Lake Monroe Watershed Management Plan

Maggie Sullivan
February 23, 2022

FRIENDS OF LAKE MONROE

Acknowledgements

Development of the Lake Monroe Watershed Management Plan was funded in part by the United States Environmental Protection Agency under assistance agreement (C9-97548218) to the Indiana Department of Environmental Management. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Additional financial support was provided by the Monroe County Stormwater Board, the City of Bloomington Utilities Service Board, City of Bloomington Office of Economic and Sustainable Development and Sassafras Audubon Society. This project would not have been possible without their generous support.

Many thanks to our other partners including the Indiana Department of Environmental Management; Monroe, Brown, and Jackson Soil and Water Conservation Districts; Natural Resource Conservation Service; Indiana University Limnology Lab; the Indiana Department of Natural Resources; the U.S. Army Corps of Engineers; the U.S. Forest Service; The Nature Conservancy; the League of Women Voters of Bloomington and Monroe County; the League of Women Voters of Brown County; Visit Bloomington; Indiana Geological and Water Survey; Monroe County Council; Bloomington Chamber of Commerce; Bloomington Environmental Commission; Monroe County Commission; and Brown County Regional Sewer District;

Many thanks to our steering committee members: Terry Ault (Jackson County Soil & Water Conservation District), Cara Bergschneider (Natural Resources Conservation Service), Lee Florea (Indiana Geological and Water Survey), Richard Harris (Friends of Lake Monroe), Bill Jones (Sassafras Audubon Society), Erin Kirchhofer (Brown County Soil & Water Conservation District), Melissa Laney (Indiana University School of Public and Environmental Affairs), Mary Madore (Friends of Lake Monroe), Mike McAffee (Visit Bloomington), Duane McCoy (Indiana Department of Natural Resources Forestry Division), Chad Menke (Hoosier National Forest), Martha Miller (Monroe County Soil & Water Conservation District), Sherry Mitchell-Bruker (Friends of Lake Monroe), Melissa Moran (The Nature Conservancy), Cheryl Munson (Monroe County Council), Dave Parkhurst (Bloomington Environmental Commission), Sarah Powers (Indiana University Limnology Lab), Erin Predmore (Bloomington Chamber of Commerce), Cate Reck (Indiana University Department of Chemistry), Jim Roach (Indiana Department of Natural Resources Parks Division), Allison Shoaf (Natural Resources Conservation Service), Tyler Steury (City of Bloomington Utilities), Tony Smith (Fourwinds Marina), Julie Thomas (Monroe County Commissioners), Lauren Travis (City of Bloomington Economic and Sustainable Development), Sam Whiteleather (Indiana Department of Natural Resources Fish and Wildlife Division), and Zac Wolf (United States Army Corps of Engineers).

Thank you to the Friends of Lake Monroe Board of Directors: Keith Bobay, Lily Bonwich, Kevin Dogan, Tom Gallagher, Richard Harris, Shelby Hoshaw, Jim Krause, Mary Madore, Sherry Mitchell-Bruker, Cheryl Munson, Joe Ryan, and Carolyn Waldron.

Special thanks to the League of Women Voters of Bloomington and Monroe County, the League of Women Voters of Brown County, the First United Methodist Church, and the Brown County Public Library for their assistance with our community forums. Many thanks to Vickie Dacey for creating our forum surveys and Dave Simcox for organizing the events. Thank you to Anne Fraker, Ann Birch, Nancy Boerner, Joe Bonnert, Patty Dennison, Tom Duffy, Gini Emigh, Julie Lowe, Shari Frank, Elaine Gaul, Kara Hammes, George Hegeman, JoAnne Himebaugh, Jeanne Lager, Deborah Meader, Heather Nicholson, Pam Raider, Allison Shoaf, Laura Teal, Susan Wensel, MaryAnn Williams, and Laura Young for facilitation at the forums.

We are grateful to Roger Kelso and Robin Willey of the Nashville Sewage Treatment Plant; Mike Kelly and Jeff Riegel of Stone Head Nature Preserve; and Clint Studebaker of the Brown County Regional Sewer District for presenting during our Lake Monroe Watershed Tour.

Special thanks to Amanda Duba for assistance with graphic design and to Chuck Wills of Content Management Systems, Inc. for web support.

We are grateful to the Hoosier Trails Council Boy Scouts of America in Bloomington, Brown County Inn in Nashville, Story Inn in Story, Gatesville Country Store in Gatesville, and the Pershing Volunteer Fire Department in Freetown for hosting our volunteers during the watershed sampling blitz events. Huge thanks to Lynnette Murphy for coordinating the event. Thank you to all the volunteers who assisted with sample collection.

Table of Contents

Index of Figures

Index of Tables

Appendices

Appendix A – Stakeholder Concerns
Appendix B – Practitioner Survey
Appendix C – Tributary and Lake Monroe Monitoring Lab Data 2020-2021 IU Limnology Lab
Appendix D – Tributary and Lake Monroe Monitoring Field Data 2020-2021 IU Limnology Lab
Appendix E – Lake Monroe Watershed Monitoring Blitz Data 2020-2021 IU Limnology Lab
Appendix F – Brown County Regional Sewer District E. Coli Sampling Data
Appendix G – Fecal Contamination Source Sampling Methodology and Results
Appendix H – CBU Contaminant Testing List
Appendix I – HUC-12 Subwatershed Ranking Methodology
Appendix J– Detailed HUC-12 Subwatershed Detailed Assessment
Appendix K – Best Management Practices
Appendix L – Water Budget, Nutrient Budget, and Flow Frequency Analysis Calculations

Commonly Used Acronyms

BCRSD	Brown County Regional Sewer District
CAFO	Concentrated Animal Feeding Operation
CBU	City of Bloomington Utilities
CFO	Confined Feeding Operation
CFS	Cubic Feet per Second
CFU	Colony Forming Units
CQHEI	Citizens Qualitative Habitat Evaluation Index
FEMA	Federal Emergency Management Agency
FLM	Friends of Lake Monroe
HUC	Hydrologic Unit Code
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IU	Indiana University
IUPUI	Indiana University Purdue University Indianapolis
LARE	Lake and River Enhancement Program (IDNR)
mIBI	Macroinvertebrate Index of Biotic Integrity
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NWI	Nastional Wetlands Inventory
QHEI	Qualitative Habitat Evaluation Index
SPEA	School of Public and Environmental Affairs
SRP	Soluble Reactive Phosphorus
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index

TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USFS	United States Forest Service
USGS	United States Geological Survey
WMP	Watershed Management Plan
WWTP	Waste Water Treatment Plant

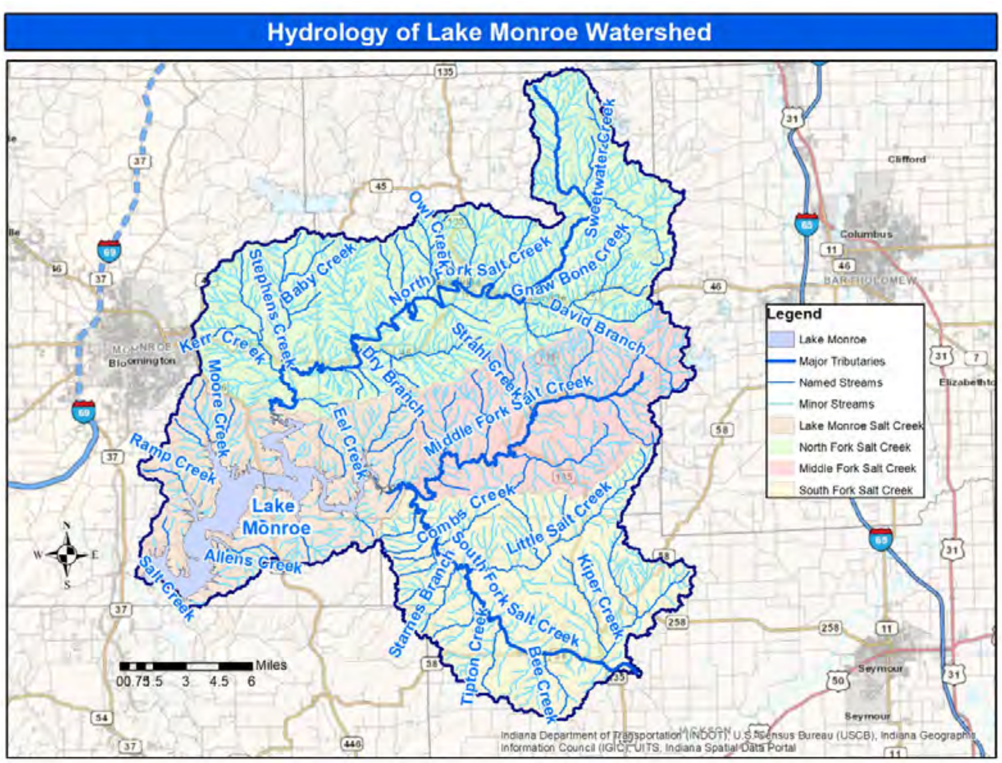
Executive Summary

Friends of Lake Monroe has published a watershed management plan

Lake Monroe is the largest lake in Indiana, providing drinking water for over 130,000 people and generating over $40 million annually in recreational spending. Friends of Lake Monroe worked for three years to develop the 2022 Lake Monroe Watershed Management Plan. This report identifies the top threats to water quality in Lake Monroe and provides an action plan to address those threats over the next 20 years. Protecting water quality in Lake Monroe will require reducing phosphorus, nitrogen, sediment, and E. coli loads entering the lake from the watershed.

The Lake Monroe watershed spans 441 square miles

Water quality in the lake is directly connected to activities in its watershed, the area of land that drains into the lake. Lake Monroe's watershed is large (441 square miles) and spans portions of Brown, Jackson, and Monroe Counties. Topography is steep and soil is highly erodible. Over 82% of the watershed is forested and farming is generally limited to the wide valleys of Lake Monroe's three main tributaries (North Fork, Middle Fork, and South Fork Salt Creek). The area is largely rural and an estimated 9,000 households are served by on-site septic systems. Pollutants in the watershed such as fertilizer, animal manure, sediment, and septic system leakage are washed into the lake when it rains.



Hundreds of community members and organizations participated

A big part of the planning process was building community support and collaboration. More than 20 partner organizations spanning Monroe, Brown, and Jackson Counties participated in the plan development. Over 100 community members attended our public forums and voiced their concerns about Lake Monroe. Over 200 community members learned about the project through public presentations and school programs. Over 100 community members volunteered to assist with water quality sampling in the watershed.

Hundreds of measurements were made to understand water quality

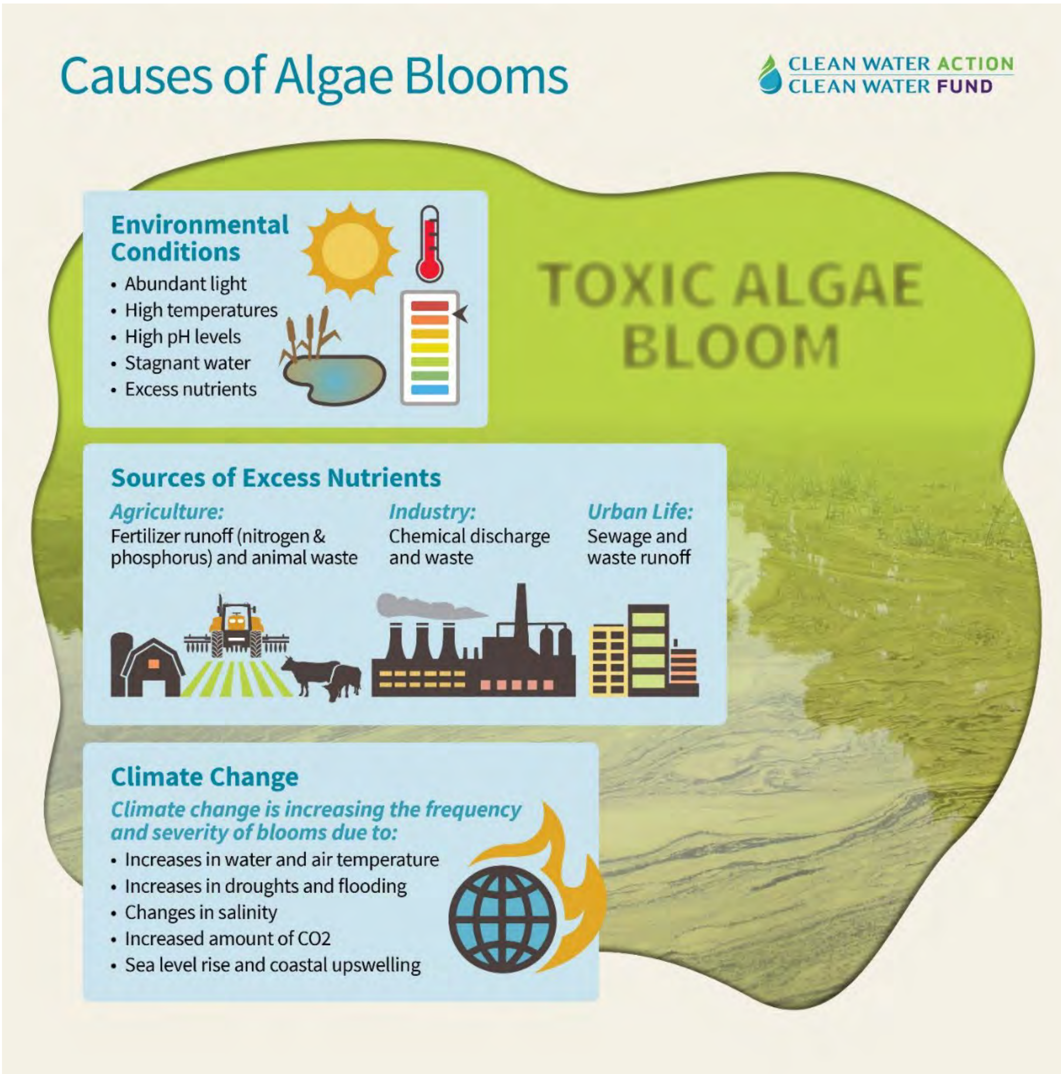
Our water quality monitoring program had three main components. Lake Monroe was sampled monthly from April 2020 – October 2020. Four tributaries feeding Lake Monroe and the tailwaters leaving Lake Monroe were sampled monthly from April 2020 – March 2021. Two sampling blitz events were held to collect samples from 125 sites in the watershed to get a snapshot view of water quality in both large and small streams. Over 240 stream crossings throughout the watershed were inspected to document streambank erosion, width of riparian buffer, livestock access to streams, and other stream conditions. This information was used to develop sediment and nutrient budgets for the lake and to identify areas of concern in the watershed.

Harmful algal blooms impact recreation and drinking water treatment

Harmful algal blooms (HABs) are caused by a type of plankton called cyanobacteria. Although they are often referred to as blue-green algae, they are technically bacteria. Several species of cyanobacteria have the potential to produce toxins. Even when cyanotoxins are absent, swimmers can experience skin irritation and the algae can cause taste and odor issues in drinking water. Recreational advisories based on elevated levels of blue-green algae were issued at Lake Monroe for the Fairfax and Paynetown beaches annually 2011-2021. City of Bloomington Utilities has recently upgraded their algae monitoring equipment and treatment train options to quickly respond to elevated algae levels in the raw water entering their drinking water treatment plant.

Nutrients promote harmful algal blooms

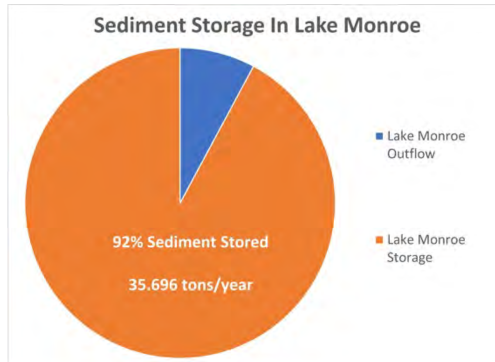
Lakes with phosphorus concentrations over 20 µg/L are considered eutrophic and can be expected to have more severe and frequent algal blooms. Phosphorus concentrations in Lake Monroe historically and today are regularly above that threshold. North Fork Salt Creek appears to be the largest contributor of phosphorus with the South Fork not far behind. Potential sources of phosphorus include fertilizer (from agricultural, commercial, or residential usage), animal manure, septic system leachate, and sediment.



