cattle, 5,504 dairy cattle, and 70 chickens. Although the registered address of these feedlots do not fall within the HUC12 boundary, many of their owners/operators also operate agricultural fields within the watershed and apply manure within the watershed. Manure is likely spread throughout the watershed year round, depending on storage capacity of each facility. Table 15 summarizes the feedlot characteristics of all registered feedlots that affect the West Indian Creek Watershed.

In addition to Minn. R. ch. 7020, Wabasha County has ordinances for new feedlots. New feedlots are prohibited within the floodplain and shoreland; 100 feet from private wells (sealed and unsealed); 1,000 feet from community wells; 300 feet from sinkholes; 200 feet from adjoining property lines or road right of way; 1,000 feet from city limits, schools, churches, platted subdivisions, parks, and neighboring feedlot.

Feedlot regulations are in place to minimize the risk of pollution, however there is always a potential for pollution. Feedlots that are at a higher risk for contributing *E. coli* to surface waters are those with open lots and/or are located in shoreland areas, feedlots with no manure storage, and feedlots with a pasture component in shoreland areas. The presence of karst also adds more risk for these operations.

Table 15. Feedlot characteristics of 45 registered feedlots in West Indian Creek area.

Feedlot Characteristic	# of Registered Feedlots (total 45)
Dairy	27
Swine	2
No manure storage	22
Within 300 ft of River/Stream	3
Within Shoreland	4
Within 1000 ft of Waterbody	4

Point sources

Feedlots and CAFO permits

No feedlots in the West Indian Creek Watershed are classified as CAFOs and none are NPDES/SDS permitted. There are 2 NPDES permitted feedlots within 0.5 miles of the West Indian Creek Watershed.

Mines and other pollutant sources

There are three quarries within the watershed boundaries. Two have been permitted for several years, and one is currently initiating the permitting process. All permitted sites are permitted for construction sand and gravel mining. At these sites, there is no dewatering and stormwater is contained on site and allowed to infiltrate. As such, these sites are not considered to be significantly contributing to the pollutant loading in the West Indian Creek Watershed. If these operations were to expand to a point where dewatering would be necessary for operation, a DNR review and permit would be required.

Table 16. Gravel extraction and mining permits in West Indian Creek Watershed

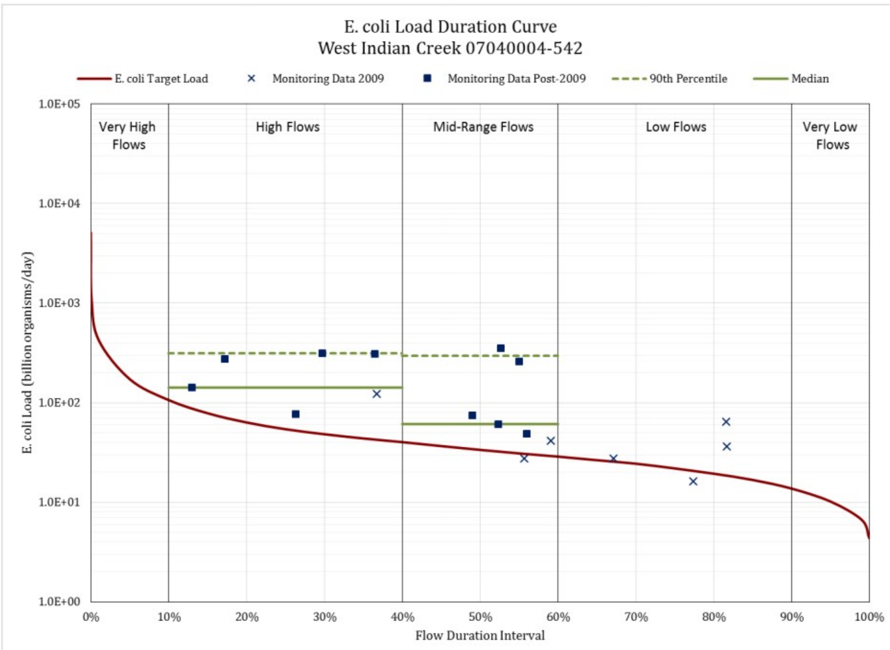
Permit No.	Operator	Permit Type	Site Name	Condition
MNG490308	Bennett & Sons Sand & Gravel	Construction Sand & Gravel Mining	Grant (Wilson) Pit (J1-1446)	No dewatering, stormwater contained & infiltrated
MNG490115	Bruening Rock Products, Inc.	Crushed Stone	Mischke Quarry-Wabasha Quarry (J2-1422)	No dewatering, stormwater contained & infiltrated
TBD	Johnson Rock Products, Inc.	TBD	TBD	TBD

Pollutant loads and water quality

Estimate of existing pollutant loads

Existing loads of *E. coli* are provided from the Zumbro River Watershed TMDL report and illustrated in Figure 21. Data collected for the TMDL show *E. coli* loads range from 27.75 to 351.58 billion organisms per day in the middle range flow zone.

Figure 21. *E. coli* load duration curve (MPCA, TMDL, figure XXX)



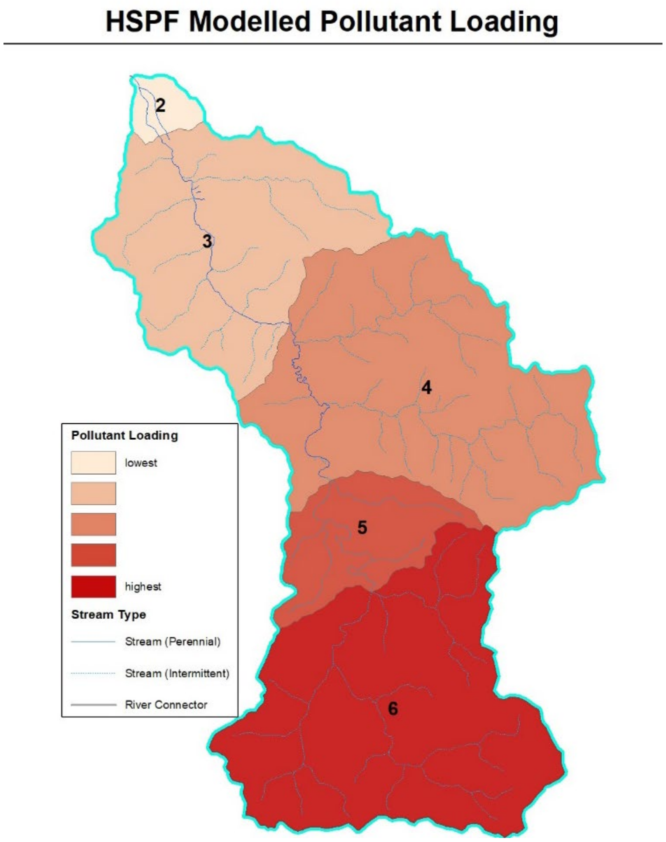
The HSPF modeling completed by Limnotech Inc. in 2016 and 2019 provides the following estimates of pollutant loading in the West Indian Creek watershed, summarized in Table 17.

Table 17. Watershed yield, TSS, TP, and TN in West Indian Creek Watershed

Sub-watershed ID	Watershed yield (inches)	Sediment yield (lbs/ac/yr)	Total Phosphorus (lbs/ac/yr)	Total Nitrogen (lbs/ac/yr)
2	9.64	257.71	0.30	5.93
3	9.49	252.97	0.35	8.12
4	9.67	306.59	0.47	10.8
5	9.45	375.49	0.63	14.35
6	9.37	616.21	0.79	16.48

Subwatershed 6 is the upstream most subwatershed and 2, the downstream most, just before the confluence with the Zumbro River. Yields for all pollutants (sediment, total phosphorus, and total nitrogen) increase from downstream to upstream, with the highest yields occurring in subwatershed 6 and lowest yields occurring in subwatershed 2. This coincides with the amount of cultivated acres, highest amounts of cultivated acres being in subwatershed 6.

Figure 22. HSPF modeled subwatersheds and relative pollutant loading



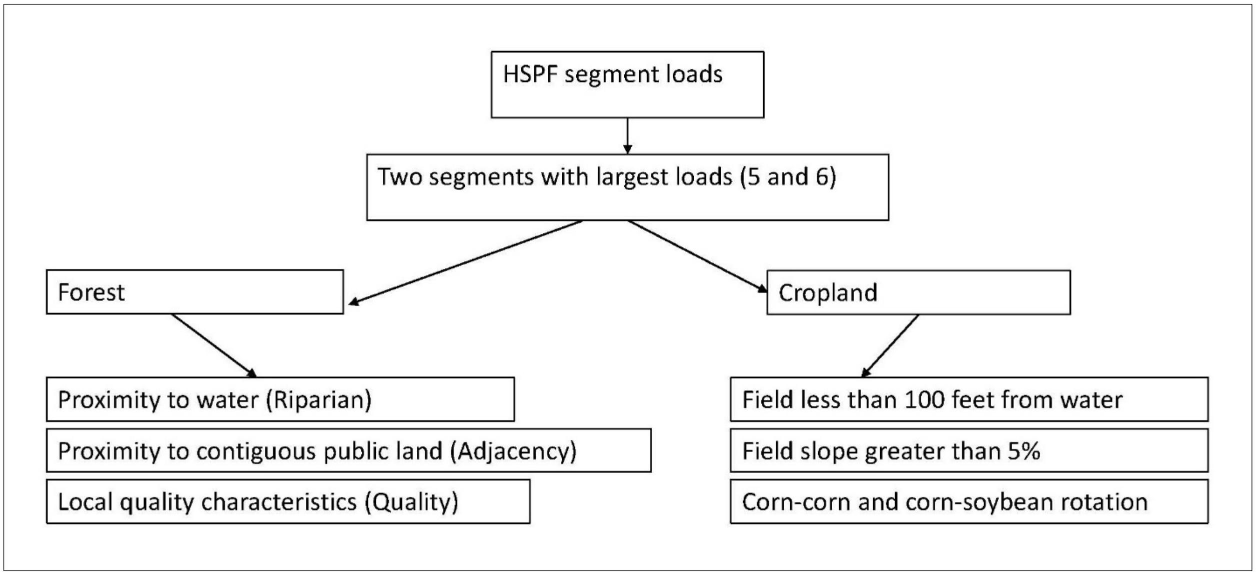
Future/buildout pollutant load estimates

There is no information available for future build out within the watershed; no significant increase in development is expected in the watershed area.

Identification of critical areas

Various tools and models have been used to target and prioritize management activities in the Zumbro River Watershed. This plan used these tools to begin identifying the critical areas contributing the most sediment and nutrients in the West Indian Creek Watershed. Further analysis using individual components of the tools provide the next level of critical area identification for use in targeting specific areas for implementation activities. Critical areas are identified for cropland and forest areas separately. Using this multi-step approach, critical area delineation is presented as a decision tree (Figure 23).

Figure 23. Schematic of critical area decision tree.

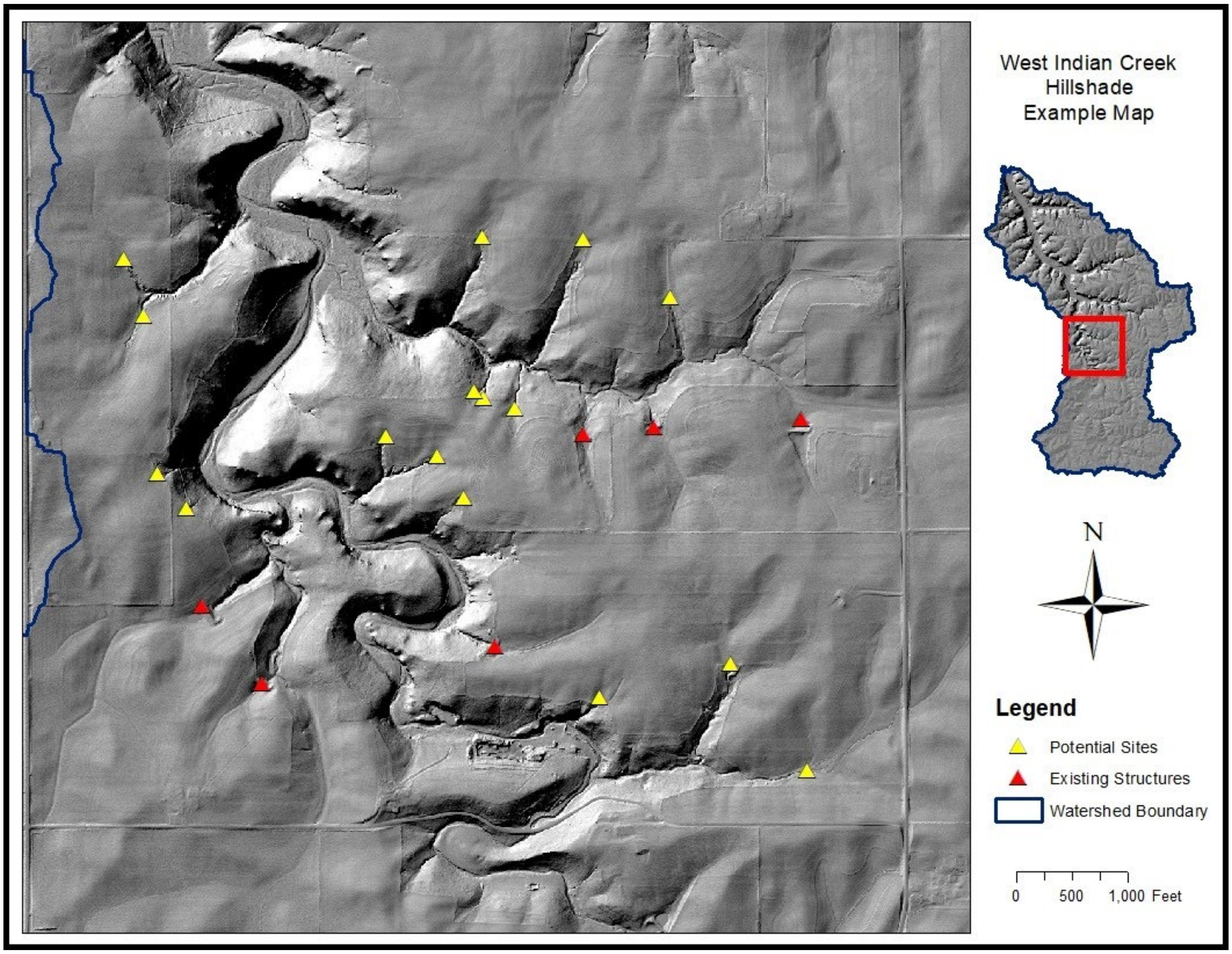


HSPF load estimates identify the two upper watershed model segments as the largest pollutant load segments of the five segments used in the model (Figure 22). The largest sources within the two segments are cropland runoff. Subwatersheds 5 and 6 are critical for the implementing structural and nonstructural practices. Increasing water storage through structural and non-structural practices in these upland, headwater sub-watersheds will have numerous benefits by reducing pollutants and runoff. Non-structural practices including perennial and cover crops and nutrient management will be most beneficial in the upland areas especially those with continuous corn, near continuous corn, and corn-soybean rotation. Practices addressing feedlots, septic systems, and wells should be prioritized by those posing the highest risk and by those located in the floodplain. Other Minnesota State agencies also have priorities within this watershed, including state forest land and riparian easements with the DNR, and DWSMA protection with MDH and MDA. Collaborating with these agencies and other sources of funding in the West Indian Creek area would be very beneficial.

Critical cropland areas

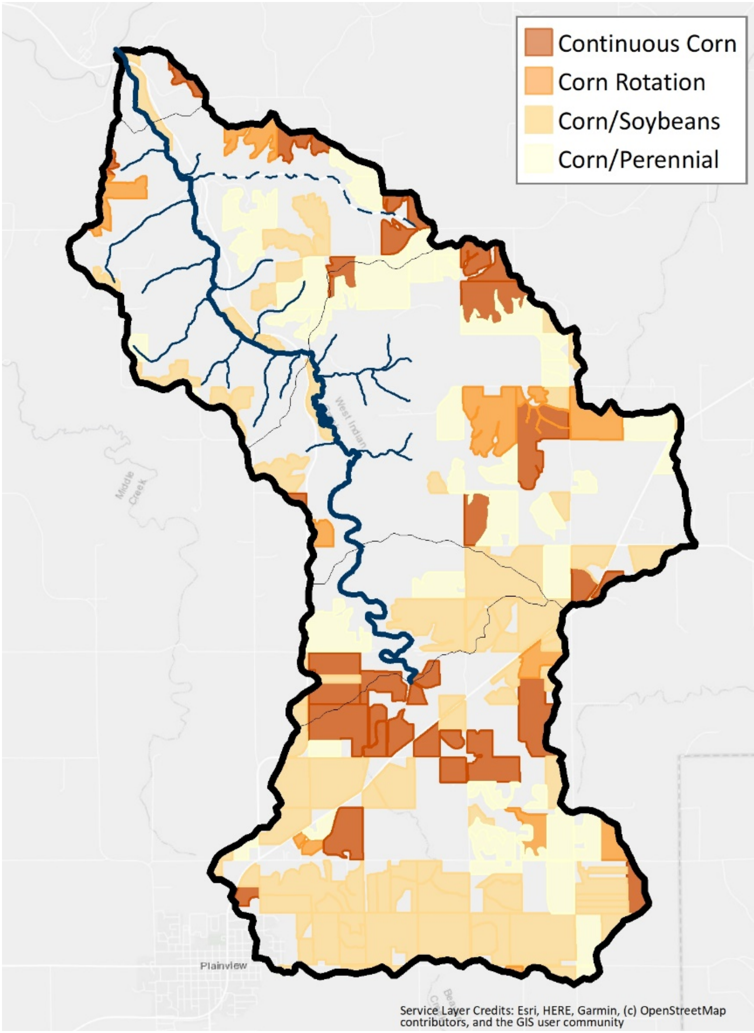
Critical areas of cropland in the watershed needing structural BMPs were identified using ACPF criteria that identify the areas with the highest runoff risk based on slope steepness and stream proximity. The most critical areas include cropland with slopes greater than 5% and within 100 feet of a stream. Areas along field edges showing a gully signature with the LiDAR digital elevation model (DEM) are also used to define critical areas. Examples of these areas are illustrated in in Figure 24 and Figure 25.

Figure 24. Potential structural BMP site using 2-foot contour DEM map



Cropping history records provide an additional identification of critical areas based on crop rotations that tend to have higher sediment and nutrient losses. Losses tend to be greatest in fields with corn-corn (continuous corn or near continuous corn production) and corn-soybean rotations (Figure 25). These areas are identified as critical relative to crop rotations used. Spatial analysis revealed fields with continuous corn, near continuous corn, and corn-soybean rotations account for 14, 10, and 29 percent, respectively.

Figure 25. Agriculture land used for growing corn in West Indian Creek Watershed



Critical forest areas

Critical areas of forest land in the watershed that will be addressed were identified using the Riparian, Adjacent, Quality (RAQ) scoring system developed by BWSR and MAWSCWCD Technical Services Area 8 to identify the highest value forest land to maximize the return on investment for public benefits for forest management activities. The priority critical areas are based on the individual forest parcels' proximity to water (Riparian), proximity to contiguous tracts of existing county, state, or federal land (Adjacency), and local quality characteristics of the parcel (Quality) using a 0-3 point scale for each factor. Quality characteristics included: springs, trout streams, sites of biodiversity significance, rare species, DNR wildlife action rank (med-high or high), wellhead protection/DWSMAs, old growth forest, et. al. Parcels with RAQ scores greater than five (out of 9 points) are considered first priority areas. Percent slope, percent land cover, and TNC resiliency and connectivity measures were also used along with RAQ to identify high priority work areas.

Critical riparian areas

Riparian area critical zones are identified by the potential runoff delivery through them and the width of the shallow water table beneath the areas with high potential for each representing the critical riparian areas for management.

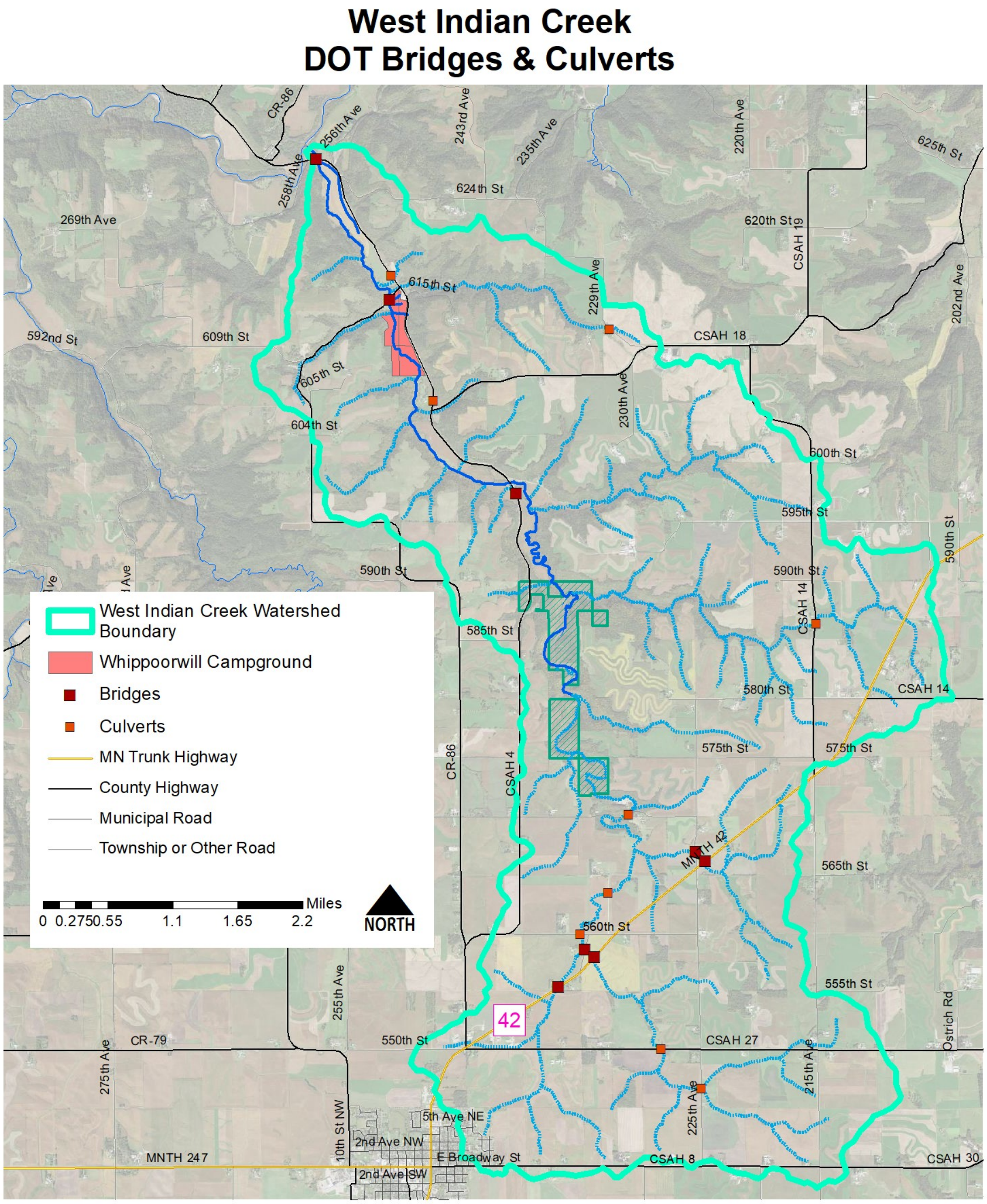
Critical *E. coli* areas

Additional critical areas for *E. coli* specifically, include properties with aging and potentially failing septic systems and feedlots throughout the watershed, large and small.

Critical infrastructure areas

The Wabasha County Highway Department has identified the upland areas of West Indian Creek as an area where upland storage would have a positive effect on road/bridge infrastructure (Figure 26) (D. Flesch, personal communication, 8/30/18). Key locations include the County Road 4 Bridge, the Whippoorwill Campground, and County Road 86 bridge.

Figure 26. Bridges and culverts that would benefit from upland water retention in the West Indian Creek



Watershed

Zonation and Landscape Stewardship Priority Parcel work identifies key locations of properties surrounding the Outstanding Biodiversity areas within the watershed for protection.

Watershed goals

LimnoTech Inc was contracted by the MPCA to complete HSPF modeling for the Zumbro River Watershed (Table 18). Water quality data collected between 1996 through 2018 was used to calibrate and validate the model for hydrology and water quality. Base conditions or baseline simulations, constructed on the collected water quality and quantity data, were developed for the major nutrients, phosphorus and nitrogen, and sediment. The model was also applied to evaluate various management scenarios. This provides information on how effective specific pollutant reduction practices may be for decreasing sediment and nutrient loading and improving water quality. Of the 10 different management scenarios that were developed, only the scenarios that evaluate nonpoint practices are applicable to the West Indian Creek watershed. The table below provides some of the management scenarios, descriptions, and percent load reduction for each of the subwatersheds in WIC. These scenarios are applied based on specific characteristics of each subwatershed, therefore some aspects seem to have a smaller impact on pollutant reduction than others. For example, subwatershed 2 has less cropland than subwatershed 6.

The memorandum for the HSPF model development project can be read in Appendix B.

Table 18. BMP scenarios by HSPF modeling

Management Scenario	Description	Subbasin	% Reduction from baseline for TN	% Reduction from baseline for TP	% Reduction from baseline for TSS
D Nonpoint	Conservation tillage management practices applied to 30% of the cropland acres with the highest sediment yields from model baseline landscape predictions	2	6.1%	25.7%	19.8%
		3	0.7%	3.4%	3.1%
		4	1.3%	6.14%	6.2%
		5	2.4%	11.6%	12.9%
		6	1.2%	5.5%	5.8%
G Nonpoint	Pre-settlement Vegetation, no point sources, no agricultural or developed land, and pre-settlement atmospheric nitrogen deposition rate	2	83.3%	85.2%	60.8%
		3	87.1%	87.1%	65.2%
		4	90.2%	89.9%	69.4%
		5	91.6%	89.3%	69.3%
		6	93.2%	92.2%	71.1%
WRAPS BMP	Strategies described in Zumbro River WRAPS (2017), Target P_2O_5 rate, reduced tillage, riparian buffers, cover crops, controlled drainage, alternative tile intakes, injection/incorporation of manure	2	34.8%	25.8%	11.1%
		3	34.9%	15.3%	-1.8%
		4	39.6%	22.4%	6.1%
		5	46.4%	33.6%	24.2%
		6	43.8%	34.7%	45.9%

Key pollutant load reduction targets

The Zumbro River Watershed Total Maximum Daily Load Report (2017) provides an *E. coli* TMDL for West Indian Creek, detailed in Table 19. Based on these limits and existing loads, average load reductions needed to meet the TMDL have been calculated. These include, on average, 24.9% load reduction at low flows, 48% load reduction at mid-range flows, and 28.1% reduction at high flows.

Table 19. *E. coli* TMDL summary for West Indian Creek Watershed

West Indian Creek 07040004-542 TMDL Summary	Flow Regime				
	VHigh	**High**	**Mid**	**Low**	**VLow**
	Billions of Organisms/day				
***E.coli* Loading Capacity (TMDL)**	172.67	54.29	33.67	21.92	10.19
Wasteload Allocation (WLA)	NA	NA	NA	NA	NA
Load Allocation	155.40	48.86	30.30	19.73	9.17
10% Margin of Safety	17.27	5.43	3.37	2.19	1.02
Average Load Reduction Needed	--	99.6	91.9	15.2	--

Although West Indian Creek does not have nitrogen, phosphorus, or total suspended solids impairments, the Zumbro River WRAPS report does have measureable goals for these pollutants in the Lower Zumbro HUC10 watershed, provided in Table 20.Taken from Minnesota's Nutrient Reduction Strategy (2014), the timeline to achieve these load reductions is by 2025. This closely coincides with the update of the Zumbro River WRAPS, which will allow for re-examination of conditions and goals.

Employing the estimates of pollutant loading provided by the HSPF modeling and pollutant load reduction goals from the Zumbro WRAPS, the following table provides an estimate of the average target pollutant loads for West Indian Creek watershed.

Table 20. Pollutant reductions for West Indian Creek Watershed

Pollutant	Pollutant Reduction Goal for Lower Zumbro HUC10	Average target load for West Indian Creek
Sediment yield	14%	317.58 lbs/ac/yr
Total Phosphorus	12%	0.47 lbs/ac/yr
Total Nitrogen	20%	6.4 lbs/ac/yr

The primary transport mechanisms for nitrate loading in surface waters of the Zumbro River watershed are tile drainage and leaching to groundwater, as a result, the response time of nitrate concentrations in wells, springs, and streams relative to changes in land use practices will vary with differing hydrogeologic settings (Runkel et al, 2014). 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 combinations of BMPs) 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 behind 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).

Identification of management strategies

Restoration strategies provided in the Zumbro River WRAP report are focused on core combinations of BMPs that were examined closely by technical practitioners and vetted with local stakeholders. The nutrient BMP spreadsheets for both nitrogen and phosphorus (developed by the University of Minnesota) were used to iteratively examine the combinations of practices. HSPF model scenario simulations showed general agreement with the reduction estimates provided by the spreadsheets.

The implementation strategies outlined in this plan will be achieved through an extensive partnership network, to include but not limited to NRCS, FSA, USFWS, DNR (forestry, fisheries, wildlife, waters), MDH, MDA, BWSR, MPCA, SE Landscape Committee, TNC, Fishers and Farmers, Sand County Foundation, MASWCD, Wabasha County, TU, National Fish and Wildlife Foundation, and landowners.

To achieve the 2025 nitrogen and phosphorus reduction goals, the following combination of BMPs was identified by using the BMP Tool Spreadsheet for nitrogen (Table 21) and phosphorus (Table 22).

Table 21. BMP Tool spreadsheet output for nitrogen

Nitrogen (N) BMPs	Lower Zumbro HUC-10 (05), % Adoption or Acres Treated	Zumbro HUC-8, % Adoption or Acres Treated
Acres of Cropland	**137,000**	**578,000**
Corn acres receiving target N rates, no inhibitor/shift	90% or 66,010	90% or 234,190
Fall N target rate acres receiving N inhibitor		90% or 42,500
Fall N applications switched to Spring	100% or 4,360	50% or 2,360
Tile line bioreactors		20% or 5,600
Saturated Buffers		20% or 5,600
Riparian Buffers, 100/2= 50ft wide [model adjustment]	96% or 3,670	96% or 12,600
Rye cover crop on corn/soybean acres	10% or 7,150	25% or 22,670
Short season crops planted to a rye cover	80% or 5,240	80% or 21,000
Perennial crop % of marginal corn bean acres	50% or 4,440	**20% or 6,960**
Cropland N load reduction % with these Adoption Rates or Acres Treated	24.00%	19.40%
Treatment Cost/yr.	$1,870,000	$5,960,000
N fertilizer cost savings from reduced inputs	$1,110,000	$3,620,000
Net BMP Treatment Cost	$760,000	$2,340,000

Table 22. BMP Tool spreadsheet output for phosphorus

Phosphorus (P) BMPs	Lower Zumbro HUC-10 (05), % Adoption or Acres Treated	Zumbro HUC-8, % Adoption or Acres Treated
Acres of Cropland	137,000	578,000
Target P205 rate	80% or 90,940	80% or 412,000
Fall corn fertilization to pre-plant/starter	50% or 1,950	50% or 9,000
Use reduced tillage on corn, soy, and small grains >2%	80% or 32,890	80% or 154,000
Riparian Buffers, 50 ft. wide, 100 ft. treated	95% or 10,340	95% or 32,000
Perennial crop % of marginal corn and soybean land	50% or 4,250	20% or 7,000
Rye cover crop on corn/soybean acres	7% or 7,470	10% or 34,000
Short season crops planted to a rye cover crop	80% or 5,550	80% or 22,000
Controlled Drainage		20% or 6,000

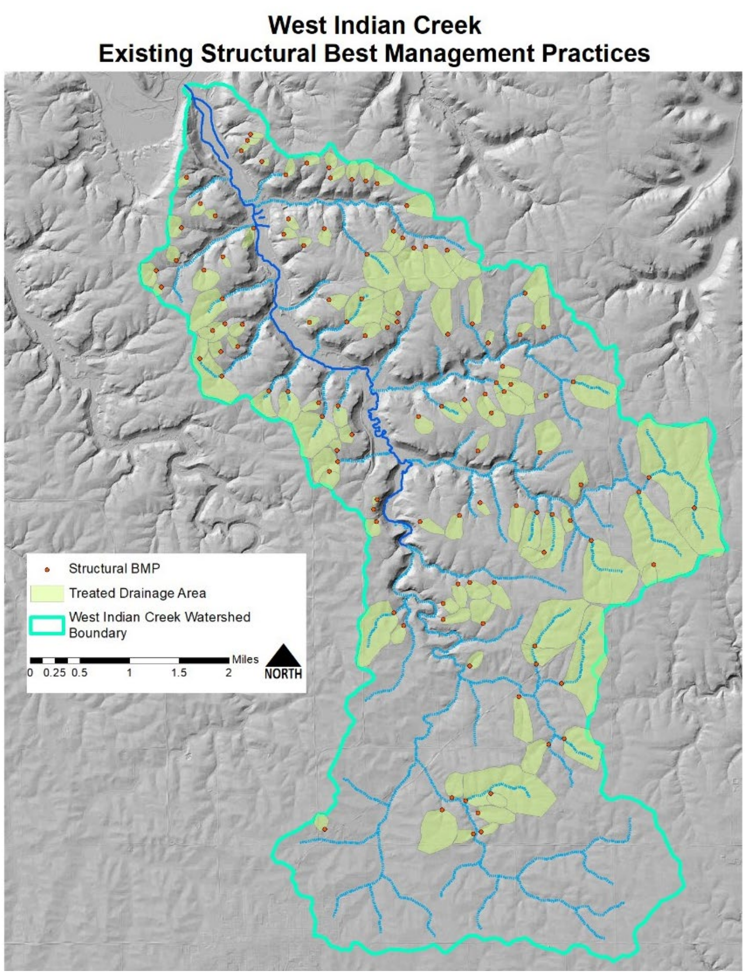
Phosphorus (P) BMPs	Lower Zumbro HUC-10 (05), % Adoption or Acres Treated	Zumbro HUC-8, % Adoption or Acres Treated
Alternative Tile Intakes		20% or 15,000
Inject/incorporate manure	50% or 7,450	50% or 24,000
Cropland P load reduction % with these Adoption Rates	16.20%	17.20%
Treatment Cost/yr	$1,500,000	$4,150,000
P fertilizer cost savings from reduced inputs	$1,330,000	$3,160,000
Net BMP Treatment Cost	$170,000	$990,000

Existing management strategies

Structural controls

During the development of the Zumbro River WRAPS, existing structural best management practices (BMP) were mapped throughout the watershed. Figure 27 shows the existing water and sediment control basins (WASCOB) in the West Indian Creek watershed as of 2014. There are 117 WASCOBs treating a total of approximately 4,598 acres or 26.7% of the watershed. The upstream most section or sub-watershed 6 has the least number of WASCOBs and acres treated at only roughly 16% of the sub-watershed treated.

Figure 27. Existing structural BMPs in the West Indian Creek Watershed



Nonstructural controls

There are a number of existing nonstructural controls in the watershed, including the previously described stream restoration/habitat improvement projects on nearly three miles of West Indian Creek and watershed wide compliance with the Buffer Law. The Minnesota Groundwater Protection Rule with fall nitrogen fertilizer restrictions throughout the watershed take effect in September of 2020 which will help reduce nitrate from fertilizer leaching. BMPs that are installed with the support of state funds are tracked and published on MPCA's Healthier watersheds webpage. According to this database, 92 BMPs have been installed in WIC watershed since 2004. These BMPs include six acres of grassed waterway, 1,102 acres covered by nutrient management plans, more than 500 acres with reduced tillage and residue management, and various other BMPs (Table 23). These existing BMPs have not been included in the estimated pollutant load reductions presented in this plan. Additionally, Minnesota's Agricultural Water Quality Certification Program (MAWQCP) is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect our water. Those who implement and maintain approved farm management practices will be certified. There are five MAWQCP producers in the West Indian Creek Watershed.

Table 23. Summary of BMPs implemented in West Indian Creek Watershed as reported by Healthier Watersheds (eLINK reports and NRCS)

Strategy	Practice Description	Total BMPs	Installed Amount (by unit)	Units
Designed erosion control	Grassed Waterway	10	6	Acres
Nutrient management (cropland)	Nutrient Management	17	1,102	Acres
Converting land to perennials	Critical Area Planting	5	2	Acres
Living cover to crops in fall/spring	Cover Crop	4	199	Acres
Tillage/residue management	Residue and Tillage Management, No-Till	3	550	Acres
Tillage/residue management	Residue and Tillage Management, Reduced Till	3	550	Acres
Tillage/residue management	Residue Management, No-Till/Strip Till	1	83	Acres
Tile inlet improvements	Grade Stabilization Structure	2	2	Count
Tile inlet improvements	Subsurface Drain	1	729	Feet
Pasture management	Prescribed Grazing	3	52	Acres
Drainage ditch modifications	Grade Stabilization Structure	2	2	Count
Stream banks, bluffs & ravines	Grade Stabilization Structure	2	2	Count
Septic System Improvements	Septic System Improvement	1	1	Count
Crop Rotation	Conservation Crop Rotation	4	70	Acres
Feedlot runoff controls	Waste Water & Feedlot Runoff Control	1	1	Count
Other	Karst Sinkhole Treatment	8	10	Count
Other	Roofs and Covers	4	1	Count

Strategy	Practice Description	Total BMPs	Installed Amount (by unit)	Units
Other	Fence	3	15,200	Feet
Other	Forage Harvest Management	3	1,073	Acres
Other	Livestock Pipeline	2	3,050	Feet
Other	Mulching	2	0	Acres
Other	Waste Management System	2	2	Count
Other	Watering Facility	2	6	Count
Other	Comprehensive Nutrient Management Plan - Written	1	1	Count
Other	Conservation Completion Incentive Second Year	1	1	Count
Other	Cooperative Weed Management Area	1	1	Count
Other	Environmental Quality Assessment	1	1	Count
Other	Erosion Control	1	1	Count
Other	Forage and Biomass Planting	1	16	Acres
Other	Forest Management Plan - Written	1	2	Count
Other	Heavy Use Area Protection	1	2,600	Acres
Other	Waste Storage Facility	1	1	Count
Other	Waste Transfer	1	1	Count
Other	Well Decommissioning	1	1	Count

Other strategies needed to achieve goals

Structural controls

According to the NRCS, WASCOB spillways and outlets should be inspected yearly, accumulated sediment and debris should be removed on a regular basis, vegetative cover should be maintained, and any necessary repairs should be made following each large storm event. Many of the WASCOBs in the watershed have been in place for several decades and it is suspected that maintenance recommendations are often not followed, as a result, WASCOBs do not always function optimally. In addition, since many of the structures have been in place for several decades, they do not meet the updated NRCS specifications. A comprehensive inventory of WASCOBs, including operational status, should be completed to determine where maintenance should be prioritized. This could be completed through aerial imagery review. Additional modeling, such as Agricultural Conservation Planning Framework (ACPF), should be completed to prioritize locations where WASCOBs and other grade stabilization structures would be beneficial. In the Root River Field to Stream Partnership, the results of ACPF modeling help guide the field walk over process with land owners to prioritize projects on their properties.

Nonstructural controls

Although there are many BMPs that have been installed over the last sixteen years in WIC watershed, the water quality data show that more must be done.

Given the rising trend in nitrate concentrations, it is recommended that nutrient management plans, cover crops, conservation crop rotation, and measures to increase soil health be employed at a higher rate. These strategies will work to reduce leaching and surface runoff thereby reducing pollutant concentrations in West Indian Creek.

