Lower Muskegon River Watershed Management Plan

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Muskegon River Watershed Assembly

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For a watershed management plan to be successful, there needs to be a dedicated group of local people involved in its creation. This involvement will help ensure long-term success. In developing the Lower Muskegon River Watershed Management Plan there were several committed individuals from the Muskegon River Watershed Assembly (MRWA), Trout Unlimited (TU), Grand Valley State University, the Newaygo Conservation District, the Michigan Department of Environment, Great Lakes, and Energy (EGLE), and Encompass Socio-ecological Consulting. These partners are committed to carrying out goals and objectives outlined in the plan.

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ACRONYMS

303(d)	Impaired Waters and Total Maximum Daily Loads section of Clean Water Act
303(d) list	state list of water bodies that do not meet water quality standards
319 NPS	Nonpoint Source Pollution Control Grants, Clean Water Act Section 319
ac	acres
ACPF	Agricultural Conservation Planning Framework
AIS	aquatic invasive species
AUID	Assessment Unit Identification
AWRI	Robert B. Annis Water Research Institute, Grand Valley State University
BMP	best management practice
BOD	biochemical oxygen demand
C	Celsius
CAFP	Concentrated Animal Feeding Operation
CCD	County Conservation District
CDC	County Drain Commission
CFS	cubic feet per second
cfu	colony-forming unit
CHD	County Health Department
CLMP	Cooperative Lakes Monitoring Program
CPD	County Parks Department
CW	coldwater
DNR	Department of Natural Resources
DOT	Department of Transportation
EGLE	Department of Environment, Great Lakes, and Energy, State of Michigan
EPA	Environmental Protection Agency, United States
EQIP	Environmental Quality Incentives Program
F	Fahrenheit
ft	feet
FSU	Ferris State University
GIS	geographic information system
GLFT	Great Lakes Fishery Trust
GLRI	Great Lakes Restoration Initiative
GVSU	Grand Valley State University
ha	hectares
HUC	Hydrologic Unit Code
I&E	Information and education
IR	Integrated Report
K	known pollutant
K factor	soil erodibility
l/s	liters per second
lbs/yr	pounds per year
LCWM `	Land Conservancy of West Michigan
LID	Low impact development

LiDAR	Light Detection and Ranging remote sensing method
LLWFA	Landscape Level Wetland Functional Assessment
LMR	Lower Muskegon River
LMRW	Lower Muskegon River Watershed
LMRWMP	Lower Muskegon River Watershed Management Plan
LS	Local schools
LRBOI	Little River Band of Ottawa Indians
MAEAP	Michigan Agriculture Environmental Assurance Program
MCCI	Midwest Cover Crops Initiative, Ducks Unlimited
MCRRC	Muskegon County Resource Recovery Center
MDARD	Michigan Department of Agriculture & Rural Development
MDNR	Michigan Department of Natural Resources
mg	milligram
mg/L	milligrams per liter
mi	miles
ml	milliliter
MiCorps	Michigan Clean Water Corps
MNFI	Michigan Natural Features Inventory
MRI	Michigan Rivers Inventory
MRWA	Muskegon River Watershed Assembly
MRWMP	Muskegon River Watershed Management Plan
MSUW	Michigan State University Extension
NCD	Newaygo Conservation District
NRCS	Natural Resources Conservation Service
NPS	Nonpoint source pollution
NREPA	Natural Resources and Environmental Protection Act
NWI	National Wetlands Inventory
OHWM	Ordinary High-Water Mark
PCBs	polychlorinated biphenyls
PFAS	per- and polyfluoroalkyl substances
PLET	Pollution Load Estimation Tool
QAPP	Quality Assurance Project Plan
RCPP	Regional Conservation Partnership Program
S	Suspected pollutant
SESC	Soil Erosion and Sedimentation Control
SOGL	Sustain Our Great Lakes
SPI	Stream Power Index
TMDL	Total Maximum Daily Loads
TN	Total Nitrogen
TP	Total Phosphorus
TP/h	Total Phosphorus per hour
TP-P	Total Phosphorus as Phosphorus
TSS	Total Suspended Solids
TSS/h	Total Suspended Soils per hour

TU	Trout Unlimited
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Service
VSEC	Valley Segment Ecological Classification
WASCOB	Water and Sediment Control Basin
WRP	Wetlands Reserve Program
WMP	Watershed Management Plan
WQC	Water Quality Criteria
WQS	Water Quality Standards
WW	warmwater

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- **Know the location of the Lower Muskegon River Watershed**
- **Understand the purpose of a watershed management plan**
- **Learn how the public was informed and involved in this process**

Introduction

1.1 Chapter 1 Summary

Highlighted below are some of the major points that you will learn in Chapter 1.

⇒ A watershed is the land that water flows across or under on its way to a river, lake, wetland, or body of water.

⇒ Every watershed is different in terms of its shape, size, and landscape features. However, one thing remains the same—everyone lives in a watershed.

⇒ The Muskegon River Watershed is the 2nd largest in the State of Michigan and covers 261 square miles. To effectively manage the watershed a more focused approach is needed.

⇒ The focus of this plan, the Lower Muskegon River Watershed (LMRW), includes four subwatersheds located in parts of Muskegon and Newaygo counties in west central Michigan.

⇒ To make land use decisions that will not jeopardize environmental and human health, a natural boundary — such as a watershed — should be recognized.

⇒ An appropriate tool for management within this natural boundary is the watershed management plan. This plan provides a broad understanding of watershed function and status, and recommends actions for appropriate resource management.

⇒ For a watershed management plan to be successful, there needs to be a dedicated group of local people involved in its creation and who implement the recommendations. In developing the Lower Muskegon River Watershed Management Plan (LMRWMP) there were several committed individuals from the following organizations: Muskegon River Watershed Assembly, Trout Unlimited, Grand Valley State University, the Newaygo Conservation District, Michigan Department of Environment, Great Lakes, and Energy and Encompass Socio-ecological Consulting.

⇒ Public involvement is a critical component in the watershed planning process. Through meaningful public input, needs from watershed stakeholders can be addressed and a shared mission can be developed to protect the watershed.

The Lower Muskegon River.

1.2 What is a watershed?

A watershed is the land that water flows across or under on its way to a river, lake, wetland, or other body of water. As precipitation falls to the ground, the water is pulled downhill by gravity, which causes it to flow over the landscape or infiltrate through the soil into the groundwater (Figure 1.1). Watershed boundaries can be identified by tracing along the highest elevations between two areas, often a ridge and sometimes referred to as a divide. Therefore, watersheds do not follow political boundaries and can include many counties and even span across several states or different countries.

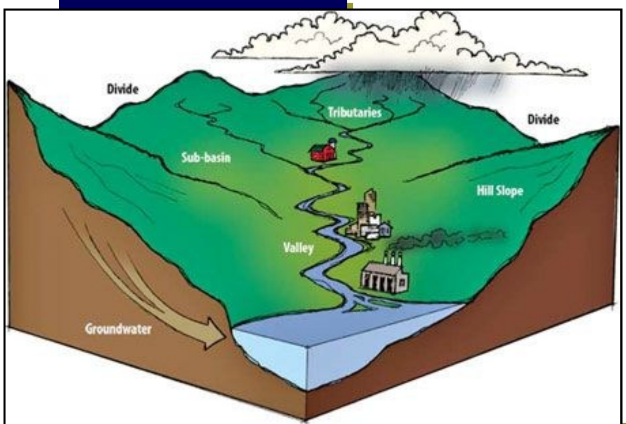


Figure 1.1. A diagram of a watershed. Diagram provided by Ducks Unlimited.

Watersheds can be identified on different scales. Large-scale watersheds are composed of smaller areas called subwatersheds. For example, there are 40 subwatersheds that make up the LMRW. The Muskegon River Watershed is part of the larger Lake Michigan Watershed (Figure 1.2).

Every watershed is different in terms of its shape, size, and landscape features. But one thing remains the same: everyone lives in a watershed. You are part of a watershed community and everything you do, good or bad, in your watershed affects the soil, water, air, plants, and animals.

1.3 Why focus on the Lower Muskegon River Watershed?

The Muskegon River Watershed drains more than 2,500 square miles of land area, second only to the Grand River Watershed. Because of the immense size, the initial Watershed Management Plan identified the need for updates that focused on smaller segments to provide more detailed and thorough inventories and recommendations. The intent of the 'focusing' is to gain site-specific information to measure water quality improvements and identify areas of pollutants, which will lead to best management practices (BMP) recommendations that are tailored to the specific needs of individual sites. Further, much has changed in the watershed and project area since the current plan was written in 2002, with an increase in urbanization and other significant land use shifts.

Accordingly, the focus of this watershed management plan update is the Lower Muskegon River Watershed (LMRW), it contains approximately 10.5% of the land area compared to the Muskegon River Watershed and allows for a much more focused approach. The reduced area is in parts of two counties, beginning near Croton Dam and extending approximately 30 miles downstream to US-31 to the lower river wetland complex (Figure 1.3). It includes four subwatersheds; Bigelow Creek, Hess Lake, Brooks Creek and Mosquito Creek. The area is likely most used for fishing, watercraft, and agricultural production. The waterways within the four subwatersheds show a high range of differences for water quality and land use including temperature fluctuations, percent agricultural land, and percentage of natural areas (forests and wetlands). Understanding these differences is important when developing appropriate recommendations for BMPs and identifying the status of designated uses.

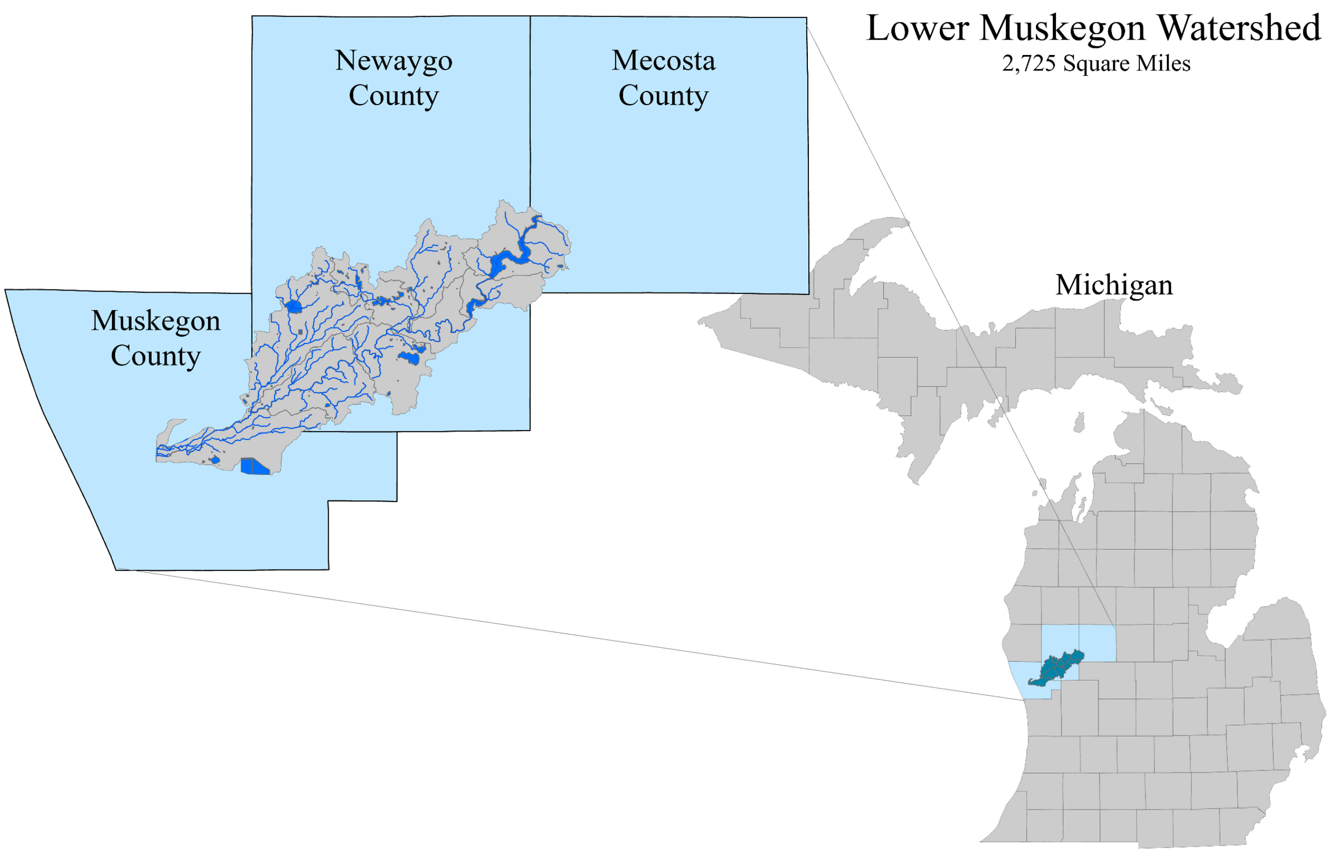


Figure 1.2. Watershed Reference Map. Produced by TU, 2023.

1.4 What is the purpose of a watershed management plan?

There are interconnections between human activities on land and what happens to water and subsequently to the organisms that use the water. Traditionally, land use planning has been based on jurisdictional boundaries established by humans and includes states, Native American treaty boundaries, townships, counties, or school districts. Many organizations and municipalities have recognized that this compartmentalized land use planning approach does not always adequately protect the environment.

To make land use decisions that protects and improves environmental and human health, an ecosystem approach needs to be considered. By acknowledging a natural boundary, such as a watershed, relationships between the natural environment and human activities can be addressed. An appropriate tool for management within this natural boundary is the watershed management plan. A watershed management plan can provide a broad understanding of watershed function and status, and can recommend actions for appropriate resource management. This can help to identify relevant ecosystem considerations that can be integrated into land use planning and decisions.

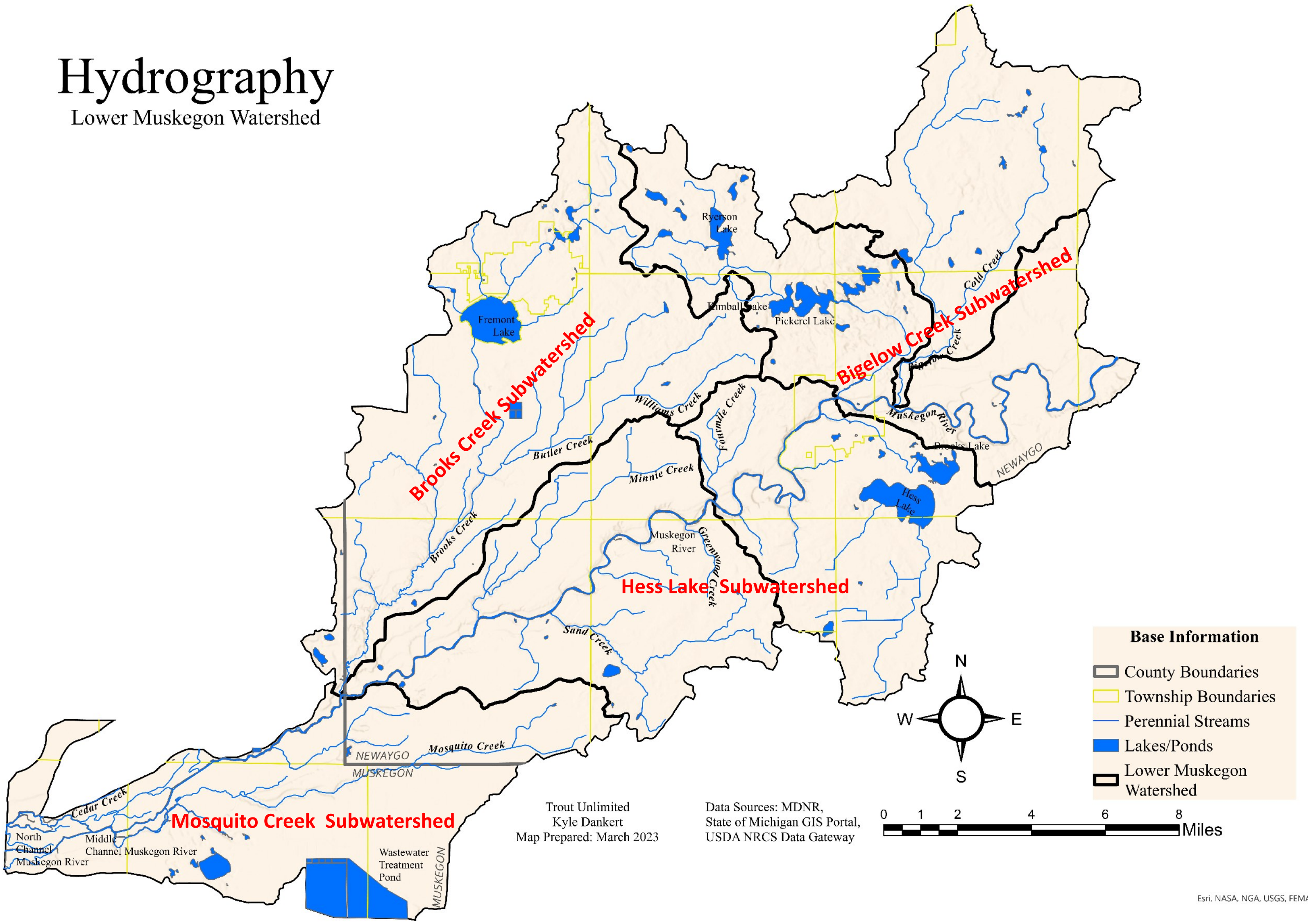


Figure 1.3. Political boundaries, hydrography, and subwatershed boundaries of the Lower Muskegon River Watershed project area. Produced by TU, 2023.

1.5 Who helps to develop a watershed management plan?

For a watershed management plan to be successful, there needs to be a dedicated group of local people involved in its creation. This involvement will help ensure long-term success. In developing the LMRWMP there were several committed individuals from the Muskegon River Watershed Assembly, Trout Unlimited, Grand Valley State University, the Newaygo Conservation District, the Michigan Department of Environment, Great Lakes, and Energy, and Encompass Socio-ecological Consulting. These partners are committed to carrying out goals and objectives outlined in the plan.

Four project articles were written and two stakeholder meetings hosted to gather public input and share watershed-related information. Public involvement is a critical component in a watershed planning process. Government consultation is also important, and along with local governments experts from the Michigan Department of Natural Resources Fisheries Division, the Little River Band of Ottawa Indians Natural Resources Department and the United States Fish and Wildlife Service provided conversational feedback and reports relevant to the management plan. Through meaningful public and government input, needs from watershed stakeholders can be addressed and a shared mission can be developed to protect the watershed.

Decisions we make on the land affect the health of our waterways. The information in a watershed management plan can help to integrate land use and planning with the needs of our environment.

1.6 Resources

Listed below are sites where you can learn more about watersheds, watershed planning, and the groups involved in creating the Lower Muskegon River Watershed Management Plan.

- ⇒ An introduction to Michigan Watersheds for teachers, students and residents: www.mi-wea.org/docs/11-405-Watershed-Teaching-Guide-rev-2012.pdf
- ⇒ Muskegon River Watershed Management Plan: https://mrwa.org/wp-content/uploads/repository/MuskegonManagementPlan.pdf
- ⇒ Muskegon River Watershed Assessment (1997 Michigan DNR Report by Rich O'Neal): https://mrwa.org/wp-content/uploads/2022/01/Muskegon-River-Watershed-Assessment-Appendices.pdf
- ⇒ Muskegon River Watershed Data Repository: https://mrwa.org/repository/
- ⇒ Muskegon Futures (8 volume summary of the Mega Model): https://mrwa.org/?s=muskegon+futures&region=0&topic=0&post_type=data_repository
- ⇒ Grand Valley State University Robert B. Annis Water Resources Institute: www.gvsu.edu/wri/
- ⇒ Michigan Department of Environment, Great Lakes, and Energy: www.michigan.gov/egle/
- ⇒ Newaygo Conservation District: www.newaygocd.org/
- ⇒ Trout Unlimited: www.tu.org
- ⇒ Book: Alexander, J. (2007). The Muskegon: The Majesty and Tragedy of Michigan's Rarest River.

Chapter 2: Watershed Characteristics

INSIDE THIS CHAPTER:

- **Understand the geology of the watershed**
- **Learn historical uses of the watershed**
- **Discover the ecology of the watershed**
- **Illustrate land use in the watershed**
- **Understand social characteristics of the watershed**

Introduction

2.1 Chapter 2 Summary

Highlighted below are some of the major points that you will learn in Chapter 2.

⇒ The landforms and soils that control the shape and distribution of streams and drainages in the Muskegon River Watershed are the direct result of glacial processes.

⇒ The soil in the study area typically includes permeable sands mixed with varying proportions of clay, silt and gravel. The topography generally has flat ground and low hills. Some streams have carved channels with steep slopes.

⇒ An ancient prophecy led the Anishinaabek to the area known today as the Muskegon River Watershed. This watershed remains as a place for their sacred connectedness to the land and inherent autonomy as a People.

⇒ Humans gain many vital services from the watershed that include recreation, cultural uses, and economy.

⇒ The lower watershed harbors over 77 species of fish and is considered one of the most diverse fisheries on the eastern shoreline of Lake Michigan. It includes the state threatened lake sturgeon, healthy populations of warmwater species such as smallmouth bass and catfish, as well as a relatively abundant coldwater-coolwater fishery with native species (brook trout). There is also a desirable, non-native fishery for Chinook salmon and steelhead trout.

⇒ The Maple River area of the watershed is highly diverse, there are 12 natural community types of the 77 that exist in Michigan. These natural communities harbor rare animal species, including the bald eagle, Blanding's turtle, wood turtle, Massasauga rattle snake, and red-shouldered hawk.

⇒ The Lower Muskegon River Watershed (LMRW) had approximately 39,270 acres of wetland prior to European habitation compared to a 2005 estimate of 21,749 acres—a 45% wetland loss.

⇒ Land use in the LMRW is a mix of forest (60%), agriculture (34%), with urban areas (5%)—cities of Fremont and Newaygo.

⇒ Climate change is a global problem with unique local impacts. In general, a warmer atmosphere holds more moisture, leading to more frequent and intense rainstorms and floods.

⇒ The LMRW is contained by Muskegon and Newaygo counties and 18 townships. The socio-political character of these counties and townships, reflects a range of community types, from an industrialized urban center in Fremont and Newaygo to rural places surrounded by the Huron-Manistee National Forest and the Muskegon State Game Area.

⇒ Many governmental organizations create the mosaic of jurisdictional and political characteristics of the watershed. Federal, State, Tribal and local laws and regulations govern how the watershed is managed and used.

2.2 Geology

Geology is the study of the Earth, the materials of which it is made, the structure of those materials, and the processes acting upon them. Geology is important because it gives us insight as to why there are different landscapes within the watershed.

Glacial History

The landforms and soils that control the shape and distribution of streams and drainages in the Muskegon River Watershed are the direct result of glacial processes. Around 75,000 years ago glaciers in northern Canada began growing and expanding southward during what is called the Wisconsin Glaciation (Figure 2.1). The maximum extent of this glaciation occurred about 23,000 years ago when the ice margin reached central Ohio and Indiana. Ice at the glacier margin began to retreat back to the north about 21,500 years ago and by about 13,000 years ago ice had melted completely off the Lower Peninsula.

As the glaciers expanded and flowed over bedrock they ripped up rock fragments that became incorporated within the ice. These rock fragments were then transported within the ice where they gradually broke down into a wide range of sizes from clay to sand to pebbles, cobbles and boulders. When the ice margin began to melt back, this rock debris was freed from the ice and deposited in different ways. In the upstream region of the LMRW study area, the glacial deposits are primarily composed of sediments deposited in meltwater streams (outwash), and directly from glacial ice (till). Lake sediments deposited during high stands of ancient Lake Michigan are present downstream in the study area from about Maple River Island to Muskegon. Each of these sediment types resulted in characteristic soils and landforms.

Figure 2.1. The Wisconsin Glaciation. Provided by Steven Earle, 2019.

Soils and Topography

The primary factors controlling soil types in Michigan are the parent material from which the soil develops and time (other factors include climate, organic activity, and topography). The parent materials in the lower watershed are the sediments that comprise the lake, outwash and till deposits. Geologically, these deposits are quite young so soil formation has not significantly altered the original parent material and soils do not typically extend too deep (1-2 meters). Therefore, as in most of Michigan, soils in the LMRW strongly reflect the original glacial sediment types (Figure 2.2).

The glacial lake sediments found from the City of Muskegon to upstream of Maple Island were deposited during a high stand of ancient Lake Michigan when lake waters extended well inland of the present-day shoreline. These sediments, and the soils that have formed on them, are typically quite permeable sands mixed with varying proportions of clay, silt and gravel (Figures 2.3 and 2.4). The topography of this area reflects the original lake environment of deposition with generally flat ground and low hills. As the original lake levels dropped to present-day elevations, streams cut down through the exposed lake sands to carve channels, often with steep slopes. Along and near the Lake Michigan shoreline, these ancient lake sands have been moved by wind action to build the prominent sand dunes that are now found there.

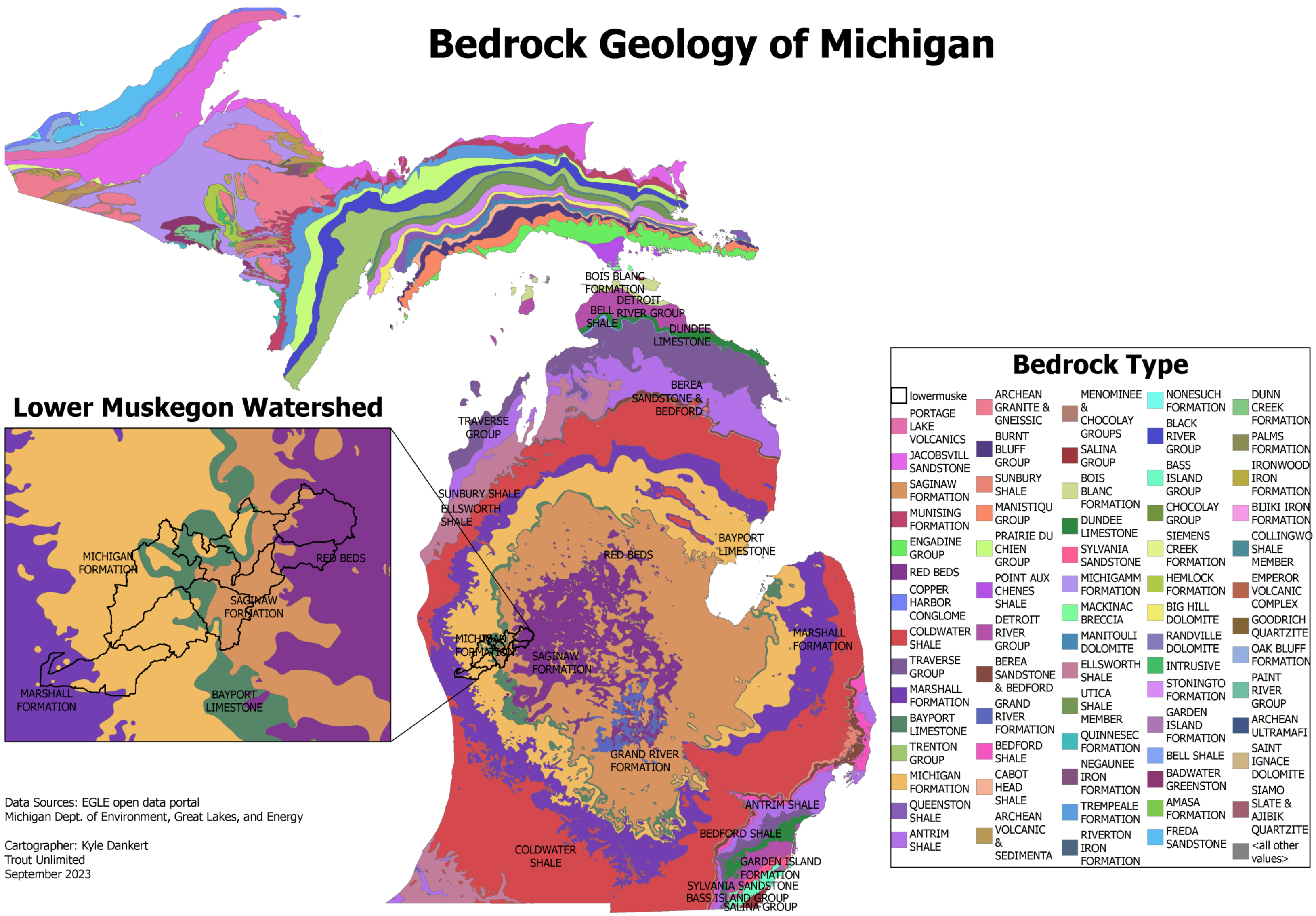


Figure 2.2. Surface Geology in Michigan. Produced by TU, 2023.

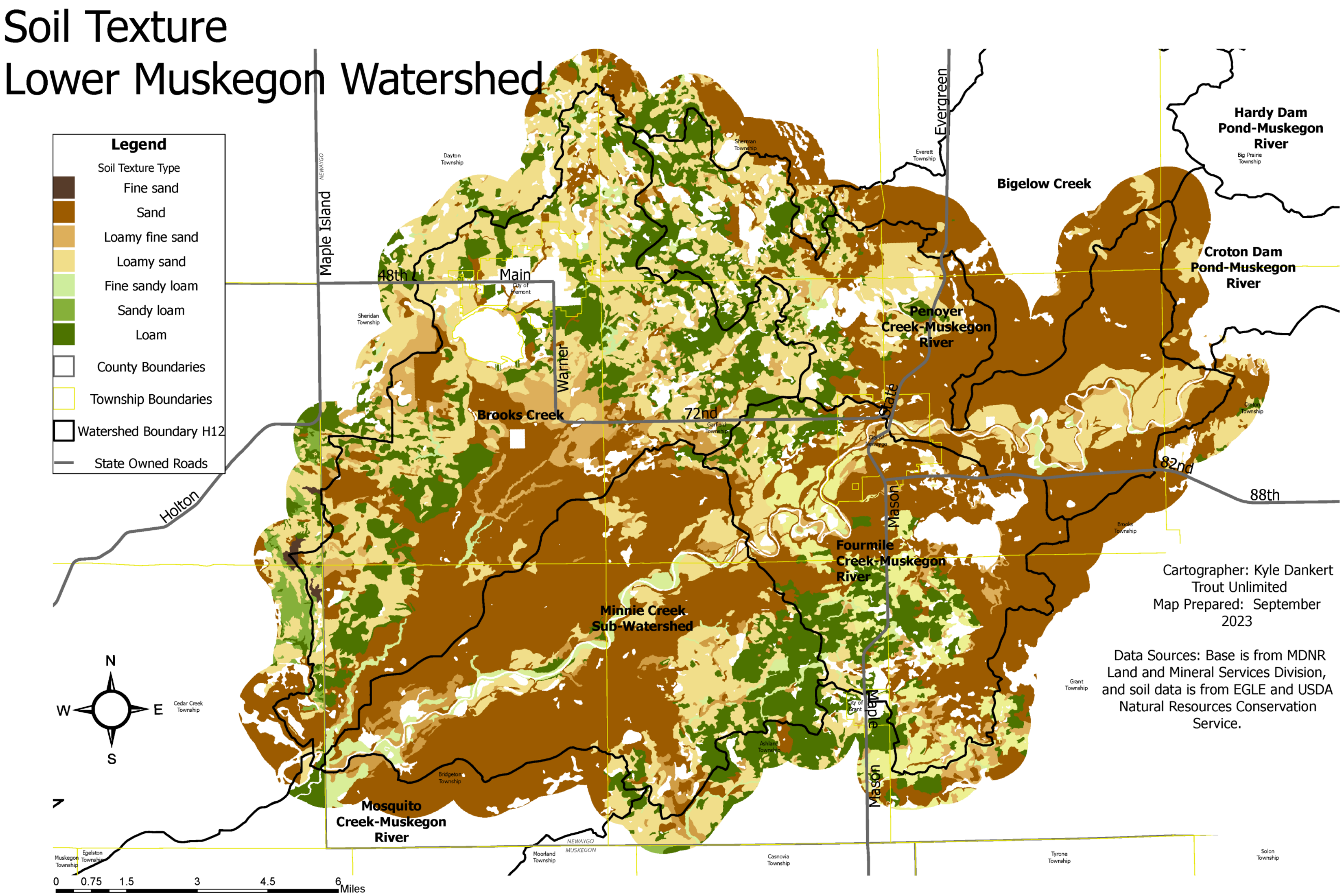


Figure 2.3. Soil Texture in the Lower Muskegon River Watershed. Produced by TU, 2023.

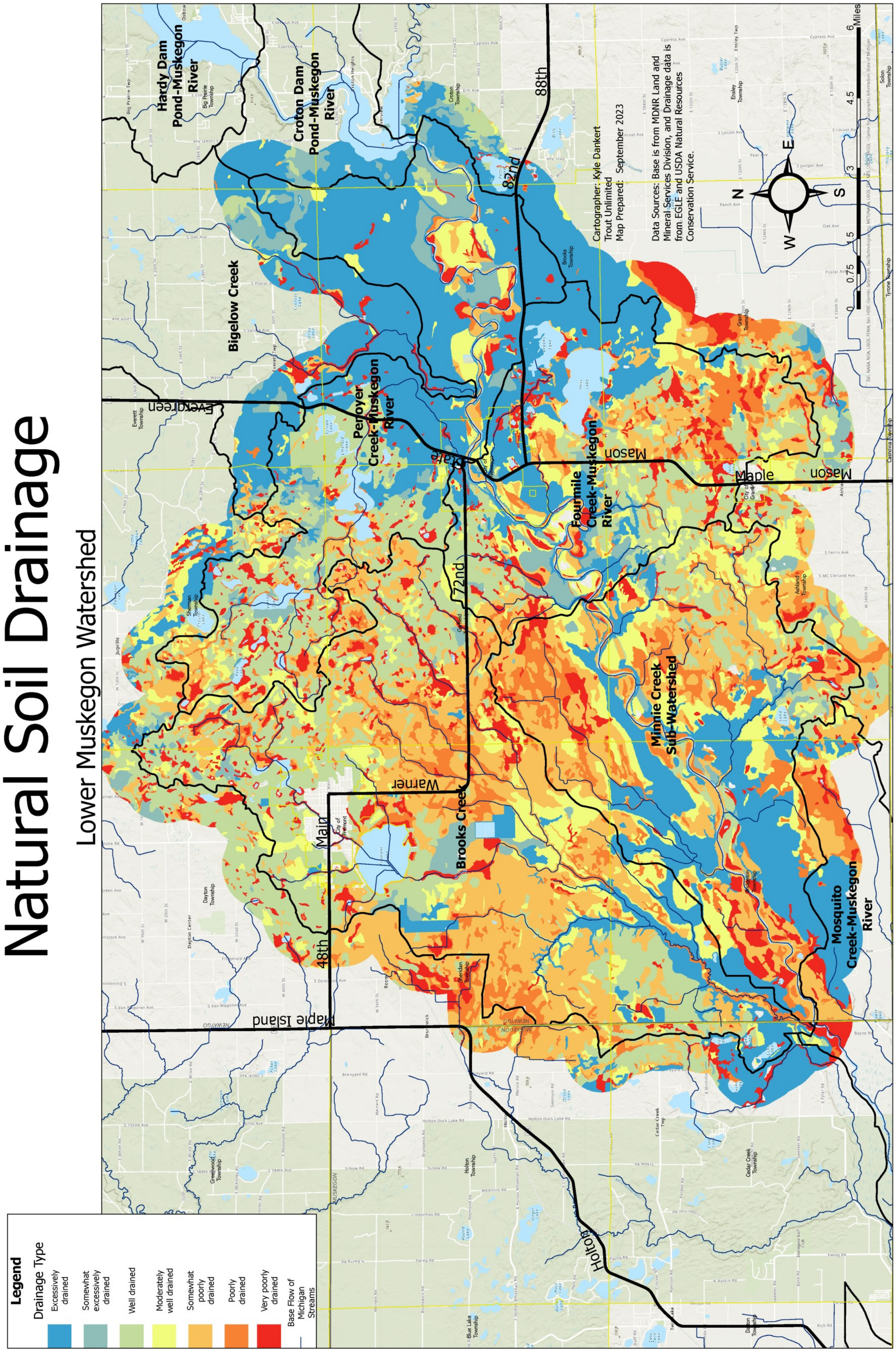
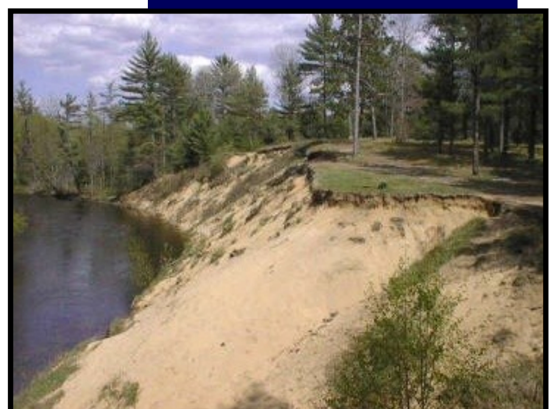


Figure 2.4. Natural soil drainage in the Lower Muskegon River Watershed. Produced by TU, 2023.

2.2 Geology (continued)

In upstream regions of the LMRW, glacial outwash and till are the primary sediment types. Outwash sediments were deposited by meltwater streams flowing away from the ice margins. The soils formed on these sediments are, like the lake deposits, permeable sands with differing proportions of clay, silt and gravel. Topographically, outwash typically forms upland plateaus that have relatively low relief except where incised by post-glacial streams which can carve deep valleys with steep slopes. Within the LMRW, the steep banks and flat terraces along the Muskegon River were formed as its ancestral meltwater stream cut down through previously deposited outwash and till sediments.

Till sediments are deposited directly from melting ice so there is little opportunity for stream or wave action to sort these sediments into the sand rich deposits of lake and outwash sediments. Till is therefore a random mix of clay, silt, sand, gravel and larger rocks. Most tills, and the soils that form on them, have a much higher clay content than the lake or outwash sediments. Therefore, these soils have a relatively low permeability that slows the downward movement of water and results in a higher soil moisture content than is found in the sandier soils (Figure 2.5). The topography resulting from till deposition can take a variety of forms. A relatively low-relief landscape of rolling hills forms when till is deposited as ground moraine during an active retreat of the ice front. Till deposited along a stationary ice margin results in end moraines which we see today as the prominent, high-relief hills and ridges within the LMRW. Both ground and end moraines can be partially or completely buried by a veneer of outwash sediments as meltwater streams flowed over previously deposited till.



Eroding streambank that deposits sand into the Muskegon River. Photo courtesy of J. M. Holtgren.

Together, the varied landforms and soil types described above controlled the drainage patterns seen within the LMRW today. Steep slopes within outwash plains, as well as stream-cut banks and terraces along streams formed as water flowed away from the ice front and eroded down through the previously deposited sediments. Although they occur much more slowly today, these processes are still active as streams continue to incise the landscape (Figure 2.6). Clay-rich till is much more resistant to stream erosion than outwash sands and gravels. Therefore, the hills and ridges of glacial till often controlled the original paths of present-day streams and drainages as meltwater was forced to flow around them.

2.3 Historical Uses of the Lower Muskegon River Watershed

For millennia, humans have been a part of the Muskegon River Watershed and the Anishinaabek, are known as the original inhabitants and caretakers of the watershed. The inherent connection of the Anishinaabek, as a place-based people to this region, is intrinsically coupled with their self-determined obligation as its caretaker. This historical connection is understood from the passing down of knowledge in their oral tradition, generation to generation, and through scientific investigation. A deep connection to the Mishkigon (Muskegon River) has remained since their arrival, to present times. The name Muskegon, a corrupted spelling of the phrase “Mishkigon”, translates into English as "the place abundant with our healing Medicines".

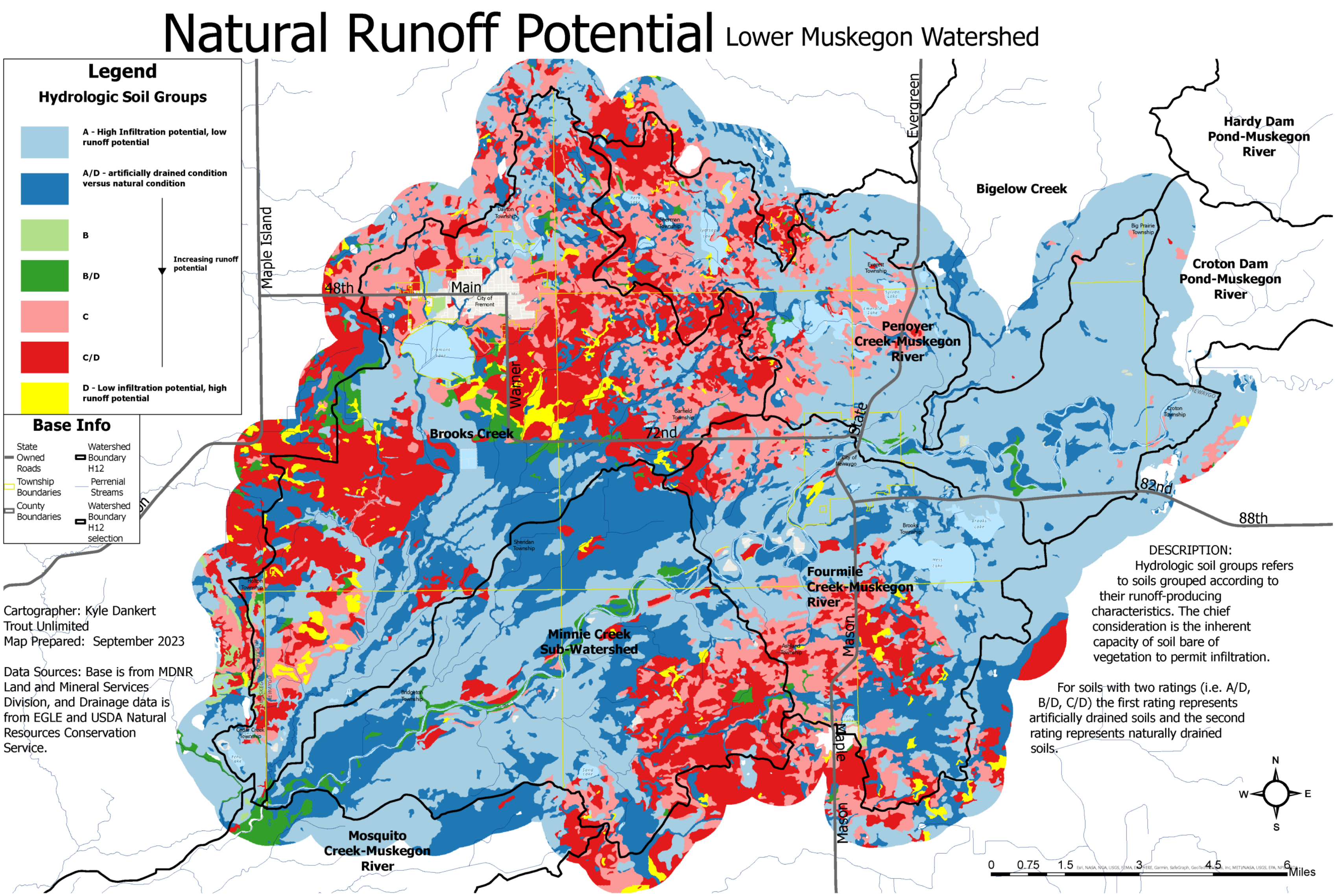


Figure 2.5. Natural runoff potential in the Lower Muskegon River Watershed. Produced by TU, 2023.

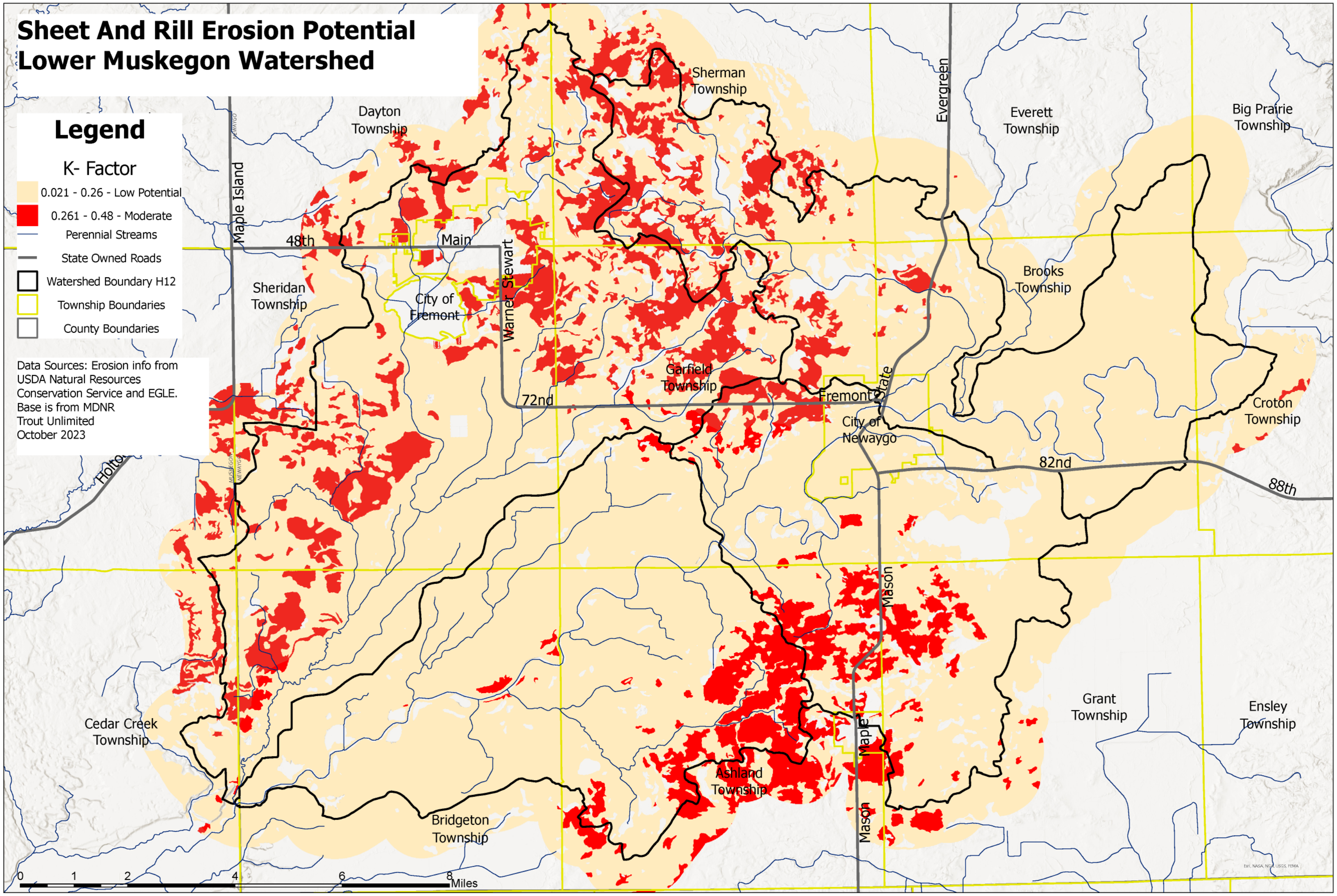


Figure 2.6. Sheet and rill erosion potential in the Lower Muskegon River Watershed. Produced by TU, 2023.

2.3 Historical Uses (continued)

Many Anishinaabek hold the belief that a millennia ago, a prophecy foretold the Anishinaabek, of new people who would either accept them as family or come bearing the fate of their annihilation. The prophecy urged the Anishinaabek to begin a migration from their existing homelands along the eastern shore of North America westward until they discovered a place "where food grows upon the water". The long and arduous journey brought the Anishinaabek to reside in many places within and around the Great Lakes Region where manoomin (wild rice), the food that grows upon the water, was found. The Mishkigon (Muskegon) Watershed had a seemingly endless bounty of naturally occurring food, culturally significant resources, and vast network of navigable waterways. Many of the current roads and trails in the watershed are from historic trails (Figure 2.7).

Maanomin (wild rice) is a food source for Anishinaabek in the Muskegon River watershed. Photo courtesy of the Little River Band of Ottawa Indians Natural Resources Department.

The Anishinabek inhabiting the Muskegon River Watershed continue to practice one of the oldest surviving belief structures from ancient times, known as Baamaadziwin (Mitchell 2013). In the English language it is described as one "living in a good and respectful way" as within one's environment. By practicing the tenets of Baamaadziwin, this obligates practitioners to recognize each impact they make within their environment. These impacts, while necessary for survival in the present, are managed by remaining mindful during the harvesting activity. This mindfulness occurs whether collecting berries or hunting live animals where the amount of anything taken from the environment must be considered and the harvesting ceased when enough is acquired. Falling prey to the desire to take more than is needed or perhaps all, is viewed as committing a sin. This time-honored method of conservation, ensures future generations of all species existing within the watershed, including the Anishinaabek are allowed to co-exist within the fragile balance that Nature so kindly provides, generation after generation. For hundreds of years the Anishinaabek have lived sustainably in the watershed and established villages, seasonal harvest practices, and ceremonies.

Tribal people and governments continue to protect watersheds and have government departments that focus on restoring, reclaiming and enhancing the Muskegon River Watershed. In the 1836 Treaty of Washington, the Tribes ceded millions of acres of land to the United States and retained the right to hunt, fish and gather and to conduct projects that protect and im-

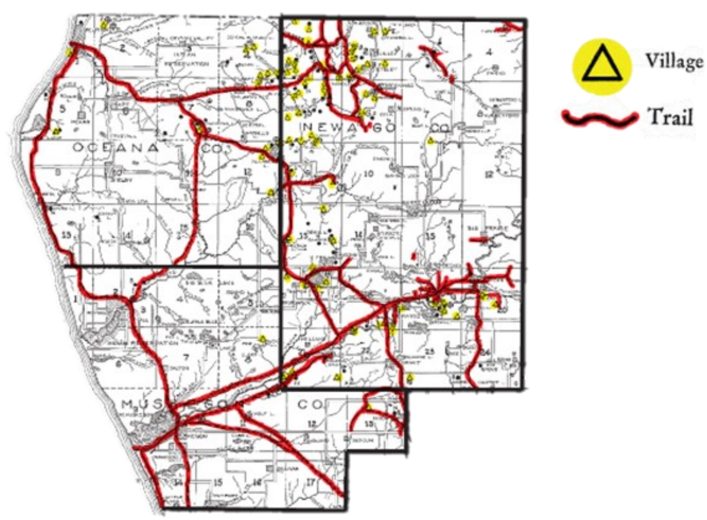
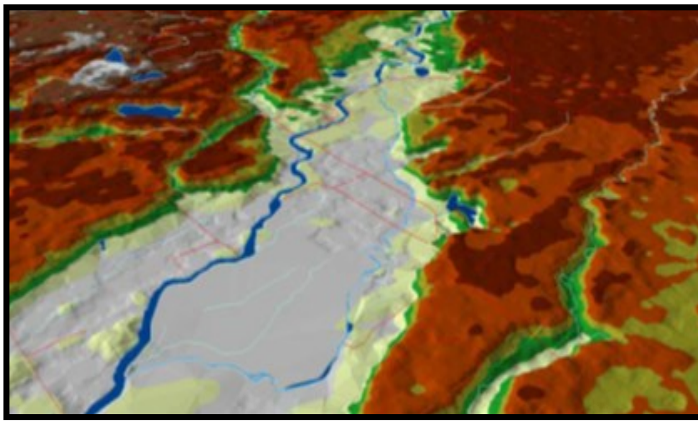


Figure 2.7. Map of Indian Trails in the 1800s.

Maple River

The Maple River area is a treasured portion of the LMRW and houses the Muskegon State Game Area which supports a wide range of natural community types and species. Within the Muskegon State Game Area are swamps, bogs, wetlands, prairies, and forests that are home to a number of rare species such as the bald eagle, a Threatened Species of wild rice, Blanding's turtle, wood turtle and the eastern massasauga rattlesnake. The Maple River is positioned at a defining geological point in the watershed where the river valley transitions near the intersection of two counties (Newaygo and Muskegon). At the head of Maple Island the river valley is only 0.8 miles wide, though in only 2 miles downstream the valley width quickly doubles, the high elevation valley walls disappear into relatively flat riverbanks and the river generally becoming more tranquil.



The change in river valley height and width. Just upstream of Maple River. The Muskegon River is shown in dark blue, the Maple River is shown in light blue with Maple Island as the gray landmass between the two.

The Maple River has been severely degraded due to historical damage. Prior to the 1800's, the Maple River was a flowing anabranch of the Muskegon River (a split of equal size), but in the late 19th century, the Maple River was closed to elevate the water level on the mainstem to improve floating of logs down to Muskegon Lake. The 4.6 mile channel is still a clearly identifiable riverbed that is largely intact although it has been disconnected from the mainstem and remained mostly dry for over 100 years.

The historic blocking of the Maple River has caused many changes to the function and ecology of both the mainstem and the Maple River. Because aquatic habitat has been disconnected, the Muskegon River has a more abundant and diverse fish assemblage while the Maple River is largely home to only tolerant species, such as central mudminnows and minnow species. The Maple River function has changed with its reduced capacity to naturally transport rainwater, nutrients and sediment. This has caused nutrients and sediment to concentrate rather than being naturally transported. The reduced capacity to move rainwater has caused the community around the Maple River to endure severe flooding of agricultural land, blockages at road-stream crossings, property loss due to erosion, and a decrease in recreational and cultural value.

The tolerant central mudminnow fish species.

Through support by the local community, governments, and tribes an effort is underway to evaluate options to address detrimental effects caused by the historic damming of the Maple River. After a major flood in 2011, the Muskegon River Watershed Assembly was approached by local farming families who for generations have harvested crops from the Maple River area, to study the problem. The Muskegon River Watershed Assembly, University of Michigan, and the Michigan Department of Natural Resources began a project to evaluate the ecological effects of reopening the river, conduct a preliminary flood analysis, and host a series of public meetings. In 2015, the study was completed, and the results suggested many benefits could occur by reconnecting the abandoned river channel to the Muskegon River. These benefits included more stable Muskegon River flows, reduced flooding and erosion, increased fish habitat and wetlands, greater capacity to handle flood flows, and improved nurturing of wild rice. Currently a fine-scale hydraulic study is being conducted by the Army Corps of Engineers, the Little River Band of Ottawa Indians and Muskegon River Watershed Assembly to more fully analyze options and best practices for reconnecting the river.

2.3 Historical Uses (continued)

Until 1836, the watershed was largely an unbroken wilderness. This changed when speculators and explorers visited the watershed and realized the untapped potential for profit. A major change occurred when Native American bands and the United States signed the 1836 Treaty of Washington. Under duress and pressure for removal, the Native American chiefs ceded the land (almost 1/3 of what is now the State of Michigan) which transferred “ownership” to the U.S. while the Native American bands retained the “right to hunt, fish and gather under the usual privileges of occupancy”. When Michigan gained statehood in 1837 the Muskegon River Watershed could be settled and the sixty-year logging era began as did the industrialization of the river.

The first Muskegon River sawmill opened in 1837. Logs were taken to banks of rivers, where they were piled twenty to thirty feet high awaiting the spring thaw. When the rivers melted, the logs were pushed into the flooded river and floated to the mills. Photo from the Muskegon Chronicle file.

White pine, the wood most in demand for construction in the nineteenth century, grew in abundance in the watersheds forests. To profit from the white pine the first Muskegon River sawmill opened at the mouth of Penoyer Creek in 1837 with many others opening soon after. Many tributaries and landmarks in the lower watershed still hold the names of business partners that founded the mills, such as Penoyer Creek, Brooks Creek, Ryerson Creek and Gerrish Township. The logs were taken to banks of rivers, where they were piled twenty to thirty feet high awaiting the spring thaw. When the rivers melted, the logs were pushed into the flooded river and floated to the mills. By 1888, around 80 billion board feet of timber had been harvested, leaving most of the watershed barren (Alexander 2006). The logging practices dramatically changed the character of the watershed. The forest canopy was gone and no longer provided soil stabilization and cooling of the water, the river became more shallow and wider because of severe erosion, and riverbed habitat had been scoured during the log drives no longer providing fish habitat.

The first major dam was built on the Muskegon River at Newaygo in 1854 to power a sawmill. The Croton Dam, on the mainstem of the Muskegon and the largest in the lower watershed, was built in 1907 to produce hydroelectric power. The backwater of the dam provides fishing, skiing, swimming and boating, but the dam also fragments animal migration, traps nutrients and sediment, and warms water temperatures. Currently, around 100 dams are found in the watershed with many no longer serving their intended purpose and present public safety hazards.

Although many of the negative environmental factors affecting wildlife and fisheries in the watershed are still present, the end of the lumber and dam building era gave rise to tourism, farming, and industry. Industrial development and chemical technology have brought significant economic benefits, but have also come with associated environmental contamination. Many industrial pollutants entered the watershed because of limited knowledge, lenient or absent laws regulating discharge of certain contaminants, or through non-compliance. Although sources of these industrial pollutants have stopped, many of these chemicals require long periods to break down, and will remain in the system in perpetuity. There has been a changing land ethic wherein the watershed is now viewed as a valuable and intrinsic resource to protect and sustain for future generations.

2.4 Ecological Communities

The LMRW has a vast diversity of habitats and organisms. There are many reports which have inventoried different ecosystems in the watershed (see Section 2.9), but more information should be collected. By identifying and assessing the quality of these habitats and the organisms that live in them, we can better protect them.

Ecological Classification Zones

The LMRW is home to thousands of plant and animal species. The watershed is known for its high biological diversity which is due to the wide-range of habitat types and topography. To categorize this diversity, and to characterize areas that are ecologically similar, the entire Muskegon River and its tributaries have been divided into a series of ecologically similar zones or reaches (collectively called VSEC units). There are 107 separate VSEC units contained in the watershed. Using VSEC allows us to identify similar ecological units over an area through catchment processes and how they interact with local physical features. In Michigan rivers these ecological units are classified by the physical channel unit termed the valley segment. These ecological classification zones, and the richness and diversity of species, are often found to change dramatically at stream junctions, slope breaks, and boundaries of local landforms (Seelbach et al. 1997).

Fisheries

Currently, at least 77 fish species are present in the watershed, with seven introduced to the region (O'Neal 1997). Five species of fish found in the watershed are listed as Threatened Species in Michigan: sauger, lake herring, lake sturgeon, river redhorse, and mooneye. Sauger and lake herring are extirpated (locally extinct) from the watershed. The lower section of the watershed has a notable fish community including lake sturgeon, walleye, salmon, trout and smallmouth bass.

The lake sturgeon population in the Muskegon River is one of the few self-sustaining populations on the eastern shoreline of Lake Michigan . Photo courtesy of the Little River Bands of Ottawa Indians.

Both the river redhorse and lake sturgeon are limited in distribution and spawning habitat because of Croton Dam. The lake sturgeon holds an important role in Native American culture, and uses the lower river for spawning and early-life stages. Each spring fewer than 100 sturgeon ascend the river to spawn in areas below Croton Dam and after spawning exit the river system. Some of the newly hatched fish are known to occupy the river through the first year of life. When lake sturgeon are young they can be impacted during the chemical treatment of the invasive sea lamprey in the Muskegon River. To protect the sturgeon, the Little River Band of Ottawa Indians leads a program to remove the young sturgeon from the river and protect them in a streamside facility until after the treatment has been completed, and then release them back into the river.

The walleye population naturally reproduces but it is variable and maintained through stocking. The Muskegon River has been selected by the Michigan DNR as a walleye egg-take location used for stocking other systems because the population has high abundance, a large size structure, and is a genetically distinct population.

All of the mainstem between Croton and Lake Michigan is designated trout stream (Figure 2.8). The purpose of this designation is to protect the populations of riverine rainbow and brown trout, Chinook salmon, steelhead, and coho salmon. Tributary streams with good trout fisheries in the LMRW include Bigelow Creek, Cedar Creek, and Mosquito Creek. Bigelow Creek in particular has the highest average brown trout biomass of all Michigan Department of Natural Resource Status and Trends Fixed Sites statewide (Tonello 2020).

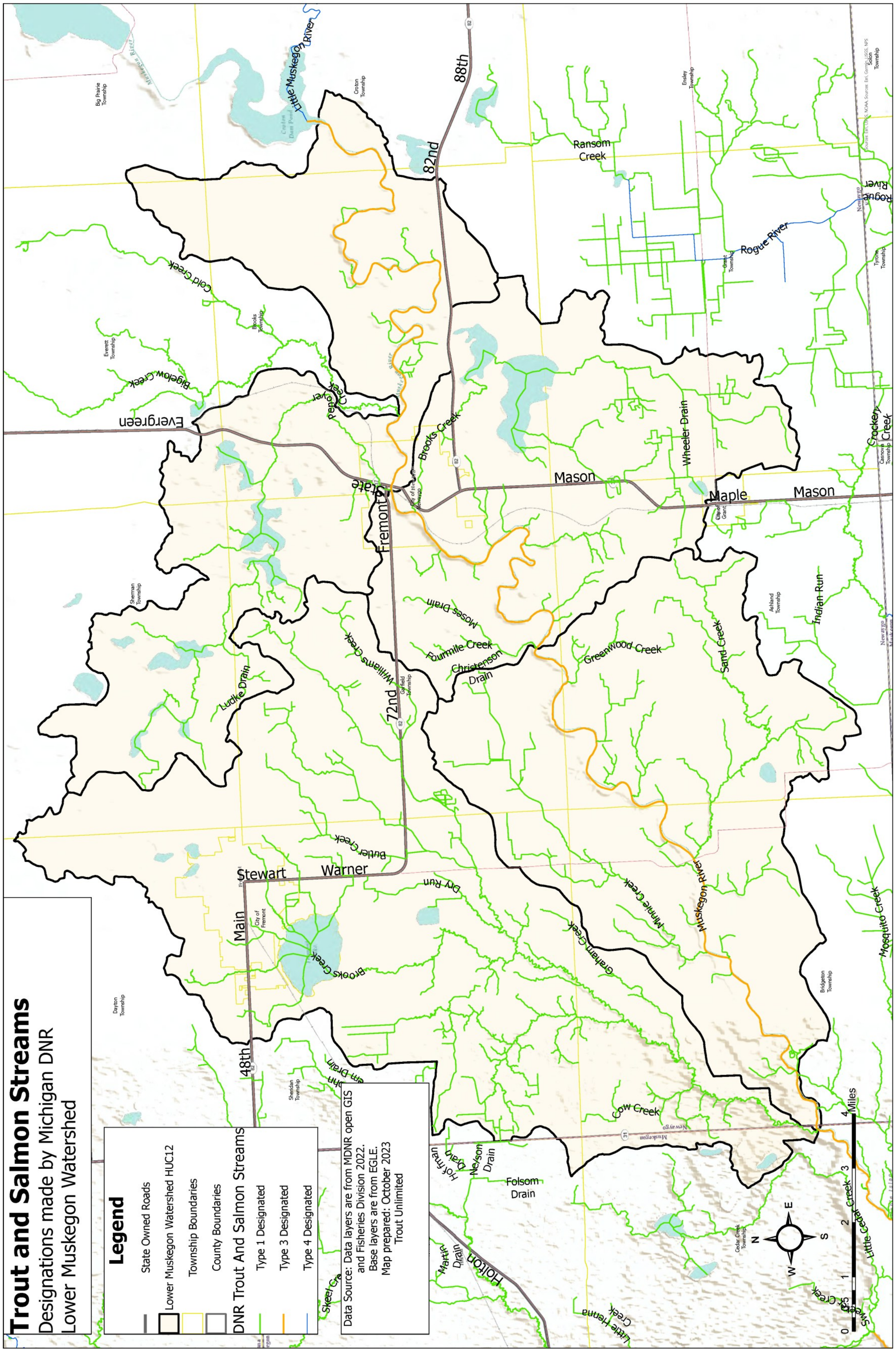


Figure 2.8. Trout streams and lakes in the Lower Muskegon River Watershed. Produced by TU, 2023.