Elevated nitrogen concentrations also increase the likelihood of harmful algal blooms. Nitrogen levels in Lake Monroe were above target levels in more than half of the 2020 samples. South Fork Salt Creek appears to be the largest contributor of nitrogen by a significant margin. This correlates strongly with the fact that the South Fork sub-watershed has the highest percentage of agricultural land. Potential sources of nitrogen include fertilizer, animal manure, septic system leachate, and sediment.

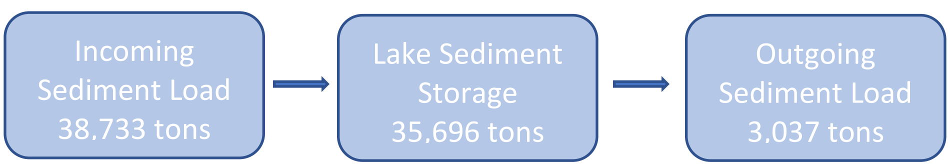
There are other factors that influence algal blooms such as high water temperature and low mixing of water, seen most commonly in the late summer. Climate change models suggest that Indiana is likely to experience warmer weather and more severe summer droughts, which would encourage algal blooms. Since the weather is beyond our control, it is critical to reduce nutrient loads entering Lake Monroe.

Sediment carries nutrients and accumulates in the lake

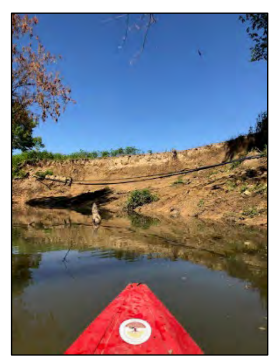


Sediment carries both phosphorus and nitrogen as it moves through the watershed. While sediment movement is natural in streams and rivers, human activity can increase the rate of sedimentation due to soil disturbance, channelized streams, and faster runoff rates. Reservoirs accumulate sediment, so minimizing sedimentation is key to maximizing the lifespan of Lake Monroe. Sediment can also carry other pollutants.

Water quality monitoring in Lake Monroe showed generally low levels of total suspended solids. However, monitoring of the main tributaries and the outlet of the lake showed that significant volumes of sediment are accumulating in the lake. Lake Monroe retains almost 92% of the sediment that enters, with an estimated accumulation rate of 35,696 tons per year. The North Fork sub-watershed appears to be the largest contributor of sediment.



Multiple sources of sediment were identified



Approximately 76% of the Lake Monroe watershed is considered highly erodible due to its steep slopes and soil type. One potential source of sediment is streambank erosion, which was documented at 86% of observed stream sites. Another potential source is conventionally tilled cropland. There are roughly 10,000 acres of cropland (4% of the watershed) and conventional tillage is still commonly practiced. Other potential sources of sediment include livestock with free access to streams, construction sites with insufficient erosion control, and forestry sites with insufficient erosion control.

Community members expressed concern that boating may be contributing to lakeshore erosion. While insufficient data was available to quantify the impact of boating on erosion, established no-wake zones should be respected to reduce the possibility of exacerbating shoreline erosion and stirring up sediment from the lake bottom.

Fecal contamination from humans and animals is widespread in streams

E. coli is an indicator of fecal contamination. While E. coli itself is generally not harmful, many other harmful bacteria and viruses are present in fecal matter. E. coli levels in all the 2020 Lake Monroe samples were well below the state standard of 235 CFU/100 ml (CFU = colony forming units of bacteria). However, historical beach sampling data shows E. coli exceedances in 2015 and 2016 ranging from 632 CFU/100 ml to >2,400 CFU/100 ml.

There were multiple E. coli exceedances in streams throughout the watershed. The South Fork sub-watershed appears to be the largest contributor of E. coli. Source analysis indicates that both human and animal fecal contamination are present. This widespread contamination renders streams unsafe for swimming or wading and contributes to nutrient overloading in the lake. Potential sources include livestock manure, pet waste, wildlife manure, and septic system leachate.

Actions in the watershed are needed to improve water quality in the lake

Anything on the ground in the watershed can be washed into the lake when it rains. The key to protecting and improving water quality in the lake is to keep pollutants such as sediment, fertilizer, animal manure, and septic system leakage from reaching the streams that flow into Lake Monroe. A key strategy will be increasing the use of best management practices on agricultural, forested, residential, and urban land in the watershed.

Best management practices for livestock can reduce nutrient and bacteria input

Livestock are one potential source of nutrients and bacteria. This source can be addressed by increasing the use of conservation practices like fencing livestock out of streams (as shown in photo to the left), installing heavy use area protection, and improving manure management. Streams can be further protected by planting pollinator habitat or trees along streams to create a riparian buffer that filters runoff before it reaches the stream and helps stabilize the stream banks.

Septic system maintenance and repair can reduce nutrient and bacteria input

Poorly functioning septic systems are another potential source of nutrients and bacteria. There are over 9,000 septic systems in the watershed. Many homeowners are unaware that their septic tank should be pumped and inspected about every 3 years. While a properly functioning septic system can be highly effective, another strategy to reduce potential leakage is to expand existing sewer lines and decrease the number of active septic systems.

Best management practices for cropland and forest can reduce sediment and nutrient input

Any activity that disturbs the soil increases the likelihood of sediment (and its associated nutrients) being washed into Lake Monroe. Common examples of soil disturbance are tillage for planting crops, building trails for timber harvests, and clearing sites for construction. Best management practices are available for all these situations that decrease the amount of sediment loss.

For crop land, strategies include cover crops, reduced tillage, filter strips of permanent vegetation at the edge of crop fields, and riparian buffers of permanent vegetation along stream banks. For forested land, strategies include developing a forest management plan, carefully planning trail locations, installing water bars, and seeding trails that are not in use.

Streambank and shoreline stabilization can reduce sediment and nutrient input

While some erosion of stream banks is inevitable (streams by nature move sediment downstream), human activities in the watershed can increase the volume of sediment being transported. Fluctuations in water level within the lake are also believed to directly exacerbate erosion of both the lakeshore and the stream banks. Strategies to address stream bank and lakeshore erosion include stabilization in areas where erosion is severe, fencing livestock out of streams, installing riparian buffers of permanent vegetation along stream banks, adding vegetation to existing riprap, and instituting operational changes at the dam that would reduce water level fluctuations in Lake Monroe.

Our Action Plan is a twenty-year plan

Improving water quality by modifying the watershed is a long-term process. The 2022 Lake Monroe Watershed Management Plan outlines a twenty-year timeline of activities. Key strategies include

- Increasing the adoption of best management practices on agricultural and forested land.
- Expanding riparian buffer along streams.
- Maintaining and repairing septic systems.
- Encouraging green boating practices and “leave no trace” principles.
- Stabilizing key sections of shoreline and streambanks.
- Protecting and restoring floodplains, especially along the three main tributaries (South Fork, Middle Fork, and North Fork Salt Creek).
- Reducing the amount of littering in the watershed.
- Promoting collaboration between different governmental bodies in the watershed.
- Monitoring water quality to evaluate impacts.

Our first steps begin in 2022

Friends of Lake Monroe has launched the “Lake Monroe Community Action Initiative” to promote the watershed management plan and begin implementation. This program is supported in part by the Community Foundation of Bloomington and Monroe County. The focus of this effort is to inform the local community about the watershed plan and engage their support in implementation. Specific components include hosting public forums, organizing a watershed summit for local leaders, launching a social media campaign about how to protect water quality in Lake Monroe, and laying groundwork for a larger implementation project this fall.

Another component of the initiative is a pilot septic system maintenance cost-share program in the Lake Monroe watershed portion of Monroe County. It will help reduce the cost of the septic tank pumpout that should be done every three years to keep a septic system in good shape and catch any problems while they are small. We hope to expand the program into neighboring counties in the future.

Best Management Practice Cost-Share Program 2022-2025

This fall, Friends of Lake Monroe anticipates receiving a second round of funding through the 319 grant program of the Indiana Department of Environmental Management. This grant would pay for a cost-share program subsidizing the installation of best management practices on land throughout the watershed. Examples include establishing pollinator habitat or trees adjacent to streams, fencing livestock out of streams, planting cover crops, and reforesting floodplains. The grant would also fund a variety of education and outreach programs including agricultural field days, forestry trainings, septic system maintenance workshops, boat tours, trash cleanups, green boating campaigns, and educational brochures mailed to every resident in the watershed.

Education and outreach will engage the community in making the plan a reality

Community support at both the individual and governmental level is key to making the Lake Monroe Watershed Management Plan successful. Making improvements to the watershed is a long-term effort that will require participation from governing bodies, landowners, and residents. Our goal is to activate the local community throughout the watershed to collaborate and protect our local water resources. Together we can ensure the health of Lake Monroe and its tributaries for years to come.

For more information, please contact
Maggie Sullivan, Watershed Coordinator
watershed@friendsoflakemonroe.org
(812) 558-0217
www.friendsoflakemonroe.org

Executive Summary Photo Credits

1. Lake Monroe paddler photo courtesy of Visit Bloomington; 2. Hydrology of Lake Monroe map by Friends of Lake Monroe; 3. Community forum photo by Martha Fox; 4. Lienne Sethna sampling photo by Lynnette Murphy; 5. Blue-green algae photo courtesy of CSIRO; 6. Causes of Algal Blooms graphic by Clean Water Fund; 7. Sediment storage pie chart by Friends of Lake Monroe; 8. Sediment storage graphic by Friends of Lake Monroe; 9. Streambank erosion photo by Allison Shoaf; 10. Lakeshore erosion photo by Cathy Meyer; 11. Beach closure sign image courtesy of Indiana Department of Environmental Management; 12. Livestock exclusion fencing courtesy of Western Pennsylvania Conservancy; 13. Septic pumping photo by Daniel Friedman; 14. Riparian buffer photo by Lynn Betts of NRCS/SWCS; 15. Stream restoration photo courtesy of Little Almance Creek Healthy Streams Cooperative; 16. Lake Monroe Needs You graphic by Friends of Lake Monroe; 17. Streambank tree planting photo by Jeff Vanuga of NRCS/SWCS.

1 Community Watershed Initiative

While several research projects and watershed improvement plans were conducted within the Lake Monroe watershed in the late 1990's, the development of a comprehensive watershed management plan can be traced back to the creation of the non-profit Friends of Lake Monroe (FLM) in 2016. The mission of FLM is "to protect and enhance Lake Monroe and its watershed through science, advocacy, and public involvement: working collaboratively with citizens, government, and business to improve and support lake water quality." The group initially focused on compiling existing water quality data, educating the public, and hosting volunteer events such as lakeshore cleanups.

Data compiled by FLM revealed that Lake Monroe can be characterized as eutrophic by national trophic state index (TSI) rankings and at times exceeds this threshold, becoming hypereutrophic with all TSI parameters (total phosphorus, Secchi depth transparency, and chlorophyll-a). Additionally, the Indiana Department of Environmental Management (IDEM) has reported elevated levels of harmful algal blooms in Lake Monroe during each of the 10 years that samples were taken, leading to the issuance of recreational advisories. These recreational advisories have a negative impact on the local economy, as Lake Monroe is a recreational destination that attracts nearly 1,000,0000 visits (person-days) annually per the United States Army Corps of Engineers. Algal blooms also correspond with increased concentrations of total organic carbon (TOC) which can contribute to elevated levels of disinfectant by-products in drinking water produced by the City of Bloomington. Algal blooms can additionally cause taste and odor issues in drinking water. Over 130,000 residents in Monroe, Brown, and Lawrence Counties depend on Lake Monroe as their only source of drinking water. Within the watershed, several streams have been designated as impaired due to elevated levels of E. coli.

As discussed in past studies, the best way to address these and other concerns is with a comprehensive watershed management plan for the Lake Monroe watershed. In 2018, FLM brought together local public officials and concerned citizens to apply for a 319 grant from IDEM to develop a plan. Over thirty organizations submitted letters of support in order to preserve and improve Lake Monroe water quality. In November 2019, FLM hired Maggie Sullivan to be the watershed coordinator and assembled a steering committee (Table 1-1). The organization also began a campaign to increase public awareness with several local newspapers publishing articles as well as radio and TV interviews about the project.

1.1 Community Leadership

The Lake Monroe Watershed Management Plan development was guided by a steering committee with members who represent a multitude of stakeholder groups within the watershed. Individuals representing farmers, businesses, city government, town government, county government, natural resource professionals, educational entities, land managers, and environmental groups comprised the steering committee. Many members came from partnering organizations and stakeholders who had supported the initial grant application.

Potential members were solicited via direct mailing, phone calls, and personal communication. The first informational/steering committee meeting was held on January 20, 2020.

Table 1-1 Steering Committee Members for the Lake Monroe Watershed Management Plan

First Name	Last Name	Organization
Terry	Ault	Jackson County Soil and Water Conservation District
Cara	Bergschneider	Natural Resources Conservation Service
Lee	Florea	Indiana Geological and Water Survey
Richard	Harris	Friends of Lake Monroe
Bill	Jones	Sassafras Audubon Society
Erin	Kirchhofer	Brown County Soil and Water Conservation District
Melissa	Laney	Indiana University School of Public and Environmental Affairs
Mary	Madore	Friends of Lake Monroe
Mike	McAfee	Visit Bloomington
Duane	McCoy	Indiana Department of Natural Resources Forestry Division
Chad	Menke	Hoosier National Forest
Martha	Miller	Monroe County Soil and Water Conservation District
Sherry	Mitchell-Bruker	Friends of Lake Monroe
Melissa	Moran	The Nature Conservancy
Cheryl	Munson	Monroe County Council
Dave	Parkhurst	Bloomington Environmental Commission
Sarah	Powers	Indiana University School of Public and Environmental Affairs
Erin	Predmore	Bloomington Chamber of Commerce
Cate	Reck	Indiana University Chemistry
Jim	Roach	Indiana Department of Natural Resources Parks Division
Allison	Shoaf	Natural Resources Conservation Service
Tyler	Steury	City of Bloomington Utility Service
Tony	Smith	Fourwinds Marina
Julie	Thomas	Monroe County Commission
Lauren	Travis	City of Bloomington Economic and Sustainable Development
Sam	Whiteleather	Indiana Department of Natural Resources Fish and Wildlife Division
Zac	Wolf	United States Army Corps of Engineers

1.2 Stakeholder Involvement

Two community forums were held at the beginning of the project with support from the Bloomington-Monroe County and Brown County chapters of the League of Women Voters. These forums were promoted through articles in local newspapers and organizational e-newsletters as well as via direct e-mail invitations to key community members identified by the League of Women Voters. The first forum was held in Bloomington (Monroe County) in November 2019. The second forum was held in Nashville (Brown County) in January 2020. Both forums followed the same format. Participants were asked to complete a pre-session survey upon arrival. Dr. Sherry Mitchell-Bruker, president of Friends of Lake Monroe, gave a brief presentation about Lake Monroe and the watershed management plan development process. Then participants worked in small groups of 6-8 to brainstorm concerns about the lake. Each group identified their top three concerns and reported back to the entire forum. At the end of the event, each participant completed a post-session survey.

There were three primary goals of the community forums.

1. Explain the purpose and process of developing a watershed management plan.
2. Solicit input from the public on their concerns for Lake Monroe and its watershed.
3. Inform the public on how they can be involved and stay updated on the project.

In total, 114 citizens participated in the forums. Feedback about the forums was very positive. About 60% of attendees were from Monroe County, about 25% were from Brown County, and about 1% were from Jackson County. The remainder included representatives whose agencies work within the watershed but are located in other geographic areas (e.g., Army Corps of Engineers in Louisville, Indiana Department of Natural Resources and other organizations in Indianapolis, Hoosier National Forest in Bedford, etc.) Friends of Lake Monroe created a contact list of all the attendees to provide updates and solicit volunteers for the project. Updates were also provided to the general public at FLM meetings, through the FLM website, through FLM posts on Facebook, as well as in press releases sent to local newspapers.

1.3 Stakeholder Concerns List

After the forums were concluded, the concerns were compiled and consolidated. A full list of stakeholder concerns can be found in Appendix A. The top three concerns from each group were compiled and duplicates were eliminated. The resulting list of 46 concerns is presented below.