Soil health's significance for watershed restoration and protection comes from 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 landscapes. By decreasing runoff and leaching, soils have an innate capacity for improving water quality. Increasing soil organic matter and decreasing bulk density are two long-term goals that farmers can use to measure the soil health of their fields, thereby increasing the fertility of their soils and benefitting water quality. These two measures are objective, quantifiable, and inexpensive. By tracking soil organic matter and bulk density, farmers can help to achieve the water quality goals for reducing sediment, nitrogen, phosphorus, and *E. coli.*

There are environmental, agronomic, and economic benefits to increasing soil health. According to the NRCS, there are five basic principles to increasing soil health which are: armoring the soil, minimizing soil disturbance, plant diversity, continual living plant/root, and livestock integration. All of these strategies are recommended for improving the water quality of West Indian Creek.

A global framework for sustainable fertilizer management was developed through cooperative efforts of the International Plant Nutrition Institute (IPNI), The Fertilizer Institute (TFI), the Canadian Fertilizer Institute (CFI), and the International Fertilizer Industry Association (IFA), along with their members and other organizations. This framework is described as "4R Nutrient Stewardship" and is centered on four key areas of nutrient management: using the right nutrient source, applied at the right rate, at the right time, in the right place. Utilization of the 4Rs and nutrient management plans will benefit water quality in West Indian Creek.

Cover crops are recommended throughout the Zumbro River WRAPS as a cost-effective means to achieve nitrogen runoff reduction as well as to prevent leaching to groundwater. Cover crops, reduced tillage and retention basins are all recommended practices in WIC.

Forestry is a priority in Wabasha County and previous forestry based projects have yielded quantifiable water quality results using forest management practices. Thinning, invasive management, tree planting for quality and increasing quality understory on steep slopes helps improve water quality. Poor quality woodlands show earthworms often consume leaf litter and invasive species take over quality vegetation on bare slopes beneath tree cover. Both of these events make gullies and erosion to streams carrying nutrients and increasing stream sedimentation more likely. Similar issues occur with quality understory in riparian areas. Forest planting and management plans along with invasive management will be important practices to both protect and enhance water quality as well as the areas of biodiversity significance.

The landscape of WIC watershed is dominated by the presence of AFOs, with feedlots, cattle housing structures, and the fields needed to grow feed. The last of the five soil health principles is livestock integration. The benefits of returning livestock to the landscape are numerous; for soil health, for agronomic inputs, for weeds, for livestock, and for water quality. Prescribed grazing, rotational grazing, and other practices that help facilitate the return of livestock to the landscape (fencing, water supply, well testing) will be promoted.

It is important to note that these recommendations extend beyond the WIC watershed boundary as the area contributing to the flow of WIC includes a larger groundwater recharge zone (Figure 9). As described in previous sections, groundwater is a significant component here and must be taken into consideration if real impact is to be made.

Outreach and education is another important non-structural component in West Indian Creek. As was found in the RRFSP and many other projects, strong relationships are key for achieving goals and this is especially true in rural areas and in projects that require voluntary participation. The RRFSP found great success in taking time to meet with area agricultural producers, understand their operations and gather input about the best approach for field walkovers. This method, although very time intensive, resulted in 100% farmer participation in the program. (https://www.mda.state.mn.us/sites/default/files/2020-03/rrfspwalkover.pdf) Through outreach activities and one-on-one meetings, the results of water quality monitoring, BMP modeling, and other watershed efforts are discussed with farmers, landowners, fertilizer dealers, water managers, and community leaders to promote an advanced level of conservation planning and delivery in the watershed between 0.5 and 1.

Implementation program design

The West Indian Creek Watershed implementation table (Table 23) was developed following the nonpoint source management strategies described in the Zumbro River WRAP report. These management strategies were modelled for each HUC 10 basin using HSPF. Percentages of total cropland acres receiving BMPs in the Lower Zumbro HUC 10 were used as a starting point for implementation in West Indian Creek. HSPF model outputs for the non-point WRAP BMP scenario, on average, resulted in 39.9% total nitrogen, 26.4% total phosphorus, and 17.1% total suspended solids reductions in West Indian Creek watershed. Pollutant reduction goals given in the Zumbro WRAP report for the Lower Zumbro HUC 10 and in the Minnesota Nutrient Reduction Strategy are exceeded using these strategies in West Indian Creek, based on HSPF model outputs. The percent of cropland acres receiving BMPs calculated for use in the HSPF modeling in the Lower Zumbro HUC 10 were simply applied to the cropland acres in West Indian Creek as a starting point using the Spreadsheet Tool for Estimating Pollutant Load (STEPL). The example strategies and levels of adoption were constructed during the WRAP process by Zumbro River watershed stakeholders and resource managers focused on non-point source nutrient reductions.

Even though the modeling and STEPL outputs show that these example strategies and levels of adoption exceed the pollutant reduction goals laid out in this plan, there is a local desire to have even higher rates of implementation and participation as well as inclusion of a broader set of practices. The desire for practices not included in the WRAP BMP scenario have been included in Table 23 of this plan, however the desire for higher levels of implementation and participation are not entirely reflected in the table. The implementation program presented in Table 23 represents a base-line for the West Indian Creek watershed, a base-line for levels of implementation and a base-line for associated costs. Additional implementation and participation would require additional funding.

Table 24. Treatment types, milestones, goals, assessment criteria, and costs to reach water quality goals in the West Indian Creek Watershed

	Milestones					Long-Term Goals		Assessment	Costs
Treatment type	2-year (2023)	4-year (2025)	6-year (2027)	8-year (2029)	10 year (2031)				
Cropland									
Increase Contour Farming and Stripcropping (NRCS Code 330, 585))	44 acres	44 acres	44 acres	44 acres	44 acres	220 acres	Cooperate with agricultural producers to reduce nitrogen loading to groundwater & WIC through implementation of field practices and reduction of fertilizer rates/increased nitrogen use efficiency. Increase storage in the watershed prioritizing headwater and/or high yield subwatersheds. Reduce E. coli loading to a level safe in order to support aquatic recreation use in WIC. Reduce phosphorus load leaving WIC as called for by the nutrient reduction strategy (NRS). [nitrogen 20%, phosphorus 12%, sediment 14%, E. coli 26.8%]	# of acres treated	$3,247.50
Whole Farm Conservation Plans	5 farmers	5 farmers	5 farmers	5 farmers	5 farmers	Work with 25 farmers to develop whole farm conservation plans that list resource concerns, these plans can be revisited every 2 years to work toward implementing practices identified in the plan		# of plans developed	$250,000 plan development, $100,000 for tech assistance on revisiting plans ea yr
Increase Water and Sediment Control Basin in headwaters (NRCS Code 638)	53 acres	53 acres	53 acres	53 acres	53 acres	265 acres/30 WASCOBs		# of acres treated	$600,000.00
Increase Grassed Waterway (NRCS Code 412)	52 acres	52 acres	52 acres	52 acres	52 acres	260 acres/10 Grassed Waterways		# of acres treated	$100,000.00
Develop site-specific nutrient management plans (NRCS Code 590)	1188 acres	1188 acres	1188 acres	1188 acres	1188 acres	5940 acres/30 plans		# of acres treated	$106,920.00
Increase and incentivize gridded soil sampling to guide precision nutrient application	Engage 3 producers in gridded soil sampling and precision nutrient application and provide cost share	Engage 3 producers in gridded soil sampling and precision nutrient application and provide cost share	Engage 3 producers in gridded soil sampling and precision nutrient application and provide cost share	Engage 3 producers in gridded soil sampling and precision nutrient application and provide cost share	Engage 3 producers in gridded soil sampling and precision nutrient application and provide cost share	15 producers utilizing gridded soil sampling precision nutrient application		# of producers engaged	
Increase and incentivize Residue and Tillage Management, Reduced Till (NRCS Code 345)	160 acres	160 acres	160 acres	160 acres	160 acres	800 acres		# of acres treated	$17,208.00
Increase and incentivize Residue and Tillage	20 acres	20 acres	20 acres	20 acres	20 acres	100 acres		# of acres treated	$2,151.00

	Milestones					Long-Term Goals		Assessment	Costs
Treatment type	2-year (2023)	4-year (2025)	6-year (2027)	8-year (2029)	10 year (2031)				
Management, No Till (NRCS Code 329)									
Increase and incentivize conservation crop rotation (NRCS Code 328)	27 acres	27 acres	27 acres	27 acres	27 acres	135 acres		# of acres treated	$5,297.20
~~Promote conservation crop rotation~~	~~Contact 5 producers for 1:1 conversations to discuss crop rotation~~	~~Contact 5 producers for 1:1 conversations to discuss crop rotation~~	~~Contact 5 producers for 1:1 conversations to discuss crop rotation~~	~~Contact 5 producers for 1:1 conversations to discuss crop rotation~~	~~Contact 5 producers for 1:1 conversations to discuss crop rotation~~	~~25 producers with 1:1 conversations discussing crop rotation~~			~~$1,500~~
Promote 5 soil health principles (soil armoring, minimizing soil disturbance, plant diversity, continual live plant/root, livestock integration) with demonstration site and field days	Contact 3 producers for 1:1 conversations to discuss crop rotation	Contact 3 producers for 1:1 conversations to discuss crop rotation	Contact 3 producers for 1:1 conversations to discuss crop rotation	Contact 3 producers for 1:1 conversations to discuss crop rotation	Contact 3 producers for 1:1 conversations to discuss crop rotation	15 producers contacted	Increased awareness of soil health practices, Develop and maintain inventory to quantify and track extent of soil health practices used in the watershed	# of producers contacted	$100,000.00
Land retirement - Conservation Cover (NRCS Code 327)	36 acres	36 acres	36 acres	36 acres	36 acres	180 acres		# of acres treated	$58,500.00
Cover Crop (NRCS Code 340)	171 acres	171 acres	171 acres	171 acres	171 acres	855 acres		# of acres treated	$32,472.90
Land retirement - Pasture (NRCS Code)	27 acres	27 acres	27 acres	27 acres	27 acres	135 acres		# of acres treated	$34,000.00
Streambank Erosion Practices/Restoration		1 streambank restoration project covering ~0.75stream miles		1 streambank restoration project covering ~0.75stream miles		114.7 acres		# of stream miles restored	$1,000,000.00
Implement Field Borders, Vegetative Barriers, Forest Edge Buffers, or Filter Strips at edge of field (NRCS Code 386, 601, 393)	30 acres	30 acres	30 acres	30 acres	30 acres	150 acres/ Work with agricultural landowners to implement as part of their conservation plan, native grasses or hay		# of acres implemented	$110,550.00
Increase Karst Sinkhole Treatment (NRCS Code 527), Filter Strips around sinkholes (NRCS Code 393)	2 sinkholes	2 sinkholes	2 sinkholes	2 sinkholes	2 sinkholes	10 sinkholes addressed	Minimize groundwater contamination resulting from infiltration near sinkholes and other areas of karst geology through incentives and education	# of sinkholes addressed	$62,500.00
Increase the enrollment of floodplain lands in RIM,	25 acres	25 acres	25 acres	25 acres	25 acres	125 acres		# of acres enrolled	$450,000.00

	Milestones					Long-Term Goals		Assessment	Costs
Treatment type	2-year (2023)	4-year (2025)	6-year (2027)	8-year (2029)	10 year (2031)				
CREP, similar programs (Critical Area Planting NRCS: 342)									
SWCD Technical & Admin Assistance	0.21 FTE	0.21 FTE	0.21 FTE	0.21 FTE	0.21 FTE				$200,000.00
Pastureland									
Grazing Land Management (rotational grazing)	18 acres	18 acres	18 acres	18 acres	18 acres	90 acres		# of acres treated	$10,000.00
Alternative Water Supply/Livestock Pipeline (NRCS Code 516)	18 acres	18 acres	18 acres	18 acres	18 acres	90 acres		# of acres treated	$10,000.00
Heavy Use Area Protection (NRCS Code 561)	2.5 acres	2.5 acres	2.5 acres	2.5 acres	2.5 acres	12.5 acres		# of acres treated	$9,225.00
Pasture & Hayland Planting (NRCS Code 550)	18 acres	18 acres	18 acres	18 acres	18 acres	90 acres	Increase rotational/managed grazing	# of acres treated	$45,000.00
Livestock Exclusion Fencing (NRCS Code 382)	187 acres	187 acres	187 acres	187 acres	187 acres	935 acres	Fencing to keep livestock out of riparian areas, WASCOBS, and forest areas	# of acres treated	$32,000.00
SWCD Technical & Admin Assistance	0.15 FTE	0.15 FTE	0.15 FTE	0.15 FTE	0.15 FTE				$150,000.00
Feedlots									
Provide financial assistance for installation of Livestock Waste Handling (Livestock Waste Storage Facilities NRCS: 313, Waste Treatment Lagoons NRCS: 359, Manure Waste Treatment NRCS: 629)	1 Livestock Waste Handling System	1 Livestock Waste Handling System	1 Livestock Waste Handling System	1 Livestock Waste Handling System	1 Livestock Waste Handling System	5 Livestock Waste Handling systems		# of systems installed	$1,500,000.00
Promote Filter Strips around feedlots (NRCS Code: 393)	2 acres	2 acres	3 acres	2 acres	3 acres	12 acres		# of acres treated	$7,800.00
Build relationships with small feedlot operators	3 new farmer connections	3 new farmer connections	3 new farmer connections	3 new farmer connections	3 new farmer connections	15 new farmer connections		# of farmer connections made	$150,000.00
Provide financial assistance for small feedlot fixes/improvements (Watering Facility NRCS: 614, Fence NRCS: 382, Filter Strip NRCS: 393, Vegetated Treatment Area NRCS: 635, Stormwater Runoff Control NRCS: 570, Livestock Shelter Structure NRCS: 576)	3 feedlots addressed	3 feedlots addressed	3 feedlots addressed	3 feedlots addressed	3 feedlots addressed	Improvements on 15 feedlots	Build relationships with small feedlot operators, promote rotational grazing, reduce run off from feedlots, promote appropriate manure storage, handling, and appropriately timed land application/incorporation. Utilize MinnFarm calculator to show pollutant reductions.	# of feedlots addressed	$450,000.00

	Milestones					Long-Term Goals		Assessment	Costs
Treatment type	**2-year (2023)**	**4-year (2025)**	**6-year (2027)**	**8-year (2029)**	**10 year (2031)**				
Promote Forage and Biomass Planting, Range Planting (NRCS Code: 512, 550)	27 acres	27 acres	27 acres	27 acres	27 acres	135 acres		# of acres treated	$13,495.28
SWCD Technical & Admin Assistance	0.16 FTE	0.16 FTE	0.16 FTE	0.16 FTE	0.16 FTE				$100,000.00
Forest									
Promote Forest Stand Improvement (NRCS Code 666)	157 acres	157 acres	157 acres	157 acres	157 acres	785 acres		# of acres treated	$471,900.00
Provide financial and technical support to assist landowners in developing forestry plans	189 acres	189 acres	189 acres	189 acres	189 acres	945 acres		# of acres treated	$33,031.25
Work with MDNR and other partners to provide local technical assistance in support of projects addressing invasive species (NRCS Code: 314)	38 acres	38 acres	38 acres	38 acres	38 acres	190 acres	Protect, expand, and increase the value of forest stands and significant biodiversity	# of acres treated	$103,812.50
SWCD Technical & Admin Assistance	0.16 FTE	0.16 FTE	0.16 FTE	0.16 FTE	0.16 FTE				$100,000.00
Urban									
Provide financial assistance for Well Decommissioning (NRCS Code 351)	1 well	2 wells	2 wells	2 wells	2 wells	9 wells	Reduce E. coli loading to a safe level that supports aquatic recreation use in WIC. Remove public health threats. Remove the threat of rapid pollutant pathways found in unused wells.	# of wells treated	$18,000.00
Provide financial assistance for septic upgrades	7 systems	7 systems	8 systems	8 systems	7 systems	37 systems		# of systems treated	$259,000.00
SWCD Technical & Admin Assistance	0.1 FTE	0.1 FTE	0.1 FTE	0.1 FTE	0.1 FTE				$100,000.00
Monitoring									
Monitor effectiveness of practices using lysimeters and spring monitoring to determine what the observable reduction is for specific practices	Identify test site, begin monitoring key springs	Install lysimeters & begin monitoring	Continue monitoring & review effectiveness	Continue monitoring & review effectiveness	Continue monitoring & review effectiveness	Assess effectiveness of implementation	Monitor effectiveness of implementation at key 'middle points' between fields and stream, further understand impacts in karst landscape	2 reports discussing effectiveness	$60,000.00
Inventory of sinkholes	landowner outreach	landowner outreach	landowner outreach	Complete inventory	use information gathered to adjust plan as necessary	Guide implementation	Cooperate with and assist landowners with existing sinkholes, be a known point of contact for future sinkhole issues	Completed inventory	$25,000.00
Inventory of abandoned/outdated wells	landowner outreach	landowner outreach	Complete inventory	use information gathered to adjust plan as necessary		Guide implementation	Cooperate with and assist landowners with private wells, be a known point of contact for future private well issues. Landowners are proactive about well maintenance.	Completed inventory	$25,000.00

	Milestones					Long-Term Goals		Assessment	Costs
Treatment type	**2-year (2023)**	**4-year (2025)**	**6-year (2027)**	**8-year (2029)**	**10 year (2031)**				
Inventory of outdated SSTS	landowner outreach	Complete inventory	Use information gathered to adjust plan as necessary			Guide implementation	Cooperate with and assist landowners with SSTS. Landowners are proactive about SSTS maintenance.	Completed inventory	$25,000.00
Inventory of existing WASCOBs, including operational status	Inventory WASCOBs in subwatershed 2	Inventory WASCOBs in subwatershed 3	Inventory WASCOBs in subwatershed 4	Inventory WASCOBs in subwatershed 5	Inventory WASCOBs in subwatershed 6	Guide implementation	A comprehensive inventory of existing WASCOBs in the watershed, including operational status to guide implementation and maintenance	Completed inventory	$25,000.00
Work with DNR, MDH, and others to inventory current spring flow (location, quantity, source, and quality) monitor any changes over time to determine effectiveness of treatments	identify key springs to be monitored	install monitoring equipment, begin monitoring	Continue monitoring & review effectiveness	Continue monitoring & review effectiveness	Continue monitoring & review effectiveness	Know how changes on the land surface in WIC change spring characteristics and as a result, change WIC		Completed inventory	$70,000.00
Monitor private groundwater wells for nitrate, bacteria, and other emerging contaminants to characterize effectiveness of implementation	Identify 7 key well owners willing to participate	begin well sampling	Continue monitoring & review effectiveness	Continue monitoring & review effectiveness	Continue monitoring & review effectiveness	# of private wells monitored	Establish nitrate-nitrogen trends for monitored private wells with average concentrations ≥3ppm, identify systems with chronically high nitrate concentrations	7 Nodes filled for MDH nitrate monitoring network, establishment of targeted monitoring network	$50,000.00
Review waters not subject to buffer law to identify additional priority areas for which technical assistance can be provided to protect	remote spatial analysis to identify potential priority areas	field verify priority areas identified through remote spatial analysis	Provide technical assistance to landowners interested in protecting 33% of identified priority areas	Provide technical assistance to landowners interested in protecting 33% of identified priority areas	Provide technical assistance to landowners interested in protecting 34% of identified priority areas	A large amount of the watershed is not considered ‘public waters’ and therefore not currently subject to the MN buffer law. These areas are often found in the headwaters where increased protection would be beneficial.		Completed review of additional priority areas	$50,000.00
Database of invasive species presence	2 newspaper article/letters, 1 watershed event	2 newspaper article/letters, 1 watershed event	2 newspaper article/letters, 1 watershed event	2 newspaper article/letters, 1 watershed event	2 newspaper article/letters, 1 watershed event	10 news articles/letters, 5 events	Cooperate with and assist landowners with invasive species. Utilize UMN Extension resources that allow landowners to map invasive presence.	# of articles and events	$20,000.00
Install nested well in, including both aquifers contributing flow to WIC	work with state agencies to determine optimum well location	install nested well	Collect aquifer samples annually to analyze for nitrates, bacteria, and other emerging contaminants to characterize effectiveness of implementation	Collect aquifer samples annually to analyze for nitrates, bacteria, and other emerging contaminants to characterize effectiveness of implementation	Collect aquifer samples annually to analyze for nitrates, bacteria, and other emerging contaminants to characterize effectiveness of implementation	Installation of nested well and annual sampling			$50,000.00

	Milestones					Long-Term Goals	Assessment	Costs
Treatment type	**2-year (2023)**	**4-year (2025)**	**6-year (2027)**	**8-year (2029)**	**10 year (2031)**			
Promote citizen stream monitoring	Engage at least 2 landowners in the watershed to collect monthly stream clarity, temperature and general observations.	Maintain at least 2 landowners in the watershed to collect monthly stream clarity, temperature, and general observations	Maintain at least 2 landowners in the watershed to collect monthly stream clarity, temperature, and general observations	Maintain at least 2 landowners in the watershed to collect monthly stream clarity, temperature, and general observations	Maintain at least 2 landowners in the watershed to collect monthly stream clarity, temperature, and general observations	2 or more local landowners monitoring the stream monthly Engage landowners in the watershed to observe general, visual stream water quality to both have more eyes on what is going on in the watershed and to give landowners and sense of ownership and connection to stream water quality.	# of landowners engaged in citizen stream monitoring	$10,000
Continue pollutant monitoring at existing long term monitoring site (S004-452) and newly established upstream site -either existing site S003-811 or further upstream and downstream site S005-733(MPCA)	Monthly baseflow sampling of TSS, Total nitrogen, Total phosphorus	Monthly baseflow sampling of TSS, Total nitrogen, Total phosphorus	Monthly baseflow sampling of TSS, Total nitrogen, Total phosphorus	Monthly baseflow sampling of TSS, Total nitrogen, Total phosphorus	Monthly baseflow sampling of TSS, Total nitrogen, Total phosphorus	Monthly baseflow sampling of TSS, Total nitrogen, Total phosphorus to determine effectiveness of implementation	Continued pollutant monitoring	
Continue fishery monitoring at existing long term monitoring site (DNR)	Annual DNR Stream assessment	Annual DNR Stream assessment	Annual DNR Stream assessment	Annual DNR Stream assessment	Annual DNR Stream assessment	Sustain or improve stream conditions and coldwater IBIs	Continued stream assessments	
Continue invasive species monitoring, specifically poison hemlock	Work with 3 landowners	Work with 3 landowners	Work with 4 landowners	Work with 3 landowners	Work with 3 landowners	Prioritize landowners adjacent to state owned land	# of landowners	$40,000.00
Continue regular inspection of projects receiving cost-share	Each project inspected 1, 5, and 10 years after installation	Each project inspected 1, 5, and 10 years after installation	Each project inspected 1, 5, and 10 years after installation	Each project inspected 1, 5, and 10 years after installation	Each project inspected 1, 5, and 10 years after installation	Maintain quality and integrity of implemented projects, inspect all funded projects	All projects inspected on a regular basis	$40,000.00
Outreach								
Identify a producer-leader in the watershed to establish demonstration site	identify 2 producers/landowners, reach out to additional key producers/landowners	2 local champion(s) reach out to other producers/landowners	Maintain 2 local champion(s)	Maintain 2 local champion(s)	Maintain 2 local champion(s)	Local champion(s) to help build relationships with producers and landowners within the watershed. Maintain 2 key local champions in the watershed.	# of local champions assisting with outreach	$10,000.00

	Milestones					**Long-Term Goals**		**Assessment**	**Costs**
Treatment type	**2-year (2023)**	**4-year (2025)**	**6-year (2027)**	**8-year (2029)**	**10 year (2031)**				
Host field day events		1 field day	1 field day	1 field day		3 field days		# of field days held	$12,000.00
Producer-leader demonstration site/field trials		Establish demonstration sites (2)	Maintain demonstration sites	Maintain demonstration sites	Maintain demonstration sites	40 demonstration acres	Improve the local confidence in practices recommended in this plan	# of demonstration sites	$20,000.00
Conduct outreach with landowners and area youth regarding forestry and soil health	2 newspaper article/letters, 2 outreach events	2 newspaper article/letters, 2 outreach events	2 newspaper article/letters, 2 outreach events	2 newspaper article/letters, 2 outreach events	2 newspaper article/letters, 2 outreach events	10 newspaper articles/letters, 10 outreach events	Increased awareness of forest land management and forestry industry, Increased awareness of soil health practices and more youth interest in continuing family farm	# of articles/letters and events	$25,000.00
Distribute information materials increasing resident awareness of groundwater issues, testing, and best practices	2 newspaper article/letters, 1 testing event	2 newspaper article/letters, 1 testing event	2 newspaper article/letters, 1 testing event	2 newspaper article/letters, 1 testing event	2 newspaper article/letters, 1 testing event	10 newspaper articles or letters and 5 testing events	Increased awareness of potential groundwater contamination, Increased private well owner testing	# of articles/letters and events	$10,000.00
Ongoing outreach and compliance checks for buffer law		Complete review of watershed		Complete review of watershed		Maintain 100% compliance with buff law and increase the quality of vegetation in buffers. Provide encouragement for landowner success w/ buffer law in critical areas, provide financial and technical assistance to landowners struggling with buffer law		3 year reviews of buffers completed, increased interest in managing/maintaining buffers	$3,500.00
Promote enrollment in conservation programs and protection of biologically significant elements in the watershed through distribution of educational materials	2 newspaper article/letters, staff target funding sources	2 newspaper article/letters, staff target funding sources	2 newspaper article/letters, staff target funding sources	2 newspaper article/letters, staff target funding sources	2 newspaper article/letters, staff target funding sources	10 newspaper articles/letters and new funding sources identified	Increased awareness of conservation programs and ecosystem services	# of articles/letters and funding sources	$10,000.00
Provide educational materials regarding the Minnesota Agricultural Water Quality Certification Program	1 certified farmer	1 certified farmers	1 certified farmers	1 certified farmers	1 certified farmers	5 certified farmers	Increase the number of producers certified through Minnesota's AWQCP	# of certified farmers	$25,000.00
Work with agriculture retailers and crop consultants on workshops / field days / other outreach activities	1 outreach event	1 outreach events	1 outreach events	1 outreach events	1 outreach events	5 outreach events	Foster relationships to create a more unified message and approach to agricultural production	# of outreach events	$10,000.00
Conduct field walkovers, tech support, kitchen-table meetings	3 site visits	3 site visits	3 site visits	3 site visits	3 site visits	15 site visits		# of site visits	$45,000.00
Total cost									**$7,176,610.63**

Estimated load reductions

Reductions have been calculated using the Spreadsheet Tool for Estimating Pollutant Load (STEPL) for the practices planned (Table 25). Reductions by land usage are summarized in Table 26. It is expected that practices described in this plan will achieve load reductions needed to meet water quality standards and goals when fully implemented. The estimated current loads using STEPL for nitrogen (N) phosphorus (P), total suspended solids (TSS), and *E. coli* are provided in the table below as well as the estimated reductions. Full details for STEPL are included in Appendix A.

Table 25. Estimated pollutant loads before and after BMPs, with estimated load reductions, in the West Indian Creek Watershed

	Estimated Current Loading				**Estimated Reduction to Loading**			
	N load	**P load**	**Sediment load**	***E. coli* load**	**N reduction**	**P reduction**	**Sediment reduction**	***E. coli* reduction**
Watershed	**lb/yr**	**lb/yr**	**t/yr**	**Billion MPN/yr**	**lb/yr**	**lb/yr**	**t/yr**	**Billion MPN/yr**
W1	10443.33	2142.732	147.64	2272.135	3788.99	1119.18	40.29	2111.64
W2	40159.99	7876.584	2036.42	14897.51	9729.33	3203.08	516.80	13571.53
W3	163760.84	25629.36	3407.23	33232.41	51331.60	12018.48	817.34	29512.65
W4	15258.42	3468.681	1049.25	9284.49	3373.79	1366.78	259.12	8756.30
W5	149490.53	27123.62	5457.94	40889.14	47631.85	11906.28	1317.19	38294.81
Total	379113.11	66240.98	12098.47	100575.7	115855.56	29613.79	2950.74	92246.93
	Estimated Future Loading (with BMPs)							
	N Load	**P Load**	**Sediment Load**	**E. coli Load**	**N reduction**	**P reduction**	**Sediment reduction**	***E. coli* reduction**
Watershed	**lb/yr**	**lb/yr**	**t/yr**	**Billion MPN/yr**	**%**	**%**	**%**	**%**
W1	6654.34	1023.55	107.35	160.49	36%	52%	27%	93%
W2	30430.66	4673.51	1519.62	1325.98	24%	41%	25%	91%
W3	112429.24	13610.89	2589.89	3719.76	31%	47%	24%	89%
W4	11884.63	2101.90	790.13	528.20	22%	39%	25%	94%
W%	101858.68	15217.34	4140.74	2594.34	32%	44%	24%	94%
Total	263257.55	36627.18	9147.74	8328.77	31%	45%	24%	92%

Table 26. Estimated percent pollution reduction by land use in the West Indian Creek Watershed

Sources	Cropland	Pastureland	Forest	Feedlots	Septic	Total
N Load (lb/yr)	30%	8%	0%	38%	100%	30%
P Load (lb/yr)	42%	13%	0%	54%	100%	44%
Sediment Load (t/yr)	26%	15%	0%	--	--	24%
E. coli Load (Billion MPN/yr)	75%	18%	0%	39%	100%	13%

The BMPs often function as a system, and the reductions summarized in Table 25 and Table 26 were modeled using the combined efficiencies of the practices (Table 28). The BMPs identified were modeled to estimate reductions by practice to inform implementation decisions and support adaptive management.

Table 27. STEPL pollutant load reduction by practice

Land use	BMP	Acres treated	N lbs/yr	P lbs/yr	Sediment t/yr	*E. coli* billion MPN/yr
Cropland	Cover Crop 3	100	531.3	170	87.8	75.1
Cropland	Nutrient Management 2	100	220.7	123.6	0	135.1
Cropland	Conservation Tillage (60% Residue or more)	100	587.3	185.4	91.4	97.6
Cropland	Land Retirement	100	1195.7	325.7	113.9	135.1
Cropland	Grassed Waterways	100	461.6	190	73.6	45
Cropland	Perennial Crop	100	565.2	139.3	59.3	75.1
Cropland	Land Retirement - Pasture	100	955.1	239.9	89	0
Cropland	Contour Farming	100	596.5	199.4	83.1	0
Cropland	WASCOB (Water & Sediment Control Basin)	100	1074.6	319.2	106.8	45
Cropland	Streambank Erosion Practices	100	1146.1	330.2	106.8	45
Pastureland	Grazing Land Management (rotational grazing w/ fenced areas)	100	242.3	36.9	18.2	65.6
Pastureland	Alternative Water Supply	100	57.6	9.5	5.7	65.6
Pastureland	Heavy Use Area Protection	100	86.6	16.7	10.1	0
Pastureland	Pasture & Hayland Planting	100	53.7	3.3	0	0
Pastureland	Livestock Exclusion Fencing	100	120.4	29.9	18.8	65.6
Feedlots	Waste Mgmt System	1	2433.1	322	0	0
Feedlots	Filter Strip	1	0	304.1	0	0
Feedlots	Runoff Mgmt System	1	2281	268.3	0	0

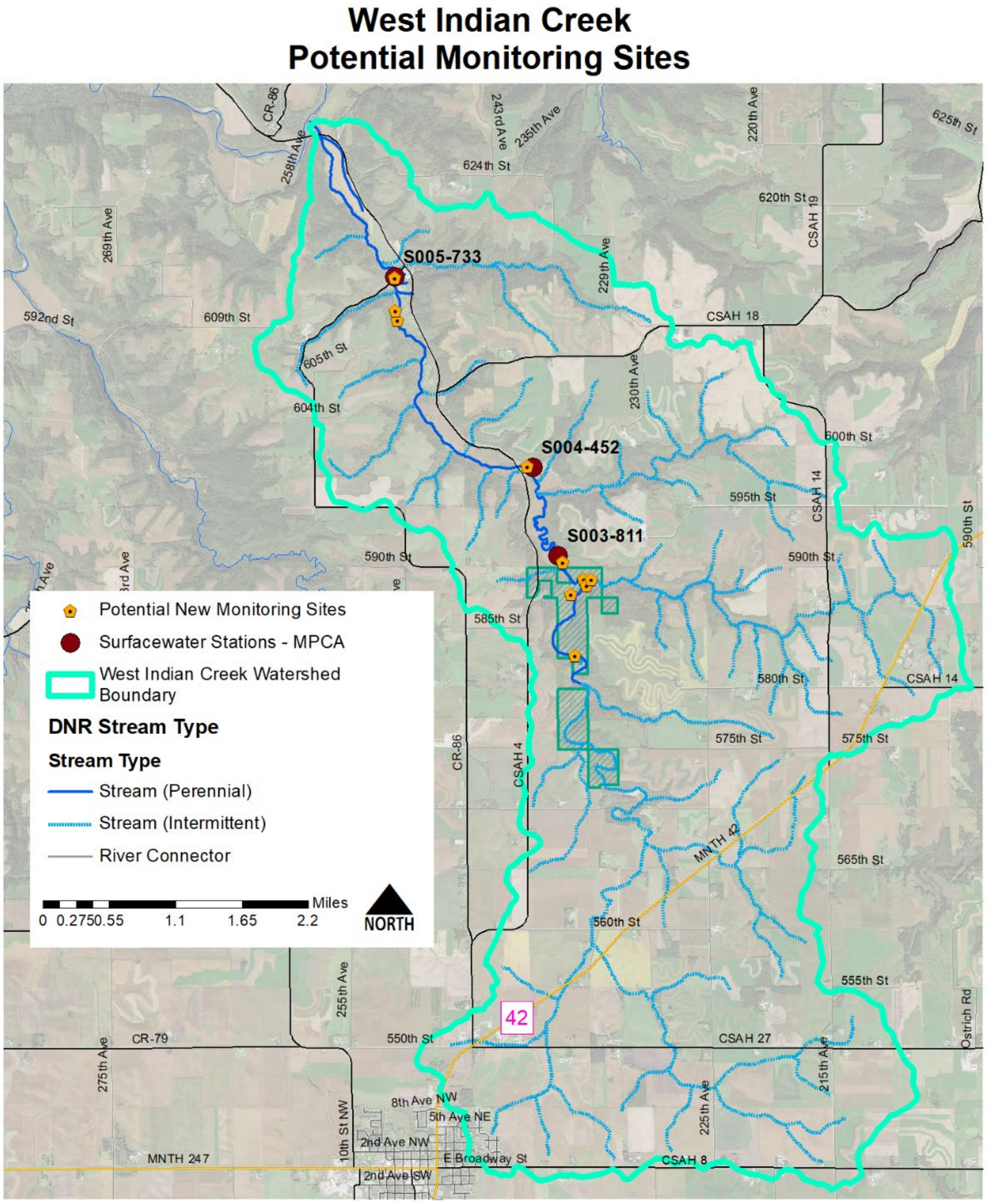
Monitoring approach

As is outline in previous sections, state of Minnesota agencies and local partners, including the Wabasha County SWCD, have identified West Indian Creek as a priority stream. This is evident from the long term biological and chemical monitoring completed by the DNR and MPCA in West Indian Creek since 2007. Regular biological and chemical monitoring will continue with the DNR and MPCA as it has since 2007 at least through the duration of this project. Proposed monitoring sites are shown on Figure 28.

To determine the effectiveness of treatments proposed in this plan, additional monitoring will be required. Previous sections discuss the importance of groundwater in this watershed and that nitrate concentrations of soil water and shallow wells or springs in the upper bedrock units may allow for monitoring of middle points between land use practices and surface water monitoring stations. This type of monitoring can help address the issues of lag time of groundwater dominated systems, where nitrate concentrations in surface water can lag changes in land use practices by decades. Installation of lysimeters below the root zone of targeted agricultural fields will show whether land use changes such as cover crops and nutrient management are reducing the amount of pollutants leaching into the subsurface. Nested monitoring wells in the two aquifers contributing to West Indian Creek will show whether land use practices within the surficial watershed are making a difference in pollutant concentrations in the groundwater. If no significant change is shown over time, it is anticipated that the larger groundwater contributing area (subsurface watershed) should be included in the project. Groundwater monitoring will be completed in consultation with Minnesota Departments of Health and Agriculture as well as the Minnesota Geologic Survey.

Additional discharge and pollutant monitoring downstream, near the confluence with the Zumbro River will help isolate effectiveness of implementation and other changes in the different areas of the watershed, as well as the overall pollutant load being delivered from West Indian Creek to the Zumbro River and any reductions thereof. Connecting localized and broader changes in the water quality with land use changes and implementation of BMPs within West Indian Creek and sharing this information and feedback with local partners will hopefully keep them invested in the process and will help inform how well the BMPs are performing. The collected information can also be used in watershed predictive models to provide better estimates of effectiveness of BMPs especially in the unique landscape of southeastern Minnesota.

Figure 28. Potential monitoring sites for the West Indian Creek Watershed



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Appendix A: STEPL output and assumptions

The STEPL was used to estimate P, TSS, and *E. coli* loads and reductions for the watershed. The loads estimated in STEPL were comparable with the loading that was estimated using HSPF-SAM for the development of the draft TMDLs in the watershed.

The reductions for BMPs identified in the ten-year milestone table were summed and entered as combined efficiency practices in STEPL. Reduction efficiencies for *E. coli* were assumed from MPCA (2011) and Wright Water Engineers, Inc. (2010) and added to the "BMPList" worksheet in STEPL. The practices and assumed reduction efficiencies are shown in Table 32. The Combined Efficiencies of the BMPs with area of subwatershed treated is described in Table 28. The treatment efficiencies for the BMPs that are not in the original list of BMPs and reduction efficiencies (BMPList) in STEPL were assigned based on the similarity of the treatment processes with selected BMPList practices.

Combined pollutant reduction efficiencies for subwatersheds

The STEPL program for modeling watershed reductions calculates the efficiencies of combined BMPs by land use. When BMPs are combined on the area of landscape, the efficiency of removal of the pollutant is changed. Each of the combined BMPs for land use and subwatershed is described in Table 28.