2.4 Ecological Communities (continued)

Biologically Significant and Rare Habitats

Protecting aquatic, terrestrial, and avian habitat is important because it maintains biodiversity and provides for resilience to change, fosters ecosystem integrity, and bolsters ecosystem services. The LMRW contains many ecological features that provide habitat for rare and biologically significant species. Prominent habitat features include the river and its floodplain, wetlands, vernal pools, bogs, forests and lakes, all of which support insect, reptile, amphibian, bird, mammal, plant, and aquatic communities. In 1999, The Nature Conservancy identified a large amount of acreage in the watershed that contained a significant amount of biodiversity priority areas in Newaygo and Muskegon counties. The area is largely in the Mosquito Creek subwatershed where they identified five federally endangered or threatened species including the bald eagle, the Karner blue butterfly, the piping plover, Kirtland's warbler, and pitcher's thistle. Since the two counties are not entirely contained in the LMRW, it is not certain how many of the five species are found within the watershed boundaries except for the bald eagle. A core feature of the LMRW that hosts rare species is the Muskegon State Game Area and protection of its habitats are critical for stewardship of biodiversity. Scientists conducting a Michigan Natural Features Inventory found that out of 77 natural community types in Michigan the Muskegon State Game Area contained 12 (Lincoln et al. 2019). Numerous state threatened and state protected species were documented including 9 plants, 10 birds, 6 reptiles and amphibians, and 7 mussels.

Wetlands

Wetlands play an essential role in the functioning of healthy ecosystems that is often disproportionate to their area. Wetlands perform key functions for a watershed, contributing significant value to a community, and therefore must be considered in any approach to watershed management. Wetland functions include floodwater storage, groundwater recharge, filtration of pollutants, nutrient recycling, biological productivity, wildlife habitat, and climate resiliency. Wetlands also add value to society. These values can be economic, social, or ecological and are measured by the estimated worth of its services. For example, wetlands provide valuable goods like building products and food by fostering suitable habitat. Wetlands also provide services that benefit society like mitigating floods, improving water quality, and offering recreational opportunities and natural beauty.

Wetland functions include floodwater storage, groundwater recharge, filtration of pollutants, nutrient recycling, biological productivity, wildlife habitat, and climate resiliency.

However, due to wetland loss, watershed health is at risk of losing these important wetland functions and values (Figure 2.9). There have been several efforts to document and understand wetland loss in Michigan, some of which are summarized in 'Status and Trends of Michigan Wetlands: Pre-European Settlement to 2005', a report by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) in 2014. According to the report, the quality and acreage of wetlands has been on the decline since the beginning of European habitation. Michigan originally contained approximately 10.7 million acres of wetland prior to European habitation, but by 1978, that number had dropped to approximately 6,506,044 acres. Since the passage of Michigan's wetland protection law in 1979, the rate of wetland loss has declined dramatically.

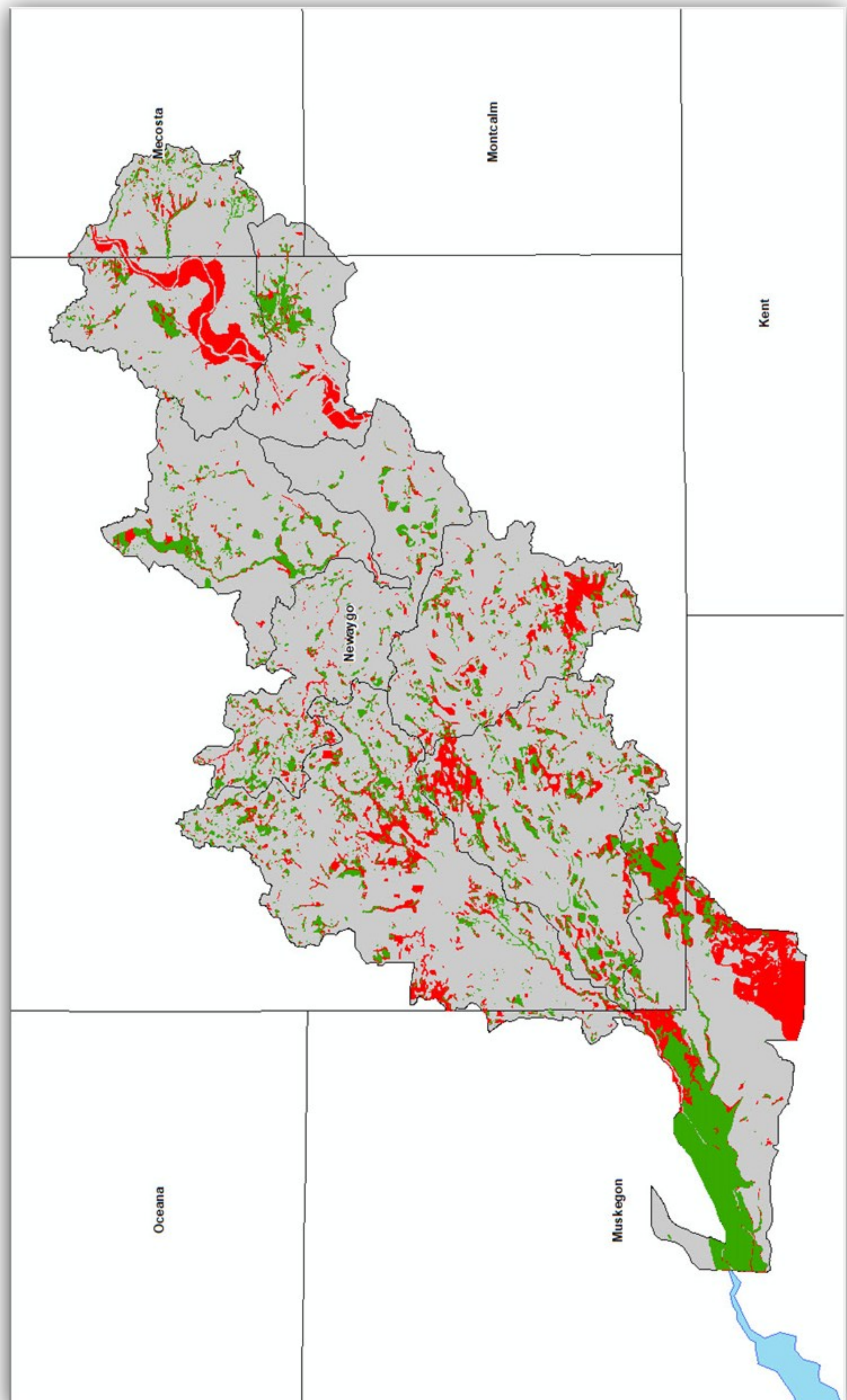


Figure 2.9. Approximate wetland loss (red) in 2005 from Pre-European Habitation to wetlands (green) in the Lower Muskegon River Watershed. Produced by EGLE, June 2022.

2.4 Ecological Communities (continued)

Wetlands (continued)

The total decline since 1978 is estimated at 41,000 acres, with the rate of decline slowing between the periods 1978 to 1998 (loss of approximately 1,642 acres per year) and 1998 to 2005 (loss of approximately 1,157 acres per year)." In 2005, approximately 6,465,109 acres of wetlands remained in Michigan (EGLE, 2014).

A subsequent EGLE Landscape Level Wetland Function Assessment (LLWFA) of the LMRW found that approximately 45% of wetlands were lost from the Pre-European habitation era (Figure 2.9). The LMRW had approximately 39,270 acres of wetland prior to European habitation compared to a 2005 estimate of 21,749 acres. This is a loss of 17,521 acres of wetlands (Appendix A).

The Manistee National Forest acts as a buffer zone around the river and protects it from development and local run-off. Photo by Cobi Pellerito.

2.5 Land Use

How we use our land is the foundation of environmental quality. It represents cultural and economic activities in a given place. Nearly every environmental problem has a land use origin. Prior to widespread European habitation in the 1800's, the dominant native vegetation was beech, sugar maple, and hemlock forests, white pine and mixed hardwood forests, and mixed conifer swamps (Figure 2.11). Fragmentation, degradation, and conversion of land use have changed the landscape in the Muskegon River Watershed (Figures 2.11 and 2.12). A majority of the watershed is still classified as forest (approximately 60%) with a portion of the watershed included in the Manistee National Forest and is managed for the protection of woodland and wildlife habitat (MDNR 2001). The Manistee National Forest acts as a buffer zone around the river and protects it from development and local runoff. Although forests, both hardwood and coniferous, dominate almost half of the watershed, much of the original 1,743,717 acres are now used for agriculture (Figure 2.10).

Agricultural land use exists throughout the lower watershed with the bulk occurring in the middle and lower portions. In the lower watershed, it includes both cropland and pasture areas with approximately 34% agricultural (Figure 2.13) In the lower watershed, urban areas include Newaygo, and Fremont. Residential and commercial/industrial developments account for approximately 5% of the land use.

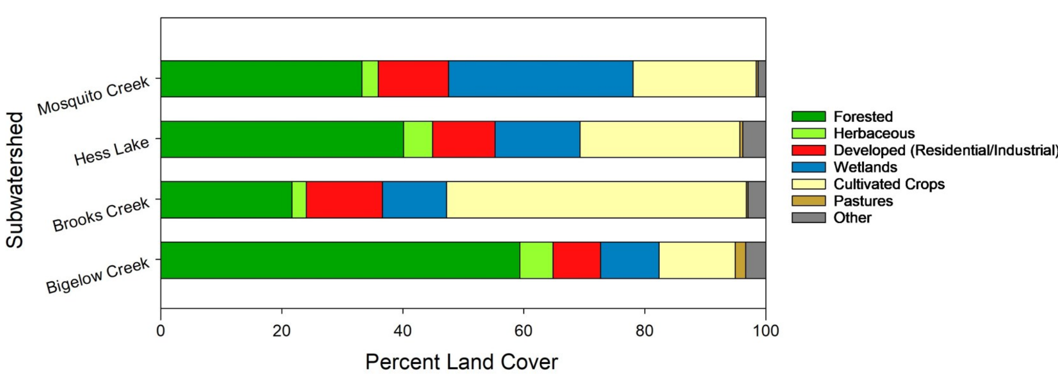


Figure 2.10. Land cover in the Lower Muskegon River Watershed.

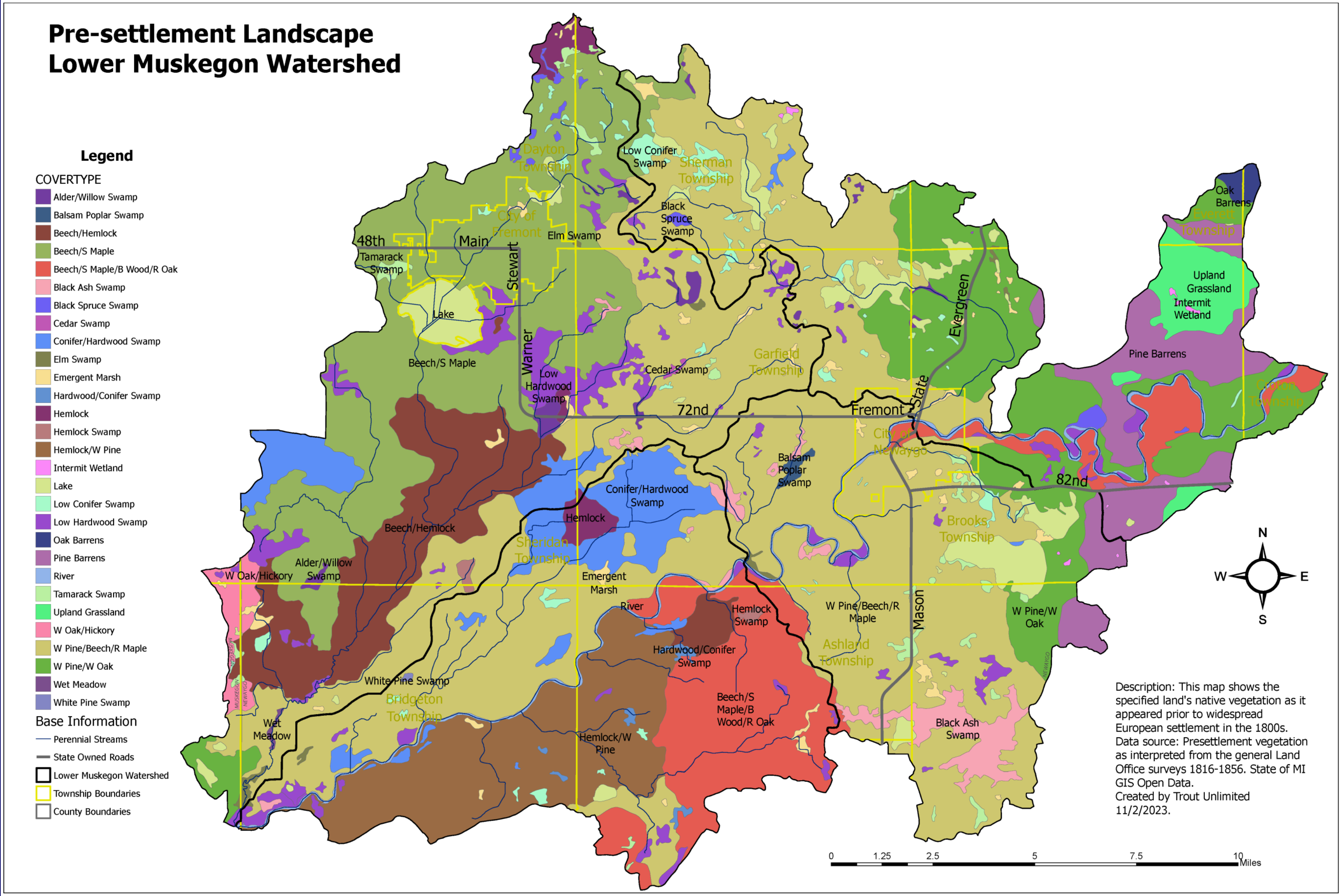


Figure 2.11. Pre-settlement landscape in the Lower Muskegon River Watershed. Produced by TU, 2023.

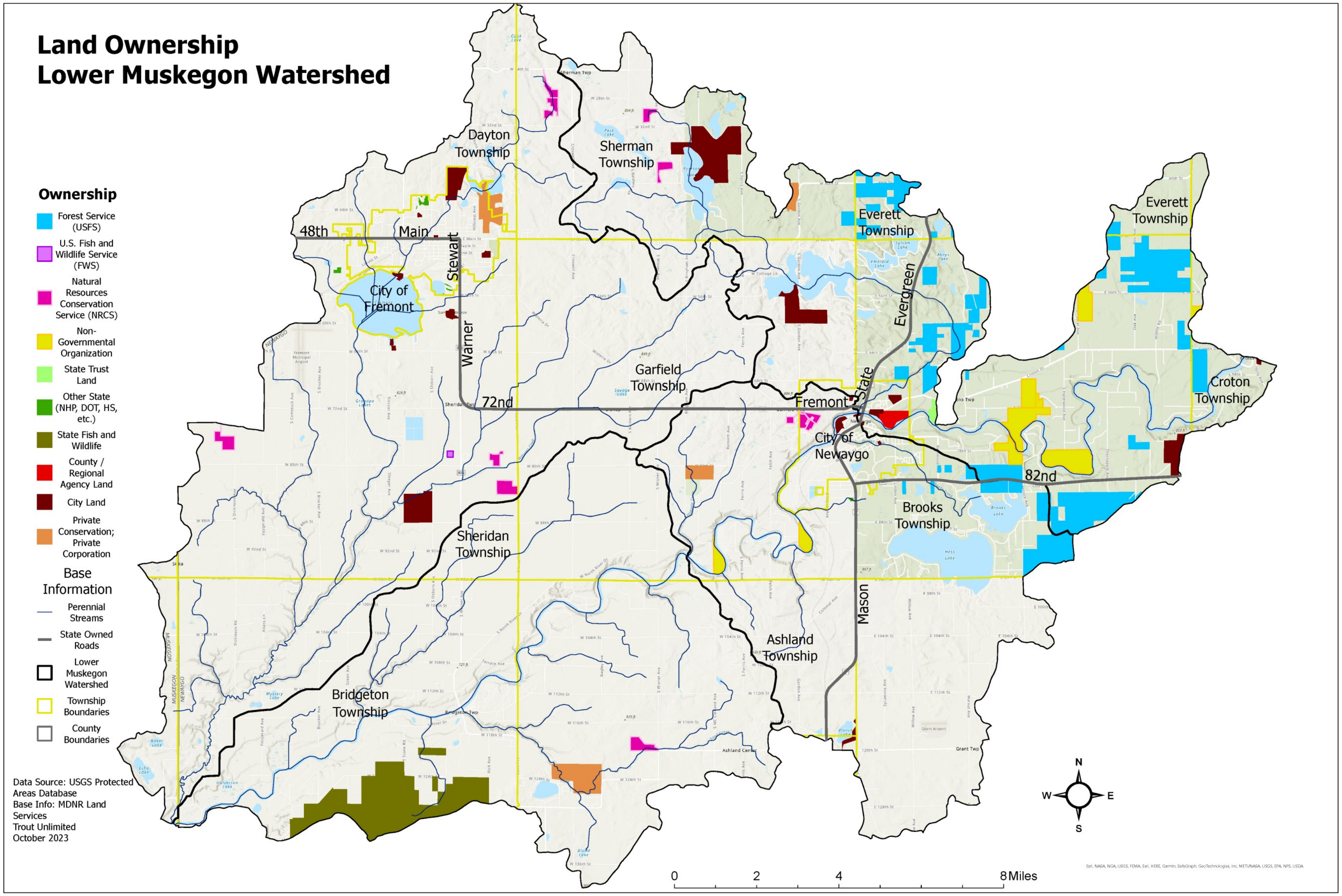


Figure 2.12. Land ownership in the Lower Muskegon River Watershed. Produced by TU, 2023.

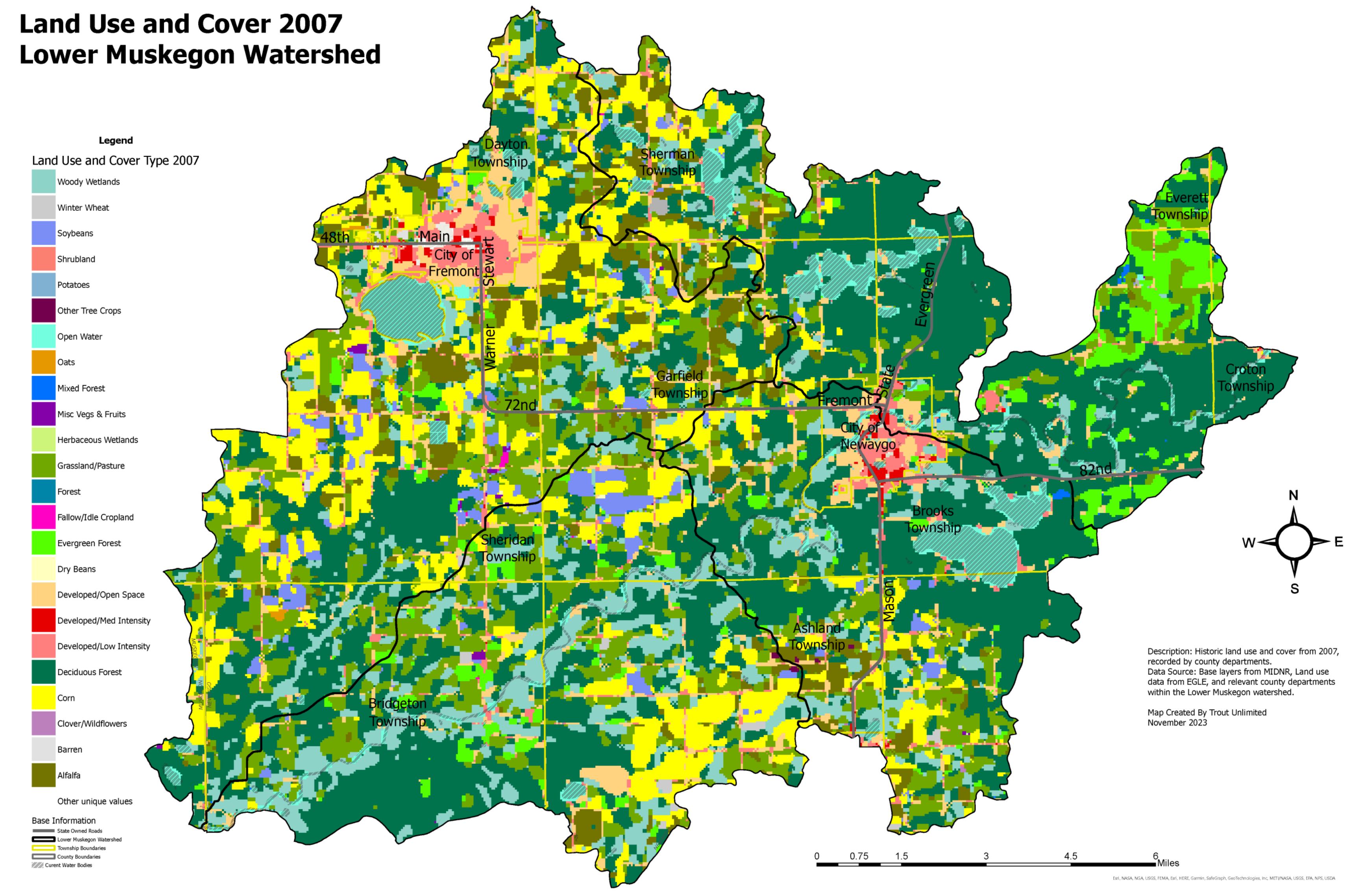


Figure 2.13. Land use and cover in the Lower Muskegon River Watershed. Produced by TU, 2023.

2.6 Climate Change

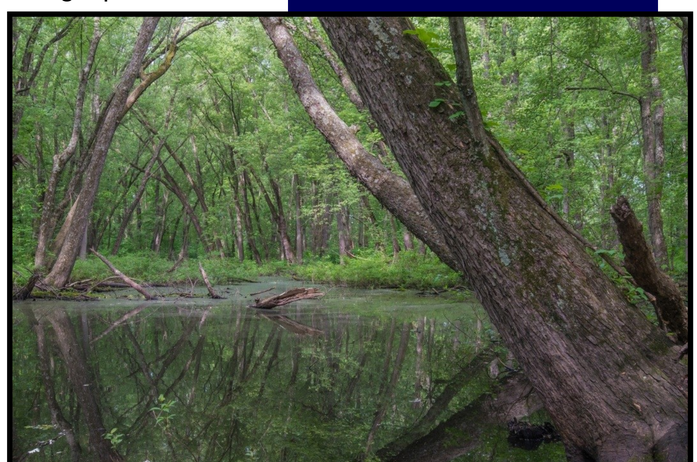
Climate change is a global problem with unique local impacts. In general, a warmer atmosphere holds more moisture, leading to more frequent and intense rainstorms. This is especially true in the Great Lakes region. This has a substantial effect on hydrology and water quality including surface runoff, soil erosion, and pollutant transport. Warming temperatures are also expected to shift species ranges north, leading to the replacement of cold weather species with those tolerant of warmer conditions. The composition of forests in the Great Lakes region is changing with many tree species shifting northward while being replaced by more southerly varieties. Adapting to climate change is becoming an important strategic concern to managing runoff and non-point source pollution in watersheds.

Climate change projections for changes in temperature, precipitation and vegetation patterns need to be considered when selecting, designing and installing best management practices (BMPs). BMPs such as green infrastructure and low impact development can be implemented to mitigate temperature change by (1) reducing summer stormwater runoff of warm water into surface waters, and (2) enhancing groundwater recharge to provide more coolwater input to surface waters. For precipitation change mitigation, install practices that protect and restore wetlands and floodplains to rivers to absorb stormwater runoff to (1) minimize the magnitude of streambank erosion from high flow stream events, and (2) increase the amount of groundwater recharge to streams during the low-flow summer period. With vegetative practices consider using a diverse set of plant species, paying particular attention to those species with the ability to survive warmer, longer and drier summers, yet are also able to withstand longer periods of saturated spring soil.

2.7 Social Characteristics of the Watershed

The LMRW is contained by two distinct counties: Muskegon and Newaygo. The socio-political character of these counties, including the LMRW, reflects a range of community types, from an industrialized urban center in Fremont and Newaygo to rural places surrounded by the Huron-Manistee National Forest and the Muskegon State Game Area. Both of these counties provide commuters to the Grand Rapids and Muskegon metropolitan areas.

The Mosquito Creek subbwatershed is in Muskegon County. Based on the 2020 Census, Muskegon County was the 12th largest county in Michigan with 175,824 residents, representing a 2.1% growth since 2010 (Figure 2.14). Muskegon County is considered an Urbanized Area, which is defined as any county containing at least 50,000 people. In 2010 the estimated population per square mile was 344.9 (US Census Bureau). The county is contained in the Muskegon-Norton Shores Metropolitan Statistical Area, which is part of the larger Grand Rapids-Muskegon-Holland Combined Statistical Area. The majority of the Mosquito Creek subwatershed is contained in the 15,338-acre Muskegon State Game Area. This area, dedicated in 1950, protects the unique semi-wilderness state of the lower Muskegon River delta and surrounding bluffs. This land, along the Muskegon/Newaygo County border, is managed by the Michigan Department of Natural Resources and is important ecologically because it provides critical habitat for a myriad of game and non-game species and supports 7,285 acres of forest and 9,726 acres of wetlands.



The Muskegon State Game Area is important ecologically because it provides critical habitat for a myriad of game and non-game species and supports 7,285 acres of forest and 9,726 acres of wetlands. Photo by Aaron P. Kortenhoven.

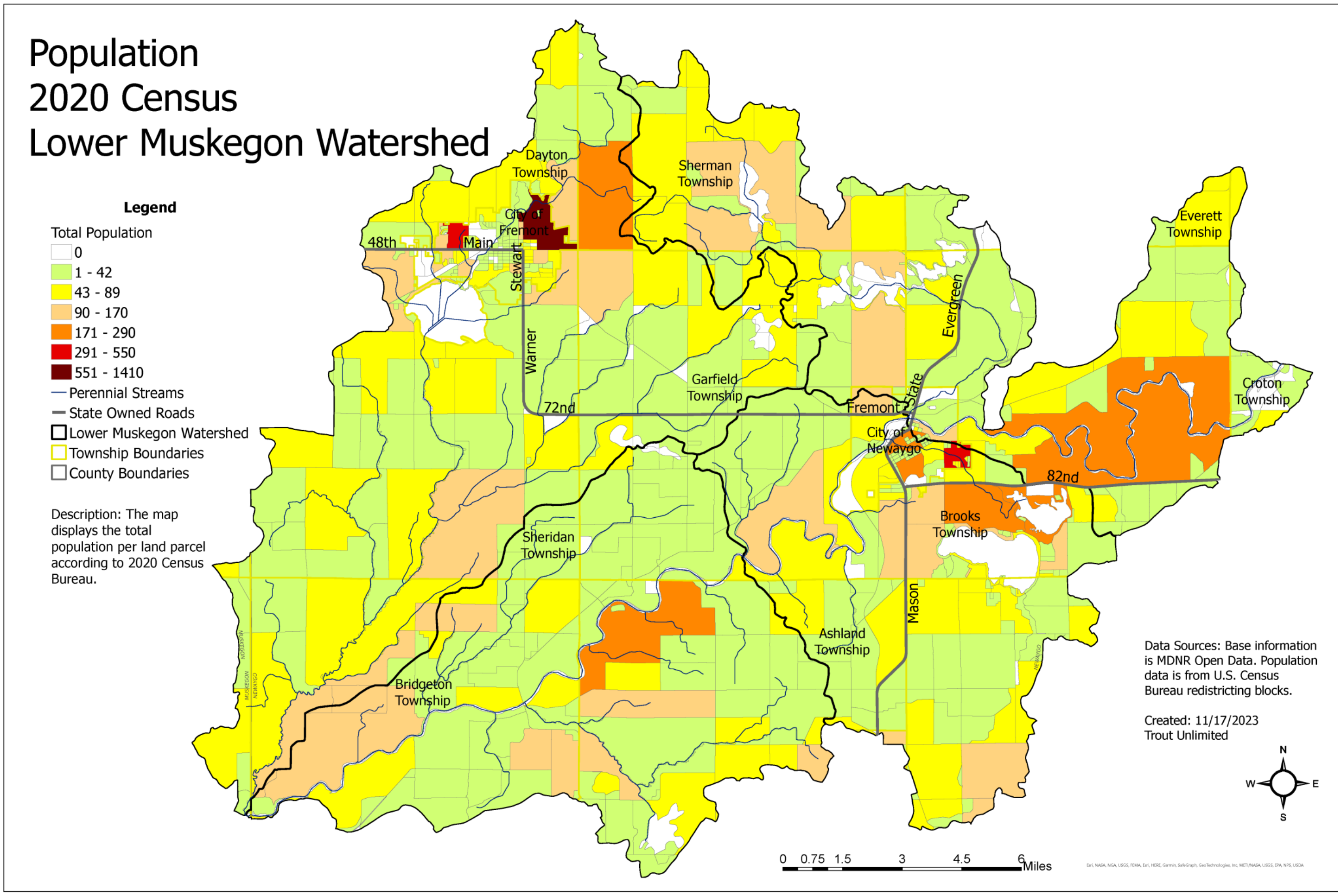


Figure 2.14. Population density in the Lower Muskegon River Watershed. Produced by TU, 2023.

2.7 Social Characteristics of the Watershed (continued)

Newaygo County contains the Bigelow, Hess, and Brooks subwatersheds and the LMRW's largest cities of Fremont and Newaygo. Newaygo County is the 37th most populus county in Michigan with 49,978 residents in 2020. Since 2010 the county has seen a growth of 3.1% and the estimated population per square mile was 59.6. Less than one quarter of the county is farm-land, mostly devoted to livestock. Food processing and other manufacturing are also important economic activities in the county. International baby food manufacturer Gerber Products Company is currently the county's largest employer. With nearly half the county covered by the Huron-Manistee National Forest, hunting, fishing, boating, and other outdoor recreational activities have also become important to the county's economy. Newaygo County is part of the Grand Rapids-Wyoming Metropolitan Statistical Area due to the number of workers commuting to the Grand Rapids area. At the same time, the county's closeness to this urban area attracts considerable second home development.

2.8 Jurisdictional and Political Characteristics of the Watershed

Water quality issues are too large and complex to be solved by any single community acting on its own. Water does not follow jurisdictional boundaries and is affected by shared communities across many jurisdictional boundaries. To understand how the natural resources in the LMRW are managed we need to understand the political layers of regulatory jurisdictions that are involved and coordinate. Within the watershed there are state, tribal, federal and municipal units that assist in protecting the watershed. Within the LMRW's four subwatersheds are parts of two counties and 18 townships which all influence the water quality and have their own rules and regulations. The State of Michigan and authorized Tribes assess and manage water resources and identify waters that do not meet water quality standards as required under the federal 1972 Clean Water Act. The Act requires that these jurisdictions establish priority rankings for water on the lists and develop action plans, called Total Maximum Daily Loads (TMDL), to improve water quality. The Muskegon River Watershed is in the boundary of the 1836 Treaty of Washington of five Tribal nations and provides them management rights and responsibility. In 2007, a Consent Decree (agreement) was entered into by five treaty Tribes, the State of Michigan and the United States. This agreement recognized the tribes' right to conduct biological assessments and engage in restoration, reclamation and enhancement projects which benefit the natural resources and the tribe's unique needs for watersheds. More detail about regulatory authorities responsible for implementing management measures can be found in Appendix B.

2.9 Resources

Listed below are resources where you can learn more about the geology, ecology, land use, and the social and political characteristics of the Lower Muskegon River watershed.

- ⇒ Bigelow Creek, Newaygo County, Muskegon River Watershed. State of Michigan Department of Natural Resources. https://www.michigan.gov/-/media/Project/Websites/dnr/Documents/Fisheries/Status/folder2/Bigelow_Creek_2020.pdf?rev=055b2c8f09b442d785a025d751fd06df
- ⇒ Muskegon River Watershed Assessment. State of Michigan Department of Natural Resources. https://wmsrdc.org/wp-content/uploads/2018/04/Muskegon-River-Fisheries-Assessment.pdf
- ⇒ Muskegon State Game Area Master Plan. State of Michigan Department of Natural Resources https://www.michigan.gov/-/media/Project/Websites/dnr/Documents/WLD/SGA/muskegon_sga_mp.pdf?rev=a71ca8d079b94611b1a7bf37e2581448
- ⇒ Status and Trends of Michigan Wetlands: Pre-European Settlement to 2005 https://www.michigan.gov/documents/deq/wrd-wetlands-status-trends_556006_7.pdf
- ⇒ US Census Bureau http://www.census.gov/
- ⇒ West Michigan Shoreline Regional Development Commission—demographics information https://wmsrdc.org/

Chapter 3: Watershed Condition

INSIDE THIS CHAPTER:

- Learn Water Quality of Subwatersheds
- Know the Designated and Desired Uses
- Understand the Pollutants Causing Impairments and Threats
- Learn the Sources and Causes of Pollutants

Introduction

3.1 Chapter 3 Summary

Highlighted below are some of the major points that you will learn in Chapter 3.

⇒ The historical and current water quality and land use data were reviewed to identify pollutants in the watershed. In addition, specific water quality monitoring data was collected (parameters include *E. coli*, Total Phosphorus, Total Suspended Solids, and water temperature) along with wetland and dam inventories.

⇒ Designated uses are recognized uses of water established by state, tribal and federal water quality programs. These designated uses are given ratings to identify if a use is meeting the standard or is impaired, threatened, or not assessed. In the Lower Muskegon River Watershed (LMRW) there are impaired uses for "Other Indigenous Aquatic Life and Wildlife" and "Fish Consumption". Threatened uses across the entirety of the watershed include "Coldwater Fishery", "Partial Body Contact", and "Total Body Contact".

⇒ Desired uses for the LMRW include "Recreational", "Aesthetics", "Social" and "Cultural" uses.

⇒ High priority pollutants for the lower watershed include thermal pollution, nutrients, and sediment. The moderate priority pollutants are *E. coli* and Fecal coliform and hydrologic flow. Invasive species and toxic substances were considered low priority pollutants for the watershed plan because invasive species are addressed by the Michigan Invasive Species Program and many toxic substances (i.e. mercury) are Statewide designations where action to be implemented are at a larger scale than a watershed management plan.

⇒ Monitoring data collected in 2022 and 2023 suggested *E. coli*, Total Phosphorous and Total Suspended Solids are exceeding values that impact areas of the watershed. Water temperatures showed that the streams in the lower subwatersheds ranged from cool-transitional (July mean temperatures ~73° F) to cold (July mean temperatures ≤63.5° F).

The Lower Muskegon River.

⇒ In the lower subwatersheds, agricultural and forested lands dominate the landscape. Many areas are not supported for Fish Consumption and Other Indigenous Aquatic Life and Wildlife. Risks to the subwatersheds include nutrients from eleven Concentrated Animal Feeding Operation (CAFOs) found in or very near Hess Lake and Brooks Creek subwatersheds (EGLE CAFO program), eroding and non-vegetated banks in all subwatersheds, and livestock access to waterways in Bigelow Creek, Brooks Creek, and Hess Lake subwatersheds.

3.2 Methods to Identify Watershed Condition

For each subwatershed in the Lower Muskegon River Watershed (LMRW), historical and current water quality and land use data were reviewed to determine pollutants. In addition, monitoring data were collected in 2022 and 2023 in each subwatershed. This information was presented at a community meeting where stakeholders reviewed the data and provided insights. This information was combined and used to assess if the LMRW is meeting water quality standards and what pollutants are impacting human and animal use of the resource (Designated Uses).

EGLE's Integrated Report which assesses the quality of the waters in the state.

3.3 Designated Uses

The primary measurement of water quality is whether the water body meets designated uses. Designated uses are the recognized uses of water established by state, federal and tribal water quality programs. These designated uses, specified in Part 4 Rules issued in accordance with Part 31 of the NREPA (1994 PA 451, as amended), are protected, by law, and include:

⇒ Agriculture

⇒ Navigation

⇒ Industrial water supply

⇒ Warmwater fishery

⇒ Other indigenous aquatic life and wildlife

⇒ Partial body contact recreation, and fish consumption.

In addition, all surface waters of the state are designated and protected for total body contact recreation (activities with a high probability of full or partial immersion in water, such as swimming) from May 1 to October 1.

Most designated uses have one or more assessment types that may be used to determine if the uses are supported. These assessments include biological, habitat, physical/chemical, toxicological, pathogen indicators, other public health indicators, and other aquatic life indicators.

Definitions of Designated Uses

Below is a description of each designated use and its status in the LMRW. Status refers to whether the designated use is supported or impaired (not supported). Even though a designated use is supported it can be categorized as threatened, meaning the use currently meets water quality standards but is at risk in the future. Criteria used to determine impaired or threatened areas are listed in Appendix B and sections of waterbodies not meeting designated uses.

Navigation — Reaches of waterways that are large enough for boats, canoes, kayaks and float tubes, must maintain navigable conditions. The Lower Muskegon River (LMR) is a hotspot for float trips. It is important to keep obstructions out of the river that may impede navigation. This designated use is supported in the LMRW.

Muskegon River kayakers. Photo by Kevin Feenstra.

Definitions of Designated Uses

Agriculture — Surface water must be a consistently safe source for agriculture including irrigation, livestock watering, and crop spraying. Brooks Creek subwatershed has the highest agricultural land use in the LMRW (Figure 3.1). This designated use is supported in the LMRW.

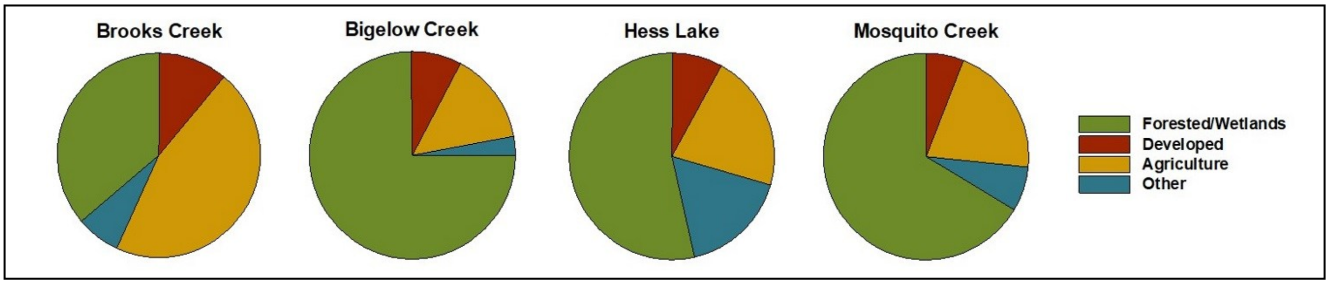


Figure 3.1. Land use in the Lower Muskegon River Watershed. Produced by MRWA, 2023.

Industrial Water Supply — Refers to a water source intended for use in commercial or industrial applications or for non-contact food processing. There are no surface water intakes for industrial water supplies in the watershed.

Warmwater Fishery — Is considered to have summer temperatures between 60-70°F and supporting warmwater fish species. This designated use must support a balanced and adaptive community of fish species that thrive in relatively warm water, including bass, pike, walleye, and panfish. This designated use is supported in the LMRW.

Coldwater Fishery — Is considered to have summer temperatures below <60°F and able to support natural or stocked trout populations. This designated use must support a balanced and adaptive community of fish species that thrive in relatively cold water, generally including trout, salmon, whitefish, and cisco. This designated use is supported but is being threatened in the LMRW.

Other Indigenous Aquatic Life and Wildlife - Plant and animal populations in the ecosystem should be protected with sustainable habitat that supports a resilient ecosystem. This designated use is supported if the water body will not likely cause population-level impacts to mammal and birds from lifetime exposure as a source of drinking water and food. For portions of all subwatersheds in the lower watershed, this use is not supported (impaired) due to Mercury and PCBs (EGLE 2022).

Fish Consumption — This designated use allows surface waters to provide a fishery appropriate for human consumption consistent with the level of protection provided by state rules. In the LMRW this use is not supported (impaired) for portions of streams in all the subwatersheds due to PCBs, Chlordane, and Mercury (EGLE 2022).

Citizen's wading during MiCorps sampling for stream quality.

Partial/Total Body Contact Recreation — This designated use protects activities involving direct contact of some part of the human body with water. For partial body contact recreation, it does not normally involve immersion of the head or ingesting water. Examples include fishing, wading, hunting, and dry boating. For total body contact recreation, it includes activities with water to the point of complete submergence, particularly of the head, with considerable risk of ingesting water. Portions of the watershed with high agricultural and developed land uses are threatening this use, including Brooks Creek subwatershed which has the highest amount of agricultural and developed land in the Lower watershed (Figure 3.1). This designated use is supported but is being threatened in the LMRW.

3.4 Desired Uses

Desired uses are determined by discussing how we want to use our watershed, or how we want it to look. The Muskegon River Watershed Management Plan identifies a number of desired uses for the watershed:

⇒ Recreational: Any other recreational use not applicable to categories in designated uses (i.e., camping, hiking, or biking)

⇒ Aesthetics: Emotional desires for watershed protection/enhancement by individuals living both within and outside of watershed boundaries.

⇒ Cultural: Includes the inherent cultural desires of watershed inhabitants (e.g., historically valued sites, tribal subsistence harvest and gathering).

⇒ Education and Stewardship: Includes educational programming, sampling, and signage to increase community knowledge and foster care for the watershed.

3.5 Pollutants Causing Impairments and Threats

To address what is impairing and threatening these designated uses, pollutants impacting the watershed were determined. The Lower Muskegon River Management Plan (LMRWP) project partners ranked the pollutants based on their current and potential impact in the watershed. The high priority pollutants included those where reducing the pollutants cost the least and yet water quality benefits are the greatest. The moderate and low priority pollutants are still important, but many are already being addressed as we focus our attention on high priority pollutants.

High Priority Pollutants: The lower watersheds' high priority pollutants are temperature, nutrients, and sediment.

⇒ Temperature: Temperature governs the aquatic life that can live in a stream and influences water chemistry. If temperatures are too far outside an aquatic organism's preferred range, they will die or migrate from the area. Increasing temperature decreases water's ability to hold dissolved oxygen, thereby reducing the oxygen available to fish and other aquatic life. Temperature has the potential to negatively impact cool and cold-water streams in the LMRW. Temperature changes occur through solar warming of stagnant pond water, stormwater and surface runoff, climate change, and a lack of streambank shade. The main sources of increased temperature in the LMRW are lake-level control structures (man-made structures that influence the water table and water flow), dams (including those that are hydroelectric), and a lack of riparian/streamside canopy.

⇒ Nutrients: Nutrients, such as nitrogen and phosphorus, are essential to the growth of living organisms, including aquatic plants. In terms of water quality, nutrients can be considered pollutants when their concentrations are sufficient for excessive growth of aquatic plants and algae. When blooms of algae, resulting from nutrient enrichment, eventually die and decompose, they remove oxygen from the water. This can lead to dissolved oxygen levels that are insufficient to sustain life, and in turn reduce the recreational value by making the water unpleasant and undesirable for swimming, fishing, or boating. Possible sources of nutrients to the lower watershed resulting from human activities include inputs of sewage, municipal wastewater discharges, fertilizer runoff from lawns and golf courses, runoff from agricultural lands and animal feed lots, detergents, and surface runoff.

⇒ Sediment: Sediment can be defined as fine inorganic particles that flow with the current in a river and cause turbidity, or that become deposited on the streambed, suffocating benthic organisms and resulting in loss of fish habitat. Natural sedimentation from wind and water erosion is present in all stream environments. Excessive sedimentation caused by human alterations can severely degrade a stream system by burying the gravel, rocky, and woody habitat areas, thereby leading to decreases in habitat diversity and aquatic plant production. Sedimentation caused by streambank erosion may increase channel widening and cause changes in stream water temperature. Sources of sediment include road-stream crossings, the clearing of land for agriculture and development, agricultural grazing and field runoff, and urbanization and development.

Moderate Priority Pollutants: The LMRW's moderate priority pollutants are *E. coli* and *Fecal coliform* and hydrologic flow.

⇒ *E. coli* and *Fecal coliform*: Surface water contaminated with human waste or livestock manure is responsible for the spread of contagious diseases. The presence of *Escherichia coli (E. coli)* and *Fecal coliform* is used to indicate that human waste or livestock manure is present in the water. Potential sources of *E. coli* in the lower watershed include dairy and other livestock operations, manure fertilizer, and improperly functioning or failing septic systems.

⇒ Hydrologic Flow: Hydrologic flow encompasses all factors regulating stream flow and discharge in a watershed. Severe fluctuations in stream flow may disrupt habitat, strand aquatic organisms, and interfere with recreational uses. Dams, water withdrawals (for residential and agriculture irrigation), and channelization are the main causes for fluctuation in hydrologic flow. Land use in the watershed can also greatly influence stream character and water quality. Excessive sediment, fertilizers, and pesticides from farmlands and residential areas are pollutants that can travel over ground through surface water runoff and into a stream after a rainstorm.

Area where livestock have access to a waterway in the lower watershed. Photo by Newaygo Conservation District.

Low Priority Pollutants: The lower watersheds' low priority pollutants include invasive species and toxic substances.

⇒ Invasive Species: An invasive species is not native to an area and causes harm to the environment, economy or human health. Since the early 1800's, at least 180 new aquatic organisms have established in the Great Lakes. On average, one invader is recorded every eight months since 1970. These species are highly invasive and are degrading local habitats. Some invasive species in the lower watershed include the rusty crayfish (*Orconectes rusticus*), spiny water flea (*Bythotrephes cederstroemi*), zebra mussels (*Dreissena polymorpha*), and the sea lamprey (*Petromyzon marinus*).

⇒ Toxic Substances: Toxic substances may contaminate water bodies through unlined landfills, municipal and industrial discharges, and runoff from urban or agricultural land. Most of the pollution coming from toxic substances in the LMRW is from stormwater and urban runoff containing oils, grease, and solids. Urbanized areas with high amounts of impervious surfaces, such as those found in Newaygo and Fremont, all contribute toxic substances to the watershed during storm and snowmelt events when water runs from the streets, parking lots, and roofs, and enters storm drains. Areas with a high density of agriculture or drains, such as Brooks Creek subwatershed, can also contribute toxic substances. These toxic substances can include fertilizers, excess nutrients, and animal waste. Some toxic substances in the lower watershed are treated at the Muskegon County Resource Recovery Center wastewater treatment plant. This operation treats waste that is high in suspended solids, BOD, color, nutrients, and man-made organics.

3.6 Sources and Causes of Pollutants Resulting in Impaired or Threatened Designated Uses

To reduce pollutants impairing and threatening the designated uses in the watershed, the origin of pollutants needs to be determined (i.e. sources and causes).

⇒ Known Pollutant (k): If the origin of a pollutant was verified through monitoring and available information

⇒ Suspected Pollutant (s): if the sources and causes of a pollutant haven't been verified but are based on professional judgement by local experts, local knowledge, and perceptions (i.e. septic systems). It is recommended that in the future, additional monitoring be conducted to verify these suspected pollutants, sources, and causes.

The sources and causes were ranked for each pollutant. The high priority items (1/orange colored) were determined considering sources and causes that contribute the most to each pollutant. By addressing these sources and causes first, we were able to achieve the greatest pollutant reduction, leading to the greatest water quality benefit and cost effectiveness. The next highest sources and causes were categorized as moderate priority (2/yellow colored) and low priority (3/green colored) items.

The following charts help to outline each of the pollutants, sources, and causes that impair/threaten designated uses in the LMRW and their ranking. (Figures 3.2-3.8) A coloring, lettering, and numbering system has been used to identify known (k) and suspected (s) items and their ranking:

⇒ High (orange) - 1

⇒ Moderate (yellow) - 2

⇒ Low (green) - 3

For example, thermal pollution is a known pollutant that is a high priority (identified by k and colored orange). Impoundments are a known source ranked as a medium priority (identified by k and colored yellow). The known cause (holding back water because of the impoundment) is a medium priority cause (identified by k and colored yellow). Maps later in this chapter, and tables in Appendix C, help to visualize where these pollutants are coming from in the watershed and their impact (pollutant loadings).

Flooding in the Maple Island area (Cedar Creek township) in 2011 caused by disruption of natural flow of water. Photo by the Muskegon Chronicle.

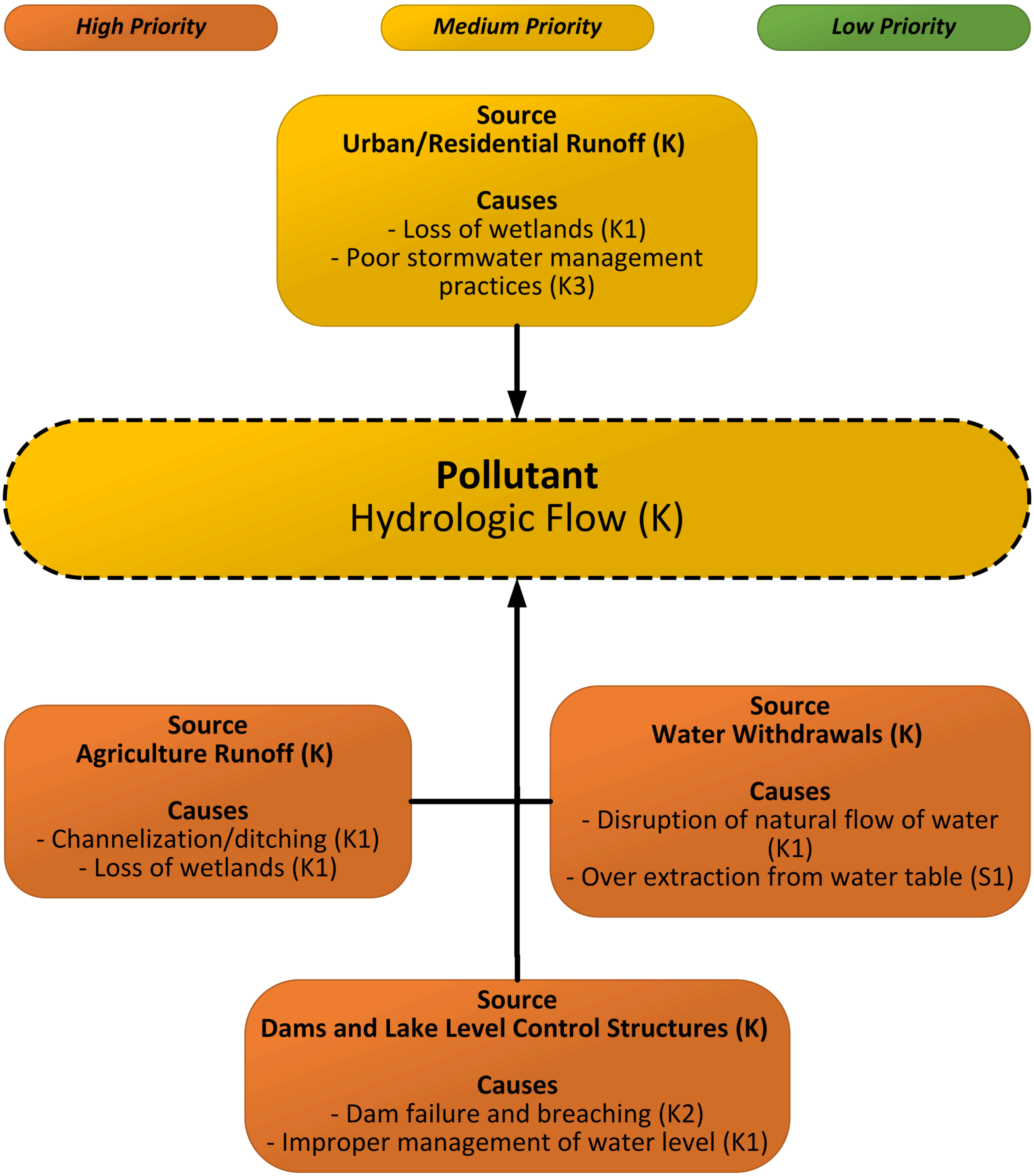


Figure 3.2. Hydrologic flow pollutant sources and causes.

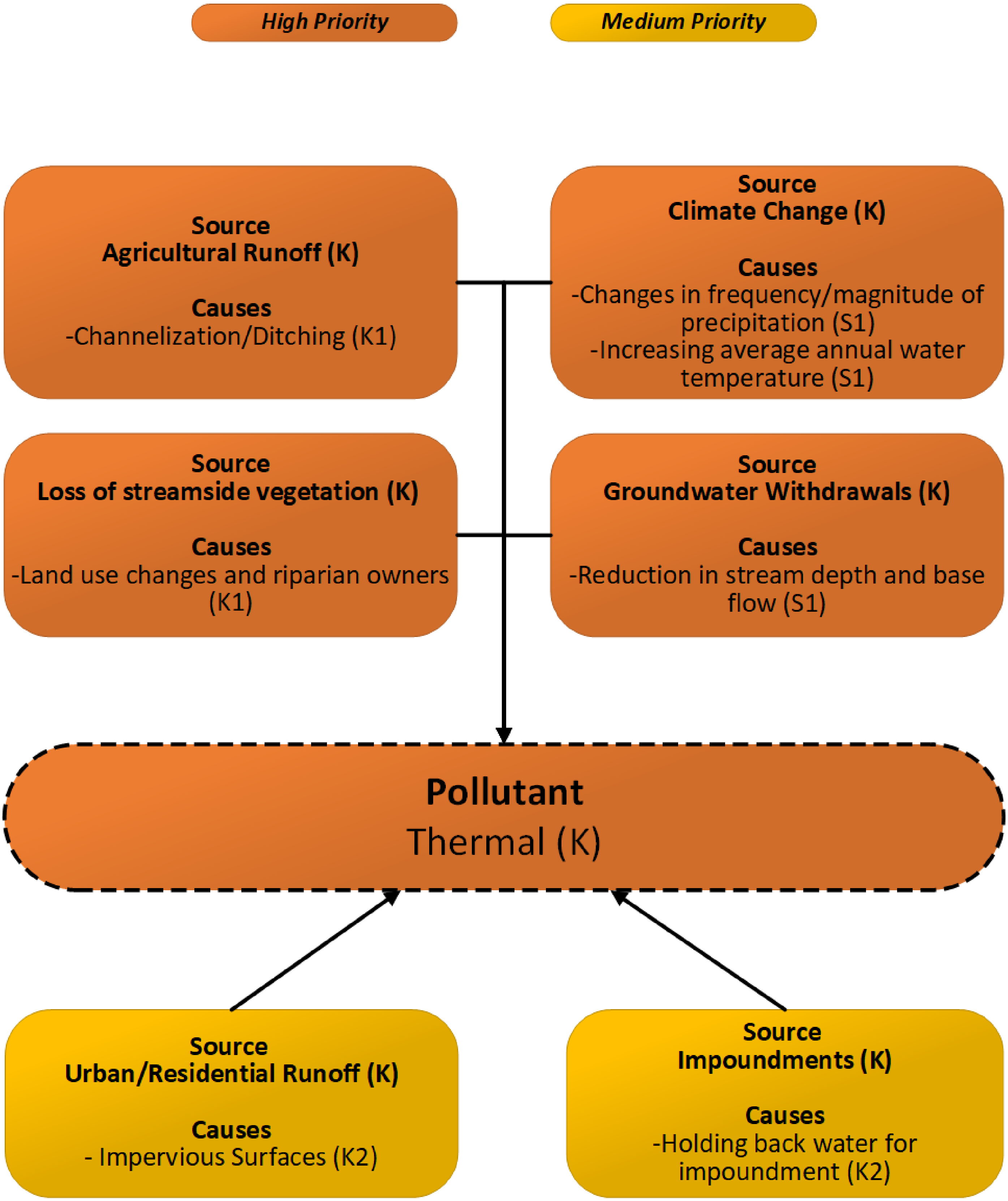


Figure 3.3. Temperature pollutant sources and causes.

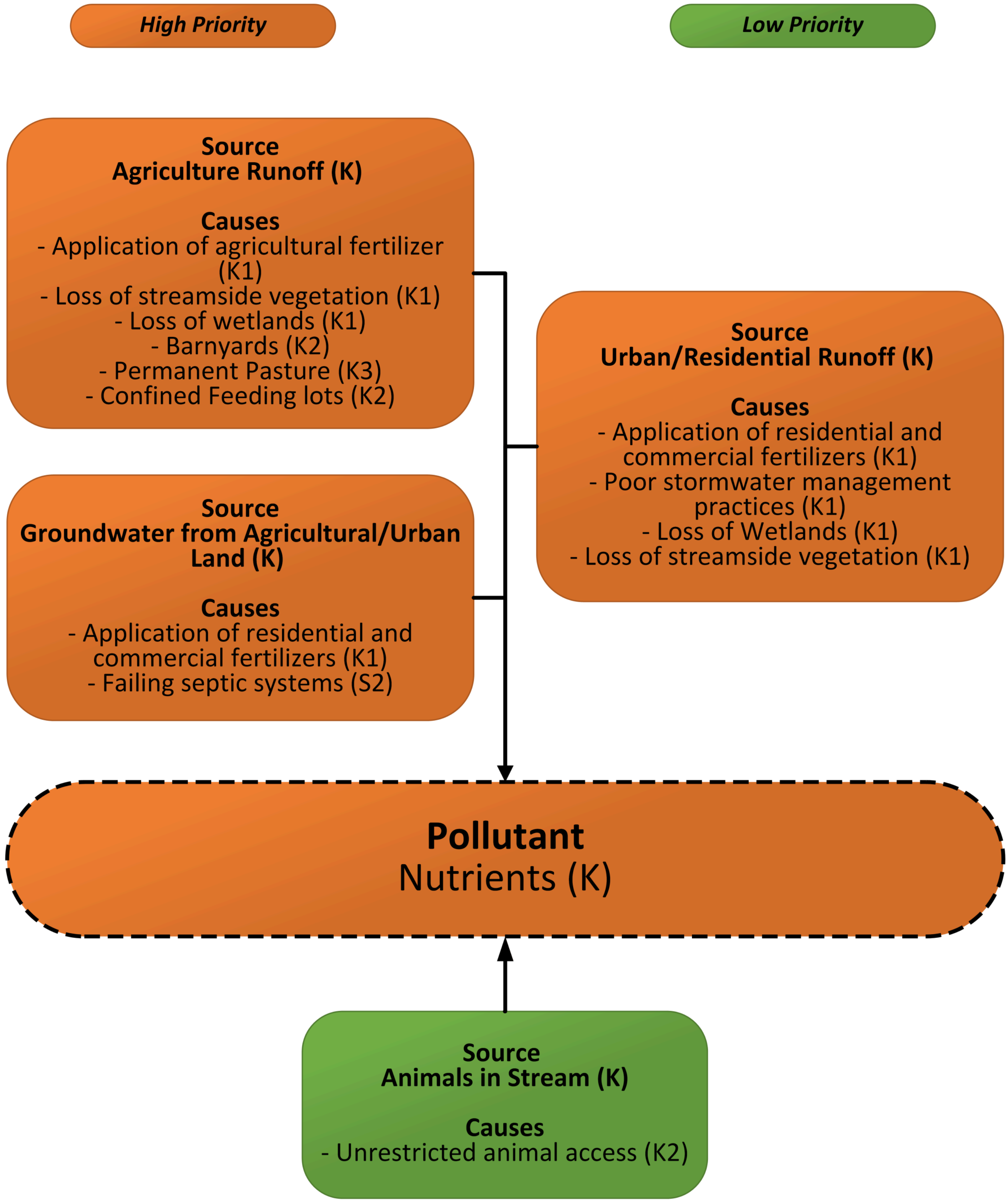


Figure 3.4. Nutrient pollutant sources and causes.

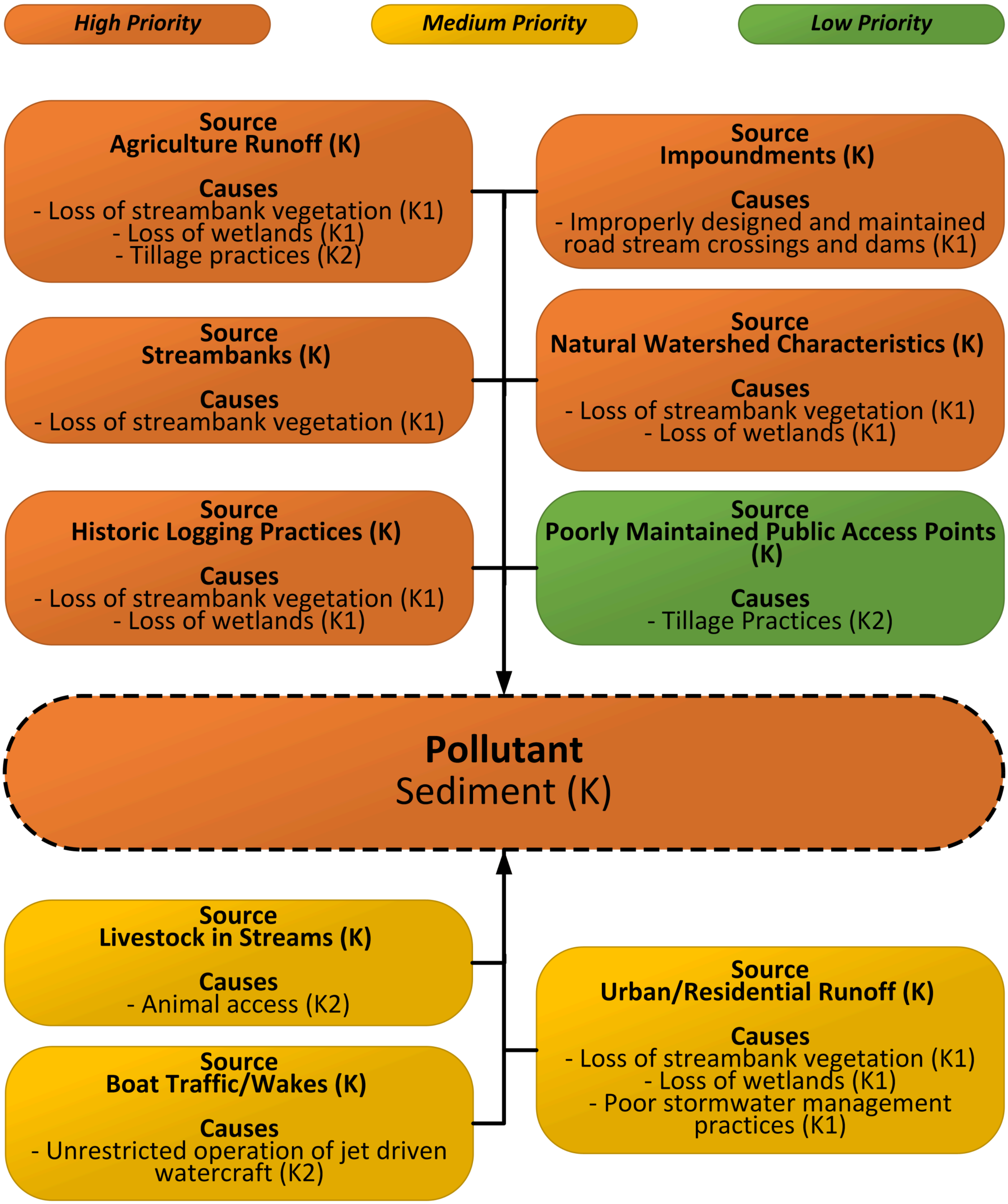


Figure 3.5. Sediment pollutant sources and causes.