Table 1-2 Stakeholder Concerns for the Lake Monroe Watershed

Category	Concern
Drinking Water	• Drinking water quality (nitrates, phosphates, dangerous bacteria, E. coli, toxic blue-green algae) • Drinking water treatment costs as a homeowner • Taste and odor issues with drinking water • Actual ownership of water; ensure water stays here • Fear that lake water would be so undrinkable so it is no longer available as our water supply • Algae blooms affect drinking water treatment
Sedimentation, Siltation, and Erosion	• Silting in of lake – can we stop it • Lake getting more shallow due to sedimentation • Need to quantify siltation rate and identify source(s) • Shoreline erosion • Sedimentation/erosion - entire watershed
Nutrients and Algae	• Algae blooms caused by nutrient loading make the lake unswimmable • Nutrient loading (urban lawns, agriculture, septic systems) • Inappropriate agricultural practices • Lawn maintenance (and its downstream effects) • Effects of septic systems on nutrient loading
Pathogens and E coli	• Waterways are not up to standards; clean up E coli • Pathogens from humans and animals • Failed septic systems • Ensure that boat toilets are properly sealed
Pollution - Chemicals and Trash	• Trash and plastic pollution • Need to quantify what chemicals/pollutants are entering lake • Use of herbicides/pesticides in residential/commercial • Toilet flush of prescription pharmaceuticals
Development	• Development on and around the lake
Forestry	• Effects of logging/forest management (herbicides – amphibians, heavy equipment – road damage) • Keep forests as forests • Unregulated forest management
Invasive Species	• Invasive plants • Asian Carp • Effects of invasive species control

Category	Concern
Lack of Knowledge or Education	• Poor public understanding of how lakes/watersheds function • Educate public and school children • Need more data about water quality and trends
Lack of Management or Clear Jurisdiction	• Lack of oversight/enforcement of polluters, landowners • Uneven distribution of economic return from the lake • Long-term management plan implementation, monitoring, and funding • No drainage ordinance • Deregulation of environmental protection • Collaboration between multiple governments required for implementation; unclear who is in charge
Recreation	• Maintain recreational value • Recreational pollution - how to limit effects, dispel myths • Recreation - boating impacts; responsible use • Large boat engines contribute to erosion, turbidity

1.4 Practitioner Survey

In addition to soliciting input from the general public, a selection of land managers and conservation professionals in the watershed were interviewed to gain a better understanding of conservation practices currently used in the watershed. Melissa Moran with the Nature Conservancy and Richard Harris of Friends of Lake Monroe conducted fifteen interviews with conservation professionals, public land managers, and private landowners. The goal was to understand the best management practices that are working well, the work they would like to implement to better protect Lake Monroe, the current level of investment in conservation work, and what range of investment might be needed to implement the desired but currently unfunded practices. The full report is provided in Appendix B.

The conservation practitioners interviewed represent the Natural Resources Conservation Service (NRCS) offices and the Soil and Water Conservation Districts (SWCD) serving Monroe, Brown, and Jackson counties. These agencies collaborate regularly and work directly with individual landowners to promote conservation of natural resources. Their general takeaways were as follows:

- These organizations in the three counties see many of the same practices implemented, including access roads, brush management, comprehensive nutrient management plans, cover crops, critical area plantings, forest management plans, forest stand improvement, heavy use area pads, high tunnels, invasive species management, mulching, nutrient management plans, and underground outlets.

- However, each county has a different landscape and different property sizes which leads to a different emphasis on soil and water conservation practices in each county.
  - Brown – small to medium projects to assist small livestock operations while leading the way in the implementation of forestry-related practices.
  - Monroe – smaller projects with a diverse mix including livestock, crops, forestry, and urban projects.
  - Jackson – larger projects with an emphasis on crop management, particularly cover crops. Their work is most concentrated in the eastern portion of the county, with few projects in the Lake Monroe watershed.
- They identified the top challenge as increasing public awareness of what conservation practices and funding opportunities are available.
- Specific practices where they would like to see increased implementation to address water quality:
  - More livestock practices such as heavy use area protection, exclusion fencing, watering facility and pipeline, and prescribed grazing.
  - More cover crop adoption.
  - Connecting with hobby farm owners who may not be as aware of erosion issues and conservation programs as traditional farmers.
  - Educating forest owners about forestry best management practices before they conduct a timber harvest so they can implement conservation practices from the beginning (rather than reaching out for help after a harvest has taken place without good BMPs).
  - Streambank stabilization, though there are limited funding opportunities for these projects through NRCS and SWCDs.

The public land managers interviewed represent the Indiana Department of Natural Resources (IDNR) State Park Division, IDNR Forestry Division, United States Forest Services (USFS), United States Army Corps of Engineers (USACE), and Camp Atterbury. Each agency has its own set of internal requirements for BMP application and each agency indicated that their requirements are protective of water quality. Some of their challenges center around lack of capacity in terms of staff and financial resources. Specific challenges are as follows:

- IDNR used to have funds to provide cost-sharing on forest BMPs on private property which they felt was very valuable but budget keeps decreasing.
- IDNR used to offer a logger training at low-to-no cost but will likely need to charge a fee in the future.
- Multiple organizations mentioned the challenges of maintaining trails and a desire for more resources to reduce potential soil compaction, erosion, and sedimentation.
- Multiple organizations mentioned the challenge of upgrading stream crossings to restore natural hydrologic functions, reducing channel incision, and allowing aquatic organisms to pass through easily.
- USFS mentioned floodplain restoration as a goal, with an emphasis on protecting and restoring forested riparian buffer along streams.

- Brown County State Park mentioned the challenge of managing horse manure at their horseman's camp which can contain as many as 600 horses during peak usage; they are pursuing a plan to have the manure hauled away.
- Two organizations mentioned concerns about managing shoreline erosion around Lake Monroe. USFS is currently exploring potential stabilization projects.
- IDNR mentioned that logjam removal is an ongoing challenge that they have not had sufficient resources to tackle.
- Another commonly mentioned challenge was invasive species management.

Three private landowners were interviewed who collectively manage livestock, crops, and forest. They utilize a range of different BMPs. Areas where these landowners see a need for improvement include:

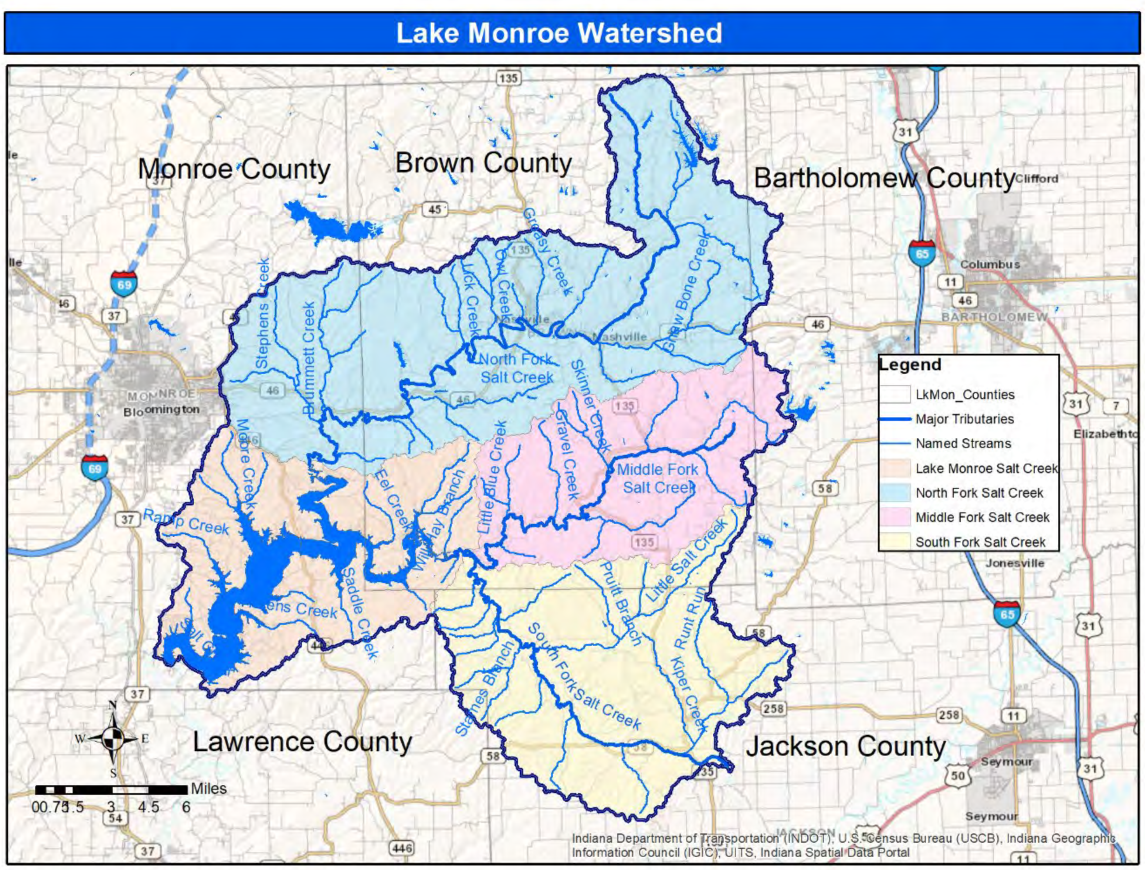
- Education of landowners is key to increasing conservation practice adoption. One landowner noted that it is easier to engage landowners in conservation practices if they have personal ownership and economic ties to their land, rather than landowners who don't earn a living or income from the land.
- All three landowners participate in programs through NRCS and mentioned the importance of outreach and education conducted by NRCS and the county soil and water conservation districts. One landowner participates in the Classified Forest Program through IDNR and mentioned forestry management trainings through IDNR, the Indiana Forestry and Woodland Owners Association, and The Nature Conservancy.
- Landowners in Brown County and Jackson County may not benefit directly from Lake Monroe and may require a different approach to explaining the importance of water quality protection.
- Planting trees, shrubs, grasses, or other buffer vegetation along streams and in floodways is key for protecting water quality though it can be hard to convince famers to take land out of production when crop prices are high.
- Several landowners mentioned that log jam removal is important but also difficult and potentially hazardous.
- Invasive species were also mentioned as an ongoing concern.

2 Description of the Lake Monroe Watershed

Lake Monroe was constructed by the United States Army Corps of Engineers (USACE) in 1964 by damming Salt Creek approximately 10 miles southeast of Bloomington. One primary purpose of the reservoir is to provide flood control in the Ohio River basin and the East Fork of the White River. Another is to provide water supply to the State of Indiana which is currently used as Drinking water for the City of Bloomington. The USACE is also required to store water for low-flow augmentation of Salt Creek and the East Fork of the White River when needed. Other benefits of the lake include recreational use, wildlife preservation, and economic development.

The drainage basin (Fig 2-1) is 441 square miles (282,240 acres) with the majority located in Brown County (56%), followed by significant portions located in Monroe County (21%), Jackson County (21%), and very small portions of Bartholomew County (2%) and Lawrence County (<1%). The drainage basin can be divided into four 10-digit Hydrologic Unit Code (HUC) regions – one for each main tributary and a fourth for the area directly surrounding Lake Monroe. The four 10-digit HUCs are Lake Monroe Salt Creek (0512020807), North Fork Salt Creek (0512020806), Middle Fork Salt Creek (0512020805), and South Fork Salt Creek (0512020804).

Figure 2-1 Lake Monroe Watershed

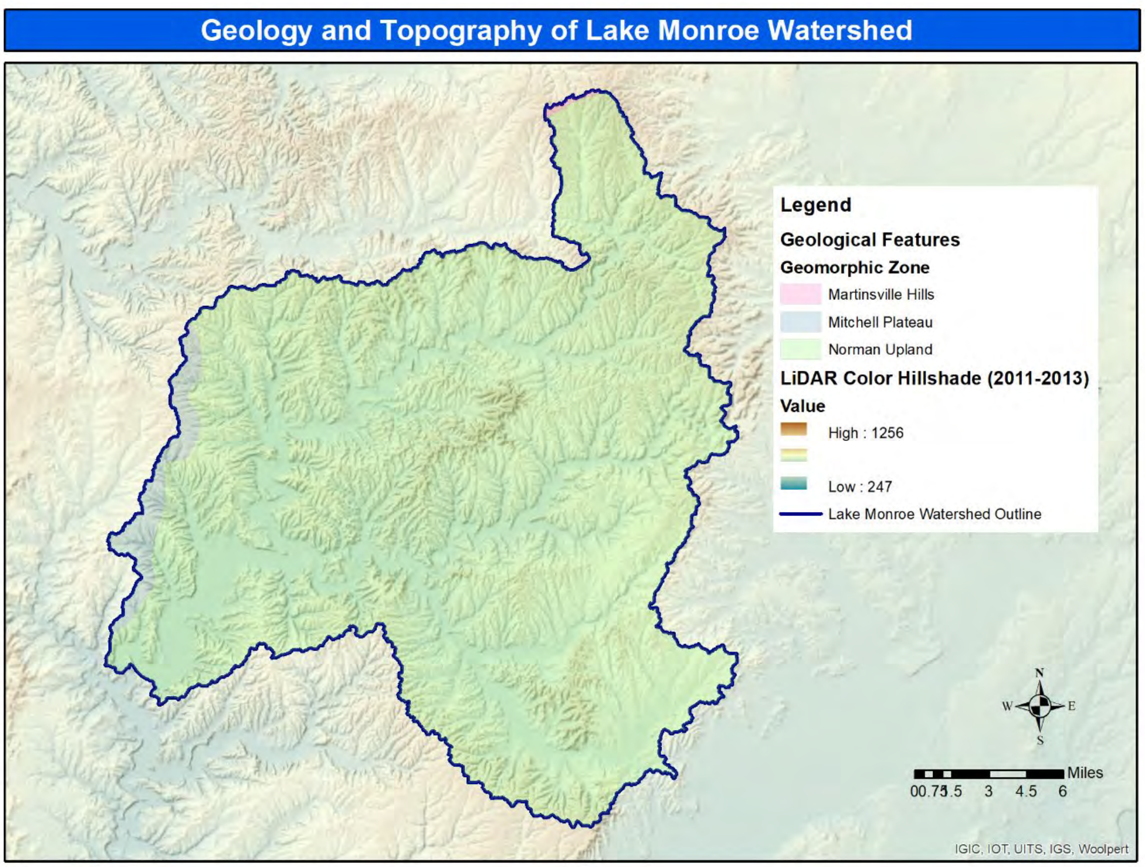


2.1 Geology and Topography

The Lake Monroe watershed lies almost entirely within the unglaciated part of the Norman Upland physiographic unit of southern Indiana (see Figure 2-2). The Norman Upland features steep, high hills and narrow valleys carved into siltstone and shale bedrock. Soils can be thin and patchy in many places, leading to limited suitability for septic systems. Topography ranges between 4 and 26 percent with an average slope of around 15 percent. Steep slopes combined with slow permeability leads to soils that are highly susceptible to erosion.

Karst features are rare in the Norman Upland area, particularly when contrasted with the Mitchell Plateau to the immediate west. A handful of sinkholes are present in the watershed, primarily in Monroe County. Sinkholes provide a potential pathway for surface water to move rapidly and directly into the subsurface with little or no filtration by soil and bedrock. For that reason, it is important to keep potential water pollutants away from sinkholes.