Table 28. Combined efficiencies of BMPs by land use and subwatershed in the West Indian Creek Watershed

Combined efficiencies for BMPs and acres treated as STEPL inputs for West Indian Creek subwatershed 1					
Cropland					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
10.6	Cover Crop 3 (Group A Traditional Early Planting Time) (High till only for TP and Sediment)	0.28	0.28	0.74	0.5
73.78	Nutrient Management 2 (Determined Rate Plus Additional Considerations)	0.247	0.56	0	0.9
11.18	Conservation Tillage 2 (Equal or more than 60% residue)	0.33	0.33	0.77	0.65
2.24	Land Retirement	0.93	0.84	0.96	0.9
10.6	Streambank Erosion Practices	0.9	0.9	0.9	0.3
1.7	Perennial Crop	0.42	0.3	0.5	0.5
1.7	Land Retirement - Pasture	0.75	0.59	0.75	0
111.8	Total acres and combined efficiencies	0.344	0.545	0.271	0.76
Pastureland					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
1.5	Livestock Exclusion Fencing - WASCOBs	0.203	0.304	0.62	0.65
20	Livestock Exclusion Fencing - Forest	0.203	0.304	0.62	0.65
1	Alternative Water Supply	0.133	0.115	0.187	0.65
1	Grazing Land Management (rotational grazing w/ fenced areas)	0.62	0.65	0.6	0.65
1	Pasture & Hayland Planting (Forage Planting)	0.181	0.15	0	0
0.5	Heavy Use Area Protection	0.183	0.193	0.333	0

25	Total acres and combined efficiencies	0.142	0.199	0.376	0.402
Feedlot					
Area (ac)	BMP	N	P	TSS	*E. coli*
1	Waste Mgmt System	0.8	0.9	0	0.9
0.25	Filter strip	0	0.85	0	0.3
1.25	Total acres and combined efficiencies	0.4	0.556	0	0.488
Combined efficiencies for BMPs and acres treated as STEPL inputs for West Indian Creek subwatershed 2					
Cropland					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
134.12	Cover Crop 3 (Group A Traditional Early Planting Time) (High till only for TP and Sediment)	0.28	0.28	0.74	0.5
931.78	Nutrient Management 2 (Determined Rate Plus Additional Considerations)	0.247	0.56	0	0.9
141.18	Conservation Tillage 2 (Equal or more than 60% residue)	0.33	0.33	0.77	0.65
28.24	Land Retirement	0.93	0.84	0.96	0.9
29.98	Grassed Waterways	0.253	0.45	0.62	0.3
21.2	Perennial Crop	0.42	0.3	0.5	0.5
21.2	Land Retirement - Pasture	0.75	0.59	0.75	0
104.1	Streambank Erosion Practices	0.9	0.9	0.9	0.3
1411.8	Total acres and combined efficiencies	0.331	0.535	0.265	0.76
Pastureland					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
20.25	Livestock Exclusion Fencing - WASCOBs	0.203	0.304	0.62	0.65
339.04	Livestock Exclusion Fencing - Forest	0.203	0.304	0.62	0.65
20.8	Alternative Water Supply	0.133	0.115	0.187	0.65
20.8	Grazing Land Management (rotational grazing w/ fenced areas)	0.62	0.65	0.6	0.65
20.8	Pasture & Hayland Planting (Forage Planting)	0.181	0.15	0	0
2	Heavy Use Area Protection	0.183	0.193	0.333	0
423.69	Total acres and combined efficiencies	0.089	0.124	0.231	0.251
Feedlot					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
2.5	Waste Mgmt System	0.8	0.9	0	0.9
2	Filter strip	0	0.85	0	0.3
2	Runoff Mgmt System	0.75	0.75	0.7	0.5
6.5	Total acres and combined efficiencies	0.35	0.545	0.14	0.385
Combined efficiencies for BMPs and acres treated as STEPL inputs for West Indian Creek subwatershed 3					
Cropland					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
222.5	Cover Crop 3 (Group A Traditional Early Planting Time) (High till only for TP and Sediment)	0.28	0.28	0.74	0.5

1545.8	Nutrient Management 2 (Determined Rate Plus Additional Considerations)	0.247	0.56	0	0.9
234.21	Conservation Tillage 2 (Equal or more than 60% residue)	0.33	0.33	0.77	0.65
46.8	Land Retirement	0.93	0.84	0.96	0.9
111.33	Grassed Waterways	0.253	0.45	0.62	0.3
35.1	Perennial Crop	0.42	0.3	0.5	0.5
35.1	Land Retirement - Pasture	0.75	0.59	0.75	0
111.33	WASCOB (Water & Sediment Control Basin)	0.82	0.85	0.9	0.3
2342.17	Total acres and combined efficiencies	0.31	0.521	0.257	0.76
Pastureland					
Area (ac)	BMP	N	P	TSS	*E. coli*
20.25	Livestock Exclusion Fencing - WASCOBs	0.203	0.304	0.62	0.65
475.56	Livestock Exclusion Fencing - Forest	0.203	0.304	0.62	0.65
40	Alternative Water Supply	0.133	0.115	0.187	0.65
40	Grazing Land Management (rotational grazing w/ fenced areas)	0.62	0.65	0.6	0.65
40	Pasture & Hayland Planting (Forage Planting)	0.181	0.15	0	0
4	Heavy Use Area Protection	0.183	0.193	0.333	0
619.81	Total acres and combined efficiencies	0.072	0.097	0.176	0.194
Feedlot					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
3	Waste Storage Facility	0.9	0.9	0.9	0.9
4.5	Waste Mgmt System	0.8	0.9	0	0.9
6	Filter strip	0	0.85	0	0.3
6	Runoff Mgmt System	0.75	0.75	0.7	0.5
19.5	Total acres and combined efficiencies	0.36	0.545	0.23	0.385
Combined efficiencies for BMPs and acres treated as STEPL inputs for West Indian Creek subwatershed 4					
Cropland					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
76.67	Cover Crop 3 (Group A Traditional Early Planting Time) (High till only for TP and Sediment)	0.28	0.28	0.74	0.5
532.69	Nutrient Management 2 (Determined Rate Plus Additional Considerations)	0.247	0.56	0	0.9
80.7	Conservation Tillage 2 (Equal or more than 60% residue)	0.33	0.33	0.77	0.65
16.14	Land Retirement	0.93	0.84	0.96	0.9
30.4	Grassed Waterways	0.253	0.45	0.62	0.3
12.1	Perennial Crop	0.42	0.3	0.5	0.5
12.1	Land Retirement - Pasture	0.75	0.59	0.75	0
46.3	WASCOB (Water & Sediment Control Basin)	0.82	0.85	0.9	0.3
807.1	Total acres and combined efficiencies	0.315	0.525	0.26	0.76
Pastureland					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***

1.5	Livestock Exclusion Fencing - WASCOBs	0.203	0.304	0.62	0.65
45	Livestock Exclusion Fencing - Forest	0.203	0.304	0.62	0.65
5.29	Alternative Water Supply	0.133	0.115	0.187	0.65
5.29	Grazing Land Management (rotational grazing w/ fenced areas)	0.62	0.65	0.6	0.65
5.29	Pasture & Hayland Planting (Forage Planting)	0.181	0.15	0	0
1	Heavy Use Area Protection	0.183	0.193	0.333	0
63.37	Total acres and combined efficiencies	0.055	0.073	0.126	0.14
Feedlot					
Area (ac)	**BMP**	**N**	**P**	**TSS**	**E. coli**
1	Waste Mgmt System	0.8	0.9	0	0.9
1.5	Filter strip	0	0.85	0	0.3
2.5	Total acres and combined efficiencies	0.2	0.544	0	0.338
Combined efficiencies for BMPs and acres treated as STEPL inputs for West Indian Creek subwatershed 5					
Cropland					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
411.21	Cover Crop 3 (Group A Traditional Early Planting Time) (High till only for TP and Sediment)	0.28	0.28	0.74	0.5
2856.8	Nutrient Management 2 (Determined Rate Plus Additional Considerations)	0.247	0.56	0	0.9
432.85	Conservation Tillage 2 (Equal or more than 60% residue)	0.33	0.33	0.77	0.65
86.57	Land Retirement	0.93	0.84	0.96	0.9
86.57	Grassed Waterways	0.253	0.45	0.62	0.3
65.9	Perennial Crop	0.42	0.3	0.5	0.5
65.9	Land Retirement - Pasture	0.75	0.59	0.75	0
216.4	Contour Farming	0.37	0.44	0.7	0
106.3	WASCOB (Water & Sediment Control Basin)	0.82	0.85	0.9	0.3
4328.5	Total acres and combined efficiencies	0.303	0.511	0.255	0.745
Pastureland					
Area (ac)	**BMP**	**N**	**P**	**TSS**	***E. coli***
20	Grazing Land Management (rotational grazing w/ fenced areas)	0.62	0.65	0.6	0.65
20	Alternative Water Supply	0.133	0.115	0.187	0.65
5	Heavy Use Area Protection	0.183	0.193	0.333	0
20	Pasture & Hayland Planting (Forage Planting)	0.181	0.15	0	0
9.75	Livestock Exclusion Fencing - WASCOBs	0.203	0.304	0.62	0.65
74.75	Total acres and combined efficiencies	0.023	0.023	0.025	0.034
Feedlot					
Area (ac)	**BMP**	**N**	**P**	**TSS**	**E. coli**
5	Waste Storage Facility	0.9	0.9	0.9	0.9
4	Waste Mgmt System	0.8	0.9	0	0.9
4.4	Filter strip	0	0.85	0	0.3

10	Runoff Mgmt System	0.75	0.75	0.7	0.5
23.4	Total acres and combined efficiencies	0.42	0.54	0.32	0.40

STEPL inputs

The STEPL model allows users to enter information about each of the subwatersheds. This is described in Table 29.

Table 29. Watershed land use input in acres for the West Indian Creek Watershed

Watershed	Urban	Cropland	Pastureland	Forest	Feedlots	% feedlot paved	Total
W1	4.4	111.8	38	137.8	2	0-24%	294
W2	195.3	1411.8	1040	1295.9	10	0-24%	3953
W3	156.15	2342.17	1930.83	1240.45	30	0-24%	5699.6
W4	48.1	807.1	264.3	332	4	0-24%	1455.5
W5	322.29	4328.9	956.1	139.7	36	0-24%	5783.99

SSTS reductions

The STEPL model does not include the estimated pollutant reductions in the watershed reduction table. Instead, the reductions associated with the replacement and upgrades of the SSTS in West Indian Creek Watershed are summarized in Table 30.

Table 30. STEPL output for SSTS *E. coli* load reductions in the West Indian Creek Watershed

Number of SSTS in subwatersheds, population per SSTS and failure rates								Hourly Load		
Watershed	**# of SSTS**	**Pop per SSTS**	**Failure rate**	**Failing SSTS**	**Pop on failing SSTS**	**Failing SSTS gal/day**	**Failing SSTS flow L/hr**	**N load lb/hr**	**P load lb/hr**	***E. coli* MPN/hr (billion)**
1	3	2.43	25%	0.75	1.8225	127.575	20.122	0.003	0.001	190754.95
2	21	2.43	25%	5.25	12.7575	893.025	140.853	0.019	0.007	1335284.68
3	45	2.43	25%	11.25	27.3375	1913.625	301.827	0.040	0.016	2861324.32
4	14	2.43	25%	3.5	8.505	595.35	93.902	0.012	0.005	890189.78
5	60	2.43	25%	15	36.45	2551.5	402.437	0.053	0.021	3815099.09

Annual Load			Load after Reduction		
N load lb/yr	**P load lb/yr**	***E. coli* billion MPN/yr**	**N load lb/yr**	**P load lb/yr**	***E. coli* billion MPN/yr**
23.3	9.1	1671.0	0	0	0
163.2	63.9	11697.1	0	0	0
349.7	137.0	25065.2	0	0	0
108.8	42.6	7798.1	0	0	0
466.3	182.6	33420.3	0	0	0

STEPL assumptions

There are assumptions made to effectively use the STEPL mode to calculate watershed pollutant reduction. The STEPL was used to estimate phosphorus and E. coli loads and reductions for the watershed. The default sediment, phosphorus, and nitrogen reduction efficiencies were used. Reduction efficiencies for E. coli were assumed from MPCA (2011) and Wright Water Engineers, Inc. (2010) and added to the BMP List worksheet. Some of the assumptions are described below.

- Feedlot land uses are assumed to have roughly 2 acres of strictly feedlot area. This does not include barns where animals are housed or pastures.
- Watershed land use areas were obtained using a combination of HSPF subwatershed areas and six year cropping history / land use information obtained from the ACPF database.
- The general pollutant reduction goals were taken from the NRS recommendations for the Lower Zumbro, West Indian *E. coli* TMDL mid-range flow reductions, and Zumbro River WRAPS BMP scenario.
- The number of total cropland areas assumed to receive BMPs for P reduction (Zumbro WRAPS report (Table 31). These assumptions were calculated to fit the West Indian Creek Watershed, as described in the Estimated Load Reduction section.

Table 31. Percentage of acres needed to achieve P reductions in the Lower Zumbro River Watershed

Management practice	Lower Zumbro River Watershed
Target P2O5 rate	66.0%
Use reduced tillage on corn, soy, and small grains	24.0%
Riparian buffers, 50ft wide, 100 ft treated	7.5%
Perennial crop % of marginal corn ^ soybean land	3.1%
Rye cover crop on corn and soybean acres	5.5%
Short season crops planted to a rye cover crop	4.1%
Controlled drainage	0%
Alternative tile intakes	0%
Inject/incorporate manure	5.4$

Table 32. STEPL practices, efficiencies and assumptions for the West Indian Creek Watershed

	N	P	Sediment	E. coli	Assumptions and additions
Cropland					
0 No BMP	**0**	**0**	**0**	**0**	**Added all E. coli efficiencies**
Bioreactor	**0.453**	**ND**	**ND**	**0.9**	**Assume treats 20 acres**
Buffer - Forest (100ft wide)	0.478	0.465	0.586	0.9	
Buffer - Grass (35ft wide)	0.338	0.435	0.533	0.65	
Conservation Cover	0.204	0.15	0.2	0.5	Added Conservation Cover, assuming same efficiencies as STEPL practice Cover Crop 3
Conservation Tillage 1 (30-59% Residue)	0.15	0.356	0.403	0.3	

	N	P	Sediment	E. coli	Assumptions and additions
Conservation Tillage 2 (equal or more than 60% Residue)	0.25	0.687	0.77	0.65	
Contour Farming	0.279	0.398	0.341	ND	
Controlled Drainage	0.388	0.35	ND	ND	
Cover Crop 1 (Group A Commodity) (High Till only for Sediment)	0.008	ND	ND	ND	
Cover Crop 2 (Group A Traditional Normal Planting Time) (High Till only for TP and Sediment)	0.196	0.07	0.1	ND	
Cover Crop 3 (Group A Traditional Early Planting Time) (High Till only for TP and Sediment)	0.204	0.15	0.2	0.5	
Critical Area Planting	0.898	0.808	0.95	0.9	Added cropland Critical Area Planting, assuming same efficiencies as STEPL practice land Retirement
Detention Basin	0.253	0.308	0.4	0.3	Assume each basin is 10 acres and each basin treats 100 acres. Assume same efficiencies as STEPL practice Terrace.
Diversions	0.898	0.808	0.95	0.9	Added Diversions, assuming same efficiencies as STEPL practice Land Retirement
Drainage Water Management	0.253	0.308	0.4	0.3	Added Drainage Water Management, assuming same efficiencies as STEPL Practice Terrace, assume 50 acres treated per practice
Field Borders	0.253	0.308	0.4	0.3	Added Field Borders, assuming same efficiencies as STEPL practice Filter Strips (Terrace)
Filter Strips	0.253	0.308	0.4	0.3	Added Filter Strip, assuming same efficiencies as STEPL practice Terrace, assume 50 acres treatment per acre of filter strip (assume 1,000 ft=1 acres)
Filtration Practices	0.253	0.308	0.4	0.3	Added Filtration Practices, assuming same efficiencies as STEPL practice Terrace, assuming 40 acres treated per practice
Grade Stabilization Structures	0.253	0.308	0.4	0.3	Added Grade Stabilization Structures, assuming same efficiencies as STEPL practice

	N	P	Sediment	E. coli	Assumptions and additions
					Terrace, assume 40 acres treated per practice.
Grassed Waterways	0.253	0.308	0.4	0.3	Added Grassed Waterways, assume 1,000 ft of grassed waterways treats 50 acres, assume same efficiencies as STEPL practice Terrace
Impoundment	0.898	0.808	0.95	0.9	Added Impoundment, assume same efficiencies as STEPL practice Land Retirement
Land Retirement	0.898	0.808	0.95	0.9	Added Nutrient/Manure Management, Assuming same efficiencies as STEPL practice Nutrient Management 1, increased e. coli efficiencies to .9
Manure/Nutrient Management	0.154	0.45	ND	0.9	
Nutrient Management 1 (Determined Rate)	0.154	0.45	ND	0.5	
Nutrient Management 2 (Determined Rate Plus Additional Considerations)	0.247	0.56	ND	0.9	
Residue/Tillage Management	0.15	0.356	0.403	0.3	Added Residue/Tillage Management, assuming same efficiencies as STEPL practice Conservation Tillage 1
Saturated Buffer	0.338	0.435	0.533	0.65	Added Saturated Buffer, assuming same efficiencies as STEPL practice Buffer-Grass; Assume 1,000 ft with treatment as 40 ac/mil (1/8 mile width) as Two-Stage Ditch
Side water inlets	0.253	0.308	0.4	0.3	Added Side Water inlets, assumed same efficiencies as Terrace
Streambank Erosion Practices	0.253	0.308	0.4	0.3	Added Streambank Erosion Practices, assuming same efficiencies as STEPL practice Terrace, assuming 5 practices treat 100 acres
Streambank Stabilization and Fencing	0.75	0.75	0.75	0.3	
Terrace	0.253	0.308	0.4	0.3	
Two-Stage Ditch	0.12	0.28	ND	0.3	
WASCOB (Water and Sediment Control Basin	0.253	0.308	0.4	0.3	Added WASCOB, assuming the same efficiencies as Terrace, assuming 40 acres treated per WASCOB

	N	P	Sediment	E. coli	Assumptions and additions
Water Control Structures	0.253	0.308	0.4	0.3	Added cropland Water Control Structures, assuming same efficiencies as STEPL practice Terrace, assume 40 acres treated per practice installed
Wetland Restoration	0.898	0.808	0.95	0.9	Added Wetland Restoration, assuming same efficiencies as STEPL practice Land retirement assuming 40 acres treated per acre of wetland
Pastureland					
0 No BMP	**0**	**0**	**0**	**0**	
30m Buffer with Optimal Grazing	0.364	0.653	ND	0.65	
Alternative Water Supply	0.133	0.115	0.187	0.65	
Cattle Exclusions	0.203	0.304	0.62	0.65	Added pastureland Cattle Exclusions, assuming same efficiencies as STEPL practice Livestock exclusion fencing
Critical Area Planting	0.175	0.2	0.42	ND	
Fencing and Watering Projects	0.203	0.304	0.62	0.65	Added pastureland Fencing and watering projects, assuming same efficiencies as STEPL practice Livestock Exclusion Fencing
Forest Buffer (minimum 35 feet wide)	0.452	0.4	0.533	ND	
Grass Buffer (minimum 35 feet wide)	0.868	0.766	0.648	ND	
Grazing Land Management (rotational grazing with fenced areas)	0.43	0.263	ND	0.65	
Heavy Use Area Protection	0.183	0.193	0.333	ND	
Litter Storage and Management	0.14	0.14	0	ND	
Livestock Exclusion Fencing	0.203	0.304	0.62	0.65	
Multiple Practices	0.246	0.205	0.221	ND	
Pasture and Hayland Planting (also called Forage Planting)	0.181	0.15	ND	ND	
Prescribed Grazing	0.408	0.227	0.333	ND	
Rotational Grazing	0.43	0.263	0.333	0.65	Added pastureland Rotational Grazing, assuming same efficiencies as STEPL practice Grazing Land Management, and

	N	P	Sediment	E. coli	Assumptions and additions
					TSS reduction from Prescribed Grazing
Streambank Protection w/o Fencing	0.15	0.22	0.575	0.3	
Streambank Stabilization and Fencing	0.75	0.75	0.75	0.65	
Use Exclusion	0.39	0.04	0.589	0.9	
Winter Feeding Facility	0.35	0.4	0.4	ND	
Forest					
0 No BMP	**0**	**0**	**0**	**0**	
Road dry seeding	ND	ND	0.41	ND	
Road grass and legume seeding	ND	ND	0.71	ND	
Road hydro mulch	ND	ND	0.41	ND	
Road straw mulch	ND	ND	0.41	ND	
Road tree planting	ND	ND	0.5	ND	
Site preparation/hydro mulch/seed/fertilizer	ND	ND	0.71	ND	
Site preparation/hydro mulch/seed/fertilizer /transplants	ND	ND	0.69	ND	
Site preparation/steep slope seeder/transplant	ND	ND	0.81	ND	
Site preparation/straw/ crimp seed/fertilizer/ transplant	ND	ND	0.95	ND	
Site preparation/straw/ crimp/net	ND	ND	0.93	ND	
Site preparation/straw/net/ seed/fertilizer/ transplant	ND	ND	0.83	ND	
Site preparation/straw/ polymer/seed/fertilizer/ transplant	ND	ND	0.86	ND	
Feedlots					
0 No BMP	**0**	**0**	**0**	**0**	
Diversion	0.45	0.7	ND	ND	
Filter strip	ND	0.85	ND	0.3	
Runoff Mgmt System	ND	0.825	ND	0.5	
Solids Separation Basin	0.35	0.31	ND	ND	
Solids Separation Basin w/Infilt Bed	ND	0.8	ND	0.9	
Terrace	0.55	0.85	ND	ND	

	N	P	Sediment	E. coli	Assumptions and additions
Waste Mgmt System	0.8	0.9	ND	0.9	
Waste Storage Facility	0.65	0.6	ND	0.9	
Urban					
0 No BMP	**0**	**0**	**0**	**0**	
Alum Treatment	0.6	0.9	0.95	ND	
Bioretention facility	0.63	0.8	ND	0.9	
Bioretention practices	0.63	0.8	0.85	0.95	Added Urban STEPL Bioretention practice, efficiencies for TSS and E. coli based on MN Stormwater manual (https://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_bioretention)
Combined BMPs-Calculated	0	0	0	0	
Concrete Grid Pavement	0.9	0.9	0.9	ND	
Dry Detention	0.3	0.26	0.575	ND	
Extended Wet Detention	0.55	0.685	0.86	0.9	
Filter Strip-Agricultural	0.5325	0.6125	0.65	0.3	
Grass Swales	0.1	0.25	0.65	ND	
Infiltration Basin	0.6	0.65	0.75	0.9	
Infiltration Devices	ND	0.83	0.94	ND	
Infiltration Trench	0.55	0.6	0.75	ND	
LID*/Cistern	0	0	0	0	
LID*/Cistern+Rain Barrel	0	0	0	0	
LID*/Rain Barrel	0	0	0	0	
LID/Bioretention	0.43	0.81	ND	ND	
LID/Dry Well	0.5	0.5	0.9	ND	
LID/Filter/Buffer Strip	0.3	0.3	0.6	ND	
LID/Infiltration Swale	0.5	0.65	0.9	ND	
LID/Infiltration Trench	0.5	0.5	0.9	ND	
LID/Vegetated Swale	0.075	0.175	0.475	ND	
LID/Wet Swale	0.4	0.2	0.8	ND	
Oil/Grit Separator	0.05	0.05	0.15	ND	
Porous Pavement	0.85	0.65	0.9	ND	
Raingardens	0.6	0.65	0.75	0.9	Added Urban STEPL raingardens, assuming same efficiencies as STEPL practice Infiltration basin (urban)
Sand Filter/Infiltration Basin	0.35	0.5	0.8	ND	
Sand Filters	ND	0.375	0.825	ND	
Settling Basin	ND	0.515	0.815	ND	
Vegetated Filter Strips	0.4	0.4525	0.73	ND	

	N	P	Sediment	E. coli	Assumptions and additions
Weekly Street Sweeping	ND	0.06	0.16	ND	
Wet Pond	0.35	0.45	0.6	ND	
Wetland Detention	0.2	0.44	0.775	ND	
WQ Inlet w/Sand Filter	0.35	ND	0.8	ND	
WQ Inlets	0.2	0.09	0.37	ND	

Table 33. Current loading and estimated pollutant reductions for BMPs described in this plan

	Estimated Current Loading by subwatershed				**Estimated Reduction to Loading**			
	N load (no BMP)	**P load**	**TSS load**	***E. coli* load**	**N reduction**	**P reduction**	**TSS reduction**	***E. coli* reduction**
Watershed	**lb/yr**	**lb/yr**	**t/yr**	**billion MPN/yr**	**lb/year**	**lb/year**	**t/year**	**billion MPN/yr**
W1	10443.33	2142.732	147.64	2272.135	3788.99	1119.18	40.29	2111.64
W2	40159.99	7876.584	2036.42	14897.51	9729.33	3203.08	516.80	13571.53
W3	163760.84	25629.36	3407.23	33232.41	51331.60	12018.48	817.34	29512.65
W4	15258.42	3468.681	1049.25	9284.491	3373.79	1366.78	259.12	8756.30
W5	149490.53	27123.62	5457.94	40889.14	47631.85	11906.28	1317.19	38294.81
Total	**379113.11**	**66240.98**	**12098.47**	**100575.7**	**115855.56**	**29613.79**	**2950.74**	**92246.93**
	Estimated Future Loading							
	N load (with BMP)	**P load (with BMP)**	**TSS load (with BMP)**	***E. coli* load (with BMP)**	**N reduction**	**P reduction**	**TSS reduction**	***E. coli* reduction**
Watershed	**lb/yr**	**lb/yr**	**t/yr**	**billion MPN/yr**	**%**	**%**	**%**	**%**
W1	6654.34	1023.55	107.35	160.49	36%	52%	27%	93%
W2	30430.66	4673.51	1519.62	1325.98	24%	41%	25%	91%
W3	112429.24	13610.89	2589.89	3719.76	31%	47%	24%	89%
W4	11884.63	2101.90	790.13	528.20	22%	39%	25%	94%
W5	101858.68	15217.34	4140.74	2594.34	32%	44%	24%	94%
Total	**263257.55**	**36627.18**	**9147.74**	**8328.77**	**31%**	**45%**	**24%**	**92%**

Appendix B
Zumbro River Watershed HSPF model development project – Phase II memorandum

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Memorandum

From: Amanda Flynn, Derek Schlea, Todd Redder, Hans Holmberg

Date: September 21, 2015
Revised October 19, 2015

To: Justin Watkins (MPCA)
Benjamin Roush (MPCA)

CC:

Project: Zumbro River Watershed HSPF Model Development Project – Phase II

Subject: Task 3: Technical Memorandum to Document Tasks 1 and 2 - Refinement of the ZRWHSPF Watershed Model and Application to Management Scenarios

Statement of Purpose

This memorandum has been prepared for the Minnesota Pollution Control Agency (MPCA) to document Phase II of the "Zumbro River Watershed HSPF Model Development Project" and serves as one of two deliverables, as outlined in Task 3 of the Work Plan, Contract No. 20534. The second deliverable consists of a model package that includes model updates and scenario runs performed in Task 1 and Task 2. The model package will be delivered electronically to MPCA in conjunction with this memorandum.

The tasks outlined for this phase work include the following:

- Task 1: Refine the Zumbro River Watershed Hydrological Simulation Program - FORTRAN (ZRWHSPF) model developed in Phase I
- Task 2: Apply the ZRWHSPF model to assess various management scenarios
- Task 3: Reporting and model package

The objective of Task 1 was to refine point source inputs based on updated MPCA datasets; refine the sediment calibration, as needed, based on new data and information; and evaluate the model calibration/validation following the model refinements to ensure the model performs as good or better than the Phase 1 version. The objective of Task 2 was to apply the ZRWHSPF model to explore the potential hydrologic and water quality changes in response to implementing management practices in the Zumbro River watershed. As part of this effort, a total of ten (10) management scenarios were evaluated. The sections below document the work performed in Tasks 1 and 2 of this project.

Project Background

The MPCA is undertaking a watershed restoration and protection (WRAP) approach at the HUC8 (8-digit Hydrologic Unit Code) scale. This represents an ambitious and comprehensive 10-year statewide effort to assess watershed conditions, develop Total Maximum Daily Loads (TMDLs), and implement watershed protection and restoration strategies for its 81 HUC8 watersheds.

The Zumbro River HUC8 watershed (Figure 1) includes waters impaired by excessive fecal coliforms, mercury, PCBs, and turbidity. Lake Zumbro, a highly valued water resource, is also impaired by excessive nutrients. The MPCA has selected the HSPF model to simulate watershed hydrology and water quality. The HSPF model is an important tool in developing an understanding of existing conditions, simulating conditions under various management scenarios, and informing the development of implementation strategies and plans to restore and protect streams and lakes.

In Phase 1 of this project, the ZRWHSPF model was developed to simulate hydrology, sediment and suspended solids (TSS), water temperature, nutrients (phosphorus and nitrogen), biochemical oxygen demand (BOD), dissolved oxygen (DO), phytoplankton and benthic algae. The scale of the watershed model is at the HUC8 watershed level with a subbasin delineation intermediate between the HUC12 and HUC16 scale. The model simulation period is from 1995-2009. The model was successfully calibrated and validated for hydrology and water quality based on the datasets and information available at the time the work was conducted.

In Phase II of this project, the ZRWHSPF model was refined based on new data and information. The model was then applied to evaluate various management scenarios to help provide information on how effective a specific action may be for reducing sediment and nutrient loading in the watershed and for improving water quality. A primary objective of this work is to provide the foundation for the Lake Zumbro Phosphorus Total Maximum Daily Load (TMDL).

Zumbro River Watershed HSPF Model

In the HSPF model, a watershed is comprised of delineated subbasins (or subwatersheds) that have a single, representative reach segment per subbasin. In the ZRWHSPF model, the watershed is divided into 109 subbasins (Figure 2). The average area per subbasin is 678 acres and ranges from 17 acres to 37,565 acres. The subbasins and reach segments are networked (or connected) together in the model to represent a watershed drainage area. A subbasin is conceptualized as a group of individual hydrologic response units (HRUs) (also called land segments) that are all routed to a representative reach (or stream) segment.

The purpose of defining a set of HRUs is to divide a watershed into individual land segments that are assumed to produce homogeneous hydrologic and water quality responses due to similar land use, soils, topography, climate, and land management activities. The model contains a total of 1,740 HRUs. The average area per HRU is 518 acres and ranges from <1 acre to 15,888 acres. It is important to note that the individual HRUs are not spatially explicit within a subbasin model. For example, all forest land with a hydrologic soil group (HSG) of A/B in a subbasin would be lumped or grouped as a single unit without reference to the varying spatial locations of that HRU type scattered across a subbasin. The geographic (or spatial) location of a subbasin is known and maintains a spatially explicit location in the model.

Complete documentation of the ZRWHSPF watershed model, including development, calibration, and validation is provided in the "Zumbro River Watershed HSPF Model Development Project" final report (LimnoTech 2014).

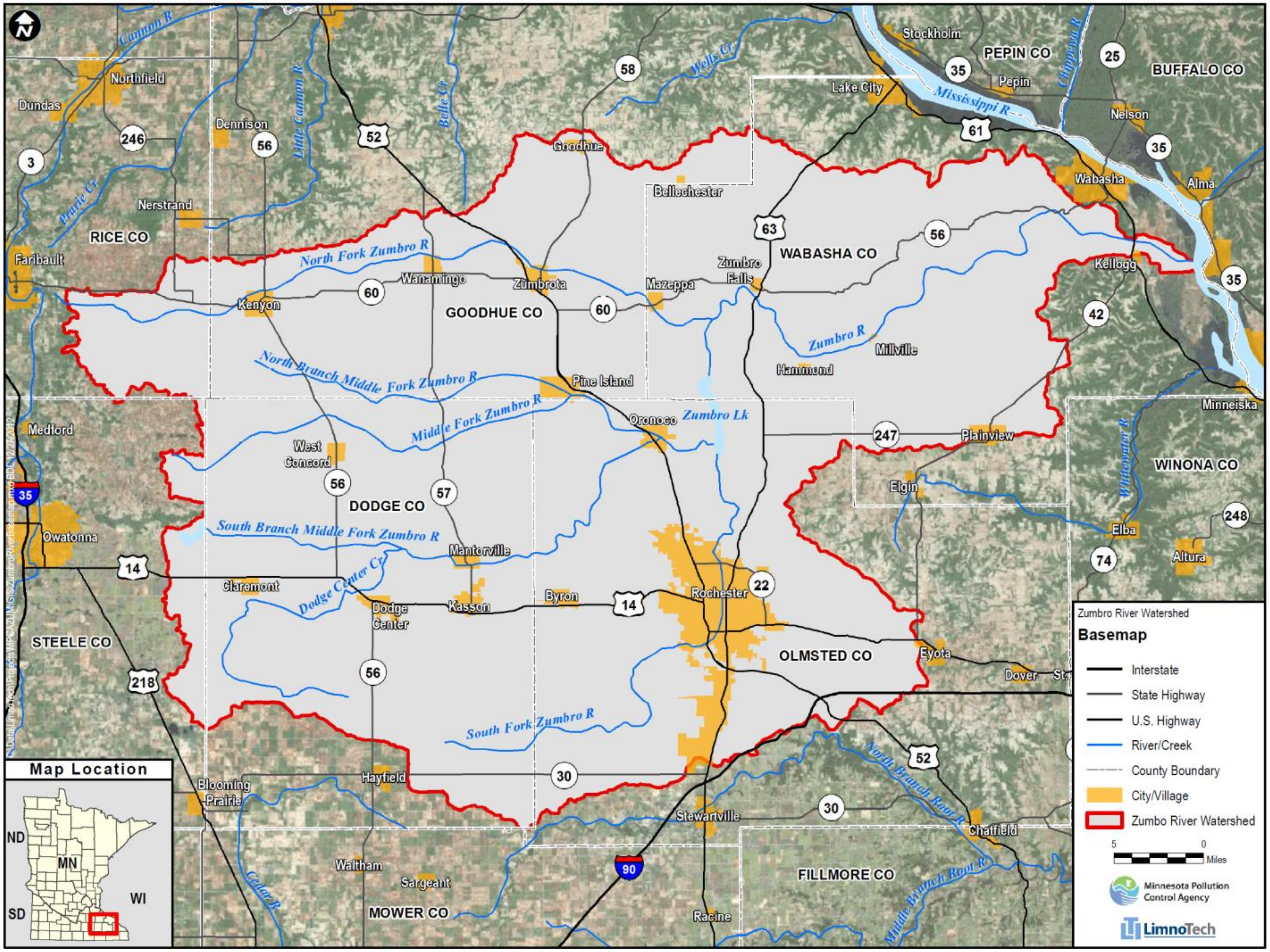


Figure 1. Basemap of the Zumbro River watershed, Minnesota

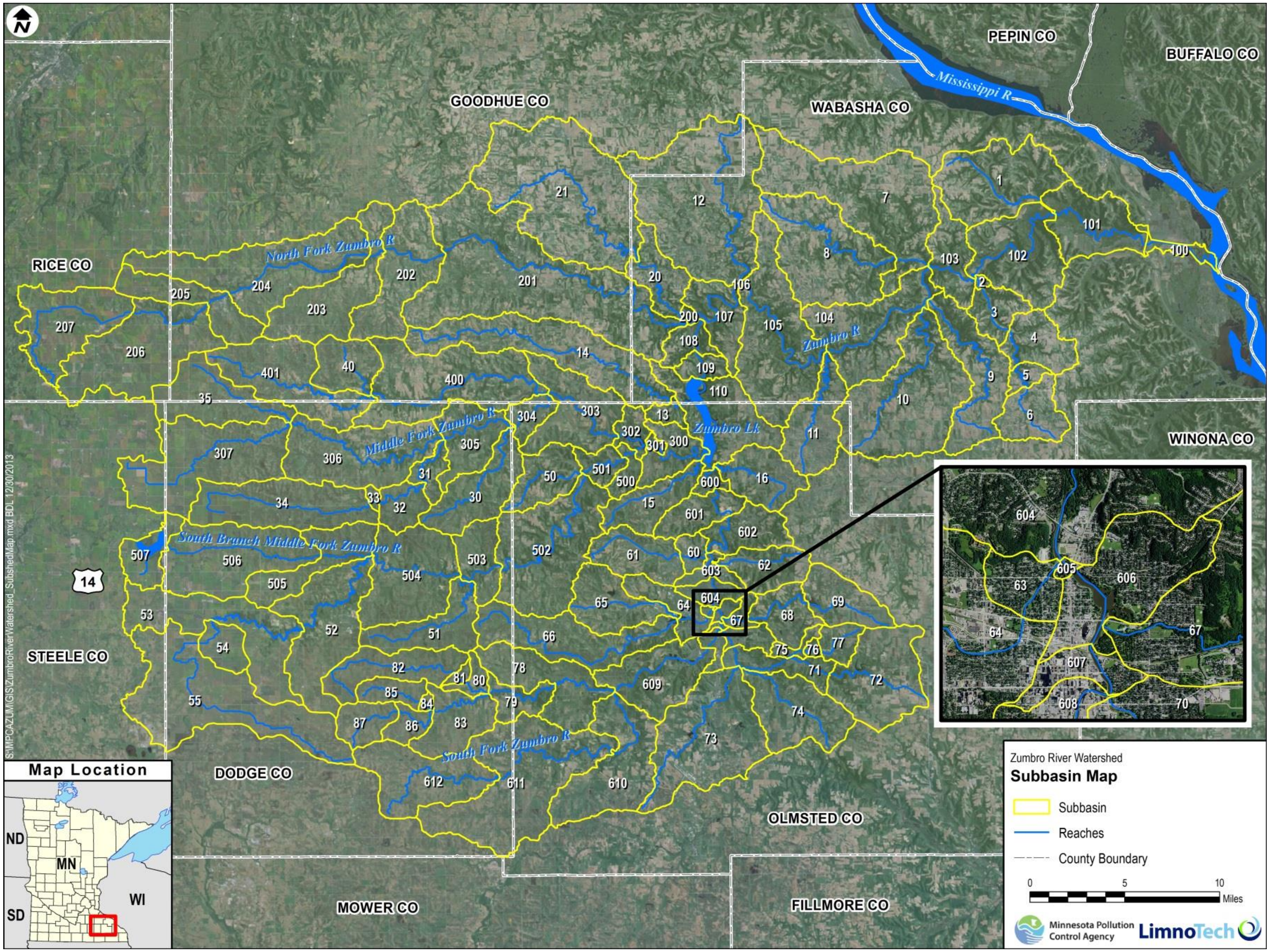


Figure 2. Map of the ZRWHSPF model subbasins

Task 1: Refine the ZRWHSPF Model Developed in Phase 1

The purpose of Task 1 was to revise point source inputs and refine the sediment calibration, as needed, based on new and more accurate datasets and information. Additional revisions and refinements were made to atmospheric deposition inputs, model reach hydraulic function tables, and the nutrient and algae calibration to improve the model representation of the watershed. A description of the model revisions and refinements is provided in the sections below.

Point Sources

Point source inputs were revised based on improved and more accurate datasets. Revisions were made to both major and minor point source inputs and included the following:

- Rochester Wastewater Treatment Plant (WWTP)/Water Reclamation Plant: Revised or corrected total phosphorus (TP) input concentrations based on new information provided by MPCA. The changes were primarily made to data points in 2004 and 2005.

- Zumbrota WWTP: Revised the flow, carbonaceous biochemical oxygen demand (CBOD), TSS, and DO input concentrations for 2002 based on monthly discharge monitoring report (DMR) summary data provided by MPCA. Because data were still not available for pH, TP, and ammonium plus ammonia (NH4+NH3), the input values for these parameters were not revised. These input values are based on an overall monthly average calculated from all years with available data (LimnoTech 2014).

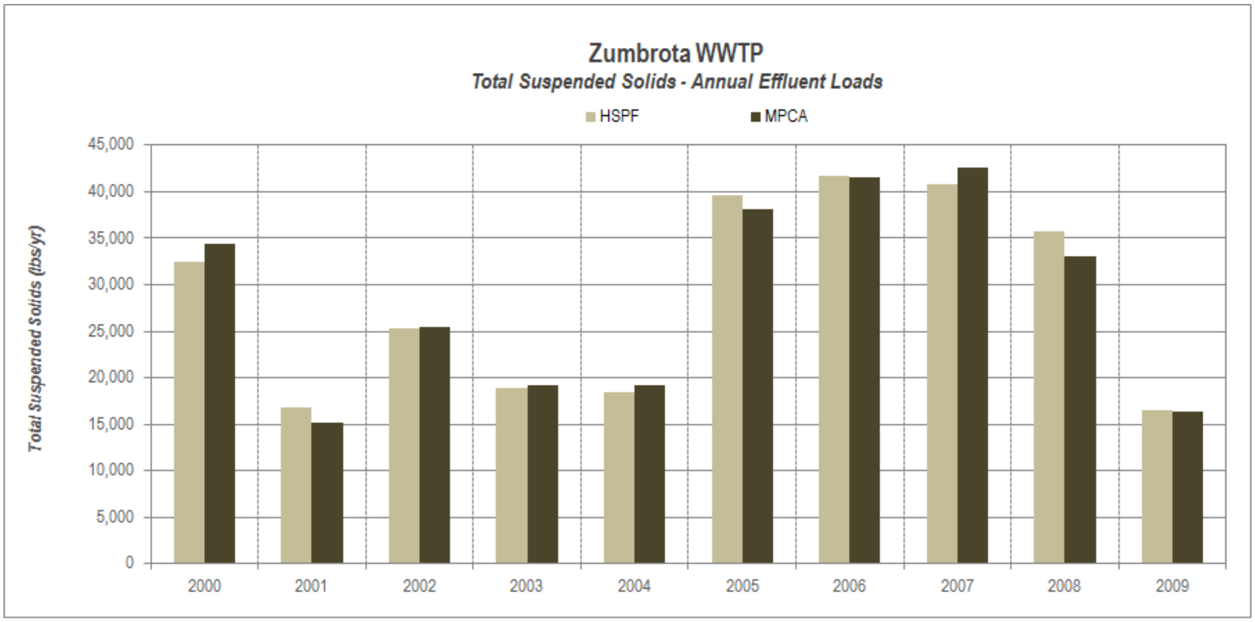
- For the minor point sources with limited data, a few adjustments were made to the previously assumed concentrations based on further review of the available data and literature sources of typical effluent concentrations by facility type. Table 1 outlines the revised minor point source input assumptions.