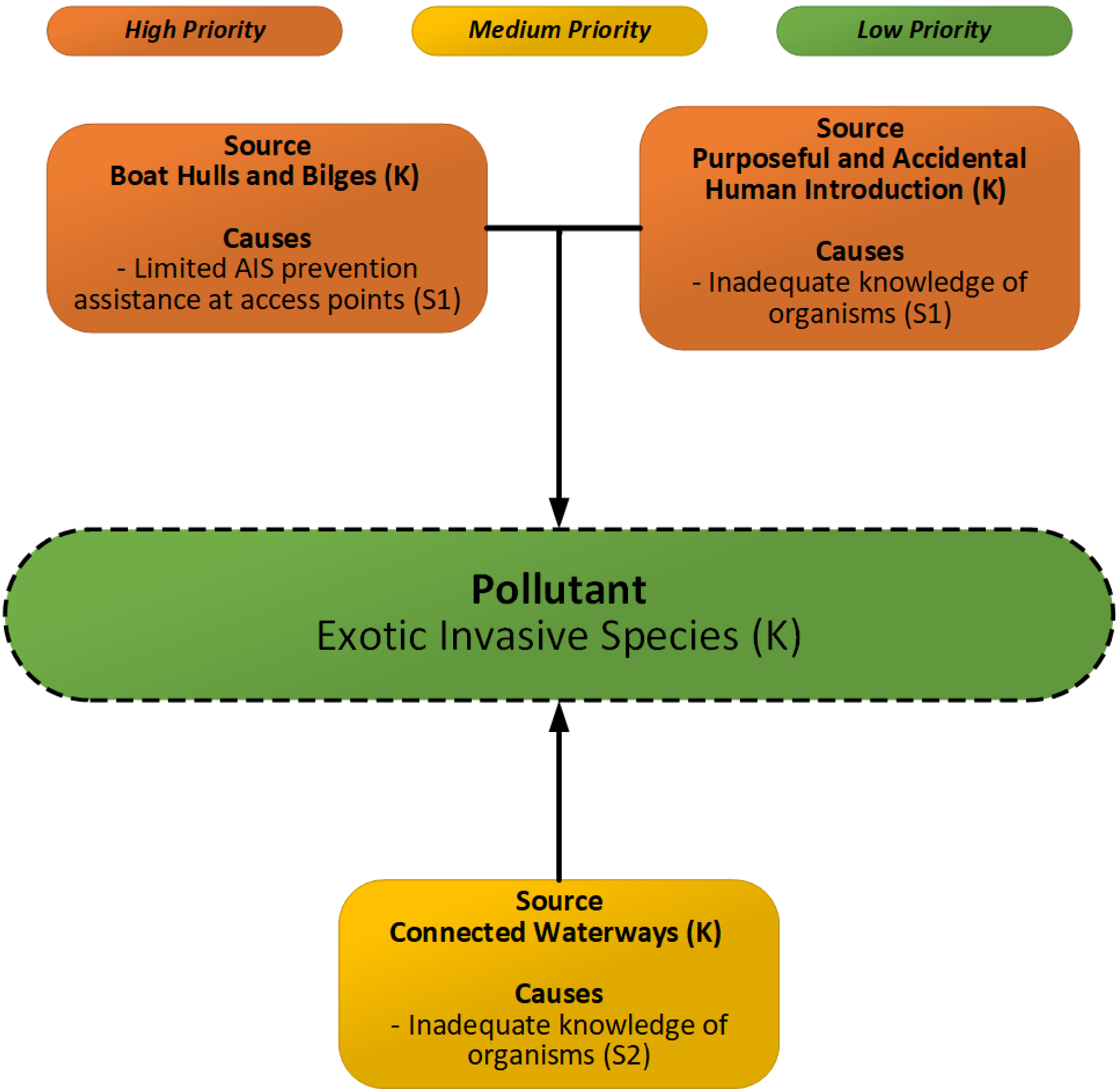


Figure 3.6. Exotic invasive species pollutant sources and causes.

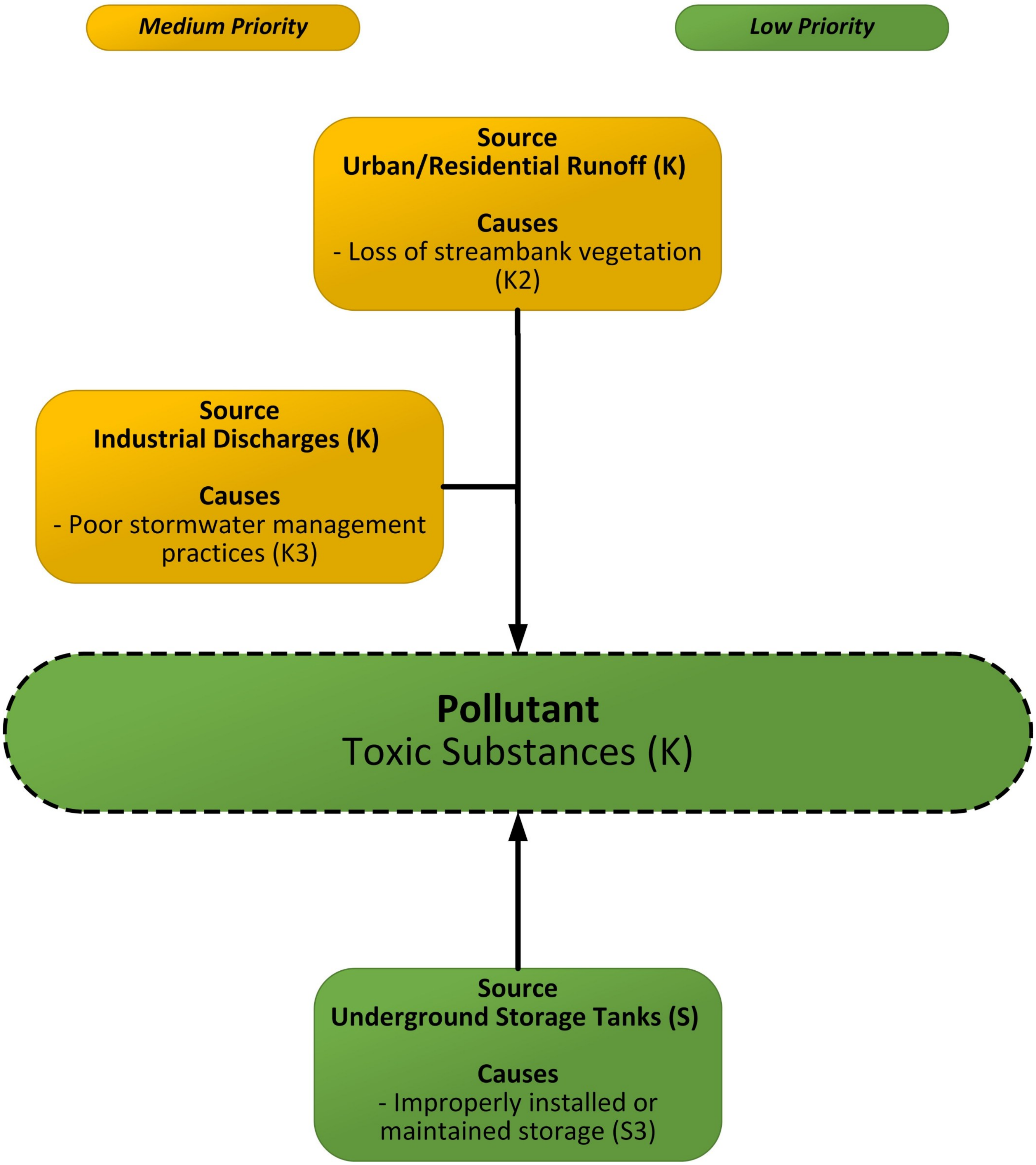


Figure 3.7. Toxic substance pollutant sources and causes.

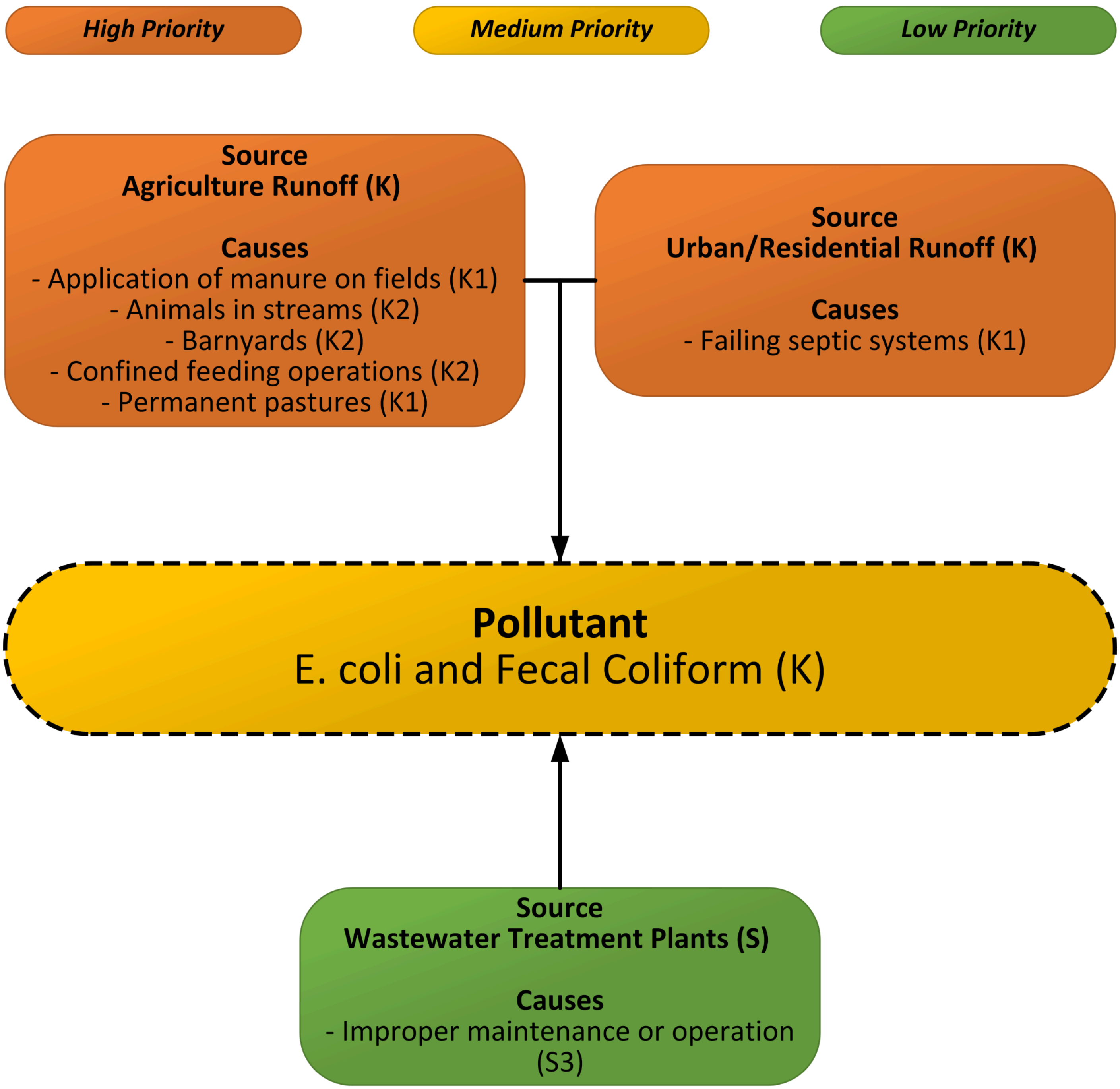


Figure 3.8. E. coli and fecal coliform pollutant sources and causes.

3.7 Condition of Subwatersheds

The general condition of each subwatershed is summarized below.

Mainstem of the Muskegon River

Below Croton Dam, the Muskegon River flows through the LMRW for about 45.5 miles before ending near US31. The Muskegon River acts as a partial boundary for each of the subwatersheds of this plan. Croton Dam is the lower most of three hydroelectric dams, built in the early 1900's, and continues to pose major impacts. According to Michigan DNR's Muskegon River Watershed Assessment (O'Neal 1997), the dams have taken swift moving water and replaced them with 'ponds', which has affected how the gradient of the river is distributed, altering fish passage, temperature, sediment transport, and several functions in the process. All high gradient areas are impounded and only 16% of the moderate gradient water remains accessible to fish migrating from Lake Michigan. For instance, the highest gradient portion of the mainstem occurs between Hersey and Newaygo; however, this section is almost completely impounded by hydroelectric dams.

Muskegon River steelhead (Photos courtesy of Kevin Feenstra)

The LMR has one of the most productive introduced fisheries in the Great Lakes with 'magnificent' angling opportunities for steelhead, Chinook salmon, and brown trout (Alexander 2006). Anglers come from across the nation, and even globally, to fish below Croton Dam. However, these fisheries are largely dependent on stocking, and threatened by warm water temperatures and the lack of thermal refugia, as well as bank erosion which may infill spawning habitat.

Temperature data collected below Croton Dam in 2022 showed July average temperatures at 70°F (Appendix D). This portion of the Muskegon is classified as a Cool Large River system by MDNR Fisheries Division. Cool Large Rivers occur in landscapes of fine and medium textured geologies and gentle topographic relief, where groundwater deliveries to stream channels are moderate. The typical summer fish assemblage of a Michigan Cool Large River includes 22-27 fish species, many of which adapted to transitional temperatures (chubs, daces, suckers, bullheads, and burbot). All of these are found in the Muskegon River. Due to the large water volume of the river, July temperature fluctuations are modest, allowing a number of warm-adapted fishes to be supported (minnows, suckers, pikes, sunfishes, darters, and walleyes). Annually, the Michigan DNR stocks brown trout and rainbow trout below Croton Dam where average water temperatures of 70°F may cause significant stress and mortality to the young fish.

Many of the coldwater and coolwater creeks that would serve as a temperature refugia for salmon and trout are blocked by Croton Dam. The dam also blocks passage for a small population of lake sturgeon that annually use the lower Muskegon River for spawning; within this population the young hatchlings stay in the river for at least the first few months of life. In the springtime, anglers and canoers are astounded and excited to see the sturgeon congregate in a small section of the lower river to spawn. Although sturgeon still reside in the watershed, the population is small, with low levels of natural reproduction and survival.

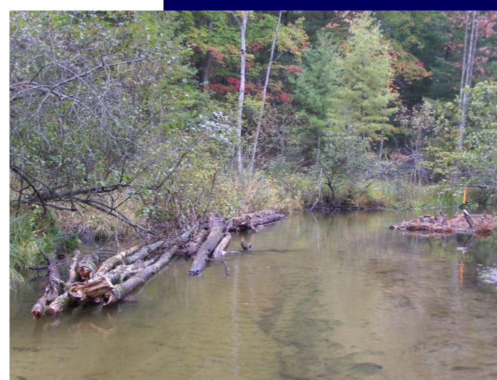
Other notable fisheries include walleye, smallmouth bass and sucker species.

Considerable riverbank erosion, and property loss, occurs throughout the LMR and will be described for each of the subwatersheds in Chapter 4. In the LMR, the water quality monitoring sites generally had low E. coli and TSS estimates, although TP concentrations were often above the concentration considered the transition point for stream quality (Appendix D).

Bigelow Creek Subwatershed

The Bigelow Creek subwatershed is in Newaygo County, northeast of the City of Newaygo. It contains two major creeks — Bigelow and Penoyer. This subwatershed is ranked 20th out of 40 for its size in the Muskegon River Watershed, with an overall area of 73.6 mi^2. The subwatershed has a high ratio of forest, wetland, and open field land cover (Figure 3.1). It also receives most of its hydrologic input as groundwater, with a high proportion of coldwater streams and low stream temperature fluctuation, except in areas impacted by dams (lower Penoyer Creek). The subwatershed is ranked as a High-Quality Area which means it is among the most critical natural areas within the LMRW and should be targeted for conservation efforts (AWRI 2002).

The sources of pollutants include dams, road-stream crossings, eroding streambanks, a lack of adequate streambank riparian zones, and areas of stream livestock access. There are over 30 eroding streambanks in the upper watershed, mainly along the Muskegon River and near Ryerson Lake. There are also numerous areas that lack streambank vegetation to create an adequate riparian buffer. Additionally, there are five areas where livestock can access streams and are known to cross and graze (Figure 3.9).



Large wood installed in Bigelow Creek for fish habitat. Photo courtesy of MRWA.

Bigelow Creek

Bigelow Creek originates from an agricultural drainage system southeast of White Cloud. From there it flows south, joined by many tributaries, as it makes its 15-mile trip down to the Muskegon River. Approximately a mile before entering the Muskegon River, Bigelow Creek has one of the highest stream gradient reaches (50ft/mi) in the watershed (O'Neal 2014).

The landscape that surrounds the Bigelow Creek watershed is relatively undeveloped and primarily forested, with a few scattered agricultural and wetland areas. Much of the subwatershed lies in federal ownership as part of the Huron-Manistee National Forest. The last half mile of Bigelow Creek flows through state-owned forest land before entering the Muskegon River. The forests within the subwatershed typically consist of aspen, white pine, and northern hardwoods (Tonello 2020).

There are no known dams in Bigelow Creek and since it flows into the Muskegon River below Croton Dam, the creek is accessible to migratory salmonids, including rainbow trout (steelhead), Chinook salmon, and coho salmon. Bigelow Creek is classified as a Cold Stream with a top-quality trout mainstream and tributaries that are top-quality trout feeder streams. Temperature data collected in 2022 showed July average temperatures at 67°F in the upper reaches and 64°F in the lower reaches (Appendix D). Cold Streams typically have regions where hills made of coarse-textured materials develop large aquifers that deliver strong groundwater inputs downslope to the stream channel. They also occur where streams drain steep valley walls of incised river valleys and receive strong groundwater inputs from upslope aquifers. Michigan has the most abundant Cold Streams resource in the Midwestern U.S.

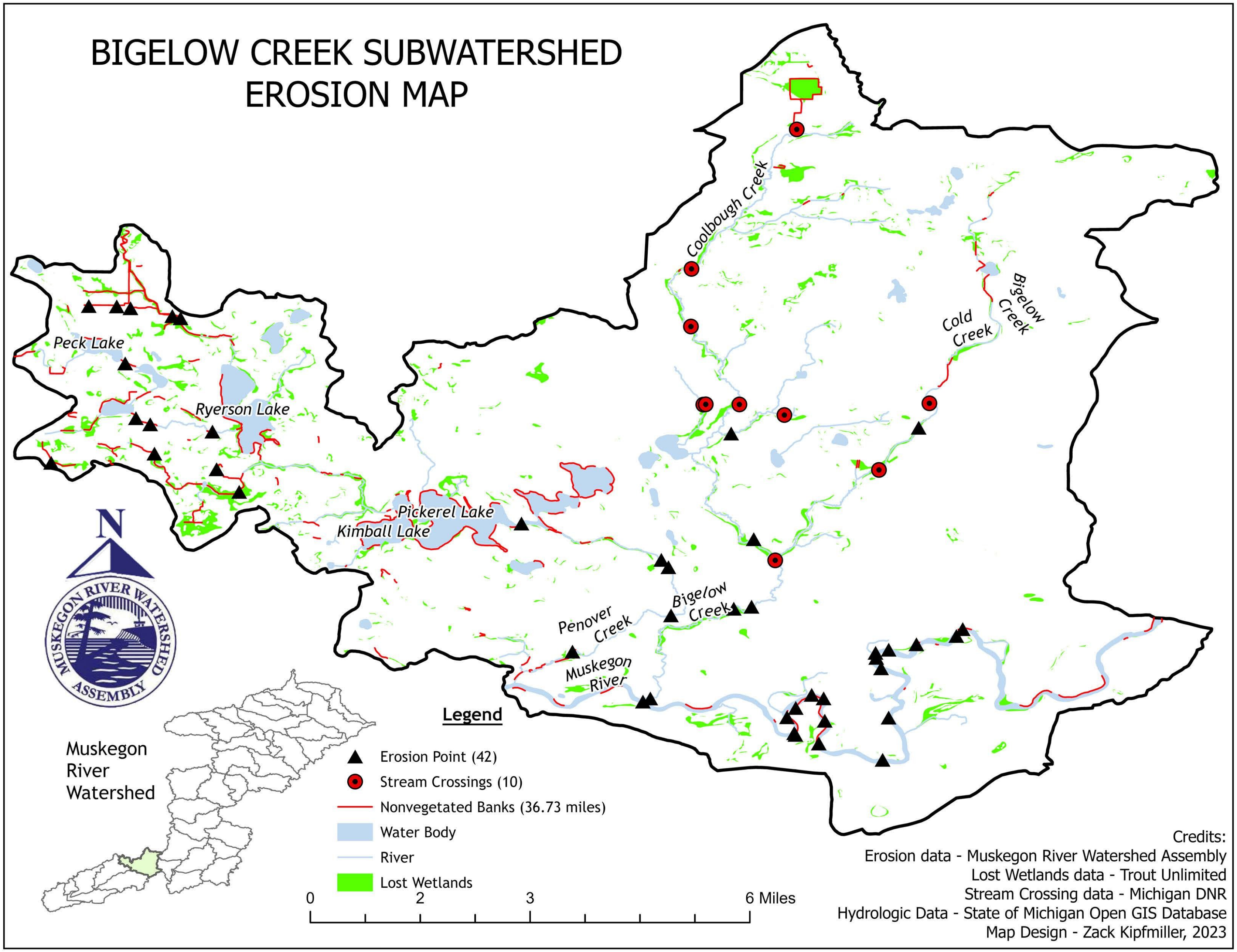


Figure 3.9. The Bigelow Creek sources and causes of pollutants that threaten designated uses.

3.7 Condition of Subwatersheds (continued)

As a self-sustaining trout and salmon stream, Bigelow Creek is an extremely valuable fisheries resource, both from a recreational and economic viewpoint (Tonello 2020). To help fish movement in Bigelow Creek, the Muskegon River Watershed Assembly, the USDA Forest Service, the Newaygo County Road Commission, and Trout Unlimited have worked to inventory road-stream crossings. Problem road-stream crossings have been prioritized and to date, six of the eight crossings identified have been improved.

Bigelow Creek was our most upstream tributary for monitoring. The upstream water sampling site was located at the 58th Street road-stream crossing, and the downstream stream site was just upstream of the confluence with the Muskegon River. TP concentrations were relatively low and ranged between 0.007 mg/L and 0.027 mg/L. Concentrations at both sites were generally similar on each sample date, suggesting that the watershed between 58th Street and the confluence contributes relatively little TP to the creek. Our data suggests that background TP concentrations are between 0.01 mg/L and 0.015 mg/L, at the upper range of that concentration is where shifts in biological communities may begin to occur. TSS concentrations ranged from 2mg/L to 14.3 mg/L. The TSS concentrations are relatively low and did not cause Bigelow Creek to look turbid or cloudy. These low concentrations are likely the result of Bigelow Creek supporting good vegetational cover (Appendix D).

Bigelow Creek does not have the number of drains, or mileage of drains, compared to the other creeks in the subwatershed, due to the low number of agricultural fields along the creek. The creek also has adequate streambank riparian zones throughout its reach, with only a handful of areas that are nonvegetated. There are less than 10 eroding streambank sites. There are two livestock access sites within 0.5 miles of the creek, but there are forested vegetation buffers between the farmland and the creek and no livestock access across the creek (Figure 3.9).

Penoyer Creek

Penoyer Creek is approximately five miles in length and discharges into the Muskegon River in the Village of Newaygo. Land ownership along Penoyer Creek is mostly private, although it does flow through several parcels of the Huron-Manistee National Forest and one state-owned parcel. Land use in Penoyer Creek watershed is almost entirely forested, with very little development (Figure 3.1). The primary landcover is northern hardwoods, with some conifers along the stream corridor. Over its 5-mile course, Penoyer Creek drops approximately 120 feet for a gradient of approximately 24 ft/mi (Tonello 2023).

Lower Penoyer Creek during the summer. Photo by MRWA.

The creek's origin begins with several small natural lakes including Peck Lake, Ford Lake, and Harmson Lake, which all have outlets that flow into Ryerson Lake. The outflow from Ryerson Lake (locally known as "Sandbar Creek") is a lake level control structure that regulates flows into Kimball Lake, which then flows directly into Pickerel Lake. The outflow from Pickerel Lake is also a lake level control structure and it joins with the outflow from Sylvan and Emerald Lakes just downstream of the Pickerel Lake outlet to form Penoyer Creek (Tonello 2019). These headwater lakes have a significant warming effect on Penoyer Creek but the stream accrues groundwater and cools quickly as it proceeds downstream (Tonello 2023). Temperature data collected in 2022 (Appendix D) showed how Penoyer Creek had much warmer summer water temperatures in the headwaters with average July temperatures of 73°F, but as the stream moved downstream the average temperatures decreased swiftly to 59°F in the lower reaches.

3.7 Condition of Subwatersheds (continued)

However, about a half mile before Penoyer Creek meets the Muskegon River, the creek flows into a three-dam complex which warms peak water temperature by over 5°F in the summer. All three dams are currently a focus for removal (Appendix D provides more detail on Penoyer Creek's dams).

The most downstream dam is part of the abandoned and crumbling Henry Rowe Manufacturing Company which produced wood products during the early 1900s. When people see the outlet of Penoyer Creek into the Muskegon River, it is not easy to forget.

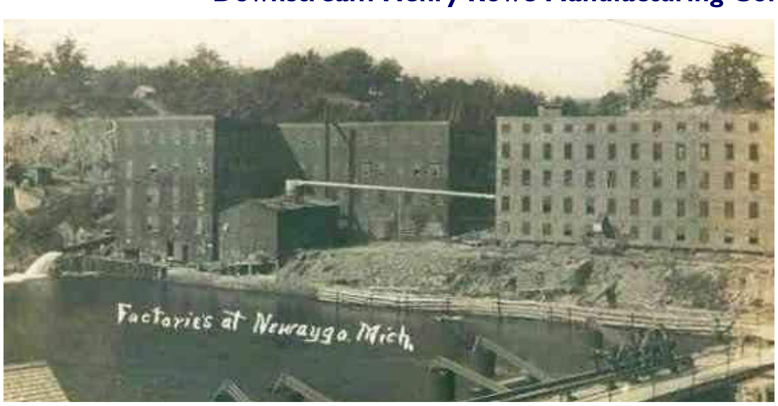
Penoyer Creek's Legacy of Dams

The Lower 3-Dam Complex

Upstream Rowe Dam #2

Middle Rowe Dam #1

Downstream Henry Rowe Manufacturing Company Dam



Photos courtesy of MRWA

Its notable feature is a blast of water launched into the air from concrete and metal chutes before joining the Muskegon River. This outlet prevents migratory fish, such as Chinook salmon or steelhead, from accessing the creek.

Penoyer Creek is a Designated Trout Stream with a self-sustaining population of brook trout, the only salmonid species in the creek. This is largely unique to the lower watershed, because other trout streams in the area are home to the generally dominant brown trout. . A 2021 fisheries survey showed that the lower half of Penoyer Creek continues to support coldwater species like brook trout. Kimball and Pickerel Lakes are classified as inland Cisco lakes. The Cisco, a state threatened species, is a member of a trout and salmon subfamily that usually occupies the cooler and deeper niches of high-quality freshwater and inland lakes and many parts of the Great Lakes. This species is very sensitive to habitat degradation and has been extirpated from lakes where minimum thermal and dissolved oxygen conditions are not met (EGLE 2020).

Phosphorus, suspended solids and *E. coli* concentrations were all found to be relatively low during all sampling events, likely due to the high forested and wetland area (Appendix D). Due to low development along Penoyer Creek there are few eroding streambanks (<10) and adequate streambank riparian zones. The nonvegetated areas are concentrated in the upper portion of the creek and there are no known areas of livestock access.

Brooks Creek Subwatershed

The Brooks Creek subwatershed is found in the southwest section of Newaygo County. This subwatershed is ranked 15th out of 40 for its size with an overall area of 61.6 mi^2 (AWRI 2002). The subwatershed begins as a series of lakes and streams where Brooks Creek flows from the headwaters of Fremont Lake and empties into the Muskegon River at the Muskegon County line (MDNR 1992). Tributaries to Brooks Creek include Dry Run Creek, Kempf School Creek, and Graham Creek. Dry Run Creek drains through agricultural land, followed by forested lands. Kempf School Creek flows through a forested valley. Graham Creek originates in a forested area.

Branstrom Park Dam impoundment (above) and downstream culvert (below).

Compared to other subwatersheds, the Brooks Creek subwatershed has relatively few dams. Only two are not associated with court-established lake level control structures. The first, Branstrom Park Dam, owned by the City of Fremont, is a complete barrier to fish. The dam spans eight feet, with a hydraulic drop of 1.5 ft from the top of the dam spillway to the water surface below. The impoundment behind the dam averages around 0.5 acres and varies seasonally. The dam influences stream temperature, although the impoundment is small and has a relatively low impact compared to the upstream lakes. The next downstream dam is Peterson Dam, located on Brooks Creek, which is approximately 1.6 miles downstream from Fremont Lake, where it forms the 12-acre Grandpa Lake. The dam acts as a complete blockage for fish passage. Water control structures exist at Fremont Lake and the chain of lakes, including First, Second, Third, and Fourth Lakes.

3.7 Condition of Subwatersheds (continued)

The entirety of Brooks Creek is a State of Michigan-designated Trout Stream. Temperature data collected in July 2022 showed average temperatures at 67°F in both the upstream and downstream sections. Brooks Creek is classified as a Cool Stream (MDNR, Fisheries Division) and is the result of fine and medium textured geologies and gentle topographic relief, where groundwater deliveries to stream channels are moderate. Cool Streams are home to a variety of fish species that tolerate cool and variable temperatures. The typical summer fish assemblage of a Michigan Cool Stream consists of 15-20 fish species, most of which are adapted to transitional and somewhat variable temperatures (minnows, daces, suckers, bullheads, mudminnows, and darters), as well as a few warm-adapted species (shiners, chubs, pikes, and sunfishes).

The Brooks Creek subwatershed is high in agricultural land use, which comprises 46% of the total area. Around 11% of the land use area is developed for other uses (Figure 3.1). In the original management plan (AWRI 2002), the Brooks Creek subwatershed was identified as the only Critical Area with a total ranking score of 10 (11 being the highest found in the entire watershed) because of high pollutant loading, largely from agriculture. The scores factored in temperature fluctuations, surface water runoff, and land use. The scores for both the land use and surface water were a 4, which was the highest critical score of the three categories. Temperature fluctuations scored a 2, as a low critical area.

In 2010, Annis Water Research Institute documented Brooks Creek as one of the two largest contributors to the Muskegon River for phosphorus and suspended solids during peak flows—the other contributor being Daisy Creek (AWRI 2010). The 2016 MSU Fremont Lake Water Quality Plant Assessment Report indicated Brooks Creek contributed a relatively small nitrogen load (MSUE 2016). However, for TSS, the study documented an increase from 4 mg/L in May to 105 mg/L in August. For nitrogen, the concentration doubled from 4 mg/L in May to 8 mg/L in August. Concentrations were higher downstream, but the overall load of nitrogen was only slightly higher in May compared to upstream. In August, Brooks Creek had lower concentrations downstream, but the flow was minimal during sampling. If there was a storm event in August to increase the streamflow, Brooks Creek could bring a considerable amount of nitrogen to Fremont Lake. The sediment and phosphorus in Brooks Creek was considered relatively low, though there was a large difference between its upstream (0.25 mg/L) and downstream (3.2 mg/L) site in May (MSU 2016). The values were substantially lower both upstream and downstream in August due to low flow during sampling.

Unconfined water source for livestock that contributes nutrients into waterways. Photo by Newaygo Conservation District.

According to the 2021 data report from the Cooperative Lakes Monitoring Program (CLMP), Fremont Lake's classification is rated between oligotrophic and mesotrophic, leaning slightly more mesotrophic. While an oligotrophic lake is very clear, has few plants, and is poor in nutrients, a mesotrophic lake is cloudier and has an intermediate plant and nutrient level. Fremont Lake retains some dissolved oxygen at the lake bottom into early summer, but becomes stratified by mid to late summer with the bottom layers functionally devoid of oxygen. The nutrient levels in the lake have remained largely unchanged since CLMP began monitoring in 2006.

The City of Fremont presented its Water Quality Report for 2021 which showed the city's water quality and safety met or exceeded all EGLE and EPA standards for drinking water. Any contaminants found in the water, such as microbes, inorganics, pesticides, organic chemicals, or radioactive concerns were far below the maximum allowed levels.

3.7 Condition of Subwatersheds (continued)

The 2022 sampling data for statewide mercury and TMDL locations revealed many areas not supported for the designated use of fish consumption. Concerns of PCBs were also found in several lakes and creeks. Another parameter used to determine water quality conditions within the subwatershed was the MiCorps macroinvertebrate data for stream quality. Samples were taken downstream and upstream of the Branstrom Park Dam. The downstream sample resulted in good quality on May 14th, 2022, whereas it rated as poor quality upstream, likely because of impounding effects from the dam. Both sites rated as good quality on September 19th, 2022.

Other known impairments of the subwatershed include eroding streambanks (Figure 3.10), a lack of adequate streambank riparian zones, areas of livestock stream access, and Concentrated Area Feeding Operations (CAFOs). There are over 50 eroding streambanks throughout the subwatershed, plus numerous areas that lack the streambank vegetation to create an adequate riparian buffer. Additionally, there are four areas of livestock access in the subwatershed where livestock is crossing over streams to graze. Finally, there are eight CAFOs either in the subwatershed or within 0.5 miles.

Agricultural area without a riparian buffer. Photo courtesy of the Newaygo Conservation District.

CAFOs are areas with high animal densities, meaning they can be a source of manure into the waterways. Manure can contain high nutrient levels and E. coli. This can cause algal blooms or for the water to be unsafe for human or animal contact/ingestion.

In 2022, water chemistry sampling occurred in Brooks Creek and, because of elevated levels of suspended solids and phosphorus, the creek was again sampled in 2023. The high amount of agricultural land in the subwatershed produces significant levels of both pollutants that are transported downstream into the Muskegon River (Appendix D).

Hess Lake Subwatershed

The Hess Lake subwatershed drains an area of 77.6 mi^2, the 17th largest out of 40. Hess Lake subwatershed is in Newaygo County between the City of Newaygo, Michigan and Maple Island Road to the southwest. There are four major tributaries: Brooks Creek and Sand Creek, located south of the Muskegon River, and Fourmile Creek and Minnie Creek to the north. Almost 20 miles of the Muskegon River mainstem is contained within the subwatershed. Only six lakes are found in the subwatershed, although Hess Lake (764 ac.) and Brooks Lake (259 ac.) are in the five largest for surface area in the Lower Muskegon River Watershed. Agricultural land use makes up 22% of the subwatershed area, with the amount of forested land (54%) becoming more abundant downstream as it approaches Bridgeton (Figure 3.1). As indicated in the original management plan (AWRI 2002), the Hess Lake subwatershed was considered a high-quality area with a ranking of 8 (11 being the highest found). This ranking is from the high forest, wetland, and open field land cover, which get most of their hydrologic input from groundwater and have a proportion of coldwater streams with minimal temperature fluctuation. The high-quality ranked areas are the most critical natural areas within the Muskegon River Watershed and should be targeted for conservation efforts.

Despite the high-quality ranking, there are threats to the Hess Lake subwatershed including dams, >150 eroding streambanks, a lack of adequate streambank riparian zones, one area where livestock can directly access waterbodies, and three CAFOs, either in or within 0.5 miles of the subwatershed (Figure 3.11).

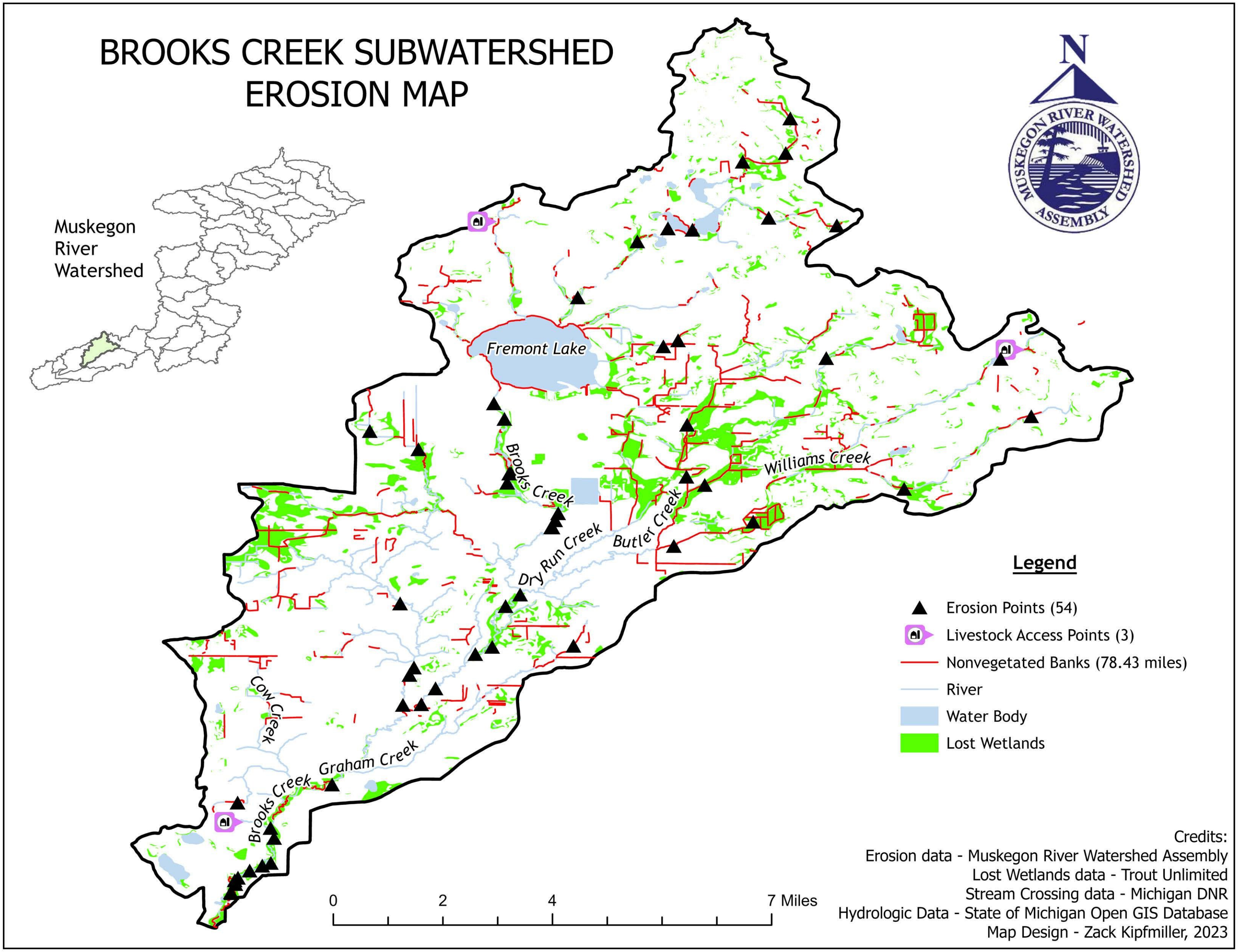


Figure 3.10. The Brooks Creek sources and causes of pollutants that threaten designated uses.

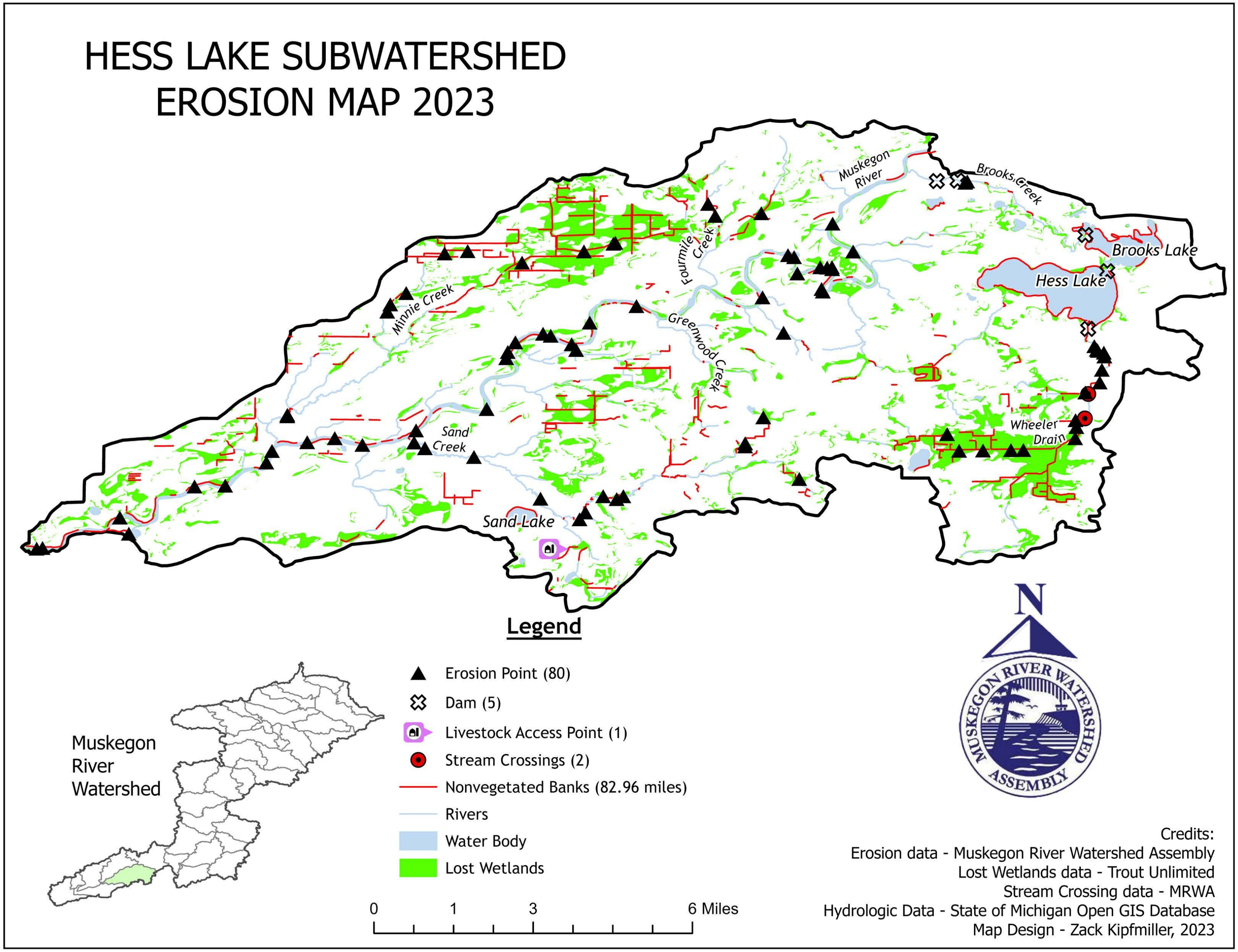


Figure 3.11. The Bigelow Creek sources and causes of pollutants that threaten designated uses.

3.7 Condition of Subwatersheds (continued)

Brooks Creek

In the southeast section of the Hess Lake subwatershed, Brooks Creek originates near the City of Grant from Wheeler Drain. The upstream Brooks Creek drainage underwent major watershed alteration in 1916 when the Wheeler Drain, which flowed into Rice Lake and the Grand River through the Rogue River, was routed into Hess Lake. This increased the size of the Brooks Creek drainage to almost three times its original size (SES 2022). The drain largely transports water from agricultural land, with the upstream portion of the drain being low grade and flashy because it is runoff fed. This leads to the transport and release of fine particulate matter downstream during rainfall events. Along the downstream stretch of Wheeler Drain, near Hess Lake, the channel has high, steep banks and no floodplain to slow the water during storm events and control erosion. This has caused flashy hydrologic flow and increased inputs of sediment and nutrient pollution into Hess Lake and Brooks Lake, the two largest lakes in the subwatershed. As the Wheeler Drain flows away from Brooks Lake, it becomes Brooks Creek. The stream gradient increases to moderate, with a more naturalized channel form, and land use changing from agricultural to more forested. About one-mile from the confluence with the Muskegon River, the stream elevation drops an impressive 100 feet as it flows through a high-gradient, steep-walled valley in the City of Newaygo (O'Neal 2015). The lower Brooks Creek, from Barton Street to the Muskegon River, flows for approximately 0.75 miles and is a State of Michigan Designated Trout Stream known to host migratory salmon (Chinook and coho), steelhead, and brown trout.

Brooks Creek and Wheeler Drain host the three dams found in the subwatershed. Two are court-determined lake level control structures; one on Brooks Lake and the other on Hess Lake. The lake level control structures increase the lakes' impounded areas, warm water temperatures, disrupt nutrient flow, and block fish migration. A significantly impactful dam is found at Barton Street in the City of Newaygo, at the upstream portion of the high gradient portion of the creek. The dam — which is a complete barrier to fish migration — is actively deteriorating, and has a height of 18 feet with a 10 foot water surface elevation difference upstream to downstream. The dam spillway creates a focused chute of water through the spillway, with high water velocity present all times of the year. The dam creates an upstream impoundment (~1 acre) which captures sediment and nutrients, produces algal and macrophyte growth, and increases water temperatures during the summer. If the dam was removed, it would restore hydraulic flow characteristics and nutrient transport, decrease water temperature, and open approximately three miles of river where fish could freely move from the Muskegon River to Brooks Lake. The most upstream dam of Brooks Creek is at the confluence of Wheeler Drain and Hess Lake, where a retention basin was constructed to partially remove phosphorus from entering Hess Lake from the drain. There are also road crossings in Wheeler Drain that are poorly aligned and perched that create fish passage barriers.

High gradient reach of Brooks Creek downstream of Barton Street Dam in the City of Newaygo. Photo by Caroline Gottschalk.

Fourmile Creek

Fourmile Creek empties into the north side of Muskegon River, eight miles downstream from the City of Newaygo, and is the tributary immediately downstream of Brooks Creek. The creek's drainage area is relatively small at 3.6 square miles, with most of the headwaters dedicated to agricultural land usage. While the upper portion of Fourmile Creek flows through agricultural land, there are only a few areas where the riparian zone is threatened, including an area flowing through a golf course between W. 80th Street to N. River Drive. There are few eroding streambanks along Fourmile Creek and no known areas of livestock access (Figure 3.11).

Sand Creek and Minnie Creek

Sand Creek empties into the south side of the Muskegon River at Bridgeton Township, and Minnie Creek empties into the north side of the river about 1.8 miles downstream at a transitional point in the Muskegon River Watershed. The two creeks define the upstream boundary of the lower watershed where the slope and geology of the river changes. Accordingly, both streams are low-slope and runoff driven with flashy flows during heavy rains and snowmelt (AWRI 2002). The origins of both rivers are in agriculture land and gradually changes to a more forested landscape approaching the Muskegon River. There are no known dams on either of the creeks, although Sand Creek includes numerous culverts that may be creating barriers to fish passage and increasing streambank erosion.

Temperature data collected in Sand Creek during 2022 showed July average temperatures of 66°F in the upper reach and 64°F in the lower reach. Sand Creek is classified as a Cold Stream (MDNR, Fisheries Division). Cold Streams anchor the cold end of the summer water temperature range for Michigan river systems and support excellent populations of coldwater fishes. Temperature data was also recorded in one location in the upstream section of Minnie Creek. The July average temperature was 67°F, supporting the MDNR's classification as a Cool Stream. Cool Streams are home to a variety of fish species that tolerate cool and viable temperatures, and smaller waters. The typical summer fish assemblage of a Michigan Cool Stream includes 15-20 fish species: most adapted to transitional and somewhat variable temperatures (minnows, daces, chubs, suckers, bullheads, mudminnows, and darters), and a few warm-adapted (shiners, chubs, pikes, and sunfishes).

During 2022 sampling, TP and TSS were relatively high in Minnie Creek at levels known to impact aquatic resources. In Sand Creek, phosphorus concentrations were consistently near concentrations considered the transition point for stream quality. Concentrations of TSS are above the concentration sufficient to alter water clarity (Appendix D).

For both Sand Creek and Minnie Creek, the upper portions have large areas of inadequate streambank riparian zones, due to high concentrations of agriculture fields and drains, while the lower portions are highly forested and have an adequate riparian zone. Both Sand Creek and Minnie Creek have less than 15 eroding streambanks each. There is a livestock access site within 0.5 miles of Sand Creek, but the access site does not cross the creek. The site is separated from the creek by a residential property and vegetation (Appendix D).

Mosquito Creek Subwatershed

The Mosquito Creek Subwatershed drains an area of 48.5 mi^2 and is the 7th smallest in size out of 40 subwatersheds. It is located in the upstream area of Maple Island in Newaygo County, reaching down to the City of Muskegon in Muskegon County. In the lower section of the subwatershed the Muskegon River "braids" into an extensive wetlands complex where two predominant channels form and empty into Muskegon Lake. Although the subwatershed's appearance is largely forested and undeveloped, it has undergone heavy use and alteration due to clearcutting of the forests and the floating of tons of logs down the mainstem.

3.7 Condition of Subwatersheds (continued)

One such alteration was the closing of the Maple River channel in the 1800's, which has left only Mosquito Creek as a major tributary to the Muskegon River. Mosquito Creek runs approximately 10 miles to its confluence with the Muskegon River, originating in an agricultural area on state-owned land (part of the Muskegon State Game Area) near the southern border of Newaygo County (Tonello 2023). A notable feature of the subwatershed is that only two road crossings to cross Mosquito Creek.

Mosquito Creek is a Designated Trout Stream and home to self-sustaining brook trout and rainbow trout populations, as well as many other fish including burbot, suckers, sculpin, and minnow. Temperature data collected in 2022 showed July average temperatures in Mosquito Creek at 60°F in the upper reaches and 65°F in the lower reaches. Mosquito Creek is classified as a Cold Stream (MDNR, Fisheries Division) supporting species adapted to cold or thermally-transitional conditions.

The Maple River anabranch (Chapter 2, Page 14) historically flowed through the subbasin, but in the 1850's the anabranch was identified as a problem for floating logs in the Muskegon River and dams were built as early as 1878 at the head of the Maple River. The damming has resulted in flooding impacts where farm fields are inundated with water, destroying crops. There are three road-crossings over the historic Maple River channel, each of which has been known to be overtopped with water during high-flow events. An initiative to re-open the Maple River is underway with an effort being led by local community members, MRWA, and numerous governmental agencies. The goal is to improve fish and wildlife habitat, recreation, and resiliency to high water events.

Log end stamped from the Ryerson Company pulled from the Maple River. Photos courtesy of MRWA.

The undersized Maple Island Road culvert which backs-up the Maple River during high flows.

Compared to other subwatersheds, the number of lakes is low, with only two exceeding 10 acres: Wolf Lake (221 ac.) and Maple Lake (13 ac.). The Mosquito Creek subwatershed also has the highest amount of forested land use (60%) followed by agriculture at 20% (Figure 3.1). Land ownership is largely public, including two features that account for well over 60% of the total overall area: the state-owned Muskegon State Game Area and the county-owned Muskegon County Resource Recovery Center (MCRRC). The Muskegon State Game Area is composed of an East Unit in Newaygo County and a West Unit in Muskegon County. According to the Michigan Natural Features Inventory (Lincoln 2020), the two units consist of 15,691 acres and is used for birding, trapping, hunting, and fishing. Within the SGA are swamps, bogs, wetlands, prairies, and forests that are home to several rare species such as the bald eagle, a Threatened Species of wild rice, Blanding's turtle, the wood turtle, and the eastern massasauga rattlesnake.

Massasauga rattlesnake. Photo courtesy of Michigan Natural Features Inventory.

The Muskegon County Resource Recovery Center (MCRRC) is a wastewater treatment plant on an 11,000-acre property that treats a broad spectrum of waste at a maximum of 42 million gallons per day. The MCRRC has a mixed aeration cell, an aerated settling cell, and two 850-acre storage lagoons. The water from the lagoons irrigate 5,100 acres of crop lands. The water outflow originally discharged into Mosquito Creek until the 1980's, when it was routed into the Muskegon River. The MCRRC was identified as a PFAS point of concern by EGLE's Industrial Pretreatment Program, due to concerns of leachate from the landfill located adjacent to the plant and wastewater from various industries and groundwater clean-ups containing PFAS. Between 2018 and 2022, a total of 19 samples out of 63 had detections above groundwater clean-up criteria. Elevated levels of PFAS were found in the storage lagoons and interceptor ditches.

The Muskegon County Resource Recovery Center. Photo by MLive.

Other known Mosquito Creek subwatershed impairments include eroding streambanks and a lack of streambank vegetation. There are over 30 eroding streambanks and numerous areas that lack the streambank vegetation necessary to create an adequate riparian buffer spread throughout the subwatershed (Figure 3.11).

As indicated in the original MRWMP, the tributaries in the Mosquito Creek subwatershed are runoff-driven with moderate to low baseflow and moderate to high peak flows. These streams have the potential to be flashy during heavy rainstorms and snowmelt events. However, during fisheries assessments in July 2022, temperatures at two sites was found to range from 60.2-66.7°F, which is relatively cold relative to air temperatures around 74-8°F at the time of sampling (Tonello 2023). The high-quality area ranking of the subwatershed was moderate, with a score of 7 (11 being the highest found). The scores factored in temperature fluctuations, surface water runoff, and land use. Land use scored a 3 due to the relatively high amount of natural landcover largely provided by the SGA. Temperature fluctuation cover rated a 1 (out of 4) indicating the warm-water conditions with low weekly temperature variations. Groundwater scored a 3, highlighting the importance of protecting Mosquito Creek and other coldwater resources in the largely runoff driven subwatershed. According to the MRWMP, BMPs that reduce negative effects of polluted surface runoff are needed and the public should be generally educated on BMPs and watershed issues. Phosphorus and suspended solids in Mosquito Creek and the Maple River have been found at levels that impact aquatic resources and affect water clarity (Appendix D).

3.8 Resources

Listed below are resources where you can learn more about the water quality and subwatershed characteristics of the LMRW.

⇒ Maple River Restoration Project. https://mrwa.org/mrwa_projects/maple-river-restoration-project/

⇒ Michigan DNR Bigelow Creek Status of the Fishery Report (Tonello 2020). https://www.michigan.gov/-/media/Project/Websites/dnr/Documents/Fisheries/Status/folder2/Bigelow_Creek_2020.pdf?rev=055b2c8f09b442d785a025d751fd06df

⇒ Michigan DNR Penoyer Creek Status of the Fishery Report (Tonello 2023). https://mrwa.org/wp-content/uploads/2023/06/Penoyer-Creek-2021.pdf

⇒ The Muskegon: The Majesty and Tragedy of Michigan's Rarest River by Jeff Alexander. Michigan State University Press, East Lansing, MI. 2006. https://msupress.org/9781628964646/the-muskegon/

⇒ The Muskegon County Wastewater Management System Metro Wastewater Treatment Plant. https://mcresourcerecoverycenter.com/

⇒ Muskegon River Watershed Assessment (O'Neal 1997). https://www.michigandnr.com/PUBLICATIONS/PDFS/ifr/ifrlibra/Special/Reports/sr19.pdf

⇒ State of Michigan's Water Control and Pollution Control in Michigan Integrated Report., Department of Environment, Great Lakes & Energy. https://www.michigan.gov/egle/about/organization/water-resources/glwarm/integrated-report

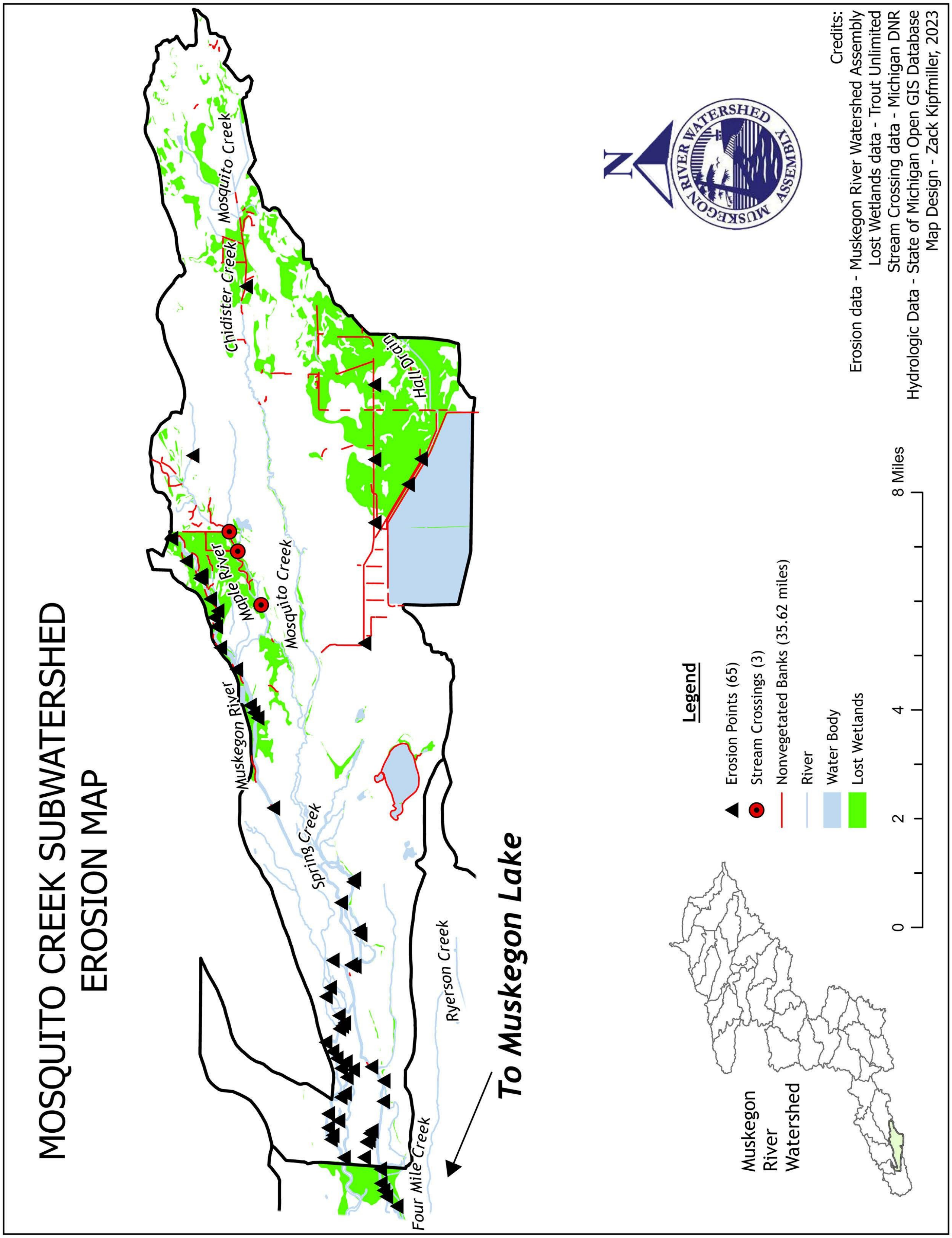


Figure 3.12. The Mosquito Creek sources and causes of pollutants that threaten designated uses.

Chapter 4: Watershed Action Plan

INSIDE THIS CHAPTER:

- **Understand the Goals for the Watershed and its Designated Uses**
- **Identify Areas of Focus for Pollution Reduction**
- **Become Familiar with Critical Areas and Areas of Focus for Preservation/ Restoration**
- **Know the Recommendations to Control Pollutants**
- **Learn Existing Policies**
- **Understand the I&E Strategy**

Introduction

4.1 Chapter 4 Summary

Highlighted below are some of the major points that you will learn in Chapter 4.

⇒ Goals developed for the watershed were based on restoring and protecting the designated and desired uses. Each goal has a set of objectives and tasks which targets the pollutants, sources, and causes that are impairing or threatening these uses in the watershed. These goals represent the anticipated future state of the Lower Muskegon River Watershed (LMRW).

⇒ In order to meet these goals and reduce the greatest amount of pollutants, areas contributing the largest pollutant loads were identified through a critical areas analysis. The analysis was done on the subwatershed scale using in-stream temperature fluctuation, surface water runoff, percentage of developed land use (agricultural and urban), streambank erosion, an agricultural modeling tool, and historic data sources. Physical inventories were also used to determine streambank erosion and dam impacts in the watershed.

⇒ The Brooks Creek subwatershed was ranked as severely critical. Other critical areas identified were smaller areas within the subwatersheds for streambank erosion, nutrients, E. coli and channelization and channel modification.

⇒ Many municipalities in the LMRW have zoning ordinances implemented that prevent harmful developments or disturbances from occurring close to water bodies.

⇒ High priority protection areas were identified for wetlands and ground water protection. Bigelow Creek subwatershed was identified as a protection area because of its high amount of groundwater inputs and valuable natural resources.

⇒ Management measures and practices to be implemented to control nonpoint source pollutants in the LMRW are listed. These management measures are grouped together based on their ability to control the pollutants of concern resulting from hydro-modification, agricultural and urban land, road stream crossings, and industry. Management measures to protect resources in the watershed are also listed.

⇒ Many of the water quality problems in the LMRW are the result of historic and current actions by individuals not aware of their impact. Consequently, the solutions will rely on individuals voluntarily taking actions that will secure the health of the watershed.

⇒ An Information and Education Strategy was developed to cultivate greater awareness in watershed stakeholders of the impact of their decisions on water quality in the LMRW from applying fertilizers and maintaining riparian buffers, to writing master plans and implementing zoning ordinances.

4.2 Goals for the Watershed

With the pollutants determined for the watershed, the next step is to establish goals that represent the anticipated future state of the Lower Muskegon River Watershed (LMRW). The goals below are based on restoring and protecting the designated and desired uses in the watershed (Section 3.3 and 3.4) and the specific subbasin goals can be found in Appendix E.

Goals to Restore and Protect Designated Uses:

⇒ Goal One: Remove the impaired reaches from the EGLE 303(d) list (Appendix B)

⇒ Goal Two: Improve quality of water entering streams and lakes by addressing hydrologic impacts from fluctuating flow and thermal conditions in the watershed. The target for water temperature will be to keep them within the range for coldwater and warmwater fisheries.

⇒ Goal Three: Improve quality of water by reducing excessive nutrient input into the watershed. The target will be to reduce nitrogen by 9,470.9 lbs/year and phosphorus by 14,082.1 lbs/year.

⇒ Goal Four: Improve quality of water by reducing excessive sediment input into the watershed. The target will be to reduce the sediment load in the watershed by 2,924 tons/year.

⇒ Goal Five: Protect/improve the recreational uses of the watershed by reducing the input of E.coli into the watershed. The target will be to stay below the water quality standards to protect the partial and total body contact designated uses.

4.3 Goals to Protect Designated Uses

Recreation: Fishing is a primary desired use along with hunting, canoeing, camping and hiking. Hunting, fishing and gathering is a desired use, and a Treaty guaranteed activity, for members of Tribes that are party to the 1836 Treaty of Washington. There are also emerging recreational uses that include mountain biking and trail running. In the middle watershed is the Dragon Trail, a world-class mountain biking location that attracts thousands of visitors per year. In the Mosquito Creek subwatershed, the 500-acre Mosquito Creek Trails is planned to eventually provide 12 miles of mountain biking trails for all skill levels.