Figure 2-2 Geology and Topography of Lake Monroe Watershed



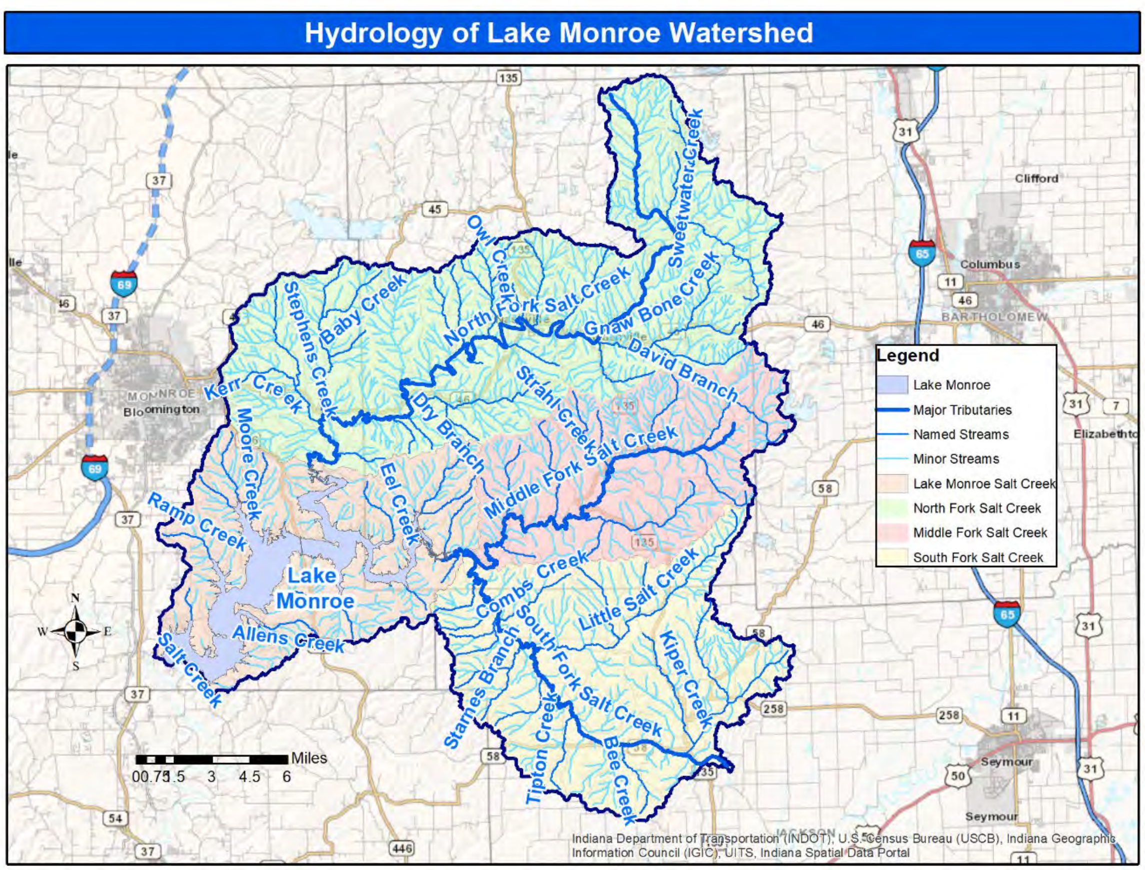
Bedrock is Mississippian and almost entirely (95%) Borden Group, comprised mostly of siltstone with lenses of crinoidial limestone in the upper part. The remaining 5% is Sanders Group, comprised mostly of skeletal limestone that is cherty in the lower part.

Topography in the Lake Monroe watershed is characterized by steep hills with a small percentage of relatively flat land located in the valleys of the three main tributaries (North Fork Salt Creek, Middle Fork Salt Creek, South Fork Salt Creek). Elevations range from about 510 feet to about 1,060 feet. Water flow is generally from east to west, converging on Lake Monroe in the southwest corner of the watershed. The steep topography is the main reason much of the watershed is forested. Attempts by early settlers to farm the hills proved unsuccessful, leading to large scale erosion and gullying. As a result, the land generally reverted to forest.

2.2 Hydrology

The Lake Monroe watershed contains approximately 1,251 miles of mapped streams (see Figure 2-3). Of these, approximately 387 miles are named. The three primary tributaries to Lake Monroe are North Fork Salt Creek, Middle Fork Salt Creek, and South Fork Salt Creek. The North Fork in particular is valued for recreational use by fishers, kayakers, and hunters. Few streams in the watershed appear to have been channelized, and no streams within the watershed are considered legal drains. There are no legal drains in Monroe or Brown Counties. The legal drains in Jackson and Bartholomew Counties are outside the Lake Monroe watershed.

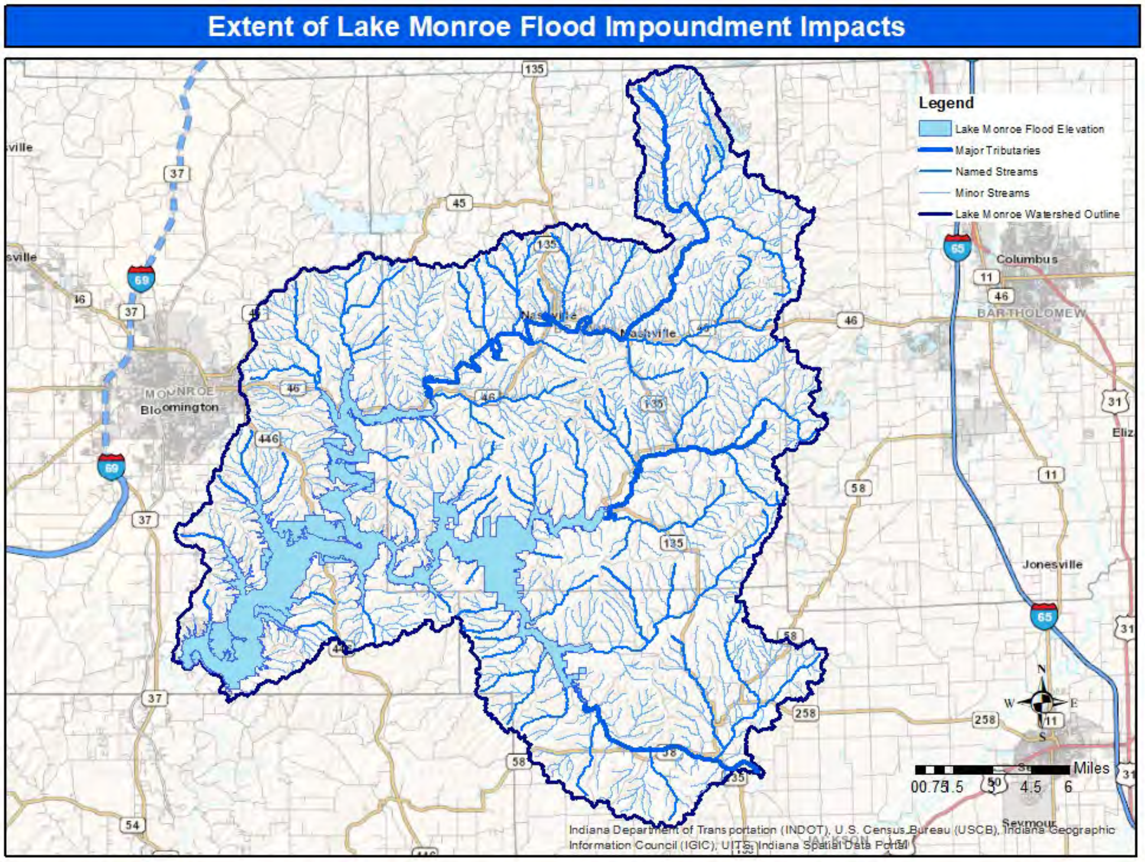
Figure 2-3 Hydrology of Lake Monroe Watershed



Many smaller streams have been dammed to create ponds and lakes for drinking water, wildlife, and recreational use (see section 2.2.4 for more details). Other hydrologic modifications include numerous bridges, culverts, and stabilization efforts along roads. Due to the steep topography of the watershed, many roads run alongside streams to take advantage of the flat valleys. As the watershed is largely rural, few storm drain systems are present and many roads rely on roadside ditches for stormwater conveyance. Ditches are periodically dredged out which leaves exposed soil that can contribute to sediment loads in the waterways. Flood control activities in Lake Monroe have the most significant impact on stream hydrology throughout the watershed. This is most notable in the streams that drain directly into the lake. In most years there is a period in the spring when heavy rains cause the water level in the lake to rise at least ten feet above normal pool elevation. In extreme flooding conditions, the level can rise as much as eighteen feet. (Normal pool elevation is 538 feet and the emergency spillway elevation is 556 feet). The Army Corps of Engineers determines how much water to release at the dam and generally the water is released slowly to prevent downstream flooding. This keeps water levels elevated in the lake for weeks or months, especially if there is heavy rainfall.

Elevated water levels in the lake affect the streams feeding into the lake, effectively turning the lower portions of the streams into still water extensions of the lake. Water flow backs up into the tributaries and becomes stagnant for several miles. This is regularly observed in the main tributaries (North Fork, Middle Fork, South Fork) as well as smaller streams that flow directly into the lake (Moore Creek, Ramp Creek, Allens Creek, Wolfpen Branch). The extent of water backing up in an extreme flood event can be approximated by examining the limits of DNR property management for Lake Monroe (see Figure 2-4) which was set based on the elevation of the emergency spillway. All areas behind the dam that are below the spillway elevation of 556 feet (area in light blue) are owned by the United States Army Corps of Engineers and managed by the Corps, the Indiana DNR, or the US Forest Service. This includes acreage along the streams that flow directly into the lake.

Figure 2-4 Extent of Lake Monroe Flood Impoundment Impacts



Impacts from water level fluctuations in the lake impact streams throughout the watershed, even the headwater ephemeral streams (personal communication with Dr. Bob Barr, IUPUI). This is true for all reservoirs. Changes in flow and streambed composition have a ripple effect that moves upstream to the very beginning of the water system. Streams by nature work to establish a steady channel slope and changes to the stream depth at the downstream end send signals to the upstream end to make adjustments. In lower elevation streams, the most commonly observed change is channel incision. Channel incision is when the streambed (bottom of the stream) digs deeper into the ground in an attempt to modify the stream slope and depth to optimize water movement. An unfortunate side effect of channel incision is that the stream becomes cut off from its floodplain, meaning it cannot overflow its regular banks as easily during large flows. The stream attempts to correct this problem by moving laterally (sideways) to try and create a new floodplain.

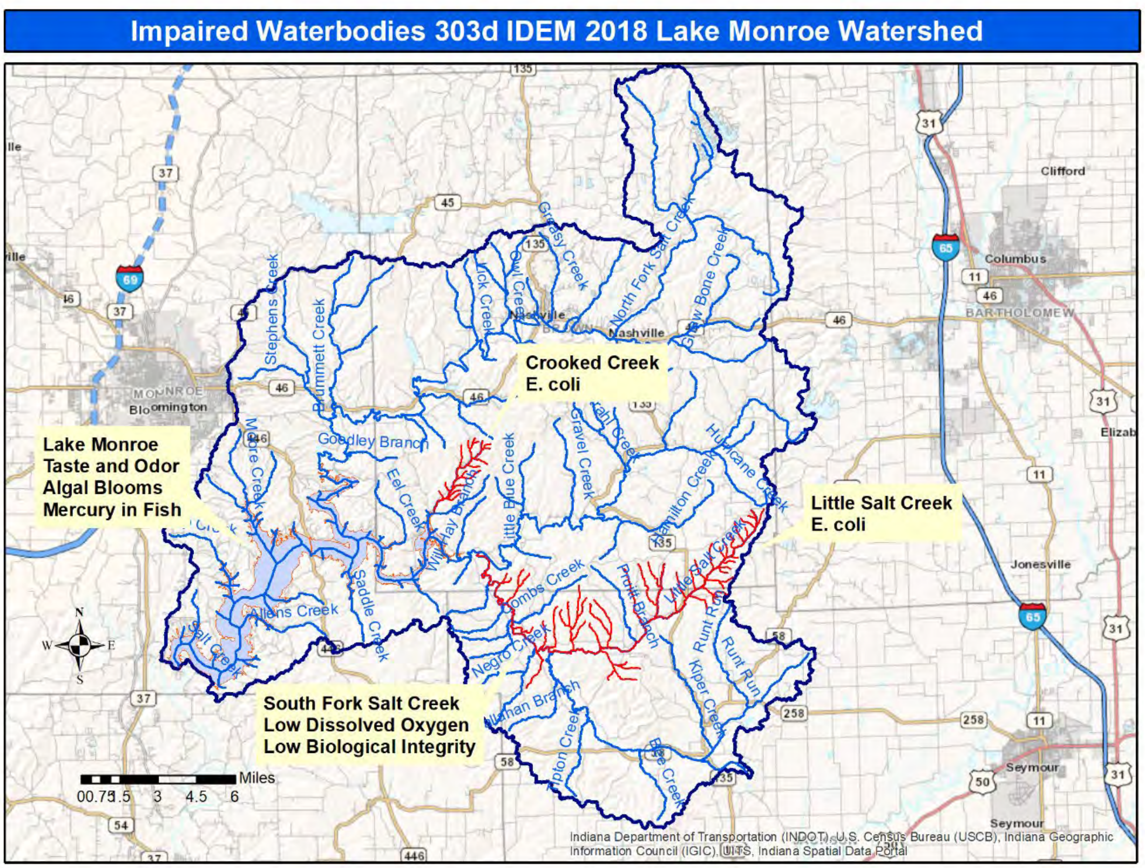
In smaller streams, particularly ephemeral headwater streams, the most commonly observed change is the creation of rills. Rills are abnormally deep channels cut into the ground where an ephemeral stream would normally be located. They often feature a headcut, meaning a location where the streambed drops suddenly in elevation. Headcuts typically migrate upstream over time as the stream attempts to find a consistent stream slope.

Channel incision, lateral movement of streams, and rills generate sediment that flows downstream and is captured in Lake Monroe. While some sediment erosion is inevitable (streams by nature move sediment downstream), these stream adjustments increase the volume of sediment being transported. Fluctuations in water level within the lake are also believed to directly exacerbate erosion of both the lakeshore and the stream banks.

2.2.1 Water Quality Impairments

According to the 2018 Impaired Water Bodies 303(d) list, there are five impaired water bodies in the Lake Monroe watershed. Little Salt Creek and Crooked Creek are impaired for E. coli. South Fork Salt Creek is impaired for dissolved oxygen and biological integrity. Both the upper and lower basins of Lake Monroe are impaired for taste and odor, algal blooms, and mercury in fish.

Figure 2-5 Impaired Water Bodies in Lake Monroe Watershed



2.2.2 Lakeshore and Stream Bank Erosion

For at least 30 years, community members have voiced concerns about Lake Monroe filling in with silt and becoming unusable for recreation or drinking water. While the issue is not nearly as dramatic or pressing as in nearby Lake Lemon, it is a valid concern for every reservoir. Reservoirs by nature trap sediment and it is important to understand the rate of sedimentation and the impacts on different sections of the lake. Anecdotal reports indicate that there are several areas around stream inlets that appear shallower than 10 or 20 years ago. More data are needed to fully understand the issue.

Figure 2-6 Lakeshore Erosion Along Lake Monroe (photo courtesy of Cathy Meyer)

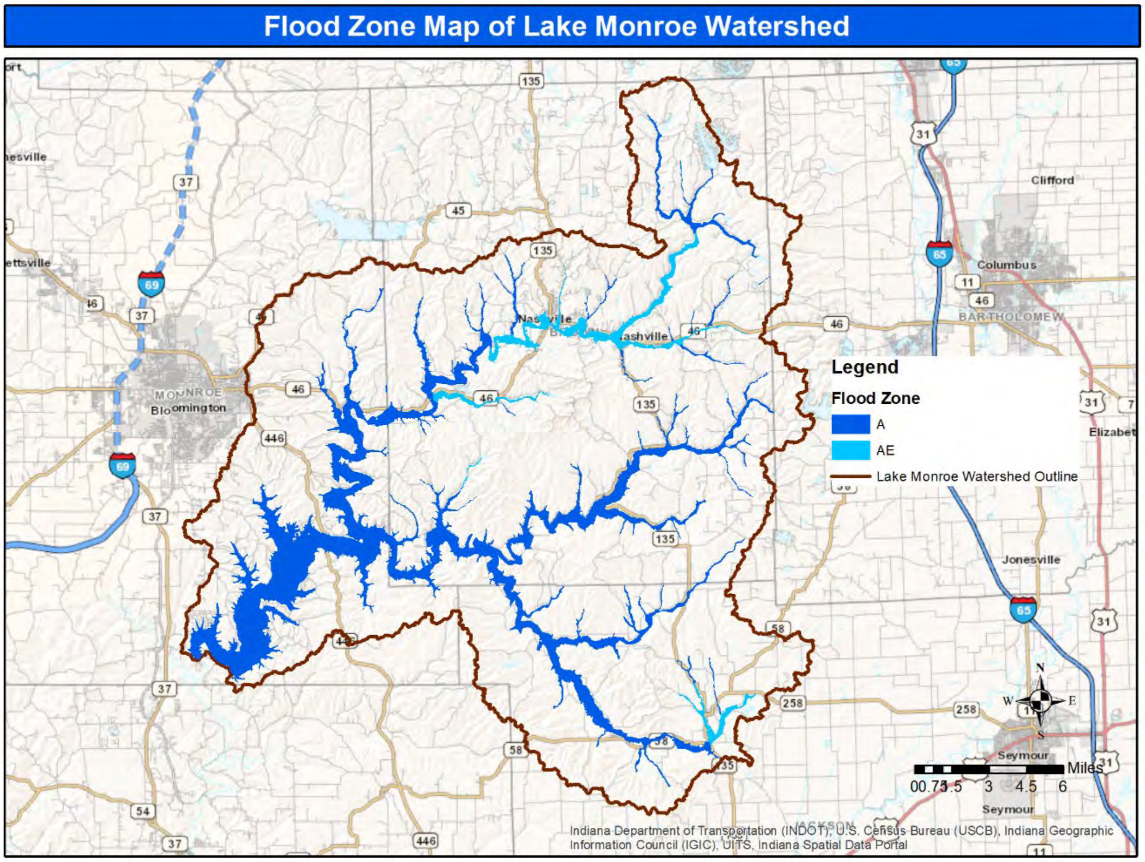
Many community members also expressed concerns about lakeshore erosion as a sediment source and an eyesore. Significant erosion is visible along several stretches of Lake Monroe's shoreline, particularly when water levels are low. Though it is difficult to quantify, shoreline erosion may be a significant source of sediment in the lake. Shoreline erosion is exacerbated by fluctuations in water level due to management of the reservoir for flood control. When water levels are elevated for an extended period of time, the soil becomes saturated and can slough off in large chunks.