Table 1. Minor point source input concentrations.

Parameter	Previously Assumed Concentration (mg/L)	New Assumed Concentration for WWTPs	New Assumed Concentration for Industrial/Other
TSS	1.0	5.0	1.0
DO	8.0	8.0	8.0
BOD5	1.0	5.0	1.0
NO3	10.0	10.0	1.0
NO2	0.1	0.1	0.1
NH3	1.0	1.0	1.0
TP	0.05 or 0.10	1.0	0.10

A check was performed between the MPCA and HSPF calculated TSS and TP loads for the two major point sources in the watershed, the Rochester WWTP and the Zumbrota WWTP. For the Rochester WWTP, the average relative percent difference between the MPCA and HSPF loads is less than 2% for TSS and TP (Figure 3). For the Zumbrota WWTP, the average relative percent difference between the MPCA and HSPF loads is 4% for TSS and 8% for TP (Figure 4). The small differences in the loads are likely attributable to variations in calculation and data gap filling methods.

Figure 3. Calculated MPCA and HSPF annual TSS and TP loads for the Rochester WWTP.



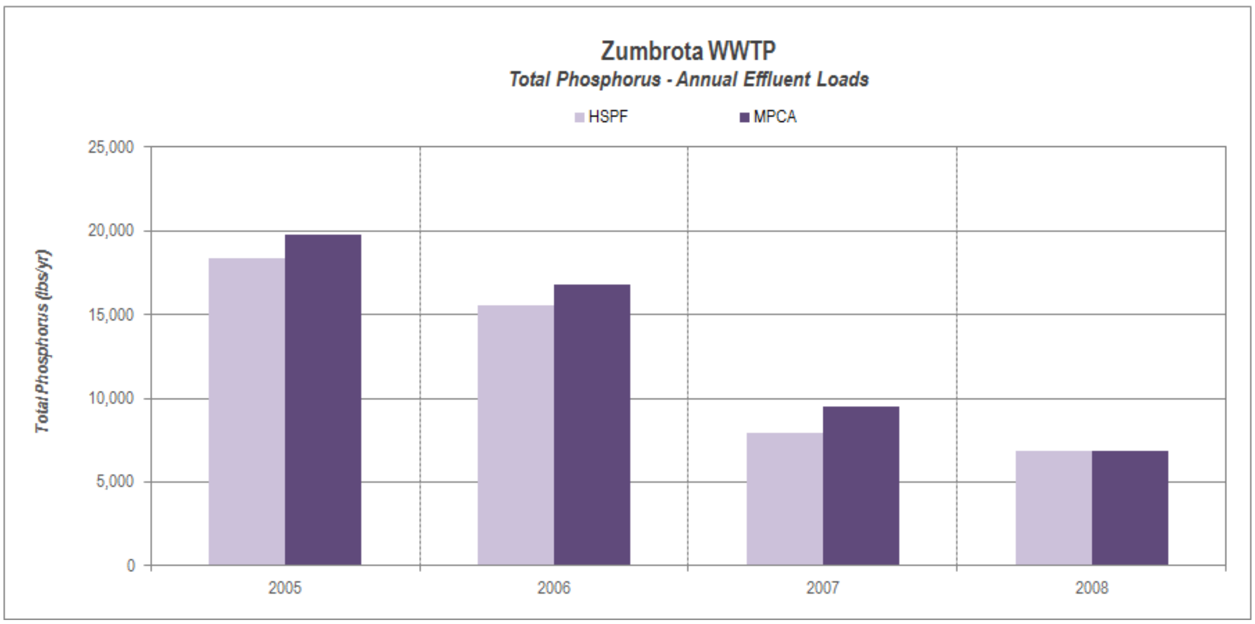


Figure 4. Calculated MPCA and HSPF annual TSS and TP loads for the Zumbrota WWTP.

Atmospheric Deposition

A revision was made in the external sources (EXT SOURCES) input block related to the wet atmospheric deposition of nitrate and ammonium on the reach and reservoir (RCHRES) water surfaces. A conversion factor is required to properly input wet atmospheric deposition concentrations on model HRUs (i.e., PERLNDs and IMPLNDs). This conversion had also been applied to the model reaches and reservoirs; however, the conversion factor is not necessary to properly input wet atmospheric deposition on a reach or reservoir due to the different method HSPF uses to track concentrations in a reach or reservoir as compared to an HRU. Therefore, the conversion factor was removed from the wet atmospheric deposition inputs to the RCHRES module in the current model.

Hydraulic Function Tables (FTABLES)

The HSPF model uses a hydraulic function table, called an FTABLE, to represent the geometric and hydraulic properties of water bodies, including both stream reaches and fully mixed reservoirs (USEPA 2007). The accuracy of the FTABLE is particularly important for the simulation of flow velocity and sediment transport (USEPA 2007). The FTABLEs for all model reaches were modified to maintain a small depth of flow at extreme low flow conditions. The FTABLES for Lake Zumbro, Rice Lake, and the storage reservoirs were not modified.

The primary purpose of this refinement was to allow for a more reasonable simulation of flow velocities, which in turn affects the simulation of sand movement. A secondary purpose of this refinement was to prevent model instabilities in the water quality simulation attributed to extreme low flow conditions. In the previous calibration, instabilities related to low flow conditions were addressed by adding small amounts of flow volume during the most susceptible time periods to reach segments exhibiting instabilities via the "special actions" module. Because the FTABLE refinement addressed the instabilities, the addition of flow volume via the "special actions" module was removed from the current model. This modification improved the representation of flow velocity at low flow conditions, improved the representation of sand movement, and addressed model instability issues in the water quality simulation that occurred during low flow conditions. The modification did not affect the overall hydrology calibration as the changes only impact extreme low flow conditions.

Sediment

The purpose of the sediment calibration review and refinement was to ensure that the ZRWHSPF model provides the best representation of sediment processes and loading based on an evaluation of new data and information. The sediment calibration was revisited and modified based on the 2014 United States Geological Survey (USGS) report titled, "Suspended-Sediment Concentrations, Loads, Total Suspended Solids, Turbidity, and Particle-Size Fractions for Selected Rivers in Minnesota, 2007 through 2011" (Ellison et al. 2014), as well as additional data and information provided by USGS and MPCA.

Based on a review of the new data and information, it appeared that the original ZRWHSPF model calibration was underpredicting sediment loading in the Zumbro River watershed. It is likely that the original calibration targets, which were primarily based on estimated TSS concentrations and loads from continuous turbidity measurements, underestimated the sediment loads delivered to the stream network and the watershed outlet. Therefore, the sediment calibration was refined and enhanced to incorporate the new data and information provided in the USGS report (Ellison et al. 2014), as was feasible given the known limitations of the HSPF model.

Complete documentation of the approach used to refine and enhance the sediment calibration is provided in the technical memorandum titled, "Zumbro River Sediment Calibration Evaluation for Potential Refinement: Summary of Approach for Sediment Calibration Refinement and Enhancement" (LimnoTech 2015). Below is a summary of the modifications made to the model and the results of the sediment calibration refinement.

Based on the new data and information available to support the revision of the original sediment calibration, the following refinements and enhancements were identified:

- Adjustments to the upland/landside sediment loading were needed to increase the sediment load transported to the stream network. The revisions would be consistent with the loadings reported in the available literature.
- The sediment trapping efficiency of Lake Zumbro was increased to an annual average target range between ~50-70%. The previous target was 30-40% sediment trapping efficiency. The new

trapping efficiency target range for the model refinement was based on a load estimate analysis (FLUX) performed by MPCA over the 2007-2008 time period where the TSS load estimated at the outflow of the lake was only 35% of the inflow loads.

- The TSS load delivered to the watershed outlet was increased to an annual average target range of 25,149 to 323,038 tons/yr (median 179,000 tons/yr), which was derived based on the USGS report (Ellison et al., 2014). The previous annual target for the original model calibration was 145,500 tons/yr.

To address the modifications listed above, the following revisions were made to the ZRWHSPF model:

- Upland and gully sediment erosion were increased using the KRER (coefficient in soil detachment equation), KSER (coefficient in soil washoff equation), and KGER (coefficient in soil matrix scour equation) parameters.
- Upland and gully sediment erosion parameterization was modified by ecoregion to represent the higher likelihood of erosion in the driftless-blufflands area and the lower likelihood of erosion in the Western Corn Belt Plain (WCBP) area.
- The instream transport of sand particles was enhanced by promoting both erosion and deposition processes with modification to the KSAND and EXPSND parameters (coefficient and exponent, respectively, in the sand load power function equation).
- The fall velocities (W) of silt and clay particles were increased for Lake Zumbro and Rice Lake to promote greater sediment trapping capacity.
- Critical shear stresses for silt and clay scour (TAUCS) and deposition (TAUCD) were modified in all reach segments.

Nutrients and Algae

Nutrient (phosphorus and nitrogen) loading; phytoplankton growth, death, and decay; and nutrient cycling are highly interdependent. A change in watershed loading and/or instream parameterization for one nutrient species may have a significant impact on another individual nutrient species. Sediment and phosphorus are also linked. The transport of phosphorus can occur in dissolved and particulate forms. The forms of particulate phosphorus include phosphorus sorbed by soil particles and organic matter eroded during runoff, and these forms may comprise a major proportion of phosphorus transported from land. As a result of these interdependencies and linkages, additional modifications were necessary to update the calibration of nitrogen and phosphorus following the sediment calibration enhancement and refinement. The following changes were made to the model to refine the nitrogen and phosphorus calibration:

- The rate of nitrification (KTAM20) was reduced;
- Benthic release rates of phosphate (BRPO4) and ammonia (BRTAM) were introduced for Lake Zumbro and Rice Lake;
- The fraction of algal preference for nitrate (ALNPR) was increased; and
- The following parameters related to phytoplankton growth were modified: the temperature below which phytoplankton growth ceases (TALGRL), the concentration of plankton not subject to advection at very low flow (MXSTAY), the outflow at which the concentration of plankton not subject to advection is midway between the low and high flow “stay” concentrations (OREF), and the chlorophyll *a* concentration above which high algal death rate occurs (CLALDH).

Model Performance

The overall model performance for sediment in the current model can be summarized as:

- The current model results for the 1996-2009 simulation period compared to observed data are "as good as" or "better than" the results obtained during the original model calibration and validation exercise.
- The prediction of landside sediment unit area loads (UALs) increased relative to the previous model calibration and validation exercise.
- The prediction of annual TSS loads to Lake Zumbro and at the Zumbro River at Kellogg location (near the watershed outlet) increased relative to the previous model calibration and validation exercise.
- The prediction of TSS trapping in Lake Zumbro increased relative to the previous model calibration and validation exercise.

Area-weighted UALs by land use type are shown in Figure 5 for both the original calibration and the current calibration. Although UALs increased from the original calibration to the current calibration to increase the sediment load transported to the stream network, absolute UALs by land use type remained within literature ranges.

A review of the sediment source apportionment revealed little change between the original calibration and the current calibration. For the entire watershed, bed and bank erosion contribution increased from 39% to 44% while gully/ravine and upland erosion decreased by approximately 2% each. A breakdown of the sediment sources is shown in Table 2.

The average annual suspended sediment load simulated at the Zumbro River at Kellogg location was 250,500 tons/year for the entire simulation period (1996-2009), which is within the revised target range and 64% higher than the 153,000 tons/year simulated in the original calibration. A comparison of annual TSS loading between the original calibration and the current calibration is shown in Table 3 for the South Fork Zumbro River and the Zumbro River at Kellogg location.

The long-term Lake Zumbro sediment trapping efficiency was simulated as 52%, which is within the revised target range of 50-70% and increased from the 33% trapping efficiency simulated in the original calibration. The average annual change in bed depth over the entire simulation period is shown for all reaches in Figure 6 for both the original calibration and the current calibration.

Comparisons of simulated daily average TSS concentrations and observed TSS concentrations from MPCA grab samples and continuous turbidity measurements for the Zumbro River at Kellogg location are shown in Figure 7 (2008 only) for both the original calibration and the current calibration and in Figure 8 (2007-2009) for the current calibration only. The time period for the current calibration evaluation is consistent with the time period used in the original calibration.

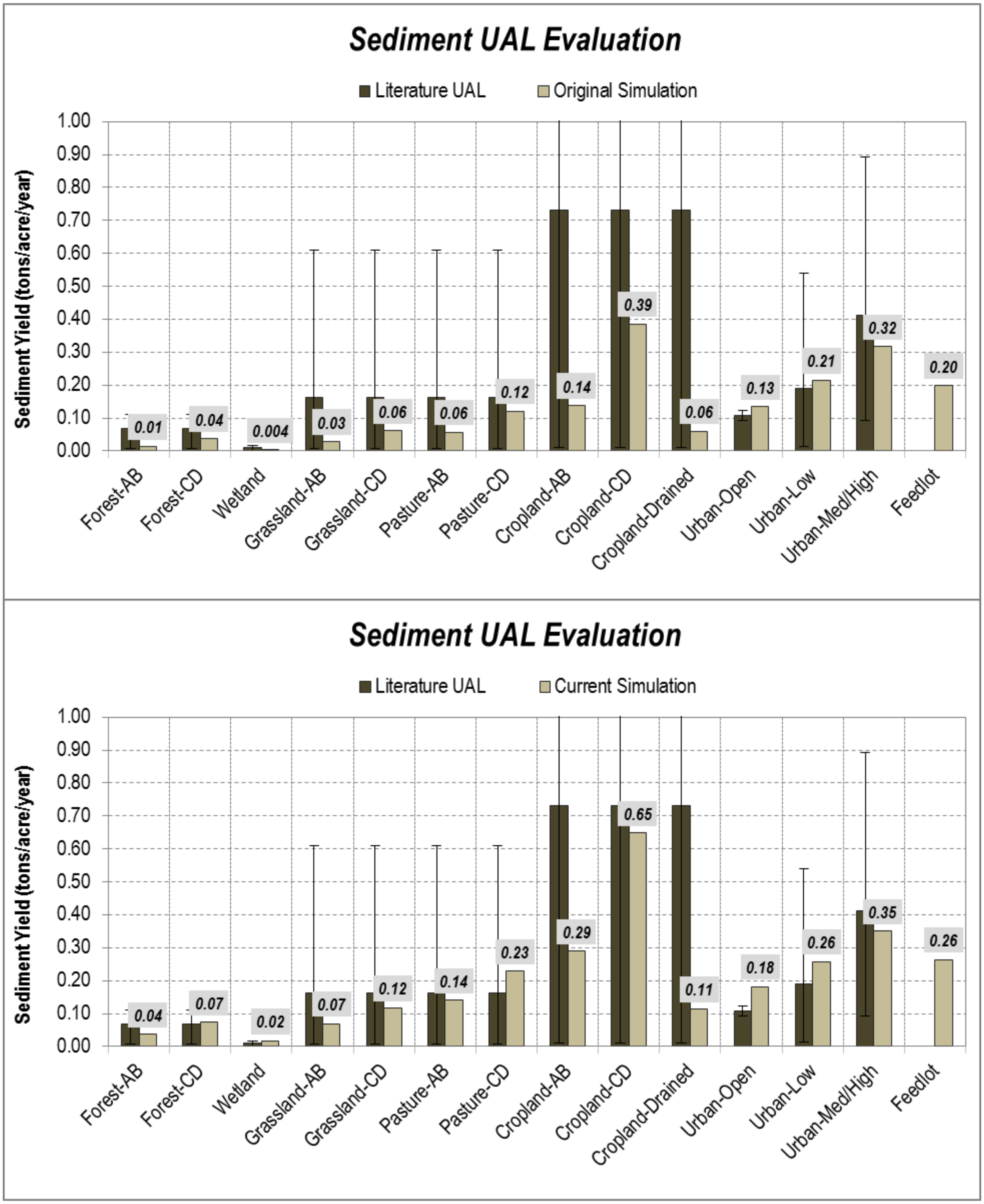


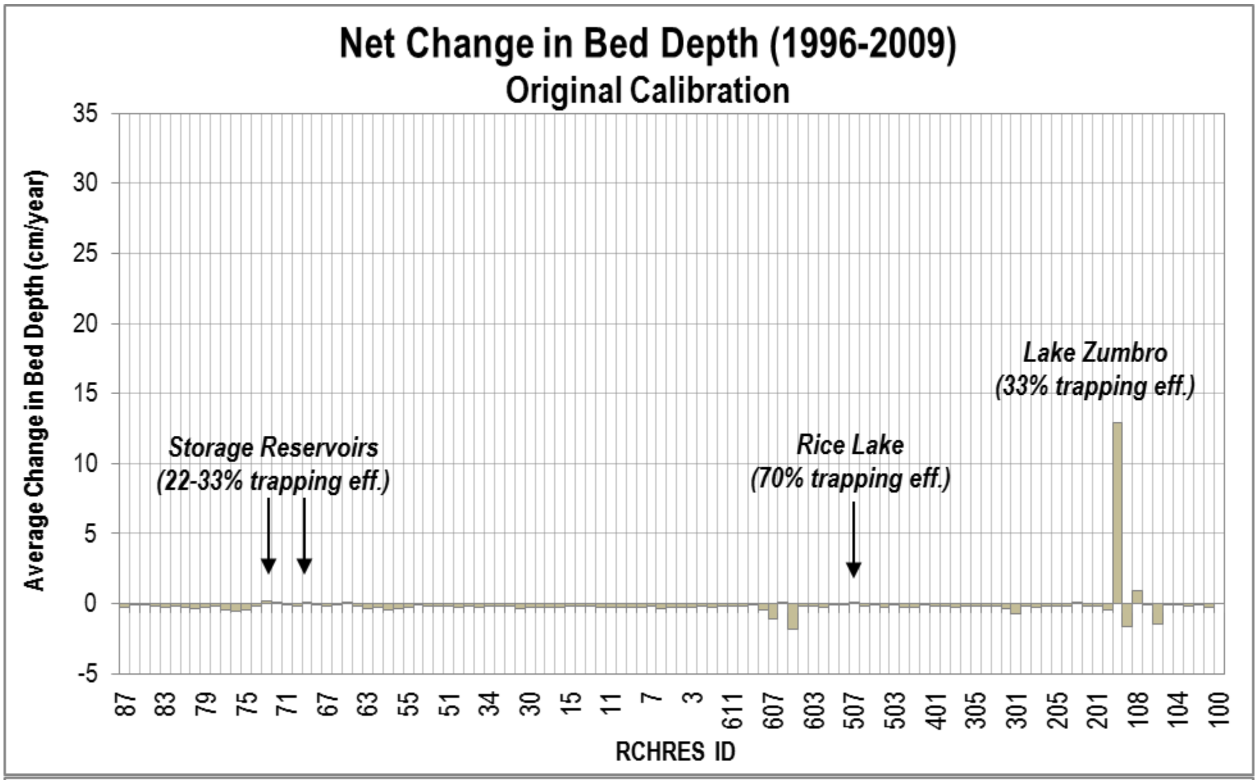
Figure 5. Area-weighted UALs for the ZRWHSPF model by land use type compared to literature averages (error bars represent minimum and maximum) (1996-2009). The top bar chart represents the original calibration, and the bottom chart represents the current calibration.

Table 2. Breakdown of sediment sources by major drainage area and for the entire ZRWHSPF model (1996-2009) for the original calibration and the current calibration.

Original Calibration					
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%
Current Calibration					
Drainage Area	Gully/Ravine	Upland	Tile Drains	Point Sources	Bed/Bank Erosion
South Fork	22%	54%	0.3%	0.2%	24%
Middle Fork	21%	48%	1.0%	0.0%	30%
North Fork	17%	62%	0.3%	0.1%	20%
Mainstem	9%	22%	0.0%	0.0%	69%
Entire Watershed	16%	40%	0.4%	0.1%	44%

Table 3. Comparison of the annual TSS loading (tons/year) between the original calibration and the current calibration.

Year	South Fork Zumbro River (Reach 604)		Zumbro River at Kellogg (Reach 101)	
	Original Calibration	Current Calibration	Original Calibration	Current Calibration
1996	20,500	29,600	62,800	126,500
1997	22,600	26,800	126,300	215,800
1998	13,200	20,200	214,600	382,000
1999	31,800	50,000	128,200	253,200
2000	94,300	158,500	109,800	174,500
2001	109,500	143,300	342,200	481,800
2002	32,100	46,800	167,700	290,900
2003	4,200	5,900	21,800	48,000
2004	71,500	104,500	285,400	406,400
2005	10,200	15,900	66,000	138,800
2006	12,900	21,000	45,100	94,400
2007	122,400	174,500	507,200	749,500
2008	15,000	25,100	56,300	120,400
2009	3,500	4,800	8,300	25,300
AVERAGE	**40,300**	**59,100**	**153,000**	**250,500**



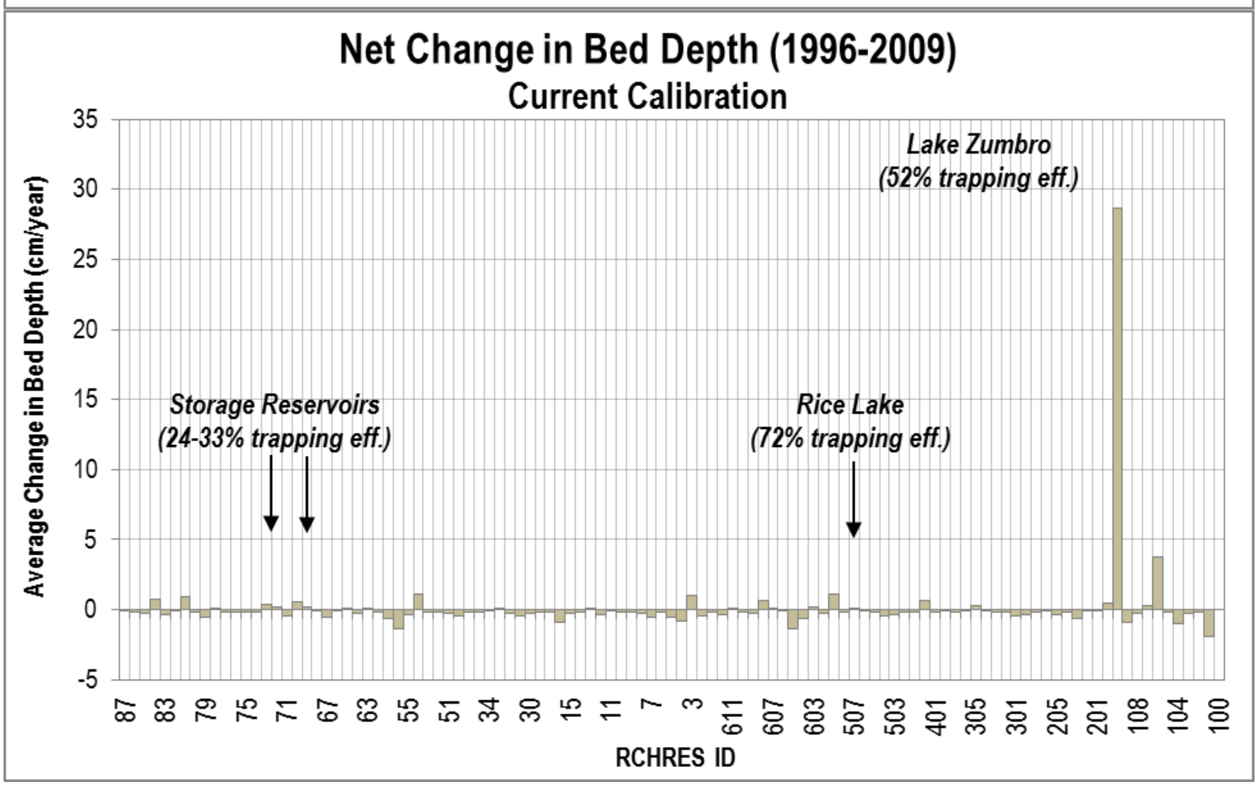


Figure 6. Average annual change in bed depth for all reaches in the ZRWHSPF model (1996-2009). The top bar chart represents the original calibration, and the bottom chart represents the current calibration.

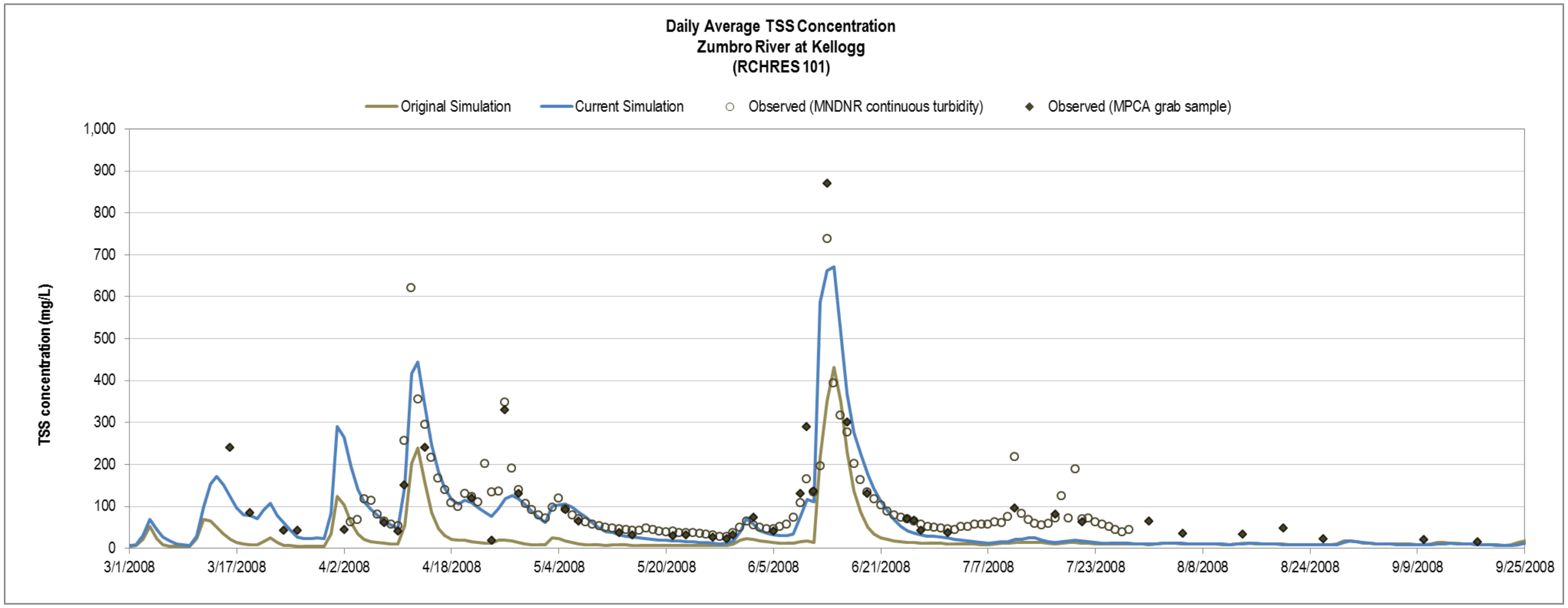


Figure 7. Comparison of the original and current calibration simulation of daily average total suspended solids concentrations for the Zumbro River at Kellogg for 2008.

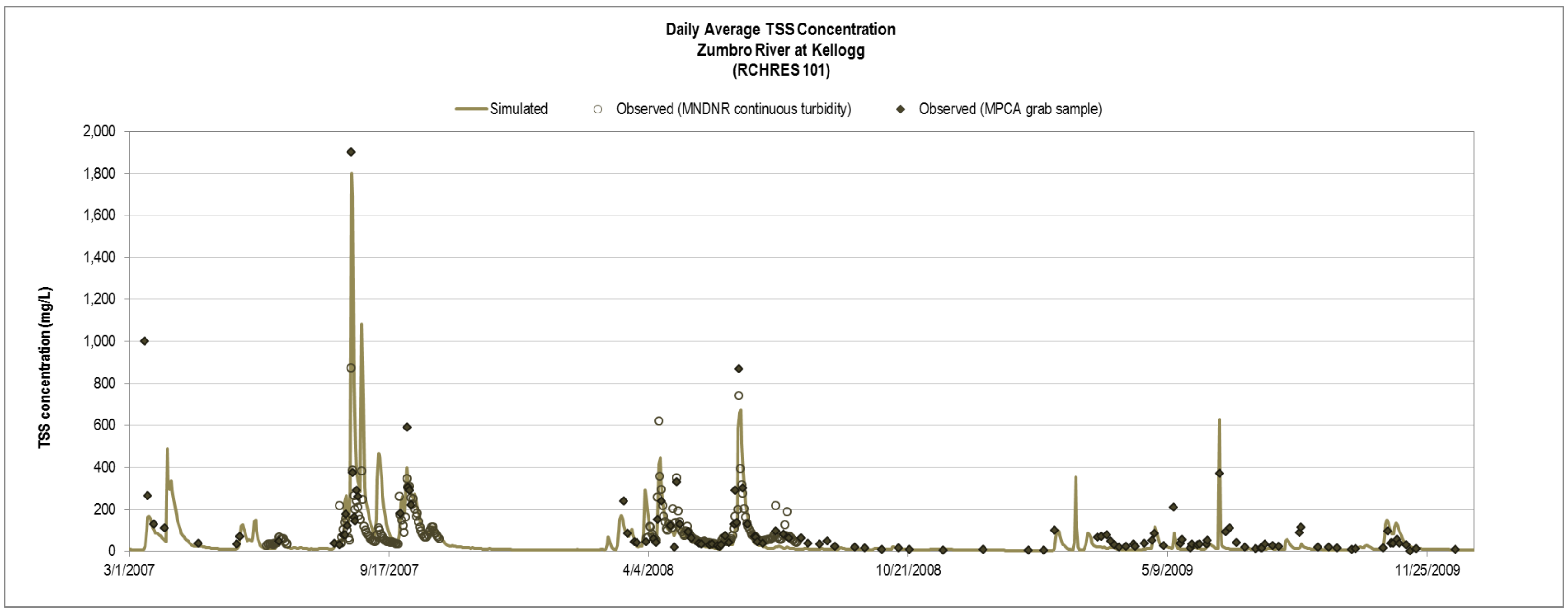


Figure 8. Current model calibration simulation of daily average total suspended solids concentrations for the Zumbro River at Kellogg (2007-2009).

Phosphorus and Nitrogen

The overall model performance of the current model for phosphorus and nitrogen can be summarized as:

- The current model results for the 1996-2009 simulation period compared to observed data are “as good as” or “better than” the results obtained during the previous model calibration and validation exercise.
- The prediction of annual TP loads increased relative to the previous model calibration and validation exercise (62% increase for the Zumbro River at Kellogg).
- The predictions of annual total nitrogen (TN) loads were relatively unchanged compared to the previous model calibration and validation exercise (i.e., less than a 1% decrease for the Zumbro River at Kellogg location).

Comparisons of simulated and observed nutrient concentrations for the Zumbro River at Kellogg are shown in Figure 9 (TP) and Figure 10 (TN) for both the original calibration and current calibration.

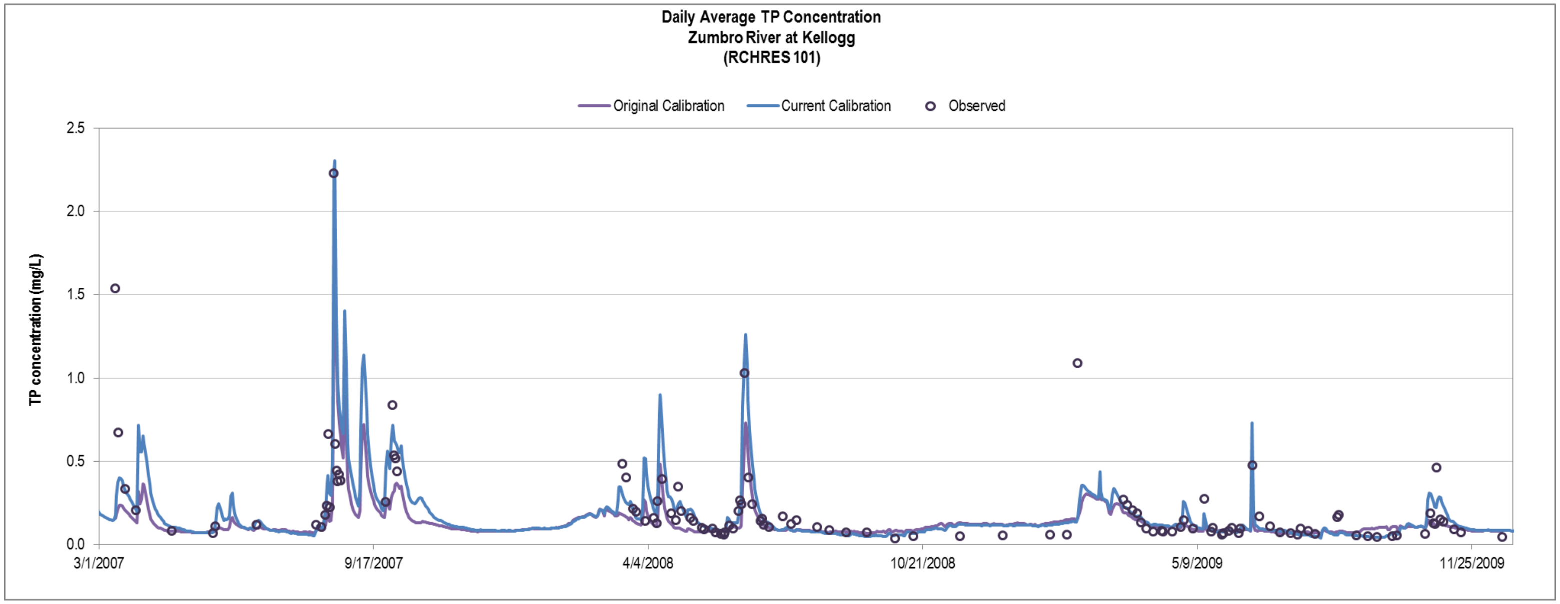


Figure 9. Comparison of the original and current calibration simulation of daily average total phosphorus concentrations for Zumbro River at Kellogg for 2007-2009.

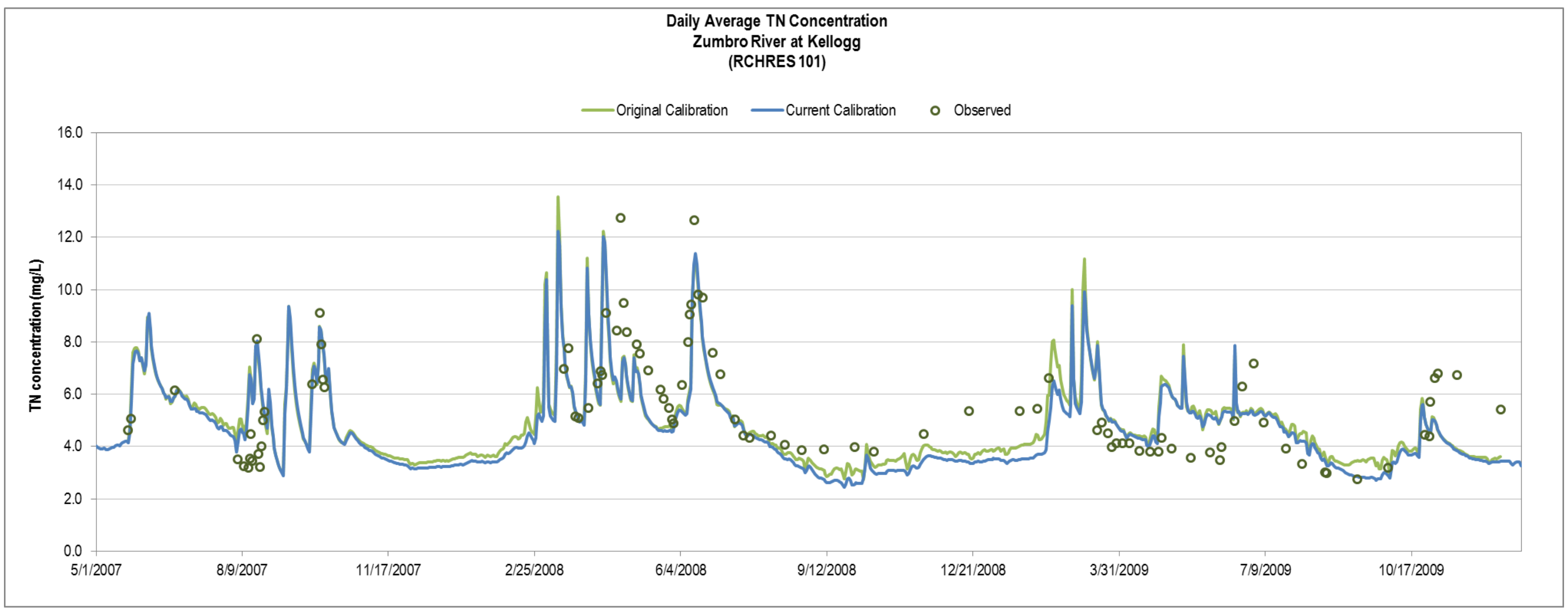


Figure 10. Comparison of the original and current calibration simulation of daily average total nitrogen concentrations for Zumbro River at Kellogg for 2007-2009.

Task 2: Apply the ZRWHSPF Model to Assess Various Management Scenarios

Following the completion of the model development, calibration, and refinement efforts, the next step of the project was to evaluate the potential load reductions from the implementation of management practices or Best Management Practices (BMPs) in the Zumbro River watershed. The sections below describe the application of the ZRWHSPF model to the Zumbro River watershed to evaluate management scenarios.

Management Scenario Descriptions

During the Zumbro Watershed Partnership (ZWP) meeting held on November 20, 2014 in Rochester, Minnesota, watershed stakeholders discussed several potential management or BMP scenarios that could be set-up and run with the ZRWHSPF model. The scope of work for this phase included the simulation of a total of eight (8) scenarios to estimate the effect of potential management practices on sediment and nutrient transport and delivery to local tributaries, Lake Zumbro, and the watershed outlet. A total of 10 scenarios were evaluated. Each scenario was a variation of the "baseline" simulation that is based on the historical conditions for the 1996-2009 time period.

Table 4. List of management scenarios simulated with the ZRWHSPF model

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

Point sources at permitted limits (A)

A scenario was constructed to evaluate the impact on instream water quality of all point sources discharging at permitted limits of flow rate, minimum DO concentration, TSS load, TP load, ammonia load, and/or BOD load. This scenario provides an upper bound on of the impacts of point sources on instream water quality in the watershed. There were several instances where a facility did not have a permit limit for a given constituent. For example, only four (4) facilities in the Zumbro River watershed had ammonia limits and zero (0) facilities had nitrate limits. In these cases, the loading time series from the baseline model was used.

Point sources at RES and 70% AWWDF (B)

A second point source scenario was constructed to serve as a lower bound to complement the first point source scenario. This scenario evaluated the impact on instream water quality of point sources discharging at a flow rate equal to 70% of the average wet weather design flow (AWWDF) and TP concentrations at proposed river eutrophication standards (RES). The effluent TP concentrations simulated under the RES ranged from 0.10 to 0.15 mg P/L, depending on the receiving stream the point source discharges to, and were applied from June 1 to September 30. The effluent TP concentration for Rochester WWTP was simulated at 0.125 mg P/L. For the remainder of the year (October 1 to May 31), the loading time series from the baseline model were applied. There are four (4) facilities that use stabilization ponds in the Zumbro River watershed. For these facilities, discharge was assumed to occur during June 1-15 and September 15-30.

Point sources at 0.40 or 0.50 mg P/L and 70% AWWDF (C)

Based on the results of point source scenario A and B, the MPCA defined a third point source scenario was constructed to investigate the effects of setting effluent TP concentrations above the proposed RES but below permitted limits for the June 1 to September 30 time period for a select group of point sources. The effluent TP concentrations for the Byron, Dodge Center, Kasson, Mantorville, and Pine Island WWTPs were simulated at 0.50 mg P/L. The effluent TP concentration for Rochester WWTP was simulated at 0.40 mg P/L. For the October 1 to May 31 time period, the loading time series from the baseline model was used for these facilities. The flow rate for these facilities was set to 70% of the AWWDF for the entire year. The flow rate and loading time series from the baseline model simulation were applied for all other facilities.