Mountain biker on Mosquito Creek Trails.

Cultural: Protecting cultural resources is intrinsically connected in many ways to the health of the watershed. Within what is now known as the Muskegon River Watershed, Native Americans have maintained sacred connections to the landscape which has sustained their communities and allow them to nurture deep relations with the human and non-human communities in the area. It is important to recognize that their needs and values may differ from those of the general population. Some of these cultural connections have been identified through communication with Tribal governments and Native People of the watershed. *Manoomin* (Wild Rice) and *Nme* (Lake Sturgeon) are examples of species whose protection maintains cultural connections.

Education and Stewardship: Education and stewardship is critical for watershed management. An educated watershed citizenry will know and understand the problems facing their community and the solutions available to resolve them. Some recent examples of education efforts in the subwatersheds include installing Aquatic Invasive Species (AIS) signage at lakes, and MiCorps Stream Macroinvertebrate and CLMP (Cooperative Lakes Monitoring Program) sampling. An AIS boat decontamination station was installed at Sandy Beach in Newaygo County to prevent the spread of AIS to nearby lakes. MRWA is also partnering with area schools to create K-12 programs for water quality sampling at Wheeler Drain and the Maple River.

4.4 Areas of Focus for Pollutant Reduction

In order to meet these goals and reduce the greatest amount of pollutants in the watershed, areas contributing the largest pollutant loads need to be identified. This identification process is called a critical areas analysis. Focusing on severe critical areas (those areas with high pollutant loadings) will help prioritize the concerns and actions within the watershed. Identifying these areas will also result in the greatest reduction in pollutants and save money by focusing limited financial and technical resources on the areas directly contributing to these pollutants. The four factors used at the subbasin scale to assess the potential for water quality degradation and to aid in the identification of critical areas were:

⇒ In-Stream Temperature Fluctuation: Identifies cool water streams with moderate to high fluctuations. These streams are sensitive to changes in stream water temperature, which can severely impact fish and other aquatic species.

⇒ Surface Water Runoff: This ranking identifies streams that receive most of their hydrological input from surface runoff. These streams are sensitive to changes in land cover and the quality of water from the surface water runoff.

⇒ Percentage of Developed Land Use (agricultural and urban): This ranking identifies subwatersheds with high to low percentages of developed land and the degree of risk to water quality and habitat of the receiving waters.

⇒ Streambank Erosion and Non-Vegetated Banks: Identifies areas of eroding streambanks, or those at risk, because erosion can be a major cause of non-point source pollution through increases in the annual sediment and phosphorus loads in a watershed and can increase water temperature due to reductions in stream canopy.

Based on these criteria, each subwatershed was categorized as severely critical, moderately critical, or slightly critical. Those ranked as severely critical are believed to be contributing a high portion of the pollutants and having a significant impact on the LMRW. Details on how criteria were selected, and in-depth analysis can be found in Appendix F. This Critical Area Analysis added the individual subwatershed rankings from each of the four categories measured: temperature fluctuation, surface water runoff, land use and erosion (Table 4.1). Subwatersheds receiving higher rankings are the critical areas most sensitive to changes within the LMRW.

The Brooks Creek subwatershed was the only one to be characterized as Severely Critical in the model. The Severe ranking was due to the risks posed to water quality by the high percentage of developed land, including agricultural land, surface water runoff and streambank erosion.

Table 4.1. Lower Muskegon River Watershed Critical Area Ranking by Subwatershed

Subwatershed Name	Temperature Fluctuation	Surface Water Runoff	% Developed Land	Streambank Erosion	Total
Bigelow Creek	1	1	1	1	4
Brooks Creek	2	4	3	4	13
Hess Lake	1	1	2	4	8
Mosquito Creek	4	2	2	2	10

Other tools were used to identify critical areas on a finer scale and included the Agriculture Conservation Planning Framework, the EPA PLET model, water quality data collected as part of this plan (Appendix D) and archival information on changes to hydraulic flow. Physical inventories informed the selection of critical areas and included evaluation of streambank erosion on the mainstem of the Muskegon River and the assessment of dam and river channelization impacts on natural stream function.

4.5 Critical Areas

4.5.1 Agricultural Land Critical Sites

The Agricultural Conservation Planning Framework (ACPF) process was used to identify 878 fields, or about 43,289 acres, as high priority (Figure 4.1). The Brooks Creek subwatershed represents about 45% of the fields from the three subwatersheds in which the survey was conducted. The agricultural inventory process is found in Appendix G.

All the fields are in close proximity to surface water and many have impactful tillage practices and lack of cover crops or other "off-season" cover. It is likely that these priority fields are contributing the majority of sediment, nutrients, pathogens and other potential pollutants. Based on the model, most of the high priority sites were in areas of highest erosion potential and clustered around the boundaries of the subbasins, where the slope of the landscape and the gradients of the streams were the highest. These areas should be prioritized for BMPs. It must be reiterated that the fields depicted here were identified based upon a model of only three subwatersheds (Mosquito Creek was excluded due to funding). Some of the fields listed may not be a source of NPS pollution if conservation practices have been implemented, and fields that are not illustrated here may have NPS issues. Therefore, fields should be examined on a site-specific basis to determine the best alternatives for keeping soil, fertilizer, etc. on the field, or for filtering or capturing runoff before it enters the stream. Based upon the PLET model, these sites are contributing an estimated 3,665 tons of sediment, 203,382 lbs. of nitrogen and 37,119 lbs. of phosphorus on an annual basis. The subwatershed loads are found in Table 4.2.

Phosphorous concentrations exceeding EPA's ambient water quality criteria recommendations (US EPA 2000) were present in several areas including Brooks Creek (Brooks Creek subwatershed), Minnie Creek, Sand Creek (Hess Lake subwatershed) and Maple River (Mosquito Creek subwatershed) (Figure 4.2). The ACPF was used to identify agricultural fields within these subwatersheds that were adjacent to waterbodies and had slopes conducive to runoff. EGLE downloadable permit database was reviewed to determine fields that potentially receive manure application. These agricultural fields were identified as critical areas for phosphorus. The map displays phosphorous critical areas that are highly influenced by agriculture within the three subwatersheds that exceed the water quality standard. Sand Creek has the highest density of critical agriculture sites, which coincides with the creek having the highest phosphorous concentrations in the LMRW.

Table 4.2. Estimated annual pollutant loading from Agricultural Lands Critical Areas.

Subwatershed	Sediment (tons/ year)*	Nitrogen (pounds/ year)	Phosphorous (pounds/year)
Bigelow Creek (Penoyer Creek subbasin)	527	39,207	6,012
Brooks Creek	1,627	89,792	16,826
Hess Lake	1,511	74,383	14,281

* Sediment load estimates exclude mainstem of the Muskegon River.

4.5.2 Streambank Erosion Critical Sites/Areas on the Mainstem of the Muskegon River

The critical streambank erosion sites were identified through an evaluation of aerial photography, field assessments at bank sites, and through physical assessments conducted by MRWA. Four critical areas were identified on the mainstem of the Muskegon River (Figure 4.3) in three of the subbasins: Bigelow Creek (1,2), Hess Lake (3) and Mosquito Creek (4). The total annual sediment pollution is presented for each reach in Table 4.3 and photos of representative eroding streambanks are found in Figure 4.4.

Reach #1

This most upstream critical area reach in the Bigelow Creek subbasin is approximately 6.4 miles in length starting just upstream of South Croton Trail downstream to Spruce Avenue. It has a relatively narrow and sinuous stream channel with high banks. Many of the streambanks in the reach are the result of historic rollways during the logging era and were exacerbated by peaking operations at Croton Dam. The erosion is severe with the largest eroding bank (latitude 43.434960, longitude -85.705889) surveyed to

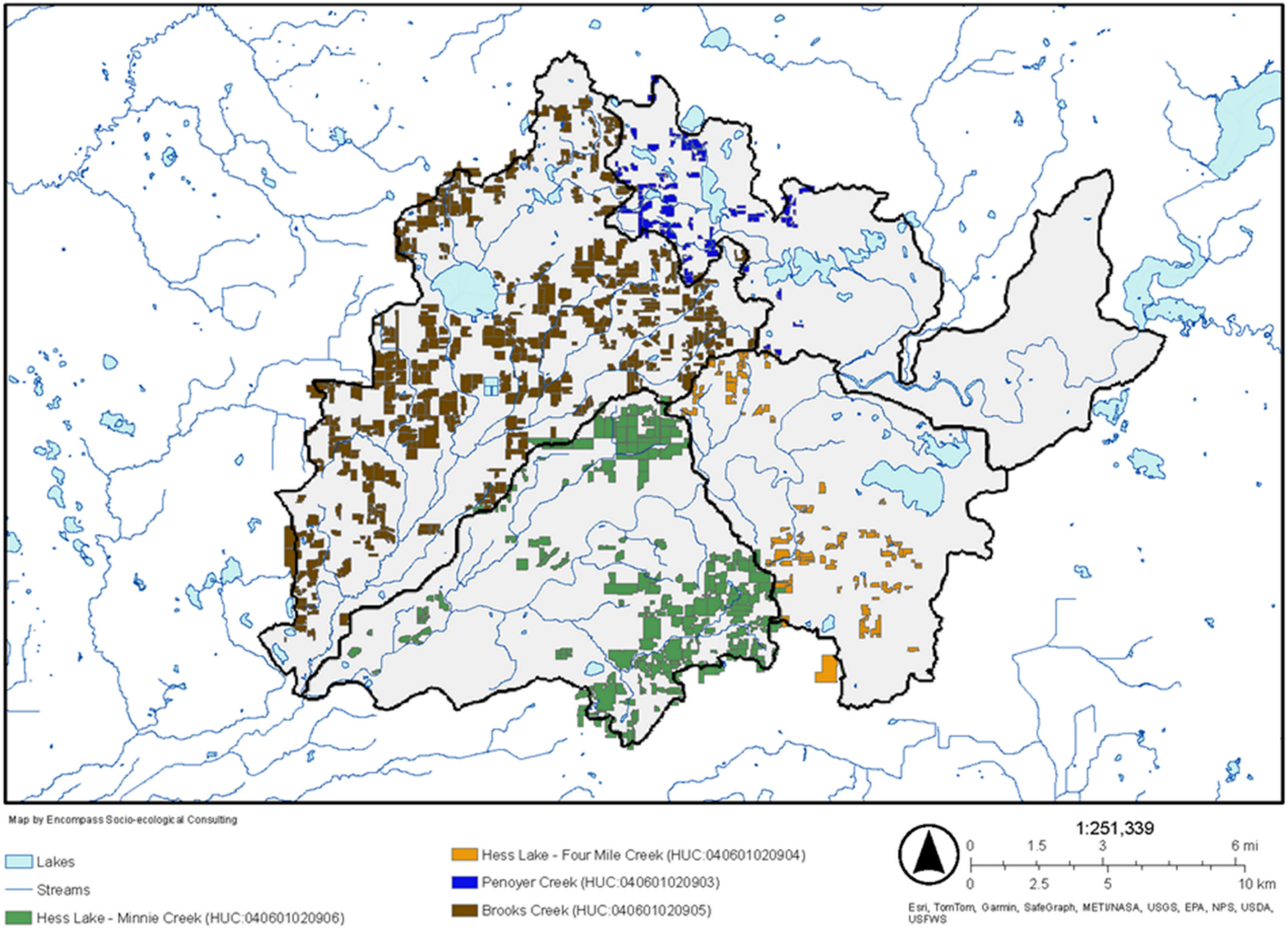


Figure 4.1. Priority fields identified in the Agricultural Conservation Planning Framework (ACPF) for three subwatersheds in the Lower Muskegon River Watershed.

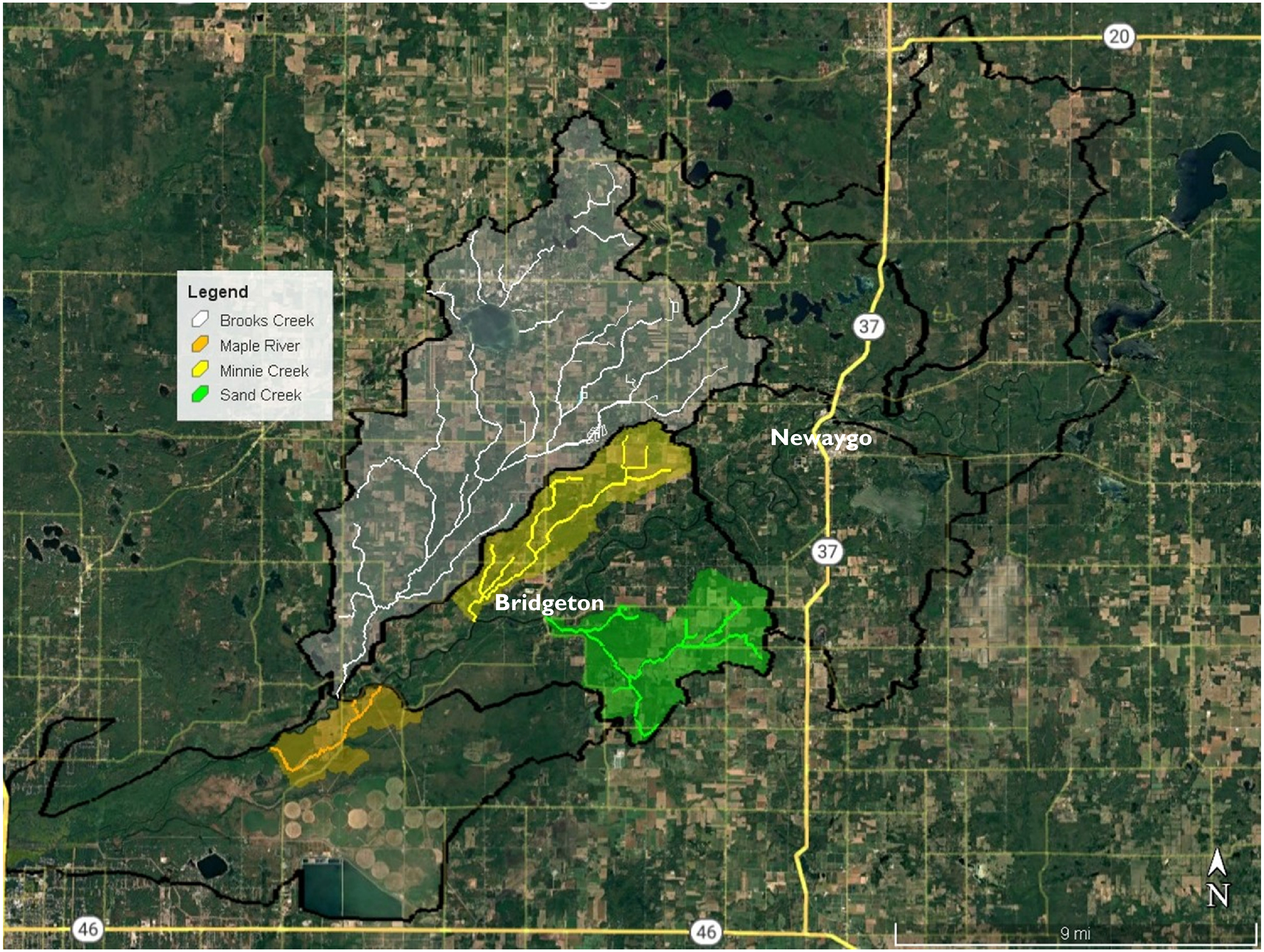


Figure 4.2. Phosphorus critical areas in Brooks Creek subwatershed, Minnie Creek and Sand Creek subbasins (Hess Lake subwatershed), and Maple River (Mosquito Creek subwatershed). The white, yellow, orange and green lines represent the reaches in need of BMPs.

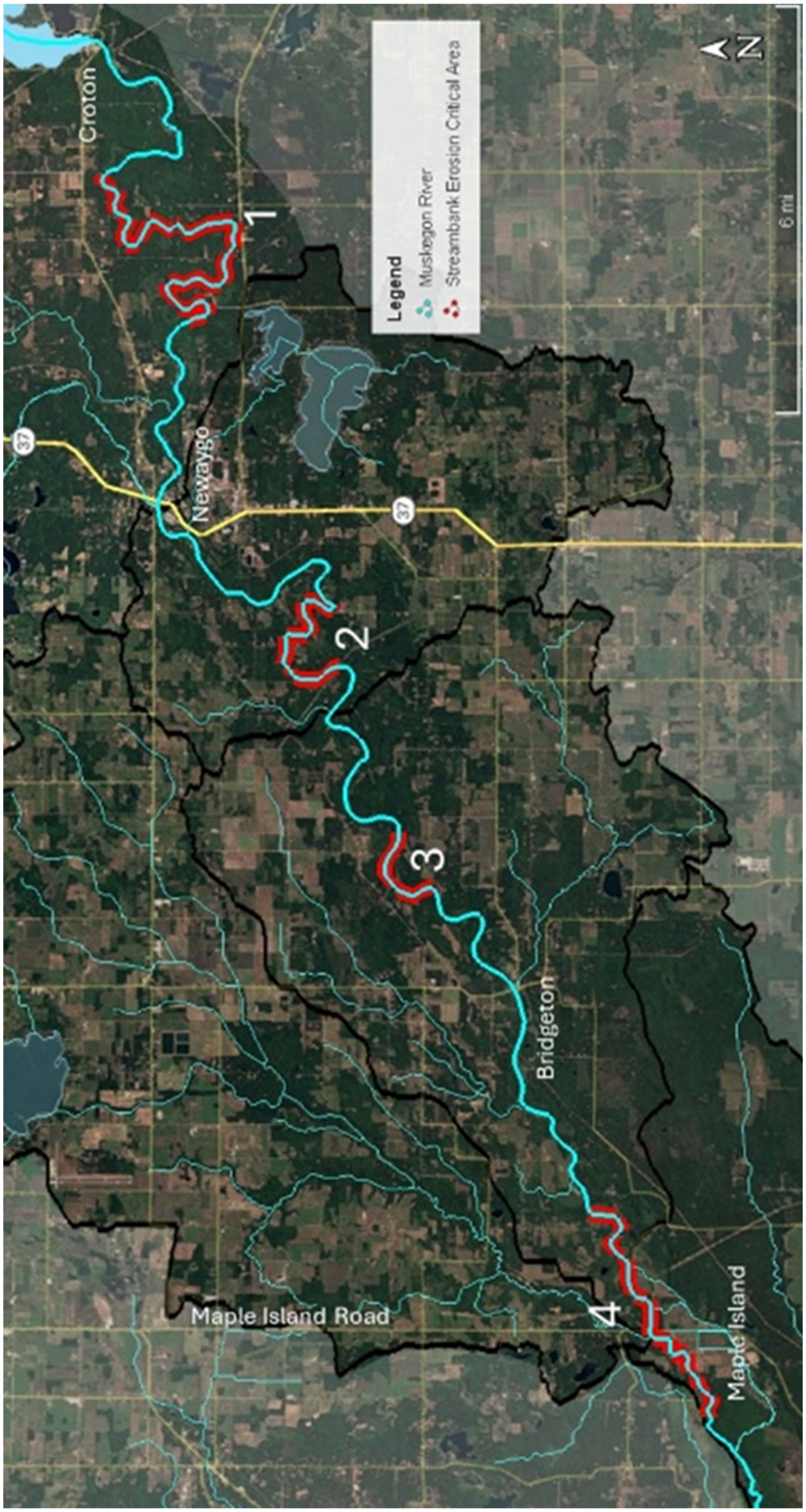


Figure 4.3. The four streambank erosion critical areas on the mainstem of the Muskegon River.

have a height of 122 feet and a length of 1,500 feet where landowner bank protection efforts have failed. The Croton Dam may have impacts on Reach #1 as the dam limits natural sediment transport. This sediment transport is important as it mitigates the rivers vertical erosive potential. When upstream sediment supplies and transport processes are altered (i.e., dam regulation), greater erosive potential occurs downstream and increases the erosive forces and angles on those banks. Groundwater seeps and unconsolidated soils, characteristic of dune deposits, make up much of the surrounding area.

Reach #2

This reach is in the Bigelow Creek subbasin and 2.7 miles in length, starting at the east end of River Lane downstream to where powerlines cross the river near the end of South Parsons Avenue. The river channel is relatively narrow and sinuous with several high banks. Many of the historic activities that damaged Reach #1 are occurring in Reach #2. The erosion is severe with one of the larger eroding banks (latitude 43.434960, longitude -85.705889) surveyed to have a height of 15-20 feet and a length of 450 feet. The site is at a campground where the bank collapses into the river each year.

Reach #3

This reach in the Hess Lake subbasin is 1.9 miles in length and starts at the end of Pepperidge Street and extends downstream near the end of 104th Street. The streams sinuosity has lessened in its sharp turns from the upstream reaches but has a tight meander at the end of the reach. Most of the erosion occurs near residential properties where lawns have replaced the vegetated landscape.

Reach #4

This reach in the Mosquito Creek subbasin is 4.4 miles in length and starts near the end of West 124th Street and extends downstream to 0.3 miles below Brickyard Road. In this reach, the Muskegon River is lower in gradient, stream sinuosity has decreased, riverbank height is relatively low (1-10 feet) and many of the banks are undercut and slumping over the river. The area is of high concern to landowners who have informed the MRWA and the Muskegon Conservation District of property loss. One large bank protection project has been completed just downstream of the outside bend from Maple Island Road.

Table 4.3. Estimated annual sediment pollutant loading from Streambank Erosion Critical Sites.

Reach	Total Length (ft)	Tons/yr
1	6,336	6,308
2	2,960	963
3	6,334	609
4	2,941	382

Figure 4.4. Examples of streambank erosion. The left image is a severe bank in Reach #1, the middle image is a campground site in Reach #2, and the right image is a bank in Reach #4 that was recently protected.

4.5.3 *E. coli* Critical Areas

E. *coli* concentrations above the EGLE water quality standard for full body contact were found in Penoyer Creek, Minnie Creek, Brooks Creek, Sand Creek and Mosquito Creek. Partial body contact exceedance was found in Sand Creek and Brooks Creek. The agricultural fields identified in the ACPF as critical areas for phosphorous are also considered critical areas for *E. coli*. This is due to the regular manure application that has a high probability of entering the tributaries through runoff. It's probable that numerous septic systems are failing throughout these subwatersheds but are difficult to trace and aren't likely contributing as much *E. coli* as manure due to the density of agriculture surrounding each tributary. The map in Figure 4.5 displays the identified critical areas for *E. coli.*

4.5.4 Channelization and Channel Modification

Three areas were identified where channel modification is a significant stressor and has altered hydraulic flow, temperature, fish passage, and sediment and nutrient transport. Many of the stream and river channels in the LMRW have been modified and this has impacted ecological diversity, decreased instream habitat and produced unstable flows resulting in flooding. In the LMRW, extreme channel modification began during the late 1800's logging era and continued into the early 19th century with the agricultural boom and wide-scale damming of rivers. The result was the draining of wetlands, removal and loss of instream habitat, straightening of river channels, destabilization of streambanks, and the widening and shallowing of streams and rivers. Continuing pressures are being faced with the increase in urban land use. The three critical areas for channelization and channel modification include;

- ⇒ the mainstem of the Muskegon River
- ⇒ the three-dam complex on lower Penoyer Creek
- ⇒ the Maple River area

The mainstem of the Muskegon River: The mainstem was the recipient of logs transported downstream to Muskegon Lake which scoured and widened the river bottom, removed the majority of large woody habitat in the river, and devegetated banks and left exposed sand.

Lower Penoyer Creek: Three dams exist within 1 mile of the confluence with the Muskegon River and they disrupt flow, block aquatic organism passage, and warm temperatures (See 3.7).

Maple River: Two inlets of the Maple River were blocked during the logging era, leaving an often-dry channel while forcefully redirecting water into the Muskegon River. This has produced a widening and shallowing of the Muskegon River, flooding of roadways and agricultural fields near the historic Maple River channel, and accelerated bank erosion.

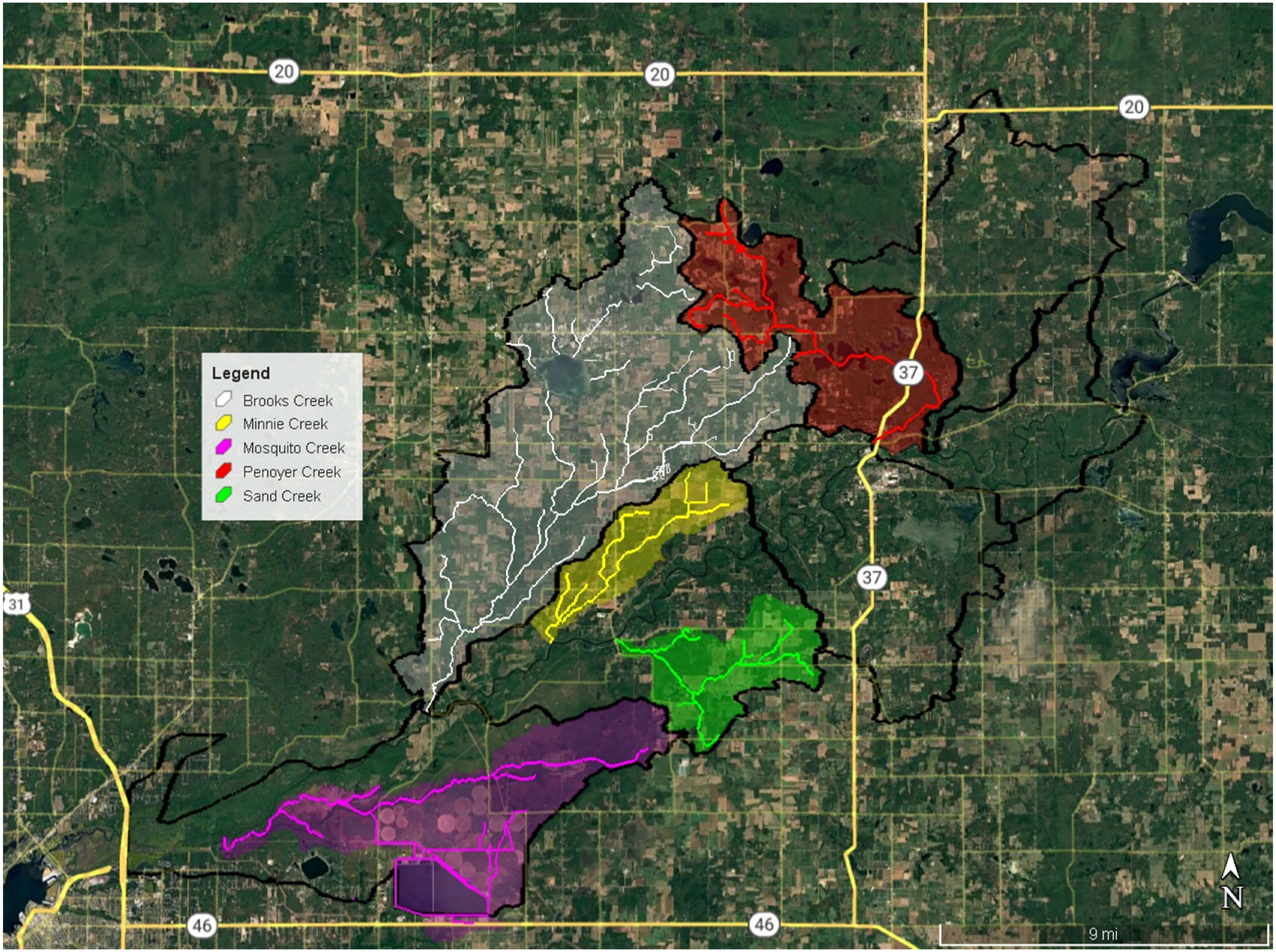


Figure 4.5. E. coli critical areas in Brooks Creek, Minnie Creek, Maple River and Sand Creek. The white, yellow, orange and green lines represent the reaches in need of BMPs.

4.6 Areas of Focus for Preservation and Restoration

Wetland and Groundwater Preservation

Wetlands and groundwater are areas of focus for preservation that span the entire LMRW. Wetlands provide groundwater filtering and recharge, recycling of waste products, flood control, breeding grounds for fish and wildlife, and water for human use. Groundwater contributes to standard stream flows and temperatures and is the water within aquifers that human residents, farms and businesses rely on. These areas are crucial for the general health of a watershed.

Under Michigan law, wetlands greater than five acres in size or contiguous with other bodies of water are generally protected from development and draining through a permitting process. However, the wetlands act allows for mitigation, such as an agreement to construct a manmade wetland in another location post removal of a natural wetland. Because wetland loss has been so great in the LMRW, all existing wetlands are recommended as priority wetlands to protect through local ordinances, which is the most cost-effective means of protecting wetlands. The wetlands are found in Appendix A. Preservation of wetlands will also improve groundwater conditions.

The best way to protect the groundwater source in the LMRW is to work with local government to regulate well-dependent developments and to write new groundwater protection ordinances where necessary. Promoting water saving and dry landscape alternatives for lawns will provide further protection.

Wetland Restoration

Loss of wetlands has altered the hydrology (increases in duration, magnitude and frequency in flow) and water quality (loss of free, natural filtering capacity) within the LMRW. Wetland restoration will be necessary to reverse negative impacts. The pre-settlement wetlands can be seen in Appendix A, a portion should be targeted for restoration. The most important consideration for restoration of these wetlands is interest and authorization from property owners. Once landowners have agreed to restoration of wetlands on their property, site-specific survey, design, cost estimation and planning can occur.

Groundwater Protection

In the initial watershed management plan, Bigelow Creek is identified as a High-Quality and one of the most critical natural areas within the Muskegon River. It should be targeted for protection and conservation efforts because of its high proportion of undeveloped and forested coldwater streams, excellent trout fishery, and low stream temperature fluctuations. Promoting forestry practices that maintain or increase water retention and canopy cover of streams, while reducing surface runoff will provide further protection.

4.7 Recommendations to Control Pollutants

Management Measures

Now that the areas of focus have been identified, recommendations on what to do in these areas need to be made. This section outlines management measures and practices to be implemented to control nonpoint source pollutants in the LMRW. These management measures are grouped based on their ability to control the pollutants of concern resulting from hydro-modification, agricultural and urban land, road stream crossings, and industry. Management measures to protect resources in the watershed are also listed. To inform the BMP options available for each critical area, Table 4.4 provides BMPs which could be implemented, the organizations that provide technical assistance and the sources of funding available. A detailed 10-year schedule with suggested BMPs, the quantity needed to meet necessary load reductions, costs, and partners needed for implementation are listed in Table 4.5.

Management measures establish performance expectations and specify actions to minimize nonpoint source pollution. These actions, or management practices, are designed to control a particular type of pollutant from specific activities and land uses. These management practices, also known as best management practices, are a method for preventing or reducing the pollution resulting from an activity.

Best management practices can be separated into two categories: structural and non-structural. Structural practices refer to engineered techniques implemented on the ground. Examples include constructed wetlands, streambank stabilization, and rain gardens. The second category, non-structural, refers to practices that change a personal behavior such as using phosphorus free fertilizer, maintaining septic systems, and applying conservation easements on your land. For best management practices to be effective, the correct method, installation, and maintenance needs to be considered.

To implement portions of this plan, many partners and sources of funding will be needed. Each partner brings unique roles and responsibilities, and each funding source a specific focus. The partners and sources of funding listed below have been identified to help implement best management practices and the I&E implementation plan (Section 4.9).

Partners are essential to implementing watershed management goals. Left photo: The Muskegon River Watershed Assembly (MRWA) and Newaygo County Parks & Recreation Commission installing an AIS decontamination station; Right Photo: Wayne Grosbeck (left), a founding member of MRWA, and Kevin Feenstra (Muskegon River fishing guide), volunteering on a nighttime survey of lake sturgeon on the Muskegon River.

Partners

CCD - County Conservation Districts

CDC - County Drain Commissions

CHD - County Health Departments

CPD - County Parks Department

CRC - County Road Commission

DNR -Michigan Department of Natural Resources

EGLE - Michigan Department of Environment, Great Lakes, and Energy

FSU - Ferris State University

GVSU – Grand Valley State University

LCWM - Land Conservancy of West Michigan

LS - Local Schools

LRBOI - Little River Band of Ottawa Indians

MAEAP - Michigan Agriculture Environmental Assurance Program

MDARD - Michigan Department of Agricultural and Rural Development

MRWA - Muskegon River Watershed Assembly

MSUE - Michigan State University Extension

TU - Trout Unlimited

USDA NRCS - US Department of Agriculture Natural Resources Conservation Service

USFS - US Forest Service

Sources of Funding

319 NPS - Nonpoint Source Pollution Control Grants: Federal Clean Water Act Section 319

GLFT-Great Lakes Fishery Trust provides funding to enhance, protect, and rehabilitate Great Lakes fishery resources (www.glft.org)

GLRI-Great Lakes Restoration Initiative administered by EPA (https://www.epa.gov/great-lakes-funding/great-lakes-restoration-initiative-glri)

MCCI - Ducks Unlimited Midwest Cover Crop Initiative

NRCS & USDA Programs

⇒ EQIP - Environmental Quality Incentives Program provides technical and financial assistance to agricultural producers and forest landowners to address natural resource concerns (https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives)

⇒ Farm Bill Programs - USDA's NRCS program to support conservation efforts of America's farmers (https://www.nrcs.usda.gov/farmbill)

⇒ RCPP - Regional Conservation Partnership Program is a partner-driven approach to conservation that funds solutions to natural resource challenges on agricultural land (https://www.nrcs.usda.gov/programs-initiatives/rcpp-regional-conservation-partnership-program)

⇒ WRP - Wetlands Reserve Program (https://www.nrcs.usda.gov/programs-initiatives/wre-wetland-reserve-easements)

SOGL-Sustain our Great Lakes Program administered by the National Fish and Wildlife Foundation (https://www.nfwf.org/programs/sustain-our-great-lakes-program)

USFWS - Fish and Wildlife Grants & Cost Share Programs

Table 4.4. General BMP Recommendations for LMRW Pollutant Critical Areas.

Critical Area	Objectives	Recommended BMPs	Techincal Assistance	Sources of Funds
Agricultural Land	**Reduce runoff of fertilizers and manure, reduce thermal pollution**	Install 35ft grass buffer between agricultural land and water body	CCD, CDC, NRCS, EGLE, MRWA, TU, Ag Industry Partners	319 NPS, NRCS Farm Bill Programs, RCPP, GLRI, MCCI
		Install cover crops prior to natural planting cycle		
		Implement tillage practices on ≥60% of the area of agriculture fields		
		Address rill/gull erosion with grassed waterways		
	Erosion and sediment control	Establish cover crops and promote residue and tillage management		
	Improve manure field applications	Manure injection or incorporation		
		Follow GAAMPS and Manure Application Risk Index recommendations to determine runoff risk of manure spreading		
	Reduce livestock access to surface water	Implement livestock exclusion fencing at access points		
		Alternate water sources for cattle		
Streambank Erosion	**Repair and/or reduce streambank erosion**	Install riparian vegetation (buffer strips) and create vegetated areas along waterways	EGLE, LRBOI, MDNR, USFS, USFWS, CCD, CDC, MRWA, TU	319 NPS, GLRI, NRCS EQIP, CRP
		Install stream bank protection practices including tree revetments and native plantings		
		Collect additional interest from landowners for potential streambank restoration . Promote MRWA Landowners Guide to Streambank Restoration website	MRWA	MRWA
		Install properly placed (aligned with stream flow) and sized (meets bankfull width) culverts	LRBOI, MRWA, TU, CRC	319 NPS, GLRI, USFWS, GLFT, MDNR, CDC
E. coli Contamination	**Reduce runoff of fertilizers and manure**	Install 35ft grass buffer between agricultural land and water body	CCD, CDC, NRCS, EGLE, Ag Industry Partners	319 NPS, NRCS Farm Bill Programs, RCPP, GLRI, MCCI
		Install cover crops prior to natural planting cycle		
		Implement tillage practices on ≥60% of the area of agriculture fields		
		Plant riparian plants along streambanks		
	Reduce animal contact with the waterbody	Implement livestock exclusion fencing at access points		
	Address human sources of E. coli	Cost share for septic repairs/replacements	CDC, CHD, EGLE, Private Septic Services Companies	319 NPS, GLRI
		Identify and remove illicit connections		N/A
		Sewer hookups or community septic systems for new developments	CDC, CHD, EGLE, Townships (Ordinances), MSUE	EPA (Clean Water State Revolving Fund), NRCS
Channelization and Channel Modification	**Repair form/function of streambed and channel**	Re-establish meandering of stream and river channels	USFS, USFWS, LRBOI, MDNR, MRWA, TU, MSUE	319 NPS, GLRI, USFWS, MDNR, NFWF, SOGL
		Install in-stream habitat including large woody debris		USFWS, GLRI, NFWF, SOGL, GLRI
	Reconnect floodplain	Remove barriers (dams) that have distrupted the natural water course	LRBOI, MDNR, USFS, USFWS, CCD, MRWA, TU	319 NPS, GLRI, MDNR, USFWS, SOGL
		Replace undersized and misaligned road crossings		
Wetland Protection	**Improve hydrology and water quality**	Local land protection ordinances	Townships, CDC, MRWA, TU	Local/county/ township
		Land protection/conservation easements	CDC, LCWM, EGLE, CPD	WRP, 319 NPS, GLRI, CPD, private donation
Wetland Restoration		Land procurement for wetland restoration	LCWM, MSUE	319 NPS, GLRI, private donation
		Restoration without procurement	CDC, LCWM, NRCS, USFWS, EGLE	NRCS/USDA programs, 319 NPS, GLRI

Table 4.5. The actions listed in the LMRW plan are the reasonable actions to be taken over the next ten years. Load reduction estimates were calculated using PLET which currently only provides estimated load reductions for sediment, nitrogen, and phosphorus.

Phase I

Action	Pollutants Addressed	Critical Areas Addressed	Estimated Costs	Outcomes	Total Milestones Reached per Phase
Phase 1: 2025 - 2028					
Install cover crops and conservation tillage practices on 7,716 acres (anually): **Minnie Creek subbasin**: 1,770.1 acres (Minnie Creek: 360.4 acres cover crop | 360.4 acres tillage; (Sand Creek: 1,409.7 acres cover crop | 1,409.7 acres tillage) **Brooks Creek subbasin**: 5,945.9 acres cover crop | 5,188.7 acres tillage	Nutrients, E. coli, Thermal	Agricultural fields, Brooks Creek Subbasin	$667,700	Annual Reductions: Phosphorus: 4,578.3 lbs/yr Nitrogen: 2,887.9 lbs/yr	Phosphorus: 4,925.5 lbs/yr Sediment: 442 tons/yr Nitrogen: 3,695.1 lbs/yr Significant reductions in E.coli and water temperature (measured through future monitoring)
Install 2.5 miles of grassed Waterways and buffer strips: **Minnie Creek subbasin**: 0.1 miles (Minnie Creek: 0.05 miles; Sand Creek: 0.05 miles) **Brooks Creek subbasin**: 2.4 miles		Agricultural fields, Brooks Creek Subbasin	$134,640	Annual Reducttions: Phosphorus: 201.5 lbs/yr Nitrogen: 273.7 lbs/yr	
Install 1.8 miles of bank stabilization and livestock exclusion fencing: **Minnie Creek subbasin**: 0.8 miles (Minnie Creek: 0.4 miles; Sand Creek: 0.4 miles) **Brooks Creek subbasin**: 1 mile		Agricultural fields , Brooks Creek Subbasin	$361,152	Annual Reductions: Phosphorus: 145.7 lbs/yr Nitrogen: 533.5 lbs/yr	
Install 0.63 miles of mainstem streambank restoration: Reach 1: 1,373 ft Reach 2: 1,505 ft Reach 3: 334 ft Reach 4: 104 ft	Sediment	Crititcal Streambank Sites	$1,658,000 (depending on bank slope and dimensions)	Annual Reductions: Sediment: 442 tons/yr	
Remove Penoyer Creek Rowe Dam #2	Thermal, Sediment, Altered Hydraulic Flow/Habitat	Channelization and channel modification crtitical sites	$1,000,000	Thermal reduction: ~2°F Natural channel configuration Natural hydraulic flow Macroinvertebrate/Fish abundance increase	Average Summer Thermal Reduction: ~2°F Significant improvements to natual channel configuration, hydraulic flow, habitat, and macroinvertebrate/fish habitat
Install 300 feet of large wood in Muskegon River			$125,000		
Replace Bayne Road and Maple Island Road stream crossing (Mosquito Creek-Subbasin Maple River)			$1,100,000		
Conduct educational workshops/events to producers/residents throughout LMRW following I&E plan (Chapter 4)	Sediment and Streambank Erosion, Nutrients, E. coli, Thermal, Altered Hydraulic Flow/Habitat	All	Watershed Outreach Coordinator staff time estimated as needed	6 township/city/stakeholder meetings with an average of 20 people reached per meeting	Approximately 36,120 people reached through educations work/events and continuous outreach Hosted approximately 6 educational workshops
Continuous outreach/education efforts to watershed residents via online, social media, newspaper, attending community events, etc. See Chapter 4 for more details		All		Average 3,000 people a month reached through various outreach efforts.	

Table 4.5. The actions listed in the LMRW plan are the reasonable actions to be taken over the next ten years. Load reduction estimates were calculated using PLET which currently only provides estimated load reductions for sediment, nitrogen, and phosphorus.

Phase 2

Action	Pollutants Addressed	Critical Areas Addressed	Estimated Costs	Outcomes	Total Milestones Reached per Phase
Phase 2: 2029-2032					
Install cover crops and conservation tillage practices 15,432 acres (anually): **Minnie Creek subbasin**: 3,540.2 acres (Minnie Creek: 720.8 acres cover crop | 720.8 acres tillage; (Sand Creek: 2,819.4 acres cover crop | 2,819.4 acres tillage) **Brooks Creek subbasin**: 11,891.8 acres cover crop | 10,377.4 acres tillage	Nutrients, E. coli, Thermal	Agricultural fields, Brooks Creek Subbasin	$1,335,400	Annual Reductions: Phosphorus: 9,156.6 lbs/yr Nitrogen: 5,775.8 lbs/yr	Phosphorus: 9,503.8 lbs/yr Nitrogen: 6,583 lbs/yr Sediment: 75 tons/yr Significant reductions in E.coli and water temperature (measured through future monitoring)
Install 2.5 miles of grassed Waterways and buffer strips: **Minnie Creek subbasin**: 0.1 miles (Minnie Creek: 0.05 miles; Sand Creek: 0.05 miles) **Brooks Creek subbasin**: 2.4 miles		Agricultural fields, Brooks Creek Subbasin	$134,640	Annual Reductions: Phosphorus: 201.5 lbs/yr Nitrogen: 273.7 lbs/yr	
Install 1.8 miles of bank stabilization and livestock exclusion fencing: **Minnie Creek subbasin**: 0.8 miles (Minnie Creek: 0.4 miles; Sand Creek: 0.4 miles) **Brooks Creek subbasin**: 1 mile		Agricultural fields, Brooks Creek Subbasin	$361,152	Annual Reductions: Phosphorus: 145.7 lbs/yr Nitrogen: 533.5 lbs/yr	
Install 0.39 of mainstem streambank restoration: Reach 1: 80 ft Reach 2: 145 ft Reach 3: 750 ft Reach 4: 1,096 ft	Sediment	Crititcal streambank sites	$828,400 (depending on bank height and dimensions)	Annual Reductions: Sediment: 756 tons/yr	
Remove Penoyer Creek Rowe Dam #1	Thermal, Sediment, Altered Hydraulic Flow/Habitat	Channelization and channel modification crtitical sites	$1,000,000	Thermal reduction: 5.5°F Natural channel configuration Natural hydraulic flow Macroinvertebrate/Fish abundance increase	Average Summer Thermal Reduction: 5.5°F Significant improvements to natual channel configuration, hydraulic flow, habitat, and macroinvertebrate/fish habitat (measured through future monitoring)
Install 500 feet of large wood in Muskegon River			$208,333		
Initiate engineering and design planning for reconnection of Maple River			Engineering costs as estimated per project scope		
Conduct educational workshops/events to producers/residents throughout LMRW following I&E plan (Chapter 4)	Sediment and Streambank Erosion, Nutrients, E. coli, Thermal, Altered Hydraulic Flow/ Habitat	All	Watershed Outreach Coordinator staff time estimated as needed	6 township/city/stakeholder meetings with an average of 20 people reached per meeting	Approximately 36,120 people reached through educations work/events and continuous outreach Hosted approximately 6 educational workshops
Continuous outreach/education efforts to watershed residents via online, social media, newspaper, attending community events, etc. See Chapter 4 for more details		All		Average 3,000 people a month reached through various outreach efforts.	

Table 4.5. The actions listed in the LMRW plan are the reasonable actions to be taken over the next ten years. Load reduction estimates were calculated using PLET which currently only provides estimated load reductions for sediment, nitrogen, and phosphorus.

Phase 3

Action	Pollutants Addressed	Critical Areas Addressed	Estimated Costs	Outcomes	Total Milestones Reached per Phase
Phase 3: 2033 - 2035					
Install cover crops and conservation tillage practices on 23,148 acres (anually): **Minnie Creek subbasin**: 5,310.3 acres (Minnie Creek: 1,081.2 acres cover crop | 1,081.2 acres tillage; (Sand Creek: 4,229.1 acres cover crop | 4,229.1 acres tillage) **Brooks Creek subbasin**: 17,837.7 acres cover crop | 15,566.1 acres tillage	Nutrients, E. coli, Thermal	Agricultural fields, Brooks Creek Subbasin	$2,003,100	Annual Reductions: Phosphorus: 13,734.9 lbs/yr Nitrogen: 8,663.7 lbs/yr	Phosphorus: 14,082.1 lbs/yr Nitrogen: 9,470.9 lbs/yr Sediment: 2,924 tons/yr Significant reductions in E.coli and water temperature (measured through future monitoring)
Install 2.5 miles of grassed Waterways and buffer strips: **Minnie Creek subbasin**: 0.1 miles (Minnie Creek: 0.05 miles; Sand Creek: 0.05 miles) **Brooks Creek subbasin**: 2.4 miles		Agricultural fields, Brooks Creek Subbasin	$134,640	Annual Reducttions: Phosphorus: 201.5 lbs/yr Nitrogen: 273.7 lbs/yr	
Install 1.8 miles of bank stabilization and livestock exclusion fencing: **Minnie Creek subbasin**: 0.8 miles (Minnie Creek: 0.4 miles; Sand Creek: 0.4 miles) **Brooks Creek subbasin**: 1 mile		Agricultural fields, Brooks Creek Subbasin	$361,152	Annual Reductions: Phosphorus: 145.7 lbs/yr Nitrogen: 533.5 lbs/yr	
Install 1.8 miles of mainstem streambank restoration: Reach 1: 2,894 ft Reach 2: 314 ft Reach 3: 2,762 ft Reach 4: 3,562 ft	Sediment	Crititcal streambank sites	$3,812,800.00 (Depending on bank height and dimensions)	Annual Reductions: Sediment: 442 tons/yr	
Install 600 feet of large wood in Muskegon River	Thermal, Sediment, Altered Hydraulic Flow/Habitat	Channelization and channel modification crtitical sites	$249,996	Natural channel configuration Natural hydraulic flow Macroinverttebrate/Fish abundance increase	Significant improvements to natual channel configuration, hydraulic flow, habitat, and macroinvertebrate/fish habitat (measured through future monitoring)
Initiate opening of Maple River inlet(s) and reconnected flow			(Depending on selected design)		
Conduct educational workshops/events to producers/ residents throughout LMRW following I&E plan (Chapter 4)	Sediment and Streambank Erosion, Nutrients, E. coli, Thermal, Altered Hydraulic Flow/Habitat	All	Watershed Outreach Coordinator staff time estimated as needed	6 township/city/stakeholder meetings with an average of 20 people reached per meeting	Approximately 36,120 people reached through educations work/events and continuous outreach Hosted approximately 6 educational workshops
Continuous outreach/education efforts to watershed residents via online, social media, newspaper, attending community events, etc. See Chapter 4 for more details		All		Average 3,000 people a month reached through various outreach efforts	

4.7.1 Management Measures to Control Nonpoint Source Pollution from Hydromodification

The US Environmental Protection Agency (USEPA 1993) defines hydromodification as the "alteration of the hydrologic characteristics of waters, which in turn could cause degradation of water resources". Several examples of hydromodification exist within the watershed and include construction in or along streams, construction and operation of impoundments, channelization, and dredging. While hydromodification activities are intended to provide some benefit to humans, they cause unintended consequences. The EPA has grouped hydromodification activities into three categories: (1) channelization and channel modification, (2) impoundments, and (3) streambank and shoreline erosion. Below are descriptions of these activities and specific management measures to be applied in the LMRW. The following information was taken from the National Management Measures Control Nonpoint Source Pollution from Hydromodification Manual (USEPA 2007) and EGLE Nonpoint Source Best Management Practices Manual (EGLE 2017).

Channelization and channel modification

Description: Historically, hundreds of channels have been straightened in the LMRW to facilitate floating of logs, construction of roadways and railways, bridges, and other types of transportation facilities. Activities under this group includes channel straightening, widening, deepening, and clearing of debris and sediment. Channelization and channel modifications are undertaken for many purposes including flood control, navigation, drainage improvement, and reduction of channel migration potential. Channelization activities can play a critical role in nonpoint source pollutants by increasing the timing and delivery of pollutants, including sediment, that enter the water. Channelization can also be a cause of higher flows during storm events. Altered flow rates resulting from channelization activities can lead to habitat degradation such as beaver dams breaking or increased rates of fine sediment transport resulting in crucial substrate types being covered.

Management Measures

⇒ Evaluate, and when appropriate, improve channel alignment through recreating the meandering of stream and river channels.

⇒ Work with drain commissioners to develop an operation and maintenance program for existing modified channels that includes identification and implementation of opportunities to restore instream and riparian habitat in those channels.

⇒ Establish and protect vegetated areas (buffer/filter strips) along water bodies.

⇒ Evaluate the potential effects of proposed channelization and channel modification on the physical and chemical characteristics of surface waters (i.e. changes to sedimentation, turbidity, temperature, nutrients, dissolved oxygen, and contaminants).

- New channelization and channel modification projects that are predicted to cause unavoidable physical or chemical changes in surface waters can also use one or more practices to mitigate the undesirable changes:
    - ◊ Noneroding roadways.
    - ◊ Streambank protection and instream sediment load controls.

◊ Vegetative cover.

- Existing channelization and channel modification projects can use one or more practices to improve the physical and chemical characteristics of a water body:
    - ◊ Vegetated areas (buffer/filter strips) along water bodies
    - ◊ Live stakings and native wildflower cover seedmixes
    - ◊ Setbacks
    - ◊ Tree revetments (Root wad revetments, wood packing, etc.)
    - ◊ Wing deflectors

Impoundments

Description: Impoundments are artificial barriers on water bodies that dam or divert water and are built for a variety of purposes such as flood control, power generation, and irrigation. While dams can provide benefits to society, they can contribute to nonpoint source pollution. For example, dams can alter flow, which ultimately can cause impacts to water quality (changes to temperature and sediment load), biology (disruption of spawning) and habitat (inundation of stream habitats) above and below the impoundments (USEPA 2007).

Management Measures

⇒ Conduct feasibility study to decide if the ecological benefits of removing the high priority impoundments outweigh the benefits of maintaining them.

⇒ Work with watershed stakeholders to obtain funding and remove high priority impoundments .

- Re-establish natural meandering of stream channels and instream habitat that includes large wood.

⇒ Implement practices to improve water quality and aquatic and riparian habitat in existing reservoir impoundments and in tailwaters:

- Providing both minimum flows to enhance the establishment of desirable instream habitat and scouring flows as necessary to maintain instream habitat.
- Establishing adequate fish passage or alternative spawning ground and instream habitat for fish species.

Streambank and Shoreline Erosion

Description: Streambank erosion occurs when the force of flowing water exceeds the ability of soil and vegetation to hold the banks in place. Eroded material is carried downstream and redeposited in the channel bottom and in point bars located along bends in the waterway. Shoreline erosion also occurs in open waterbodies when waves and currents sort coarser sand and gravels from eroded bank materials and move them along the shore away from the area undergoing erosion. In both cases, this erosion can cause severe loss of land and increase sediment in the system. It is important to note that streambank and shoreline erosion are natural processes; however, this has accelerated dramatically across Michigan due to the logging era, as well as other human activities along or adjacent to streambanks and shorelines. These human activities include agricultural development, urbanization, shoreline development, boat wakes, and excavation (USEPA 2007).

Management Measures:

⇒ Installation of stream bank protection practices. Several systems of practices can be used but emphasis should be given to "softer", less rigid structure (vegetative practices):
  - Rootwad and tree revetments, brush layering and mattressing.

⇒ The MRWA hosts a website providing landowners with information on streambank protection practices in the watershed where streambank work was done appropriately and how streambank protection can decrease property loss, erosion, and runoff while improving habitat and stream function. https://mrwa.org/restoration-showcase/restoration-showcase-getting-started/

4.7.2 Management Measures to Control Nonpoint Source Pollution from Agriculture

The primary agricultural nonpoint source pollutants of concern in the LMRW include nutrients, sediment, E. Coli, and animal wastes. Agricultural activities also have the potential to directly impact the habitat of aquatic species through physical disturbances caused by livestock and equipment. Below are descriptions of specific management measures to be applied in the LMRW. This information was taken from the National Management Measures Control Nonpoint Pollution from Agriculture Manual (USEPA 2007) and EGLE Nonpoint Source Best Management Practices Manual (EGLE 2017).

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Nutrients

Description: Nitrogen and phosphorus are two major nutrients from agricultural land that degrade water quality. Nutrients are applied in many forms to agricultural land and come from various sources including commercial fertilizer, manure from animal production, and irrigation water. Nitrogen and phosphorus are present in aquatic environments at natural levels, however introduced at higher rates they become a problem and results in excessive aquatic plant growth which eventually dies and decays leading to depleted oxygen levels that can reduce the quality of fish habitat and other aquatic organisms.

Management Measures:

⇒ Conduct research to determine areas contributing large nutrient loads in the watershed.

⇒ Establish vegetated areas (buffer/filter strips) along water bodies.

⇒ Establish cover crops and promote residue and tillage management on fields for seasonal protection.

⇒ Conduct research to evaluate the use of water control structures ("phosphorous removal systems" in reducing the amount of phosphorus from subsurface drain (tile) flows and other subsurface and surface phosphorus-containing runoff outflows. Sources of agricultural outflows may include agricultural tile drains, ditches and animal heavy use areas (NRCS 782).

⇒ Promote the MDARD report, "Generally Accepted Agricultural and Management Practices for Irrigation Water Use, Nutrient Utilization, Manure Management and Utilization, and Site Selection for new and expanding livestock production facilities"

⇒ Restore wetlands that act as filters and remove pollutants from runoff.

⇒ Establish watercourse crossings and fencing to keep livestock out of waterways.

⇒ Educate producers about the nutrient resources available, which at a minimum include:

- Soil tests for pH, phosphorus, nitrogen, and potassium
- Nutrient analysis of manure, mortality compost (birds, pigs, etc.), or effluent
- Nitrogen contribution to the soil from legumes grown in the rotation (if applicable); and
- Other significant nutrient sources (e.g., irrigation water, atmospheric deposition)

⇒ Promote practices that improve the efficiency of nutrient use and limit the potential for nutrient loss to surface and ground waters.

Erosion and Sediment Control

Description: Sediment is the solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by wind, water, gravity or ice (USEPA, 2007). Soil erosion is characterized as the transport of particles detached by rainfall, flowing water, or wind. The types of erosion associated with agriculture that produce sediment are (1) sheet and rill erosion, (2) gully erosion, (3) wind erosion, and (4) streambank erosion. Eroded sediment in aquatic systems can reduce the amount of sunlight available to aquatic plants, cover fish spawning areas, clog and harm gills of fish, and bury aquatic insects.

Management Measures:

⇒ Establish vegetated areas (buffer/filter strips) along water bodies and between impervious surfaces and water bodies.

⇒ Establish cover crops and promote residue and tillage management on fields for seasonal protection and soil improvement.

⇒ Restore and protect wetlands which act as filters and remove pollutants from runoff.

⇒ Establish herbaceous wind barriers such as trees/shrubs to reduce wind erosion within fields.

⇒ Establish terraces for crops and reduce slope length to the water body.

⇒ Install practices that prevent edge-of-field sediment loss.

⇒ Trap sediment before it reaches riparian areas.

Animal Wastes

Description: E. coli in water is an indication of animal waste. Most E. coli by itself is not dangerous to humans, but fecal materials can, in some instances, spread diseases. Two ways these bacteria can enter water are from livestock in stream and runoff of manure applied on fields.

Management Measures:

⇒ Conduct research to determine watershed areas contributing large E. coli loads.

⇒ Establish watercourse crossings and fencing to keep livestock out of waterways.

⇒ Promote the MDARD report, "Generally Accepted Agricultural and Management Practices for Manure Management and Utilization and Site Selection for new and expanding livestock production facilities"

⇒ Establish vegetated buffers around livestock fields such as a field border or a vegetative filter strip between the field and water body.

⇒ Establish a waste storage facility for proper disposal or further use of waste on crops.

⇒ Install runoff capture units such as rain barrels to reduce nutrient loads from roof runoff.

4.7.3 Management Measures to Control Nonpoint Source Pollution from Urban/ Residential Areas

Water quality problems in urban waterbodies are often caused by runoff that is inadequately controlled. These problems include changes in flow, increased sedimentation, higher water temperature, lower dissolved oxygen, degradation of aquatic habitat, loss of fish and other aquatic organisms, and increased levels of nutrients, metals, and bacteria.

To manage runoff, the EPA has divided urban/residential activities into categories. To address urban/ residential issues in the LMRW the categories include (1) new development, (2) existing development, and (3) pollution prevention. Below are descriptions of these activities and specific management measures to be applied. This information was taken from the National Management Measures Control Nonpoint Source Pollution from Urban Areas Manual (USEPA 2007) and Guidebook for Best Management Practices for Michigan Watershed (MDEQ 1998).

New Development

Description: Development in and around urban areas is inevitable as the population grows; however, by recommending standards for new development, we can reduce environmental damage. Potential environmental damage includes increased erosion and sediment disruption, destruction of habitat (terrestrial, in-stream, and riparian), and discharge of pollutants.

Management Measures:

⇒ Implement one or more filtering practices to reduce the post-development loadings of total suspended solids (TSS) so that the average annual TSS loadings are no greater than the predevelopment loadings.

- ♦ Maximize preservation of current vegetated areas around land development
- ♦ Install rain gardens and water filtering practices
- ♦ Improve riparian zones near land development
- ♦ For disturbances too large for vegetative practices to manage, install sediment trap and non-pervious surfaces

⇒ Work with local units of government to update master plan and zoning ordinances to incorporate Low Impact Development (LID) techniques and natural resources protection. This update can address issues such as:

- Promote designs that preserve and minimize impacts to predevelopment site hydrology and topography by maintaining natural drainage features and storage areas that help infiltrate flows and filter pollutants
- Protecting environmentally sensitive areas and open space (wetlands, springs, groundwater recharge areas, surface water, forests, highly erodible areas, etc.)
- Reduce the average annual TSS loadings by a minimum of 80 percent of the influent concentration of TSS (USEPA, 2005) (https://www.epa.gov/sites/default/files/2015-09/documents/urban_guidance_0.pdf)

Existing Development

Description: Maintaining water quality becomes increasingly difficult as urbanization occurs and areas of impervious surface increase. Increase peak runoff volumes from impervious surfaces result in alteration of stream channels, which results in increased bank cutting, streambed scouring, increases in instream temperature, and siltation (USEPA 2007).

Management Measures:

⇒ Implement filtering practices that capture and temporarily store runoff and pass it through a filter bed of soil (i.e. bioretention systems—rain gardens)

⇒ Establish vegetated areas (buffer/filter strips) along waterbodies

⇒ Restore wetlands that act as filters and remove pollutants from runoff.

⇒ Identify undeveloped and privately owned land for acquisition (i.e. conservation easements). The acquisition and preservation of open space in developed areas can protect against the threat of further development, reduce runoff volume, and provide stormwater treatment.

⇒ Limit destruction of natural conveyance systems.

Pollution Prevention

Description: Everyday activities of citizens and businesses contribute to nonpoint source pollutant loadings. Activities to be addressed under pollution prevention include lawn/turf grass and septic system maintenance. Pollution includes nitrogen compounds, phosphorus, biochemical oxygen demand (BOD) and can cause harmful algal blooms (USEPA, 2005).

Management Measures:

⇒ Implement filtering practices that capture and temporarily store runoff and pass it through a filter bed of soil (i.e. bioretention systems—rain gardens).

⇒ Establish vegetated areas (buffer/filter strips) along waterbodies.

⇒ Restore wetlands that act as filters and remove pollutants from runoff.

⇒ Ensure appropriate lawn fertilization by having a soil test done through the Home*A*Syst program https://www.canr.msu.edu/uploads/resources/pdfs/home_assessment_guide.pdf.

- ⇒ Work with county governments to develop and adopt a phosphorus fertilizer ordinance.
- ⇒ Educate the public with respect to the proper handling of fertilizers, pesticides, water, and yard waste, highlighting effective practices such as lawn conversion, soil building, pest management (reduce materials that attract pests) and sensible irrigation.
- ⇒ Promote the Michigan Turfgrass Environmental Stewardship Program to golf courses in the watershed.
- ⇒ Detect and eliminate illicit connections ("illegal and/or improper connections to storm drainage systems and receiving waters").
- ⇒ Work with watershed counties to develop and adopt Septic System Point of Sale Ordinance.
- ⇒ Educate the public on septic system function and maintenance.
- ⇒ Educate the public on the connectivity of yards, streets, storms and waterbodies.

4.7.4 Management Measures to Control Nonpoint Source Pollution from Road Stream Crossings

Description: Road-stream crossings represent places where the road system and stream system intersect. Poorly constructed road-stream crossings result in an entry point for sediment and pollutants, an alteration of hydrology and water temperature, and can affect aquatic organisms including fish and aquatic invertebrates. Roads can create pollution in the form of sediment, and stream crossings are a frequent source of sediment introduction.

Below are specific management measures and practices to be applied in the LMRW. This information was taken from the National Management Measures Control Nonpoint Source Pollution from Urban Areas (USEPA 2005a) and EGLE Nonpoint Source Best Management Practices Manual (EGLE 2017).

Management Measures:

- ⇒ Work with road commissions to inventory road stream crossings and develop a strategy for improvement.
- ⇒ Use live plant materials to control road runoff, reduce erosion, and provide slope/streambank stabilization through bioretention areas, vegetated filter strips and vegetated swales.
- ⇒ Reduce the generation of pollutants from maintenance operations by minimizing the use of pesticides, herbicides, fertilizers, deicing salts and chemicals (USEPA, 2005).
- ⇒ Implement setbacks for new construction project to protect sensitive ecosystems such as wetlands.
- ⇒ Implement regular litter removals and enforce littering and illegal dumping laws.

4.7.5 Management Measures to Control Pollution from Industry

Description: Pollutants from industry are impairing fish consumption in a few of the lakes in the watershed. This impairment is due to PCBs and mercury in fish tissue, and chlordane. Sources of these pollutants include historic industry and pesticide use, and atmospheric deposition. Sedimentation, removal of helpful aquatic plants, and introduction of invasive species are other sources, which are known to impact fish and aquatic organism habitat.

Management Measures:

⇒ Conduct research to determine where/how contaminants are entering aquatic food web.