Streambank erosion was also observed throughout the watershed during the windshield survey. Severe stream erosion that threatens property was noted along several smaller creeks in the watershed. Many of these areas were on residential property that was mowed to the edge of the stream, eliminating the protection of a riparian buffer. Landowners did not seem aware that their landscaping could be contributing to the problem.

2.2.3 Flooding

Another concern related to stream hydrology is that of property damage from flooding and lateral stream movement. A flood zone map from FEMA reveals wide flood zones along the main tributaries (see Figure 2-7).

Figure 2-7 Flood Zone Map of Lake Monroe Watershed



Concerns are most prominent along North Fork Salt Creek, particularly near the town of Nashville. Several businesses at the intersection of Salt Creek Road and State Road 46 (east of Nashville) flooded in 2015, 2019, and 2020. However, flooding is extremely localized and the Town of Nashville with support from the Brown County Commissioners recently requested a Letter of Map Revision to refine the Federal Emergency Management Agency (FEMA) maps in the Nashville area to more accurately reflect which properties are at risk for flooding and require flood insurance. These revisions were not yet finalized as of November 2021.

Salt Creek Preservation Group, a community group focused on cleaning and improving North Fork Salt Creek, has been working to remove problematic obstructions (log jams) to reduce erosion, improve stream flow, and mitigate flooding. Log jams have potential to increase flooding and lateral stream movement as well as obstructing recreational boating. Log jams seem to be most prevalent on the North Fork Salt Creek but it is likely they are more commonly observed there due to higher recreational traffic levels. Salt Creek Preservation Group pursued and received two IDNR Lake and River Enhancement (LARE) grants to remove logjams in the early 2010's, including one of the state's largest logjams near the Howard farm. They are currently exploring the idea of preserving and naturalizing the floodplains of North Fork Salt Creek and Middle Fork Salt Creek.

Fewer concerns were voiced along Middle Fork Salt Creek and South Fork Salt Creek, perhaps because the areas are more sparsely populated and include a lot of United States Forest Service property. Much of the land along South Fork Salt Creek is used for agriculture, primarily row crops. The Indiana Division of Natural Resources manages two units of land along South Fork Salt Creek that are rented to tenant farmers for crop production. In two of the last four years (2017-2020), tenants were not able to farm due to flooding. Private landowners have presumably had the same experience.

Flooding of roads is another concern. Several rural roads in Monroe County have a history of flooding during high water events in the lake (Monroe County Long Term Stormwater Management Plan 2016). Two notable roads near Lake Monroe are Stipp Road and Moores Creek Road. The county is currently pursuing a project to elevate portions of both roads and enhance the roadside ditches in order to decrease the frequency of flooding. Roberts Road and Valley Mission Road are also known to flood periodically due to water levels in the lake. Additional roads are known to flood periodically due to high water levels in North Fork Salt Creek (Monroe County Long Term Stormwater Management Plan 2016). These include Brummett Creek Road, Friendship Road, Gross Road, McGowen Road, Old State Road 46, and Kent Road. Baby Creek Road is prone to flooding due to its minimal elevation above Baby Creek (a tributary to Brummett Creek, a tributary of North Fork Salt Creek).

Along South Fork Salt Creek, several roads north and west of Kurtz were identified as flooding regularly, including portions of Pike Road and Cornett Road. Several smaller stream crossings in Hoosier National Forest have been updated to improve both hydrologic flow and stream biology. These crossings were designed so aquatic wildlife could move easily upstream and downstream while also permitting larger stream flows without road flooding.

Figure 2-8 Windshield Site 905 County Road 1200N at Negro Creek in Hoosier National Forest

2.2.4 Wetlands and Ponds

Many wetland areas exist in the Lake Monroe watershed, as determined by the National Wetlands Inventory (NWI). According to the NWI, approximately 17,500 acres, or 6% of the watershed, is comprised of wetlands, mostly in the form of lakes and ponds. This estimate is slightly higher than the land cover map estimation of 4.6% water coverage due to presence of numerous small ponds and wetlands that are not captured by land cover maps (developed from satellite images) but are recorded in the NWI.

Figure 2-9 NWI Wetlands in Lake Monroe Watershed

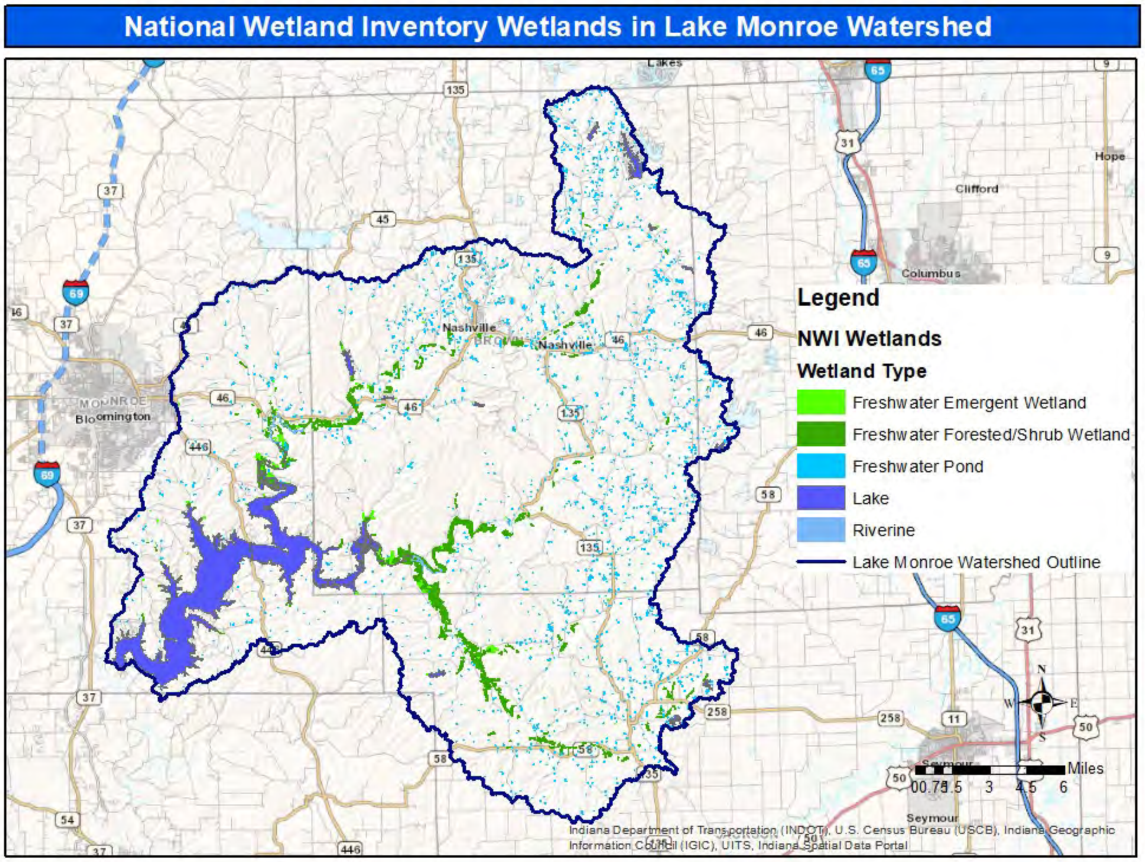


Table 2-1 Wetlands in Lake Monroe Watershed

Wetland Type	Count	Acreage	% of wetlands	% of watershed
Lake	63	11,800	67.4	4.3
Freshwater Pond	2,375	1,685	9.6	0.6
Freshwater Emergent Wetland	136	528	3.0	0.2
Freshwater Forested/Shrub Wetland	276	3,441	19.6	1.2
Riverine	3	60	0.3	0.0

Lake Monroe by itself accounts for nearly 3.8% of the watershed with other lakes making up an additional 0.5%. A summary of the 12 largest lakes is presented in Table 2-2 below. In addition, nearly 2,400 ponds are identified in the NWI, primarily in Brown County, account for another 0.6% of the watershed. Many of the ponds are used for drinking water while others are maintained for recreation, agriculture, or to attract wildlife. It should be noted that none of the lakes and ponds are naturally occurring – all are human-made impoundments.

Table 2-2 The Twelve Largest Lakes in the Lake Monroe Watershed

Lake Name	**Subwatershed**	**Approximate Acreage**
Lake Monroe	Lake Monroe	10,750
Sweetwater Lake	North Fork	280
Yellowwood Lake	North Fork	123
Lake Tarzian	South Fork	55
Green Lake	North Fork	54
Springhill Lake	South Fork	40
Sawmill Lake	Middle Fork	36
Persimmon Lake	South Fork	30
Tousley Lake	North Fork	30
Somerset Lake	North Fork	25
Hidden Valley Lake	North Fork	24
Ogle Lake	North Fork	22

Most of the remaining wetland areas (1% of the watershed) are in the form of freshwater forested/shrub wetlands. These are generally located along the three main tributaries to Lake Monroe – North Fork, Middle Fork, and South Fork Salt Creek. These stream valleys also contain freshwater emergent wetlands, which comprise about 0.2% of the watershed. Several of the wetland areas adjacent to Lake Monroe are managed for wildlife by the Indiana Department of Natural Resources, notably the Stillwater North Fork Waterfowl Resting Area, Middlefork Waterfowl Resting Area, and Southfork Marsh. These areas provide important habitat for migrating and resident waterfowl.

The Stillwater North Fork wetland complex was constructed in 1974. Low berms create multiple impoundments and small mounds create islands of dry land for nesting. IDNR staff plant a variety of crops that may include corn, millet, sunflower, sorghum, or buckwheat. The area is flooded in early October by pumping water from nearby North Fork Salt Creek to an approximate depth of 18”. The area is closed to the public October 1 to April 15 with the exception of hunting draws every three days from October through January for the 22 duck blinds in the complex. The water is slowly drained in the spring though flooding in Lake Monroe can cause water levels in North Fork Salt Creek to exceed water levels in the wetland, delaying drawdown.

2.2.5 Recreational Use

Lake Monroe is heavily used for recreation including boating, swimming, fishing, and hunting. Three public swimming beaches are available. Fairfax and Paynetown State Recreational Areas are run by the Indiana Department of Natural Resources while Hardin Ridge Recreation Area is run by the United States Forest Service. Lake Monroe also has at least one private beach (Ransburg Scout Reservation).

There are eight public boat launches on Lake Monroe operated by the Indiana Department of Natural Resources, one public boat launch operated by the United States Forest Service, and a handful of private marinas/docks. Motorboats, sailboats, kayaks, and paddle boards are all common on the lake.

According to the United States Army Corps Master Plan for Lake Monroe, there are two zones that control boat speed as well as a third unrestricted zone. Zone 1 calls for idling speeds with no wake and encompasses the entire upper basin of the lake (east of State Road 446), any area within 200 feet of the shoreline or docks, and any embayment that is less than 1,500 feet at the mouth. Zone 2 calls for idling speeds with no wake from April 16 – September 30 and is closed to watercraft to protect waterfowl habitat from October 1 to April 15. This zone encompasses the North Fork Recreational Area and the Middle Fork Recreational Area. Zone 3 is the majority of the lower basin of the lake, where there are no boating restrictions.

Some community members expressed concerns that heavy recreational use, particularly of motorboats, could be contributing to lakeshore erosion and stirring up sediment in the lakes. There are also concerns that rules are insufficiently enforced on the lake, particularly in no wake zones, and to limiting speed when passing non-motorized watercraft.

Several other lakes in the watershed also allow boating. These include Crooked Creek Lake, Yellowwood Lake, Sweetwater Lake, and Sundance Lake. Sweetwater Lake also operates a private swimming beach for its residents. Deer Run Park in Nashville has a boat launch on North Fork Salt Creek and small boats can also be launched on the creek from Brown County State Park. Brown County Wilderness Canoe Rental used to offer canoe tours of the Middle Fork Salt Creek near Story but has recently ceased operations.

Fishing is very popular in Lake Monroe and North Fork Salt Creek and occurs from boats, piers, and the shoreline. Designated waterfowl areas along the inlets of Crooked Creek, North Fork Salt Creek, and Middle Fork Salt Creek are managed for birding and hunting and are closed to the public October 1 – April 15 annually.

The Indiana Department of Natural Resources monitors algae levels at Paynetown and Fairfax public beaches in partnership with the Indiana Department of Environmental Management. Recreational advisories were issued for both beaches every year from 2011-2021 based on elevated algal cell counts.

2.2.6 Drinking Water

Lake Monroe is also a significant source of drinking water, serving over 125,000 people. Many community members expressed concerns about water quality in the lake potentially affecting drinking water quality. Others expressed concern that sediment entering the lake could accelerate the rate of siltation and lead to loss of the lake as a public water supply.
There are three organizations that the United States Army Corps of Engineers currently allows to pull water out of the reservoir:

1. City of Bloomington Utilities Water Treatment Plant (aka CBU) is permitted to draw 16-23 million gallons per day
2. Eagle Pointe Golf Resort (development on the lake in Monroe County)
3. Salt Creek Services (rural water distribution to about 90 households)

CBU distributes water directly to customers in the Bloomington area and also sells water wholesale to nine rural cooperatives. Per IDEM Drinking Water Watch, the total number of customers served via wholesale cooperatives is over 45,700.
(https://myweb.in.gov/IDEM/DWW/)

Table 2-3 Wholesale Water Distribution from Lake Monroe via CBU

Wholesale Water Company	Population Served
B and B	5,075
East Monroe	4,618
Ellettsville	12,800
Nashville	3,315
RHS	870
Shady Side	95
Southern Monroe	8,600
Van Buren	6,670
Washington Township	3,725
TOTAL WHOLESALE	**45,768**
CBU Customers	83,000
TOTAL CUSTOMERS	**128,768**

1. B and B Waters Project serves Benton and Bloomington Townships in Monroe County
2. East Monroe Water Corporation serves customers in eastern Monroe County and western Brown County.
3. Ellettsville serves the town of Ellettsville in northern Monroe County.
4. Nashville has in some years purchased water from City of Bloomington Utilities and in other years has purchased water from Brown County Utility in Morgantown.
5. The RHS Water Corporation is a rural water utility serving customers in the vicinity of Rhorer Road, Harrell Road, and Schacht Road in southern Monroe County.