Conservation tillage (D)

Practices that increase soil organic matter and provide surface cover will tend to increase the volume of water infiltration into the soil, which serves to reduce surface runoff and sediment erosion as well as to improve the health of the soil. On farm fields, the implementation of reduced tillage operations is a potential method of accomplishing an increase in soil organic matter (ZWP 2012). A scenario was constructed to reflect conservation tillage management practices applied to 30% of the cropland acres with the highest sediment yields. The selection of the highest sediment yielding cropland land segments for conservation tillage implementation was based on the ZRWHSPF model baseline landscape predictions.

The effects of changing from more intensive tillage operations (i.e., conventional, reduced, etc.) where residue cover ranges from 0 to <30% to conservation tillage operations where residue cover ranges from >30% were simulated in the model by modifying several hydrology and sediment related parameters that best translated to the real-world physical representation of managing soil residue and soil organic matter. The parameter adjustments included increasing the nominal upper zone soil moisture storage capacity (UZSN); monthly values of interception storage (MON-INTERCEP) and monthly values of the soil cover factor (MON-COVER); and decreasing the coefficients in the equations that simulate soil washoff (KSER) and gully erosion (KGER). The degree of adjustment for these parameters was determined by two criteria: (1) parameters were only adjusted by an amount that was reasonable relative to values for other land uses – for example, the soil cover factor was increased but no higher than values for forest or grassland, and (2) parameters were adjusted until the edge-of-field runoff, sediment and TP reductions relative to the baseline scenario were generally in agreement with values reported in literature or guidance manuals for BMPs. The Agricultural BMP Handbook for Minnesota provided the primary source of information with reported reduction efficiencies of 50 – 96% for sediment and 55 – 91% for TP (Miller et al. 2012). It is important to note that the reported reduction efficiencies represent load reduction from the land and not the load delivered to a stream.

Green infrastructure – 5% Implementation (E)

The first of two (2) green infrastructure scenarios assumed a range of practices would be applied to 5% of all developed areas in the Zumbro River watershed. The top sediment yielding developed land segments were targeted for green infrastructure implementation. Although different practices were not explicitly modeled, this scenario implicitly represented green roofs, porous pavement, bioretention, filtration-type, infiltration-type, swales, detention basins, and retention basins/stormwater wetlands by considering the range of sediment and nutrient removals accomplished by various practices (Simpson and Weammert 2009). An overall removal efficiency for sediment, nitrogen, and phosphorus was then determined by weighting the individual removal efficiencies based on the assumed area of implementation out of the total area of implementation (5% of the developed area in this instance, Table 5). The green infrastructure practices were represented in the model using the BMPRAC module. This module simulates the effects of BMPs by applying removal fractions to runoff and pollutant loading time series from pervious and impervious land segments before routing to the receiving stream segments. Constant removal fractions were used for flow and all constituents.

Green infrastructure – 25% Implementation (F)

The second green infrastructure scenario assumed practices would be applied to 25% of all developed areas in the Zumbro River watershed. The top sediment yielding land segments were targeted for green infrastructure implementation. The same overall removal efficiencies applied in the 5% green infrastructure scenario were used in this scenario, assuming the same proportion of various green infrastructure practices would be scaled up to treat the larger area (Table 5).

Table 5. Green infrastructure removal efficiencies and assumed fractions of implementation for individual green infrastructure types used to compute an overall, weighted efficiency for each constituent.

Green Infrastructure Type	Removal Efficiency (%)			Assumed Implementation (%) for Scenario E	Assumed Implementation (%) for Scenario F
	TN	TP	TSS		
Green Roof	43	45	31	0.25	1.25
Porous Pavement	47	50	70	0.25	1.25
Bioretention	58	68	75	1.0	5.0
Filtration Type	40	60	80	0.5	2.5
Infiltration Type	80	85	95	0.5	2.5
Bioswale	10	10	50	0.5	2.5
Retention Pond	20	45	60	1.0	5.0
Detention Basin	20	20	60	1.0	5.0
OVERALL	**37**	**47**	**67**	**5.0**	**25.0**

Pre-settlement vegetation (G)

A scenario was constructed to provide insight on sediment and nutrient loadings under pre-settlement conditions compared to current day conditions. The Minnesota Department of Natural Resources (MNDNR) maintains a digital version of a state map, originally created by Francis J. Marschner, that maps Minnesota's vegetation at the time of European settlement. The assumptions in this scenario included pre-settlement vegetation, no point sources, and pre-settlement atmospheric deposition of nitrogen. In this scenario, because it is a pre-settlement condition, agricultural or developed land does not exist. A pre-settlement atmospheric nitrogen deposition rate of approximately 0.50 kg-N/ha/year was applied in this scenario assuming the same proportions of dry/wet ammonia/nitrate as represented in the baseline model. The 0.50 kg-N/ha/year rate originates from a joint National Park Service (NPS) and U.S.

Fish and Wildlife Service (USFWS) effort to develop deposition analysis thresholds (FLAG 2002). This pre-settlement atmospheric nitrogen deposition rate represents over a 95% reduction from the rate in the baseline model (approximately 20 kg-N/ha/yr). The reservoirs remained unchanged from the baseline in the model to represent more realistic, present-day hydrologic conditions.

Cover crops (H)

A scenario was constructed that applied cover crops to a portion of the cropland acres for every simulation year. This scenario assumed a cereal rye cover crop planted in the fall when crops are typically harvested. Cover crops were implemented on 30% of the cropland acres in the watershed. The areas where cover crops were implemented in the model were based on a comprehensive evaluation of the following three elements:

1. Identification of high sediment and phosphorus yielding cropland land segments based on the ZRWHSPF model baseline landscape predictions;
2. Identification of sensitive groundwater areas; and
3. Location of tiled lands in the watershed.

The effects of cover crops were represented in the model by modifying several hydrology, sediment, and nitrogen related parameters that best translated to the real-world physical representation of adding a vegetative cover to formerly bare soil during winter and spring months. Parameter adjustments included increasing monthly values of interception storage (MON-INTERCEP), nominal upper zone soil moisture storage capacity (MON-UZSN), the index to lower zone evapotranspiration (MON-LZETPARM), and the soil cover factor (MON-COVER). The monthly nitrate concentrations in interflow (MON-IFLW-CONC) and groundwater (MON-GRND-CONC), and the coefficients in the equations that simulate soil washoff (KSER) and gully erosion (KGER) were decreased as part of this scenario to represent cover crops scavenging soil nitrogen and reducing soil erosion processes, respectively.

Parameters were adjusted until the edge-of-field sediment reductions relative to the baseline scenario were generally in agreement with values reported in literature or guidance manuals for BMPs. The Agricultural BMP Handbook for Minnesota provided the primary source of information with reported reduction efficiencies of <1 - 70% for sediment, <1 – 67% for TP, and 16 – 66% for TN (Miller et al. 2012). It is important to note that the reported reduction efficiencies represent load reduction from the land and not the load delivered to a stream. The reduction efficiency values that served as general targets were also consistent with HSPF cover crop scenario applications in other Minnesota watersheds (RESPEC 2014). However, it should be noted that Miller et al. (2012) acknowledge that while sediment erosion and phosphorus reductions commonly occur with the implementation of cover crops, there is a lack of research data in Minnesota and the upper Midwest to quantify this reduction.

Sedimentation Ponds (I)

A scenario was constructed to represent the addition of sediment basins and grade stabilization structures (hereafter referred to as ponds) in the Zumbro River watershed. The ponds serve to reduce peak flows and sediment and nutrient loading. The location selection for the addition of new ponds was based on the ZRWHSPF model baseline landscape predictions in conjunction with the critical source areas identified in the Zumbro River Watershed Restoration Prioritization study (L. Svien and P. Wotzka personal communication, ZWP 2014). Some general assumptions, based on the typical characteristics of the ponds in the watershed, were needed for this scenario. The ponds were represented in the model to be consistent with the edge-of-field ponds currently designed for implementation in the watershed by the Soil Water Conservation Districts (SWCDs). The ponds were represented as “dry ponds” (B. Kennedy and M. Kruger personal communication) and designed to capture the approximate 10-year, 24-hour rain event (B.

Kennedy personal communication). A “dry pond” for this scenario is defined as a pond that is not designed to hold water for more than 24 hours.

The existing inventory of pond structures and their respective drainage areas were used in selecting locations for the new ponds (i.e., new ponds were not added to locations where a pond already exists and is treating X acres of land). The ponds were placed in the model subbasins with the highest cropland sediment yields, and they collectively capture runoff from approximately 30% of all cropland acres in the watershed.

Ponds were represented in the model by adding new reach segments (RCHRES). The reach geometry, which is defined with an FTABLE, was constructed to mimic the water storage and peak flow reduction that results from the implementation of a new pond. As noted above, the ponds were represented as “dry ponds” or detention basins, which remain dry except during or shortly after a rain or snowmelt event. The FTABLEs were constructed to approximately capture the runoff from a 10-year, 24-hour rain event (4.37 inches). Flow from land segments was routed to the new RCHRES in the SCHEMATIC block of the model before being routed to the receiving reach segment from the baseline scenario.

Combined management scenario (J)

To understand the benefits of implementing multiple BMPs, for both point and nonpoint sources, a scenario was constructed that combined the following actions represented in scenarios C, H and I:

- Point source effluent set at 0.40 or 0.50 mg-P/L and 70% of average wet weather design flow (see scenario C);
- Cover crops applied to 30% of cropland acres (see scenario H); and
- Retention basins capturing runoff from 30% of cropland acres (see scenario I).

Assumptions were the same in this scenario as described above for the individual scenarios with respect to which point sources were modified, the locations of cropland acres receiving treatment, and the representation of the new ponds in the model.

Management Scenario Results

The ZRWHSPF model is a tool that can be used to help determine the most effective land management practices at target locations to maximize sediment and nutrient load reduction and conservation benefits in the Zumbro River watershed. Location within the watershed, land and soil properties, and existing land uses and practices all factor into prioritizing management practices that will maximize water quality and ecosystem benefits.

The quantification of sediment and nutrient load reductions for a given management practice is accomplished by comparing a “baseline” run with a “scenario” run and assessing the relative change(s) between the simulations. The two types of ZRWHSPF model runs are described below:

- The “**baseline**” run represents existing conditions in the watershed for the 1996 through 2009 time period. The run includes historical climate and hydrology conditions and sediment and nutrient sources (atmospheric deposition, point sources, nonpoint sources), and it accounts for the best available estimates of land uses and activities in the watershed.
- A “**scenario**” run represents the implementation of specific BMPs and/or management practices under historical climate and hydrology conditions for the 1996 through 2009 time period.

The analysis of the scenario results consists of the following steps:

1. Define an accurate and appropriate baseline condition for the watershed;

2. Simulate the baseline condition;
3. Define the scenarios;
4. Make changes to model inputs, parameters, and/or configuration to represent a given scenario;
5. Simulate the scenario conditions; and
6. Compare the model results from the baseline and scenario simulations to quantify the difference in local sediment and nutrient local yields (in terms of UALs) and loads delivered to the outlet (in terms of mass per year).

The management scenario results are summarized in the sections below. For the evaluation of the scenarios relative to one another, it is important to consider and keep in mind the "level of implementation" for each scenario in regard to the estimated load reduction reported for each scenario. The specified level of implementation is not the same across the scenarios and varies from 5% to 30% of specific targeted land areas (e.g., developed or agricultural).

Given the different levels of implementation, the comparison of the scenarios is not absolute but instead provides a relative comparison. The level of implementation for each scenario must be taken into consideration when using the information for making management decisions.

For reference, the management actions considered for each scenario are listed below, along with the prescribed "level of implementation":

A. Point sources at permitted limits, 100% implementation

B. Point sources at RES and 70% AWWDF, 100% implementation

C. Point sources 0.50 mg P/L and 70% AWWDF for Byron, Dodge Center, Kasson, Mantorville, Pine Island and at 0.40 and 70% AWWDF for Rochester.

D. Conservation tillage, 30% of cropland acres

E. Green infrastructure, 5% of developed land

F. Green infrastructure, 25% of developed land

G. Pre-settlement vegetation, entire watershed

H. Cover crops, 30% of cropland acres

I. Sedimentation Ponds, 30% of cropland acres

J. Combination of point source, cover crop, and retention basin scenario (C, H and I), set at the same implementation levels listed above

Sediment

A comparison of sediment yields and loading for the baseline run and the various management scenarios on an annual average basis over the simulation period (1996-2009) is provided in Tables 6-7 and Figures 11-12 below. Sediment yield refers to sediment loading on a mass per area basis (in tons/acre/yr) from the landscape. Sediment loading refers to the amount of sediment that is delivered to the watershed outlet and Lake Zumbro (in tons/yr). The relative load change is calculated as the annual average scenario load minus the baseline load, divided by the baseline load at the watershed outlet and Lake Zumbro.

For the baseline run, the model calculated an annual average sediment load of 266,264 tons/yr at the watershed outlet and 174,380 tons/yr at Lake Zumbro (Tables 6-7, Figures 11-12). The overall sediment yield calculated for the baseline run was 0.253 tons/acre/yr. The model-estimated annual sediment loading to the watershed outlet and Lake Zumbro for the point source scenarios (A, B, and C) is slightly greater (≤1%) than the baseline run (Tables 6-7, Figures 11-12). The annual sediment load for the point source scenario at the permitted limits (A) is approximately 1% greater than the baseline at the watershed outlet and at Lake Zumbro, which is attributed to permitted effluent flows and/or sediment concentrations that are higher than the baseline. The annual sediment load for the point source scenarios where the effluent flow is set at 70% AWWDF (B and C) is ≤0.4% greater than the baseline at the watershed outlet and at Lake Zumbro, which can be attributed to the 70% AWWDF flows that are higher than the baseline effluent flows.

The green infrastructure implementation scenarios (E and F) resulted in a small reduction of annual sediment loading to the watershed outlet and Lake Zumbro, ranging from ≤1% at the 5% level of implementation to 3% at the 25% level of implementation (Tables 6-7, Figures 11-12). The developed areas (e.g., residential, commercial, industrial, open space, etc.) in the Zumbro River watershed account for 8.9% of the total watershed area. Given the small area of developed land across the watershed, it is not expected that the green infrastructure implementation would result in a substantial sediment load reduction at the watershed outlet or to Lake Zumbro. However, at the more local, tributary scale where developed land cover dominates, reductions in sediment load that result from green infrastructure will likely have a greater water quality benefit.

Conservation tillage practices tend to reduce sediment load because of the increased residue cover that protects soil from erosion. The application of conservation tillage (scenario D) to 30% of the highest sediment yielding cropland acres in the model resulted in an estimated annual sediment load reduction of 14% at the watershed outlet and 25% to Lake Zumbro compared to the baseline run. The use of cover crops serves to reduce soil erosion by increasing both the canopy cover and the amount of residue left on the soil surface at post-harvest. The application of cover crops (scenario H) to 30% of the cropland acres in the model resulted in an estimated annual sediment load reduction of 12% at the watershed outlet and 21% at Lake Zumbro compared to the baseline run (Tables 6-7, Figures 11-12). As described earlier, the location of cover crop implementation was based on three elements and included the identification of high sediment and phosphorus yielding cropland acres; the identification of sensitive groundwater areas; and the location of tiled lands in the watershed. The locations of cover crop implementation were similar to the locations of conservation tillage implementation with some overlap; however, not all locations were the same between the two scenarios.

The sedimentation ponds (scenario I) were set up in the model to treat surface runoff from 30% of the cropland acres in the watershed that were not already being treated by a pond. The location of the ponds in this scenario was based on the existing inventory of pond structures and their respective drainage areas were used in selecting locations for the new ponds (i.e., new ponds were not added to locations where a pond already exists). The ponds were then placed in the model subbasins with the highest cropland sediment yields per the baseline model predictions. This location selection strategy resulted in most of the ponds being placed upstream of Lake Zumbro. The results of the sedimentation pond scenario indicate a reduction in annual sediment loading of 8% relative to the baseline at the watershed outlet. The estimated annual sediment load reduction at Lake Zumbro is 18% relative to the baseline. The level of annual sediment load reduction for this scenario is much higher at Lake Zumbro compared to the watershed outlet because the majority of new treatment ponds were added upstream of Lake Zumbro, as noted above. The reduction in peak flows, the detention of surface runoff, and subsequent settling of solids in the ponds resulted in lower sediment loading for this scenario compared to the baseline.

The combined management scenario (J) involved the application of conservation tillage practices, cover crops, and point source effluent discharge modification (scenarios C+H+I). The application of multiple management practices does not result in an additive load reduction or water quality benefit. In general, the highest level of pollutant reduction occurs with the implementation of the first BMP, with each successive BMP becoming less effective (MPCA 2015). Typically, each successive BMP (e.g., the second, third, fourth, etc.) in a treatment train or successive management practice is receiving runoff that has considerably less volume and concentration of pollutants (MPCA 2015). This means there is less load that can be reduced and a point may be reached where flow volume or concentration cannot be reduced further by a given BMP or management practice (MPCA 2015). However, as indicated by the model results, there is an additional benefit to applying multiple management practices. The annual sediment load reduction estimated is 17% at the watershed outlet and 32% at Lake Zumbro (Tables 6-7, Figures 11-12). The model results indicate that the combined management scenario provides the greatest overall sediment load reduction with the exception of the pre-settlement vegetation scenario discussed below.

The pre-settlement vegetation scenario (G) results serve as an indicator of the extent to which historical land use changes have affected sediment erosion in the Zumbro River watershed. The results of the pre-settlement vegetation scenario suggest a sediment yield of 0.075 tons/acre/yr under the pre-settlement conditions, which is approximately three-fold lower than the baseline yield of 0.35 tons/acre/yr (Tables 6-7, Figures 11-12). The pre-settlement vegetation sediment yield (0.075 tons/acre/yr) estimated by the model is consistent with the range of unit area sediment loading rates reported in the literature for forested landscape (0.01 – 0.11 tons/acre/yr) (CH2M Hill and AQUA TERRA 2002; Lin 2004). The model-estimated annual sediment loading to the watershed outlet and to Lake Zumbro is 56% and 62% less for the pre-settlement vegetation scenario, respectively, as compared to the baseline run. The results of this scenario indicate the conversion of natural landscape to agriculture and developed land uses in the watershed has significantly increased sediment loading in the Zumbro River watershed.

Sediment landscape yield scenario maps are provided in Appendix A.

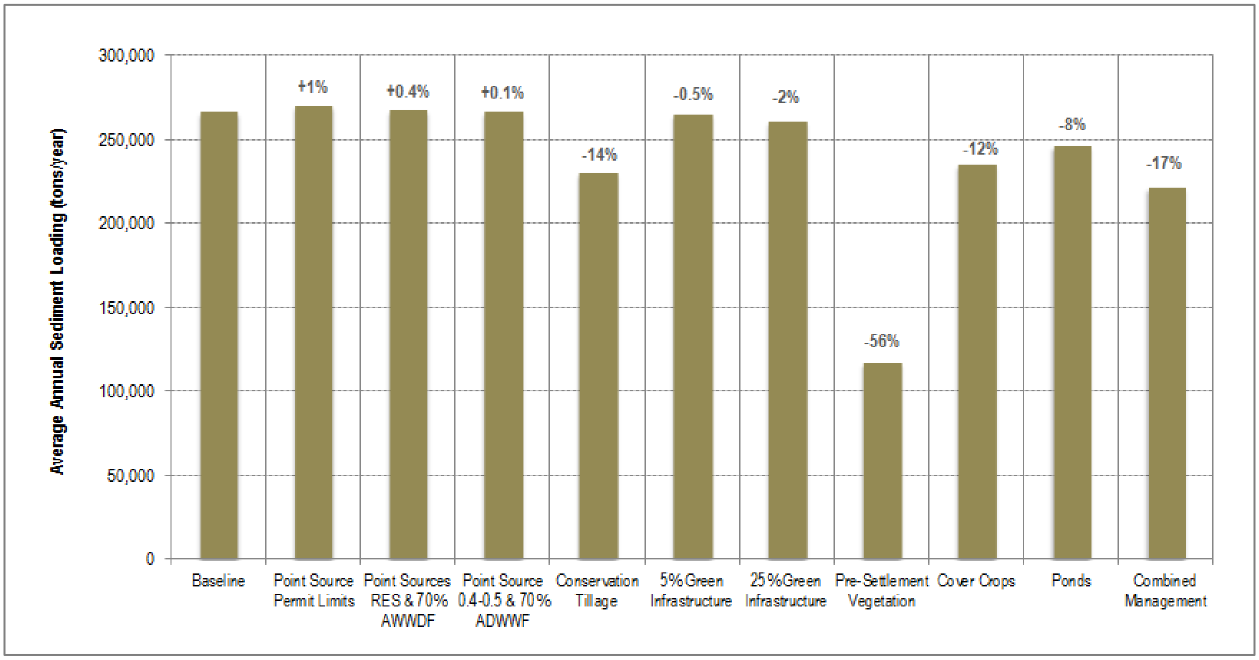


Figure 11. Annual average simulated total sediment loading at the Zumbro River watershed outlet for the baseline run and management scenarios (1996 – 2009).

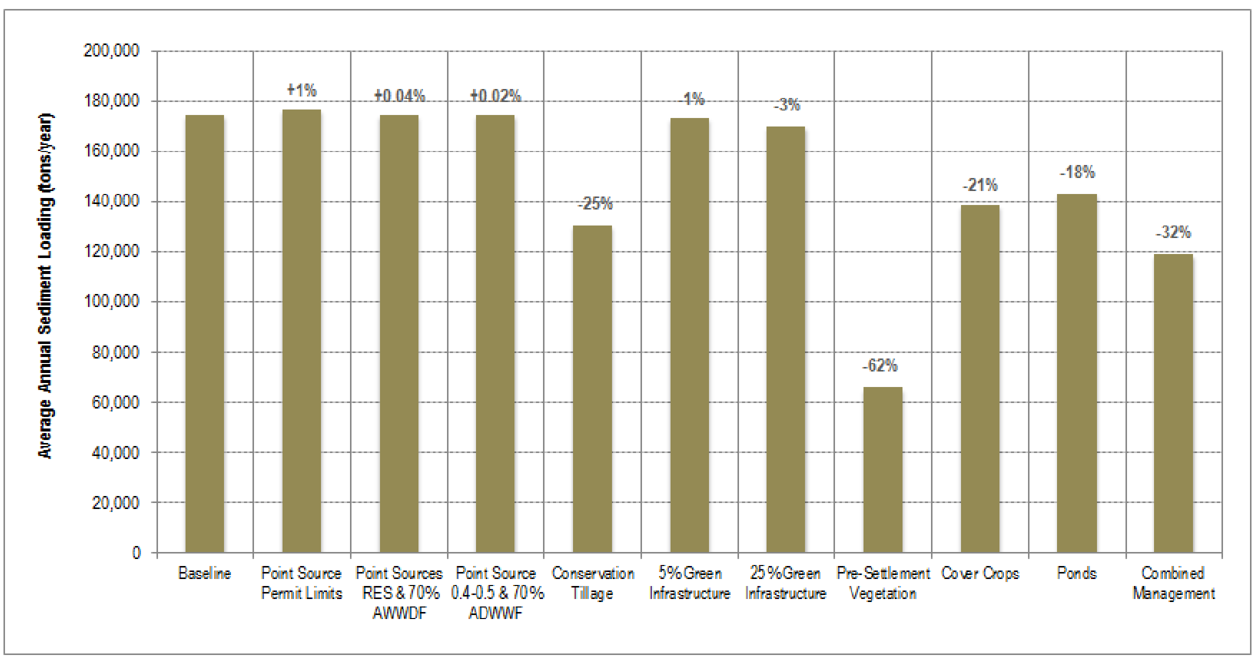


Figure 12. Annual average simulated sediment loading to Lake Zumbro for the baseline run and management scenarios (1996 – 2009).

Table 6. Summary of simulated sediment yields and loading at the Zumbro River watershed outlet for the baseline and management scenarios (1996-2009).

Scenario ID	Scenario Description	Sediment Yield (tons/acre/yr)[a]	Sediment Loading (tons/yr)[a]	Relative Sediment Loading Change
-	Baseline	0.253	266,264	-
A	Point Sources at Permitted Limits	0.253[b]	269,887	+1%
B	Point Sources at RES & 70% AWWDF	0.253[b]	267,296	+0.4%
C	Select Point Sources at 0.4-0.5 mg P/L & 70% AWWDF	0.253[b]	266,577	+0.1%
D	Conservation Tillage	0.189	230,243	-14%
E	Green Infrastructure - 5% Implementation	0.252	264,978	-0.5%
F	Green Infrastructure - 25% Implementation	0.248	260,740	-2%
G	Pre-Settlement Vegetation	0.075	116,794	-56%
H	Cover Crop	0.205	235,187	-12%
I	Sedimentation Ponds	0.200	246,275	-8%
J	Combined Management	0.171	221,476	-17%

[a]*Tons are in English tons. The yield represents a watershed-wide weighted average yield.*

[b]*Sediment yields represent the landside or landscape sediment loading; therefore, the sediment yield for the point source scenarios are the same as the baseline.*

Table 7. Summary of simulated sediment yields and loading to Lake Zumbro for the baseline and management scenarios (1996-2009).

Scenario ID	Scenario Description	Sediment Loading (tons/yr)[a]	Relative Sediment Loading Change
-	Baseline	174,380	-
A	Point Sources at Permitted Limits	176,467	+1%
B	Point Sources at RES & 70% AWWDF	174,441	+0.04%
C	Select Point Sources at 0.4-0.5 mg P/L & 70% AWWDF	174,410	+0.02%
D	Conservation Tillage	130,313	-25%
E	Green Infrastructure - 5% Implementation	173,065	-1%
F	Green Infrastructure - 25% Implementation	169,789	-3%
G	Pre-Settlement Vegetation	65,657	-62%
H	Cover Crop	138,547	-21%
I	Sedimentation Ponds	142,924	-18%
J	Combined Management	118,769	-32%

[a]*Tons are in English tons*

Phosphorus

A comparison of phosphorus yields and loading (TP and orthophosphate (PO4)) for the baseline run and the various management scenarios on an annual average basis over the simulation period (1996-2009) is provided in Tables 8-9 and Figures 13-14 below. Phosphorus yield refers to phosphorus loading on a mass per area basis (in lbs/acre/yr) from the landscape. Phosphorus loading refers to the amount of phosphorus that is delivered to the watershed outlet and to Lake Zumbro (in lbs/yr). The relative load change is calculated as the annual average scenario load minus the baseline load, divided by the baseline load at the watershed outlet and Lake Zumbro. The scenario results described below focus on TP; however, the relative change in load between the baseline run and the scenarios for orthophosphate is, in general, consistent with the TP results. As noted above, the transport of phosphorus can occur in dissolved and particulate forms. The forms of particulate phosphorus include phosphorus sorbed by soil particles and organic matter eroded during runoff and may comprise a major proportion of phosphorus transported from land, which is the case in the Zumbro River watershed.

For the baseline scenario, the model calculated annual average TP loads of 1,066,650 lbs/yr at the watershed outlet and 596,738 lbs/yr to Lake Zumbro. The TP yield calculated for the baseline run was 0.73 lbs/acre/yr. For the point source scenario set at the permitted effluent flow and constituent limits (A), the model-estimated annual TP loading to the watershed outlet and to Lake Zumbro is 6% and 11% greater, respectively, than the baseline run (Tables 8-9, Figures 13-14). The increase in the TP load is attributed to higher effluent flows and/or TP concentrations specified in the permitted limits compared to the effluent flows and TP concentrations in the baseline run, which reflects historical effluent discharges based on reported measurements.

The point source scenario where the effluent flow is set at 70% AWWDF and TP concentrations are set at the RES (B), the TP load reduction is 1% at the watershed outlet and 2% at Lake Zumbro (Tables 8-9, Figures 13-14). The decrease in TP load can be attributed to the lower TP concentrations specified by the RES. It is important to note that while the TP concentrations are lower in this scenario, the effluent flow is set at 70% AWWDF, which is higher than the baseline. The point source scenario where the effluent flow is set at 70% AWWDF and TP concentrations are set at 0.5 mg P/L for the Byron, Dodge Center, Kasson, Mantorville, and Pine Island WWTPs and 0.4 mg P/L for the Rochester WWTP (C), the TP load reduction is 0.2% at the watershed outlet and 1% at Lake Zumbro (Tables 8-9, Figures 13-14). The TP load reduction in this scenario is less than for the RES scenario (B) and is attributable to the effluent flow and TP concentrations set at the baseline for the other point sources. It should be noted that the low flow summer periods (i.e., June - September) will have different percent reductions from the annual percent reductions described above.

Similar to sediment, the green infrastructure implementation scenarios (E and F) resulted in a small reduction of annual TP loading to the watershed outlet and to Lake Zumbro, ranging from ≤1% at the 5% level of implementation to 2% at the 25% level of implementation (Tables 8-9, Figures 13-14). As with sediment it was not expected that the green infrastructure implementation would result in a substantial TP load reduction at the watershed outlet or to Lake Zumbro given the small area of developed land across the watershed. However, as with sediment, greater water quality benefits would be expected at the local, tributary scale where developed land cover dominates.

The application of conservation tillage (scenario D) to 30% of the highest sediment yielding cropland acres in the model resulted in an estimated annual TP load reduction of 13% at the watershed outlet and 22% at Lake Zumbro compared to the baseline run (Tables 8-9, Figures 13-14). The application of cover crops (scenario H) to 30% of the cropland acres in the model resulted in an estimated annual TP load reduction of 11% at the watershed outlet and 18% at Lake Zumbro compared to the baseline run (Tables 8-9, Figures 13-14). The results of the sedimentation pond scenario (I) indicate a reduction in annual TP loading of 6% at the watershed outlet and 12% at Lake Zumbro relative to the baseline (Tables 8-9, Figures 13-14). Similar to sediment, the higher level of reduction at Lake Zumbro compared to the watershed outlet for this scenario can be attributed to the majority of new treatment ponds being added upstream of Lake Zumbro. Since TP is primarily transported via surface runoff, the reduction in TP loading is consistent with the capture and "treatment" of surface runoff simulated in the detention pond scenario as compared to no "treatment" in the baseline run.

For the combined management scenario (J), the annual TP load reduction estimated is 15% at the watershed outlet and 26% at Lake Zumbro (Tables 8-9, Figures 13-14). As with sediment, the combined management scenario is estimated to provide the greatest overall load reduction with the exception of the pre-settlement vegetation scenario discussed below.

The pre-settlement vegetation scenario (G) provides a pre-settlement reference for the TP loading rates in the Zumbro River watershed. The pre-settlement loading rate of TP is 0.062 lb/acre/yr, which is approximately eleven-fold lower than the baseline run of 0.730 lbs/acre/yr (Tables 8-9, Figures 13-14). The pre-settlement vegetation TP yield (0. 062 lbs/acre/yr) estimated by the model is consistent with the range of unit area TP loading rates reported in the literature for forested landscape across the US (0.012 – 0.178 lbs/acre/yr) (CH2M Hill and AQUA TERRA 2002). Under pre-settlement vegetation conditions, the estimated annual TP loading at the watershed outlet is approximately 69% lower at the watershed outlet and 81% lower at Lake Zumbro when compared to the baseline scenario (Tables 8-9, Figures 13-14). The results of this scenario indicate the conversion of natural landscape to agriculture and developed land uses in the watershed has significantly increased the phosphorus sources and loading in the Zumbro River watershed.

Phosphorus landscape yield scenario maps are provided in Appendix B.

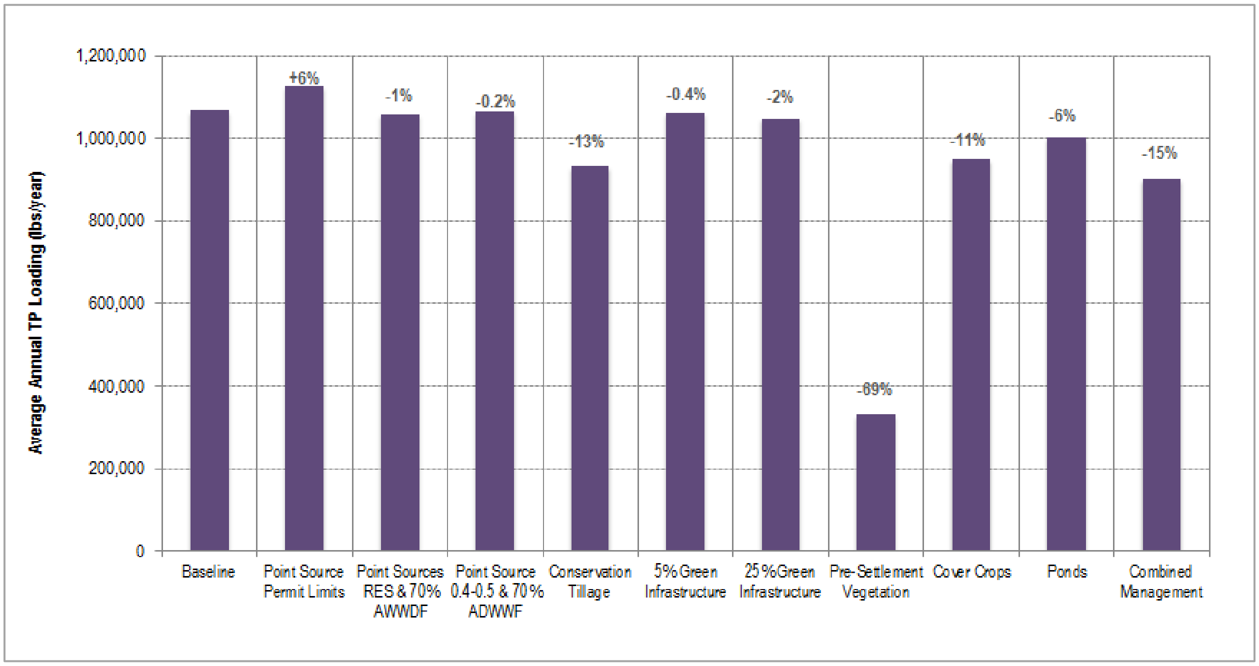


Figure 13. Annual average simulated total phosphorus loading at the Zumbro River watershed outlet for the baseline run and management scenarios (1996 – 2009).

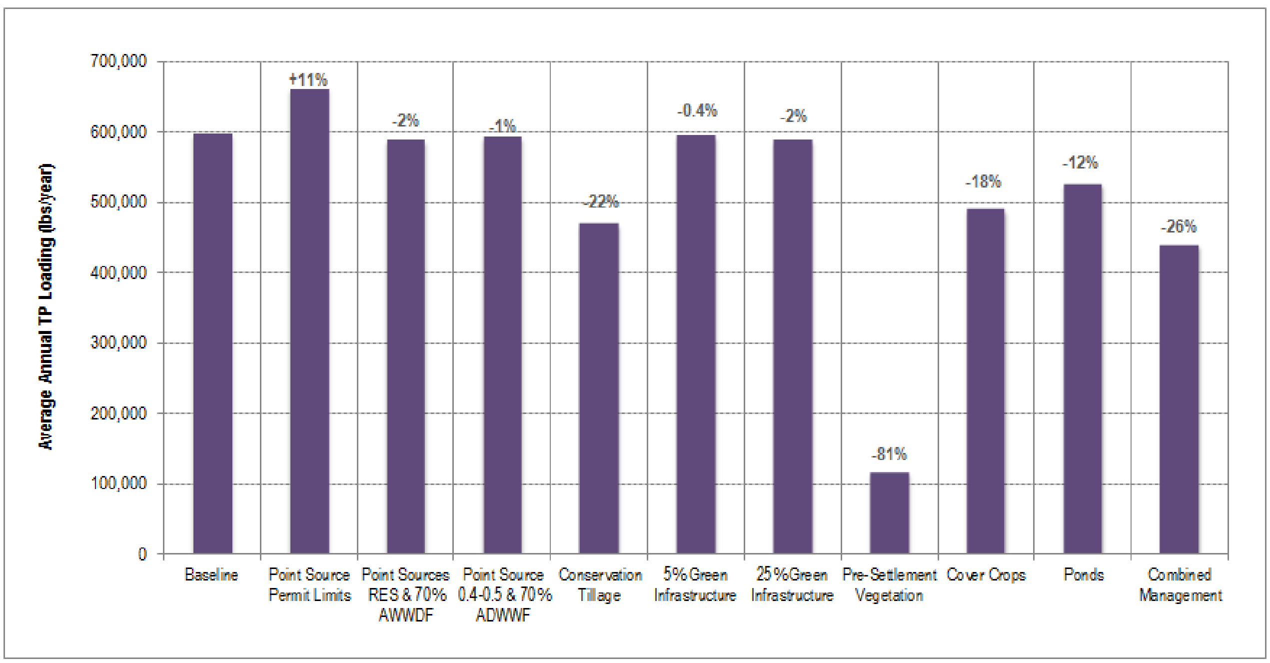


Figure 14. Annual average simulated total phosphorus loading to Lake Zumbro for the baseline run and management scenarios (1996 – 2009).

Table 8. Summary of simulated phosphorus yields and loading at the Zumbro River watershed outlet for the baseline and management scenarios (1996-2009).

Scenario ID	Scenario Description	TP Yield[a] (lbs/acre/yr)	TP Loading (lbs/yr)	Relative TP Loading Change	PO4 Yield (lbs/acre/yr)	PO4 Loading (lbs/yr)	Relative PO4 Loading Change
-	Baseline	0.730	1,066,650	-	0.659	962,285	-
A	Point Sources at Permitted Limits	0.730[b]	1,126,569	+6%	0.659[b]	1,006,688	+5%
B	Point Sources at RES & 70% AWWDF	0.730[b]	1,058,992	-1%	0.659[b]	960,243	-0.2%
C	Select Point Sources at 0.4-0.5 mg P/L & 70% AWWDF	0.730[b]	1,064,702	-0.2%	0.659[b]	961,748	-0.1%
D	Conservation Tillage	0.562	932,498	-13%	0.500	839,339	-13%
E	Green Infrastructure - 5% Implementation	0.729	1,062,163	-0.4%	0.657	958,183	-0.4%
F	Green Infrastructure - 25% Implementation	0.723	1,048,508	-2%	0.653	945,715	-2%
G	Pre-settlement Vegetation	0.062	331,001	-69%	0.045	305,344	-68%
H	Cover Crop	0.602	949,688	-11%	0.538	854,695	-11%
I	Sedimentation Ponds	0.626	1,003,553	-6%	0.551	901,826	-6%
J	Combined Management	0.533	902,321	-15%	0.467	810,821	-16%

[a.] The yield represents a watershed-wide weighted average yield.

[b]Phosphorus yields represent the landside or landscape phosphorus loading; therefore, the phosphorus yield for the point source scenarios are the same as the baseline.

Table 9. Summary of simulated phosphorus yields and loading to Lake Zumbro for the baseline and management scenarios (1996-2009).

Scenario ID	Scenario Description	TP Loading (lbs/yr)	Relative TP Loading Change	PO4 Loading (lbs/yr)	Relative PO4 Loading Change
-	Baseline	596,738		524,669	
A	Point Sources at Permitted Limits	661,130	+11%	562,843	+7%
B	Point Sources at RES & 70% AWWDF	587,740	-2%	518,549	-1%
C	Select Point Sources at 0.4-0.5 mg P/L & 70% AWWDF	592,080	-1%	521,406	-1%
D	Conservation Tillage	468,121	-22%	406,169	-23%
E	Green Infrastructure - 5% Implementation	594,353	-0.4%	522,551	-0.4%
F	Green Infrastructure - 25% Implementation	587,705	-2%	516,756	-2%
G	Pre-Settlement Vegetation	114,695	-81%	99,195	-81%
H	Cover Crop	489,164	-18%	425,499	-19%
I	Sedimentation Ponds	525,436	-12%	455,883	-13%
J	Combined Management	438,662	-26%	378,330	-28%

Nitrogen

A comparison of nitrogen yields and loading (TN and nitrate (NO3)) for the baseline run and the various management scenarios on an annual average basis over the simulation period (1996-2009) is provided in Tables 10-11 and Figures 15-16 below. Nitrogen yield refers to nitrogen loading on a mass per area basis (in lbs/acre/yr) from the landscape. Nitrogen loading refers to the amount of nitrogen that reaches or is delivered to the watershed outlet and to Lake Zumbro (in lbs/yr). The relative load change is calculated as the annual average scenario load minus the baseline load, divided by the baseline loadat the watershed outlet and to Lake Zumbro. The scenario results described below focus on TN; however, the relative changes in loads between the baseline run and the scenarios for nitrate are consistent with the TN results. This is expected because for the Zumbro River watershed, a large majority of the model simulated TN (about 90%) is in the form of nitrate. The results for nitrate are presented in detail in Tables 10 and 11.