⇒ Identify aquatic zoning ordinances and determine critical areas.

⇒ Educate the public on protecting habitat by not destroying aquatic plant beds or dredging in shallow areas.

⇒ Educate the public on appropriate disposal of illegal or harmful materials into the water.

⇒ Educate the public on exotic species and to never release exotics (including species used as bait).

4.7.6 Management Measures to Protect Resources in the Watershed

Wetlands and Riparian Areas

Wetlands and riparian areas play a significant role in protecting water quality and reducing adverse water quality impacts associated with nonpoint source pollution. They decrease the need for costly stormwater and flood protection facilities. Thus, wetlands and riparian areas are an important component in management practices that reduce nonpoint source pollution. In their natural condition, wetland and riparian areas provide habitat for feeding, nesting, cover, and breeding for many species of birds, fishes, amphibians, reptiles, and mammals. Wetland resources are especially important with future threats from increases in temperature, drought, and extreme weather events.

Below are descriptions of specific management measures to be applied in the Lower Muskegon River Watershed to protect these natural resources. This information was taken from the National Management Measures to Protect and Restore Wetlands and Riparian Areas for the Abatement of Nonpoint Source Pollution (USEPA 2005) and Guidebook for Best Management Practices for Michigan Watersheds (MDEQ 1998).

Management Measures:

⇒ Establish conservation easements on wetland and riparian areas.

⇒ Work with local units of government to update master plan and zoning ordinances to incorporate wetland and riparian area protections.

⇒ Educate landowners on the importance of wetland and riparian protection and restoration.

⇒ Restore wetlands with the goal of returning natural/historic functions to a former or degraded aquatic resource.

    ♦ Restore historic physical features such as wetland elevation and native biota.

    ♦ Install vegetated filter strips to limit runoff pollution.

⇒ Restore riparian buffers zones (inner, middle, and outer) and widths to protect water quality.

Habitat and Endangered/Threatened Species

The primary threat to the world's biodiversity is habitat destruction (loss). Habitat loss alters or eliminates the conditions needed for plants and animals to survive. Loss of habitat leads to a decline in the abundance of a species and reduces the genetic diversity within that species. This makes a species more susceptible to extinction, by making it less resistant to disease or catastrophic events.

Habitat loss also reduces the potential for population maintenance or growth, as there is not sufficient area to support more individuals. These conditions make it easier for invasive species to move in to disturbed areas and take over. The removal of large wood structures in the LMRW occurred during the logging era when it was removed to improve floating of logs and navigation. To this day, the Muskegon River and many of its tributaries lack adequate aquatic habitat because of this removal. Below are descriptions of specific management measures and practices to be applied in the LMRW.

Management Measures:

⇒ Develop management strategies to control and decrease populations of exotics.

⇒ Inventory endangered and threatened species to identify critical habitat for protection.

⇒ Restore critical habitat for native species such as wetlands.

⇒ Inventory the watershed to determine areas where fish habitat has been removed and implement stream enhancement projects to add habitat structures (large wood) and substrate to increase suitable areas of refuge and those conducive to reproduction and spawning. A primary focus for inventory and enhancement is the Muskegon River due to widespread removal during logging era.

⇒ Protect existing habitat by promoting the establishment of conservation easements.

Groundwater

The term groundwater is used to describe the water stored underground in areas of permeable materials, known as aquifers. Groundwater is a major national resource used by people for drinking, cooking, and cleaning. This water is ecologically important for wetlands, lakes and rivers. Some groundwater resources are not being used sustainably or are at risk of overextraction. Below are descriptions of specific management measures and practices to be applied in the LMRW.

Management Measures:

⇒ Work with watershed counties to develop and adopt Septic System Point of Sale Ordinance

⇒ Work with agricultural producers to follow the MDARD report, "Generally Accepted Agricultural and Management Practices for Irrigation Water Use"

⇒ Work with homeowners to utilize the Home*A*Syst program to use water resources sustainably.

⇒ Gather information on large water extraction in watershed (agriculture and commercial)

⇒ Work with local units of government to adopt local water diversion ordinances.

⇒ Conduct research to determine areas of the watershed contributing large sodium, chloride, and sulfate loads to the system. Once sources are identified, take proper management measures to address them.

4.8 Existing Policies

To build upon existing land use management tools, an analysis of local ordinances and programs was done (Appendix H). Below are some of the findings of this analysis that provide protections for the watershed:

⇒ Many municipalities have greenbelt preservation areas that require a minimum distance from 25 feet to 50 feet of vegetative strips along streams.

⇒ Several municipalities require a 25-foot minimum vegetative buffer around wetlands and for storage of harmful materials to be a minimum of 200 feet away from wetlands.

⇒ Many municipalities have a restriction on the construction of septic tanks near the high-water mark of water bodies, ranging from 40 feet to 100 feet.

⇒ A few municipalities have restrictions on the proximity of livestock operations to water bodies, ranging from 400 feet to 1,000 feet.

⇒ Two municipalities have restrictions against the size of walkways constructed near a water body.

A few actions have been suggested, such as enacting local wetland protection ordinances, stormwater management programs, restrictions on spreading sewage on land, and minimizing intensive livestock operations. These actions should be further explored for all watershed municipalities.

4.9 Information and Education Activities

Many of the water quality problems in the Lower Muskegon River Watershed are the result of actions by individuals not aware of their impact. The solutions will rely on individuals knowingly and voluntarily taking actions that will secure the health of the watershed. The I&E strategy is the proposed approach to reach target audiences with specific messaging to educate the watershed population about the priority watershed pollutants and how personal actions on the landscape impact water quality. The tables in this section discuss the focus area messages, actions that can be taken to address specific pollutants, notes on implementation, potential partners, resources needed, estimated cost, and evaluation methods.

Goals and Objectives

The objective of the I&E strategy is to create a usable guide for watershed stakeholders to disseminate information in the most effective way possible to make a measurable improvement in water quality. Targeted messages were created for specific audiences within the watershed.

Goal 1: Improve water quality to restore: natural features, ecosystem services, cultural and social engagement, and designated uses of full body and partial body contact recreation.

Goal 2: Promote sustainable agricultural practices throughout the watershed to reduce polluted runoff entering waterways.

Goal 3: Improve community understanding of NPS pollution (primarily nitrogen, phosphorous, sediment and E. coli) and associated water quality problems through education and outreach.

Goal 4: Encourage private property owners to be aware of eroding streambanks and to apply strategies to mitigate and restore these sections.

Implementing I&E Strategy

Implementation of the I&E strategy will be the responsibility of the watershed groups, municipalities, and other stakeholders in the watershed. A prescription for target audiences regarding each pollutant can be found in Tables 4.6-4.8.

Target Audiences

The four subbasins of the LMRW range from 22% to 58% agricultural land. In order to achieve the goals, the disbursement of information must be done in a way that is effective and well-received by those who live and work in the watershed. The specific target audiences will include:

⇒ Agricultural Producers and Combined Animal Feed Operations (CAFOs)

⇒ Riparian Landowners and residential landowners with septic systems

⇒ Municipalities

⇒ Schools

⇒ Recreational Users

⇒ Interested Public

Messages

Messaging must be specific for each target audience to focus their concerns with some messaging applicable to all audiences. Messages need to focus on protecting and enhancing water quality and need to be action-oriented, understandable and create a desire to change (Tables 4.6-4.8). Some messages will be applicable to all audiences. All messages should include:

⇒ General Watershed/Stormwater Awareness

- ♦ A watershed is the area of land that drains to a common waterbody.
- ♦ Groundwater and surface water within a watershed supplies several needs including drinking water, agricultural irrigation, and manufacturing processes.
- ♦ Stormwater runoff is generated from rain and snowmelt that flows over land or impervious surfaces, such as parking lots or building rooftops, that does not soak into the ground.
- ♦ Clean water supports businesses, agriculture, wildlife, recreation and community health and safety.

⇒ Sustainable Agriculture Practices

- ♦ Proper manure storage will prevent loss and contaminated runoff from entering nearby waterways.
- ♦ Creating buffer zones along the edges of crop fields using native plants will prevent erosion and increase the presence of pollinators.
- ♦ Installing grassed waterways where gullies appear will reduce soil loss and erosion.

- Adoption of no or minimal till agricultural practices will minimize the amount of bare, erosion-prone soil during non-growing seasons.
- Planting cover crops to reduce soil loss during non-growing seasons.

⇒ Proper Septic System Care

- Servicing septic systems every 3-5 years can prevent costly failures in the future. Problems that are likely to occur in a malfunctioning septic system include the release of disease-causing pathogen, E. coli or nitrate contamination of surface waters.
- Avoiding the pouring fats, grease, oil and solids down the drain can prevent clogging the drain field and cause system malfunction.
- Ensuring waste is going to a septic system, rather than straight to a stream or other drainage-way, minimizes nonpoint source pollution.

⇒ Riparian Stewardship

- Maintaining a minimum of a 10' no mow/riparian zone/buffer zone along shorelines will prevent erosion and shoreline loss.
- Planting buffer zones with native species whose roots will secure shorelines will increase habitat for both aquatic and terrestrial species.
- Using phosphorus-free fertilizer will reduce harmful algae blooms.

Delivery Mechanisms

Delivery mechanisms must be diverse to reach the largest possible audience and will include events, presentations, and visual aids including print and virtual materials. Repetition is key for changed behavior and to get the best results. Some delivery mechanisms will be more appropriate for certain target audiences than others. It is widely accepted that the method for each target audience should be awareness, education, and action. Target audiences will be made aware of the issue, educated on how to prevent, or remedy the issue, and will then likely act. An overview of the basic approaches for delivering watershed conservation methods include:

⇒ Targeted Mailings/E-mailings

- Agricultural landowners, farmers
- Riparian landowners
- Septic system owners

⇒ Social Media

- Muskegon River Watershed Assembly and Trout Unlimited
- Community pages in Lower Muskegon River Watershed
- Social media platforms of partners

⇒ Other Media Outlets

- MRWA newsletter
- Partner newsletters and local newspapers
- Township/City Newsletters
- Radio public service announcements

- Informational Signs
- Public Recreation Sites
- Trailheads
- Pet Waste Stations

⇒ Events

- Farm Demonstration Days
- Tours through areas of concern and areas applying BMPs
- Workshops
- School Presentations
- Community Gatherings

Partners

Partnerships will increase the overall reach of the I&E implementation plan. Partnerships will regulate messaging so that target audiences will receive the same information and resources from multiple trusted sources. This will increase the likelihood of awareness, education, and action. Partner roles and responsibilities are found in tables 4.4 and 4.5 (pgs. 69-72).

Information and Education tables

General messages have been developed for critical pollutants and are listed in tables 4.6 through 4.8. Messages intended for target audiences will be based on these broad messages but should be customized and targeted for delivery. Estimated costs for the distribution of these messages and plans to monitor the effectiveness of these messages are included.

4.10 Resources

Listed below are resources where you can learn more about information on management practices to control nonpoint source pollutants.

Agricultural Resources:

⇒ Michigan Commission of Agriculture Generally Accepted Agricultural and Management Practices: Information for use of nutrients and manure, care of animals, site selection, and irrigations and water. https://www.michigan.gov/mdard/environment/rtf/gaamps

⇒ United States Environmental Protection Agency National Management Measures for the Control of Nonpoint Pollution from Agriculture. Nonpoint Source: Agriculture | US EPA

⇒ Management Measures and Practices to Control Nonpoint Source Pollution from Hydromodification: United States Environmental Protection Agency National Management Measures to Control Nonpoint Source Pollution from Hydromodification. Nonpoint Source: Hydromodification and Habitat Alteration | US EPA

Channelization and Channel Modification Resources:

⇒ The Stormwater Manager's Resource Center Stream Restoration: Grade Control Structure. http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Restoration/grade_control.htm

Dam Resources:

⇒ American Rivers website hosts a variety of information related to hydromodification. http://www.americanrivers.org

Streambank and Shoreline Erosion

⇒ Muskegon River Watershed Assembly website that provides a streambank project guide. Streambank protection and restoration showcase. https://mrwa.org/restoration-showcase/

⇒ Stream Corridor Restoration practices by the USDA conservation stewardship program https://www.nrcs.usda.gov/sites/default/files/2022-11/E580A%20July%202019.pdf

⇒ Natural Resources Conservation Service Bioengineering for Upland Slope Protection and Erosion Reduction. https://nrcspad.sc.egov.usda.gov/distributionCenter/pdf.aspx?productID=711

New Development

⇒ Catching the Rain: A Great Lakes Resource Guide for Natural Stormwater Management developed by American Rivers which talks about low impact development techniques for the Great Lakes region. http://www.americanrivers.org

⇒ Management Measures and Practices to Control Nonpoint Source Pollution from Urban/Residential Areas: United States Environmental Protection Agency National Management Measures for the Control Nonpoint Source Pollution from Urban Areas. Document Display | NEPIS | US EPA

⇒ EPA has compiled a number of resources on Low Impact Development (LID).Document Display | NEPIS | US EPA

⇒ Southeast Michigan Council of Governments A Design Guide for Implementers and Reviewers Low Impact Development Manual for Michigan. http://www.semcog.org/LowImpactDevelopment.aspx

Pollution Prevention

⇒ EPA published Healthy Lawn, Healthy Environment which is a brochure that describes lawn care practices for citizens. Healthy Lawn Healthy Environment, Caring for your lawn in an environmentally friendly way

- ⇒ Soak Up the Rain written by the EPA—information on rain gardens and how you can create one. Soak Up the Rain | US EPA
- ⇒ Wildlife Reserves and Corridors in the Urban Environment: A Guide to Ecological Landscape Planning and Resource Conservation by Lowell Adams and Louise Dove. Document Display | NEPIS | US EPA

Existing Development

- ⇒ EPA's Wetland Restoration web site. Wetlands Protection and Restoration | US EPA
- ⇒ Land Conservancy of West Michigan—resources for land protection. http://www.naturenearby.org
- ⇒ Natural Resources Conservation Service's National Conservation Buffer Initiative website. http://www.nrcs.usda.gov/feature/buffers/
- ⇒ Izaak Walton League of American's Save our Streams Program provide technical assistance on stream and wetland restoration techniques. http://www.iwla.org
- ⇒ Habitat and Endangered/Threatened Species. Michigan Natural Features Inventory—Rare Species and Unique Habitats. Michigan Natural Features Inventory

Groundwater

- ⇒ Water Withdrawal Tool. WWAT-Home Page
- ⇒ Michigan's Drinking Water developed by MSU. Drinking Water - MSU Water
- ⇒ USFS Groundwater Information Pages. Groundwater: What is Groundwater? | U.S. Geological Survey

Pollution from Industry:

- ⇒ Great Lakes Fish Consumption Advisories. Great Lakes Consortium for Fish Consumption Advisories - MN Dept. of Health
- ⇒ USEPA website provides information on PCBs, mercury, and chlordane. National Primary Drinking Water Regulations | US EPA

Total Phosphorous Water Quality Standard

Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria ½ US EPA

Chapter 5: Watershed Evaluation

INSIDE THIS CHAPTER:

- Know the Evaluation and Monitoring Plan

Introduction

5.1 Chapter 5 Summary

Highlighted below are some of the major points that you will learn in Chapter 5.

⇒ The WMP requires frequent monitoring and data collection from specified groups and implementations to ensure that progress is being made towards goals and objectives. An adaptive management approach is often necessary to pivot strategies and implementations if monitoring provides negative feedback.

⇒ There are suggested strategies included for monitoring the WMP's progress over time, when to enact them, how much they will cost and partners that can assist with the monitoring.

⇒ It would be beneficial to form a committee to oversee the monitoring data for the WMP in case an adaptive management approach needs to be taken. Annual summaries to evaluate progress and an update to the WMP after ten years are suggested to keep the WMP relevant to current issues within the watershed and to update goals.

5.2 Evaluation and Monitoring Plan

Significant amounts of time and money are dedicated to implementing watershed management plans. A well-planned evaluation process, assessing whether or not these implementation efforts are successful, is important to understand the progress being made to address pollutants in the watershed. This chapter includes information on the different types of evaluation techniques that will determine the effectiveness of implementation efforts.

The goal of this WMP is to assist the LMRW community in ensuring the long-term protection and improvement of the river and surrounding lands, with a focus on the designated uses applicable to the LMRW that are mandated by state, federal and tribal water quality programs. The progress made in achieving the goals and objectives of this plan must be measured to determine overall effectiveness. Chemical, physical, and biological water quality monitoring, as well as social monitoring, can be used to help assess progress towards meeting watershed goals, including ensuring that the LMRW is meeting WQS and providing the designated uses. Data collected through monitoring should be used to take an adaptive management approach to refine the implementation of the WMP. Adaptive management is a complicated process but essentially involves accruing information necessary to guide future management. It is an iterative and ongoing process that connects project objectives, implementation, timelines, and budgets with some measure of success (monitoring).

Progress in implementing this WMP can be tracked by monitoring:

⇒ Social indicators

⇒ Use of Existing Partnership Programs

⇒ Policy Adoption and Implementation

⇒ BMP Adoption

⇒ Water quality

5.2.1 Social Indicators

Program assessments can be conducted on an ongoing basis through evaluations and surveys at workshops and educational events, focus groups, meetings, media coverage, and social media participation. Community feedback from the public can be gathered through interactive events with the public. This feedback can be used to adapt the Information and Education strategy (I&E), as needed.

Evaluation measures will provide feedback to determine what methods work and areas that still need improvement. The I&E activities (section 4.9) has specific evaluation measures for each pollutant and target audience to assess the success of each delivery mechanism. The I&E Strategy should be periodically reviewed and adjusted, as necessary. Questions that should be considered during implementation of the I&E Strategy are listed below.

⇒ Are the planned activities being implemented according to the schedule?

⇒ Is additional support needed?

⇒ Are additional activities needed?

⇒ Do some activities need to be modified or eliminated?

⇒ Are the resources allocated sufficient to carry out the tasks?

⇒ Are all of the target audiences being reached?

⇒ What feedback has been received and how does it affect the I&E strategy program

⇒ How do the Best Management Practices (BMP) implementation activities correspond to the I&E strategy?

5.2.2 Partnership Programs

Several existing programs that assist in protecting water from NPS pollutants, such as conservation easements, NRCS Farm Bill Programs, and the MAEAP, are recommended to be leveraged through this WMP. If efforts are made to encourage participation in these programs, an evaluation of participation in these programs, as compared to previous years, can be used as a monitoring benchmark.

5.2.3 Policy Adoption and Implementation

Recommendations are included in this plan related to septic system policies, wetland protection, riparian zone protection policies and other protective policies at the local municipality level, among others. The number of policies adopted and implemented should be measured as a benchmark.

5.2.4 BMP Tracking and Interim Measurable Milestones

BMPs recommended in this plan to address the watershed impairments are practices known to help improve water quality. Monitoring in areas of BMP implementation will provide evidence if consistent pollutant load reductions are happening or not. A BMP tracking work group should be created to track milestones and to determine where reductions are being met and where further focus should be applied. Specific targets have been set for reductions in Table 4.5. It is recommended that a committee of qualified and interested partners begins meeting semi-annually to organize and evaluate if reasonable progress is being made towards implementing the management measures, to determine effectiveness of BMPs, and if WQS are being met (based upon Table 5.1), if designated uses are being attained and what must be done to steer the project if no measurable progress is being made based upon the timelines established within this WMP.

5.2.5 Water Quality Monitoring

Direct surface water measurements and biological monitoring can be used to determine if the watershed is meeting the goals and objectives of this WMP. Tracking water quality improvements associated with the implementation of BMPs is a top priority. Maintaining the water quality where designated uses are currently being met and assessing subwatersheds where the conditions are unknown is a secondary monitoring priority. Specific targets have been set for reach load reductions in Table 4.5. The actions that are recommended in the table should also be the monitoring parameters for measuring progress toward implementing the management measures. Specific monitoring should include:

⇒ Periodic sampling for E. coli to document compliance or exceedances of water quality standards.

⇒ A nutrient monitoring program to develop an understanding of exceedances of WQS and impacts on designated uses.

⇒ Assessing and repairing erosion sites.

⇒ Developing stream hydrographs to document existing hydrology and to monitor change over time.

⇒ Developing temperature monitoring program for each of the tributaries .

⇒ Understanding macroinvertebrate density and diversity (including crayfish) by continuing semi-annual monitoring; at least one site on every tributary stream should be established.

⇒ Periodically monitoring the fish community to describe species composition.

⇒ Documenting occurrences of any new or particularly destructive invasive species.

Water quality monitoring should include the development of an approved QAPP (Quality Assurance Project Plan) so that results can be compared against existing WQS and WQC data for the watershed (Appendix D). Water quality monitoring results and benchmarks will be assessed to determine whether the practices are resulting in the desired water quality pollutant load reductions – the ultimate goal of this WMP is to ensure that the LMRW is meeting the designated uses described in Chapter 3. If pollutant load reductions or water quality improvements are realized following BMP adoption or I&E program implementation, it can be assumed that the BMPs are effectively achieving the goals of the WMP.

Determining the location of monitoring sites is extremely important in establishing a quality data set. Site locations will depend on a variety of factors, including the parameter being measured, the purpose of the monitoring (to describe baseline conditions, to understand long-term trends, to record change over time, to evaluate site-specific BMPs, etc.), accessibility and more. As monitoring plans are developed, the expertise of local project partners should be utilized to determine the best site locations.

It is recommended that a committee of qualified and interested partners begins meeting semi-annually to plan and implement monitoring activities. This committee will organize and evaluate data to determine effectiveness of BMPs, if WQS are being met (based upon Table 5.1), if designated uses are being attained and what must be done to steer the project if no measurable progress is being made based upon the timelines established within this WMP.

It is recommended that this WMP is updated every ten years to highlight completed implementation projects, to reassess the

Table 5.1. Recommended Water Quality Monitoring for determination if LMRW sites are meeting Water Quality Standards and if Designated Uses are being met.

Type of Analysis (Methods)	Timeline/Frequency	Estimated Cost	Responsible Party
E. *coli* Monitoring	30-day geomean; annually Wet weather sampling is needed	$75/sampling location	EGLE, CCD, GVSU
Nutrient Monitoring	Annually	75$/sampling location	EGLE CCD, GVSI
Stream Habitat (following P51) and Macroinvertebrate Assessment (Volunteer monitoring should follow MiCorps methods; EGLE or trained volunteers should follow P51)	Annually; pre-and post BMP implementation	$500/Site	EGLE, CCD, FSU, GVSI, MSUE, Local Schools, MRWA, TU
Biological Survey at stratified random and targeted sites	5-year Interval	TBD	EGLE

watershed condition, and to update the recommendations. Updates should include a summary of water quality conditions, benchmarks and improvements related to implemented programs and BMPs, changes to TMDL status, impairments or threats, changes in responsibility of existing and newly identified project partners, or additional pollutants. When implementation is underway, yearly progress summaries may be beneficial to aid communities and agencies to see progress and where more work is needed. As this WMP is implemented and monitored, an adaptive management approach should be taken. At any point in time, if additional NPS pollution-related needs arise, the WMP or implementation should be amended to address the additional need.

5.3 Resources

⇒ Evaluating Watershed Management Practices: A Practical Econometric Approach by Kerr, J. and Chung, K. 2005. Chapter 7 in Shiferaw, B., H. A. Freeman, and S. M. Swinton, eds. Natural Resource Management in Agriculture: Methods for Assessing Economic and Environmental Impacts.

⇒ Michigan Clean Water Corps. MiCorps Volunteer Stream Cleanup Program. https://www.micorps.net/stream-monitoring/

⇒ Getting in Step – A Guide for Conducting Watershed Outreach Campaigns by Tetra Tech, Inc. http://www.epa.gov/owow/watershed/outreach/documents/getnstep.pdf

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Appendix A. Wetland Verification in the Lower Muskegon River Watershed

Prepared in 2023 by: Trout Unlimited

I. Why include wetlands in watershed planning?

Wetlands play an essential role in the functioning of healthy ecosystems. Wetlands perform key functions for a watershed, contributing significant value to a community, and must be considered in any approach to watershed management. Wetland functions include floodwater storage, groundwater recharge, filtration of pollutants, nutrient recycling, biological productivity, wildlife habitat, and climate resiliency. Wetlands also add value to society. These values can be economic, social, or ecological and are measured by the estimated worth of its services. For example, wetlands provide valuable goods like building products and food by fostering suitable habitat. Wetlands also provide services that benefit society like mitigating floods, improving water quality, and offering recreational opportunities and natural beauty.

However, due to wetland loss, watershed health is at risk of losing these important wetland functions and values. There have been several efforts to document and understand wetland loss in Michigan, some of which are summarized in 'Status and Trends of Michigan Wetlands: Pre-European Settlement to 2005', a report by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) in 2014. According to the report, the quality and acreage of wetlands has been on the decline since the beginning of European settlement. "Michigan originally contained approximately 10.7 million acres of wetland prior to European settlement, but by 1978, that number had dropped to approximately 6,506,044 acres. Since the passage of Michigan's wetland protection law in 1979, the rate of wetland loss has declined dramatically. The total decline of wetland since 1978 is estimated at 41,000 acres, with the rate of decline slowing between the periods 1978 to 1998 (loss of approximately 1,642 acres per year) and 1998 to 2005 (loss of approximately 1,157 acres per year)." In 2005, Michigan had approximately 6,465,109 acres of wetlands remaining (EGLE, 2014).

An EGLE Landscape Level Wetland Function Assessment (LLWFA) was conducted of the Lower Muskegon River watershed subbasins (Figure 1). The assessment found that approximately 45% of wetlands were lost from the Pre-European settlement area. The Lower Muskegon River watershed had approximately 39,270 acres of wetland prior to European settlement compared to a 2005 estimate of 21,749 acres (Figure 2). This is a loss of 17,521 acres of wetlands.

Appendix A. Wetland Verification in the Lower Muskegon River Watershed.

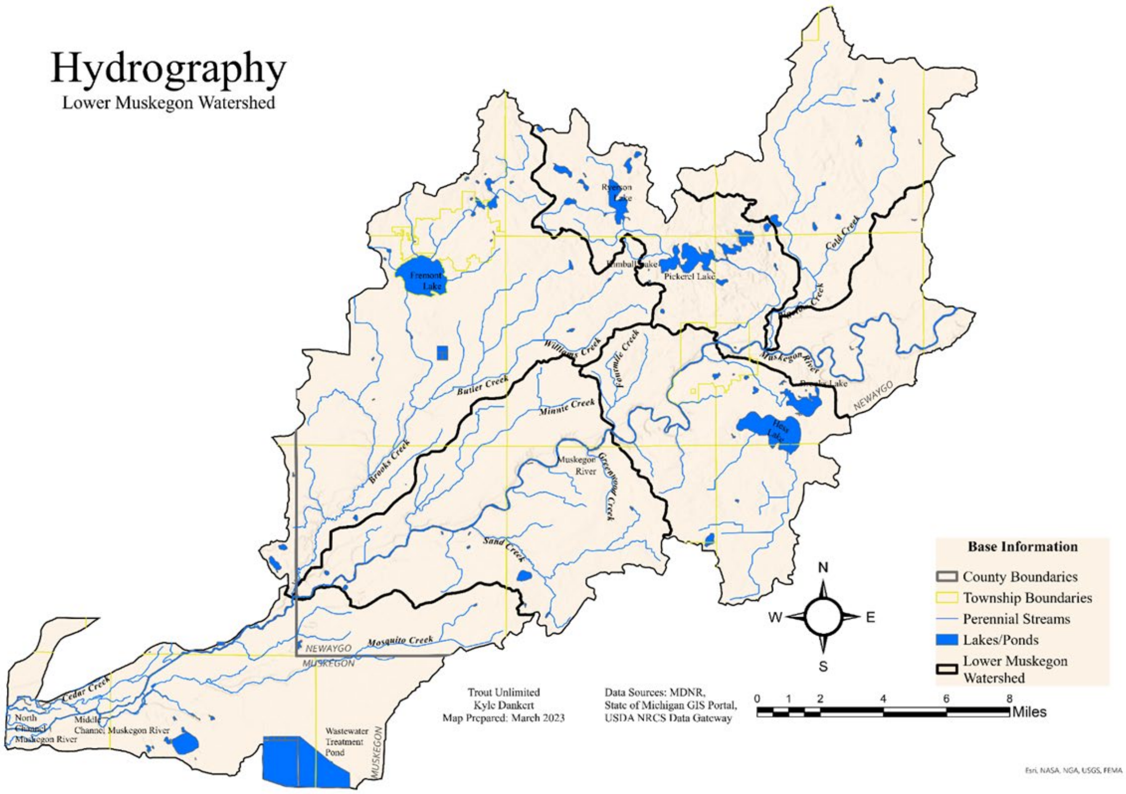
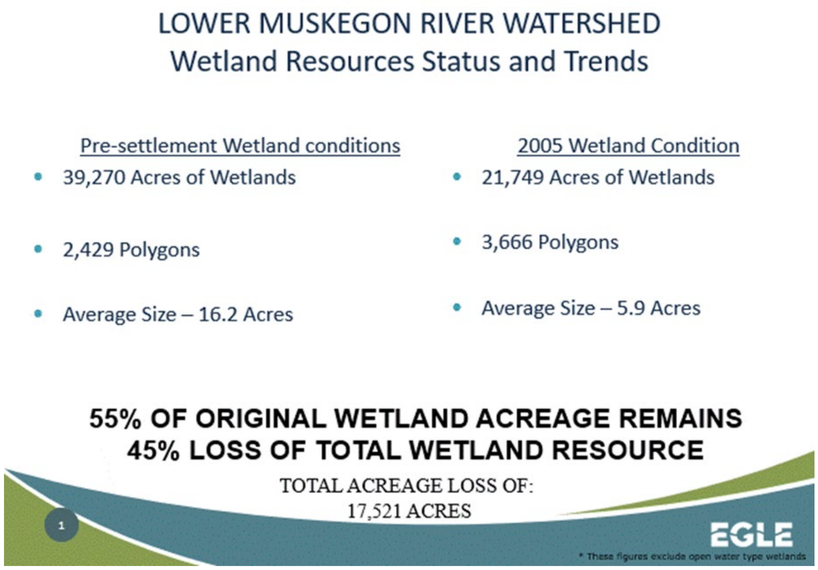


Figure I: Map of Project Area



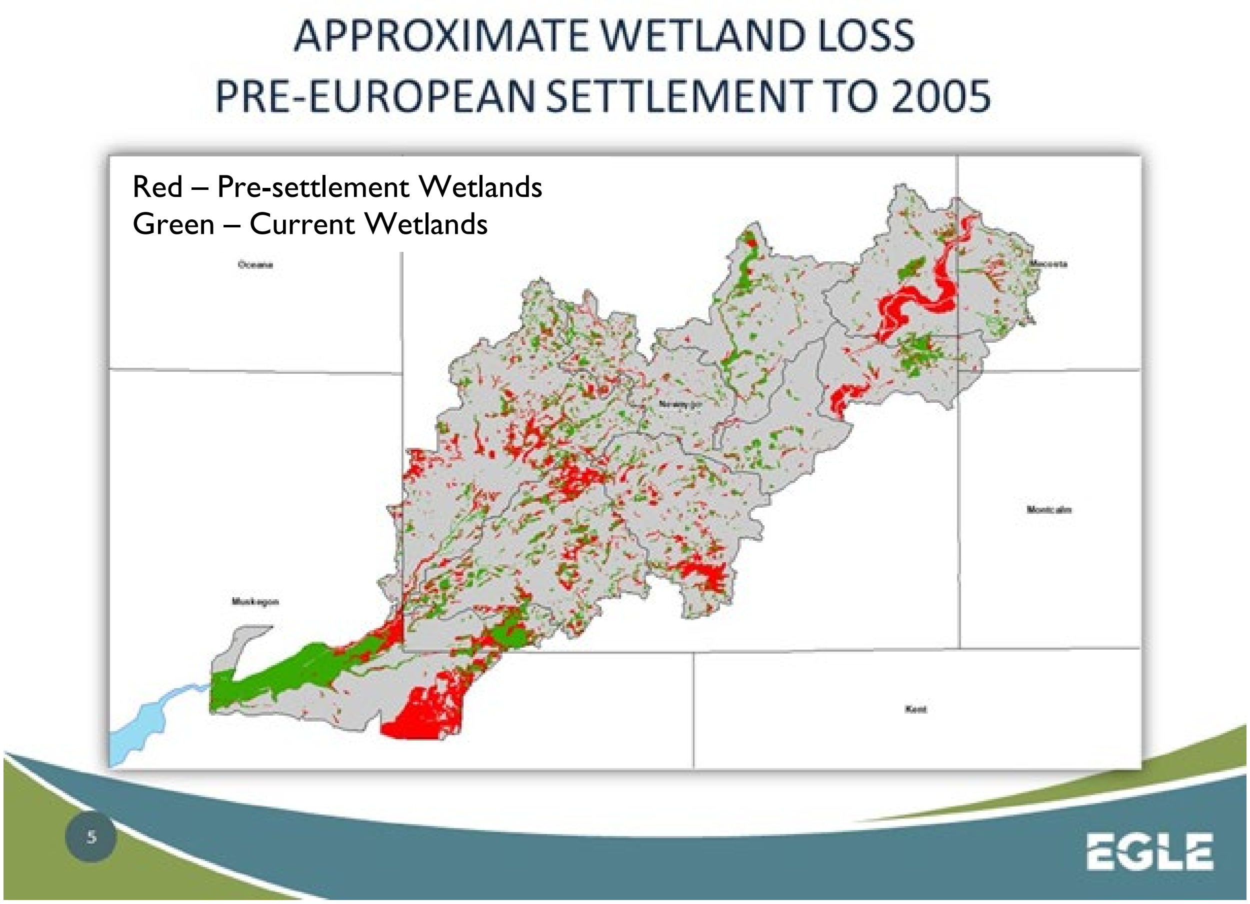


Figure 2: EGLE Lower Muskegon River Watershed Landscape Level Wetland Functional Assessment

II. Approaches for Assessing Wetlands in the Lower Muskegon River Watershed

Michigan's Landscape Level Wetland Functional Assessment (LLWFA) Tool
In 2007, EGLE received a Wetland Program Development Grant from the EPA to aid in their development of a tool to evaluate wetland functions on a watershed scale. EGLE identified the need to develop such a tool to assess wetland quantity and wetland functions to evaluate the impact that wetlands have on the entire watershed. The LLWFA tool was built using work done by the FWS which aided hydrogeomorphic descriptors to wetland polygons on National Wetlands Inventory (NWI) maps. Using the GIS data, wetland function, services, and types were able to be assessed. The tool also allows users to compare current wetland quantity and function with pre-settlement data to assess the change in both wetland extent and condition.

Lower Muskegon River Watershed Wetland Restoration Prioritization Model
Level 1 or a landscape assessment scale relies entirely on GIS data, utilizing data within the LLWFA tool. The results of this type of assessment provides a coarse gauge of wetland condition within a watershed. Level 2 or a rapid assessment uses relatively simple metrics to assess wetland condition. This is based on the readily observable hydrogeomorphic and plant community attributes of wetlands. This assessment also employs the use of a "stressor checklist." This rapid assessment method allowed us to field-verify what the GIS data is showing and provide more detail on the condition of the site and its restorability.

<u>Level 1 Landscape Level Wetland Functional Assessment Tool</u>: The LLWFA consists of overlapping data all related to wetlands in Michigan. For purposes of this project, only data in the Lower Muskegon River Watershed were analyzed. Specifically, two important data sets were used: "Pre-settlement Muskegon Wetlands" and "Current Muskegon Wetlands." These "shapefiles" present in red (Pre-settlement Wetlands) and green (Current Wetlands) (Figure 3).

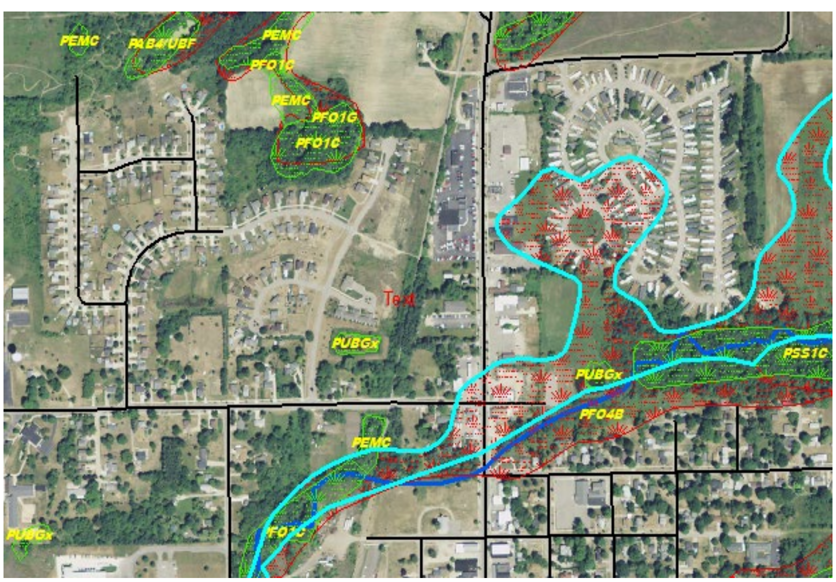


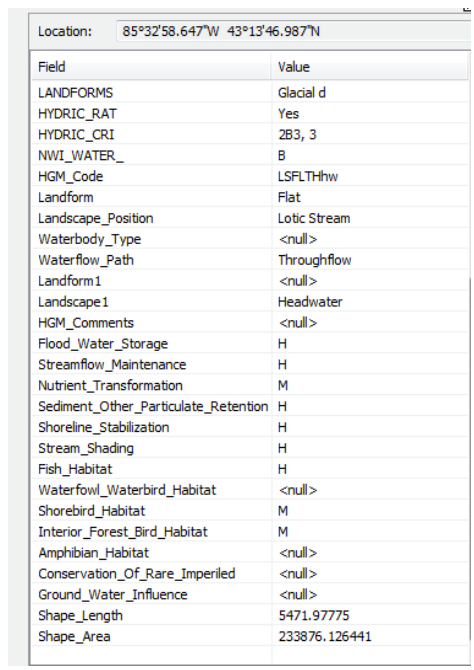
Figure 3: Pre-settlement Wetland presented in red and Current Wetlands presented in green.

Once this information was presented in the LLWFA tool, several steps were taken to narrow the list of potential wetland restoration sites. These steps are listed below:

(1) Once areas of historic, lost wetlands are visually identified using the LLWFA tool, aerial imagery files were used to determine whether the site has potential for wetland restoration. For this project, condominium sites, housing and commercial development, paved roads and other significant development are considered impediments to wetland restoration and immediately rejected. Community set aside areas within developments, however, are included in the list of potential wetland restoration sites.

(2) When an area is deemed a potentially restorable site based on the criteria in step one, property boundaries were assessed. Parcel boundaries were used to generally identify potentially restorable wetlands on single parcels or, in some cases, on multiple adjacent parcels owned by the same owner. The possibility of a wetland restoration on property owned by the same landowner will be deemed much more likely to be restored than a wetland restoration involving multiple landowners.

(3) Using the sites identified in steps one and two, the LLFWA tool was used to determine estimated historic functions of these wetlands (Figure 4). Goals of the Muskegon River Watershed Management Plan are to address thermal pollution, excess nutrients, and sediment inputs. For this project, four wetland functions were looked at: flood water storage, nutrient transformation, sediment and other particulate retention, and groundwater influence. Each of these were given a ranking with the LLFWA tool, either "Null," "Low," "Medium," or "High." A "wetland score" was established using the historic functions data from the LLFWA tool. Each of the four criteria determined was given a wetland score between 0 to 3 points, corresponding to values in the LLFWA tool from "null" to "high" (Table 1)



Location: 85°32'58.647"W 43°13'46.987"N

Field	Value
LANDFORMS	Glacial d
HYDRIC_RAT	Yes
HYDRIC_CRI	2B3, 3
NWI_WATER_	B
HGM_Code	LSFLTHhw
Landform	Flat
Landscape_Position	Lotic Stream
Waterbody_Type	<null>
Waterflow_Path	Throughflow
Landform1	<null>
Landscape1	Headwater
HGM_Comments	<null>
Flood_Water_Storage	H
Streamflow_Maintenance	H
Nutrient_Transformation	M
Sediment_Other_Particulate_Retention	H
Shoreline_Stabilization	H
Stream_Shading	H
Fish_Habitat	H
Waterfowl_Waterbird_Habitat	<null>
Shorebird_Habitat	M
Interior_Forest_Bird_Habitat	M
Amphibian_Habitat	<null>
Conservation_Of_Rare_Imperiled	<null>
Ground_Water_Influence	<null>
Shape_Length	5471.97775
Shape_Area	233876.126441

Figure 4: Wetland Functions using the LLFWA tool.

Table 1: Wetland Scoring for Level 1 Assessment

LLFWA Historical Function	Null	Low	Medium	High	Total Possible Points
Ranking/Function	0	1	2	3	12

<u>Level 2 Rapid Field Assessment</u>: Using the results of the Level 1 assessment the highest-ranking sites within each subbasin were put into a spreadsheet and mapped for a field assessment to be performed. The inventory was designed to be completed as a windshield survey that could ground truth the results of the LLWFA. The field inventory assessed a variety of easily observable parameters and a 'stressor checklist' to further determine restorability of a site. The

parameters included habitat stressors within the site, hydrology stressors, and buffer stressors. For each of the sites, the specific details from the Figure 5 data sheet, along with site sketches and photographs, are stored by Trout Unlimited on Arc online databases and available by contacting Nichol DeMol (nichol.demol@tu.org).

After recording results of the preceding parameters, the field technician determined if the site was potentially restorable and explained why or why not. If the site was no longer a feasible wetland restoration, it was removed from the potential wetland restoration spreadsheet. The field technician also determined the "qualitative disturbance score" from least (1) to highly disturbed (5). A highly disturbed site would be ranked higher than a lower disturbed site due to potential higher pollutant loading reductions.

The potential restoration/enhancement sites from the Level 1 and Level 2 assessments were compiled into a final ranked spreadsheet based on their Level 1 and Level 2 assessment rankings. From this analysis 29 sites were ranked as high (score of 15-17) for wetland restoration/enhancement practices (Figure 6). The results of this multi-level assessment approach provide a useful data driven and field verified ranking of potential wetland restoration/enhancement sites in the Lower Muskegon River watershed.

Table 2: Wetland Scoring for Level 1 and Level 2 Assessments

Ranking	Wetland Restoration/Enhancement Sites	Color
17-15	High Priority	
14-13	Medium Priority	
Less than 13	Low Priority	

III. Sustainability for Implementing Wetland Best Management Practices

Wetland restoration and enhancement will continue to be high priority work to ensure the health and function of the Lower Muskegon River watershed, its wildlife, and its communities. This wetland assessment and prioritization work funded by EGLE has laid the groundwork for many decades of successful, strategic, and impactful wetland restoration. The Muskegon River Watershed Assembly and other partners will utilize this newly created ranking of wetland restoration/enhancement sites to perform outreach to landowners, fundraise for projects, and implement high priority wetland projects to ensure wetlands can continue to contribute their essential functions and values to the Lower Muskegon River watershed and its communities. Wetlands remain a critical component of a watershed approach to management and this information will ensure that this important work will be incorporated into watershed management and stakeholder decision-making for many years to come.

Figure 5: Adapted Rapid Assessment Data Sheet

Site ID______ Date___________ Subwatershed____

Observers ____

HABITAT/PLANT STRESSORS (WITHIN SITE)

% of Area Forest ________________

Vegetation Alteration (check all present)

☐ Mowed ☐ Cleared Not Recovering

☐ Farmed ☐ Other _____________

☐ Grazed

Presence of Invasive Species ☐

If yes:

NOT Dominating

☐ < 1% ☐ 1-5% ☐ 6-50%

Dominating

☐ > 50%

Roads ☐

If yes:

☐ Non elevated road (Logging, dirt, ATV)

☐ Elevated road (dirt or gravel)

☐ Paved road

Additional comments on Habitat/Plant, Hydrology, and/or Buffer Stressors

____

____

____

____

____

____

____

____

____

____

____

HYDROLOGY STRESSORS

Ditches ☐

I yes:

☐ Slight (1-3 shallow ditches <.3m deep)

☐ Mod (>3 shallow ditches OR 1 ditch >.6m deep)

☐ Severe (>1 ditch .3-.6m deep or 1 ditch >.6m

Channelized Stream ☐

If yes:

☐ Not maintained reverting to natural channel

☐ Spoils on bank on one or both sides

☐ Natural channel incision

Weir/Dam/Road ☐

If yes:

☐ Decreasing flooding of site

☐ Impounding water <10%

☐ Impounding water 10-75%

☐ Impounding water >75%

Stormwater Inputs and Point Sources ☐

If yes:

☐ Stormwater inputs

☐ Point source (non storwmater)

☐ Excessive sedimentation in wetland

Filling, Excavation ☐

If yes:

☐ <10% of site

☐ 10-75% of site

☐ >75% of site

Microtopography Alterations ☐

If yes:

☐ <10% of site

☐ 10-75% of site

☐ >75% of site

☐ Soil subsidence and root exposure

BUFFER STRESSORS (SURROUNDING SITE)

Development ☐ If yes:

☐ Commercial, industrial

☐ Residential >2 houses/acre

☐ Residential </=2 houses/acre

☐ Residential </=1 house/acre

Roads ☐ If yes:

☐ Mostly dirt or gravel roads

☐ Mostly 2-lane paved roads

☐ Mostly 4-lane roads

Landfill/Waste Disposal ☐

☐ Channelized Streams or Ditches (>0.6m Deep)

Row Crops, Nursery Plants, Orchard ☐

☐ Poultry or Livestock Operations

Forest Harvesting within Last 15 Years ☐

☐ Golf Course

Mowed Area ☐

☐ Sand/Gravel Operation

Other ☐ ________________________________

SITE SKETCH AND PICTURES

RESTORATION POTENTIAL

Is the wetland restorable? Why or why not?

____

____

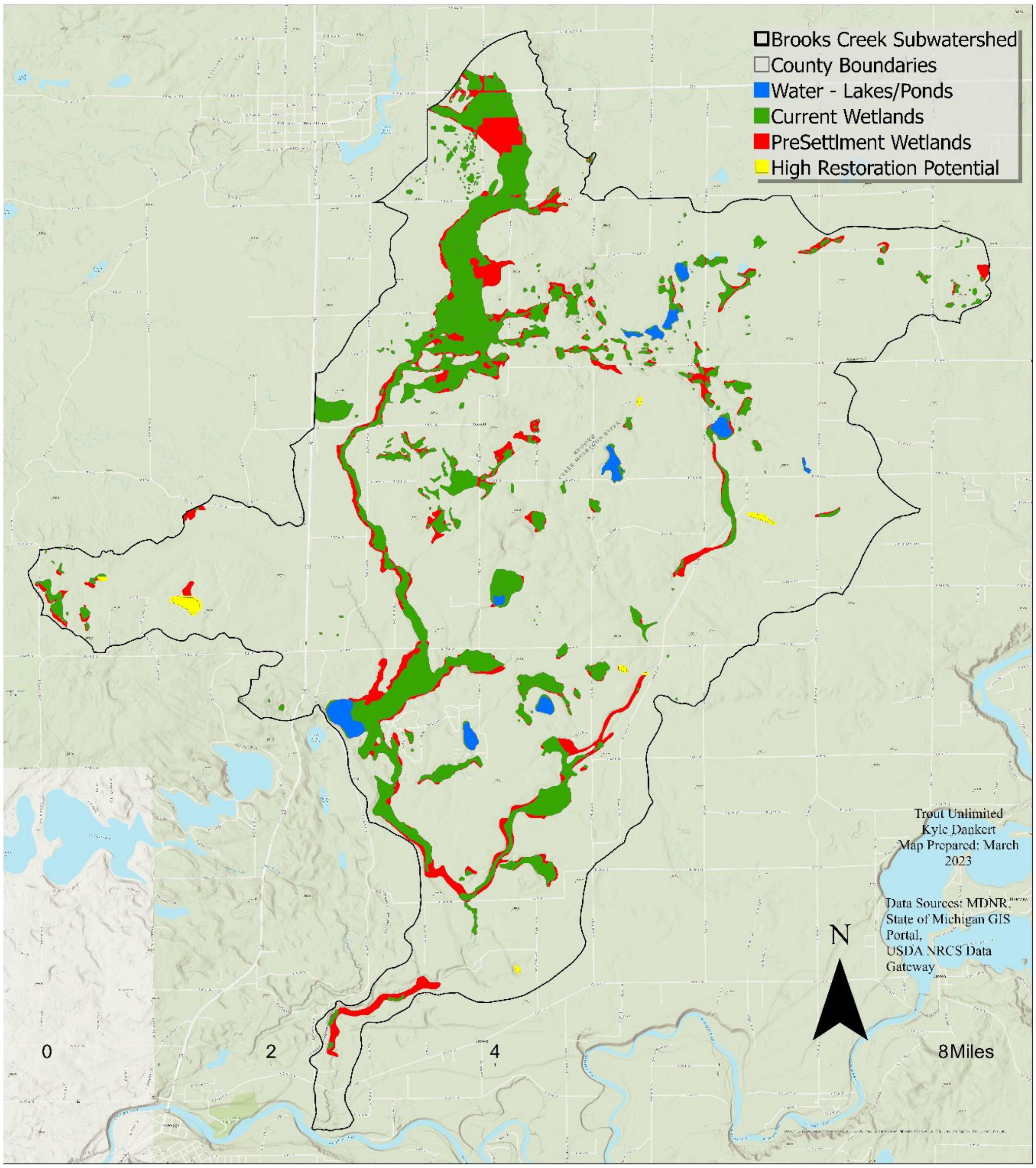
____

QUALITATIVE DISTURBANCE RANKING

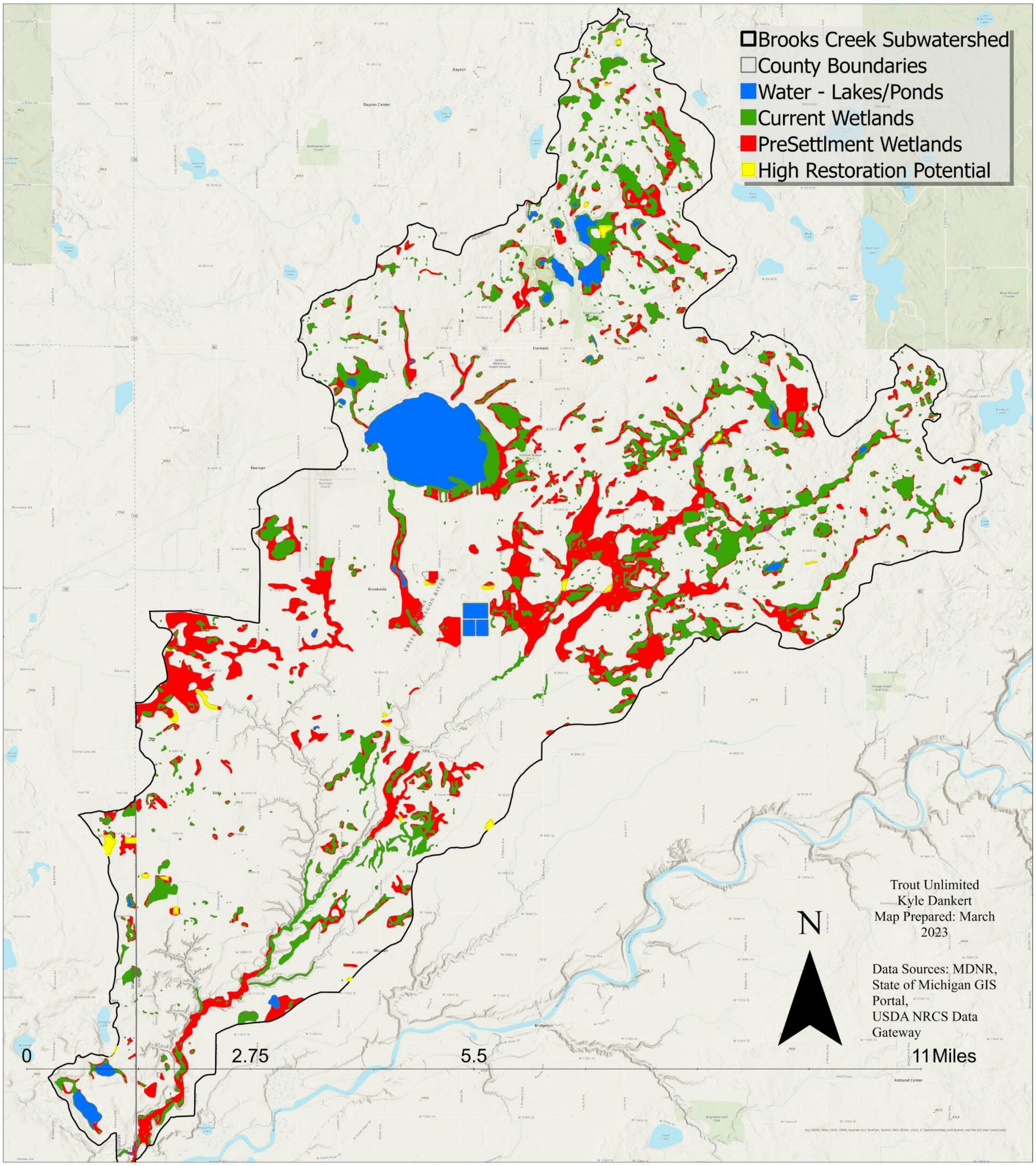
Least Disturbed 1 2 3 4 5 Highly Disturbed (circle one number)

Figure 6: Results from Level 1 & Level 2 Assessments

Bigelow Creek Sub Basin

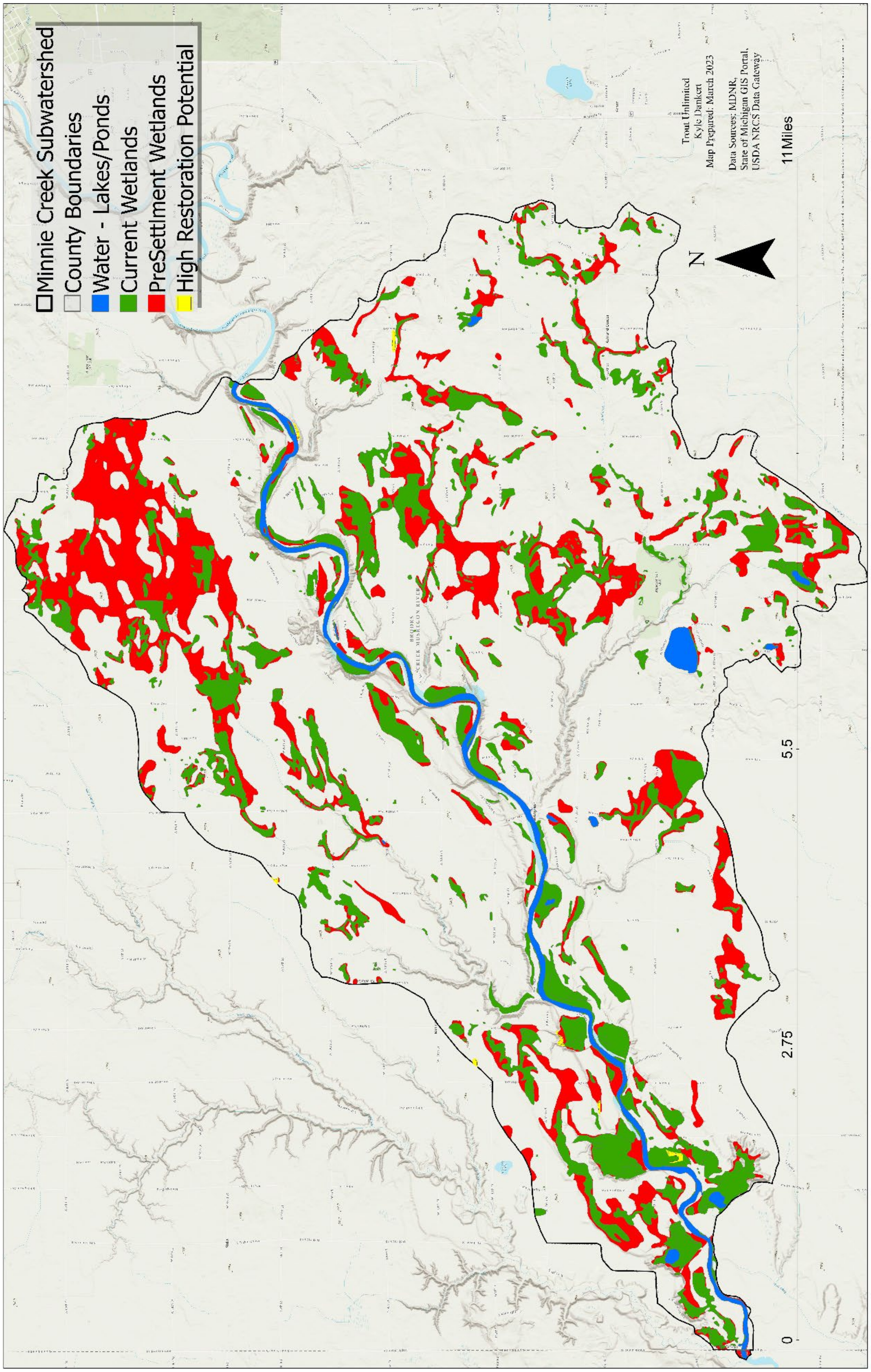


Brooks Creek Sub Basin



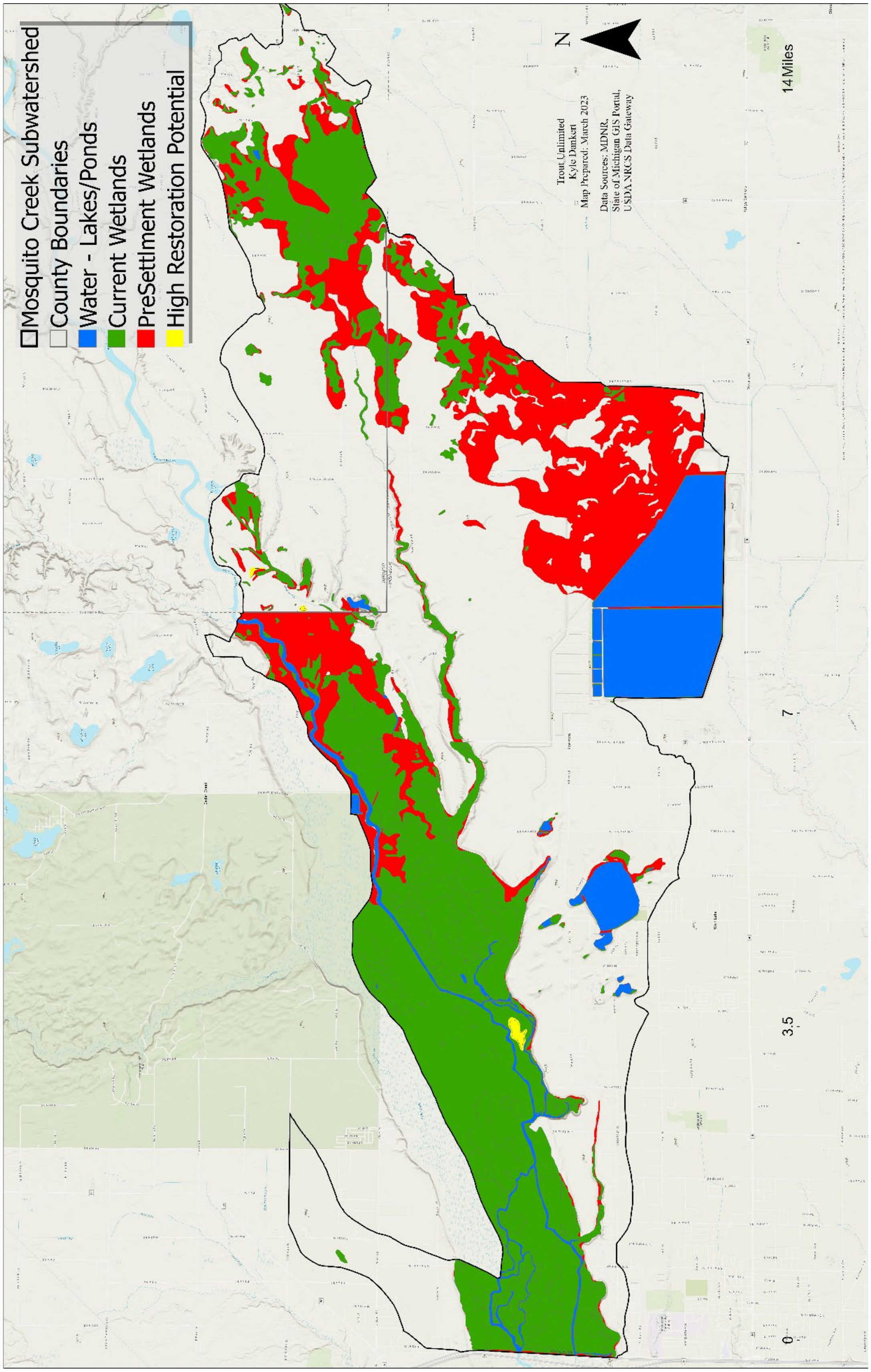
Appendix A. Wetland Verification in the Lower Muskegon River Watershed.

Minnie Creek Sub Basin

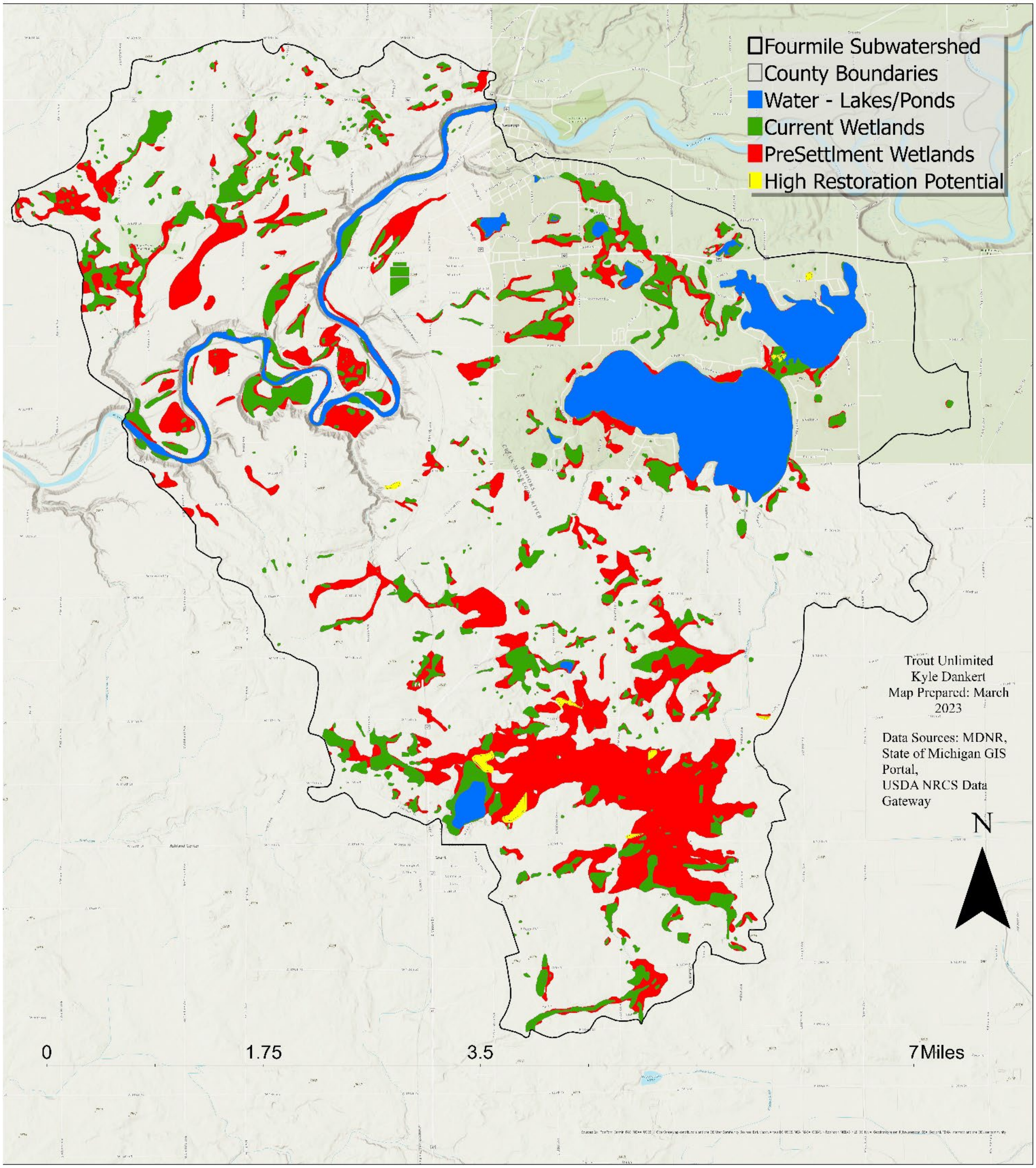


Appendix A. Wetland Verification in the Lower Muskegon River Watershed.