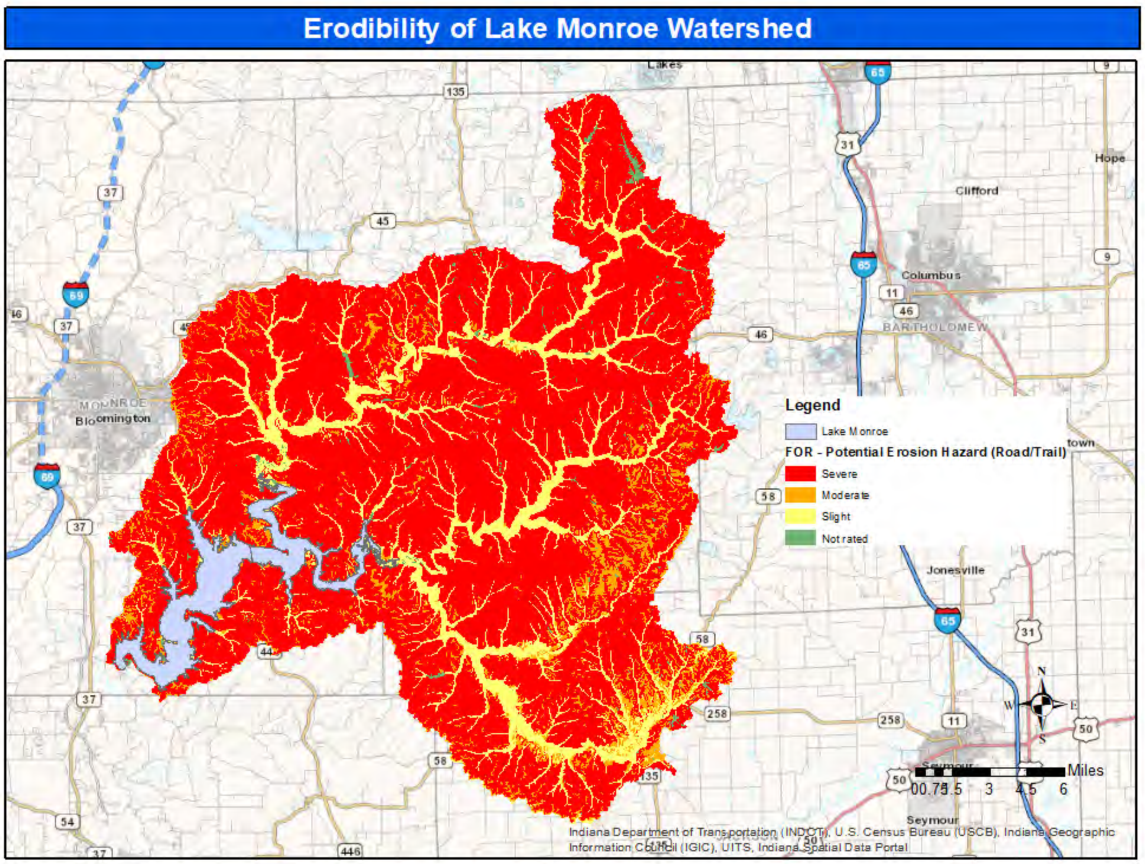
6. Shady Side serves residents on Shady Side Drive near Moore's Creek State Recreation Area.
7. Southern Monroe Water Authority serves parts of southern Monroe County near Lake Monroe in the vicinity of Fairfax Road.
8. Van Buren serves customers in Monroe and Greene Counties around the towns of Stanford and Kirksville as well as Van Buren Township and Indian Creek Township.
9. Washington Township Water serves customers in Washington, Bloomington, and Bean Blossom Townships of Monroe County; and Baker and Washington Townships of Morgan County.

2.3 Soils

2.3.1 Highly Erodible Soil

Approximately 76% of the Lake Monroe watershed is considered highly erodible due to its steep slopes and soil type. The predominant soil type (over 80%) is Wellston-Berks-Gilpin which typically occurs in upland areas and has a predominant texture of silt loam. Extensive soil erosion was recorded in the first half of the 20th century as land was cleared for farms. Subsequent efforts to restore forests and vegetative cover stabilized the remaining soil.

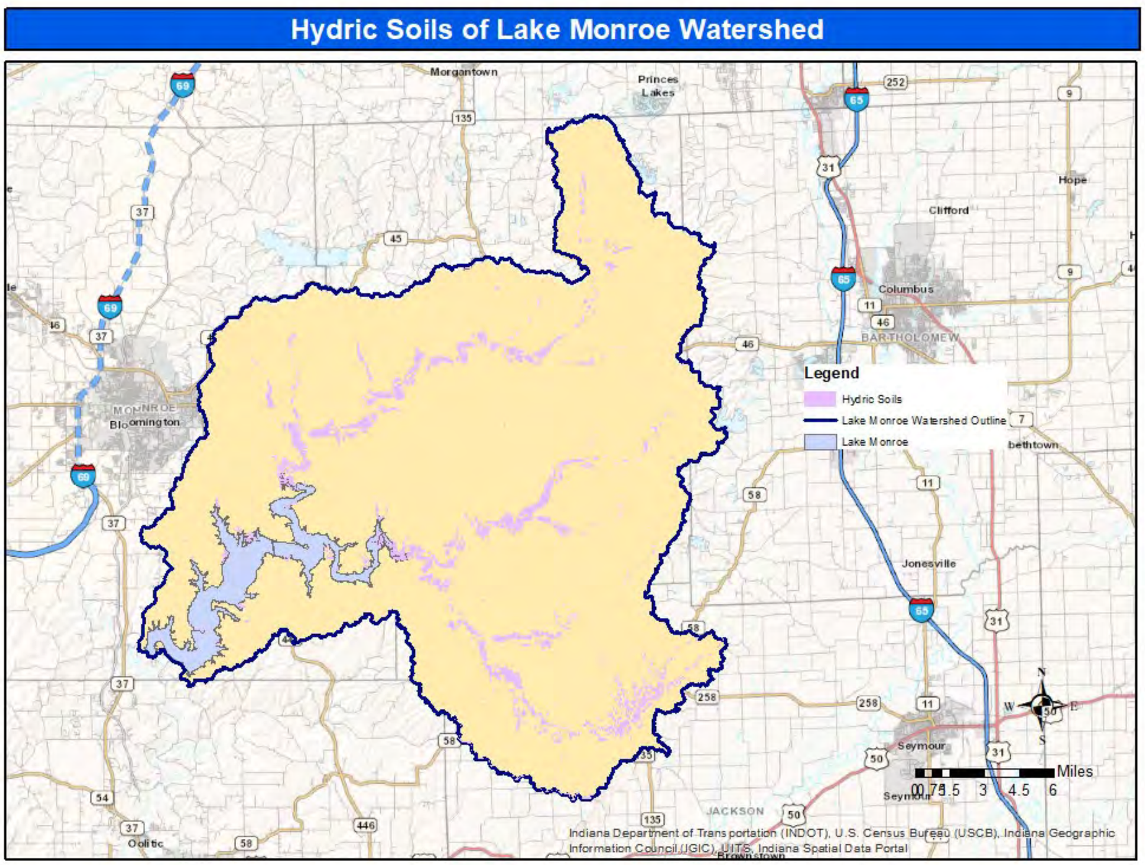
Figure 2-10 Erodibility of Lake Monroe Watershed



2.3.2 Hydric Soils

About 5% of the Lake Monroe watershed features hydric soils. These soil types are generally found in the valleys of the three branches of Salt Creek with a few instances along smaller tributaries. Several areas along the North Fork and Middle Fork are currently being preserved and managed as wetlands, as discussed in section 2.2.1. Some others are being used as farmland.

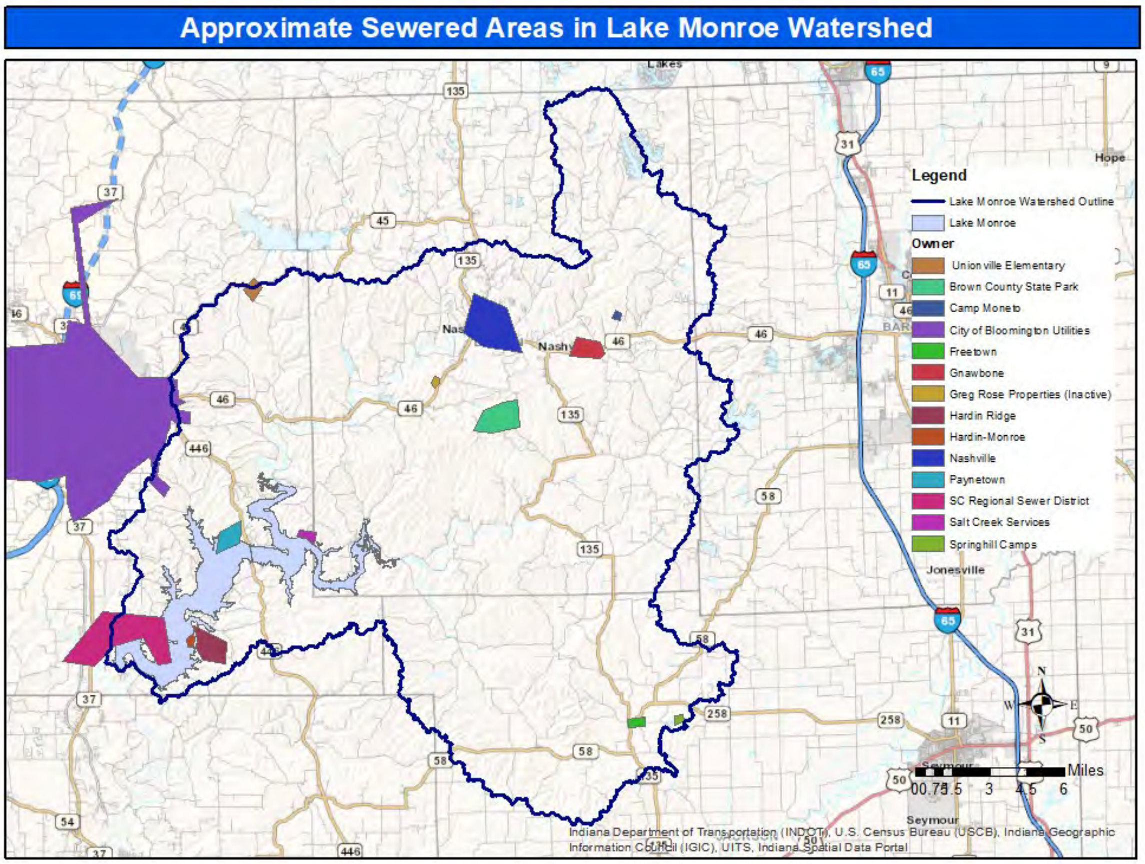
Figure 2-11 Hydric Soils in Lake Monroe Watershed



2.3.3 Septic Systems and Sewers

There are fourteen sewer systems in the Lake Monroe Watershed which serve approximately 3% of the watershed. Most of the systems are quite small, with the City of Bloomington Utilities as the primary exception.

Figure 2-12 Approximate Sewered Areas in Lake Monroe Watershed



The City of Bloomington Utilities runs a very large sewer system with two treatment plants but most of its service area and both discharge locations lie outside the watershed. The South Central Regional Sewer District also discharges outside the watershed. It serves an area along the west end of Lake Monroe that includes The Pointe, Lakewood Hills, Harbour Hills, Harrodsburg, Bryn Mawr, and Fourwinds.

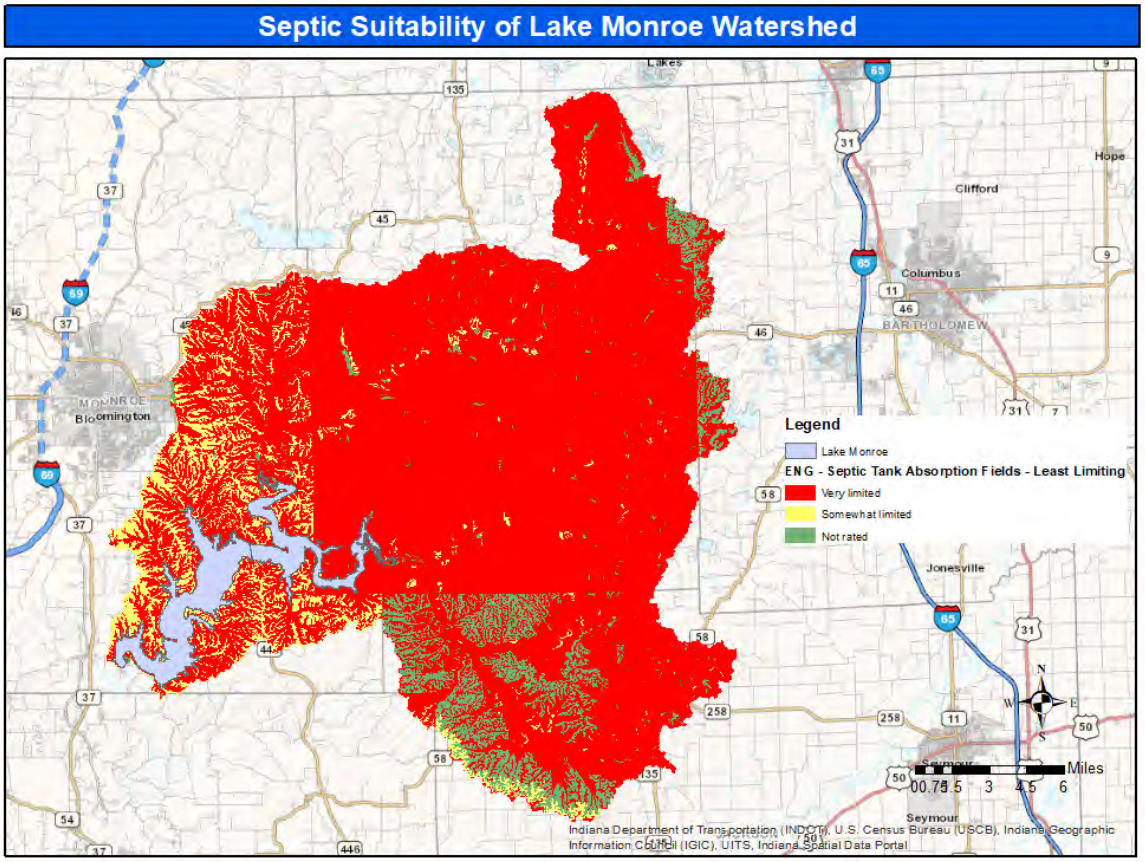
The three other significant systems in the watershed are the Town of Nashville, the Town of Gnaw Bone, and the Jackson County Regional Sewer District (in Freetown). Other systems serve small neighborhoods, recreational areas, and resident camps. The Brown County State Park treatment plant only handles the central portion of the park (campgrounds, nature center, office) while the Abe Martin Lodge sends its waste to Nashville and the horseman's camp has an on-site septic system. The Greg Rose Properties system west of Nashville has been permitted but not yet constructed as the neighborhood has not yet been developed.

Table 2-4 Sewer Systems in Lake Monroe Watershed

Wastewater Treatment Plant	Type	Discharge Location	Size
City of Bloomington (2 WWTPs)	Municipal	Outside Watershed	21.00 MGD
Town of Nashville	Municipal	North Fork Salt Creek	0.60 MGD
Town of Gnaw Bone	Municipal	Unnamed Tributary to Gnaw Bone Creek	0.05 MGD
Jackson County Regional Sewer District	Municipal	Little Salt Creek	0.09 MGD
South Central Regional Sewer District	Private	Outside Watershed	0.30 MGD
Hardin-Monroe	Private	Lake Monroe	0.03 MGD
Greg Rose Properties (Inactive)	Private	Schooner Creek	0.01 MGD
Brown County State Park	Government	Schooner Creek	0.04 MGD
Salt Creek Services	Private	Unnamed Tributary to Lake Monroe	0.02 MGD
Paynetown State Park	Government	Lake Monroe	0.05 MGD
Hardin Ridge	Government	Jarrell Ditch to Lake Monroe	0.03 MGD
Camp Moneto (near Gnaw Bone)	Private	Unnamed Tributary to Gnaw Bone Creek	0.02 MGD
Springhill Camps (near Freetown)	Private	Unnamed Tributary to Little Salt Creek	0.02 MGD
Unionville Elementary School	Semi-public	Unnamed Tributary to Brummett Creek	0.02 MGD

The remaining 97% of the watershed depends on septic systems for wastewater disposal, despite data from the NRCS Soil Survey showing that the Lake Monroe watershed is poorly suited for septic systems (see Figure 2-13). Approximately 82% is rated as “Very Limited” and another 7% is rated as “Somewhat Limited.” The remaining 11% is “Not Rated.” Several streams in the watershed are listed as impaired for E. coli in the 2018 IDEM 303d impaired streams list. Community members have expressed concerns for other streams as well, particularly in Brown County where investigations are underway to determine if additional sewer systems might be appropriate. It is unclear whether E. coli is coming from human wastewater or if the source is animals such as livestock or wildlife.

Figure 2-13 Septic Suitability of Lake Monroe Watershed



It should be noted that county soil surveys provide general information on whether or not a certain area is likely to have suitable soils. An on-site investigation may reveal an area within a particular site that is suitable for a conventional or modified onsite system to treat wastewater. Septic systems are comprised of a septic tank for settling out solids and a soil absorption field (aka leach field) to treat the wastewater via filtration through the soil.