For the baseline scenario, the model calculated an annual average TN load of 14,491,430 lbs/yr at the watershed outlet and 9,377,835 lbs/yr to Lake Zumbro. The TN yield calculated for the baseline run was 15.6 lbs/acre/yr. For the point source scenario set at the permitted effluent flow and constituent limits (A), the model-estimated annual TN loading to the watershed outlet and to Lake Zumbro is 9% and 14% greater, respectively, than the baseline run (Tables 10-11, Figures 15-16). The increase in the TN load is attributed to higher effluent flows and TN concentrations specified in the permitted limits compared to the effluent flows and TN concentrations in the baseline run, which reflects historical effluent discharges based on reported measurements. The annual TN load for the point source scenarios where the effluent flow is set at 70% AWWDF (B and C) is 1% greater at the watershed outlet and 2% greater to Lake Zumbro relative to the baseline, which can be attributed to the 70% AWWDF flows that are higher than the baseline.

Similar to sediment and phosphorus, the green infrastructure implementation scenarios (E and F) resulted in a small reduction of annual TN loading to the watershed outlet and Lake Zumbro, ranging from ≤1% at the 5% level of implementation to 1% at the 25% level of implementation (Tables 10-11, Figures 15-16). As with sediment and phosphorus, it is not expected that the green infrastructure implementation would result in a substantial TN load reduction at the watershed outlet or to Lake Zumbro given the small area of developed land across the watershed where practices were implemented in the scenario. However, an increased level of water quality benefits would be expected at the local, tributary scale where developed land cover dominates.

The application of conservation tillage (D) to 30% of the highest sediment yielding cropland acres in the model resulted in an estimated annual TN load reduction of 5% at the watershed outlet and 6% to Lake Zumbro relative to the baseline run (Tables 10-11, Figures 15-16). The application of cover crops (H) to 30% of the cropland acres in the model resulted in an estimated annual TN load reduction of 8% at the watershed outlet and 11% to Lake Zumbro compared to the baseline run (Tables 10-11, Figures 15-16). These results appear to be fairly consistent with a Minnesota study reported by Miller et al. (2012), which consisted of a three-year study in Lamberton, Minnesota where nitrate loss was reduced by 13% with cover crop implementation on a corn-soybean rotation.

The results of the sedimentation pond scenario (I) indicate a reduction in annual TN loading of 1% at the watershed outlet and 1% to Lake Zumbro relative to the baseline (Tables 10-11 Figures 15-16). Given that the majority of nitrogen is in the form of nitrate andt the residence time of the ponds is short, the low TN reduction from the implementation of ponds is expected. For the combined management scenario (J), the annual TN load reduction estimated is 8% at the watershed outlet and 10% at Lake Zumbro (Tables 10-11, Figures 15-16). The cover crop scenario is estimated to provide the greatest overall load reduction with the exception of the pre-settlement vegetation scenario discussed below. The model results indicate the combined management scenario is slightly less effective in reducing TN loads compared to the cover crop scenario. This is likely attributable to the expected low reduction of TN load with the addition of sedimentation ponds and the increase in point source discharge that result from effluent flows set to 70% AWWDF.

The pre-settlement vegetation scenario provides a pre-settlement reference for the nitrogen loading rates in the Zumbro River watershed. The pre-settlement vegetation loading rates of TN is 1.1 lb/acre/yr, which is approximately fourteen-fold lower than the baseline run of 15.6 lbs/acre/yr (Tables 10-11, Figures 15-16). The pre-settlement loading rate of TN is 1.1 lb/acre/yr is consistent with the range of unit area sediment loading rates reported in the literature for forested landscape across the US (0.635 – 5.692 lbs/acre/yr) (CH2M Hill and AQUA TERRA 2002; Lin et. al 2004). For pre-settlement conditions, the model-estimated annual TN loading at the watershed outlet is 93% lower at the watershed outlet and 94% lower at Lake Zumbro when compared to the baseline run (Tables 10-11, Figures 15-16). The results of this scenario indicate the conversion of natural landscape to agriculture and developed land uses in the watershed as well as the increase in atmospheric nitrogen deposition have significantly increased the nitrogen input to and export from the Zumbro River watershed.

Nitrogen landscape yield scenario maps are in Appendix C.

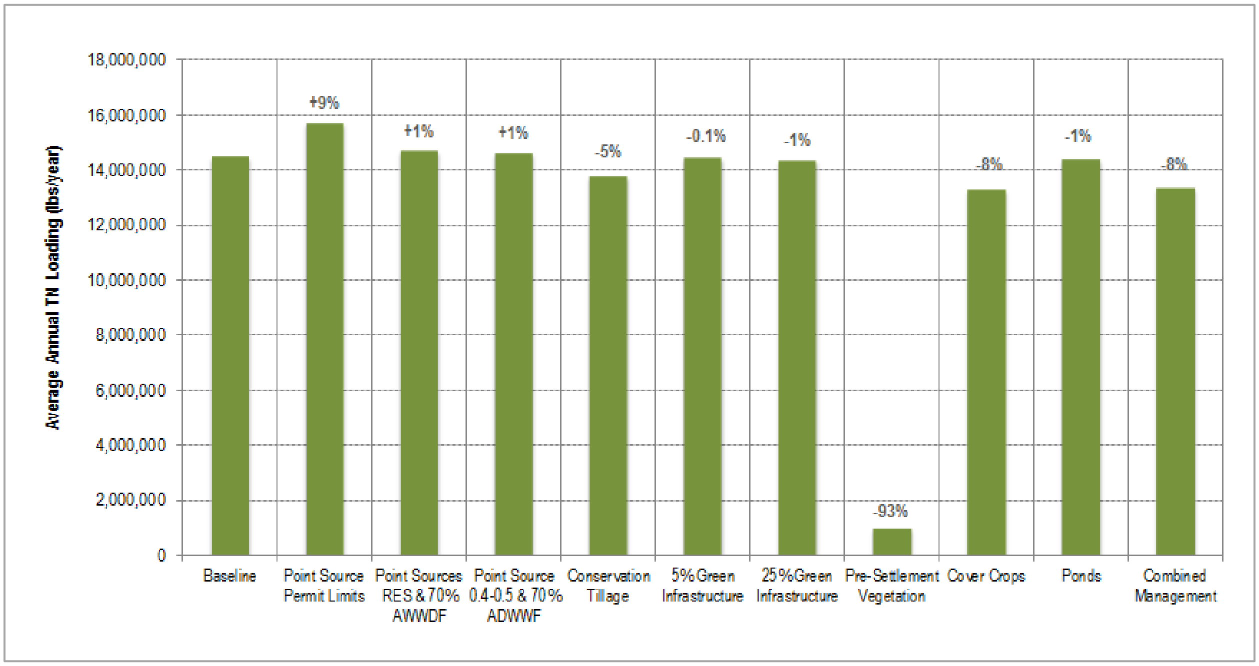


Figure 15. Annual average simulated total nitrogen loading at the Zumbro River watershed outlet for baseline and management scenarios (1996 – 2009).

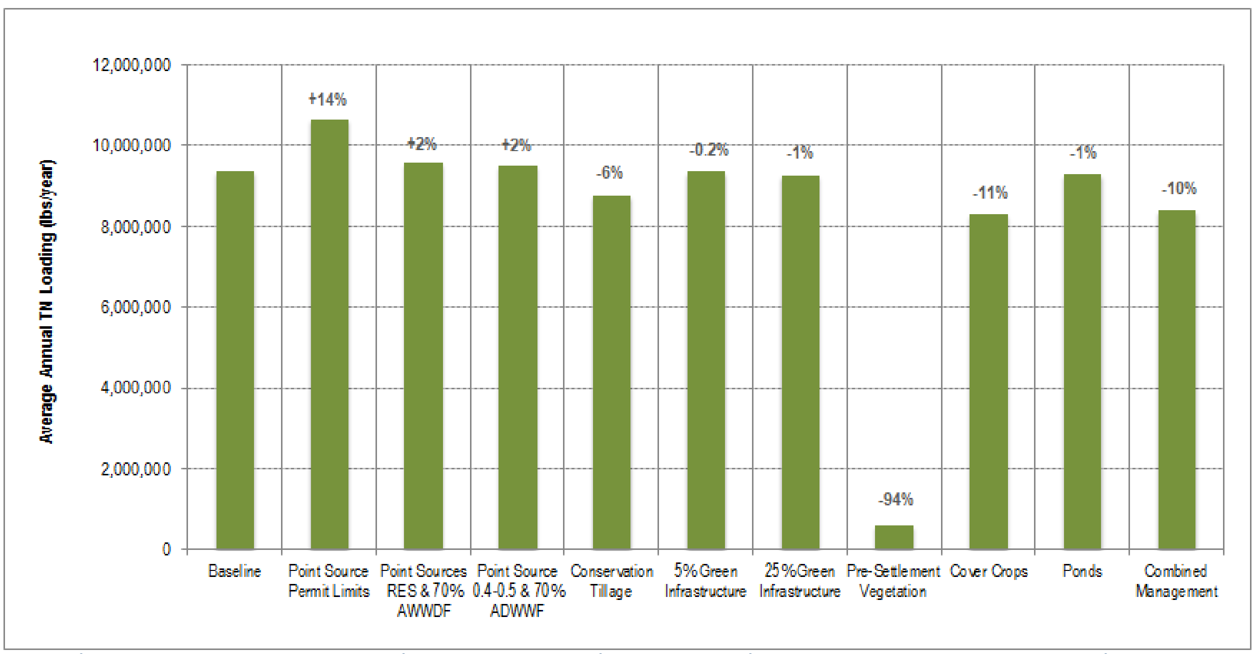


Figure 16. Annual average simulated total nitrogen loading to Lake Zumbro for baseline and management scenarios (1996 – 2009).

Table 10. Summary of simulated nitrogen yields and loading at the Zumbro River watershed outlet for the baseline and management scenarios (1996-2009).

Scenario ID	Scenario	TN Yield[a] (lbs/acre/yr)	TN Loading (lbs/yr)	Relative TN Loading Change	NO3 Yield (lbs/acre/yr)	NO3 Loading (lbs/yr)	Relative NO3 Loading Change
-	Baseline	15.6	14,491,430	-	14.2	13,267,079	-
A	Point Sources at Permitted Limits	15.6[b]	15,728,277	+9%	14.2[b]	14,105,670	+6%
B	Point Sources at RES & 70% AWWDF	15.6[b]	14,705,576	+1%	14.2[b]	13,485,826	+2%
C	Select Point Sources at 0.4-0.5 mg P/L & 70% AWWDF	15.6[b]	14,638,951	+1%	14.2[b]	13,417,747	+1%
D	Conservation Tillage	14.8	13,795,291	-5%	13.5	12,677,813	-4%
E	Green Infrastructure - 5% Implementation	15.5	14,469,738	-0.1%	14.2	13,251,253	-0.1%
F	Green Infrastructure - 25% Implementation	15.4	14,376,662	-1%	14.1	13,176,544	-1%
G	Pre-Settlement Vegetation	1.1	1,018,348	-93%	0.9	747,566	-94%
H	Cover Crop	14.2	13,287,958	-8%	12.9	12,156,770	-8%
I	Sedimentation Ponds	15.1	14,395,750	-1%	13.8	13,215,126	-0.4%
J	Combined Management	13.8	13,359,586	-8%	12.5	12,269,164	-8%

[a]*The yield represents a watershed-wide weighted average yield.*

[b]*Nitrogen yields represent the landside or landscape nitrogen loading; therefore, the nitrogen yield for the point source scenarios are the same as the baseline.*

Table 11. Summary of simulated nitrogen yields and loading to Lake Zumbro for the baseline and management scenarios (1996-2009).

Scenario ID	Scenario	TN Loading (lbs/yr)	Relative TN Loading Change	NO3 Loading (lbs/yr)	Relative NO3 Loading Change
-	Baseline	9,377,835		8,466,255	
A	Point Sources at Permitted Limits	10,667,114	+14%	8,938,253	+6%
B	Point Sources at RES & 70% AWWDF	9,588,601	+2%	8,651,405	+2%
C	Select Point Sources at 0.4-0.5 mg P/L & 70% AWWDF	9,524,906	+2%	8,612,133	+2%
D	Conservation Tillage	8,780,637	-6%	7,965,981	-6%
E	Green Infrastructure - 5% Implementation	9,357,622	-0.2%	8,452,819	-0.2%
F	Green Infrastructure - 25% Implementation	9,281,879	-1%	8,395,041	-1%
G	Pre-Settlement Vegetation	605,849	-94%	437,628	-95%
H	Cover Crop	8,315,072	-11%	7,487,565	-12%
I	Sedimentation Ponds	9,296,690	-1%	8,422,734	-1%
J	Combined Management	8,400,022	-10%	7,603,067	-10%

Management Scenario Summary

A suite of potential management practices or BMPs were evaluated with the ZRWHSPF model to estimate the potential benefits of these practices with respect to reducing present-day sediment and nutrient loads. When assessing the scenarios relative to one another, it is important to consider and keep in mind the "level of implementation" for each scenario in regard to the estimated load reduction reported for each scenario. The specified level of implementation is not the same across the scenarios and varies from 5% to 30% for specific targeted land areas. The land area coverage also differs by land use type across the watershed (i.e., more agricultural land area than developed land area). Finally, the location of management practice or BMP implementation is not the same across the scenarios. Therefore, the level of implementation, the land area coverage, and the location of implementation for each scenario must be taken into consideration when using the information to help inform management decisions. Management scenario results have been generally expressed as the "percent change relative to baseline". This approach was taken because the relative differences between the "baseline" and the individual scenarios are more certain than the absolute differences (e.g., in sediment loading).

Based on the model scenario results, the following list summarizes the management practices that are indicated as likely to be the most effective in reducing sediment and nutrient loading and improving water quality:

- Sediment: combined management (J), conservation tillage (D), cover crops (H) and sedimentation ponds (I);
- Total Phosphorus (TP) and Orthophosphate (PO4): combined management (J), conservation tillage (D) and cover crops (H); and
- Total Nitrogen (TN) and Nitrate (NO3): cover crops (H) and combined management (J).

It should be noted that the pre-settlement vegetation condition is not listed as an effective practice for reducing sediment and nutrient loading and improving water quality. This scenario does not represent a feasible management practice (i.e., the watershed will never be returned to a pre-settlement vegetation condition). The purpose of this scenario was to estimate the increased sediment and nutrient loading in the watershed resulting from the conversion of the natural landscape to agriculture and developed land uses.

Project Outcomes

The outcomes of this project include the following:

1. A refined watershed model with improved accuracy was developed for assessing impairment issues.
2. Model applications that assess various management scenarios were successfully developed, and the results can be used by decision-makers, including agency staff and stakeholders, to educate and inform the development of implementation strategies to restore and protect waters.
3. MPCA staff, local partners and citizen volunteers will be able to integrate the results of the modeling into strategies for the Watershed Restoration and Protection Plan report and implementation plan for improving water bodies on the Minnesota 303(d) List of Impaired Waters.

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Appendix A - Sediment

LANDSCAPE UNIT AREA LOADING MAPS

The annual average load generated per acre is mapped for each model subbasin. The maps only represent landscape yields and do not account for changes in point source discharge; therefore, maps are not available for the point source scenarios. Please note that the shading of a subbasin is based on a relative scale to differentiate unit area loading rates. The color of the shading is not intended to indicate whether the load generated is bad or good in terms of water quality.

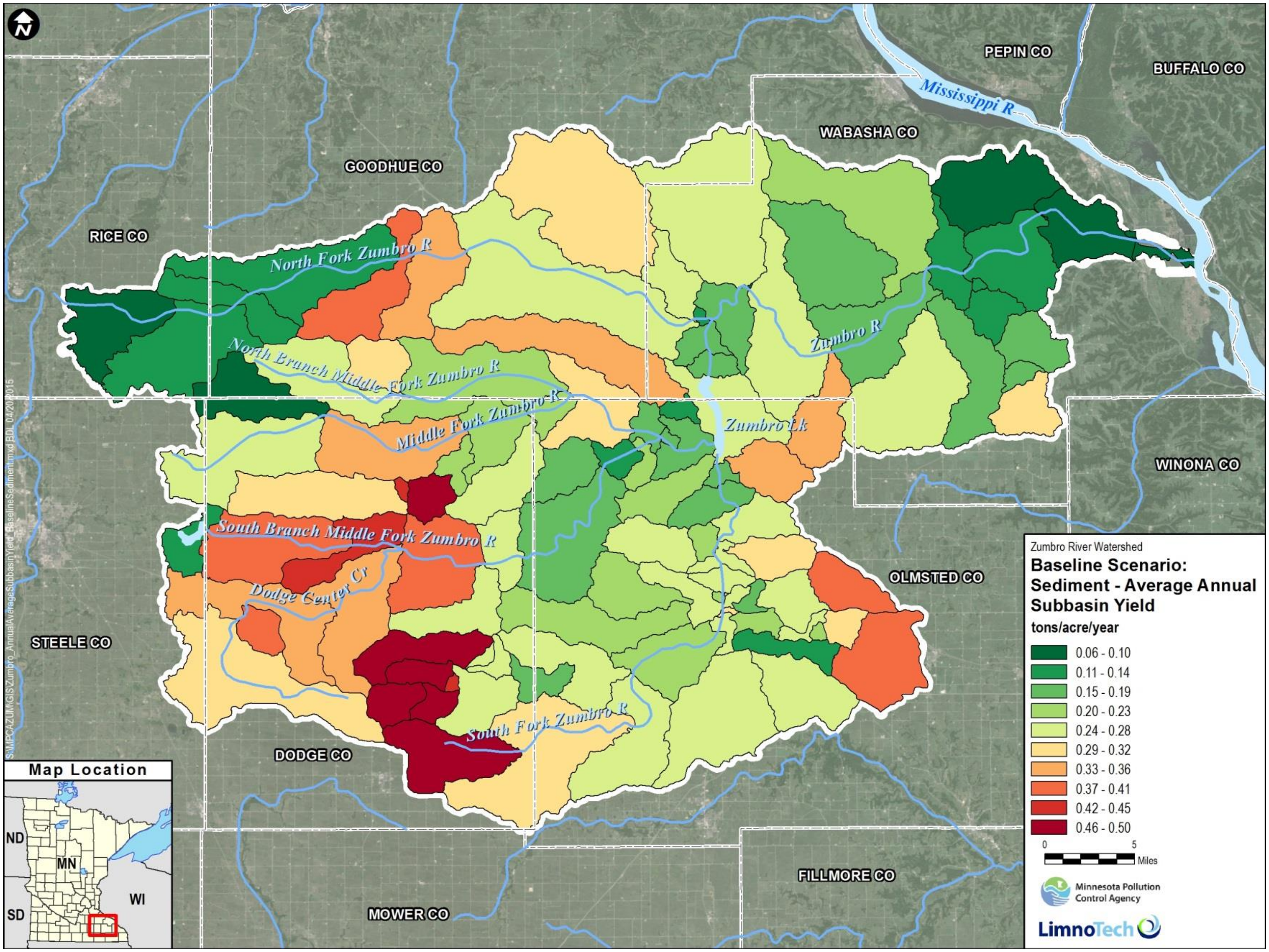

Figure A-1. Average annual sediment subbasin yield for the baseline simulation.

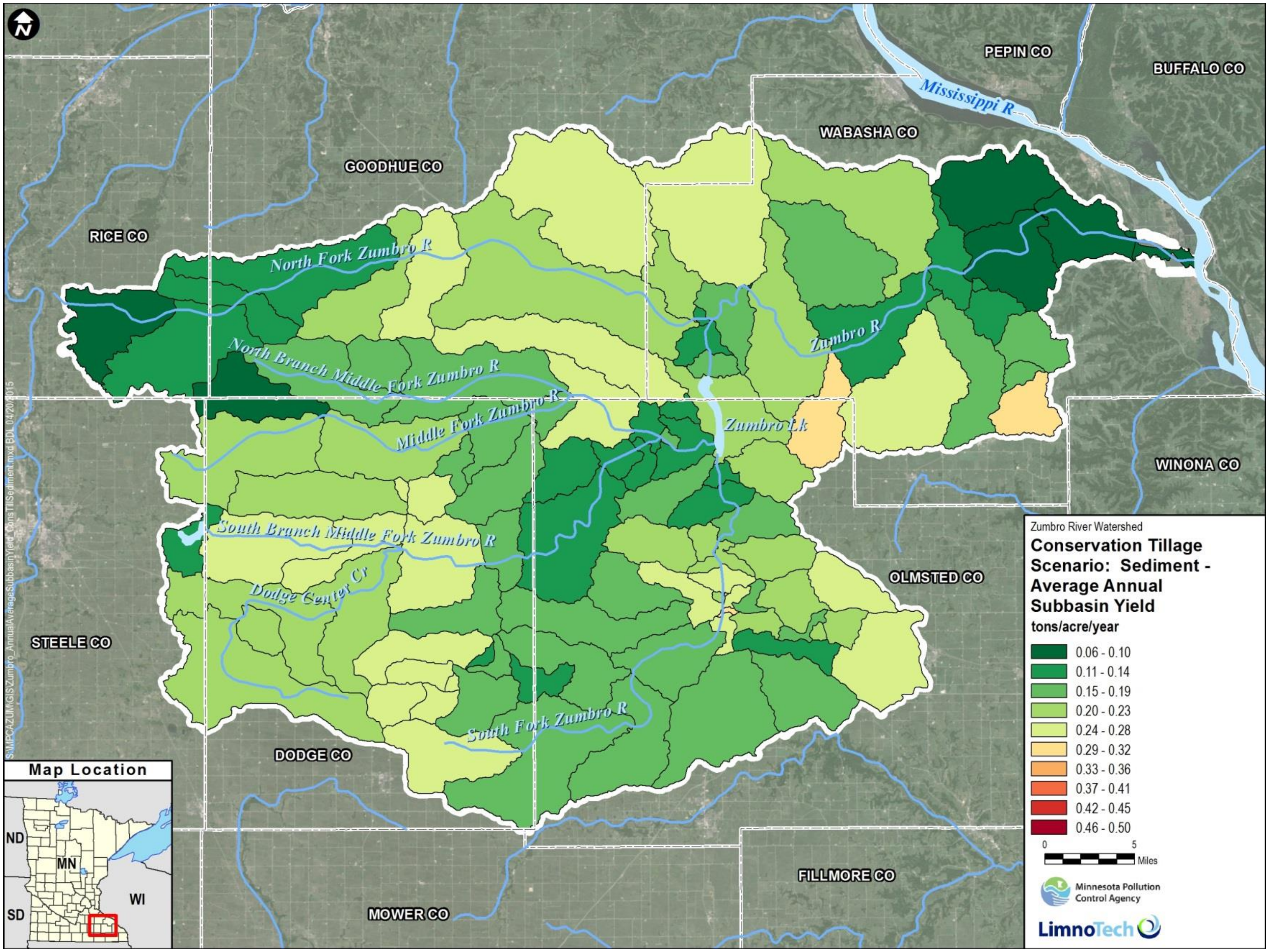

Figure A-2. Average annual sediment subbasin yield for the conservation tillage scenario.

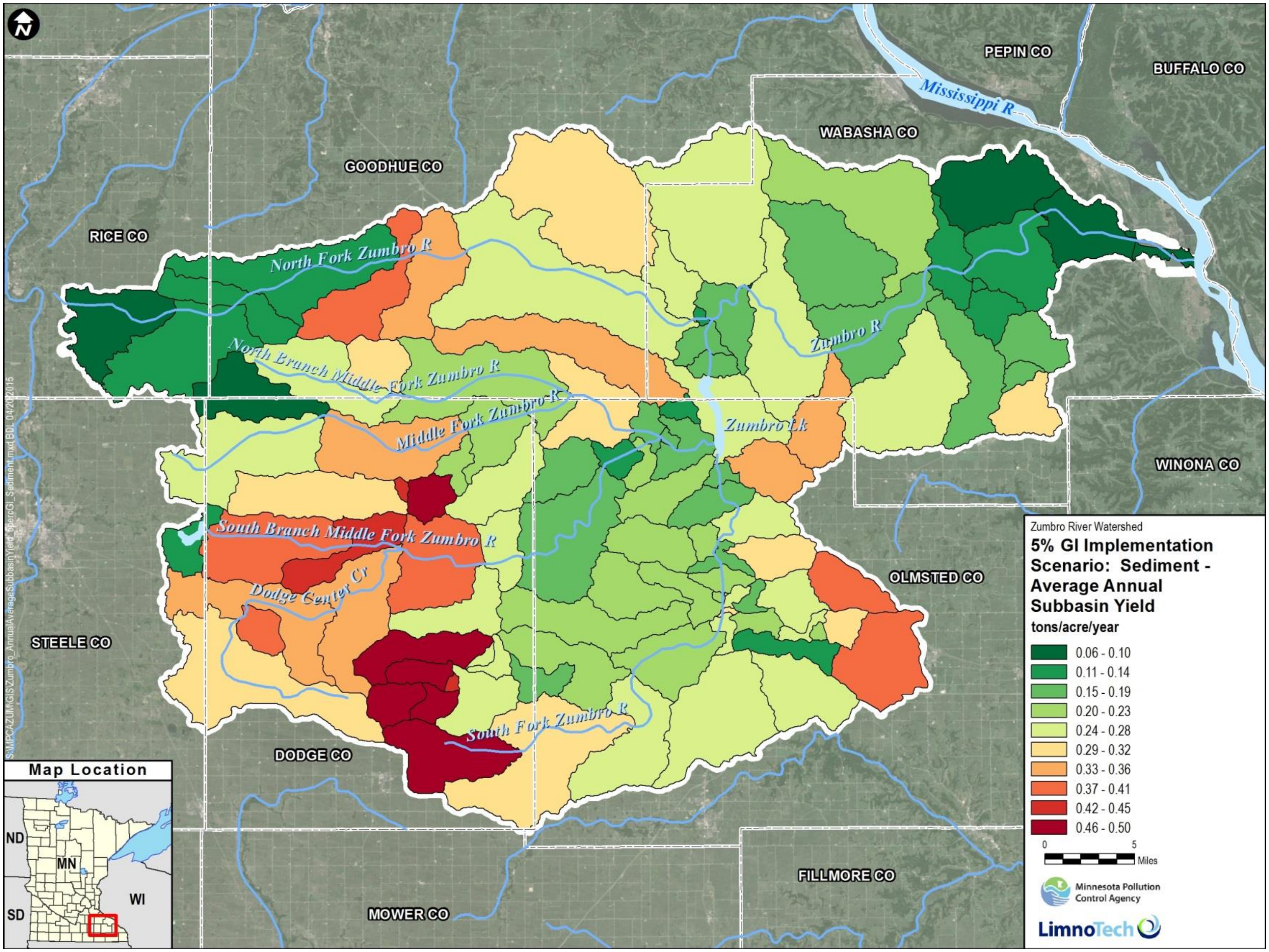

Figure A-3. Average annual sediment subbasin yield for the green infrastructure - 5% implementation scenario.

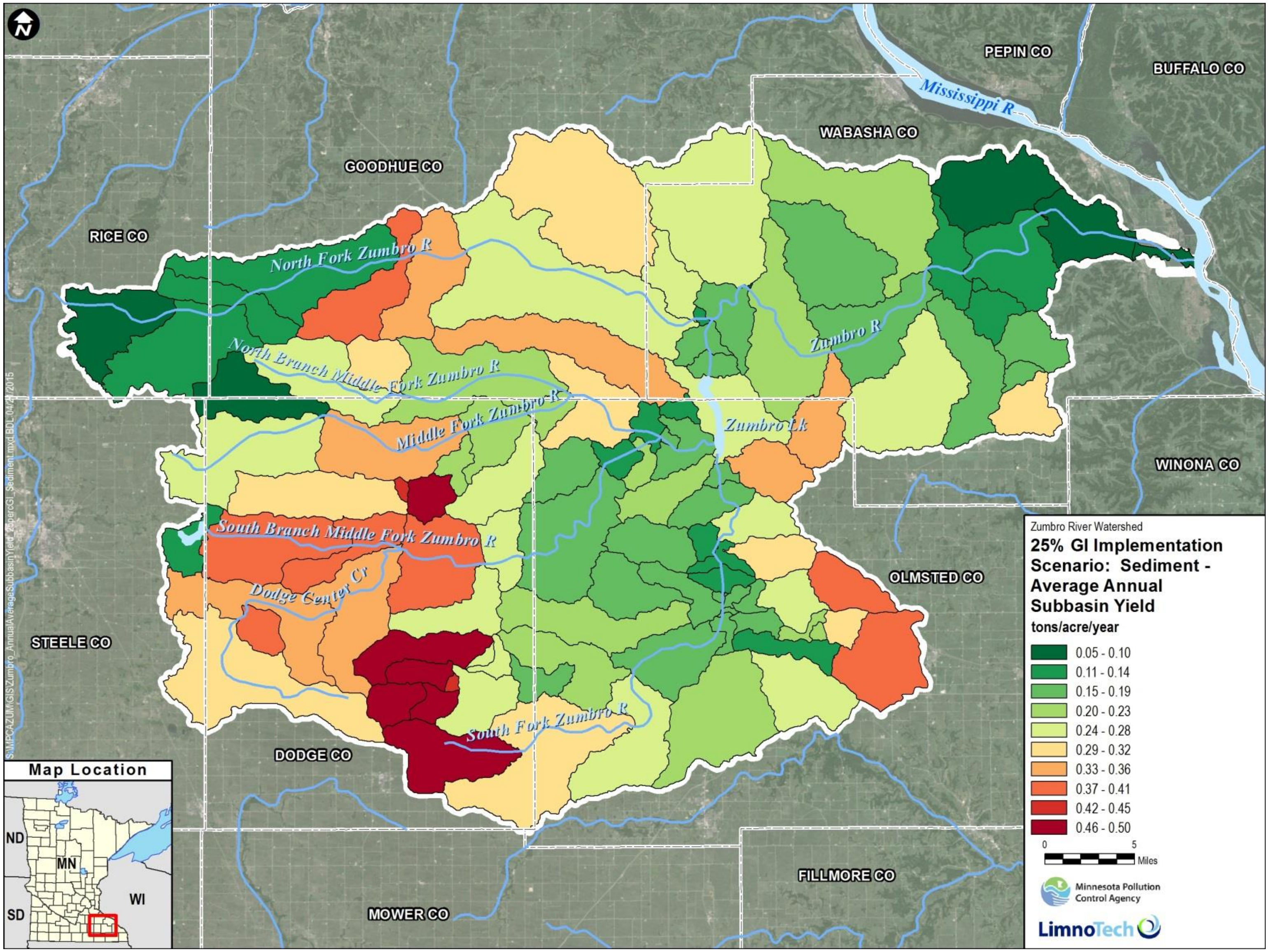

Figure A-4. Average annual sediment subbasin yield for the green infrastructure - 25% implementation scenario.

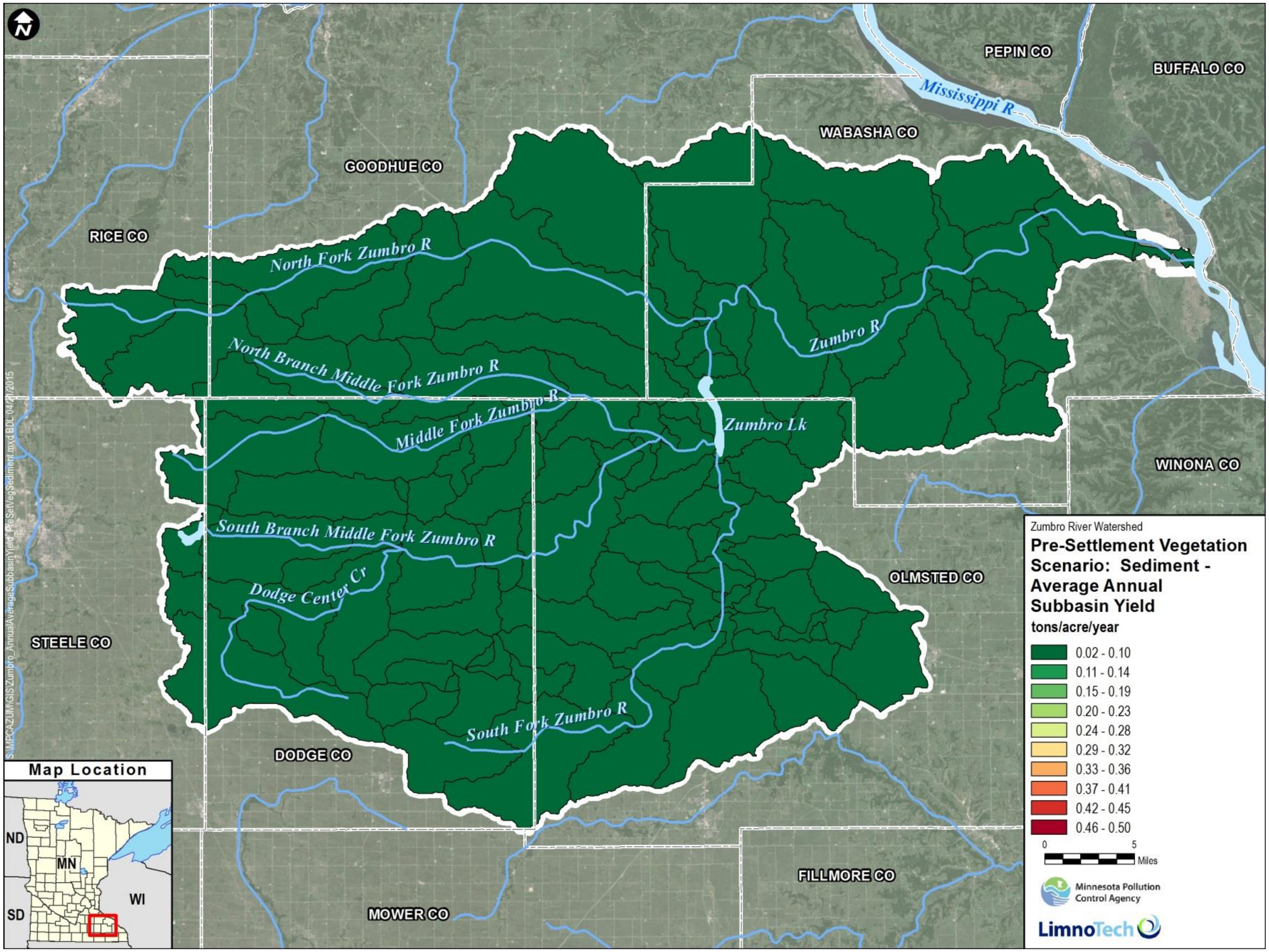

Figure A-5. Average annual sediment subbasin yield for the pre-settlement vegetation scenario.

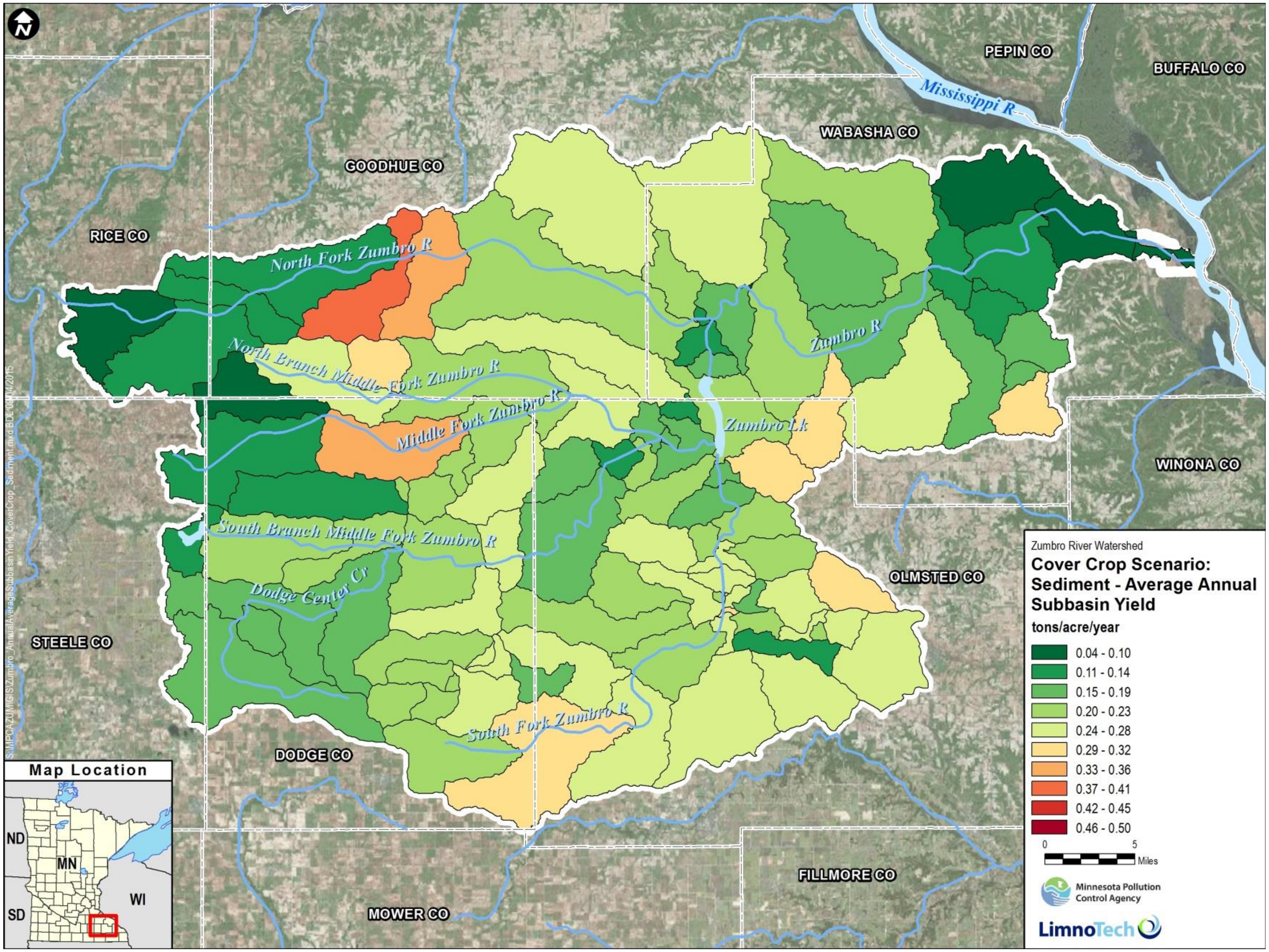

Figure A-6. Average annual sediment subbasin yield for the cover crops scenario.