Mosquito Creek Sub Basin

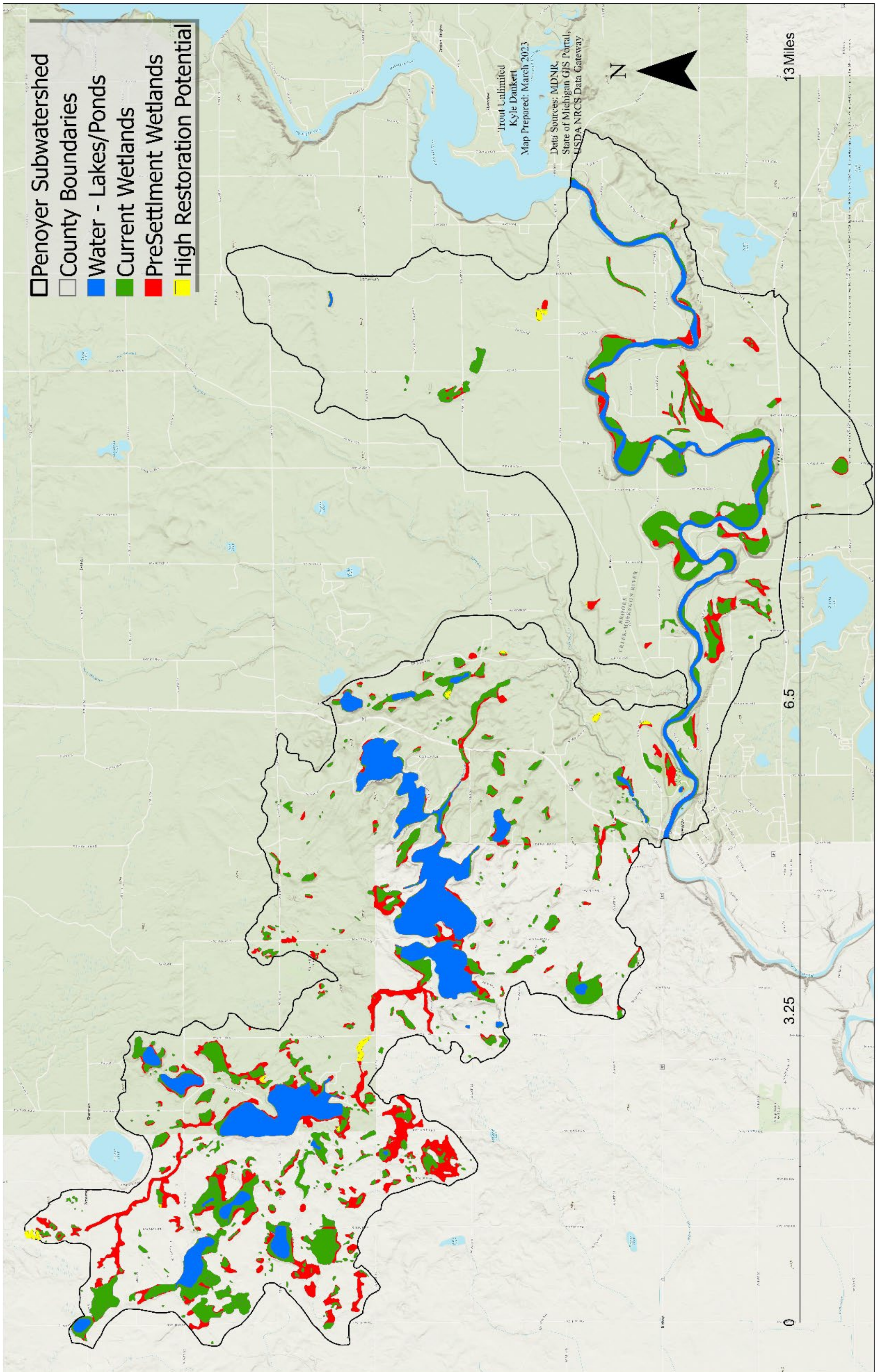


Fourmile Creek Sub Basin



Appendix A. Wetland Verification in the Lower Muskegon River Watershed.

Penoyer Creek Sub Basin



Appendix A. Wetland Verification in the Lower Muskegon River Watershed.

Acres	County	Wetland Score	Wetland ID	Qualitative Disturbance Ranking	Overall Priority Ranking	Score colo
19.71320173		12	Mu14	5	17	17 - 15
3.80306934	Newaygo County, Michigan	12	Ne334	4	16	14 - 13
1.970234624	Newaygo County, Michigan	11	Mu13	5	16	13>
4.612122767	Newaygo County, Michigan	11	Mu31	5	16	
4.612122767	Newaygo County, Michigan	11	Mu32	5	16	
1.179299312	Newaygo County, Michigan	11	Ne325	5	16	
7.639653352	Mecosta County, Michigan	11	Me503	5	16	
1.707900587	Newaygo County, Michigan	11	Ne291	5	16	
42.24743495	Newaygo County, Michigan	11	Ne76	5	16	
4.169164992	Mecosta County, Michigan	12	Me428	4	16	
3.327492024	Newaygo County, Michigan	11	Ne483	5	16	
1.560081737	Newaygo County, Michigan	11	Ne386	5	16	
2.56740951	Newaygo County, Michigan	11	Ne126	5	16	
7.154207237	Mecosta County, Michigan	11	Ne114	4	15	
1.321918027		11	Mu22	4	15	
6.150823686	Newaygo County, Michigan	10	Ne48	5	15	
1.793540198	Newaygo County, Michigan	11	Ne447	4	15	
18.64891971	Newaygo County, Michigan	11	Ne50	4	15	
1.082061475	Newaygo County, Michigan	11	Ne143	4	15	
1.267089501		12	217	3	15	
10.37253667	Newaygo County, Michigan	11	Ne440	4	15	
2.126107684	Newaygo County, Michigan	11	Ne318	4	15	
4.737180685	Newaygo County, Michigan	12	Ne263	3	15	
12.64931757	Mecosta County, Michigan	10	Me466	5	15	
1.028111311	Newaygo County, Michigan	11	Ne294	4	15	
8.002784639	Mecosta County, Michigan	11	Me25	4	15	
4.020480897	Newaygo County, Michigan	11	Ne123	4	15	
1.065380863	Newaygo County, Michigan	11	Ne381	4	15	
1.285292851	Newaygo County, Michigan	11	Ne235	4	15	
1.330919714	Newaygo County, Michigan	9	Mu33	5	14	
1.330919714	Newaygo County, Michigan	9	Mu34	5	14	
1.092939638	Newaygo County, Michigan	9	Mu35	5	14	
1.092939638	Newaygo County, Michigan	9	Mu39	5	14	
1.092939638	Newaygo County, Michigan	9	Mu41	5	14	
1.092939638	Newaygo County, Michigan	9	Mu43	5	14	
1.341651809		11	202	3	14	
1.092939638	Newaygo County, Michigan	12	Ne379	2	14	
2.575636959	Newaygo County, Michigan	10	Ne490	4	14	
4.393012885	Mecosta County, Michigan	11	Me153	3	14	
1.98740302	Newaygo County, Michigan	11	Ne436	3	14	
1.761605616	Newaygo County, Michigan	9	Ne20	5	14	
1.48405126	Newaygo County, Michigan	11	Ne140	3	14	
2.471164807	Newaygo County, Michigan	11	Ne423	3	14	
5.05866287	Newaygo County, Michigan	11	Ne146	3	14	
1.519456071	Newaygo County, Michigan	12	Ne205	2	14	
4.173794568	Newaygo County, Michigan	10	Ne468	4	14	
4.771430566	Newaygo County, Michigan	12	Ne239	2	14	
2.956310638	Newaygo County, Michigan	11	Ne212	3	14	
1.927911002	Newaygo County, Michigan	10	Ne1	4	14	
1.618260814	Newaygo County, Michigan	11	Ne112	3	14	
27.7919834	Newaygo County, Michigan	11	Ne150	3	14	
1.430979491	Newaygo County, Michigan	9	Ne518	5	14	
3.224958607	Newaygo County, Michigan	11	Ne416	3	14	
5.946769383	Newaygo County, Michigan	12	Ne214	2	14	
1.85010181	Newaygo County, Michigan	12	Ne323	2	14	
16.06101998	Mecosta County, Michigan	11	Me335	2	13	
1.41236993	Newaygo County, Michigan	10	Ne336	3	13	
5.544594359	Mecosta County, Michigan	11	Me337	2	13	
4.250390094	Mecosta County, Michigan	9	Ne338	4	13	
1.578757464	Newaygo County, Michigan	11	Me339	2	13	
4.055318063		11	Mu19	2	13	
1.092939638	Newaygo County, Michigan	9	Mu28	4	13	
1.663036		9	407	4	13	
1.327457752	Newaygo County, Michigan	11	Ne185	2	13	
5.326292589	Mecosta County, Michigan	11	Me438	2	13	
4.612122767	Newaygo County, Michigan	11	Ne18	2	13	
3.054157211	Newaygo County, Michigan	11	Ne	2	13	
1.822331628	Newaygo County, Michigan	11	Ne135	2	13	
4.790887521	Newaygo County, Michigan	12	Ne209	1	13	
3.412751861		11	509	2	13	
2.089490321	Newaygo County, Michigan	11	Ne470	2	13	
4.779036613	Newaygo County, Michigan	11	Ne116	2	13	
1.203292682		11	292	2	13	
1.595514421		11	410	2	13	
3.005627544	Newaygo County, Michigan	9	Ne491	4	13	
2.844560615	Mecosta County, Michigan	11	Me74	2	13	
20.10100528	Newaygo County, Michigan	11	Ne29	2	13	
3.934862581	Mecosta County, Michigan	9	Me479	4	13	
2.688510512		11	472	2	13	

2.06398064		9	260	4	13
2.485546727	Newaygo County, Michigan	11	Ne408	2	13
4.494489655	Newaygo County, Michigan	10	Ne218	3	13
8.196985698	Mecosta County, Michigan	11	Me241	2	13
32.15823329	Mecosta County, Michigan	10	Me37	3	13
5.386370737	Newaygo County, Michigan	9	Ne457	4	13
10.57830475	Newaygo County, Michigan	10	Ne459	3	13
1.385865812	Newaygo County, Michigan	8	Ne108	5	13
10.54522839	Newaygo County, Michigan	10	Ne173	3	13
3.641714135	Newaygo County, Michigan	9	Ne469	4	13
5.590914121	Newaygo County, Michigan	11	Ne255	2	13
5.082313018	Newaygo County, Michigan	11	Ne370	2	13
2.945296601	Newaygo County, Michigan	11	Ne317	2	13
3.9131138	Mecosta County, Michigan	11	Me233	2	13
1.391252481	Newaygo County, Michigan	11	Ne439	2	13
2.298674981	Newaygo County, Michigan	11	Ne330	2	13
1.920445794		9	315	4	13
2.572873453	Newaygo County, Michigan	11	Ne406	2	13
2.133588934	Newaygo County, Michigan	9	Ne237	4	13
20.17777135	Newaygo County, Michigan	11	Ne419	2	13
6.594263647	Newaygo County, Michigan	9	Mu12	3	12
1.065380863	Newaygo County, Michigan	7	Mu16	5	12
10.44533199	Mecosta County, Michigan	8	Mu23	4	12
3.054157211	Newaygo County, Michigan	11	Mu56	1	12
2.70806714	Newaygo County, Michigan	9	Ne257	3	12
1.468833726	Newaygo County, Michigan	11	Ne134	1	12
1.272975603		11	203	1	12
2.355144257	Newaygo County, Michigan	11	Ne349	1	12
2.799686424	Newaygo County, Michigan	11	Ne128	1	12
2.469889331	Newaygo County, Michigan	11	Ne245	1	12
5.946962832	Newaygo County, Michigan	11	Ne129	1	12
1.115098804	Newaygo County, Michigan	11	Ne190	1	12
2.203165255	Newaygo County, Michigan	11	Ne121	1	12
2.8281364	Newaygo County, Michigan	8	Ne68	4	12
15.13481457	Newaygo County, Michigan	9	Ne455	3	12
2.863069095	Mecosta County, Michigan	11	Me215	1	12
5.04739736	Newaygo County, Michigan	9	Ne77	3	12
16.76192581	Newaygo County, Michigan	7	Ne343	5	12
1.709494033	Newaygo County, Michigan	11	Ne117	1	12
1.324262907	Newaygo County, Michigan	11	Ne189	1	12
1.737287863	Newaygo County, Michigan	11	Ne216	1	12
2.084103802	Newaygo County, Michigan	10	Ne377	2	12
2.044464278	Newaygo County, Michigan	11	Ne213	1	12
10.44533199	Mecosta County, Michigan	7	Me252	5	12
3.907632026	Newaygo County, Michigan	11	Ne246	1	12
11.30696941	Mecosta County, Michigan	9	Me395	3	12
7.109417078	Newaygo County, Michigan	10	Ne332	2	12
223.0540323	Newaygo County, Michigan	11	Ne83	1	12
2.631060099	Mecosta County, Michigan	10	Me304	2	12
1.600980914	Newaygo County, Michigan	9	Ne293	3	12
1.145287335	Newaygo County, Michigan	11	Ne400	1	12
3.233466308	Mecosta County, Michigan	11	Me409	1	12
1.385865812	Newaygo County, Michigan	9	Mu51	2	11
1.385865812	Newaygo County, Michigan	9	Mu52	2	11
1.385865812	Newaygo County, Michigan	9	Mu53	2	11
1.385865812	Newaygo County, Michigan	9	Mu55	2	11
1.385865812	Newaygo County, Michigan	9	Mu57	2	11
1.385865812	Newaygo County, Michigan	9	Mu58	2	11
3.408434226	Newaygo County, Michigan	9	Ne122	2	11
4.667156772	Newaygo County, Michigan	9	Ne131	2	11
4.055318063		11	358		11
2.075436678		10	517	1	11
1.505552075	Mecosta County, Michigan	11	Me425		11
1.970234624	Newaygo County, Michigan	9	Ne287	2	11
1.315408786		11	392		11
16.24153432	Mecosta County, Michigan	9	Me306	2	11
5.306969074		7	278	4	11
7.95618353	Newaygo County, Michigan	9	Ne403	2	11
8.26186931	Mecosta County, Michigan	9	Me34	2	11
4.5047134	Mecosta County, Michigan	9	Me234	2	11
2.826155754	Newaygo County, Michigan	8	Ne106	3	11
2.748928333	Newaygo County, Michigan	9	Ne364	2	11
6.403705948	Newaygo County, Michigan	9	Ne107	2	11
6.170574054	Newaygo County, Michigan	9	Ne182	2	11
3.626721164	Newaygo County, Michigan	9	Ne148	2	11
13.61235887	Newaygo County, Michigan	7	Ne266	4	11
6.961556248	Newaygo County, Michigan	7	Ne184	4	11
1.330919714	Newaygo County, Michigan	9	Ne372	2	11
41.41025077	Newaygo County, Michigan	10	Ne465	1	11
2.489183135	Newaygo County, Michigan	9	Ne289	2	11

1.45403126	Newaygo County, Michigan	9	Ne298	2	11
1.824889604	Newaygo County, Michigan	9	Ne301	2	11
13.32752988	Newaygo County, Michigan	7	Ne344	3	10
10.44533199	Mecosta County, Michigan	8	Mu11	2	10
1.706711596	Newaygo County, Michigan	9	Ne194	1	10
6.544131083		9	340	1	10
2.26260236	Newaygo County, Michigan	9	Ne125	1	10
1.263438998	Mecosta County, Michigan	9	Me499	1	10
26.87516382	Newaygo County, Michigan	9	Ne402	1	10
1.262819308	Newaygo County, Michigan	9	Ne127	1	10
2.401937328		9	275	1	10
11.67535757	Newaygo County, Michigan	9	Ne262	1	10
5.580648457	Newaygo County, Michigan	7	Ne145	3	10
1.437132066	Newaygo County, Michigan	7	Ne492	3	10
2.0185199		8	463	2	10
2.060735038	Mecosta County, Michigan	7	Me411	3	10
8.833209691	Mecosta County, Michigan	9	Me348	1	10
1.71059775	Newaygo County, Michigan	9	Ne344	1	10
2.0185199		9	Mu54		9
1.385865812	Newaygo County, Michigan	9	Mu59		9
5.790311283		9	347		9
1.44695048	Newaygo County, Michigan	8	Ne240	1	9
4.67016373	Newaygo County, Michigan	7	Ne282	2	9
2.186768578	Mecosta County, Michigan	7	Me271	2	9
5.356467931	Newaygo County, Michigan	7	Ne322	2	9
1.023893904	Mecosta County, Michigan	9	Me267		9
15.83457952	Newaygo County, Michigan	7	Ne450	2	9
2.972310598	Newaygo County, Michigan	9	Ne449		9
1.089504867	Newaygo County, Michigan	7	Ne242	2	9
2.284157183	Newaygo County, Michigan	7	Ne210	2	9
2.008778586	Newaygo County, Michigan	7	Ne396	1	8
4.151803923		8	220		8
4.425773739		7	508	1	8
19.99663618	Newaygo County, Michigan	7	Ne118	1	8
1.251628003	Mecosta County, Michigan	7	Me238	1	8
1.180963286	Mecosta County, Michigan	7	Me380	1	8
1.000855612	Newaygo County, Michigan	7	Ne259	1	8
2.928675947	Mecosta County, Michigan	7	Me474	1	8
1.112516498	Newaygo County, Michigan	7	Ne339	1	8
1.620940738	Mecosta County, Michigan	7	Me520		7
9.953792797		0	Me60	2	2
7.891936641		0	Me502	2	2

Appendix B. Regulatory Authorities, Designated Uses, Water Quality Standards, and Impaired Designated Uses

Agencies with regulatory oversight include local county, city, and township governments, EGLE, MDNR and Tribal governments. EGLE works to enforce federal and state environmental protection laws and is the state's permitting authority for inland lakes and streams, wetlands, NPDES, concentrated animal feeding operations (CAFOs), Soil Erosion and Sedimentation Control (SESC), and storm water management. The MDNR and Tribal agencies co-manage the watersheds fish and wildlife resources.

Michigan and the other Great Lakes states and provinces have each enacted laws that regulate water uses within the Great Lakes Basin. The laws are in accordance with the Great Lakes-St. Lawrence River Basin Water Resources Compact and an international Agreement to manage groundwater and surface water resources within the Great Lakes Basin, and to prohibit diversions outside the Basin. The Water Use Program is responsible for registering large quantity withdrawals, collecting annual water use data, making determinations on potential impacts to water resources because of proposed withdrawals, and processing water withdrawal permits. The information managed by the Water Use Program provides a baseline for managing water resources in an integrated manner and strengthens the legal basis for opposing unwarranted diversions of Great Lakes water. Water withdrawals are managed through permits which regulate new or increased large quantity water withdrawals over an established baseline capacity under the authority of Part 327, Great Lakes Preservation, of the Natural Resources and Environmental Protection Act (NREPA), Public Act 451 of 1994, as amended.

County Road and Drain Commissions also have authority over watershed resources. Road commissions plan and implement road development and maintenance projects that may impact drainage patterns. Road crossings over surface waters and wetlands may require culverts or bridges. Design parameters of bridges and culverts, including size, depth and debris impaction, may affect stream hydrology or wetland function. Operations and maintenance methods for road grading, repairs, and snow and ice removal can vary in their impact on water quality. Drain commissioners have authority to maintain or alter a large percentage of the watershed's tributaries to minimize flooding. Management and maintenance methods used by drain commissioners can have a large impact on water quality. It is important for both road and drain commissions to keep current regarding BMPs for water quality.

Part 91 of Natural Resources Environmental Protection Act (NREPA) SESC is administered and enforced by EGLE through various county and local government units. Counties have a designated County Enforcing Agency, and municipalities can designate Municipal Enforcing Agencies. County Enforcing Agencies and Municipal Enforcing Agencies are responsible for reviewing soil erosion and sediment control plans, issuing permits, and reviewing compliance with Part 91, and taking enforcement actions when necessary.

All surface waters of Michigan are expected to meet Water Quality Standards (WQS) to provide eight designated uses. The State's surface waters include the Great Lakes and their connecting waters, inland lakes, rivers, streams, impoundments, open drains, wetlands, and other surface bodies of water. These designated uses are specified in Part 4 Rules issued in accordance with Part 31 of the NREPA (1994 PA 451, as amended), are protected, by law, and include:

- Agriculture – Surface water must be of the quality that it can be used for livestock watering, irrigation, and other agricultural activities.
- Industrial water supply – Surface waters must meet quality standards for use in commercial or industrial applications.
- Public water supply - After conventional treatment methods, surface waters must provide a source of water that is safe for human consumption, food processing, and cooking.
- Navigation – Surface waters must be of the quality sufficient for passage of boat traffic; for purposes of this WMP, the United States Army Corps of Engineers (USACE) definition of navigation (e.g. Commercial shipping) is not considered to be a designated or desired use of the LMRWMP.
- Warmwater/cold water fishery – Water bodies designated as warmwater (WW) fisheries should be able to sustain populations of fish species. Water bodies designated as cold water (CW) fisheries should be able to sustain populations of fish species such as trout.
- Habitat for other indigenous aquatic life and wildlife – Surface waters must support fish, other aquatic life and wildlife that use the water for any stage of their life cycle.
- Partial body contact recreation – Residents of the state should be able to use surface waters for activities that involve direct contact with the water but does not involve the immersion of the head, such as fishing and kayaking.
- Total body contact recreation between May 1 and October 31 – The waters of the state should allow for activities that involve complete submersion of the head such as swimming.

Surface waters are periodically assessed by EGLE to determine if a waterbody is attaining certain WQS and its designated uses. If a water body is not attaining any of the eight designated uses, it is defined as an impaired waterbody by the State of Michigan (EGLE 303(d) list)) and has been noted as such in this WMP. Once waterways are listed as impaired, EGLE is required to develop a Total Maximum Daily Load (TMDL) for the corresponding waterway(s) and its watersheds. A TMDL is the maximum amount of a particular pollutant a water body can assimilate without violating numerical and/or narrative WQS. Each TMDL reach is identified by a unique AUID number. Not all waterbodies are assessed by EGLE on a regular basis, thus, if a waterbody is not listed as impaired it does not mean that it meets all WQS; it may not have been assessed. Waterbodies not attaining WQS for any of the eight designated uses are found in Table 1.

Table 1. Impaired designated uses in the Lower Muskegon River Watershed (2024).

Subwatershed/*Location*	Impaired Use	Cause
Bigelow Creek		
Unnamed Tributary to Twinwood Lake	Fish Consumption	PCBs
	Other Indigenous Aquatic Life and Wildlife	Mercury in Water Column
Bigelow Creek and Cold Creek	Fish Consumption	Chlordane, PCBs, Mercury in Fish Tissue, Mercury in Water Column
	Other Indigenous Aquatic Life and Wildlife	Mercury in Water Column
Muskegon River (excluding 1 mile below Croton Dam)	Fish Consumption	Chlordane, PCBs, Mercury in Fish Tissue, Mercury in Water Column
Muskegon River (from Croton dam downstream 1 mile)	Cold Water Fishery	Dissolved Oxygen
	Fish Consumption	Chlordane, PCBs, Mercury in Fish Tissue
	Other Indigenous Aquatic Life and Wildlife	PCBs, Mercury in Water Column
Penoyer Creek	Fish Consumption	PCBs, Mercury in Water Column
	Other Indigenous Aquatic Life and Wildlife	PCBs, Mercury in Water Column
	Total Body Contact	E. coli
Sylvan Lake & Emerald Lakes	Fish Consumption	Mercury in Fish Tissue
Freska Lake	Fish Consumption	PFOS, Mercury in Fish Tissue
Brooks Creek		
Tributaries to Second, Third Fourth Lakes & Fremont Lake	Fish Consumption	PCBs, Mercury in Water Column
	Other Indigenous Aquatic Life and Wildlife	PCBs, Mercury in Water Column
Fremont Lake	Fish Consumption	PCBs, Mercury in Water Column
	Other Indigenous Aquatic Life and Wildlife	PCBs, Mercury in Water Column
Brooks Creek and Cow Creek	Fish Consumption	Chlordane, PCBs, Mercury in Fish Tissue, Mercury in Water Column
	Indigenous and Aquatic Life and Wildlife	Mercury in the Water Column
Daisy Creek and Spring Creek	Fish Consumption	PCBs, Mercury in Water Column
	Other Indigenous Aquatic Life and Wildlife	Mercury in Water
Lorden Lake Outlet & Unnamed Tributary	Fish Consumption	PCBs, Mercury in Water Column
	Other Indigenous Aquatic Life and Wildlife	Mercury in Water Column
Graham Creek	Fish Consumption	PCBs, Mercury in Water Column
	Other Indigenous Aquatic Life and Wildlife	Mercury in Water Column
Kempf School Creek	Fish Consumption	PCBs, Mercury in Water Column
	Other Indigenous Aquatic Life and Wildlife	Mercury in Water Column
Butler Creek & Williams Creek	Fish Consumption	PCBs, Mercury in Water Column
	Other Indigenous Aquatic Life and Wildlife	Mercury in Water Column
Hess Lake		
Four Mile Creek/Muskegon River	Fish Consumption	Chlordane, PCBs, and Mercury in Fish Tissue
Brooks Creek	Fish Consumption Other Indigenous Aquatic Life and Wildlife	Chlordane, PCBs, and Mercury in Fish Tissue
Wheeler Drain	Fish Consumption	PCBs
Hess Lake	Fish Consumption	PCBs
	Other Indigenous Aquatic Life and Wildlife	Total Phosphorous
Mosquito Creek		
Mosquito Creek, Maple River, Mosquito Creek, & Spring Creek	Fish Consumption	Chlordane, PCBs, Mercury in Fish Tissue

Appendix C. Pollutant Loadings in the Lower Muskegon River Watershed

Citations for the Pollutant Loading Tables

* The Newaygo Conservation District Aerial and Windshield survey results can be found in Appendix F.

** MRWA Watershed Inventory was completed using aerial GIS assessment and found in Chapter 3 figures.

*** Data from Trout Unlimited Wetland Assessment using an EGLE Landscape Level Wetland Function Assessment (LLWFA) is found in Appendix A.

**** Muskegon River Watershed Assembly Dam Inventory is found in Appendix D.
† EPA Pollutant Load Estimation Tool (2024): https://www.epa.gov/nps/plet.

†† EGLE CAFO Map (2024): https://www.michigan.gov/egle/about/organization/water-resources/cafo.

††† Muskegon Futures: Volume 7 Climate Change: https://mrwa.org/?s=muskegon+futures&region=0&topic=0&post_type=data_repository.

†††† Agicultural Conservation Planning Framework (ACPF) Toolbox: https://toolkit.climate.gov/tool/agricultural-conservation-planning-framework-acpf-toolbox.

√ Trout Unlimited Temperature Monitoring (2023) is found in Appendix D.

Pollutant Loadings in the Bigelow Creek Subwatershed

Pollutant Loadings in the Bigelow Creek Subwatershed

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Hydrologic Flow			
Agricultural runoff	Changes to the volume of water, timing with respect to rainfall, and duration of high flows.	Channelization and ditching	There are approximately 12.2 miles of channelized streams and ditches that contribute to changes in natural hydrology (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
		Loss of wetlands	There are approximately 1,094 acres of high priority wetlands that have been lost that contribute to changes in natural hydrology (TU 2023[***]).
Impoundments (Dams/ Lake Level Control)		Disruption of natural flow of water	There are two lake level controls in upper Penoyer Creek and three dam impoundments in the lower creek that contribute to changes in natural hydrology(MRWA Watershed Inventory 2023[**], MRWA Dam Inventory 2022[****]).
Urban/ residential runoff		Loss of wetlands	There are approximately 1,094 acres of high priority wetlands that have been lost that contribute to changes in natural hydrology (TU 2023[***]).
		Poor stormwater management practices	There are approximately 3,738 acres of urban/residential land that contribute to changes in natural hydrology (EPA PLET 2024[†]).
Groundwater withdrawals		Over extraction from water table	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its impact on hydrologic flow.
Pollutant - Thermal Pollution			
Agricultural runoff	Rivers, streams, and impoundments shall not receive a heat load which would warm the receiving water at the edge of the mixing zone more than 5 degrees Fahrenheit above the existing natural water temperature which ranges from 38 – 83 degrees Fahrenheit for the warmwater fishery. For the coldwater fishery, the heat load should not increase water temperature more than 2 degrees Fahrenheit above the existing natural water temperature which ranges from 38 – 63 degrees Fahrenheit (Trout Unlimited 2023[√]).	Channelization and ditching	There are approximately 12.2 miles of channelized streams and ditches that contribute to the heat load (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
Impoundments		Holding back water to create a pond or lake environment	There are two lake level controls in upper Penoyer Creek and three dam impoundments in the lower creek that contribute to changes in natural hydrology (MRWA Watershed Inventory 2023[**], MRWA Dam Inventory 2022[****]).
Urban/residential runoff		Impervious surfaces	There are approximately 3,738 acres of urban/residential land that contributes to the heat load (EPA PLET 2024[†]).
Loss of streamside vegetation & canopy		Land use change (development and agriculture) and riparian owners	There are approximately 34.3 miles of non-vegetated banks that contribute to the heat load (MRWA Watershed Inventory 2023[**]).
Groundwater withdrawals		Reduction in stream depth and base flow (reduced recharge rates)	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on temperature.
Climate change		Change in frequency and magnitude of high rain events	Broad scale changes are expected to occur over the next few decades leading to an increase in magnitude and frequency of high rain events (Muskegon Futures[†††]).
		Increasing average annual air temperature	Broad scale changes are expected to occur over the next few decades leading to an increase in average annual air temperature (Muskegon Futures[†††]).
Pollutant - Nutrients			
Agricultural Runoff	6,012.46 lbs/yr of TP and 39,207.47 lbs/yr of TN (EPA PLET 2024[†])	Application of agricultural fertilizer	There are approximately 9,890.09 acres of agricultural land that could be using agricultural fertilizer. It is estimated that agricultural fertilizer is a major contributor of the nutrient load (NCD Windshield Survey 2022[*], ACPF 2021-2022[††††]).
		Loss of streamside vegetation	There are approximately 34.3 miles of non-vegetated bank. It is estimated that the loss of bank vegetation is a moderate contributor of the nutrient load (MRWA Watershed Inv. 2023[**]).

Pollutant Loadings in the Bigelow Creek Subwatershed (Continued)

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Nutrients (Continued)			
Agricultural Runoff (continued)	6,012.46 lbs/yr of TP and 39,207.47 lbs/yr of TN (EPA PLET 2024†)	Loss of wetlands	There are approximately 1,094 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the nutrient load (TU 2023[*]).
		Barnyards	There are approximately 9,890.09 acres of agricultural land. It is estimated that barnyards are a major contributor to the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[†]).
		Permanent Pasture	There are approximately 6,344.46 acres of permanent pasture. It is estimated that permanent pastures are a major contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[†]).
		Confined feeding operations	There are 2.74 acres of confined feeding operations that are a major contributer to the nutrient load (MRWA Watershed Inventory 2023[*], EGLE 2024[††]).
Urban/residential runoff	1,902.36 lbs/yr of TP and 12,357.07 lbs/yr of TN (EPA PLET 2024[†])	Application of residential and commercial fertilizers	There are approximately 2,767.92 acres of urban/residential land. It is estimated that residential and commercial fertilizer is a minor contributor of the nutrient load (MRWA Watershed Inventory 2023[*], EPA PLET 2024[††]).
		Poor stormwater management practices	There are approximately 2,767.92 acres of urban/residential land. It is estimated that poor storm water practices are a minor contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[††]).
		Loss of wetlands	There are approximately 1,094 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a minor contributor of the nutrient load (TU 2023[***]).
		Loss of streamside vegetation	There are approximately 34.3 miles of non-vegetated banks. It is estimated that non-vegetated banks are a minor contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[††]).
Groundwater from agricultural and urban land	Suspected cause, additional monitoring is needed to determine load and effect on nutrients.	Application of residential and commercial fertilizers	There are approximately 9,890.09 acres of agricultural land and 2,767.92 acres of urban/residential land where fertilizers could be applied and these are moderate contributors to the nutrient load (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]). Residential fertilizer is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on nutrients.
		Failing septic systems	There are several lakes with high residential development that could be contributing to this load (Newaygo and Muskegon County Health Department). More monitoring will need to be conducted to determine the level of effort needed to address its effect on nutrients.
Animals in stream		Unrestricted animal access	There are 0.3 miles of stream where livestock have access to the stream which is a moderate contributor of the nutrient load (MRWA Watershed Inv. 2023[**]). This is a suspected source and cause, more monitoring will need to be conducted to determine the level of effort needed to address its effect on nutrients.
Pollutant - Sediment			
Agricultural runoff	527.08 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There are approximately 34.3 miles of non-vegetated banks. It is estimated that the loss of bank vegetation is a moderate contributor of the sediment load (MRWA Watershed Inv. 2023[**]).
Agricultural runoff	527.08 lbs/yr (EPA PLET 2024[†])	Loss of wetlands	There are approximately 1,094 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the sediment load (TU 2023[***]).

Pollutant Loadings in the Bigelow Creek Subwatershed (Continued)

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Sediment (Continued)			
Agricultural runoff (Continued)	527.08 lbs/yr (EPA PLET 2024[†])	Tillage practices	There are approximately 9,890.09 acres of agricultural land that could be implementing bad tillage practices. It is estimated that these tillage practices are a moderate contributor of the sediment load (MRWA Watershed Inventory 2023[**], ACPF 2021-2022[††††], EPA PLET 2024[†]).
		Loss of streambank vegetation	There are 2.2 miles of eroding stream bank that are a major contributor of the sediment load (MRWA Watershed Inventory 2023[**]).
Urban/residential runoff	284.53 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There are approximately 34.3 miles of non-vegetated banks. It is estimated that the loss of bank vegetation a moderate contributor of the sediment load (MRWA Watershed Inv. 2023[**]).
		Loss of wetlands	There are approximately 1,094 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the sediment load (TU 2023[*])
		Poor stormwater management practices	There are approximately 3,738 acres of urban/residential land. It is estimated that poor storm water practices are a moderate contributor of the sediment load (EPA PLET 2024[†]). This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on sediment.
Livestock in streams	Suspected cause, additional monitoring is needed to determine load and effect on sediment.	Animal access	There is 1 area (0.34 ac.) where livestock have access to the stream that is a minor contributor to the sediment load (MRWA Watershed Inventory 2023[**]).
Boat traffic/wakes		Unrestricted operation of jet driven watercraft	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on sediment.
Pollutant – *E. coli* and Fecal Coliform			
Agricultural runoff	This becomes a problem if the *E. coli* exceeds water quality standards - total body contact no more than 130 *E. coli* per 100 milliliters, partial body contact no more than 1000 *E. coli* per 100 milliliters. The following sources and causes are suspected. More monitoring will need to be conducted to determine *E. coli* loadings.	Application of manure on fields	There are approximately 9,890.09 acres of agricultural land that could be using manure which is a major contributor to *E. coli* loads (MRWA Watershed Inventory 2023[**], EPA Plet 2024[†]).
		Animals in stream	There are few areas where livestock have access to the stream that could be a moderate contributor to *E. coli* loads (MRWA Watershed Inventory 2023**).
		Barnyards	There are approximately 9,890.09 acres of agricultural land. Some of this agricultural land is used for barnyards which could be contributing to *E. coli* loads (MRWA Watershed Inventory 2023[**], ACPF 2021-2022[††††], EPA PLET 2024[†]).
		Confined feeding operations	There are approximately 2.74 acres of confined feeding operations which are a moderate contributor to *E. coli* loads (MRWA Watershed Inventory 2023[*], EGLE 2024[††])
		Permanent pasture	There are approximately 6,334.46 acres of permanent pasture that are a moderate contributor to *E. coli* loads (MRWA Watershed Inventory 2023[*], EGLE 2024[††]).
Urban/residential runoff		Failing septic systems	There are several property owners in the Lower Muskegon River Watershed with septic systems that could be a major contributor to *E. coli* loads (Newaygo County Health Department). More monitoring will need to be conducted to determine the level of effort needed to address its effect on *E. coli* and fecal coliform.

Pollutant Loadings in the Brooks Creek Subwatershed

Pollutant Loadings in the Brooks Creek Subwatershed

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Hydrologic Flow			
Agricultural runoff	Changes to the volume of water, timing with respect to rainfall, and duration of high flows.	Channelization and ditching	There are approximately 47.1 miles of channelized streams and ditches that contribute to changes in natural hydrology (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
		Loss of wetlands	There are approximately 1,094 acres of high priority wetlands that have been lost that contribute to changes in natural hydrology (TU 2023[***]).
Impoundments (Dams/Lake Level Control)		Disruption of natural flow of water	There are two impoundment and several lake control structures that contribute to changes in natural hydrology (MRWA Watershed Inventory 2023[**], MRWA Dam Inventory 2022[***]).
Urban/residential runoff		Loss of wetlands	There are approximately 3,362 acres of high priority wetlands that have been lost that contribute to changes in natural hydrology (TU 2023[***]).
		Poor stormwater management practices	There are approximately 4,311.8 acres of urban/residential land that contribute to changes in natural hydrology (EPA PLET 2024[†]).
Groundwater withdrawals		Over extraction from water table	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its impact on hydrologic flow.
Pollutant - Thermal Pollution			
Agricultural runoff	Rivers, streams, and impoundments shall not receive a heat load which would warm the receiving water at the edge of the mixing zone more than 5 degrees Fahrenheit above the existing natural water temperature which ranges from 38 – 83 degrees Fahrenheit for the warmwater fishery. For the coldwater fishery, the heat load should not increase water temperature more than 2 degrees Fahrenheit above the existing natural water temperature which ranges from 38 – 63 degrees Fahrenheit (Trout Unlimited 2023[√]).	Channelization and ditching	There are approximately 47.1 miles of channelized streams and ditches that contribute to the heat load (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
Impoundments		Holding back water to create a pond or lake environment	There are two impoundment and several lake control structures that contribute to changes in natural hydrology (MRWA Watershed Inventory 2023[**], MRWA Dam Inventory 2022[****]).
Urban/residential runoff		Impervious surfaces	There are approximately 4,311.8 acres of urban/residential land that contributes to the heat load (EPA PLET 2024[†]).
Loss of streamside vegetation & canopy		Land use change (development and agriculture) and riparian owners	There are approximately 80 miles of non-vegetated banks that contribute to the heat load (MRWA Watershed Inventory 2023[**]).
Groundwater withdrawals		Reduction in stream depth and base flow (reduced recharge rates)	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on temperature.
Climate change		Change in frequency and magnitude of high rain events	Broad scale changes are expected to occur over the next few decades leading to an increase in magnitude and frequency of high rain events (Muskegon Futures[†††]).
		Increasing average annual air temperature	Broad scale changes are expected to occur over the next few decades leading to an increase in average annual air temperature (Muskegon Futures[†††]).
Pollutant - Nutrients			
Agricultural Runoff (Continued)	16,826.42 lbs/yr of TP and 89,791.57 lbs/yr of TN (EPA PLET 2024[†])	Application of agricultural fertilizer	There are approximately 22,269.25 acres of agricultural land that could be using agricultural fertilizer. It is estimated that agricultural fertilizer is a major contributor of the nutrient load (NCD Windshield Survey 2022[*], ACPF 2021-2022[††††]).
		Loss of streamside vegetation	There are approximately 80 miles of non-vegetated bank. It is estimated that the loss of bank vegetation is a moderate contributor of the nutrient load (MRWA Watershed Inv. 2023[**]).
		Loss of wetlands	There are approximately 3,362 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands are a moderate contributor of the nutrient load (TU 2023[*]).

Pollutant Loadings in the Brooks Creek Subwatershed (Continued)

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Nutrients (Continued)			
Agricultural Runoff	16,826.42 lbs/yr of TP and 89,791.57 lbs/yr of TN (EPA PLET 2024[†])	Barnyards	There are approximately 22,269.25 acres of agricultural land. It is estimated that barnyards are a major contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[†]).
		Permanent Pasture	There are approximately 8,698.07 acres of permanent pasture. It is estimated that permanent pastures are a major contributor of the nutrient load (MRWA Watershed Inv. 2023[**], EPA PLET 2024[†]).
		Confined feeding operations	There are 136.30 acres of confined feeding operations that are a major contributor to the nutrient load (MRWA Watershed Inventory 2023[*], EGLE 2024[††]).
Urban/residential runoff	2,847.94 lbs/yr of TP and 18,498.52 lbs/yr of TN (EPA PLET 2024[†])	Application of residential and commercial fertilizers	There are approximately 4,316.68 acres of urban/residential land. It is estimated that residential and commercial fertilizer is a minor contributor of the nutrient load (MRWA Watershed Inventory 2023[*], EPA PLET 2024[††]).
		Poor stormwater management practices	There are approximately 4,312.68 acres of urban/residential land. It is estimated that poor storm water practices are a minor contributor of the nutrient load (MRWA Watershed Inventory 2023[*], EPA PLET 2024[††]).
		Loss of wetlands	There are approximately 3,362 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the nutrient load (TU 2023[***]).
		Loss of streamside vegetation	There are approximately 80 miles of non-vegetated banks. It is estimated that non-vegetated banks are a moderate contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[††]).
Pollutant – Nutrients (continued)			
Groundwater from agricultural and urban land	Suspected cause, additional monitoring is needed to determine load and effect on nutrients.	Application of residential and commercial fertilizers	There are approximately 22,269.25 acres of agricultural land and 4,312.68 acres of urban/residential land where fertilizers could be applied which are a major contributor to the nutrient load (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]). Residential fertilizer is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on nutrients.
		Failing septic systems	There are several lakes with high residential development that could be contributing to this load (Newaygo and Muskegon County Health Department). More monitoring will need to be conducted to determine the level of effort needed to address its effect on nutrients.
Animals in stream		Unrestricted animal access	There is 3 area where livestock have access to the stream which is a contributor to the nutrient load (MRWA Watershed Inventory 2023[**]). This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on nutrients.
Pollutant - Sediment			
Agricultural runoff	1,627.21 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There are approximately 80 miles of non-vegetated banks. It is estimated that the loss of bank vegetation is a moderate contributor of the sediment load (MRWA Watershed Inv. 2023[**]).
		Loss of wetlands	There are approximately 3,362 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the sediment load (TU 2023[***]).

Pollutant Loadings in the Brooks Creek Subwatershed (Continued)

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Sediment (Continued)			
Agricultural runoff (Continued)	1,627.21 lbs/yr (EPA PLET 2024[†])	Tillage practices	There are approximately 22,269.25 acres of agricultural land that could be implementing bad tillage practices. It is estimated that these tillage practices are a moderate contributor of the sediment load (MRWA Watershed Inventory 2023[**], ACPF 2021-2022[†††], EPA PLET 2024[†]).
		Loss of streambank vegetation	There is 1 mile of eroding stream bank that is a major contributor to the sediment load (MRWA Watershed Inventory 2023[**]).
Urban/residential runoff	425.99 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There are approximately 80 miles of non-vegetated banks. It is estimated that the loss of bank vegetation is a moderate contributor of the sediment load (MRWA Watershed Inv. 2023[**]).
		Loss of wetlands	There are approximately 3,362 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the sediment load (TU 2023[***]).
		Poor stormwater management practices	There are approximately 4,312.68 acres of urban/residential land. It is estimated that poor storm water practices are a moderate contributor of the sediment load (EPA PLET 2024[†]). This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on sediment.
Livestock in streams	Suspected cause, additional monitoring is needed to determine load and effect on sediment.	Animal access	There is 0.33 area where livestock have access to the stream that is a minor contributor to the sediment load (MRWA Watershed Invetory 2023[**]).
Boat traffic/wakes		Unrestricted operation of jet driven watercraft	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on sediment.
Pollutant – *E. coli* and Fecal Coliform			
Agricultural runoff	This becomes a problem if the *E. coli* exceeds water quality standards - total body contact no more than 130 *E. coli* per 100 milliliters, partial body contact no more than 1000 *E. coli* per 100 milliliters. The following sources and causes are suspected. More monitoring will need to be conducted to determine *E. coli* loadings.	Application of manure on fields	There are approximately 22,269.25 acres of agricultural land that could be using manure which is a major contributor to *E. coli* loads (MRWA Watershed Inventory 2023[**], EPA Plet 2024[†]).
		Animals in stream	There is 0.33 acres where livestock have access to the stream that could be a moderate contributor to *E. coli* loads (MRWA Watershed Inventory 2023**).
		Barnyards	There are approximately 22,269.25 acres of agricultural land. Some of this agricultural land is used for barnyards which could be contributing to *E. coli* loads (MRWA Watershed Inventory 2023[**], ACPF 2021-2022[†††], EPA PLET 2024[†]).
		Confined feeding operations	There are 136.30 acres of confined feeding operations that area a moderate contributor to the *E. coli* loads (MRWA Watershed Inventory 2023[*], EGLE 2024[††]).
		Permanent pasture	There are approximately 8,698.07 acres of permanent pasture that are a moderate contributor to *E. coli* loads (MRWA Watershed Inventory 2023[**] and EPA PLET 2024[†]).
Urban/residential runoff		Failing septic systems	There are several property owners in the Lower Muskegon River Watershed with septic systems that could be a major contributor to *E. coli* loads (Newaygo and Muskegon County Health Department). More monitoring will need to be conducted to determine the level of effort needed to address its effect on E. Coli and fecal coliform.

Pollutant Loadings in the Hess Lake Subwatershed

Pollutant Loadings in the Hess Lake Subwatershed

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Hydrologic Flow			
Agricultural runoff	Changes to the volume of water, timing with respect to rainfall, and duration of high flows.	Channelization and ditching	There are approximately 46.3 miles of channelized streams and ditches that contribute to changes in natural hydrology (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
		Loss of wetlands	There are approximately 5,226 acres of high priority wetlands that have been lost that contribute to changes in natural hydrology (TU 2023[***]).
Impoundments (Dams/Lake Level Control)		Disruption of natural flow of water	There are two lake level control structures on Wheeler Drain and two Brooks Creek dams (Barton Street and lower mill dam) impound and contribute to changes in natural hydrology (MRWA Watershed Inventory 2023[**], MRWA Dam Inventory 2022[****]).
Urban/residential runoff		Loss of wetlands	There are approximately 5,226 acres of high priority wetlands that have been lost that contribute to changes in natural hydrology (TU 2023[***]).
		Poor stormwater management practices	There are approximately 3,901.7 acres of urban/residential land that contribute to changes in natural hydrology (EPA PLET 2024[†]).
Groundwater withdrawals		Over extraction from water table	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its impact on hydrologic flow.
Pollutant - Thermal Pollution			
Agricultural runoff	Rivers, streams, and impoundments shall not receive a heat load which would warm the receiving water at the edge of the mixing zone more than 5 degrees Fahrenheit above the existing natural water temperature which ranges from 38 – 83 degrees Fahrenheit for the warmwater fishery. For the coldwater fishery, the heat load should not increase water temperature more than 2 degrees Fahrenheit above the existing natural water temperature which ranges from 38 – 63 degrees Fahrenheit (Trout Unlimited 2023[√]).	Channelization and ditching	There are approximately 46.3 miles of channelized streams and ditches that contribute to the heat load (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
Impoundments		Holding back water to create a pond or lake environment	Two lake level control structures on Wheeler Drain and two Brooks Creek dams (Barton Street and lower mill dam) impound and contribute to changes in natural hydrology (MRWA Watershed Inventory 2023[**], MRWA Dam Inventory 2022[****]).
Urban/residential runoff		Impervious surfaces	There are approximately 3,901.7 acres of urban/residential land that contributes to the heat load (EPA PLET 2024[†]).
Loss of streamside vegetation & canopy		Land use change (development and agriculture) and riparian owners	There are approximately 83.5 miles of non-vegetated banks that contribute to the heat load (MRWA Watershed Inventory 2023[**]).
Groundwater withdrawals		Reduction in stream depth and base flow (reduced recharge rates)	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on temperature.
Climate change		Change in frequency and magnitude of high rain events	Broad scale changes are expected to occur over the next few decades leading to an increase in magnitude and frequency of high rain events (Muskegon Futures[†††]).
		Increasing average annual air temperature	Broad scale changes are expected to occur over the next few decades leading to an increase in average annual air temperature (Muskegon Futures[†††]).
Pollutant - Nutrients			
Agricultural Runoff	14,281.21 lbs/yr of TP and 74,382.81 lbs/yr of TN (EPA PLET 2024[†])	Application of agricultural fertilizer	There are approximately 17,557.61 acres of agricultural land that could be using agricultural fertilizer. It is estimated that agricultural fertilizer is a major contributor of the nutrient load (NCD Windshield Survey 2022[*], ACPF 2021-2022[††††]).
		Loss of streamside vegetation	There are approximately 83.5 miles of non-vegetated bank. It is estimated that the loss of bank vegetation is a moderate contributor of the nutrient load (MRWA Watershed Inventory 2023[**]).

Pollutant Loadings in the Hess Lake Subwatershed (Continued)

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Nutrients (Continued)			
Agricultural Runoff (Continued)	14,281.21 lbs/yr of TP and 74,382.81 lbs/yr of TN (EPA PLET 2024[†])	Loss of wetlands	There are approximately 5,226 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the nutrient load (TU 2023[*]).
		Barnyards	There are approximately 17,557.61 acres of agricultural land. It is estimated that barnyards are a major contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[†]).
		Permanent Pasture	There are approximately 6,388.73 acres of permanent pasture. It is estimated that permanent pastures are a major contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[†]).
		Confined feeding operations	There are approximately 79.57 acres of confined feeding operations that are a major contributor of the nutrient loads (MRWA Watershed Inventory 2023[*], EGLE 2024[††]).
Urban/residential runoff	2,886.31 lbs/yr of TP and 18,748.03 lbs/yr of TN (EPA PLET 2024[†])	Application of residential and commercial fertilizers	There are approximately 4,231.95 acres of urban/residential land. It is estimated that residential and commercial fertilizer is a major contributor of the nutrient load (MRWA Watershed Inventory 2023[*], EPA PLET 2024[††]).
		Poor stormwater management practices	There are approximately 4,231.95 acres of urban/residential land. It is estimated that poor storm water practices are a major contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[††]).
		Loss of wetlands	There are approximately 5,226 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the nutrient load (TU 2023[***]).
		Loss of streamside vegetation	There are approximately 9.2 miles of non- vegetated banks. It is estimated that non-vegetated banks are a moderate contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[††]).
Groundwater from agricultural and urban land	Suspected cause, additional monitoring is needed to determine load and effect on nutrients.	Application of residential and commercial fertilizers	There are approximately 17,557.61 acres of agricultural land and 4,231.95 acres of urban/residential land where fertilizers could be applied and are major contributors to the nutrient load (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
		Failing septic systems	There are several lakes with high residential development that could be contributing to this load (Newaygo and Muskegon County Health Department). More monitoring will need to be conducted to determine the level of effort needed to address its effect on nutrients.
Animals in stream		Unrestricted animal access	There is 0.04 area where livestock have access to the stream which is a moderate contributor to the nutrient load (MRWA Watershed Inventory 2023[**]). This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on nutrients.
Pollutant - Sediment			
Agricultural runoff	1,510.66 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There are approximately 83.5 miles of non-vegetated banks. It is estimated that the loss of bank vegetation is a moderate contributor to the sediment load (MRWA Watershed Inventory 2023[**]).
		Loss of wetlands	There are approximately 5,226 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the sediment load (TU 2023[***]).

Pollutant Loadings in the Hess Lake Subwatershed (Continued)

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Sediment			
Agricultural runoff (Continued)	1,510.66 lbs/yr (EPA PLET 2024[†])	Tillage practices	There are approximately 17,557.61acres of agricultural land that could be implementing bad tillage practices. It is estimated that these tillage practices are a moderate contributor of the sediment load (MRWA Watershed Inventory 2023[**], ACPF 2021-2022[†††], EPA PLET 2024[†]).
Stream banks	1,516.84 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There is 1.9 miles eroding stream bank that is a major contributor to the sediment load (MRWA Watershed Inventory 2023[**]).
Urban/residential runoff	284.53 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There are approximately 83.5 miles of non-vegetated banks. It is estimated that the loss of bank vegetation is a moderate contributor of the sediment load (MRWA Watershed Inventory 2023[**]).
		Loss of wetlands	There are approximately 5,226 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the sediment load (TU 2023[*]).
		Poor stormwater management practices	There are approximately 4,231.95 acres of urban/residential land. It is estimated that poor storm water practices are a moderate contributor of the sediment load (EPA PLET 2024[†]). This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on sediment.
Livestock in streams	Suspected cause, additional monitoring is needed to determine load and effect on sediment.	Animal access	There is 0.04 area where livestock have access to the stream that is a minor contributor the sediment load (MRWA Watershed Inventory 2023[**]).
Boat traffic/wakes		Unrestricted operation of jet driven watercraft	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on sediment.
Pollutant – E. coli and Fecal coliform			
Agricultural runoff	This becomes a problem if the *E. coli* exceeds water quality standards - total body contact no more than 130 *E. coli* per 100 milliliters, partial body contact no more than 1000 *E. coli* per 100 milliliters. The following sources and causes are suspected. More monitoring will need to be conducted to determine *E. coli* loadings.	Application of manure on fields	There are approximately 17,557.61 acres of agricultural land that could be using manure which is a major contributor to *E. coli* loads (MRWA Watershed Inventory 2023[**], EPA Plet 2024[†]).
		Animals in stream	There is 1 area where livestock have access to the stream that could be a moderate contributor to the *E. coli* loads (MRWA Watershed Inventory 2023[**]).
		Barnyards	There are approximately 17,557.61 acres of agricultural land. Some of this agricultural land is used for barnyards which could be contributing to *E. coli* loads (MRWA Watershed Inventory 2023**, ACPF 2021-2022[†††], EPA PLET 2024[†]).
		Confined feeding operations	There are approximately 79.57 acres of confined feeding operations that are a moderate contributor to the *E. coli* loads (MRWA Watershed Inventory 2023[*], EGLE 2024[††]).
		Permanent pasture	There are approximately 6,388.73 acres of permanent pasture that are a moderate contributor to *E. coli* loads (MRWA Watershed Inventory 2023[**], EPA PLET 2024[†]).
Urban/residential runoff		Failing septic systems	There are several property owners in the Lower Muskegon River Watershed with septic systems that could be a major contributor to *E. coli* loads (Newaygo County Health Department). More monitoring will need to be conducted to determine the level of effort needed to address its effect on *E. coli* and fecal coliform.

Pollutant Loadings in the Mosquito Creek Subwatershed

Pollutant Loadings in the Mosquito Creek Subwatershed

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Hydrologic Flow			
Agricultural runoff	Changes to the volume of water, timing with respect to rainfall, and duration of high flows.	Channelization and ditching	There are approximately 25.8 miles of channelized streams and ditches that contribute to changes in natural hydrology (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
		Loss of wetlands	There are approximately 6,600 acres of high priority wetlands that have been lost that contribute to changes in natural hydrology (TU 2023[***]).
Impoundments (Dams/Lake Level Control)		Disruption of natural flow of water	The dammed Maple River channel contributes to changes in natural hydrology (MRWA Watershed Inventory 2023[**], MRWA Dam Inventory 2022[****]).
Urban/residential runoff		Loss of wetlands	There are approximately 6,600 acres of high priority wetlands that have been lost that contribute to changes in natural hydrology (TU 2023[***]).
		Poor stormwater management practices	There are approximately 3,528 acres of urban/residential land that contribute to changes in natural hydrology (EPA PLET 2024[†]).
Groundwater withdrawals		Over extraction from water table	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its impact on hydrologic flow.
Pollutant - Thermal Pollution			
Agricultural runoff	Rivers, streams, and impoundments shall not receive a heat load which would warm the receiving water at the edge of the mixing zone more than 5 degrees Fahrenheit above the existing natural water temperature which ranges from 38 – 83 degrees Fahrenheit for the warmwater fishery. For the coldwater fishery, the heat load should not increase water temperature more than 2 degrees Fahrenheit above the existing natural water temperature which ranges from 38 – 63 degrees Fahrenheit (Trout Unlimited 2023[√]).	Channelization and ditching	There are approximately 25.8 miles of channelized streams and ditches that contribute to the heat load (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
Impoundments		Holding back water to create a pond or lake environment	The dammed Maple River channel contributes to changes in natural hydrology (MRWA Watershed Inventory 2023[**], MRWA Dam Inventory 2022[****]).
Urban/residential runoff		Impervious surfaces	There are approximately 3,528 acres of urban/residential land that contributes to the heat load (EPA PLET 2024[†]).
Loss of streamside vegetation & canopy		Land use change (development and agriculture) and riparian owners	There are approximately 36.2 miles of non-vegetated banks that contribute to the heat load (MRWA Watershed Inventory 2023[**]).
Groundwater withdrawals		Reduction in stream depth and base flow (reduced recharge rates)	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on temperature.
Climate change		Change in frequency and magnitude of high rain events	Broad scale changes are expected to occur over the next few decades leading to an increase in magnitude and frequency of high rain events (Muskegon Futures[†††]).
		Increasing average annual air temperature	Broad scale changes are expected to occur over the next few decades leading to an increase in average annual air temperature (Muskegon Futures[†††]).
Pollutant - Nutrients			
Agricultural Runoff	7,477.46 lbs/yr of TP and 45,082.11 lbs/yr of TN (EPA PLET 2024[†])	Application of agricultural fertilizer	There are approximately 8,004.42 acres of agricultural land that could be using agricultural fertilizer. It is estimated that agricultural fertilizer is a major contributor of the nutrient load (NCD Windshield Survey 2022[*], ACPF 2021-2022[††††]).
		Loss of streamside vegetation	There are approximately 36.2 miles of non- vegetated bank. It is estimated that the loss of bank vegetation is a moderate contributor of the nutrient load (MRWA Watershed Inv. 2023[**]).
		Loss of wetlands	There are approximately 6,600 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the nutrient load (TU 2023[*]).

Pollutant Loadings in the Mosquito Creek Subwatershed (Continued)

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Nutrients (Continued)			
Agricultural runoff	7,477.46 lbs/yr of TP and 45,082.11 lbs/yr of TN (EPA PLET 2024[†])	Barnyards	There are approximately 8,004.42 acres of agricultural land. It is estimated that barnyards are a major contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[†]).
		Permanent Pasture	There are approximately 4,127.19 acres of permanent pasture. It is estimated that permanent pastures are a major contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[†]).
		Confined feeding operations	There are 1.18 acres of confined feeding operations that are a major contributor to the nutrient load (MRWA Watershed Inventory 2023[*], EGLE 2024[††]).
Urban/residential runoff	1,511.43 lbs/yr of TP and 9,799.53 lbs/yr of TN (EPA PLET 2024[†])	Application of residential and commercial fertilizers	There are approximately 1,895.92 acres of urban/residential land. It is estimated that residential and commercial fertilizer is a minor contributor of the nutrient load (MRWA Watershed Inventory 2023[*], EPA PLET 2024[††]).
		Poor stormwater management practices	There are approximately 1,895.92 acres of urban/residential land. It is estimated that poor storm water practices are a minor contributor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[††]).
		Loss of wetlands	There are approximately 6,600 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a minor contributor of the nutrient load (TU 2023***).
		Loss of streamside vegetation	There are approximately 36.2 miles of non-vegetated banks. It is estimated that non-vegetated banks are a minor contirbutor of the nutrient load (MRWA Watershed Inventory 2023[**], EPA PLET 2024[††]).
Groundwater from agricultural and urban land	Suspected cause, additional monitoring is needed to determine load and effect on nutrients.	Application of residential and commercial fertilizers	There are approximately 8,004.42 acres of agricultural land and 1,895.92 acres of urban/residential land where fertilizers could be applied which are a major contributor to the nutrient load (NCD Windshield Survey 2022[*], MRWA Watershed Inventory 2023[**]).
		Failing septic systems	There are several lakes with high residential development that could be contributing to this load (Newaygo and Muskegon County Health Department). More monitoring will need to be conducted to determine the level of effort needed to address its effect on nutrients.
Animals in stream		Unrestricted animal access	There is 0 area where livestock have access to the stream (MRWA Watershed Inventory 2023[**]).
Pollutant - Sediment			
Agricultural runoff	609.53 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There are approximately 36.2 miles of non-vegetated banks. It is estimated that the loss of bank vegetation is moderate contributor of the sediment load (MRWA Watershed Inventory 2023[**])
		Loss of wetlands	There are approximately 8,004.42 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the sediment load (TU 2023[***]).
		Tillage practices	There are approximately 8,004.42 acres of agricultural land that could be implementing bad tillage practices. It is estimated that these tillage practices are a moderate contributor of the sediment load (MRWA Watershed Inventory 2023[**], ACPF 2021-2022[††††], EPA PLET 2024[†]).
Stream banks	502.70 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There is 2.5 miles of eroding stream bank that are a major contributor to the sediment load (MRWA Watershed Inventory 2023[**]).