Purdue University published a Census of Wastewater Disposal by Indiana County using soil survey data and census data from 1990 (the last year census takers were asked about wastewater disposal). Despite the fact that soils have poor septic system suitability, they are widely used. In 1990, 90% of Brown County households were served by onsite systems as were 35% of Jackson County households and 30% of Monroe County households. Using household counts from the 2018 census, percentage of septic system usage from the 1990 census, and approximate acreage within the watershed for each county, this data indicate that there are roughly 9,000 septic systems in the watershed. Over half are in Brown County and only about a tenth are in Jackson County. The Monroe County estimates may be a little high – the number of households in Monroe County increased significantly between 1990 and 2018 (approximately 35%) and it is unclear how much was in the Lake Monroe watershed and how much within the watershed was within sewered areas.

Table 2-5 Estimated Number of Septic Systems in Lake Monroe Watershed

County	1990 Percent of Households on Septic*	% of the county that is in the watershed**	2018 Census Data Households per County	2018 Estimated Number of Households on Septic in Watershed
Brown	90%	78%	6,093	4,286
Jackson	35%	18%	16,746	1,056
Monroe	30%	23%	55,537	3,754
TOTAL				**9,096**

*Note: Percent of households with each wastewater disposal method are from the 1990 Census, which continues to be the most recent information.
https://engineering.purdue.edu/~frankenb/NU-prowd/census.htm
**Note: The percentage of the county that is in the watershed is different from the previously referenced percentage of the watershed that is in each county.

Brown County in particular has grappled with questions about septic systems for many years. There were no rules for septic systems until approximately 1977 so it is unclear what kinds and sizes of systems were installed for homes built in the 1950's and 1960's. Records are limited for systems built throughout the 20th century. The Brown County Health Department is currently working to digitize its records and the Brown County Regional Sewer District is working to develop a strategic wastewater management plan for all unsewered areas within the county (further discussed section 2.5.5).

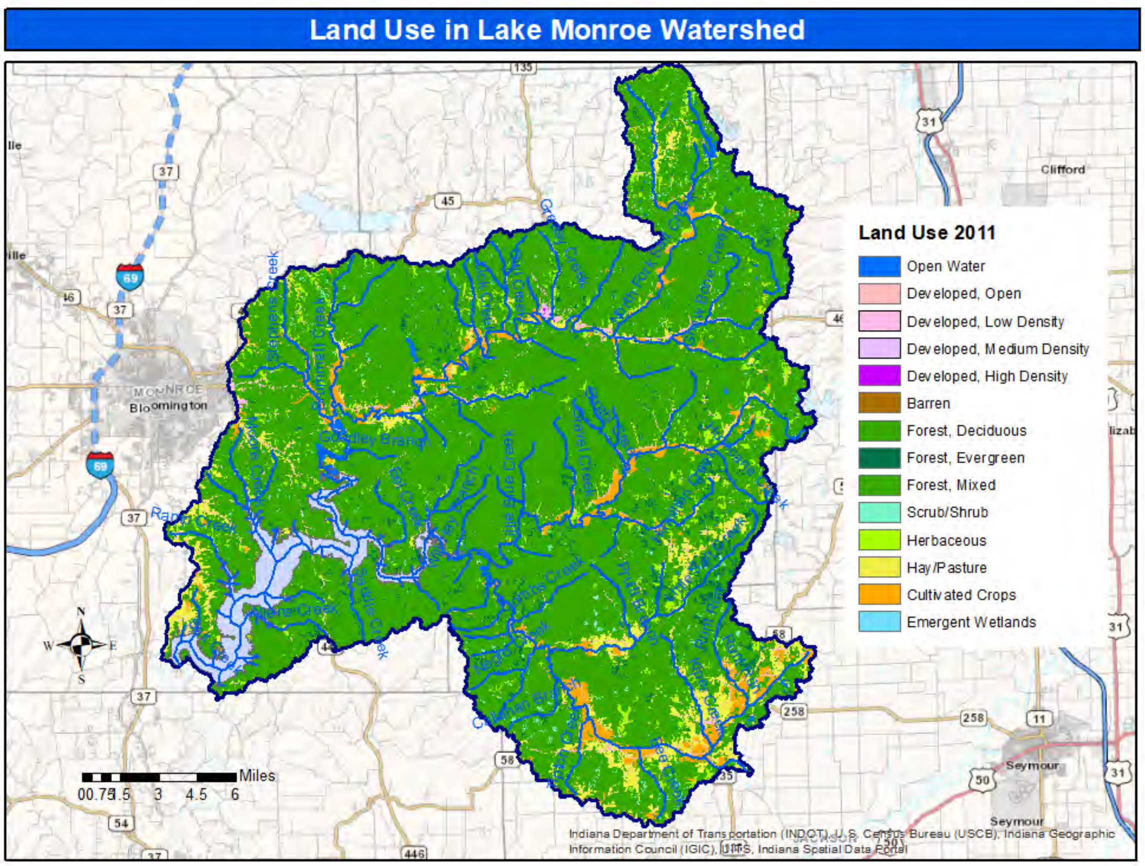
There are a few high density residential areas within the watershed that are not served by wastewater treatment plants. Probably the densest is Sweetwater Lake, part of the Cordry-Sweetwater Conservancy in northeastern Brown County. Approximately 1,500 houses have been built around the two lakes in a 2,300-acre area and all are served by septic systems. The Conservancy conducts a mandatory inspection and maintenance program to ensure that septic systems within the Conservancy are fully operational.

2.4 Land Cover

2.4.1 Overview

Unlike most watersheds in Indiana, the Lake Monroe watershed is largely forested (see Figure 2-14). Approximately 82% of the watershed is forested including large tracts of land managed by the Indiana DNR and the United States Forest Service. Other forested areas in Brown and Jackson County are generally comprised of small homesteads where the owners may or may not actively manage their forest.

Figure 2-14 Land Cover in Lake Monroe Watershed



Many community members expressed concern about potential water quality impacts from forest management activities such as logging, burning, and applying herbicides/pesticides. While Indiana has developed guidelines for Forestry Best Management Practices, there are no laws or regulations requiring their use. There were anecdotal reports of timber buyers offering owners cash and coming to harvest timber without developing a contract, management plan, or erosion control strategy and without engaging a certified forester.

Development is very low density with only the town of Nashville and the outskirts of the city of Bloomington registering as medium intensity developed land. Development in Nashville and Brown County is relatively slow, with the county population projected to decline over the next twenty years. In contrast, development is increasing in Bloomington and Monroe County, with many new subdivisions appearing southeast of Bloomington in the Lake Monroe watershed. Monroe County has restrictions in place to guide development in the watershed via the Environmental Constraints Overlay (ECO) Zone and construction sites are regularly inspected through the MS4 storm water program, as discussed in the planning section below.

There are three golf courses located within the watershed. The Golf Club at Eagle Pointe is located in Monroe County along the west end of Lake Monroe. Salt Creek Golf Course is located just east of Nashville in Brown County and straddles North Fork Salt Creek. Brown County Country Club is located just north of Nashville and recently (circa 2016) transitioned into a disc golf course. These are likely to be areas that regularly apply fertilizer, along with lawns in the more developed sections of the watershed.

Developed areas are also more likely to have concentrated amounts of pet waste, though it was not explicitly mentioned during community forums. Wildlife were identified as a potential source of fecal contamination, particularly in the forested portion of the watershed. Deer are prevalent in the area along with many species of birds and small mammals. Geese were mentioned as a concern at Sweetwater Lake and are likely present at smaller lakes and ponds around the watershed as well.

Agriculture is primarily limited to the valleys formed by each branch of Salt Creek (North Fork, Middle Fork, and South Fork) and a few of the larger tributaries. The primary agricultural activity is hay/pasture for cows and horses, followed by cultivated crops (generally a rotation of corn and soybeans).

Table 2-6 Land Cover in Lake Monroe Watershed

Land Cover	Approximate Acreage	Approximate Percentage
Forested	230,937	81.8%
Water/Wetlands	13,004	4.6%
Hay/Pasture	11,670	4.2%
Cultivated Crops	9,926	3.5%
Herbaceous	8,333	3.0%
Developed	6,085	2.2%
Other	2,285	0.8%

Both cows and horses are common in Brown and Jackson Counties. Horses are more prevalent in Brown, as are small “hobby farms.” Some of the land identified as herbaceous is likely to be hay fields or fallow fields.

Land cover was also analyzed at the subwatershed level to give a general idea of variation. The South Fork subwatershed contains the highest concentration of pasture, crops, and developed land though the densest development is in the North Fork subwatershed. The Lake Monroe Basin subwatershed has the highest concentration of open water.

Table 2-7 Land Cover by HUC-10 Subwatershed

Subwatershed	Forest	Water/ Wetlands	Hay/ Pasture	Crops	Herbaceous	Developed	Other
North Fork	86.5%	1.0%	2.6%	3.1%	3.5%	2.5%	0.8%
Middle Fork	87.7%	0.3%	2.1%	4.0%	3.9%	1.4%	0.5%
South Fork	78.3%	0.5%	8.4%	6.5%	2.7%	2.6%	1.1%
Lake Monroe	72.4%	19.6%	3.7%	0.5%	1.4%	1.6%	0.7%

2.4.2 Tillage Transect

Tillage transects are conducted twice a year by county soil and water conservation districts. These windshield surveys provide county-level data of the usage of cover crops and conservation tillage. The fall transect measures how many farms have left crop residue on the field (rather than tilling after harvest) and how many farms have planted a cover crop for winter soil stabilization. The spring transect determines how many farms are practicing conservation tillage (including no-till farming) by planting into crop residue without tilling the soil. Both evaluations differentiate between crop land that was most recently used for corn and crop land that was most recently used for soybeans. Corn leaves a heavier crop residue than soybeans.

Table 2-8 Conservation Practices in Lake Monroe Watershed per Tillage Transect

Conservation Practice Adoption by Percentage	Brown County	Monroe County	Jackson County	Statewide Average
Spring Corn Residue Not Tilled (%)	23	44	72	23
Spring Soybean Residue Not Tilled (%)	71	55	72	51
Fall Corn Residue Not Tilled (%)	98	100	85	71
Fall Soybean Residue Not Tilled (%)	100	98	85	76
2019 Cover Crops in Corn (%)	17	0	23	6
2019 Cover Crops in Soybeans (%)	42	13	29	10.5
2019 Cover Crops (acres)	1,148	989	26,469	N/A

Based on the fall tillage transects, most farms in Brown, Monroe, and Jackson Counties retain crop residue on their fields for the winter months. Brown and Monroe Counties have almost 100% participation while Jackson County is at 85% for both corn and soybeans, still significantly above the state average of 71% for corn and 76% for soybeans.

Based on the spring tillage transects, conservation tillage is most prevalent in Jackson County with 72% of both corn and soybean farms retaining crop residue during spring planting. In Brown and Monroe Counties, conservation tillage was much more common for fields that had previously been planted in soybeans, perhaps because soybean residue is minimal compared to corn. Brown County had 71% conservation tillage while Monroe County had 55% compared to a statewide average of 51%. For fields that had previously been planted in corn, Monroe County had 44% use of conservation tillage while Brown County matched the statewide average of 23%.

With the exception of corn fields in Monroe County, cover crop usage in the target counties is much higher than the statewide average, in terms of percentage. Cover crops on soybean fields ranged from 13-42% as compared to the statewide average of 10.5%. Cover crops on corn fields were more varied, with 0% adoption recorded in Monroe County, 17% in Brown, and 23% in Jackson versus a statewide average of 6%. It appears that the use of cover crops on fields that previously held soybeans is more common than on fields that previously held corn.

Table 2-9 Conservation Practices in Lake Monroe Watershed by Acreage

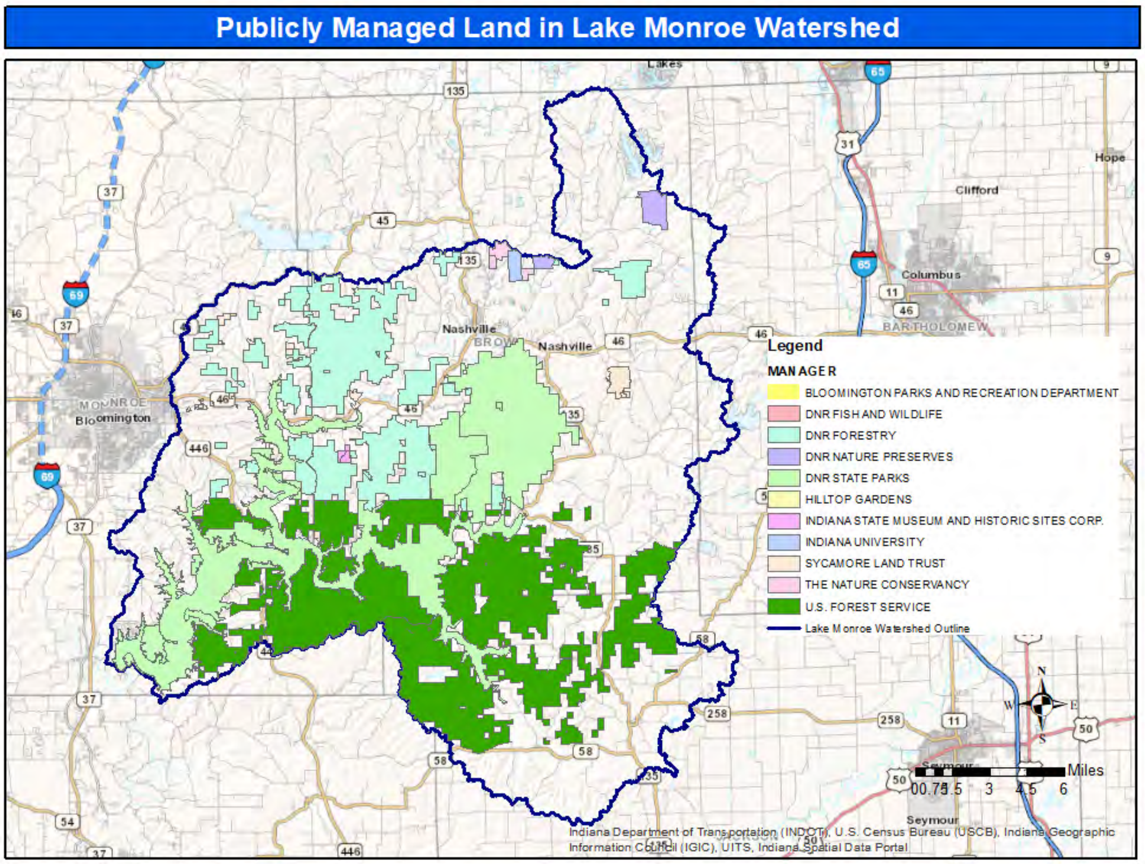
Conservation Practice Adoption by Acreage	Brown County	Monroe County	Jackson County	Statewide Total
Spring Corn Residue Not Tilled (acres)	424	2,532	39,601	1,230,000
Spring Soybean Residue Not Tilled (acres)	1,617	3,897	56,086	3,125,000
2019 Cover Crops in All Crops (acres)	1,148	989	26,469	950,000
2019 Cover Crops in Corn (acres)	334	0	7,929	330,000
2019 Cover Crops in Soybeans (acres)	814	989	18,540	585,000
2019 Cover Crops in Fallow Land (acres)	512	378	6,912	230,000

It should be noted that row crops are much more prevalent in Jackson County than in Brown or Monroe. Per the 2017 USDA Census of Agriculture, Jackson County has over 130,000 acres of cropland compared to roughly 10,000 acres in Monroe County and 3,000 acres in Brown County. There is also significant variation of farm size within each county. Generally, farming is more prevalent and farms are much larger outside the Lake Monroe watershed, meaning the county-level data may not always represent farms within the watershed, particularly in Jackson County.

2.4.3 Public Lands

Approximately 42% of the land in the Lake Monroe watershed is publicly owned by either Indiana or the United States (see Figure 2-15). About 27% is owned by the federal government and 16% is owned by the state government. Of the federal property, about two-thirds belongs to the United States Forest Service (USFS) and about a third belongs to the United States Army Corps of Engineers (USACE). The USACE property contains Lake Monroe and most of the surrounding land up to the designated flood elevation, which includes portions of North Fork, Middle Fork, and South Fork Salt Creek. This area, totaling 22,663 acres and comprising 9% of the watershed, is leased to and managed by the Indiana Department of Natural Resources State Parks Division. This lease was extended in the early 21st century to run until 2032. Therefore, from a management standpoint, 18% of the land in the watershed is managed by the federal government and 25% is managed by the state government.