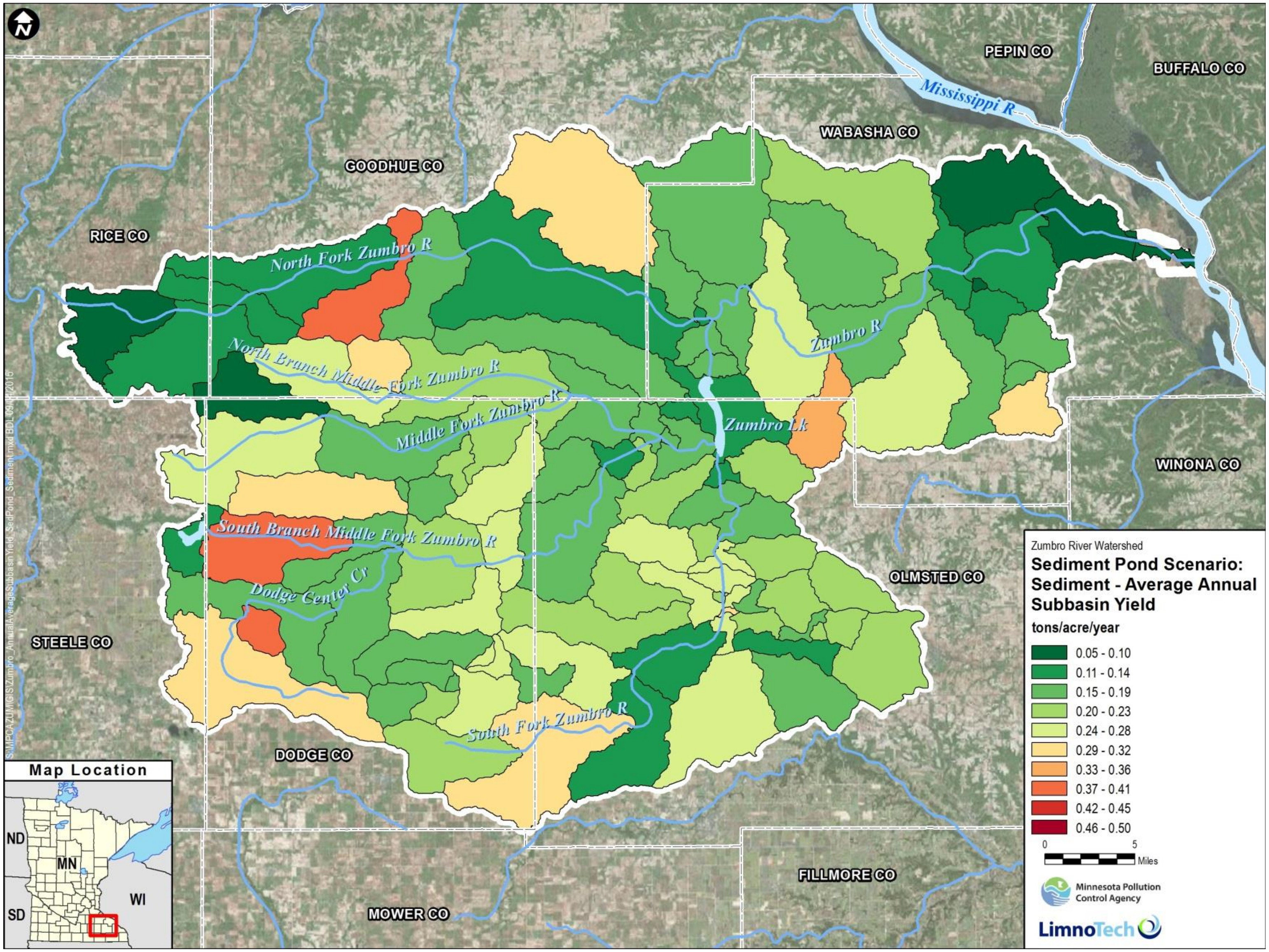

Figure A-7. Average annual sediment subbasin yield for the sedimentation pond scenario.

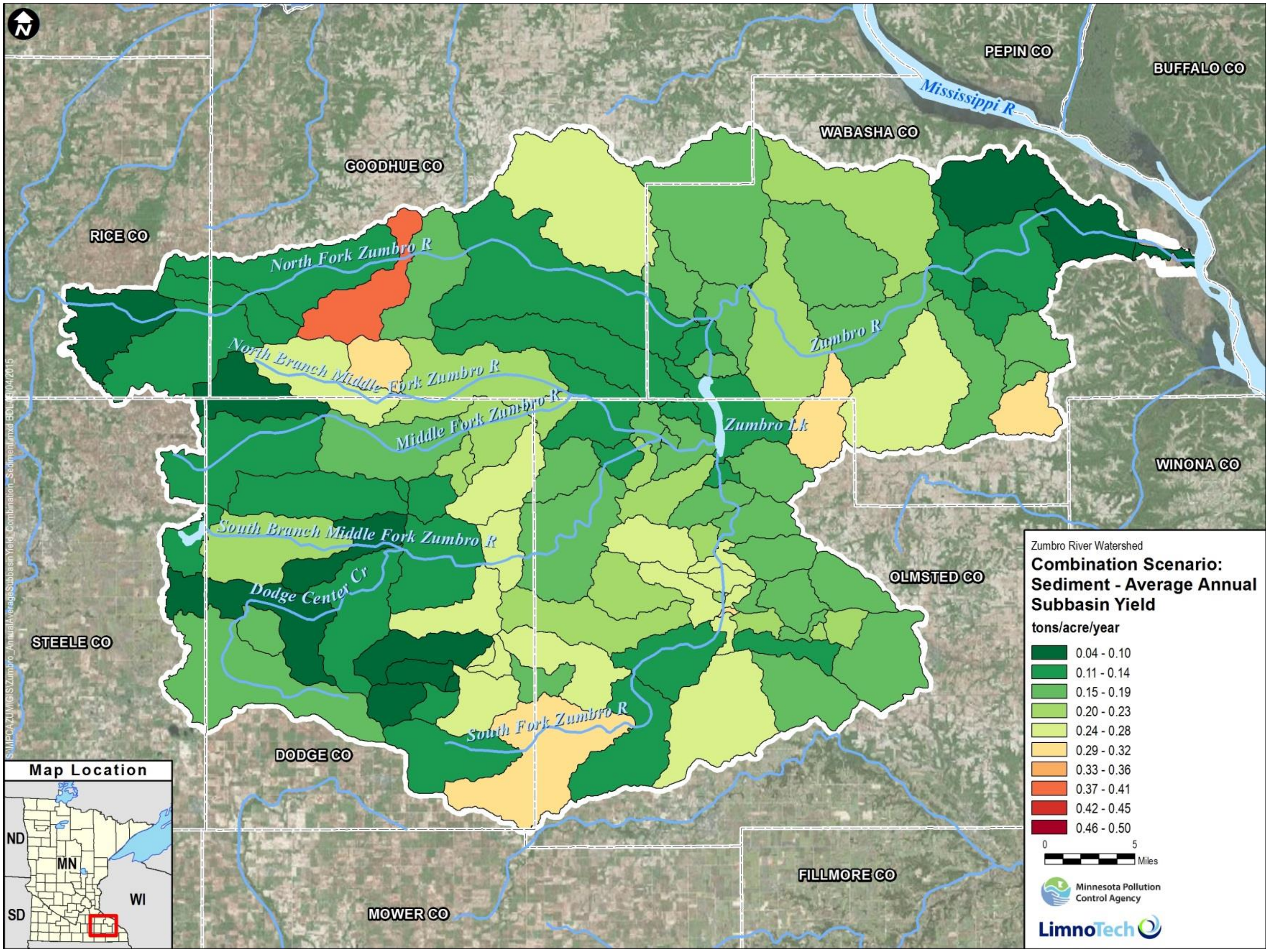

Figure A-8. Average annual total sediment subbasin yield for the combination scenario. Note that the maps only represent landscape yields and do not account for changes in point source discharge.

Appendix B - Phosphorus

LANDSCAPE UNIT AREA LOADING MAPS

The annual average load generated per acre is mapped for each model subbasin. The maps only represent landscape yields and do not account for changes in point source discharge; therefore, maps are not available for the point source scenarios. The scales change between constituents. Please note that the shading of a subbasin is based on a relative scale to differentiate unit area loading rates. The color of the shading is not intended to indicate whether the load generated is bad or good in terms of water quality.

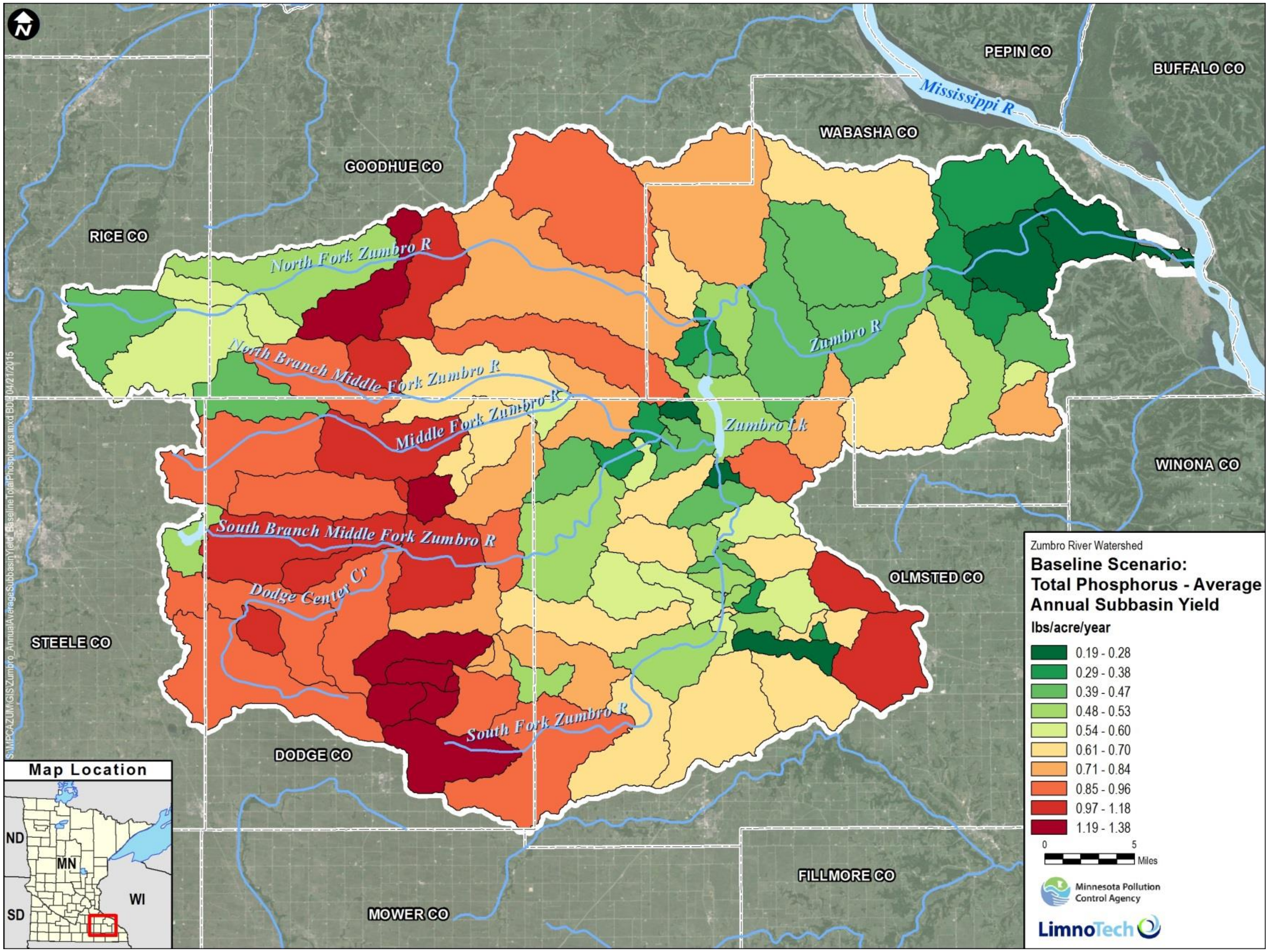

Figure B-1. Average annual total phosphorus subbasin yield for the baseline simulation.

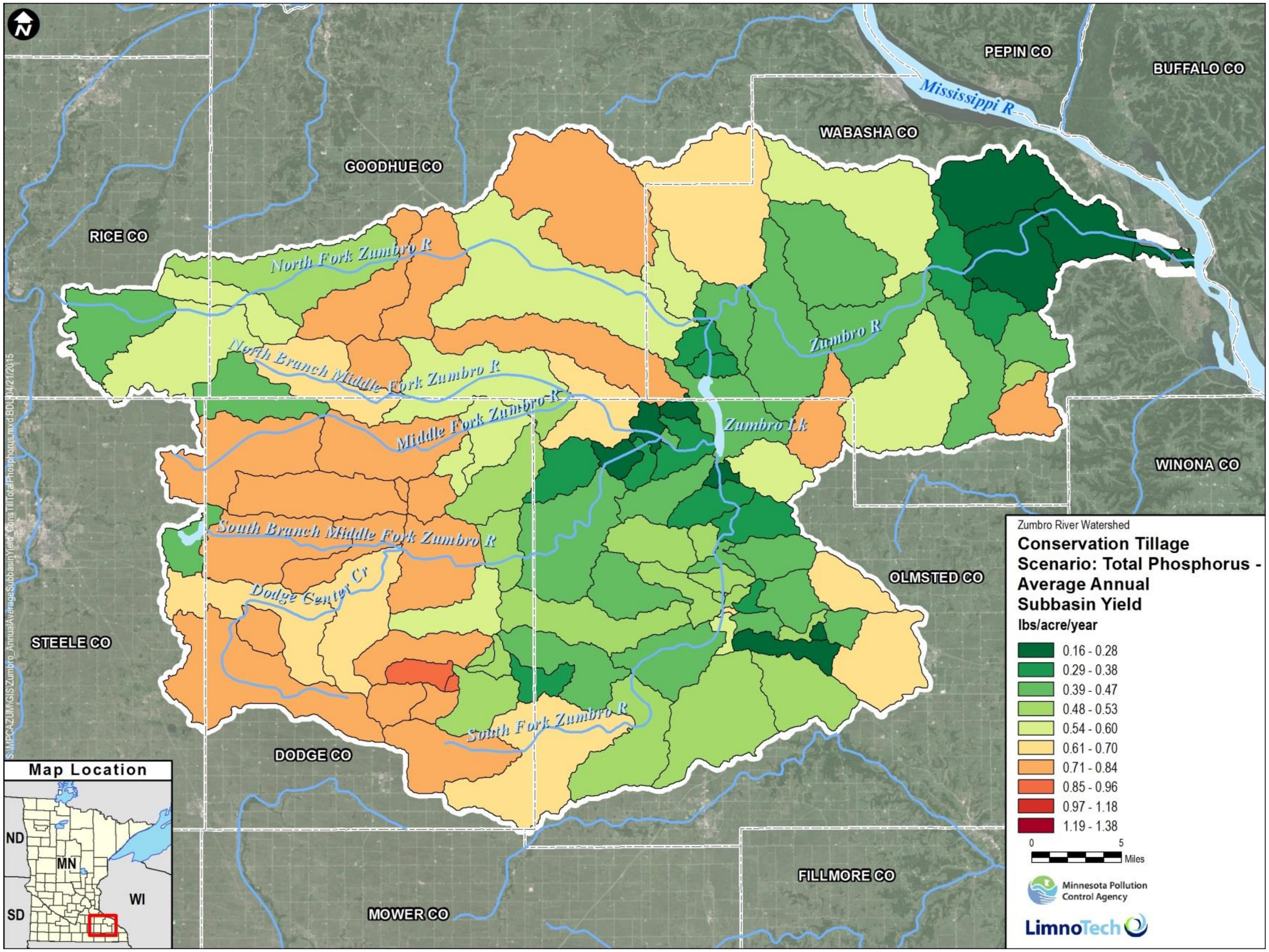

Figure B-2. Average annual total phosphorus subbasin yield for the conservation tillage scenario.

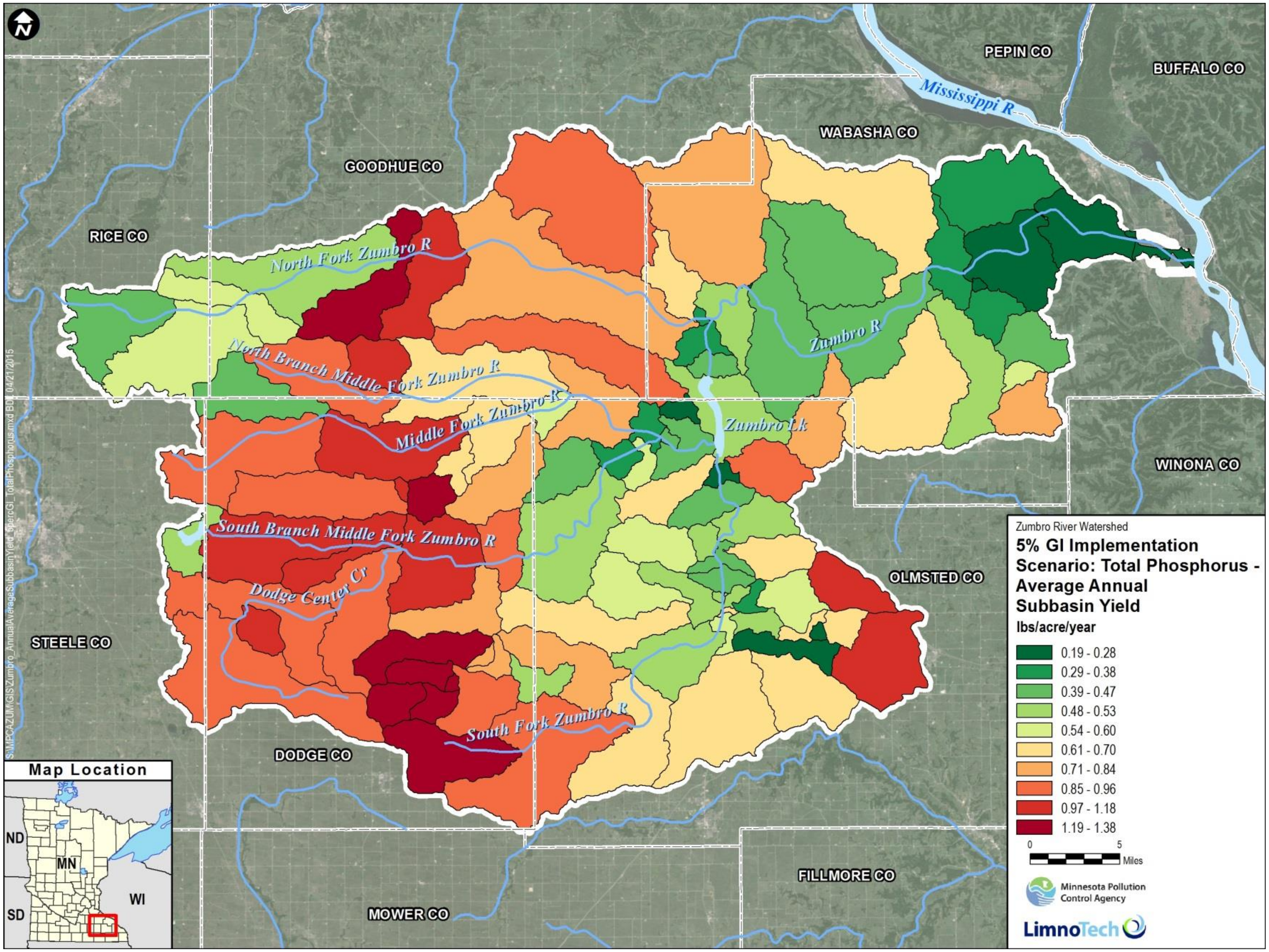

Figure B-3. Average annual total phosphorus subbasin yield for the green infrastructure - 5% implementation scenario.

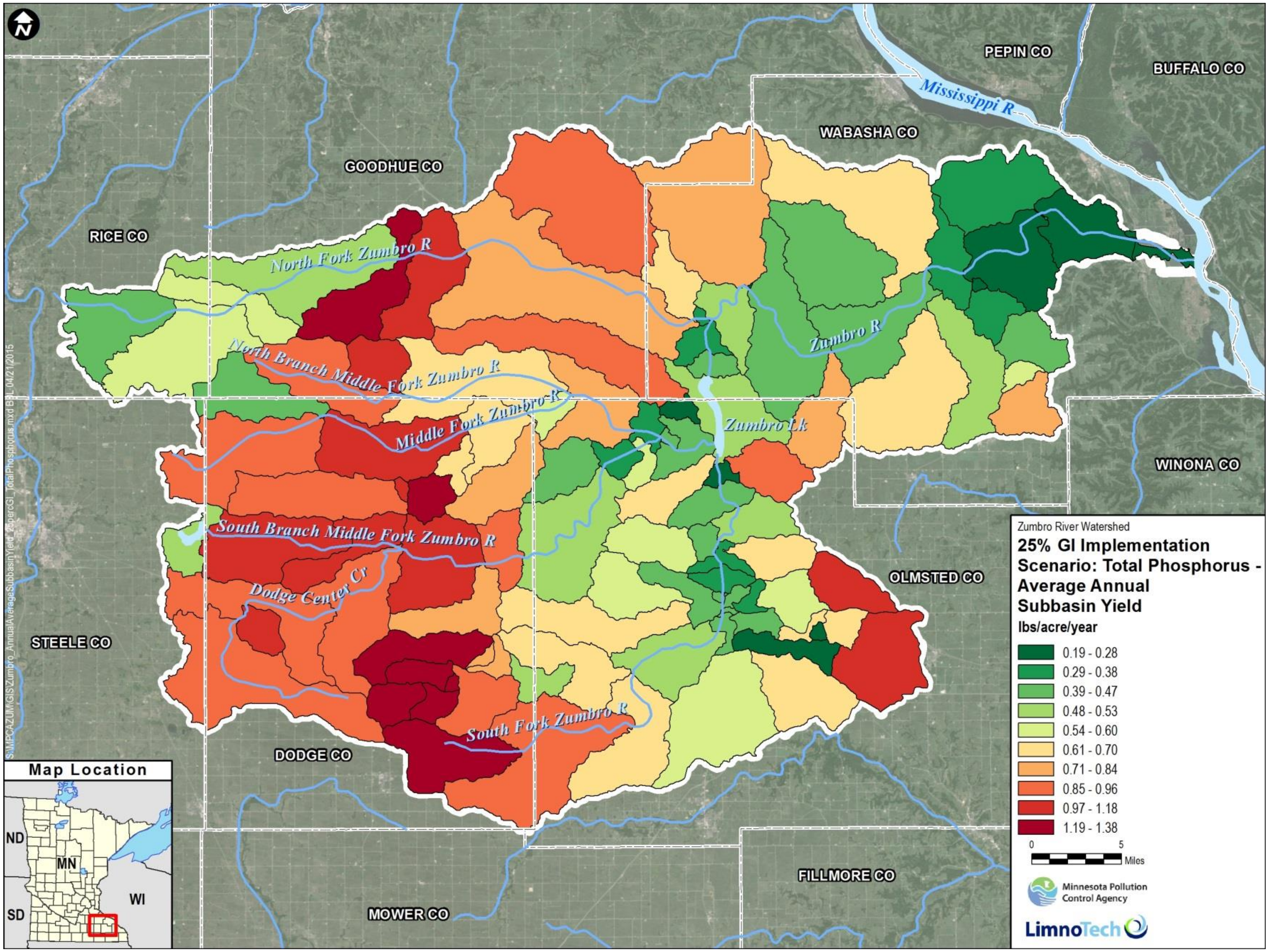

Figure B-4. Average annual total phosphorus subbasin yield for the green infrastructure - 25% implementation scenario.

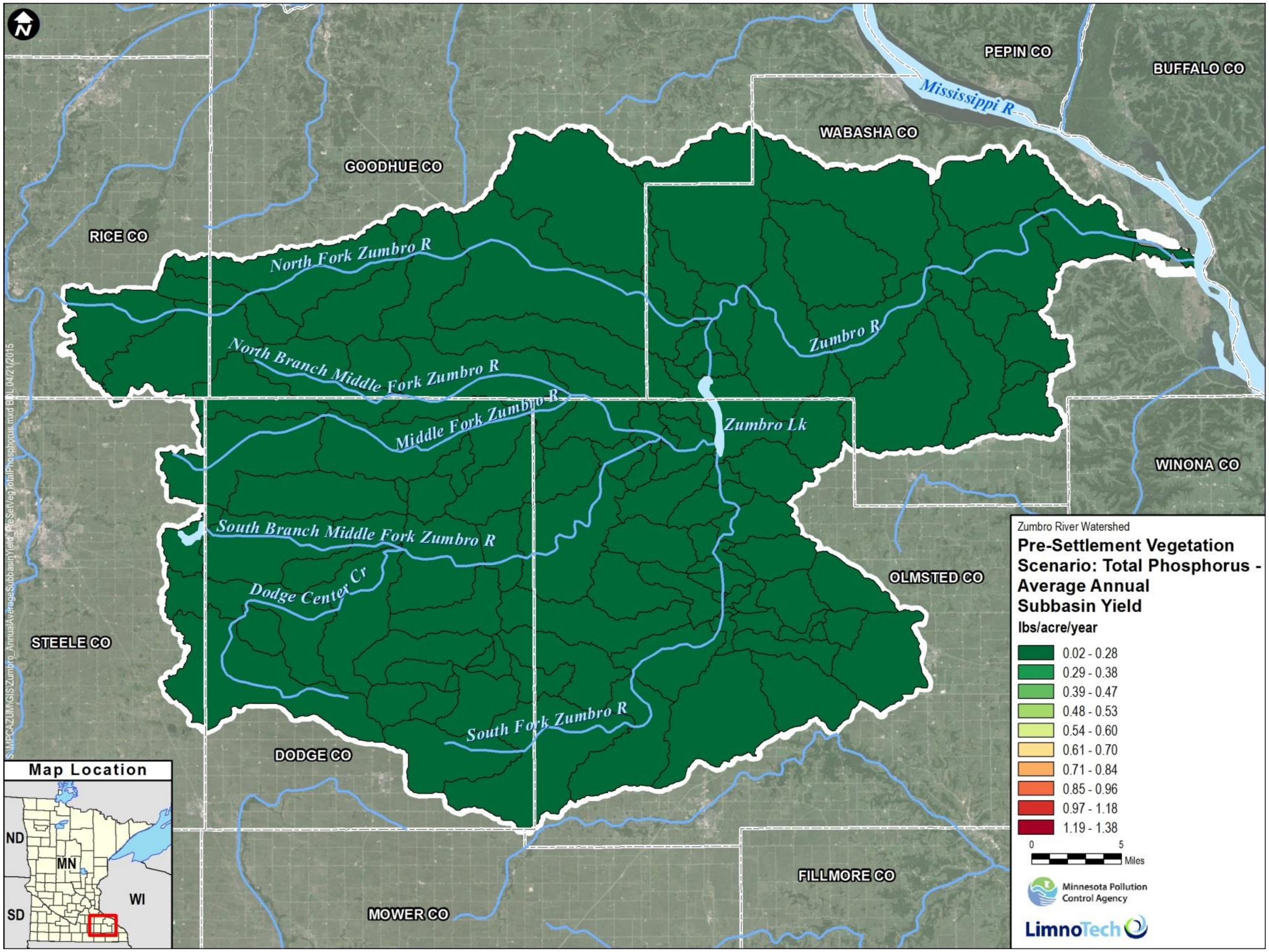

Figure B-5. Average annual total phosphorus subbasin yield for the pre-settlement vegetation scenario.

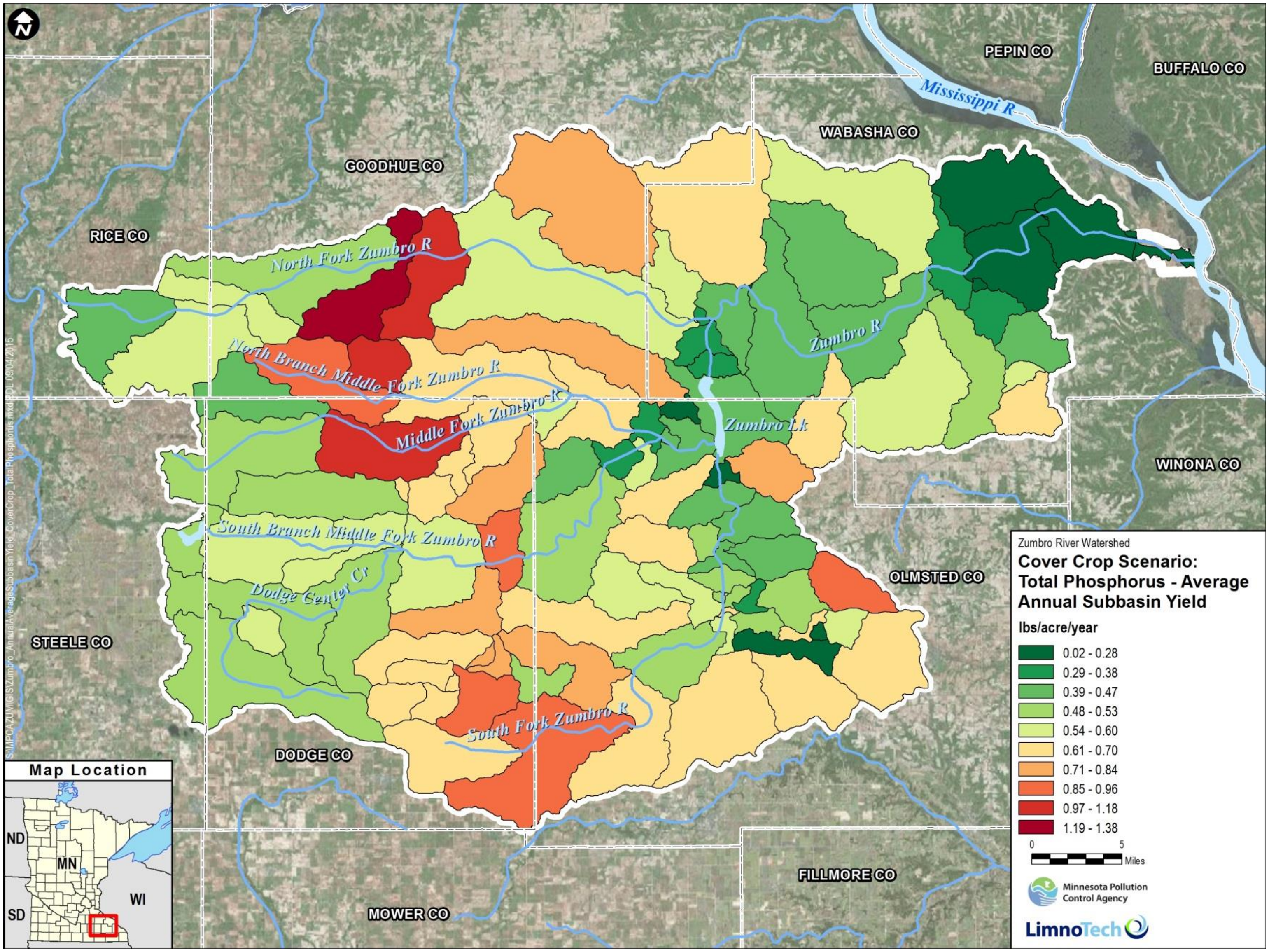

Figure B-6. Average annual total phosphorus subbasin yield for the cover crops scenario.

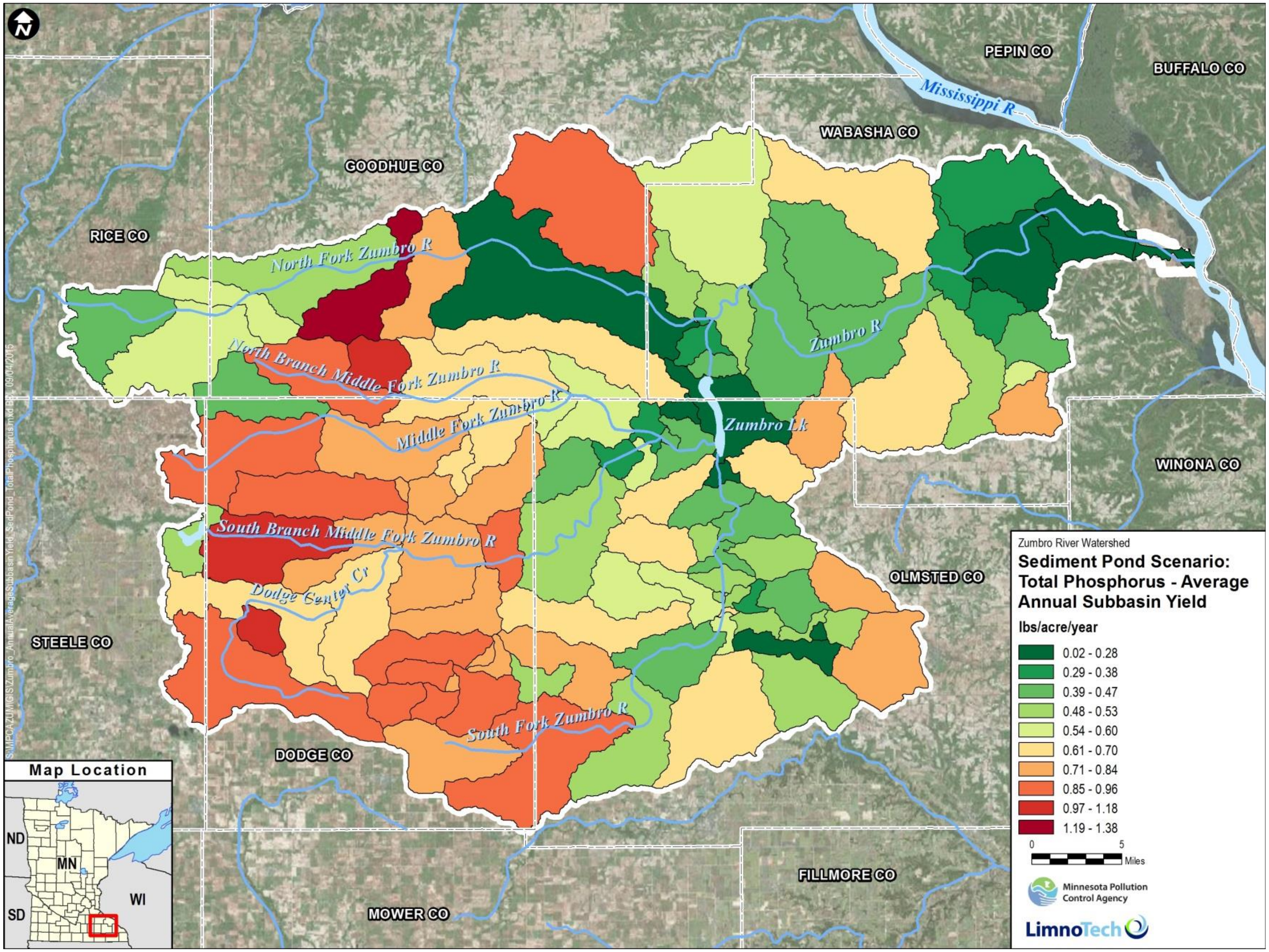

Figure B-7. Average annual total phosphorus subbasin yield for the sedimentation pond scenario.

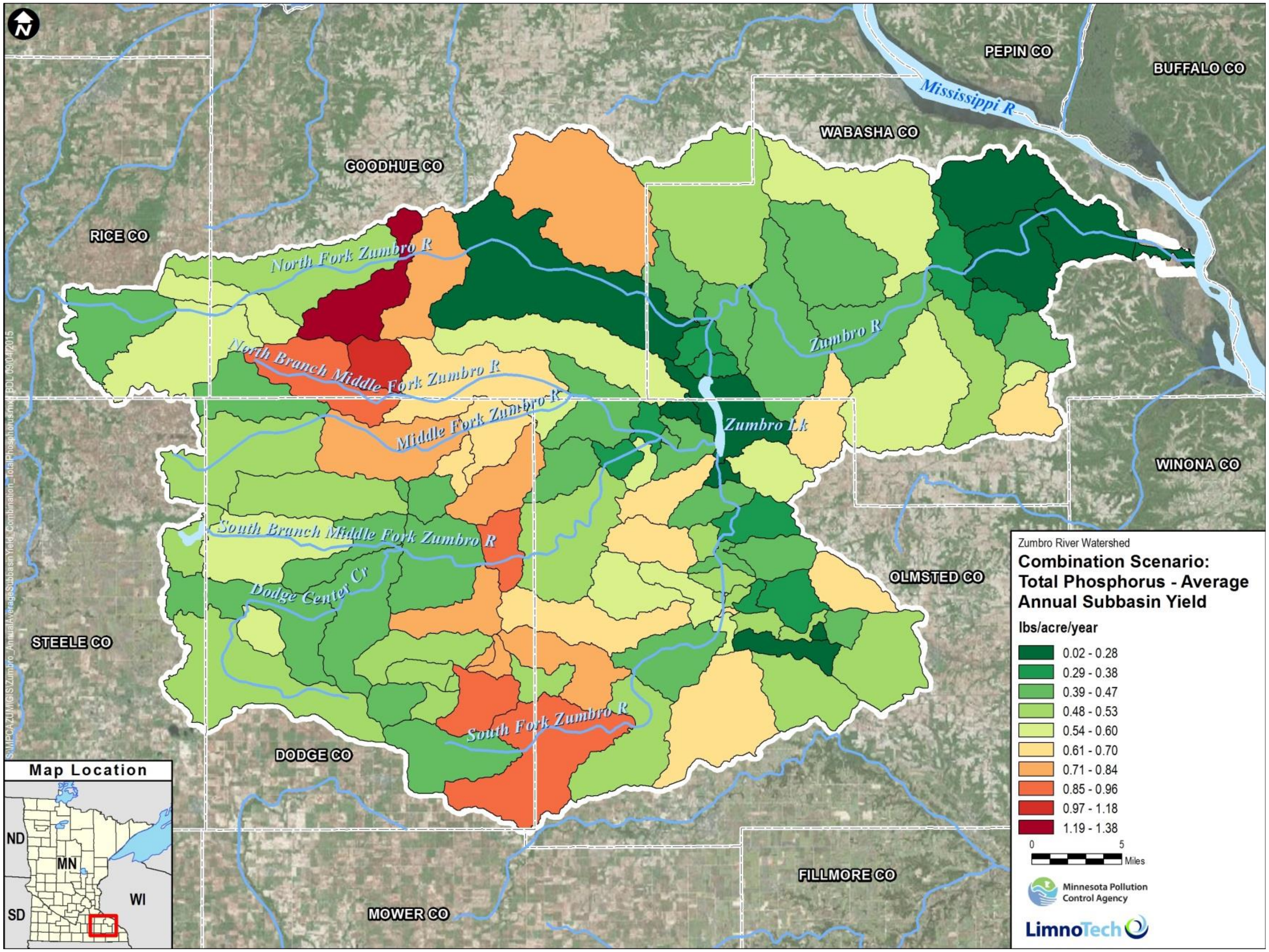

Figure B-8. Average annual total phosphorus subbasin yield for the combination scenario. Note that the maps only represent landscape yields and do not account for changes in point source discharge.

Appendix C - Nitrogen

LANDSCAPE UNIT AREA LOADING MAPS

The annual average load generated per acre is mapped for each model subbasin. The maps only represent landscape yields and do not account for changes in point source discharge; therefore, maps are not available for the point source scenarios. Please note that the shading of a subbasin is based on a relative scale to differentiate unit area loading rates. The color of the shading is not intended to indicate whether the load generated is bad or good in terms of water quality.