Pollutant Loadings in the Mosquito Creek Subwatershed (Continued)

Source	Load from Source	Causes	Quantification of Causes
Pollutant - Sediment (Continued)			
Urban/residential runoff	225.23 lbs/yr (EPA PLET 2024[†])	Loss of streambank vegetation	There are approximately 36.2 miles of non- vegetated banks. It is estimated that the loss of bank vegetation is a moderate contributor of the sediment load (MRWA Watershed Inv. 2023[**]).
		Loss of wetlands	There are approximately 6,600 acres of high priority wetlands that have been lost. It is estimated that the loss of wetlands is a moderate contributor of the sediment load (TU 2023*).
		Poor stormwater management practices	There are approximately 1,895.92 acres of urban/residential land. It is estimated that poor storm water practices are a moderate contributor of the load (EPA PLET 2024[†]). This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on sediment.
Livestock in streams	Suspected cause, additional monitoring is needed to determine load and effect on sediment.	Animal access	There is 0 area where livestock have access to the stream that is contributing to this sediment load (MRWA Watershed Inventory 2023[**]).
Boat traffic/wakes		Unrestricted operation of jet driven watercraft	This is a suspected source and cause, therefore more monitoring will need to be conducted to determine the level of effort needed to address its effect on sediment.
Pollutant – *E. coli* and Fecal Coliform			
Agricultural runoff	This becomes a problem if the *E. coli* exceeds water quality standards - total body contact no more than 130 *E. coli* per 100 milliliters, partial body contact no more than 1000 *E. coli* per 100 milliliters. The following sources and causes are suspected. More monitoring will need to be conducted to determine *E. coli* loadings.	Application of manure on fields	There are approximately 8,004.42 acres of agricultural land that could be using manure which is a major contributor to *E. coli* loads (MRWA Watershed Inventory 2023[**], EPA Plet 2024[†]).
		Animals in stream	There is 0 area where livestock have access to the stream that could be contributing to *E. coli* loads (MRWA Watershed Inventory 2023[**]).
		Barnyards	There are approximately 8,004.42 acres of agricultural land. Some of this agricultural land is used for barnyards which could be contributing to *E. coli* loads (MRWA Watershed Inventory 2023[**], ACPF 2021-2022[†††], EPA PLET 2024[†]).
		Confined feeding operations	There are 1.18 acres of confined feeding operations that are a moderate contributor to the *E. coli* loads (MRWA Watershed Inventory 2023[*], EGLE 2024[††]).
		Permanent pasture	There are approximately 4,127.19 acres of permanent pasture that are a moderate cotnributor to *E. coli* loads (MRWA Watershed Inventory 2023[**] and EPA PLET 2024[†]).
Urban/residential runoff		Failing septic systems	There are several property owners in the Lower Muskegon River Watershed with septic systems that could be a major contributor to *E. coli* loads (Newaygo and Muskegon County Health Department). More monitoring will need to be conducted to determine the level of effort needed to address its effect on E. Coli and Fecal Coliform.

Appendix D. Summary of Monitoring Data Collected for the Update of the Lower Muskegon River Watershed Management Plan

Contents

Appendix D1: Temperature Monitoring in the Lower Muskegon River Watershed

Prepared in 2023 by: Trout Unlimited

Why measure temperature?

Temperature is a critical water quality and environmental parameter because it governs the kinds and types of aquatic life, regulates the maximum dissolved oxygen concentration of the water, and influences the rate of chemical and biological reactions.

The organisms within the ecosystem have preferred temperature regimes that change as a function of season, organism age or life stage, and other environmental factors. With respect to chemical and biological reactions, the higher the water temperature the higher the rate of chemical and metabolic reactions and the lower the amount of dissolved gases it can contain. As water temperature increases, its ability to hold dissolved oxygen decreases, thereby reducing the amount of oxygen in the water available to fish and other aquatic life. When thermal stress occurs, fish cannot efficiently meet energetic demands.

Monitoring and Data Collection

To monitor temperature in the Lower Muskegon River watershed, Trout Unlimited deployed 16 HOBO temperature loggers between June 2022 – October 2022 (Figure 1). Unfortunately, three loggers were lost (P1, P6, and P9) so data was not collected at these sites. The following parameters were reported using the temperature data collected:

- Daily measures – Maximum, Mean, Median
- Monthly measures – Maximum, Mean, Median
- Yearly measures - Maximum, Mean, Median, Warmest 7-day average
- For MI DNR stream classifications July mean water temperature will be used.
    - Cold: July mean water temperature ≤63.5° F (17.5°C)
    - Cold-transitional: July mean water temperature >63.5° F (17.5°C) and ≤67° F (19.5°C)
    - Cool (or warm transitional): July mean water temperature >67° F (19.5°C) and≤70° F (21°C)

A summary of the temperature data (Figure 2) shows the mainstem of the Muskegon River near Croton Dam had a July mean temperature of 70 degrees Fahrenheit. Penoyer Creek had the coldest July mean temperature at the lowest site (P13) at 59.56 degrees Fahrenheit. The highest recorded July mean temperature was also Pennoyer Creek in the upper section (P14 - 73.21 degrees Fahrenheit). These temperatures are supported by taking a closer look at Penoyer Creek. The headwaters start from the warm outflow of Pickerel and Emerald Lakes. As the stream moves downstream it accrues groundwater and cools quickly.

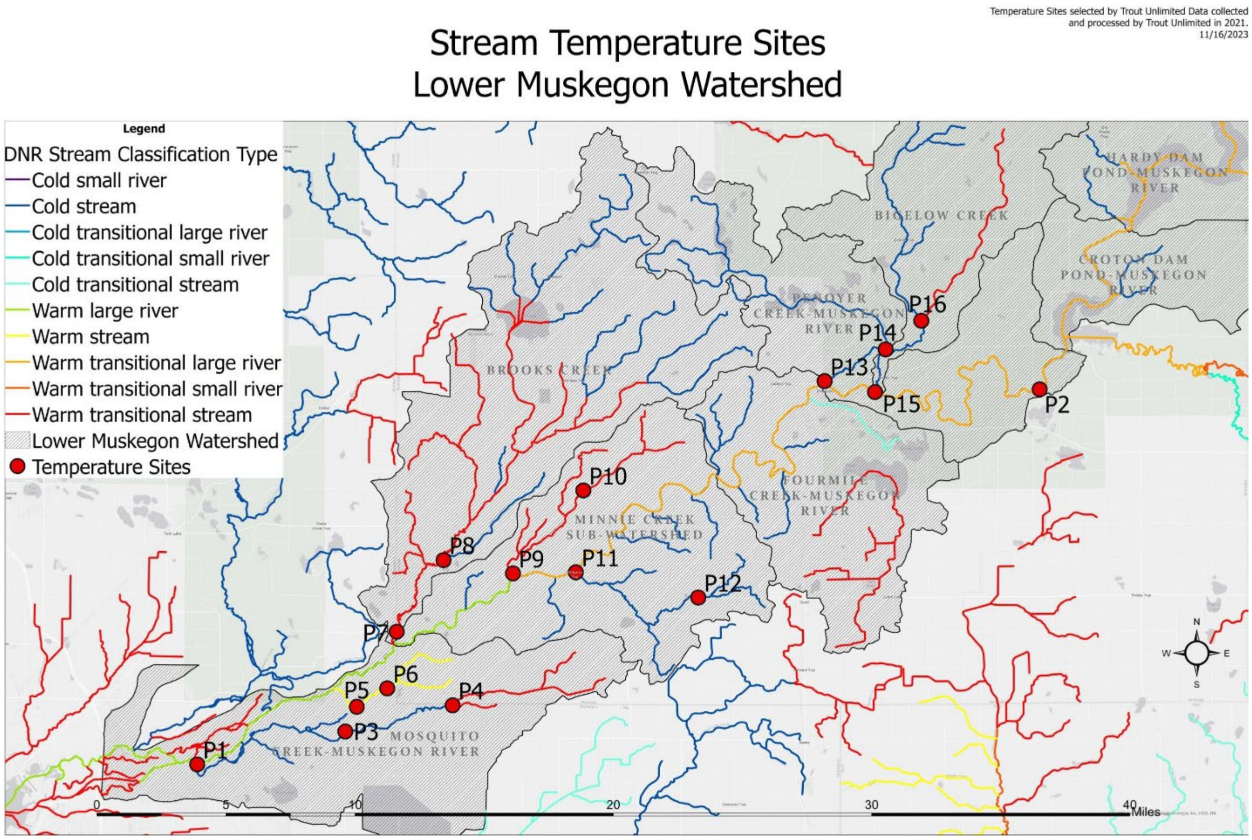


Figure 1. Stream temperature logger locations in the Lower Muskegon River watershed.

P2	Upper Muskegon	Mean	Median	Max	Min	MI DNR Classification
	Annual	69.07814896	70.0935	76.375	60.7	
	June	66.42291444	66.87835417	73.472	60.775	
	July	70.73682392	70.55770833	76.114	66.214	Cool or warm transitional
	August	72.05787903	71.99925	76.375	69.343	
	September	69.29239722	68.10995833	74.943	61.977	
	October	62.00241137	63.46479167	69.728	NA	
P3	Lower Mosquito Creek	Mean	Median	Max	Min	MI DNR Classification
	Annual	62.88226956	62.919	79.435	37.513	
	June	65.09234991	65.40821212	79.435	53.82	
	July	65.83305242	65.295	78.121	55.733	Cold-transitional
	August	63.89312903	63.89495833	75.942	55.256	
	September	59.06638472	60.2776875	69.814	46.571	
	October	58.0193064	57.43220833	70.974	37.513	
P4	Upper Mosquito Creek	Mean	Median	Max	Min	MI DNR Classification
	Annual	59.93400619	60.368	71.533	37.751	
	June	60.4155151	59.65804167	71.533	52.509	
	July	60.78226478	60.56404167	67.028	54.037	Cold
	August	61.32279435	61.34245833	68.185	54.604	
	September	58.10690694	59.29833333	65.359	47.557	
	October	57.86062542	57.25716667	68.142	37.751	
P5	Lower Maple	Mean	Median	Max	Min	MI DNR Classification
	Annual	66.70046186	67.114	86.029	37.225	
	June	68.86526998	69.04245833	86.029	54.995	
	July	70.53353898	69.713125	81.997	61.977	Cool or warm tranitional
	August	68.53968952	68.28479167	79.963	59.272	
	September	62.61884028	64.34772917	73.429	48.272	
	October	58.28223232	57.35008333	70.286	37.225	
P7	Lower Brooks Creek	Mean	Median	Max	Min	MI DNR Classification
	Annual	65.00458801	65.916	73.731	37.702	
	June	65.60713854	65.5701875	73.731	55.863	
	July	67.56352823	67.191125	73.17	62.019	Cool
	August	66.83302688	66.97908333	73.688	58.541	
	September	62.59344306	63.44939583	70.416	51.633	
	October	58.71697306	57.63920833	68.142	37.702	
P8	Upper Brooks Creek	Mean	Median	Max	Min	MI DNR Classification
	Annual	64.69039414	65.145	75.942	36.842	
	June	64.87725933	65.27229167	74.899	54.516	
	July	67.00110081	66.98320833	75.16	58.541	Cold-transitional
	August	66.55648522	66.49329167	75.942	58.582	
	September	62.63037639	63.36045833	68.742	52.466	
	October	58.90601338	57.19870833	68.828	36.842	
P10	Upper Minnie Creek	Mean	Median	Max	Min	MI DNR Classification
	Annual	64.17462386	64.674	88.351	37.13	
	June	65.39346892	65.84577083	88.351	55.081	
	July	67.04234274	66.508125	74.899	57.463	Cold-transitional
	August	65.93109005	65.76291667	75.942	57.807	
	September	60.89207778	62.30879167	69.643	49.116	
	October	58.23802357	57.051375	69.213	37.13	
P11	Lower Sand Creek	Mean	Median	Max	Min	MI DNR Classification
	Annual	62.22135952	62.748	86.617	37.609	
	June	62.73734991	63.38572917	86.617	53.602	
	July	64.9528629	65.00066667	81.909	53.776	Cold-transitional
	August	64.39106183	64.93804167	81.819	51.589	
	September	58.66995972	60.29695833	71.964	44.674	
	October	57.57492256	57.22729167	68.999	37.609	
P12	Upper Sand Creek	Mean	Median	Max	Min	
	Annual	63.65150782	64.204	87.528	44.946	
	June	64.831254	65.23083333	87.528	55.256	
	July	66.32397984	65.658625	73.342	57.549	Cold-transitional
	August	65.53383602	65.435875	74.943	57.506	
	September	60.40142639	61.96329167	69.386	47.914	
	October	57.88413468	55.12120833	68.056	44.946	
P13	Lower Penoyer	Mean	Median	Max	Min	
	Annual	59.82203485	59.916	72.912	37.13	
	June	60.1381048	59.81527083	72.912	50.047	
	July	59.56017876	58.71175	70.029	50.047	Cold
	August	61.3559543	60.69679167	72.523	54.343	
	September	58.99946111	60.09925	69.427	48.049	
	October	58.04240468	58.44016667	68.698	37.13	
P14	Upper Penoyer	Mean	Median	Max	Min	MI DNR Classification
	Annual	70.70799804	72.093	82.263	37.225	
	June	71.69201421	72.04929167	81.687	59.788	
	July	73.21174462	73.82420833	81.554	60.733	Cool
	August	74.1389879	73.755625	82.263	66.643	
	September	68.16183056	69.88729167	77.727	54.169	
	October	60.18382215	60.96141667	67.714	37.225	
P15	Lower Bigelow Creek	Mean	Median	Max	Min	MI DNR Classification
	Annual	61.53904824	62.362	70.459	37.179	
	June	62.36247425	62.63891667	70.459	54.43	
	July	64.03208737	64.110375	70.158	58.109	Cold-transitional
	August	62.9245	62.83066667	69.085	56.728	
	September	58.5464625	59.65110417	65.916	48.805	
	October	57.51708081	57.22695833	68.698	37.179	
P16	Upper Bigelow Creek					MI DNR Classification
	Annual	64.13284485	64.418	77.684	37.13	
	June	65.58906217	66.02322917	77.072	55.038	
	July	67.35079301	67.35125	77.684	58.712	Cold-transitional
	August	65.69208065	65.45375	75.594	57.636	
	September	60.586275	61.55791667	70.803	48.895	
	October	58.00306397	57.51029167	67.586	37.13	

Figure 2. Summary of temperature data collected in the Lower Muskegon River watershed.

Appendix D2. Preliminary Water Quality Assessment of the Lower Muskegon River Watershed

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Purpose

To update the Muskegon River Watershed Management Plan for the lower watershed, water quality sampling was completed to assess TP-P (total phosphorous), TSS (Total Suspended Solids), E coli and discharge. The water quality sampling sites were at select locations in the Lower Muskegon River watershed, including the mainstem and the six largest tributaries (Figure 1). The sites were selected to estimate nonpoint source pollutant loads for the areas of largest potential inputs for solids and nutrients for each subwatershed. The tributaries selected for sampling included the Maple River, Mosquito Creek, Brooks Creek, Minnie Creek and Sand Creek (Hess Lake subbasin) and Penoyer Creek (Penoyer Creek and Bigelow Creek subbasins). The Muskegon River and each tributary had a downstream site and an upstream site. Sampling for TP-P, TSS and E. coli began in November 2021 and continued through September 2022. The analyses were completed to identify key issues and areas of concern where Best Management Practices should be focused to reduce inputs of nonpoint source pollution.

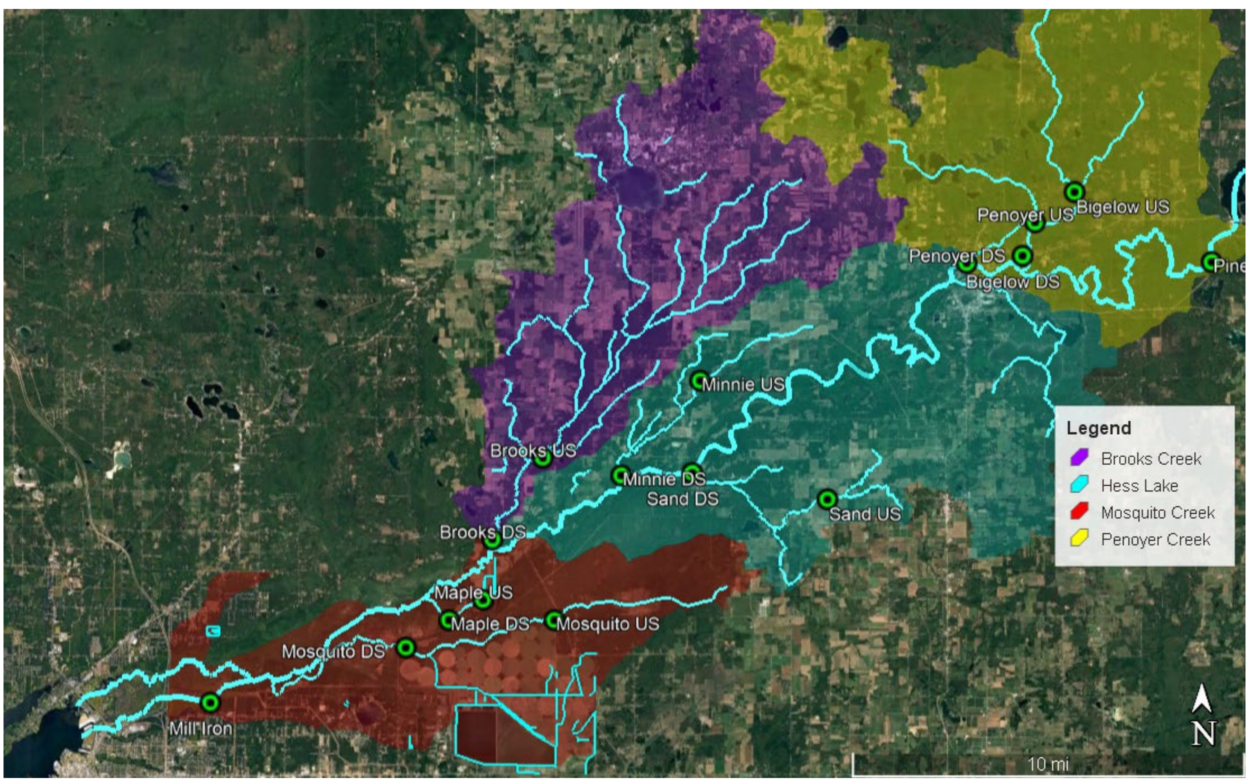


Figure 1. Location of water quality sample sites in the lower portion of Lower Muskegon River Watershed. DS=downstream study reach; US=upstream study reach.

The original monitoring plan included provisions to sample each site at least six times. However, various events prevented a complete sampling record for a few sites identified below. The events included road reconstruction, limited stream access due to high water levels, and a lab refrigerator failure. Samples for E. coli estimates were collected twice during the sampling period. Discharge was also measured except during extreme flow conditions, when it was deemed hazardous for wading.

Loading estimates were calculated for each stream; although, the estimates were not calculated each sample date due to unwadeable conditions (very high flows or soft sediments). We were not able to estimate total loads at the downstream Muskegon River site for any dates due to water depth. However, a total load for the upstream Muskegon River site was calculated using data gathered from the USGS guage at Croton Dam. A summary of minimum and maximim values, along with load estimates, for TP-P and TSS total suspended solids can be found in Table 1 (page 10).

Both of the E. coli analyses were conducted during 2022, once in June and once in September. We did not attempt to time an E. coli sample event with a rain event because most of the tributaries sampled are flashy and the probability of anyone swimming during a rain event seemed low. Consequently, we concentrated the sampling and analyses on times when individuals, particularly children, would likely be in the water. For this report, E. coli is reported in colony forming units (cfu) per 100 ml of culture. A geometric mean of three samples was calculated to compare with the water quality standard. A summary of E. coli measurements can be found in Table 2 (Page 10).

The EGLE water quality standard for E. coli, TP-P and TSS are included below to be used as a reference point against each section of river tested:

E. coli:
Total Body Contact (May 1 - October 31): Daily Maximum Geometric Mean: 300 E. coli per 100 milliliters.
Partial Body Contact (All year): Daily Maximum Geometric Mean: 1,000 E. coli per 100 ml.

Total Phosphorous: To achieve ≤0.03125 mg/l.

Total Suspended Solid: ≤80 mg/l (in-stream TSS concentration for wet weather runoff events).

Summary of Findings by Subwatershed

Bigelow Creek Subwatershed

Bigelow Creek is located within the Bigelow Creek subwatershed and the most upstream tributary tested. The upstream sample site was located at the 58th Street road-stream crossing, and the downstream sample site was just upstream of the confluence with the Muskegon River. TP-P measurements ranged from 0.007 mg/L in November to 0.027 mg/L in May. TSS measurements ranged from 2.25 mg/L in November to 14.25 mg/L in May. The load estimate for TP ranged from 252.8 mg TP/h to 48,217 mg TP/h. The load estimate for TSS ranged from 67,693.6 mg TSS/h in September to 1,053,172.6 mg TSS/h in September. The average colony forming units of E. coli per 100ml in the summer were 243 at the upstream site and 208 at the downstream site. The average units during fall were 176 at the upstream site and 118 at the downstream site. The TSS concentrations did not cause Bigelow Creek to appear turbid or cloudy. These low concentrations are likely the result of relatively intact vegetation cover and lower urban and agricultural land use in the subbasin.

Penoyer Creek is relatively short in distance where a significant portion flows through forested landscape. The upstream site was located at a National Forest Service access point off of Basswood Drive and the downstream site was approximately 67 meters upstream of the M-82 bridge. TP-P measurements ranged from <0.007 mg/L during the months of November, December and June to 0.028 mg/L in May. TSS measurements ranged from 0.5 mg/L in December to 4 mg/L in November. The load estimate for TP ranged from 87.4 mg TP/h in September to 22,692 mg TP/h. The load estimate for TSS ranged from 67,693 mg TSS/h in September to 109,331.2 mg TSS/h in May. The average colony forming units of E. coli per 100 ml in the summer were 580 at the upstream site and 282 at the downstream site. The average units during fall were 43 at the upstream site and 74 at the downstream site.

Hess Lake Subwatershed

Sand Creek drains an agricultural area south of the Muskegon River and upstream of Bridgeton. Samples were collected at the corner of Wisner Avenue and West 120th Street. TP-P measurements ranged from <0.007 mg/L in November to 0.262 mg/L in May. TSS measurements ranged fom 1 mg/L in November to 29.3 mg/L in May. The load estimate for TP ranged from 146.9 mg TP/h in March to 32,376.6 mg TP/h in November. The load estimate for TSS ranged from 67,693 mg TSS/h in March to 407,607 mg TSS/h in May. The average colony forming units of E. coli per 100 ml in the summer were 8,012 at the upstream site and 551 at the downstream site. The average units during fall were 768 at the upstream site and 803 at the downstream site.

Minnie Creek flows into the Muskegon River from the North at a location just downstream of Bridgeton. Our upstream sample site was located at the West 96th Street road crossing and the downstream site was the Minnie Creek/Muskegon River confluence. TP-P measurements ranged from <0.007 mg/L in the months of November and December to 0.04 mg/L in May. TSS measurements ranged from 1.67 mg/L in September to 38 mg/L in May. The load estimate for TP ranged from 64.6 mg TP/h in December to 499 mg TP/h in May. The load estimate for TSS ranged from 7,235.2 mg TSS/h in September to 152,231.1 mg TSS/h in May. The average colony forming units of E. coli per 100 ml in the summer were 520 at the upstream site and 456 at the downstream site. The average units during fall were 330 at the upstream site and 498 at the downstream site.

Brooks Creek Subwatershed

Brooks Creek sampling occurred at West 112th Street and at Maple Island Road. TP-P measurements ranged from <0.007 mg/L in November to 0.087 mg/L in May. TSS measurements ranged from 1.5 mg/L in November to 26.5 mg/L in May. The load estimate for TP ranged from 1,220.6 mg TP/h in March to 73,782 mg TP/h in November. The load estimate for TSS ranged from 93,870.2 mg TSS/h to 1,412,895.1 mg TSS/h in September. The average colony forming units of E. coli per 100ml in the summer were 508 at the upstream site; measurements were not collected at the downstream site due to road construction. The average units during fall were 1,332 at the upstream site and 1,421 at the downstream site.

Mosquito Creek Subwatershed

The Maple River sample sites were located at Bayne Road and just west of the Department of Natural Resources field office at the Muskegon State Game Area at Messinger Road. Stream flow was often not evident (visually) and the soft sediment made it difficult for aquiring an accurate measure of discharge. TP-P measurements ranged from 0.013 mg/L in March to 0.065 mg/L in June. TSS measurements ranged from 1 mg/L during the months of December, March and September to 13.5 mg/L in June. The load estimate for TP ranged from 145.8 mg TP/h in September to 453.8 mg TP/h in May. The load estimate for TSS ranged from 17,095 mg TSS/h in March to 82,571.8 mg TSS/h in June. The average colony forming units of E. coli in the summer were 171 at the upstream site and 103 at the downstream site. The average units for the fall were 793 at the upstream site and 84 at the downstream site.

The Mosquito Creek sample site replaced the initial downstream sample site which was within the Muskegon State Game Area, downstream of Maple Island Road. The site location was moved to the bridge at Maple Island Road after the first sample event. The upstream sample site was located at the Fitzgerald Ave./N. Swanson Rd. crossing. The upper end of Mosquite Creek flows through relatively intact forest although it does pass through a powerline right-of-way. TP-P measurements ranged from <0.007 mg/L in November to 0.030 mg/L in June. TSS measurements range from 0.5 mg/L in Novemeber to 9.750 mg/L in June. The load estimate for TP ranged from 94.1 mg TP/h in September to 697.3 mg TP/h in May. The load estimate for TSS ranged from 6,116.4 mg TSS/h in November to 193,814.3 mg TSS/h in June. The average colony forming units of E. coli in the summer were 256 at the upstream site and 383 at the downstream site. The average units during fall were 473 at the upstream site and 487 at the downstream site. Although Mosquito Creek flows past the Muskegon County Resource Recovery facility, the stream appears to be in relatively good condition.

Muskegon River Mainsteam (Bigelow Creek, Hess Lake and Mosquito Creek Subwatersheds)

The Muskegon River upstream site was located at the Pine Street boat launch near Croton and the downstream site was located at the Mill Iron public access point east of Muskegon. TP-P measurements ranged from 0.005 mg/L in March to 0.043 mg/L in September. TSS measurements ranged from 0.25 mg/L in September to 5 mg/L in September. Load estimates were not attempted from the downstream site because it was too deep to safely obtain wading measurements. The load estimate for TP ranged from 14,577.5 mg TP/h in June to 1,352,495.3 mg TP/h in November. The load estimate for TSS ranged from 923,835.6 mg TSS/h in November to 7,964,100 mg TSS/h in May. The average colony forming units of E. coli in the summer were <1 at the upstream site and 55 at the downstream site. The average units for the fall were 13 at the upstream site and 124 at the downstream site. The Pine Street site had consistantly low TSS concentrations, likely due to the Croton reservoir. The dam interrupts the continuity of flow including the transport of upstream sediment while depriving downstream reaches of the sediments which are essential for channel forming processes and repleneshing downstream aquatic habitats.

General Conclusions

Phosphorus:

Several tributaries and the Muskegon river main stem had phosphorus samples taken that exceeded the EGLE water quality standard. The Sand Creek upstream site, Minnie Creek downstream site and Brooks Creek downstream site exceeded the phosphorus water quality standard in May. It's notable that the Sand Creek value of 0.262 is significantly larger than any other sample taken from the LMRW and the water quality standard. This occurred in a single instance and likely represents an upper bound of pollutants entering the stream. The Maple River upstream site exceeded the phosphorus water quality standard in June. The mainstem upstream site exceeded the phosphorus water quality standard in September. While not exceeding the water quality standard, it's worth mentioning that the downstream site for Bigelow Creek and the upstream site for Penoyer Creek in May and the downstream site for Mosquito Creek in June were all close to the water quality standard.

E. coli:

At several locations, E. coli concentrations exceeded the EGLE total body contact water quality standard and at one site the partial body contact standard. Therefore, E. coli concentrations should be a priority for improvement. During the summer, the Penoyer Creek upstream site, both sites on Sand Creek, both sites on Minnie Creek, the Brooks Creek upsteam site, and the Mosquito Creek downstream site exceeded the total body contact water quality standard of 300 cfu per 100ml. It is important to note that the Penoyer Creek downstream site was close to exceeding the limit with a value of 282, and not collected during a high water event. The Sand Creek upstream site value of 8,012 is significantly higher than the partial body contact limit of 1,000 cfu per 100 ml.

During September, both sites on Sand Creek, both sites on Minnie Creek, both sites on Brooks Creek, the Maple River upstream site, and both sites on Mosquito Creek exceeded the total body contact standard of 300 cfu per 100 ml. Both sites on Brooks Creek exceeded the partial body contact standard of 1,000 cfu per 100 ml.

Table 1: Minimum and maximum values of phosphorous, total suspended solids and their load estimates for seven tributaries and the Muskegon River mainstem during 2021 and 2022.

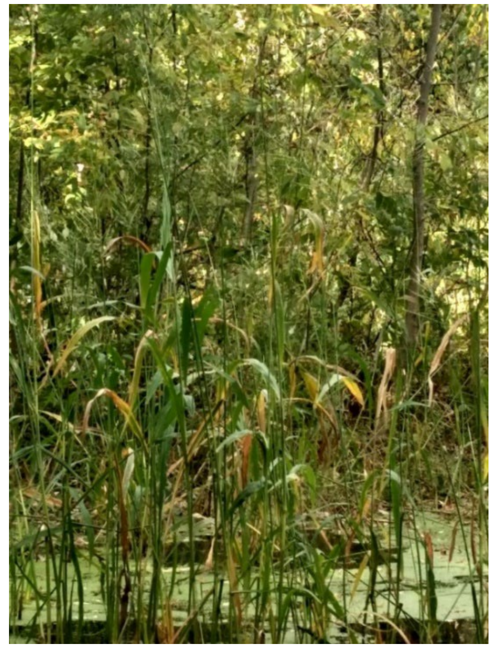
	TP-P (mg/L)		TSS (mg/L)		mg TP/h		mg TSS/h	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Bigelow Creek	0.007 November Upstream	0.027 May Downstream	2.250 November Downstream	14.250 May Downstream	252.800 December Upstream	48,217.000 November Upstream	67,693.600 September Upstream	1,053,172.600 September Upstream
Penoyer Creek	<0.007 Nov,Dec,June Downstream	0.028 May Upstream	0.500 December Downstream	4.000 November Upstream	87.400 September Upstream	22,692.000 November Upstream	67,693.000 September Upstream	109,331.200 May Upstream
Sand Creek	<0.007 November Downstream	0.262 May Upstream	1.000 November Downstream	29.250 May Upstream	146.900 March Upstream	32,376.600 November Upstream	15,630.000 March Upstream	407,607.100 May Upstream
Minnie Creek	<0.007 Nov (Up,Down) Dec (Down)	0.040 May Downstream	1.670 September Upstream	38.000 May Downstream	64.600 December Upstream	499.000 May Upstream	7,235.200 September Upstream	152,231.100 May Downstream
Brooks Creek	<0.007 November Downstream	0.087 May Downstream	1.500 November Downstream	26.500 May Downstream	1,220.600 March Upstream	73,782.000 November Upstream	93,870.200 November Upstream	1,412,895.100 September Downstream
Maple River	0.013 March Downstream	0.065 June Upstream	1.000 Dec,March,Sep Downstream	13.500 June Upstream	145.800 September Upstream	453.800 May Upstream	17,095.000 March Upstream	82,571.800 June Upstream
Mosquito Creek	<0.007 November Upstream	0.030 June Downstream	0.500 November Upstream	9.750 June Downstream	94.100 September Upstream	697.300 May Upstream	6,116.400 November Upstream	193,814.300 June Downstream
Muskegon River	0.005 March Downstream	0.043 September Upstream	0.250 September Downstream	5.000 September Downstream	14,577.500 June Upstream	1,352,495.300 November Upstream	923,835.600 November Upstream	7,964,100.000 May Upstream

Table 2: Average Colony forming units of E. coli per 100 ml for seven tributaries and the Muskegon River mainstem during summer and fall of 2022.

Geomean E. coli #cfu/100ml				
Season	Summer		Fall	
Site	Upstream	Downstream	Upstream	Downstream
Bigelow Creek	243	208	176	118
Penoyer Creek	580	282	43	74
Sand Creek	8,012	551	768	803
Minnie Creek	520	456	330	498
Brooks Creek	508	N/A	1,332	1,421
Maple River	171	103	793	84
Mosquito Creek	256	383	473	487
Muskegon River	<1	55	13	124

Appendix A. Photographs of Sample Sites

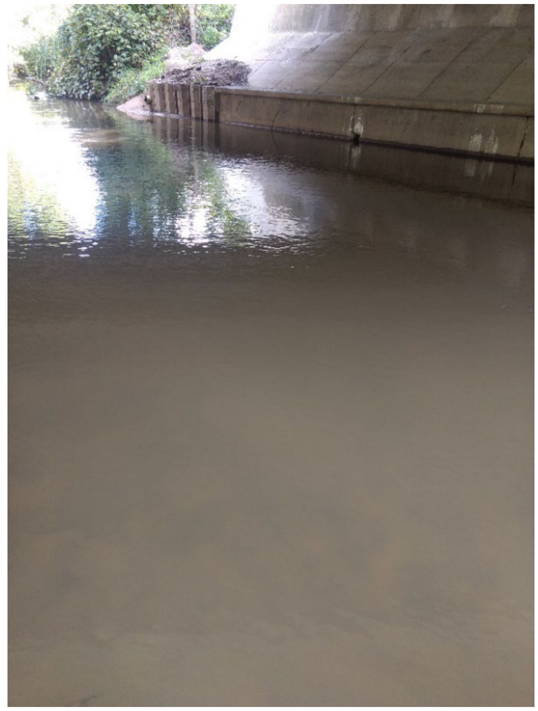
Lower Maple River 6-30-22



Lower Maple River 9-22-22

Upper Maple River 6-30-22

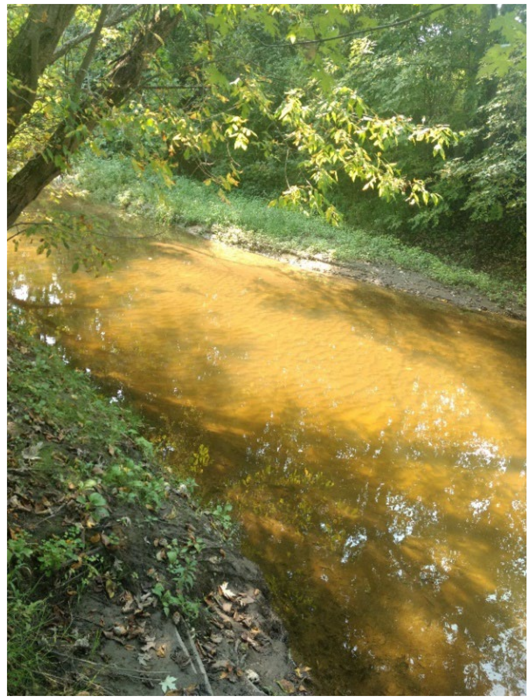
Upper Mosquito Creek 9-22-22



Lower Brooks Creek 9-22-22

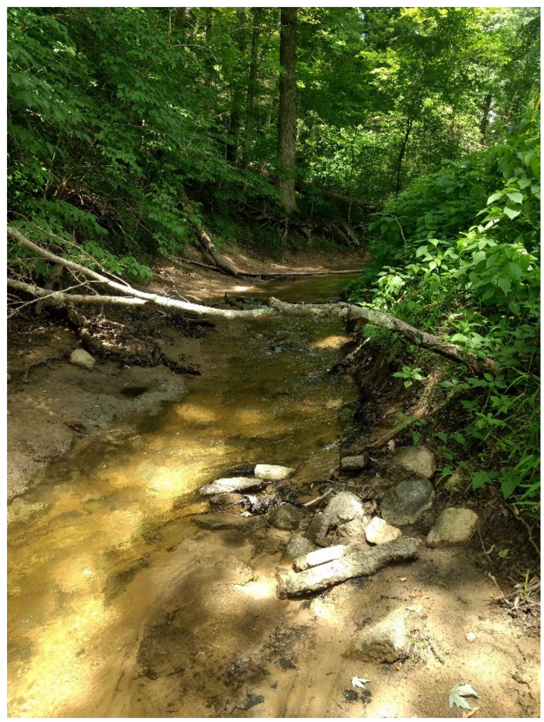
Upper Brooks Creek 6-30-22

Lower Sand Creek 5-26-22



Lower Sand Creek 9-22-22

Lower Minnie Creek 5-3-22



Lower Minnie Creek 6-30-22

Upper Minnie Creek 6-30-22

Upper Penoyer Creek 3-25-22

Upper Penoyer Creek 9-14-22

Upper Bigelow Creek 5-26-22

Appendix B. Water Quality Sampling Data for Each Site and Date

Results of TP-P, TSS and load estimates of water samples collected November 2021.

Sample Date	Station	TSS mg/L	TP-P mg/L
11/6/2021	Mill Iron	0.75	0.018
11/1/2021	Pine St	0.25	0.024
11/12/2021	Mosquito Cr down	8.75	0.020
11/6/2021	Mosquito Cr up	0.50	<0.007
11/6/2021	Maple down	1.25	0.020
11/12/2021	Maple up	1.50	0.015
11/6/2021	Brooks Cr down	1.50	<0.007
11/12/2021	Brooks Cr up	2.50	0.013
11/12/2021	Minnie Cr down	2.00	<0.007
11/12/2021	Minnie Cr up	1.75	<0.007
11/5/2021	Sand Cr down	1.00	<0.007
11/5/2021	Sand Cr up	4.25	0.016
11/2/2021	Penoyer Cr down	1.75	<0.007
11/2/2021	Penoyer Cr up	4.00	0.007
11/1/2021	Bigelow Cr down	2.25	0.007
11/1/2021	Bigelow Cr up	2.50	0.011

Date	Station	Discharge CFS	Discharge l/s	mg TSS/h	mg TP/h
11/6/2021	Mill Iron				
11/1/2021	Pine St	2175	61589.0	923835.6	1352495.3
11/12/2021	Mosquito Cr down	Soft Sed			
11/6/2021	Mosquito Cr up	7.2	203.9	6116.4	*
11/6/2021	Maple down	Soft Sed			
11/12/2021	Maple up	deep			
11/6/2021	Brooks Cr down	deep		*	*
11/12/2021	Brooks Cr up	22.1	625.8	93870.2	73782.0
11/12/2021	Minnie Cr down	13	368.1	44174.2	*
11/12/2021	Minnie Cr up	6.5	184.1	19326.2	*
11/5/2021	Sand Cr down	deep		*	*
11/5/2021	Sand Cr up	4.7	133.1	33937.7	32376.6
11/2/2021	Penoyer Cr down	24.48	693.2	72785.5	*
11/2/2021	Penoyer Cr up	7.95	225.1	54028.5	22692.0
11/1/2021	Bigelow Cr down	26.9	761.7	102832.5	44423.6
11/1/2021	Bigelow Cr up	17.2	487.0	73057.3	48217.8

Results of TP-P, TSS and load estimates of water samples collected December 2021. Samples for Mosquito Creek up, Maple River up, the field blank and the field duplicate were lost due to a refridgerator failure.

Sample Date	Station	TSS mg/L	TP-P mg/L
12/15/2021	Mill Iron	1.25	0.016
12/15/2021	Pine St	0.50	0.010
12/15/2021	Mosquito Cr down	1.25	0.010
	Mosquito Cr up		
12/15/2021	Maple down	1.00	0.018
	Maple up		
12/15/2021	Brooks Cr down	8.75	0.038
	Brooks Cr up		
12/16/2021	Minnie Cr down	2.25	<0.007
12/16/2021	Minnie Cr up	3.50	0.010
12/16/2021	Sand Cr down	3.50	0.018
12/16/2021	Sand Cr up	16.75	0.057
12/16/2021	Penoyer Cr down	0.50	<0.007
12/16/2021	Penoyer Cr up	0.50	0.008
12/16/2021	Bigelow Cr down	6.50	0.010
12/16/2021	Bigelow Cr up	4.25	0.008

Date	Station	Discharge CFS	Discharge l/S	mg TSS/h	mg TP/h
12/15/2021	Mill Iron				
12/15/2021	Pine St	3500	99108.8	2973264.0	58870.6
12/15/2021	Mosquito Cr down	25.1	710.8	53306.4	443.5
	Mosquito Cr up	7.8	220.9	*	*
12/15/2021	Maple down	NA			
	Maple up	6	169.9	*	*
12/15/2021	Brooks Cr down	deep			
	Brooks Cr up	29.2	826.9	*	*
12/16/2021	Minnie Cr down	deep			
12/16/2021	Minnie Cr up	3.8	107.6	22596.8	64.6
12/16/2021	Sand Cr down	deep			
12/16/2021	Sand Cr up	5.45	154.3	155098.2	523.2
12/16/2021	Penoyer Cr down	26.1	739.1	22172.1	*
12/16/2021	Penoyer Cr up	11.4	322.8	9684.3	147.2
12/16/2021	Bigelow Cr down	28.1	795.7	310323.8	463.1
12/16/2021	Bigelow Cr up	18.6	526.7	134306.6	252.8

Results of TP-P and TSS analysis of water samples collected March 2022.

Sample Date	Station	TSS mg/L	TP-P mg/L
3/22/2022	Mill Iron	1.50	0.005
3/22/2022	Pine St	<1.0	0.006
3/26/2022	Mosquito Cr down	1.75	0.012
3/26/2022	Mosquito Cr up	3.25	0.014
3/26/2022	Maple down	1.00	0.013
3/26/2022	Maple up	1.50	0.029
3/22/2022	Brooks Cr down	6.75	0.024
3/22/2022	Brooks Cr up	7.75	0.020
3/25/2022	Minnie Cr down	13.75	0.013
3/25/2022	Minnie Cr up	4.25	0.011
3/25/2022	Field dup	3.00	0.012
3/29/2022	Sand Cr down	6.25	0.017
3/29/2022	Sand Cr up	2.00	0.019
3/29/2022	Field dup	1.75	0.016
3/25/2022	Penoyer Cr down	1.50	0.015
3/25/2022	Penoyer Cr up	1.75	0.026
3/22/2022	Bigelow Cr down	5.25	0.017
3/22/2022	Bigelow Cr up	4.00	0.016
3/25/2022	Mill Iron	1.25	0.011
3/25/2022	Pine St	<1.0	0.012

Date	Station	Discharge CFS	Discharge l/s	mg TSS/h	mg TP/h
3/22/2022	Mill Iron				
3/22/2022	Pine St	3490	98825.6	*	33798.4
3/26/2022	Mosquito Cr down	23.2	656.9	68979.7	457.2
3/26/2022	Mosquito Cr up	6.4	181.2	35339.4	154.4
3/26/2022	Maple down	NA		*	*
3/26/2022	Maple up	6.7	189.7	17075.0	329.0
3/22/2022	Brooks Cr down	deep		*	*
3/22/2022	Brooks Cr up	36.1	1022.2	475340.0	1220.6
3/25/2022	Minnie Cr down	deep		*	*
3/25/2022	Minnie Cr up	9.85	278.9	71124.7	189.1
3/25/2022	Field dup	9.85	278.9	50205.7	199.1
3/29/2022	Sand Cr down	deep		*	*
3/29/2022	Sand Cr up	4.6	130.3	15630.9	146.9
3/29/2022	Field dup	4.6	130.3	13677.0	125.0
3/25/2022	Penoyer Cr down	17.4	492.7	44344.1	446.4
3/25/2022	Penoyer Cr up	7.7	218.0	22894.1	336.2
3/22/2022	Bigelow Cr down	35.2	996.8	313976.7	1034.6
3/22/2022	Bigelow Cr up	26	736.2	176696.8	706.8
3/25/2022	Mill Iron	*	*	*	*
3/25/2022	Pine St	4440.0	125726.6	*	92031.9

Results of TP-P and TSS analysis of water samples collected early May 2022.

Sample Date	Station	TSS mg/L	TP-P mg/L
5/3/2022	Mill Iron	<1.0	0.020
5/2/2022	Pine St	1.25	0.024
5/3/2022	Mosquito Cr down	1.00	0.014
5/3/2022	Mosquito Cr up	5.50	0.029
5/3/2022	Maple down	1.75	0.031
5/3/2022	Maple up	2.25	0.033
5/3/2022	Brooks Cr down	26.50	0.087
5/3/2022	Brooks Cr up	19.25	0.065
5/3/2022	Minnie Cr down	38.00	0.040
5/3/2022	Minnie Cr up	3.25	0.021
5/3/2022	Sand Cr down	9.00	0.053
5/3/2022	Sand Cr up	29.25	0.262
5/2/2022	Penoyer Cr down	2.00	0.015
5/2/2022	Penoyer Cr up	2.75	0.015
5/2/2022	Bigelow Cr down	6.75	0.024
5/2/2022	Bigelow Cr up	4.50	0.021
5/2/2022	Field dup	4.50	0.019
5/2/2022	Field Blank	<1.0	<0.007

Sample Date	Station	TSS mg/L	TP-P mg/L
5/24/2022	Mill Iron	2.75	0.015
5/24/2022	Pine St	1.25	<0.007
5/24/2022	Mosquito Cr down	3.25	0.016
5/24/2022	Mosquito Cr up	2.00	0.017
5/24/2022	Maple down	2.25	0.038
5/24/2022	Maple up	4.25	0.048
5/24/2022	Brooks Cr down	10.00	0.034
5/24/2022	Brooks Cr up	7.75	0.029
5/26/2022	Minnie Cr down	8.75	0.012
5/26/2022	Minnie Cr up	3.25	0.020
5/26/2022	Sand Cr down	7.50	0.028
5/26/2022	Sand Cr up	3.75	0.057
5/26/2022	Penoyer Cr down	2.25	0.013
5/26/2022	Field dup	1.75	0.017
5/26/2022	Penoyer Cr up	3.50	0.028
5/26/2022	Bigelow Cr down	14.25	0.027
5/26/2022	Bigelow Cr up	11.75	0.025
5/26/2022	Field Blank	<1.0	<0.007

Appendix D. Summary of Monitoring Data

Date	Station	Discharge CFS	Discharge l/s	mg TSS/h	mg TP/h
5/3/2022	Mill Iron				
5/2/2022	Pine St	3750	106188.0	7964100.0	149725.1
5/3/2022	Mosquito Cr down	27	764.6	45873.2	646.8
5/3/2022	Mosquito Cr up	14.3	404.9	133627.0	697.3
5/3/2022	Maple down	NA		*	*
5/3/2022	Maple up	6.3	178.4	24083.4	357.5
5/3/2022	Brooks Cr down	deep		*	*
5/3/2022	Brooks Cr up	deep		*	*
5/3/2022	Minnie Cr down	deep		*	*
5/3/2022	Minnie Cr up	14.2	402.1	78409.2	499.4
5/3/2022	Sand Cr down	deep		*	*
5/3/2022	Sand Cr up	8.2	232.2	407507.1	3650.1
5/2/2022	Penoyer Cr down	9	254.9	30582.1	224.8
5/2/2022	Penoyer Cr up	23.4	662.6	109331.2	604.3
5/2/2022	Bigelow Cr down	41.1	1163.8	471347.3	1689.9
5/2/2022	Bigelow Cr up	31.15	882.1	238158.4	1127.3
5/2/2022	Field dup	31.15	882.1	238158.4	1010.9
5/2/2022	Field Blank				

Date	Station	Discharge CFS	Discharge l/s	mg TSS/h	mg TP/h
5/24/2022	Mill Iron				
5/24/2022	Pine St	3500.0	99108.8	7433160.0	*
5/24/2022	Mosquito Cr down	14.2	402.1	78409.2	390.8
5/24/2022	Mosquito Cr up	4.1	116.1	13931.9	116.3
5/24/2022	Maple down	*	*	*	*
5/24/2022	Maple up	5.6	158.6	40436.4	453.8
5/24/2022	Brooks Cr down	51.3	1452.7	871591.1	2954.7
5/24/2022	Brooks Cr up	47.2	1336.6	621497.1	2325.6
5/26/2022	Minnie Cr down	10.2	290.0	152231.1	205.3
5/26/2022	Minnie Cr up	3.8	107.6	20982.7	126.5
5/26/2022	Sand Cr down	13.2	374.9	168711.5	638.9
5/26/2022	Sand Cr up	2.9	80.7	18158.1	275.0
5/26/2022	Penoyer Cr down	20.3	574.8	77602.2	448.4
5/26/2022	Field dup	20.3	574.8	60357.3	600.1
5/26/2022	Penoyer Cr up	8.1	229.4	48166.9	381.2
5/26/2022	Bigelow Cr down	43.5	1231.8	1053172.6	1995.5
5/26/2022	Bigelow Cr up	30.2	854.3	602294.1	1286.6
5/26/2022	Field Blank				

Appendix D. Summary of Monitoring Data

Results of TP-P and TSS analysis of water samples collected late June 2022. Samples could not be collected at Brooks Creek down due to road construction.

Sample Date	Station	TSS mg/L	TP-P mg/L
6/29/2022	Mill Iron	3.00	0.014
6/29/2022	Pine St	1.00	0.008
6/30/2022	Mosquito Cr down	9.75	0.030
6/30/2022	Mosquito Cr up	<1.0	0.018
6/30/2022	Maple down	2.00	0.059
6/30/2022	Maple up	13.50	0.065
	Brooks Cr down	no sample	
6/30/2022	Brooks Cr up	8.25	0.038
6/30/2022	Minnie Cr down	3.50	0.020
6/30/2022	Field dup	4.00	0.013
6/30/2022	Minnie Cr up	3.75	0.036
6/29/2022	Sand Cr down	13.00	0.038
6/29/2022	Sand Cr up	9.25	0.065
6/29/2022	Penoyer Cr down	1.50	<0.007
6/29/2022	Penoyer Cr up	1.75	0.020
6/29/2022	Bigelow Cr down	11.00	0.011
6/29/2022	Bigelow Cr up	6.75	0.010
6/30/2022	Field Blank	<1.0	0.005

Date	Station	Discharge CFS	Discharge l/s	mg TSS/h	mg TP/h
6/29/2022	Mill Iron				
6/29/2022	Pine St	1100.0	31148.5	1868908.8	14577.5
6/30/2022	Mosquito Cr down	11.7	331.3	193814.3	592.4
6/30/2022	Mosquito Cr up	3.2	90.6	*	95.7
6/30/2022	Maple down	NA	*	*	*
6/30/2022	Maple up	3.6	101.9	82571.8	397.0
	Brooks Cr down	Construction	*	*	*
6/30/2022	Brooks Cr up	30.2	855.2	423307.8	1960.0
6/30/2022	Minnie Cr down	6.1	172.7	36273.8	211.4
6/30/2022	Field dup	6.1	172.7	41455.8	138.9
6/30/2022	Minnie Cr up	2.7	76.5	17202.5	166.1
6/29/2022	Sand Cr down	10.0	281.8	219766.7	633.9
6/29/2022	Sand Cr up	1.9	53.8	29860.1	210.5
6/29/2022	Penoyer Cr down	17.1	484.2	43579.6	*
6/29/2022	Penoyer Cr up	5.4	152.9	16055.6	184.4
6/29/2022	Bigelow Cr down	36.3	1027.9	678413.9	672.2
6/29/2022	Bigelow Cr up	27.2	770.2	311937.9	439.0

Results of TP-P and TSS analysis of water samples collected September 2022.

Sample Date	Station	TSS mg/L	TP-P mg/L
9/14/2022	Mill Iron	5.00	0.040
9/13/2022	Pine St	1.33	0.043
9/22/2022	Mosquito Cr down	3.33	0.018
9/22/2022	Mosquito Cr up	1.33	0.019
9/22/2022	Maple down	1.00	0.048
9/22/2022	Maple up	5.33	0.029
9/22/2022	Brooks Cr down	18.00	0.053
9/22/2022	Brooks Cr up	15.67	0.038
9/14/2022	Minnie Cr down	4.33	0.013
9/14/2022	Minnie Cr up	1.67	0.018
9/14/2022	Sand Cr down	2.33	0.037
9/14/2022	Field dup	1.33	0.036
9/14/2022	Sand Cr up	4.33	0.051
9/14/2022	Penoyer Cr down	3.00	0.009
9/14/2022	Penoyer Cr up	2.33	0.008
9/13/2022	Bigelow Cr down	5.33	0.013
9/13/2022	Bigelow Cr up	2.33	0.012
9/22/2022	Field Blank	<1.0	<0.007

Date	Station	Discharge CFS	Discharge l/s	mg TSS/h	mg TP/h
9/14/2022	Mill Iron				
9/13/2022	Pine St	1700	48138.6	3841457.1	123331.0
9/22/2022	Mosquito Cr down	11.1	314.3	62800.4	337.6
9/22/2022	Mosquito Cr up	2.9	82.1	6553.1	94.1
9/22/2022	Maple down	na	*	*	*
9/22/2022	Maple up	3	85.0	27167.1	145.8
9/22/2022	Brooks Cr down	46.2	1308.2	1412895.1	4128.8
9/22/2022	Brooks Cr up	33.8	957.1	899872.8	2199.4
9/14/2022	Minnie Cr down	6.6	186.9	48554.3	141.3
9/14/2022	Minnie Cr up	2.55	72.2	7235.2	76.7
9/14/2022	Sand Cr down	9.2	260.5	36419.9	581.5
9/14/2022	Field dup	9.2	260.5	20789.1	567.4
9/14/2022	Sand Cr up	2.2	62.3	16184.8	188.8
9/14/2022	Penoyer Cr down	17.6	498.4	89707.6	266.1
9/14/2022	Penoyer Cr up	6.2	175.6	24543.9	87.4
9/13/2022	Bigelow Cr down	26.3	744.7	238165.2	563.0
9/13/2022	Bigelow Cr up	17.1	484.2	67693.6	334.1

Appendix D. Summary of Monitoring Data

Sample site codes used during the lower watershed sampling period.

1=Mill Iron (Muskegon Mainstem)	6=Maple River Upstream	11=Sand Creek Downstream	15=Bigelow Creek Downstream
2=Pine St (Muskegon Mainstem)	7=Brooks Creek Downstream	12=Sand Creek Upstream	16=Bigelow Creek Upstream
3=Mosquito Creek Downstream	8=Brooks Creek Upstream	13=Penoyer Creek Downstream	
4=Mosquito Creek Upstream	9=Minnie Creek Downstream	14=Penoyer Creek Upstream	
5=Maple River Downstream	10=Minnie Creek Upstream		

Date	Station	E. coli #cfu/100 mls	GeoMean
6/29/2022	P1 L	52	
6/29/2022	P1 C	52	55
6/29/2022	P1 R	63	
6/29/2022	P2 L	<1	
6/29/2022	P2 C	<1	<1
6/29/2022	P2 R	<1	
6/30/2022	P3 L	373	
6/30/2022	P3 C	373	383
6/30/2022	P3 R	404	
6/30/2022	P4 L	269	
6/30/2022	P4 C	241	256
6/30/2022	P4 R	259	
6/30/2022	P5 L	85	
6/30/2022	P5 C	131	103
6/30/2022	P5 R	98	
6/30/2022	P6 L	160	
6/30/2022	P6 C	169	171
6/30/2022	P6 R	185	
6/30/2022	P7 L	No Sample due to bridge repair	
6/30/2022	P7 C		
6/30/2022	P7 R		
6/30/2022	P8 L	487	
6/30/2022	P8 C	591	508
6/30/2022	P8 R	455	
6/30/2022	P9 L	638	
6/30/2022	P9 C	341	446
6/30/2022	P9 R	408	
6/30/2022	P9 L dup	379	
6/30/2022	P9 C dup	546	466
6/30/2022	P9 R dup	488	
6/30/2022	P10 L	448	
6/30/2022	P10 C	565	520
6/30/2022	P10 R	556	
6/29/2022	P11 L	448	
6/29/2022	P11 C	717	551
6/29/2022	P11 R	520	
6/29/2022	P12 L	8164	
6/29/2022	P12 C	7270	8012
6/29/2022	P12 R	8664	
6/29/2022	P13 L	75	
6/29/2022	P13 C	1137	282
6/29/2022	P13 R	262	
6/29/2022	P14 L	548	
6/29/2022	P14 C	459	580
6/29/2022	P14 R	776	
6/29/2022	P15 L	389	
6/29/2022	P15 C	160	208
6/29/2022	P15 R	145	
6/29/2022	P16 L	241	
6/29/2022	P16 C	201	243
6/29/2022	P16 R	295	
6/30/2022	FB	<1	<1

Date	Station	E. coli #cfu/100 mls	GeoMean
9/14/2022	P1 L	122	
9/14/2022	P1 C	84	124
9/14/2022	P1 R	187	
9/13/2022	P2 L	10	
9/13/2022	P2 C	20	13
9/13/2022	P2 R	10	
9/22/2022	P3 L	426	
9/22/2022	P3 C	504	487
9/22/2022	P3 R	537	
9/22/2022	P4 L	657	
9/22/2022	P4 C	426	473
9/22/2022	P4 R	379	
9/22/2022	P5 L	98	
9/22/2022	P5 C	97	84
9/22/2022	P5 R	63	
9/22/2022	P6 L	767	
9/22/2022	P6 C	697	793
9/22/2022	P6 R	933	
9/22/2022	P7 L	1553	
9/22/2022	P7 C	1467	1421
9/22/2022	P7 R	1259	
9/22/2022	P8 L	1467	
9/22/2022	P8 C	1106	1332
9/22/2022	P8 R	1455	
9/14/2022	P9 L	529	
9/14/2022	P9 C	393	498
9/14/2022	P9 R	594	
9/14/2022	P10 L	309	
9/14/2022	P10 C	298	330
9/14/2022	P10 R	389	
9/14/2022	P11 L	771	
9/14/2022	P11 C	613	753
9/14/2022	P11 R	905	
9/14/2022	P11 L dup	960	
9/14/2022	P11 C dup	733	854
9/14/2022	P11 R dup	884	
9/14/2022	P12 L	909	
9/14/2022	P12 C	657	768
9/14/2022	P12 R	759	
9/14/2022	P13 L	74	
9/14/2022	P13 C	86	74
9/14/2022	P13 R	63	
9/14/2022	P14 L	20	
9/14/2022	P14 C	63	43
9/14/2022	P14 R	63	
9/13/2022	P15 L	158	
9/13/2022	P15 C	86	118
9/13/2022	P15 R	121	
9/13/2022	P16 L	175	
9/13/2022	P16 C	171	176
9/13/2022	P16 R	183	
9/22/2022	FB	<1	
9/13/2022	FB	<1	

Appendix D3. Dam Assessment in the Lower Muskegon River Watershed.

Prepared in 2024 by: Muskegon River Watershed Assembly

Purpose

In the lower Muskegon River watershed, there are several dams that significantly impact the watershed. Most of the dams are derelict (abandoned), no longer serving their original purpose, and are candidates for removal. The dams block movement of fish and other aquatic organisms within each of the streams but also in their connection to the Muskegon River. The dams' impact natural flow characteristics, artificially warm water temperatures, and trap sediment and nutrients. The temperature impacts of dams are important to understand because of the stressors they place on aquatic organisms. Often, the dams block fish migrating to the cooler water resources found in upper portions of rivers. The temperature impacts often occur do upstream impoundments that elevate water temperatures downstream. Several areas below the dams in the watershed are supporting cool water fish communities and because of the warming these areas are on the threshold of exceeding the thermal tolerances of some fish species.

In 2019, the Muskegon River Watershed Assembly (MRWA) and natural resource partners, developed a priority list of dam removal candidates for the Muskegon River Watershed based on risks to public safety, benefit to natural resources, and cost effectiveness. The Penoyer Creek (Bigelow Creek subwatershed) and Brooks Creek (Hess Lake Subwatershed) dams that are part of this report are high priority dam removal candidates identified in the list.

The two dams on the Maple River (Mosquito Creek) that block the Muskegon River from flowing into the channel, are not part of this report. Out of all the smaller dams in the watershed, they likely have the most significant impacts. The Maple River dams are described and addressed in the critical area analysis of the Lower Muskegon River Watershed Management Plan and is a high priority for reconnection due to flooding impacts, erosion, and a severe impact to hydraulic flow.

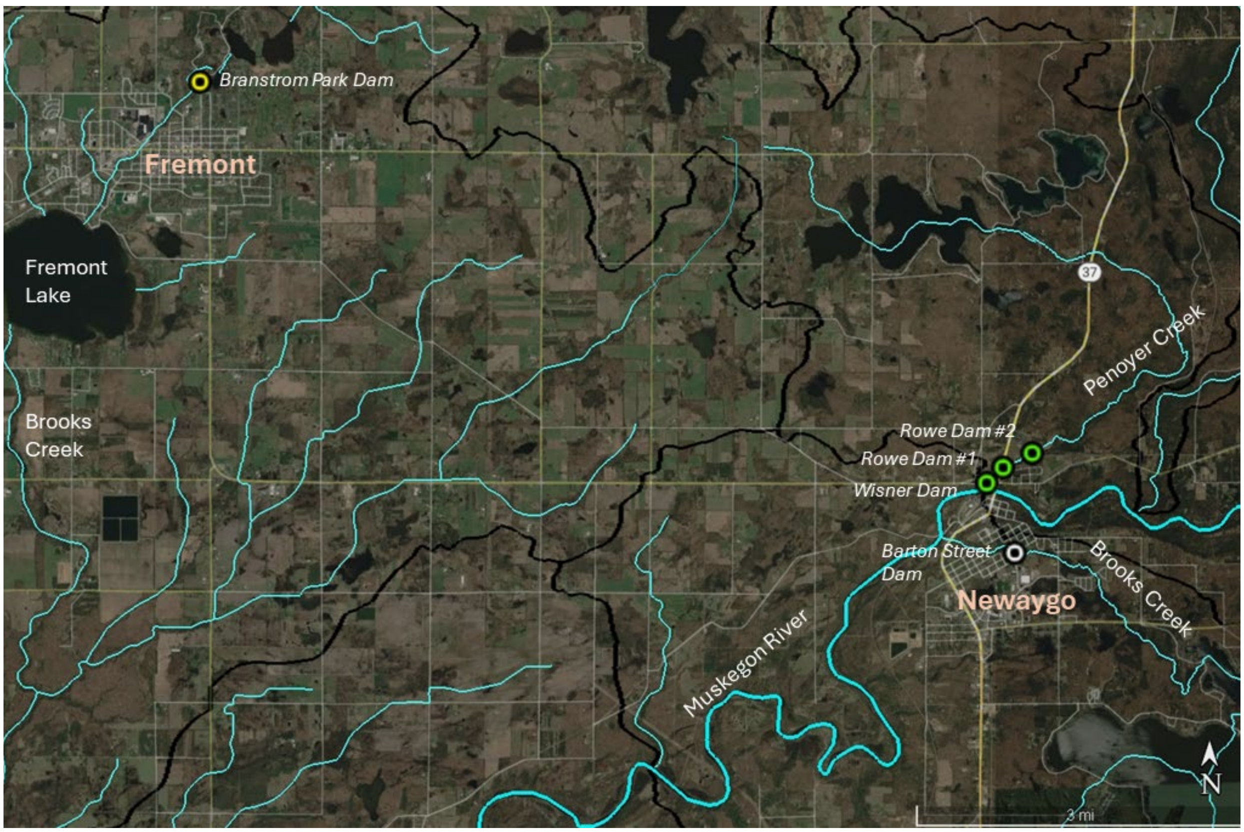
In 2020, the Muskegon River Watershed Assembly received an EGLE Watershed Council Support grant to obtain an understanding of the water quality impacts from dams in the watershed, identify potential dam-based sources and causes of nonpoint source pollution, determine areas where management practices could be altered to better protect water quality, and to prioritize these areas based on their potential to contribute nonpoint source pollutants to surface waters during runoff events. The findings from that study are reported here.

Results and recommendations from the collected data will be used to assist in the update of the Lower Muskegon Watershed Management Plan, including:

- Identification of critical areas and prioritization of sites for future outreach and best management practice implementation efforts
- Recommendations for best management practices to address specific pollutant sources.
    - WMP loading calculations and targets for future pollutant reductions.
    - Temperature reduction calculations and targets
    - Dissolved oxygen impairments and targets
    - Habitat protection and improvements

Field sampling for this report was conducted by MRWA and the Newaygo Conservation District. Sampling included a dam structural and barrier assessment, temperature, and dissolved oxygen monitoring and MiCorps benthic macroinvertebrate and habitat monitoring.