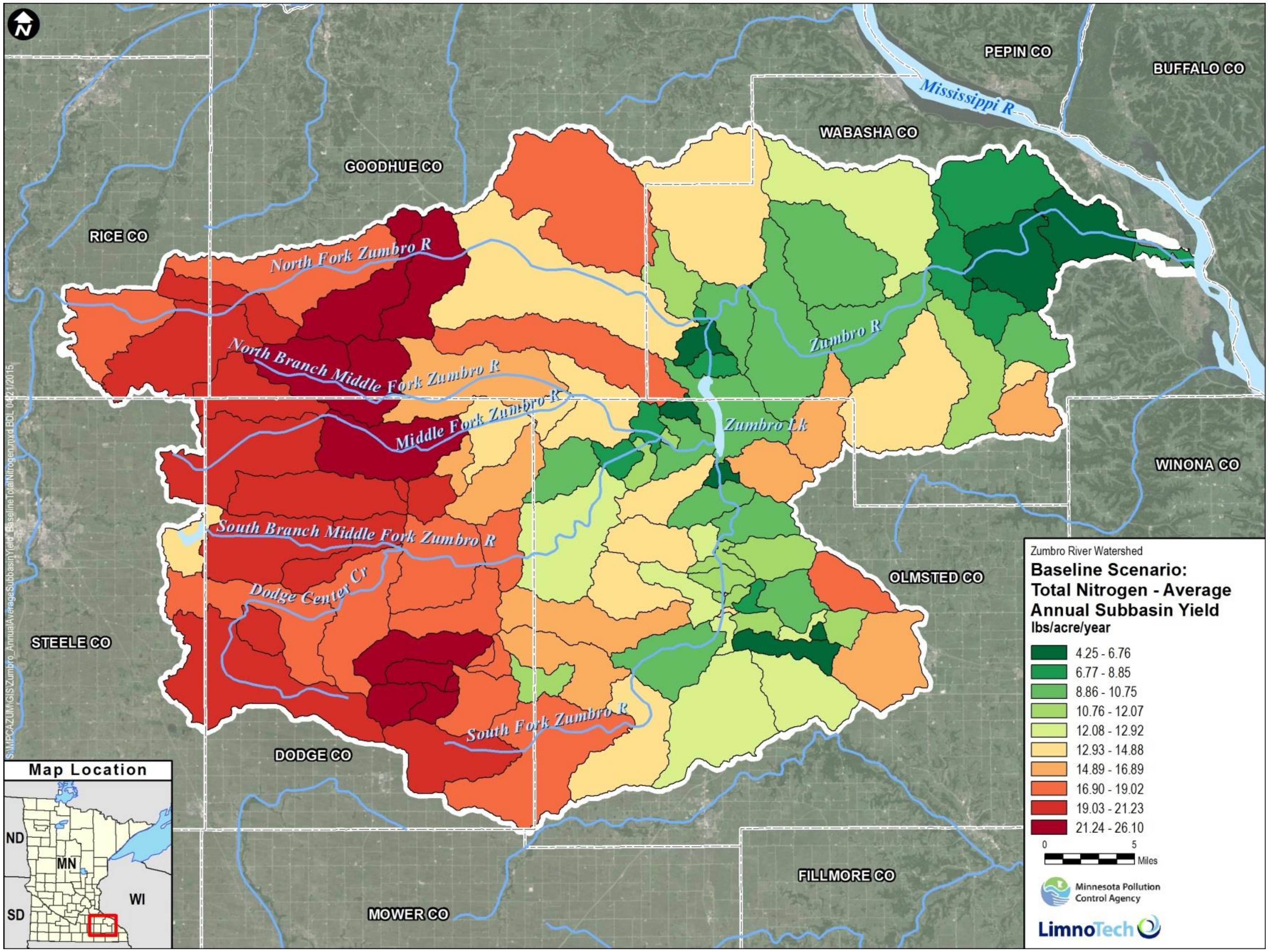

Figure C-1. Average annual total nitrogen subbasin yield for the baseline simulation.

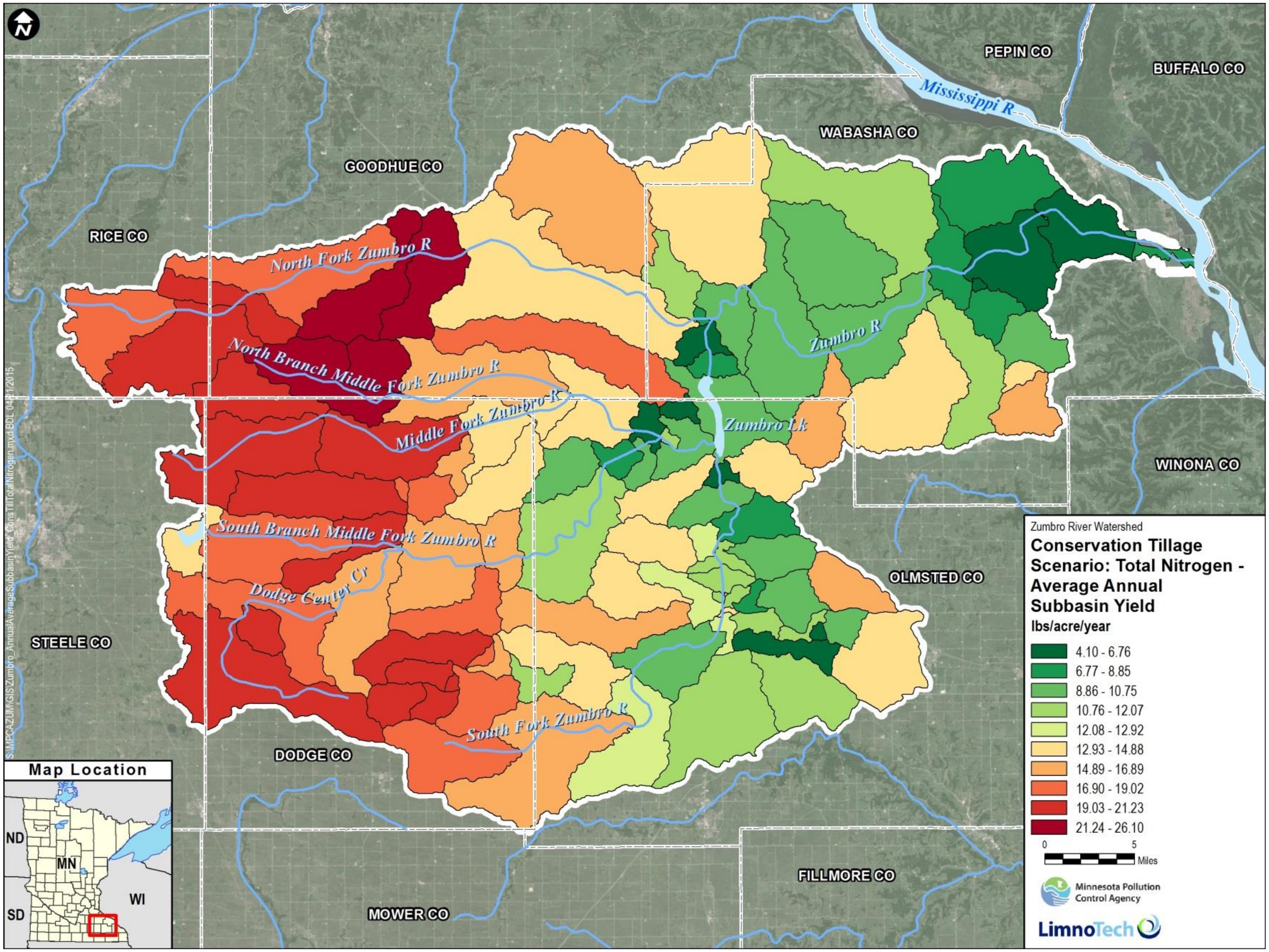

Figure C-2. Average annual total nitrogen subbasin yield for the conservation tillage scenario.

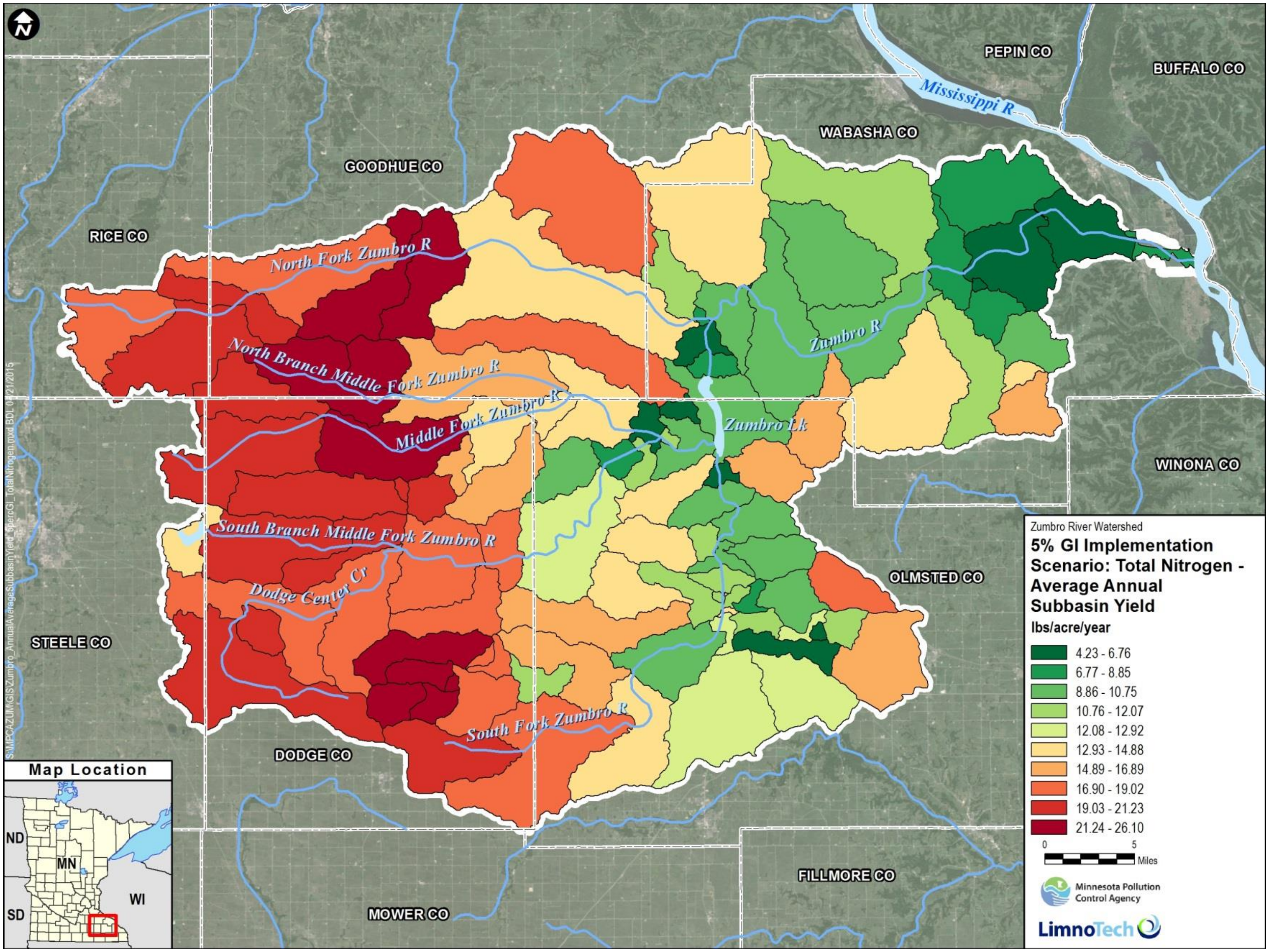

Figure C-3. Average annual total nitrogen subbasin yield for the green infrastructure - 5% implementation scenario.

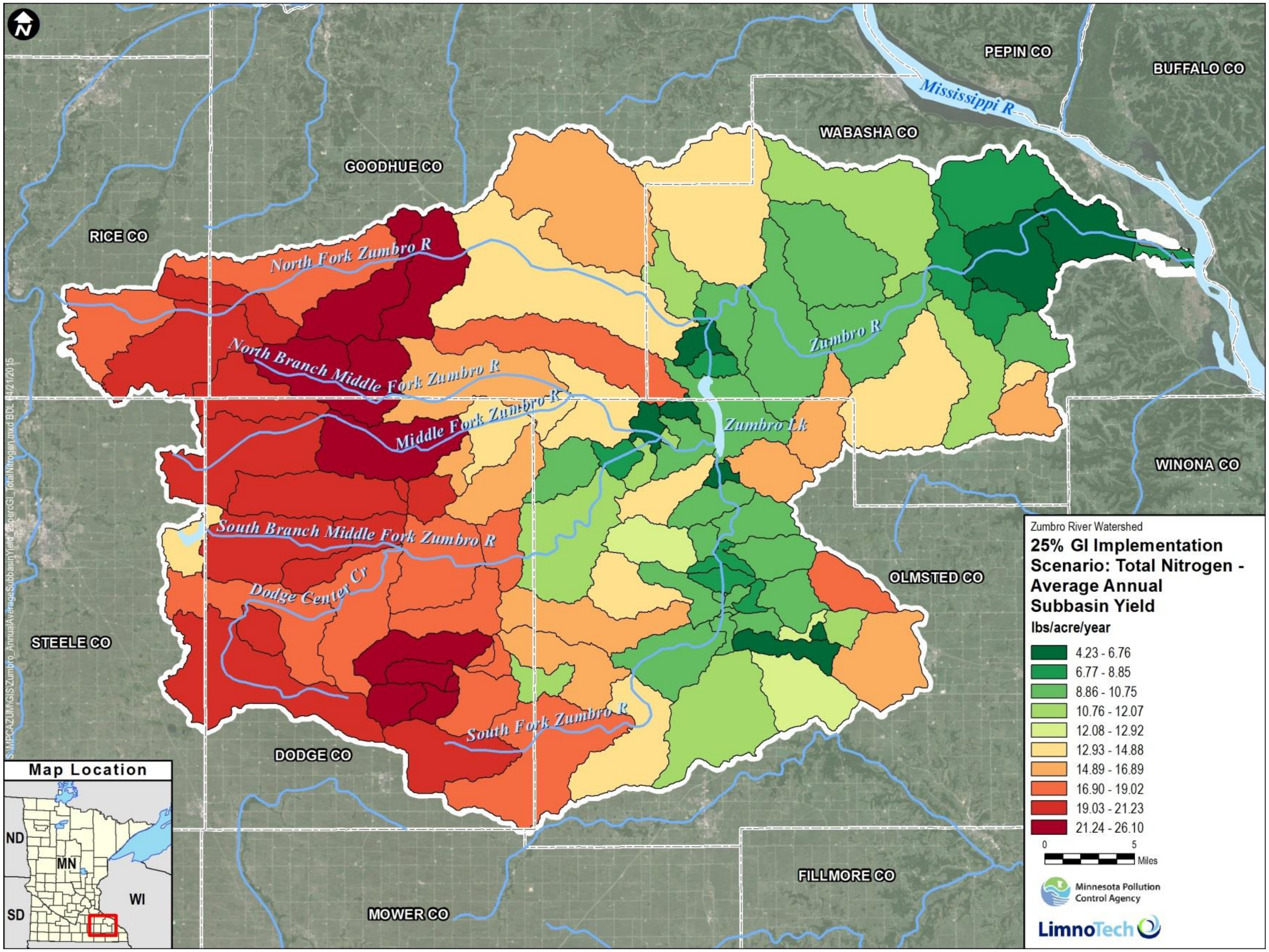

Figure C-4. Average annual total nitrogen subbasin yield for the green infrastructure - 25% implementation scenario.

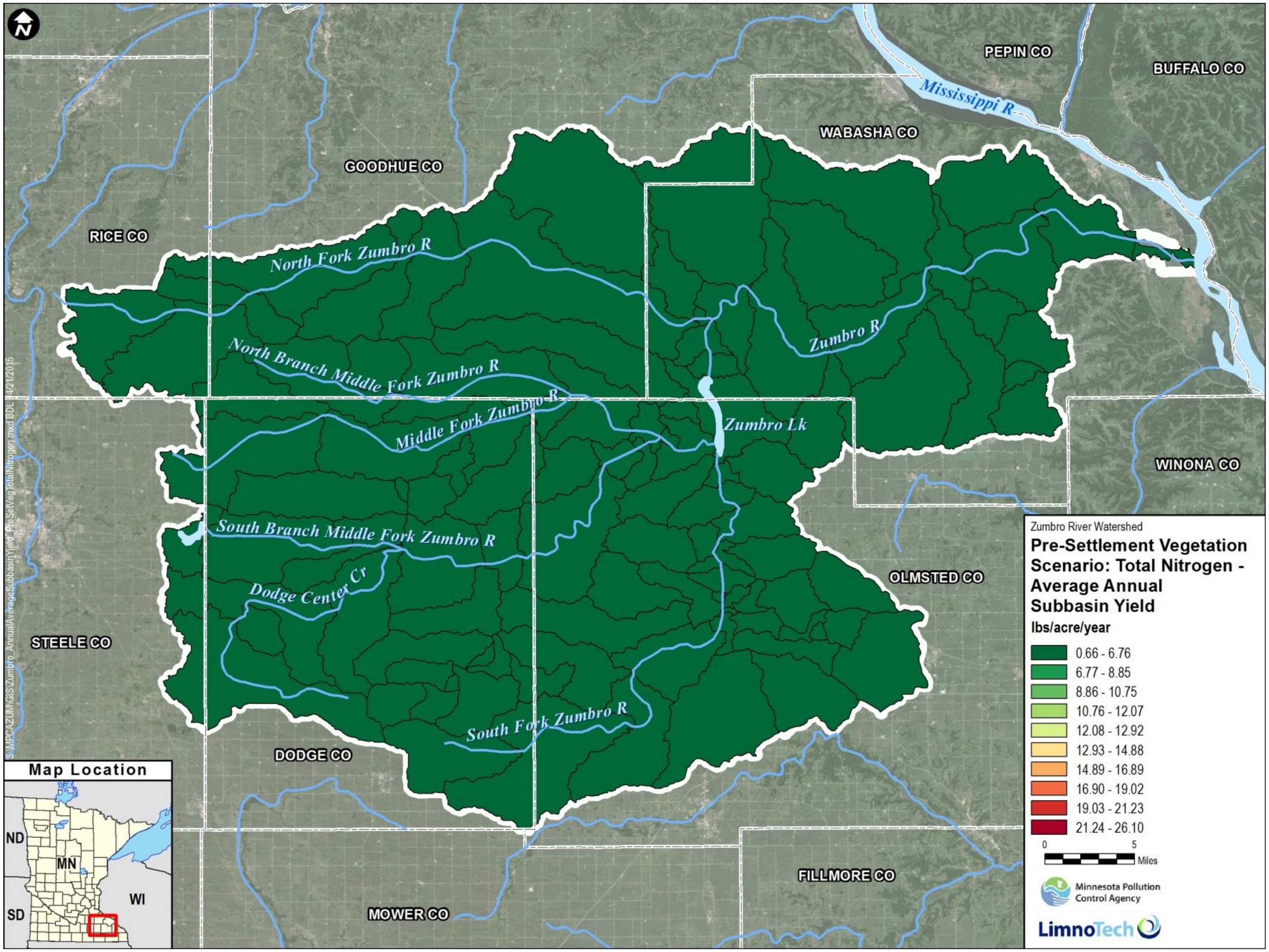

Figure C-5. Average annual total nitrogen subbasin yield for the pre-settlement vegetation scenario.

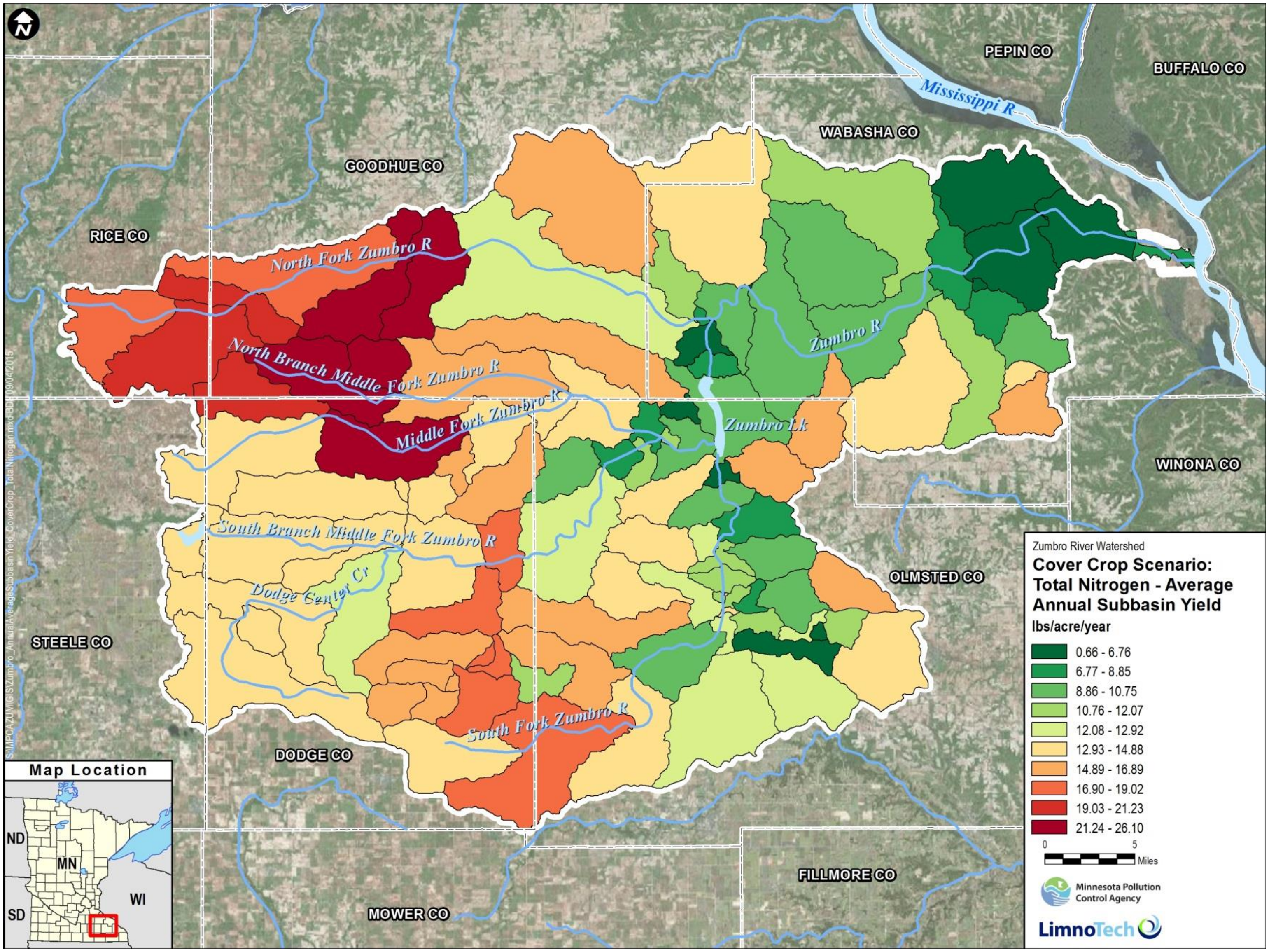

Figure C-6. Average annual total nitrogen subbasin yield for the cover crops scenario.

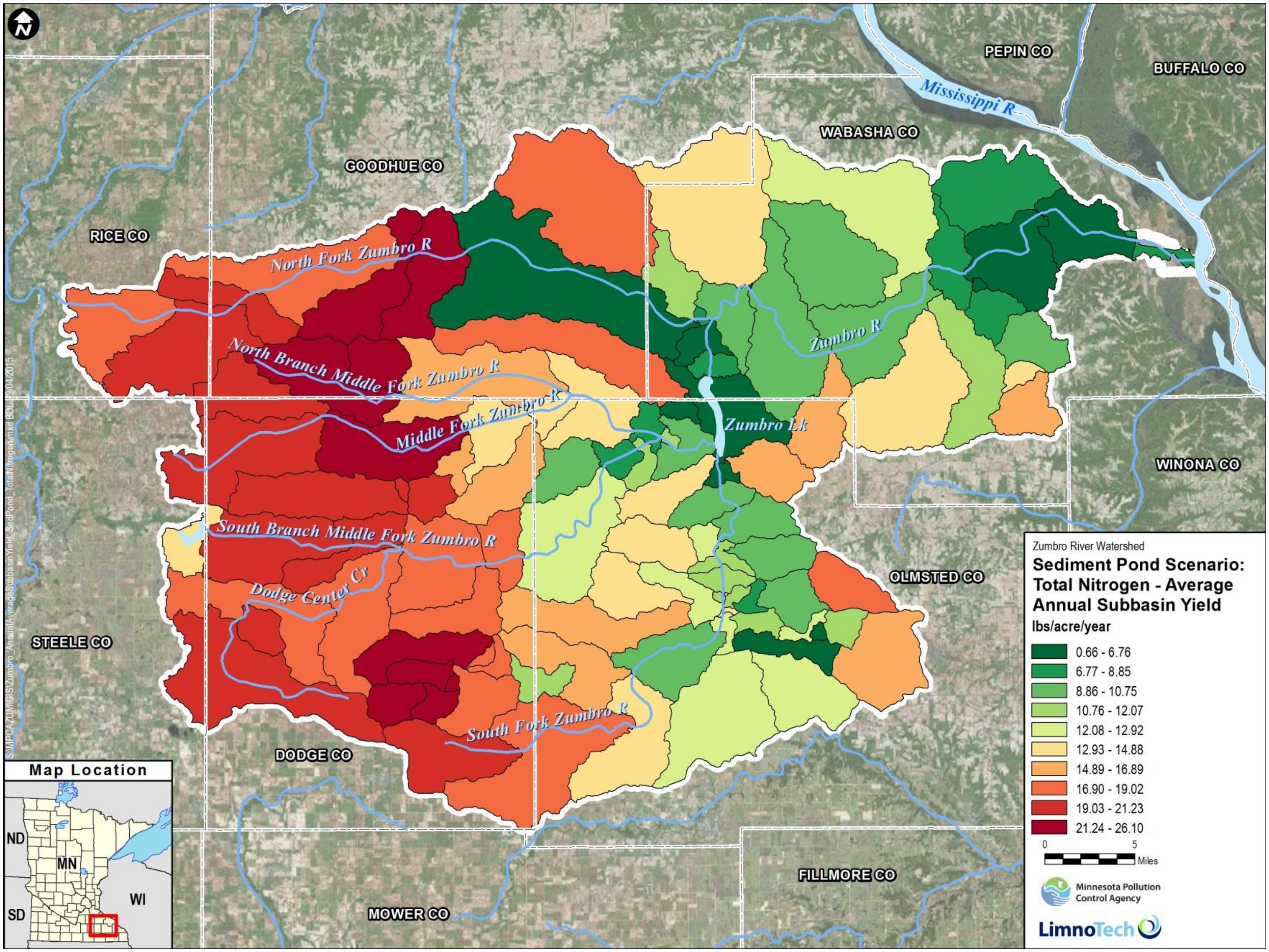

Figure C-7. Average annual total nitrogen subbasin yield for the sedimentation pond scenario.

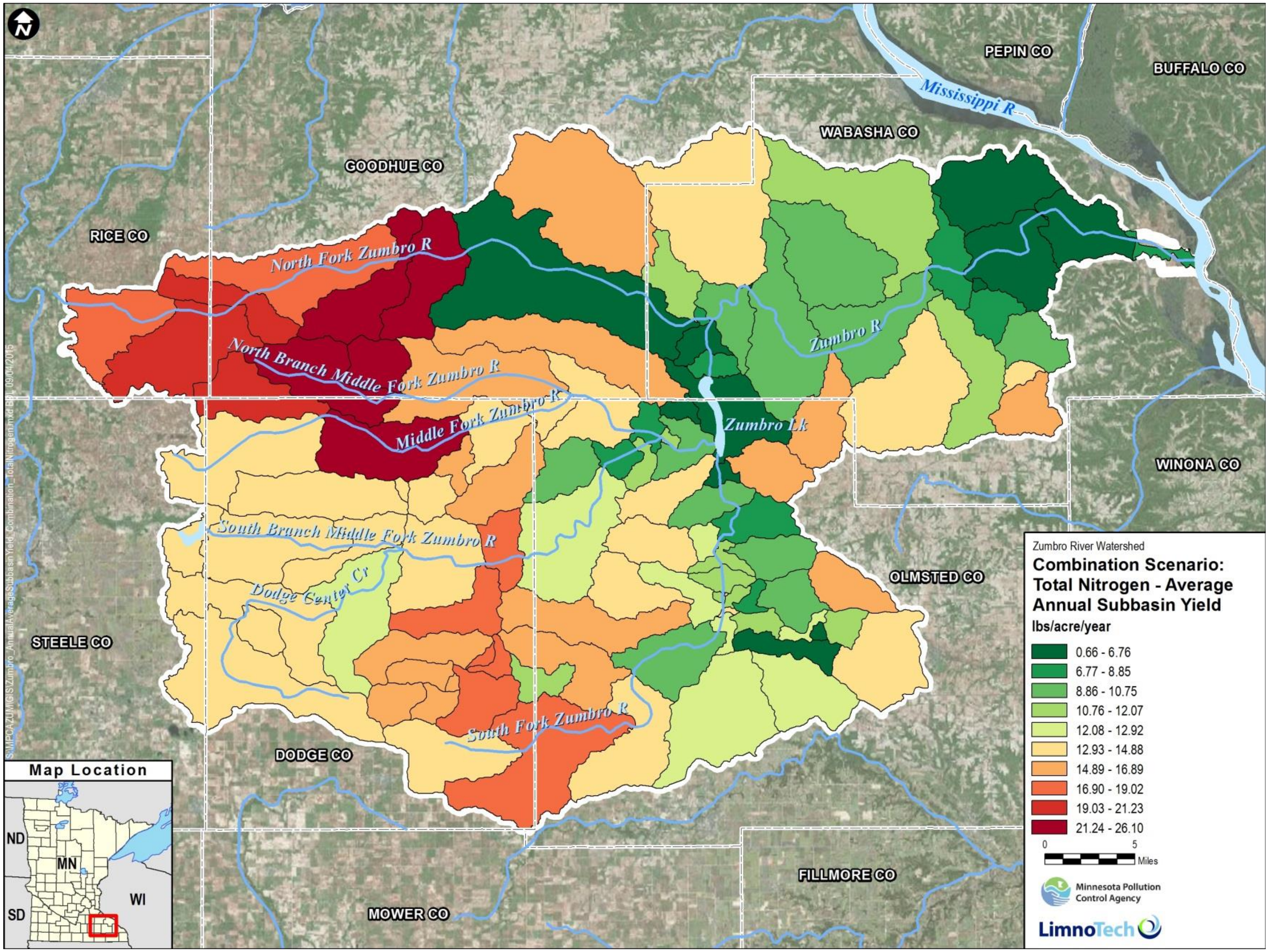

Figure C-8. Average annual total nitrogen subbasin yield for the combination scenario. Note that the maps only represent landscape yields and do not account for changes in point source discharge.

Appendix C Root River field runoff field to stream partnership

FIELD RUNOFF

Root River Field to Stream Partnership

PRIMARY PROJECT GOAL

Determine the range of sediment and nutrient losses associated with runoff from representative farming systems and small watersheds in southeastern Minnesota.

Status:

Data collected from four fields, collected over seven years (2010–2018).

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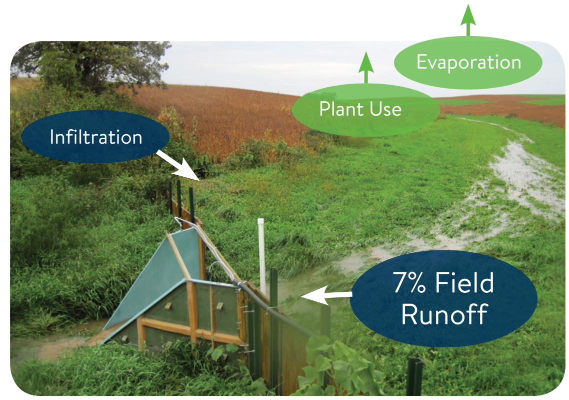
www.mda.state.mn.us/rrfsp

DEPARTMENT OF AGRICULTURE

April 2019

WHERE DOES THE WATER GO?

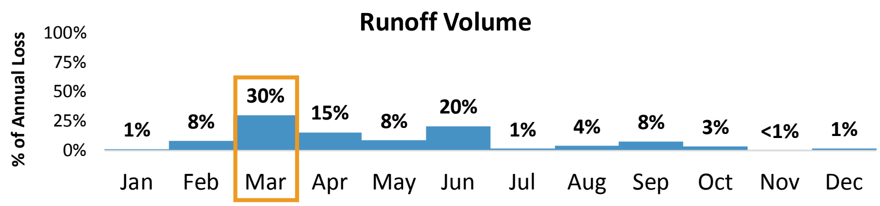


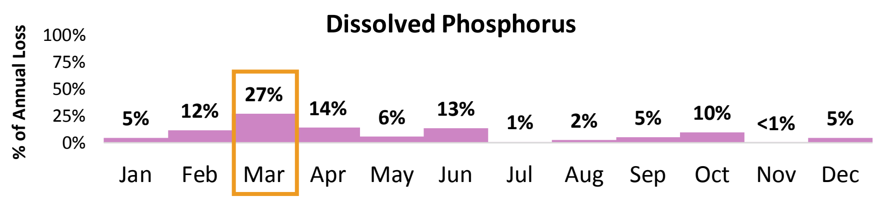
On average, 36 inches of precipitation was received annually. During the study, 7% of this total was measured as field surface runoff with a range of less than 1% in a dry year and up to 24% during a very wet year. How we manage this runoff can make a big difference for clean water.

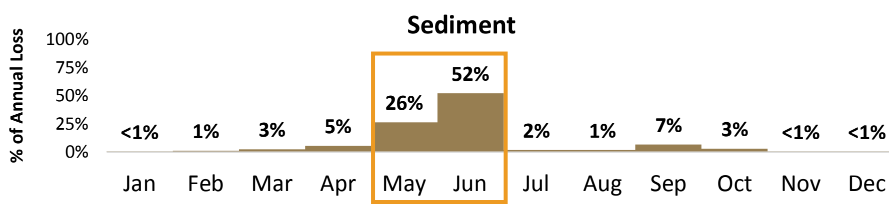
- **On average, 40% of the total runoff volume occurred when the soil was frozen.**
- Over 50% of the annual nutrient and sediment losses typically occurred during 1-2 rain events each year.

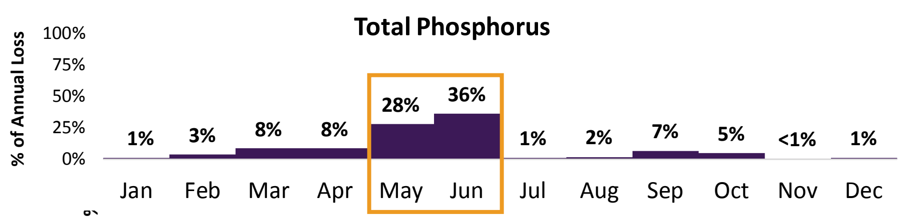
High Risk Periods

Sediment and nutrient losses peak at varying times of the year. Understanding these risk periods is key to reducing loss.









- Dissolved phosphorus losses were highest in March and often occur when the ground is frozen. **Incorporation of fertilizer and proper management of soil test phosphorus levels will help reduce these losses.**
- Nearly 80% of the sediment loss occurred during May and June. Total phosphorus loss is closely linked to soil loss. **Good soil conservation practices will help reduce these losses.**

Precipitation & Runoff

- Precipitation averaged 4% above normal during the study period with a mix of dry, normal and wet conditions.
- Field runoff averaged 2.7 inches (7% of annual precip.) with 40% occurring during frozen soil conditions.
- Field surface runoff has been observed in every month averaging 20 runoff events each year. Runoff does not occur every time it rains.

Field Sediment Loss

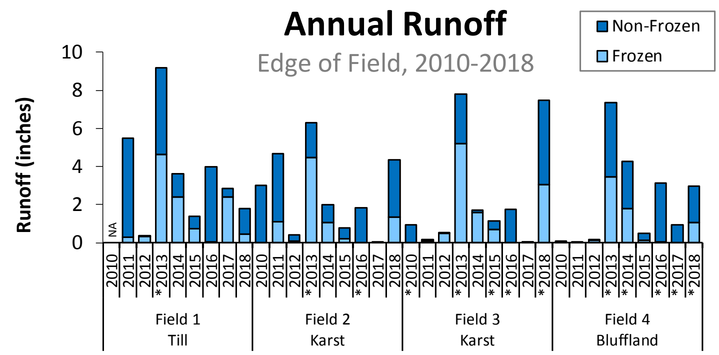
- **Average sediment loss:** 1,461 lb/ac. (0.7 tons/ac.)
  Range: <1 to 8,969 lb/ac.
- **Sustainable soil loss:** < 1,000 lb/ac./year
  If erosion is visible, losses likely exceed this.
- 78% of annual loss occurred during select storms in May & June. During this critical time, fields were prepared for planting, but not at full canopy.

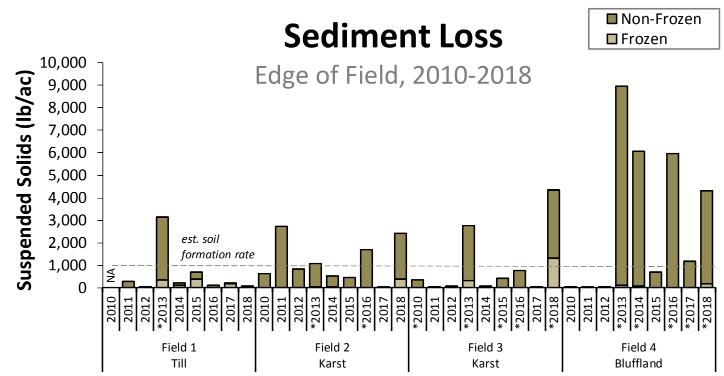
Field Phosphorus Loss

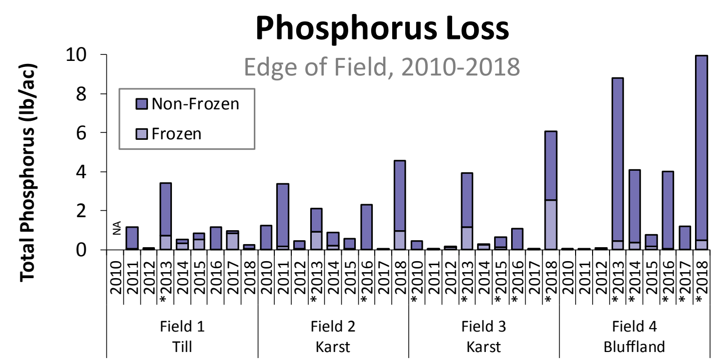
- **Average total phosphorus (P) loss:** 1.9 lb/ac.
  Range: <0.1 to 10.0 lb/ac.
- **Dissolve P (not attached to sediment):**
  Accounts for 16% of total P loss (44% of this loss occurs when the ground is frozen).
- **Particulate P (attached to sediment):**
  64% of loss occurred in May & June.
- For every 1,000 lb/ac. of sediment loss about 1.0 lb/ac. of P is lost. Goal is to keep this loss to less than 1.0 lb/ac./yr.

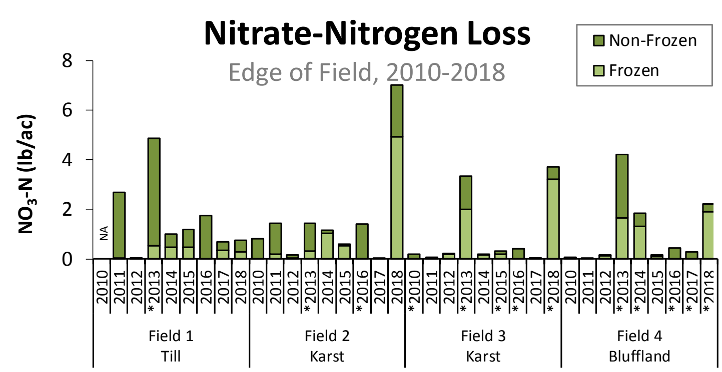
Field Nitrogen Loss

- **Average Total Nitrogen (TN) loss:**
  9.8 lb/ac. (includes organic form of N) if substantial soil loss occurs, TN in surface runoff can exceed 37 lb/ac.
  - **Nitrate-N form:** 17% of TN
    Range: <0.1 to 4.9 lb/ac.
    Surface average runoff loss: 1.6 lb/ac.
    Sub-surface average tile loss: 41 lb/ac., max 63 lb/ac.
- **Surface Runoff:** Total nitrogen transported in surface runoff can be controlled through soil conservation.
- **Sub-Surface Leaching:** Most nitrogen is lost this way and is detected as nitrate-nitrogen in tile drainage, springs, streams, rivers, and groundwater.









*Loss was underestimated during overtop events

Reducing nitrate leaching losses will be challenging, but it is a very important task. Fine-tuning nitrogen rates, split applying nitrogen, crediting legumes and manure, growing perennials, and using cover crops are important practices.