The sampling presented here was conducted at five dam sites in the lower watershed including three in the Bigelow Creek subwatershed, one in the Hess Lake subwatershed, and one in the Brooks Creek subwatershed (Figure 2).



Color Code for Dams: Yellow - Branstrom Park dam, Green - three Penoyer Creek dams, White - Brooks Creek dam.

Figure 2. Location of the five evaluated dam sites.

Summary of Sampling Data

Bigelow Creek Subwatershed – Penoyer Creek

There are three dams over a 0.5-mile reach on lower Penoyer Creek that are complete blockages to fish passage, disrupt flow, trap nutrients and sediment, and increase water temperature (Figure 3). The Wisner Dam, the lowermost dam on Penoyer Creek, is located just before the creek enters the Muskegon River (Appendix C). The structure is near 100 years old and has deteriorated to where water is leaking through cracks at several locations (Appendix D). It is the largest of the three dams, with a height of almost 30 feet. The middle Rowe Dam #1, scheduled for removal in 2026-2027, is not serving its original function of providing hydropower. The uppermost dam, Rowe Dam #2, scheduled for removal in fall of 2025, splits the creek into two channels as it flows through the dam. On March 14th, 2019, there was damage reported to the Rowe Dam #2 and a forced drawn down was completed to reduce further risk of a dam failure. Each of the three dams were identified as high priority candidates in MRWA's dam reconnaissance report. More detailed information about the structure of the dams is found in Table 3. Since 2018, the MRWA and partners have pursued removal of all three dams.

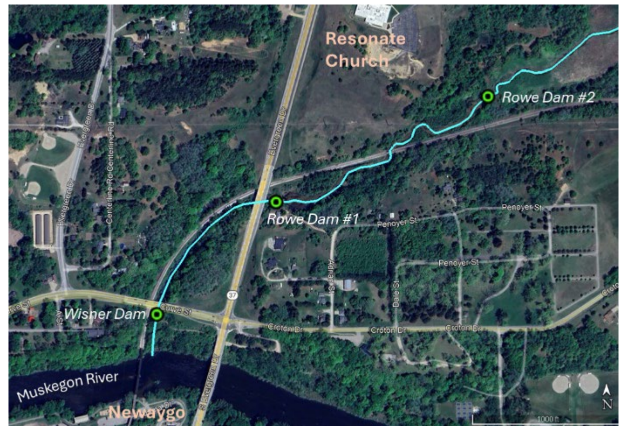


Figure 3. Location of three dams on Penoyer Creek.

Monitoring Data

The three dams warm water temperature significantly. During 2022, water temperature was monitored above Rowe Dam #1 and below the two Rowe dams. Water temperature was observed up to >9°F warmer below Rowe Dam #1 than immediately upstream of the drawn-down Rowe Dam #2 (Figure 4), demonstrating the large warming effect the dams pose. The warming continued below Wisner Dam though the difference was slightly less than 1°F. Dissolved oxygen was also lower below the dams by >3%.

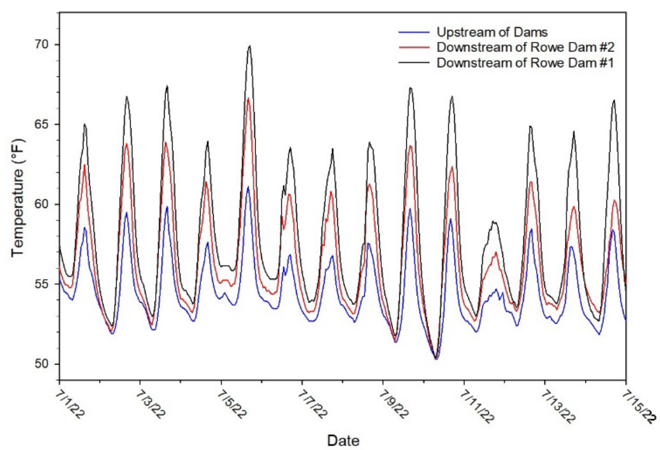


Figure 4. The temperature impact of the three-dam complex observed from July 1-15, 2022.

The two sampled sites, below Rowe dams #1 and #2, scored in the 'Good' to 'Very Good' range for MiCorps benthic macroinvertebrate sampling and had a moderate diversity of insects (Table 4). If the three-dam complex was removed, and large woody debris increased, the entire reach could achieve a 'Very Good' score during all seasons and have a higher abundance of stonefly, caddisfly and mayfly. Hellgrammites were collected, which are an indicator of high stream quality as they are not tolerant to environmental disturbance. The presence of hellgrammite shows the potential that lower Penoyer Creek has in providing an exceptional aquatic insect community.

Brooks Creek Subwatershed – Branstrom Park Dam

The Branstrom Park Dam, near the headwaters of Brooks Creek, is located upstream of the City of Fremont in a city owned park (Appendix D & E). The dam is relatively small with an 18-inch height and a hydraulic drop of approximately 9 inches. The dam produces a small impoundment, approximately 0.15 acres, and is mostly muck filled and shallow. Details on the dam structure are found in Table 3.

Monitoring Data

The dam is a blockage to fish passage during most flow conditions, disrupts flow, and traps nutrients and sediment. Although an impoundment is caused by the dam there was not an observable increase in water temperature between the upstream and downstream reaches. The reason for no observable temperature increase may be that cold water springs feed the impoundment, and although the purpose of the dam is not known, springs may have contributed to the dam being originally built to support a fishery. During the Spring of 2022, the macroinvertebrate scores were 'Poor' at the upstream reach because of aquatic worms composing almost 50% of the sample, while the downstream site was ranked as 'Good' due to a higher number of scuds than the upstream section (Table 4). In the Fall both sites were ranked as 'Good' with the downstream reach composing a high proportion of caddisfly and damselfly. The 'Poor' ranking at the upper site in the Spring was likely due to the high amount of silt likely due to the impounding effects of the dam during Spring high flows. The lakes obviously influence the stream and as the distance away from the lakes increase the benthic macroinvertebrate community becomes higher quality as shown by the lower sampling site.

Hess Lake Subwatershed – Barton Street Dam

The Barton Street Dam completely blocks fish passage and disconnects the 2.9-mile reach between Hess Lake and the Muskegon River, disrupts flow, decreases dissolved oxygen, and traps nutrients and sediment. The dam is at the top of one of the highest gradient areas in the Muskegon River watershed, but the barrier and impoundment fragment the system and degrade the habitat. The dam is located within the city limits of Newaygo and the dam is crossed by Barton Street (Appendix F). The dam is no longer used for its original purpose, although the purpose is unknown it is undoubtedly connected to the industrial nature of lower Brooks Creek at the turn of the 19^{th} century. The dam has a height of 18 feet, with an almost 10-foot hydraulic drop in water surface elevation from above the dam to the downstream Brooks Creek. Chinook salmon and steelhead are often found during the spawning migration at the base of the dam where upstream passage of both species is blocked. During the summer, impounded water behind the dam is stagnant and often has algae covering the water's surface. Details on the dam structure are found in Table 3.

During a downstream survey of the site, the remnants of a second dam were measured and included in Table 3 (titled Brooks Ravine). This dam has a section of metal sheet piling in place across the stream, approximately 8 foot high and buried into the banks although water is not impounded. There is also a portion of the wood and concrete dam structure remaining on the north bank. A third dam was historically located downstream, near Post Street. The remnants of both dams and associated structures remain in the deep valley located downstream of Barton Street.

<u>Monitoring Data</u>

During 2022 sampling, there was no significant difference between temperature upstream and downstream of the dam, likely due to the amount of groundwater entering the creek between the dam up to the Hess Lake water control structure. However, dissolved oxygen was relatively low upstream of the dam with measurements of 5.6 mg/l in September while the downstream reach was acceptable at >8 mg/l. At dissolved oxygen levels <5 mg/l, stressors to aquatic life can occur.

The two sampled sites, below Barton Street Dam and the upstream site above the impoundment, scored in the Excellent category for MiCorps benthic macroinvertebrates (Table 4). The macroinvertebrate community benefits from the high amount of large woody debris in the channel and the diversity of river bottom substrates (ie. Pebble, cobble and boulders). The excellent ranking is due to the high abundance of caddisfly and helgramitte. By removing the dam, the high-quality macroinvertebrate communities would reconnect and benefit from a more normal stream flow.

Table 3. The structural assessment of five dams.

					Dam Size (ft)			Plunge Pool (ft)				
Site ID	Dam Name	Reservoir Name	Purpose	Current Purpose	Length	Height	Water Surface Elevation	Max Depth	Max Width	Downstream Width	Fish Passage Barrier	Imoundment Acreage (ha)
BC-BP	Branstrom Park Dam	Branstrom	Unknown	Derelict	7.9	3.0	1.5	3.0	23.0	11.2	Y	0.4
B-BBS	Barton Street	Barton Street	Unknown	Derelict	58.4	18.0	9.8	3.2	34.1	27.9	Y	1.5
B-BR	Brooks Ravine	None	Unknown	Derelict	31.2	5.1	1.0	1.8	8.5	18.0	N	
PC-WD	Wisner Dam	None	Furniture Factory	Derelict	60.0	29.8	29.5	13.1	Multiple channels	NA	Y	0.75
PC-RW2	Rowe Dam #2	None	Hydropower	Derelict	25.0	8.0	2.0	3.8	25.0	39.0	Y	Drawn Down

Table 4. MiCorps benthic macroinvertebrate scores and notes for dams assessment sites.

Bigelow Creek Subwatershed - Penoyer Creek

Location	Date	Total Abundance	Total Diversity	Final Score	Final Category	Notes
Rowe Dam #2	5/15/2022	127	7	4.96	Good	73 scud
	9/19/2022	126	12	4.61	Good	1 leech; 3 aquatic worm; 63 caddisfly
Rowe Dam #1	5/15/2022	150	12	4.38	Very Good	1 Hellgrammite; 112 scud; 1 leech; 4 aquatic worms
	9/19/2022	194	8	4.94	Good	116 scud; 17 aquatic worms
Wisner Dam	5/15/2022	267	10	4.24	Very Good	196 scud; 5 leech; 1 aquatic worm
	9/19/2022	142	8	4.82	Good	80 scud; 8 aquatic worms

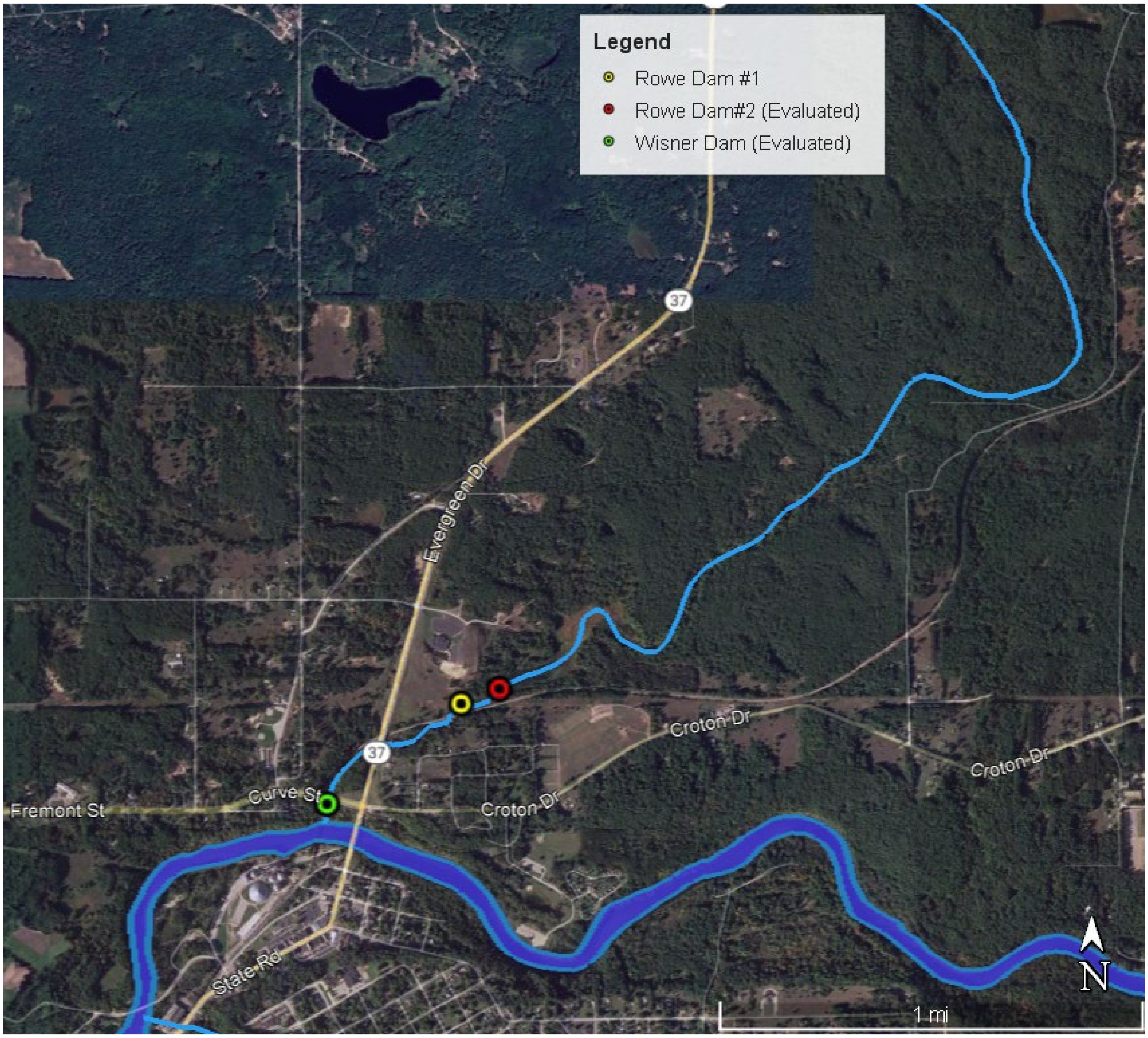
Brooks Creek Subwatershed – Brooks Creek (Branstrom Park)

Location	Date	Total Abundance	Total Diversity	Final Score	Final Category	Notes
Upstream	5/14/2022	83	8	7.92	Poor	41 aquatic worm
	9/19/2022	114	8	4.88	Good	58 scud
Downstream	5/14/2022	125	9	4.81	Good	1 leech; 9 aquatic worm; 51 scud
	9/19/ 2022	170	7	4.77	Good	2 aquatic worms; 90 caddisfly; 42 damselfly

Hess Lake Subwatershed – Brooks Creek (Barton Street Dam)

Location	Date	Total Abundance	Total Diversity	Final Score	Final Category	Notes
Upstream	5/15/2022	140	11	5.3	Good	1 clubtail dragonfly; 80 scud; 1 leech; 1 aquatic worm
	9/20/ 2022	139	9	5.84	Fair	62 scud; 41 sowbug; 1 aquatic worm
Downstream	5/16/2022	101	7	3.28	Excellent	11 Hellgrammite
	5/20/2022	127	10	3.34	Excellent	7 Hellgrammite; 1 aquatic worm; 59 caddisfly

Appendix C. Location of dams on lower Penoyer Creek in the Bigelow Creek subwatershed.



Appendix D. Photographs of dams in the Bigelow Creek, Brooks Creek and Hess Lake Subwatersheds.

Bigelow Creek Subwatershed – Penoyer Creek

Wisner Dam (most downstream dam)

One of Split Channels

Bigelow Creek Subwatershed – Penoyer Creek

Rowe Dam #1

Looking Towards Upstream Portion of Dam

Rowe Dam #2 (Upstream Dam)

Upstream

Downstream

Brooks Creek Subwatershed – Brooks Creek

Branstrom Park Dam

Downstream of Dam

Upstream of Dam

Hess Lake Subwatershed – Brooks Creek

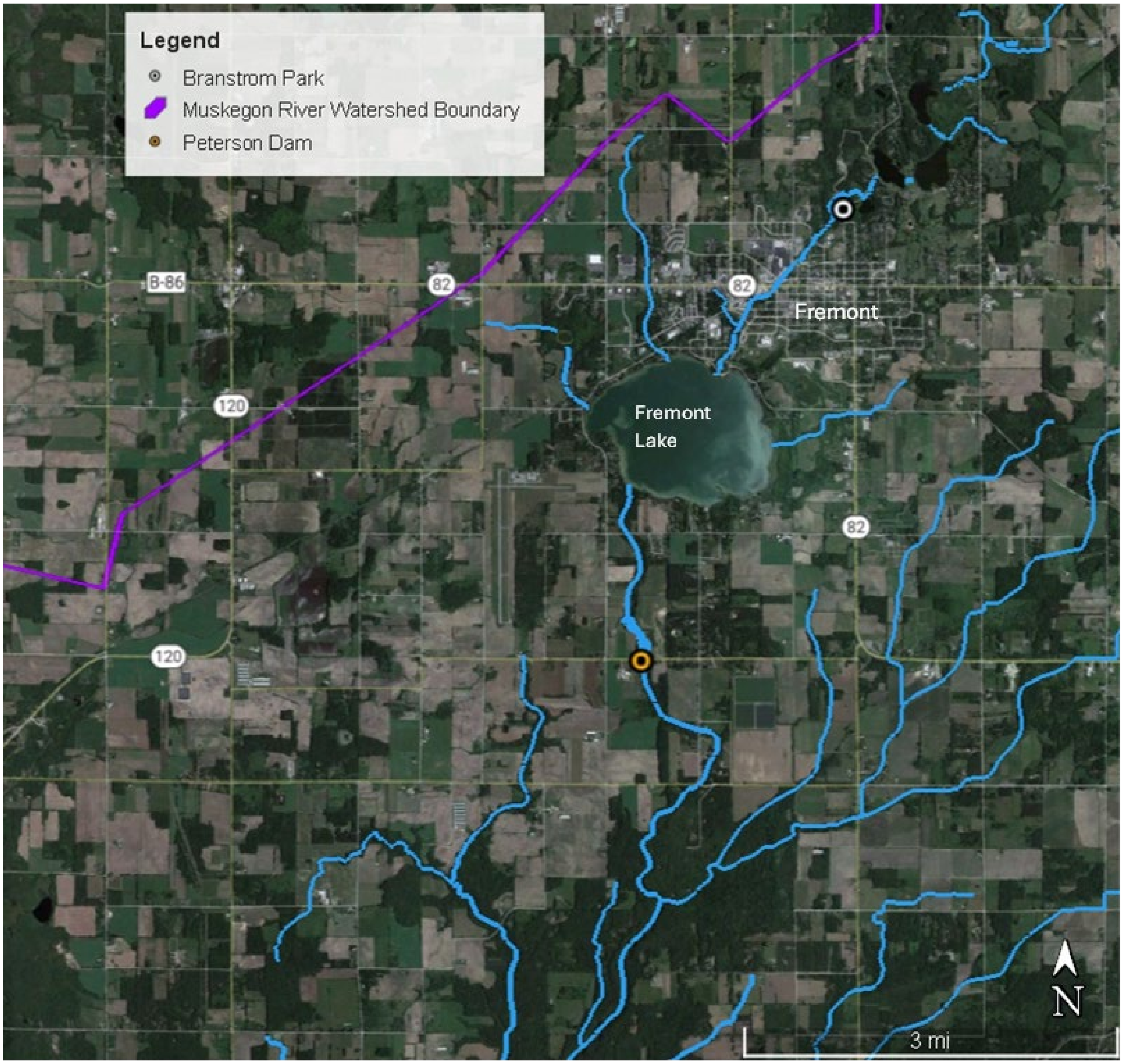
Barton Street Dam

Downstream of Dam

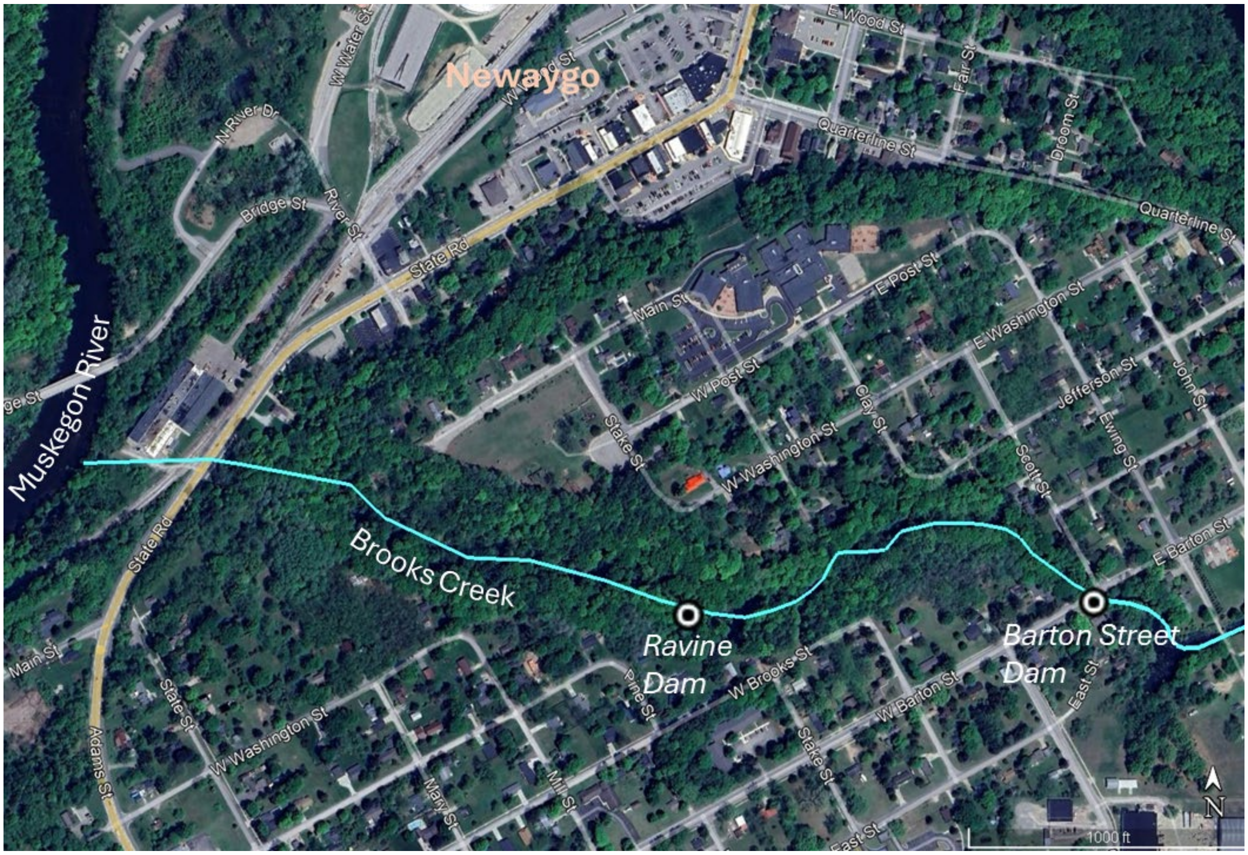
Portion of Impounded Area

Remnant of Water Control Structure

Appendix E. Location of the Branstrom Park Dam and Peterson Dam in upper Brooks Creek near Fremont, Michigan.



Appendix F. Location of the two dams on Brooks Creek from Barton Street Dam to the Muskegon River.



Appendix E. Water Quality Goals for each Lower Muskegon River Subbasin

Subwatershed	Goal
Bigelow Creek	Goal One: Remove the impaired reaches of unnamed tributary to Twinwood Lake, Bigelow Creek and Cold Creek, Muskegon River, Penoyer Creek, Sylvan and Emerald Lakes, and Freska Lake from the EGLE 303(d) list.
	Goal Two: Improve quality of water entering streams and lakes by addressing hydrologic impacts from fluctuating flow and thermal conditions in the watershed.
	Goal Three: Improve quality of water by reducing excessive nutrient input into the watershed.
	Goal Four: Improve quality of water by reducing excessive sediment input into the watershed.
	Goal Five: Protect/improve the recreational uses of the watershed by preventing *E. coli* /bacteria from entering into the watershed.
Brooks Creek	Goal One: Remove the impaired reaches of tributaries to Second, Third, Fourth and Fremont Lake, Fremont Lake, Brooks Creek and Cow Creek, Daisy Creek and Spring Creek, Lorden Lake Outlet and unnamed Tributary, Graham Creek, Kempf School Creek, and Butler Creek and Williams Creek from the EGLE 303(d) list.
	Goal Two: Improve quality of water entering streams and lakes by addressing hydrologic impacts from fluctuating flow and thermal conditions in the watershed.
	Goal Three: Improve quality of water by reducing excessive nutrient input into the watershed.
	Goal Four: Improve quality of water by reducing excessive sediment input into the watershed.
	Goal Five: Protect/improve the recreational uses of the watershed by preventing *E. coli* /bacteria from entering into the watershed.
Hess Lake	Goal One: Remove the impaired reaches of Four Mile Creek and Muskegon River, Brooks Creek, Wheeler Drain and Hess Lake from the EGLE 303(d) list.
	Goal Two: Improve quality of water entering streams and lakes by addressing hydrologic impacts from fluctuating flow and thermal conditions in the watershed.
	Goal Three: Improve quality of water by reducing excessive nutrient input into the watershed.
	Goal Four: Improve quality of water by reducing excessive sediment input into the watershed.
	Goal Five: Protect/improve the recreational uses of the watershed by preventing *E. coli* /bacteria from entering into the watershed.
Mosquito Creek	Goal One: Remove the impaired reaches of Mosquito Creek, Maple River and Spring Creek from the EGLE 303(d) list.
	Goal Two: Improve quality of water entering streams and lakes by addressing hydrologic impacts from fluctuating flow and thermal conditions in the watershed.
	Goal Three: Improve quality of water by reducing excessive nutrient input into the watershed.
	Goal Four: Improve quality of water by reducing excessive sediment input into the watershed.
	Goal Five: Protect/improve the recreational uses of the watershed by preventing *E. coli* /bacteria from entering into the watershed.

Appendix F. Lower Muskegon River Watershed Critical Area Analysis

Two methods were used to determine critical areas in the watershed.

1. A subwatershed screening tool to rank sensitivity to various pollutants.
2. A finer-scale evaluation of reach and/or waterbody level pollutant loads or risks

I. Subwatershed Screening Tool:

Five factors were used to assess critical areas in the watershed and were selected for several reasons. The first is that data for factors was readily available for the subwatersheds and they could characterize the existence of, or potential for, the pollutants perceived as the greatest threat to the Muskegon River Watershed (i.e., thermal pollution, nutrient enrichment, and sediment). Critical areas were mapped using a geographic information system (GIS) and enabled project partners to examine geographic areas of the watershed that are sensitive to various pollutants. The screening for each factor is described below.

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In-Stream Temperature Fluctuation Ranking

In-stream temperature, and how much the temperature fluctuates, governs the types of aquatic life that can live in a stream. All organisms have preferred temperature ranges and if temperatures get too far above or below this range, species will not survive. Temperature is also important because it influences water chemistry, such as the amount of oxygen in water.

This ranking identifies cool water streams with moderate to high fluctuations in average weekly temperature for the month of July, which is typically the hottest month of the year. We mirrored the same methodology used in the original Muskegon River Watershed Management Plan (MRWMP) from 2002 to rank Critical Areas to assess in-stream temperature fluctuation by using the Valley Segment Ecological Classification (VSEC) data, developed through the Michigan Rivers Inventory (MRI). The VSEC was used to determine the percentage of streams in each subwatershed with a high degree of in-stream temperature fluctuation. The VSEC calculated temperature averages and fluctuations based on catchment hydrology and size, upstream lake and shading effects, latitude, impacts from upstream land cover patterns, presence of upstream lakes, and downstream temperature conditions. The length of cold or cool water streams, with either a moderate or high diurnal (daily) temperature fluctuation, based on the VSEC, was calculated for each subwatershed and then divided by the total stream length to reach a total percentage. Temperature fluctuations were classified using three categories describing how much stream temperature deviated from the average stream temperature over the course of a week.

We also used temperature data collected during 2022 monitoring (Appendix D) to inform the VSEC study and focus on site specific locations to determine if temperature fluctuations were comparable between the two methods. The temperature data collected in 2022 indicated that broad temperature fluctuations were occurring in Mosquito Creek and confirmed through the VSEC model. The In-Stream Temperature Fluctuation Ranking was developed by numerical ranked scores based upon the following percentages of stream length sensitive to temperature fluctuations: (0-25% = 1), (26-50% = 2), (51-75% = 3), (76-100% = 4). A rank score between 1-2 was classified as a low critical area. A score of 3 ranked moderately critical and a score of 4 was highly critical (Table 23, Figure 22 of the MRWMP 2002).

In-Stream temperature fluctuation ranking.

Percent of cold or cool water streams with a moderate or high in-stream temperature fluctuation	Rank
<25%	1
25 – 50%	2
50.01 – 75%	3
>75%	4

Surface water runoff

Changes in land use can have a major effect on both the quantity and quality of surface runoff. If forested land is transformed to urban or agricultural land uses, and not properly planned and managed, there can be dramatic changes to the natural hydrology of the area. Also, pollutants associated with these land uses can be carried to nearby streams and drains by surface runoff.

This ranking identifies streams that receive the majority of their hydrological input from surface runoff (Figure 2.5, Chapter 2). These streams are sensitive to changes in land cover and the quality of water from the surface water runoff. Additionally, increases in surface runoff entering a stream may increase stream water temperatures and nutrient loading, adding to thermal pollution in the stream and excess nutrient contamination. Data from the MRI Landscape-Based V-SEC System were used to identify the total miles of stream for each subwatershed receiving most, or all, of their hydrological input from surface runoff (Seelbach et al. 1997). The total mileage of streams measured in the MRI study in each subwatershed was then used to obtain the percentage of stream length in each subwatershed sensitive to surface water runoff. Subwatersheds received a numerical rank score based upon the following percentages of stream length sensitive to surface water runoff: (0-25% = 1), (26-50% = 2), (51-75% =3), (76-100% = 4). A rank score between 1-2 was classified as a low critical area. A score of 3 ranked moderately critical and a score of 4 was highly critical. Methods and results may be found Chapter 5 of the MRWMP.

Surface water runoff ranking.

Percent of runoff driven streams	Rank
<25%	1
25 – 50%	2
50.01 – 75%	3
>75%	4

Percentage of developed land use (agricultural and urban)

This ranking identifies subwatersheds with high to low percentages of developed land.
Data for this analysis came from the 2021 National Land Cover Database (Figure 2.9 & 2.10, Chapter 2). Subwatersheds received a numerical rank score following sub-indicator criteria for land cover from the State of the Great Lakes 2022 Technical Report. The ranking definitions

are based on the degree of risk for the degradation of water/habitat quality of receiving waters based on a combination of the risk levels from both developed and agriculture land cover:

- Low Critical (1): Less than 6% land cover is urban (developed) and less than 20% land cover is classified as agriculture.
- Moderately Critical (2-3): Between 6% and 27% land cover is urban (developed), or between 20% and 50% land cover is classified as agriculture.
- Highly Critical (4): More than 27% land cover is urban (developed) or more than 50% land cover is classified as agriculture.

Percentage of developed land use ranking.

Percent of developed land use	Rank
<25%	1
25 – 50%	2
>50 – 75%	3
>75%	4

Streambank erosion and non-vegetated banks

Streambank erosion can be a major cause of non-point source pollution and increase the annual sediment and phosphorus loads in a watershed. In some cases, the total sediment load from eroding streambanks into a subwatershed has been found to range between 25% - 96% (Williams 2024). Although bank erosion is a natural and essential function of a river system, the channel erosion and sediment transport in the Muskegon River watershed increased notably after the logging era (1860-1900) and post-depression agricultural boom. When sediment loading is accelerated it can degrade fish and wildlife habitat, destroy wetlands, and reduce the recreational and aesthetic appeal of the river system.

As part of this project, a GIS inventory was conducted that identified locations with eroding streambank characteristics including number of eroding streambanks and distances of eroding shorelines and nonvegetated banks per subwatershed. The inventory identified sites where active toe and bank erosion were occurring and the total length of the eroding shoreline was ≥6' in length. Bigelow Creek has the lowest amount of streambank erosion in number of sites and distance, and for miles of non-vegetated banks and was used as a low reference for the Critical Analysis scoring.

Streambank erosion and non-vegetated banks.

Percent increase of eroding shorelines and non-vegetated banks from the low reference (Bigelow Creek)	Rank
0%	1
1-25%	2
25-50%	3
>50%	4

Total Ranking

The total ranking is derived by adding the individual rankings from each of the five categories measured for the critical subwatershed analysis. The subwatersheds receiving higher rankings are most sensitive to land use and hydrologic changes within the Lower Muskegon River

Watershed. A total ranking between 5 and 8 was classified as slightly critical, a ranking of 9 to 12 was classified as moderately critical, and a ranking of 13 to 16 was classified as severely critical. Table 1 presents the subbasin scores for each of the five categories and a total score that sums each of the categories.

Table 1. Lower Muskegon River Watershed Critical Area Parameters Ranking.

Subbasin Name	Temperature Fluctuation	Surface Water Runoff	% Developed Land	Streambank Erosion	Total
Bigelow Creek	1	1	1	1	4
Brooks Creek	2	4	3	4	13
Hess Lake	1	1	2	4	8
Mosquito Creek	4	2	2	2	10

Conclusion

The Brooks Creek Subwatershed was characterized as Severely Critical based largely on the risks posed to water quality by agricultural land use and associated practices. The criteria that led this to this determination was the high percentage of developed land, including agricultural land, surface water runoff and streambank erosion.

II. Finer-scale evaluation:

Other tools were used to identify critical areas on a finer scale and included the EPA PLET model, water quality data collected as part of this plan (Appendix D) and archival information on changes to hydraulic flow. Physical inventories also informed the selection of critical areas and included evaluation of streambank erosion on the mainstem of the Muskegon River and the assessment of dams and river channelization impacts on natural stream function.

Appendix G. Agricultural Conservation Planning Framework and Tillage/Residue Survey for the Lower Muskegon River Watershed

Surveys of agricultural farm fields were completed in three subwatersheds in the Lower Muskegon River Watershed for the Watershed Management Plan update. The survey data were collected through aerial and windshield techniques during 2021 and 2022 to identify fields which could be contributing nonpoint source pollution including E. coli, sediment, and nutrients. The surveys were designed to document crops planted, tillage practices, crop residue, and existing best management practices on cropland. The surveys were also used in conjunction with the Agricultural Conservation Planning Framework (ACPF), which will be described in the next section.

Two types of surveys were completed:

1) Fall tillage. Designed to collect information from croplands, specifically the crop that was last planted, the type of tillage used after harvest of that crop, planting of a winter crop, and the presence or absence of any existing cover crops.
2) Spring residue. Designed to collect data on the planted crop and the percentage of crop residue remaining on fields after planting. Crop residue was identified as an important parameter based on Natural Resources Conservation Service guidance that residue may reduce erosion to tolerable soil loss levels for crop production and protects water quality by holding soil in place and preventing sediment and nutrient loss that would occur if soil were left bare and exposed.

To establish fields to survey, EGLE reviewed aerial photographs of three 12-digit HUC subwatersheds: Penoyer Creek (HUC 040601020903), Hess Lake (HUC 040601020904, 06) and Brooks Creek (HUC 040601020905)) and created maps of all crop fields within those subbasins. The windshield survey entailed driving all the roads and taking notes on land management practices. During the surveys, tillage practices, crops planted, crop residue, and existing best management practices on cropland were all observed and recorded. During 2022, a Spring residue inventory was completed, and in Fall of 2021 and 2022, a Tillage inventory was completed. Table 1 presents the agricultural acreage and the acreage inventoried for each subwatershed. If fields were inaccessible or not visible from the road they were skipped and not presented in Table 1.

Table 1. Agricultural acreage and the total area inventoried during the Spring residue (2021) and Fall tillage surveys (2022) in three subwatersheds.

			Agricultural Acres Surveyed (Not Skipped) During Inventories	
Subwatershed	Subwatershed Acreage	Agricultural Acreage	Spring Residue	Fall Tillage
Bigelow Creek	47,030			
Penoyer Creek Subbasin	26,864	3,761	2,454	2,892
Brooks Creek	39,408	16,386	12,448	12,674
Hess Lake	49,664			
Four Mile Creek Subbasin	22,023	4,145	2,687	2,884
Minnie Creek Subbasin	27,642	6,960	4,863	4,380

Agricultural Conservation Planning Framework and Tillage/Residue Survey

The Agricultural Conservation Planning Framework (ACPF) is an ArcGIS compatible toolbox developed by the United State Department of Agriculture's Agricultural Research Service. The ACPF utilizes the Soil Survey Geographic Database and high-resolution LiDAR derived digital elevation model to identify candidate locations within the landscape for a variety of agricultural BMPs, including grassed waterways, water and sediment control basin (WASCOBs) and nutrient removal wetlands. The ACPF was used to identify critical agricultural fields with the greatest potential for contributing pollution (sediment, pathogens, and nutrients) to surface waters.

Findings from Tillage and Spring Residue Inventories

The inventories show that corn grain and silage, hay and soybean are the most common crops in the areas that were inventoried in the three subwatersheds. In Brooks Creek, these crops represent around 70% of all crops planted (Figure 1) and that trend holds consistently for the other basins. A portion of agricultural fields were skipped during the inventories, but it is expected that the results from the surveyed fields would be representative of the skipped fields.

In the Lower Muskegon River Watershed, the disturbance of soil through tillage occurs in all three of the subwatersheds, resulting in soil that is exposed during significant portions of the year, including times of snowmelt and spring rains when the possibility of runoff is increased. This exposed soil is prone to erosion and is transported by wind and water into drains and waterways and downstream into larger tributaries and eventually into the Muskegon River.

Two practices that minimize water quality impacts from tillage practices are cover crops and leaving residue on the fields. Cover crops reduce runoff by protecting the soil surface with living plant material, preventing erosion from wind and rain, improving soil structure by creating root channels, while adding to the soils organic matter through decomposition. Maintaining at least 30% crop residue (plant stalks and other material left after harvest) on the soil surface of these fields could improve soil health, help retain moisture in the soil, and reduce erosion and nutrient runoff.

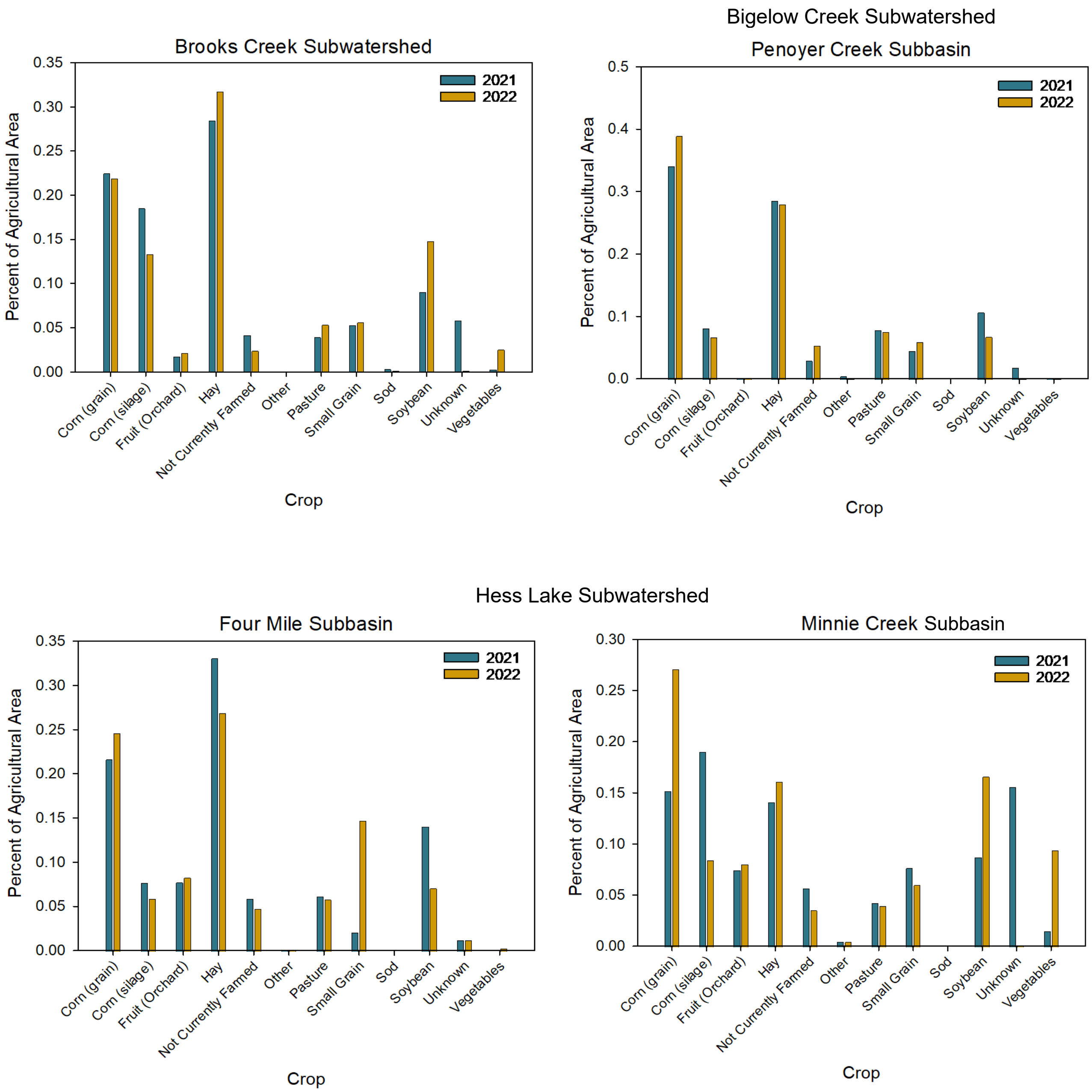

Figure 1. The percent of acres for each crop in 2021-2022 for the three inventoried subwatersheds (the Hess Lake subwatershed has two subbasins (Four Mile Creek & Minnie Creek)). The percentage of area for each of the crop types only include information from the fields that were surveyed and not those that were skipped.

Fall tillage data in 2021 showed between 14-25% of all row crop fields (excluding 'Not Applicable') underwent some type of tillage including chisel plow, and other heavy tillage techniques (Table 2). Four Mile Creek had the lowest percentage of fall tillage with 14% and Minnie Creek had the highest with approximately 25%.

Table 2. Fall tillage acreage in three subwatersheds during 2022.

Subwatershed	Total fall tillage acres surveyed	Mulch Tilled	Chisel Plowed	Strip Till	Planted	No Tillage Done	Not Applicable
Brooks Creek	12,674	422	806	7	1,640	4,948	4,851
Hess Lake							
Four Mile Creek	2,884	96	100	0	350	805	1,533
Minnie Creek	4,380	491	198	0	807	1,258	1,626
Bigelow Creek							
Penoyer Creek	2,892	116	143	0	161	1,312	1,160

The spring tillage survey found that most agricultural producers did not leave significant residue. The NRCS standard for residue is for ≥30% of the applicable agricultural area to have residue. None of the subwatersheds that were inventoried met the NRCS standard. In the Brooks Creek subwatershed and Penoyer Creek subbasin, more than 90% of fields had residue beneath the NRCS standard, and in the Minnie Creek and Four Mile Creek subbasins the number of fields below the NRCS standard was 85% and 86%, respectively (Table 3).

Table 3. Spring residue acreage in three subwatersheds during 2021.

Subwatershed	Total acreage of corn, soybean and vegetables	30%+ residue	No-Till Planted	< 30% residue	0% residue	Not Applicable
Brooks Creek	7,115	708	612	4,358	1,437	5,333
Hess Lake						
Four Mile Creek	986	142	39	643	162	1,701
Minnie Creek	3,036	400	45	1,500	1,091	1,827
Bigelow Creek						
Penoyer Creek	1,416	129	57	1,080	150	1,038

The spreading of manure over agricultural fields poses a significant pollution source to the Lower Muskegon River Watershed. The full extent of manure application is not known, however because Concentrated Animal Feeding Operations are regulated under the National Pollutant Discharge Elimination System, a minimum application rate can be estimated through the EGLE CAFO permitting database. In Brooks Creek the potential application is >35% of the agricultural area which means manure could be applied to more than 5,654 acres. The total potential acreage of CAFO permitted fields in all of the subwatersheds was at least 15,000 acres (Table 4).

Table 4. The minimum acreage and percent of agricultural area applied with manure in three subbasins of the Lower Muskegon River Watershed.

	Brooks	Hess Lake		Bigelow Creek
		Four Mile	Minnie Creek	Penoyer Creek
Agricultural Cropland Acres Applied with Manure	5,654	582	3,200	333
Percent of Agricultural Cropland Applied	35%	14%	46%	9%

To identify the highest priority fields for reducing sediment, nutrients, and E. coli into waterways, the ACPF tool was used to identify agricultural fields most at risk of contributing runoff to waterways. The criteria used to evaluate priority fields included fields with a high runoff risk index value, presence of a grassed waterways, and the likelihood of manure application. The stream power index threshold used to identify candidate locations for installing a grassed waterway, to mitigate the potential for gully formation, was set to 2.5 standard deviations above the mean.

The mapped outputs from the ACPF for Brooks Creek, Hess Lake (Minnie Creek and Four Mile Creek) and Bigelow Creek watersheds are presented in Figure 2.

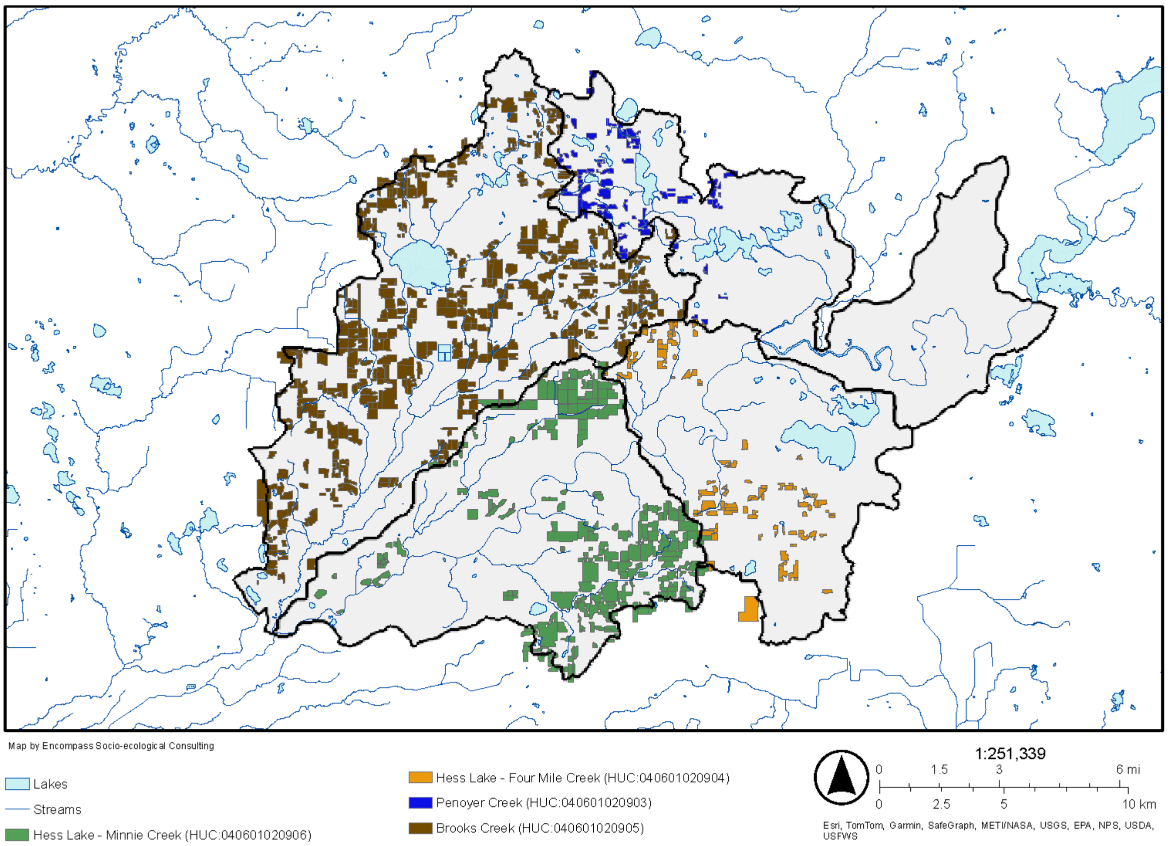

Figure 2. Priority fields identified in the Agricultural Conservation Planning Framework for three subwatersheds in the Lower Muskegon River Watershed.

The highest number of priority fields were in Brooks Creek with Hess Lake ranking as second (Table 5).

Table 5. The number and acreage of priority fields identified in the Agricultural Conservation Planning Framework for three subwatersheds in the Lower Muskegon River Watershed.

Subwatershed	Number of Fields
Brooks Creek	474
Hess Lake (Four Mile Creek subbasin)	97
Hess Lake (Minnie Creek subbasin)	234
Bigelow Creek (Penoyer Creek subbasin)	73

Appendix H. Existing Programs and Local Ordinances

Note for Table: The following existing programs and local ordinances are compiled from several municipalities located in the Lower Muskegon River Watershed. Because of the many documents that are represented, the use of the terms, “Ordinary High-Water Mark”, “Ordinary High-Water Level”, “High Water Line”, “Visual High-Water Mark”, “Normal High Water Line” and “High Water Mark” are often used interchangeably, depending on the municipality. Each of these terms generally refer to the physical line on the shoreline where the water's presence and action are so continuous that it leaves a distinct mark, separating upland and bottomland. For the purpose of Appendix H, we standardize the terminology and only use Ordinary High-Water Mark as defined in the Administrative Rules of Part 325 (https://www.michigan.gov/egle/about/organization/water-resources/submerged-lands/ordinary-high-water-mark-ohwm).

Municipality	Policies
Garfield Township	**Zoning Ordinance**- Has a Muskegon River overlay zone; a minimum buffer zone or strip of at least 35 feet in width as measured from the water’s edge or Ordinary High-Water Mark shall be maintained in its natural or vegetative state (no fertilizer or other chemicals within buffer; septic tanks must be located further than 100 feet to the OHWM of the Muskegon River.
Sheridan Charter Township	**Zoning Ordinance**- Grading or removal of vegetative cover shall not be permitted within 25 feet of a wetland; grading or removal of vegetative cover and new structures shall not be permitted within 25 feet of an intermittent stream or 50 feet of a perennial stream; lists hazardous materials standards (i.e. stored a minimum of 200 feet from any wetland, lake, or stream); a 100 foot waterfront setback shall be required for septic systems on lots adjacent to a lake, river, creek or stream; a minimum of 25 foot natural vegetative buffer shall be maintained parallel and immediately adjacent to the bank or OHWM.
Dayton Township	**Zoning Ordinance**- Grading or removal of vegetative cover shall not be permitted within 25 feet of a wetland; grading or removal of vegetative cover and new structures shall not be permitted within 25 feet of an intermittent stream or 50 feet of a perennial stream; lists hazardous materials standards (i.e. stored a minimum of 200 feet from any wetland, lake, or stream); a 100 foot waterfront setback shall be required for septic systems on lots adjacent to a lake, river, creek or stream; a

	minimum of 25 foot natural vegetative buffer shall be maintained parallel and immediately adjacent to the bank or OHWM.
Sherman Township	**Zoning Ordinance**- No septic or drainage system shall be within 40 feet of any inland lake or stream; no sewage disposal system shall be located closer than 100 feet to the OHWM on any body of water; a natural vegetation strip 50 feet wide, bordering the water's edge, shall be left undisturbed, or if disturbed shall be planted and maintained in trees and shrubs (opening to access water shall not exceed 10 feet); CAFOs should be 1000 feet from any standing body of water.
Bridgeton Township	**Zoning Ordinance**- Trees and shrubs may only be pruned or trimmed within 50 feet of the OHWM to obtain a view of the water's edge but may not be clear-cut or removed; any part of a septic system shall not be located closer than 100 feet from the OHWM.
City of Fremont	**Zoning Ordinance**- Grading or removal of vegetative cover shall not be permitted within 25 feet of a wetland; grading or removal of vegetative cover and new structures shall not be permitted within 25 feet of an intermittent stream or 50 feet of a perennial stream; lists hazardous materials standards (i.e. stored a minimum of 200 feet from any wetland, lake, or stream); a 100 foot waterfront setback shall be required for septic systems on lots adjacent to a lake, river, creek or stream; a minimum of 25 foot natural vegetative buffer shall be maintained parallel and immediately adjacent to the bank or OHWM.
City of Newaygo	**Zoning Ordinance**- Not applicable, no specific language protecting natural resources from non-point source pollution.
Newaygo County	**Newaygo County Recreation Plan**- Goal to maintain natural resources and rural character of Newaygo County through recreational uses.
Brooks Township	**Zoning Ordinance**– A 35' natural vegetative strip from the water's edge or OHWM; any walkways placed within vegetative strip should be no greater than 10' in width; requires greenbelt for lake (minimum 25' Natural Vegetative Strip); walkways no more than 5' in width; land cover restrictions (within 25' of water's edge or the OHWM, no land area or ground shall be covered by any impervious surface).
Everett Township	**Zoning Ordinance**- No wetlands shall be filled, altered or disturbed; no CAFOs, slaughterhouses, gas stations, automobile repair shops, automobile washes/oil-change establishments, industrial uses, livestock, or junk yards are allowed within 400 feet of water's edge; no septic tanks within 100 feet of the OHWM; in the surface water overlay district, a maximum of 400 square feet of land may be covered by impervious surfaces; a natural vegetative buffer shall provide a planted green belt strip of land or area 25 foot wide maintained in its natural state; vegetation of no more than 25% of the length of this buffer can be removed, provided that this cutting does not create a clear-cut opening greater than 25 feet wide for every 100 feet of shoreline.

Croton Township	**Zoning Ordinance**- A vegetative strip of at least 25 feet bordering each bank of the waterways shall be maintained in its natural, unmowed, and unfertilized vegetative state; Intensive livestock operations shall be located at least 500 feet from any body of water or floodplain (includes buildings, structures, enclosed areas or storage areas for wastes, feed or other associated material).
Big Prairie Township	**Zoning Ordinance**- A vegetative strip of not less than 25 feet shall be maintained from the OHWM as a buffer to the waterfront; within this vegetative strip a space of no greater than 25 feet in width may be selectively trimmed and pruned to allow for the placement of a private boat dock and/or view of the waterway; septic fields and systems shall be a minimum of 100 feet from the OHWM.
City of Grant	**Zoning Ordinance**- Provisions are designed to conserve and protect lands, water and other natural resources; Wellhead Protection Plan (2003).
City of Bridgeton	**Zoning Ordinance**- Trees and shrubs may only be pruned or trimmed within 50 feet of the OHWM to obtain a view of the water's edge but may not be clear-cut or removed; any part of a septic system shall not be located closer than 100 feet from the OHWM.
Ashland Township	**Zoning Ordinance**- Sanitary waste systems should be setback 50 feet from the water's edge; disposal system shall be at least 4 feet above seasonal high water table; a strip 25 feet wide bordering each river bank in the river district shall be maintained in trees or shrubs or its natural state; a 100 foot setback from the water's edge is required for any and all parts of the disposal system; no septic tank or disposal field shall be nearer than 40 feet to any subsoil drainage system emptying into the river or major tributary shown on the zoning map.
Egelston Township	**Zoning Ordinance**- No waste disposal site, dump or landfill should be allowed at any place in the Township except those licensed by the State.
Moorland Township	**Zoning Ordinance**- No garbage, rubbish, trash or other waste within any park, stream or lake or river; no primary structures or private sewage systems shall be located less than 50 feet from the OHWM of any surface body of water and all major county drains; no accessory structures shall be located less than 50 feet from the normal high water line of any surface body of water and all major county drains; a natural vegetative strip of 50 feet wide bordering each side of any river or around lakes shall be maintained.
Muskegon Township	**Zoning Ordinance**- A strip at least 25 feet in depth bordering each bank of any watercourse line shall be maintained in its natural vegetative state; a space no greater than 10 feet may be selectively trimmed and pruned to allow for walkways.
Dalton Township	**Zoning Ordinance**- In open space area developments (structures and septic systems shall not be located within 100 feet of any stream bank or

	highwater line; an undisturbed natural vegetation buffer of 25 feet in width shall be maintained immediately adjacent and parallel to any wetland, lake or stream bank or high-water line; where an open space development abuts a lake or stream, at least 50 percent of the shoreline, as well as reasonable access to it, shall be part of the common open space land); Natural features protection for Planned Unit Developments (preserve landscape and natural features; all structures at least 100 feet away from any lake or stream bank or OHWM; undisturbed natural vegetation buffer of 25 feet in width shall be maintained parallel and immediately adjacent to any wetland, lake or stream from the bank or high water mark).
Cedar Creek Township	**Zoning Ordinance**- Soil and gravel stockpiles shall not be located within 200 feet of wetlands or water bodies, extraction operations shall not occur within 100 feet of a wetland or waterbody, an undisturbed natural vegetative buffer strip shall be provided immediately adjacent to wetlands or water bodies during excavation activities.

Resources:

Brooks Township Master Plan-2017 (https://brookstownship.org/wp-content/uploads/2019/12/2017-masterplan.pdf)

Brooks Township Zoning Ordinance-2015 (https://brookstownship.org/wp-content/uploads/2019/12/7-1-15-updated-brooks-zo-book.pdf)

City of Newaygo Master Plan-2019 (https://newaygo.gov/documents/NewaygoMasterPlan_Adopted20190311B_lowrez_fykko.pdf)

City of Newaygo Zoning Ordinance (https://library.municode.com/mi/newaygo/codes/code_of_ordinances?nodeId=PTIIIZOOR)

City of Newaygo Wellhead Protection Plan-2014 (https://newaygo.gov/documents/Wellhead_Protection_Program_RnChw.pdf)

Fremont Community Joint Zoning Ordinance (applies to Dayton Township, Sheridan Charter Township and the City of Fremont)-2013 (https://fremont.ordinances.org/)

Fremont Community Joint Comprehensive and Growth Management Plan (applies to City of Fremont, Dayton Township, and Sheridan Charter Township)-2016 (https://www.cityoffremont.net/DocumentCenter/View/780/Fremont-Community-Joint-Comprehensive-Plan-2016)

Garfield Township Newaygo County Zoning Ordinance-2020 (https://www.garfieldtownship.org/_files/ugd/622fa0_b24d146d56664114b633a26b6171ecad.pdf)

Big Prairie Township Recreation Plan-2020-2024 (https://wmsrdc.org/wp-content/uploads/2019/11/Big-Prairie-Recreation-Plan-2020.pdf)

Big Prairie Township Newaygo County Zoning Ordinance-2013 (https://www.bigprairietownship.org/_files/ugd/cdd669_4eae00f9e37546c985c868ff9d73608c.pdf)

Fremont Area Parks and Recreation 5-year Master Plan (applies to Dayton Township, Sheridan Charter Township and the City of Fremont)- 2020-2024 (https://www.cityoffremont.net/DocumentCenter/View/1409/Rec-Plan-2020---rev-1-22-2020)

Sherman Township Master Plan-2019 (https://nebula.wsimg.com/c3c534e08985e7f0940d6654511ca8e0?AccessKeyId=D49288E7F43BCBBA95C7&disposition=0&alloworigin=1)

Sherman Township Zoning Ordinance (https://nebula.wsimg.com/7bd1c73e56c2b8528ab4e7d440a1d118?AccessKeyId=D49288E7F43BCBBA95C7&disposition=0&alloworigin=1)

Bridgeton Township Master Plan-2011 (https://wmsrdc.org/wp-content/uploads/2015/08/BridgetonPlanUpdate_2011.pdf)

Bridgeton Township Zoning Ordinance- (https://bridgetontownship.org/wp-content/uploads/2022/03/Zoning-Ordinances-Book-revised-2018-converted-compressed.pdf)

Everett Township Zoning Ordinance-2023 (https://nebula.wsimg.com/c3dfa9595b8cc86d3b17916390c481ba?AccessKeyId=73C488F163465925EAFB&disposition=0&alloworigin=1)

Croton Township Zoning Ordinance-2014 (https://www.crotontownship.org/my-township)

City of Grant Master Plan-2009 (https://www.cityofgrantmi.com/images/Master_Plan.pdf)

City of Grant Zoning Code-2010 (https://www.cityofgrantmi.com/images/ORDINANCE_27-2_Repeal_and_Amend_Zoning_Code_as_amended_October_2010.pdf)

City of Grant Five Year Recreation Plan-2012-2017 (https://www.cityofgrantmi.com/images/2012-17_Rec_Plan_FINAL.pdf)

Ashland Township Master Plan-2008 (https://cms3.revize.com/revize/ashlandtwp/document_center/Departments/AT_Master_Plan_Working.pdf)

Ashland Township Zoning Ordinance-2011 (https://cms3.revize.com/revize/ashlandtwp/zoning/Ashland%20Zoning%20August%202017%20final%20on%20flash.pdf)

Egelston Township Master Plan-2014 (http://www.egelstontwp.org/Portals/24/Master%20Plan/2014%20-%202019%20Approved%20Master%20Plan.pdf?ver=JHnAOinEvTDWzxBk4sbrpg%3d%3d)

Egelston Township Zoning Ordinance-2015 (http://egelstontwp.org/Portals/24/Municode%20Old%20Code%20Book/Ordinances%20Updated/CHAA%20-%20APPENDIX%20A%20%20ZONING-Amended.pdf?ver=rBBaH_-rBF20XuJDXqo75g%3d%3d)

Muskegon Township Master Plan-2022 (https://muskegontwpmi.gov/wp-content/uploads/2023/08/Master-Plan.pdf)

Muskegon Township Zoning Ordinance

(https://library.municode.com/mi/muskegon_chrtr_township,_(muskegon_co.)/codes/code_of_ordinances?nodeId=COOR_CH58ZO_ARTIIIZODI_DIV15PACODI)

Dalton Township Zoning Ordinance-2022 (https://library.municode.com/mi/dalton_township,_(muskegon_co.)/codes/zoning)

Dalton Township 2024-2028 Parks and Recreation Plan (https://library.municode.com/mi/dalton_township,_(muskegon_co.)/munidocs/munidocs?nodeId=64f68af5f9602)

North Central Muskegon County Joint Planning Commission Comprehensive Development Plan-2007 (Dalton, Blue Lake, Laketon, Fruitland, and Muskegon Townships) (https://wmsrdc.org/wp-content/uploads/2015/08/NCMC-JPC-plan-2007.pdf)

Cedar Creek Township Zoning Ordinance-2018 (https://assets-global.website-files.com/5d28aa4e0c377d83781d0682/5e6809abb81a29af9af27056_Cedar%20Creek%20Zoning%20Ordinance.pdf)

Egelston Township Parks & Recreation Plan- (http://egelstontwp.org/Portals/24/Parks%20and%20Recreation/Parks%20n%20Rec%20Part%201%202019-2024.pdf)

Newaygo County Recreation Plan- (https://wmsrdc.org/wp-content/uploads/2017/07/Newaygo-Co-Rec-Plan_2018-2022.pdf)

Moorland Township Zoning Ordinance- (https://library.municode.com/mi/moorland_township,_(muskegon_co.)/codes/compilation-general_and_zoning?nodeId=PA15_15.000REREPRORNO15-50AADAU142008)

Muskegon Township Parks and Recreation Master Plan-2022 (https://muskegontwpmi.gov/wp-content/uploads/2023/02/Muskegon-Township-Parks-Plan-2022.pdf)

Cedar Creek Township Parks and Recreation Plan- (https://assets-global.website-files.com/5d28aa4e0c377d83781d0682/638a4632782b4733e0f0b79c_Cedar%20Creek%20Township%20Community%20Park%20%26%20Rec%20Plan%2011-22%20Draft.pdf)