Figure 2-15 Publicly Managed Land in Lake Monroe Watershed



A little less than one fifth (18%) of the watershed is owned and managed by the United States Forest Service, primarily in southern Brown County and northwestern Jackson County. This includes parts of the Hoosier National Forest and all of the Charles Deam Wilderness Area. Lake Monroe up to its flood elevation (as determined by the emergency spillway elevation of 556 feet) makes up another 9%. Other significant holdings include Yellowwood State Forest (7%), portions of Morgan-Monroe State Forest (2%), and Brown County State Park (6%), all under the jurisdiction of the Indiana Department of Natural Resources.

There are also several nature preserves and research forests that are owned and protected by private and semi-private organizations such as the Nature Conservancy (0.2%), Sycamore Land Trust (0.4%), and Indiana University (0.1%).

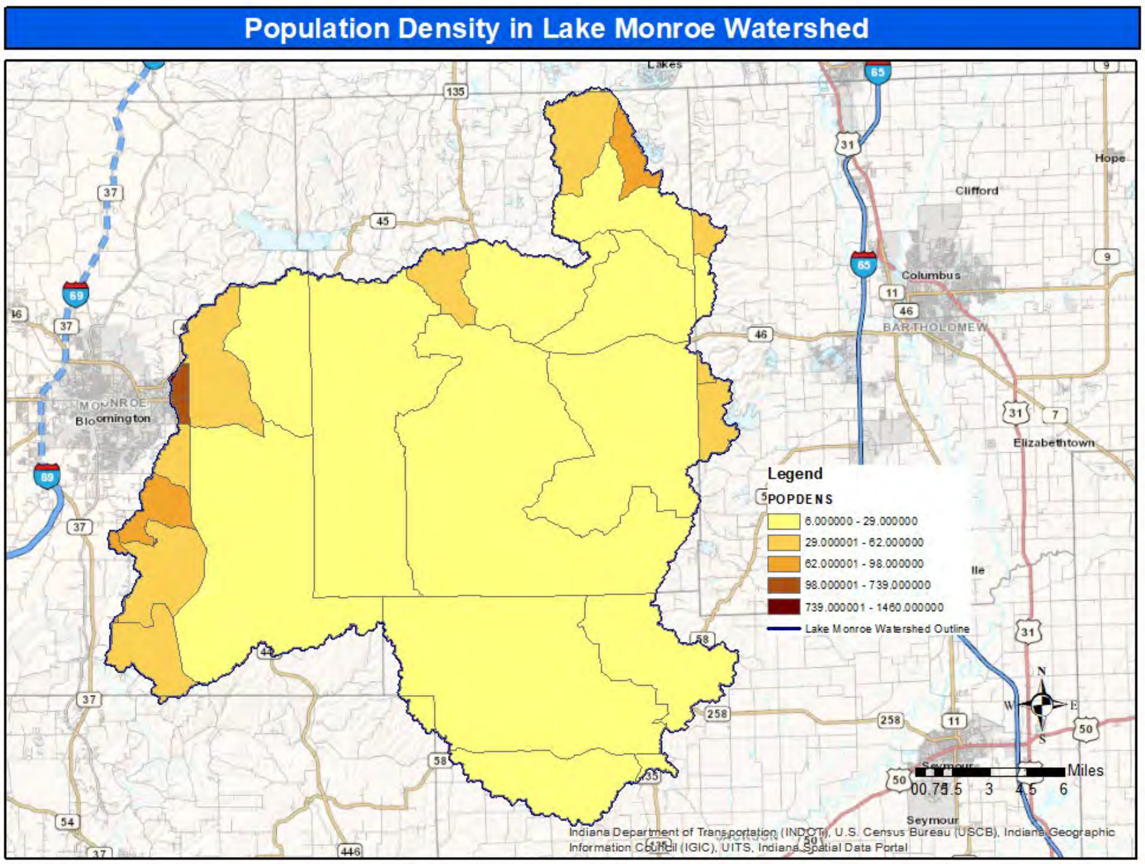
Table 2-10 Public Land in the Lake Monroe Watershed

Property	Owned By	Managed By	Acreage	% of Watershed
Hoosier National Forest	U.S. FOREST SERVICE	U.S. FOREST SERVICE	40872.92	14.8%
Charles Deam Wilderness (HNF)	U.S. FOREST SERVICE	U.S. FOREST SERVICE	9104.60	3.3%
Lake Monroe	U.S. ARMY CORPS	DNR STATE PARKS	24801.70	9.0%
Brown County State Park	DNR STATE PARKS	DNR STATE PARKS	16140.04	5.8%
Yellowwood State Forest	DNR FORESTRY	DNR FORESTRY	18932.21	6.8%
Morgan-Monroe State Forest	DNR FORESTRY	DNR FORESTRY	5142.95	1.9%
DNR Nature Preserves	DNR NATURE PRESERVES	DNR NATURE PRESERVES	1116.44	0.4%
T.C. Steele State Historic Site	INDIANA STATE MUSEUMS	INDIANA STATE MUSEUMS	192.52	0.1%

2.4.4 Population Density

Population density in the Lake Monroe watershed is generally low with over 80% of the watershed showing a density of less than 29 persons per square kilometer (compared to the national average of 36 and the state average of 72). Density is highest near Bloomington (west edge of the watershed), Nashville (north central edge), Sweetwater Lake (northeast), and Grandview Lake (east).

Figure 2-16 Population Density in Lake Monroe Watershed



2.4.5 Potential Pollution Sources

A desktop survey was conducted in 2020 to identify pollution sources that are documented in state and federal databases. IndianaMAP, a publicly available collection of Indiana geographic information system (GIS) map data, was used to determine what facilities of interest are located within the watershed.

<u>NPDES Facilities</u>

Several types of facilities and discharges are regulated by the National Pollutant Discharge Elimination System (NPDES). This program is administered by IDEM and the USEPA to regulate direct (point source) discharges. Permits are issued for each facility and limits are established for the amount of each pollutant that the facility is allowed to discharge into waters of the state. There are several different types of permits including: sanitary wastewater, construction storm water, municipal storm water, industrial storm water, and industrial process water. There are 14 sites within the Lake Monroe watershed with NPDES permits for wastewater discharges (13 from wastewater treatment plants and 1 from drinking water treatment plants) and 2 sites with unspecified NPDES permits.

Table 2-11 NPDES Facilities in the Lake Monroe Watershed

Facility	NPDES-ID	Address	City	Subwatershed
SPRINGHILL CAMPS	IN0044211	2221 W SR 258	FREETOWN	Kiper Creek (SF)
JACKSON COUNTY WWTP	IN0052949	4241 W CR 675 N	FREETOWN	Kiper Creek (SF)
GREG ROSE PROPERTIES	IN0063789	1462 SR 46 W	NASHVILLE	Clay Lick (NF)
WRIGHTS AUTO PARTS	INRM00827	4881 OLD SR 46	NASHVILLE	Clay Lick (NF)
SHELBY MATERIALS INCORPORATED	INRM01001	SR 46 E and SR 135 S	NASHVILLE	Clay Lick (NF)
NASHVILLE WWTP	IN0023876	10 W SR 46	NASHVILLE	Clay Lick (NF)
GNAW BONE WWTP	IN0060526	108 MT LIBERTY RD	GNAW BONE	Gnaw Bone (NF)
CAMP MONETO WWTP	IN0048453	551 N CAMP MONETO RD	NASHVILLE	Gnaw Bone (NF)
BROWN COUNTY STATE PARK	IN0030325	SR 46 and SR 135	NASHVILLE	Brummett (NF)
UNIONVILLE ELEMENTARY	IN0041009	8144 E SR 45	UNIONVILLE	Brummett (NF)
SALT CREEK SERVICES INC	IN0043699	GILMORE RIDGE and DECKARD RIDGE	MONROE COUNTY	Crooked (LM)
SOUTH CENTRAL INDIANA RSD WWTP	IN0050105	8980 ELLA STREET	BLOOMINGTON	Moore Creek (LM)

Facility	NPDES-ID	Address	City	Subwatershed
HARDIN MONROE INC	IN0038326	8029 HARDIN RIDGE RD	HELTONVILLE	Allens Creek (LM)
USDA FOREST SERVICE HARDIN RD	IN0024953	6464 HARDIN RIDGE ROAD	HELTONVILLE	Allens Creek (LM)
PAYNETOWN SRA WWTP	IN0030163	4850 S SR 446	BLOOMINGTON	Moore Creek (LM)
CBU/MONROE COUNTY WTP	IN0060810	7470 SHIELDS RIDGE RD	BLOOMINGTON	Moore Creek (LM)

A detailed discussion of the facilities and issues identified from a review of the IDEM Virtual Filing Cabinet is provided in the subwatershed analysis in Appendix J. Two facilities were found to have ongoing concerns.

The Nashville wastewater treatment plant has been operating under an agreed order since 2019 when IDEM issued a notice of violation and proposed agreed order for the plant. The primary issue is documented and alleged overflows to North Fork Salt Creek. The town of Nashville has been working to remedy the issues at the plant and has also started work on a sanitary sewer utility master plan. This study will determine how well the plant is currently functioning, investigate options for expansion or reconstruction, and explore possibilities for expanding service outside town limits. One of the challenges that the treatment plant faces is its location in the floodway of North Fork Salt Creek, meaning it is at high risk for flooding. There are additional studies being conducted to explore the possibility of a treatment plant that would serve multiple communities. The Brown County Regional Sewer District is working on its own plan for all areas of the county that are not currently served by wastewater treatment plants.

The Brown County State Park wastewater treatment plant handles wastewater from the central portion of the park (campgrounds, nature center, office) while the Abe Martin Lodge sends its wastewater to the Nashville treatment plant and the horseman's camp has an on-site septic system. The treatment plant has received and responded to a series of compliance letters since 2015. Issues include repeated instances of inflow/infiltration into the sewage system causing potential overflows, an exceedance in E. coli levels in June 2016, and a sewer overflow that may have reached North Fork Salt Creek in March 2020. The park will most likely close down their WWTP and begin sending all their waste to the Nashville WWTP in 2023.

CAFOs/CFOs

There are no documented Confined Feeding Operations (CFO) or Concentrated Animal Feeding Operations (CAFO) within the watershed per IDEM's Confined Feeding Operation Facilities map. There is one CFO that is right outside the Kiper Creek (South Fork) watershed and that is Rose Acre Farms Brooder Farm at 7585 CR 100W in Jackson County.

Manure Land Application

There is one large commercial dairy farm, Wagler Farms, that has permits to apply manure on cropland as fertilizer on a number of fields in Brown County. IDEM rules treat manure application as proprietary and do not require disclosure of information about how much manure is land-applied in a given watershed or a given field. There are also no local ordinances that requires reporting on this topic. Kenny Wagler stated in an interview that they do not apply manure within the Lake Monroe watershed as it is too far from the dairy to make transportation worthwhile. He did provide a tour of a farm field in the adjacent Bean Blossom watershed and explained that manure is injected into soil rather than being surface applied.

Municipal Sludge Application

Jackson County Regional Sewer District operates a waste water treatment plant in Freetown and has a permit for applying municipal sludge but it is unclear when and where sludge has been applied.

2.5 Existing Planning Efforts

2.5.1 County Comprehensive Plans

The Lake Monroe watershed encompasses portions of five counties. Approximately 56.1% of the watershed is within Brown County, 21% is within Monroe County, 20.7% is within Jackson County, 1.9% is within Bartholomew County, and 0.3% is within Lawrence County.

Brown County last updated its Comprehensive Plan in 2011. Its plan is a Policy Plan, which does not include a proposed future land use map but does outline goals, objectives, and policies. The plan emphasizes fostering economic development while conserving the county's natural and cultural heritage. Modest growth of about 7% per decade is anticipated and is encouraged to occur in areas where both approved water supply and approved sewage handling facilities can be provided. However, more recent data indicate that population growth has been negligible since 2010. Brown County does not have any local ordinances in place regarding erosion control or slope restrictions. IDEM has authority to regulate any area of land disturbance greater than one acre.

Jackson County adopted a Comprehensive Plan in 2006. Their plan has more of an emphasis on supporting agriculture and managing flood impacts than the other counties. However, common values remain such as fostering economic development and conserving natural resources. Water quality is mentioned numerous times, as is preserving natural lands. Jackson County specifically mentioned increasing recreational opportunities as a goal. Growth is predicted around existing towns. The primary area of growth identified within the Lake Monroe watershed is around Freetown. Much of the land north and west of Freetown is owned and managed by USFS as part of the Hoosier National Forest which likely precludes large-scale development.

Monroe County most recently updated their comprehensive plan in 2012. The county anticipates growth of at least 10% per decade and expresses a goal of keeping rural areas rural in character while encouraging urban densities and services in five designated communities – Bloomington, Ellettsville, Stinesville, Harrodsburg, and Smithville-Sanders. Bloomington is identified as an urbanizing area while the other four are identified as rural community areas. Growth should be directed towards areas with existing infrastructure (e.g., sewer, water, roads). Development should be avoided whenever feasible on slopes of 15% or greater. Subdivision development is to be limited within specified areas in the watersheds of Lake Lemon, Lake Griffy and Lake Monroe.

The plan acknowledges that the area around Lake Monroe is a popular area for new home construction and emphasizes the importance of the Environmental Constraints Overlay (ECO) Zone. This zoning was initially established in the late 1990's as part of the Monroe County Master Plan and was included in the most recent 2018 zoning ordinance. Much of the focus of the overlay is to prevent erosion by maintaining tree cover, minimizing grading work, and regularly inspecting erosion control measures. Any project with a grading permit is required to be inspected after heavy rains (10 year storm) and at least once every two weeks from ground breaking to stabilization. Riparian buffer zones are required with a minimum width of 100 feet from each side of all intermittent and perennial streams shown on USGS 7.5 minute topographic maps.

The ECO Zone identifies 3 areas radiating out from the 3 lakes (Monroe, Griffy, and Lemon). Area 1, closest to the lake, only allows land disturbance where slopes are less than or equal to 12%. Area 2 has a maximum land slope of 15% and the remainder of the watershed has a maximum land slope of 18%. The maximum residential density allowed is 1 house per 2.5 acres with the exception of Zone 3, where density can be increased to 3 houses per acre if sanitary sewers are present.

2.5.2 MS4 Stormwater Entities

There are two Municipal Separate Storm Sewer System (MS4) entities that have jurisdiction within the watershed. The City of Bloomington MS4 is responsible for the city of Bloomington, of which only a few acres are within the Lake Monroe watershed. The Monroe County MS4 covers all unincorporated sections of Monroe County, which includes roughly a fifth of the Lake Monroe watershed. Brown County has no MS4 entities. The MS4 entities in Bartholomew, Jackson, and Lawrence Counties are located outside the Lake Monroe watershed. Jackson County SWCD hires a company to do their Rule 5 plan review and monthly inspections on projects in the county outside the city of Seymour MS4. Brown County SWCD works with their regional IDEM stormwater specialist to do the technical review and site visits.

2.5.3 Watershed Management Plans

Several subwatersheds in the Lake Monroe watershed have developed Watershed Management Plans.

<u>Cordry-Sweetwater Watershed Management Plan 2006</u>
Cordry-Sweetwater Lake Conservancy developed a watershed management plan for Sweetwater Creek in the northeast corner of the watershed in 2006. The plan includes approximately 19 square miles that includes East Sweetwater Creek (the outlet of Sweetwater Lake), Sweetwater Creek, Wolfpen Hollow, and the headwaters of North Fork Salt Creek. While sampling revealed no obvious water quality impairments, the plan included recommendations for multiple water quality protection strategies including goose management, regular septic system inspections, and periodic water quality monitoring.

Yellowwood Lake Watershed Management Plan 2006

Yellowwood Lake also developed a watershed management plan in 2006. The plan covers the approximately 7 square miles that drain into Yellowwood Lake, which flows into Jackson Creek and then North Fork Salt Creek. The two main pollutants of concern were sediment and E. coli. The plan calls for a reduction of storm event total suspended solid (TSS) loads in Jackson Creek by 145 pounds per day and a reduction of average E coli loads by 40,000 units per day within 10 years in order to meet the state water quality standards. Yellowwood Lake was dredged as a direct result of the plan, with roughly 5.8 million cubic feet of sediment removed from the lake.

Lower Salt Creek Watershed Management Plan 2022

While not located within the Lake Monroe watershed, it is relevant to note that a watershed management plan is currently being developed for the watershed immediately downstream, the Lower Salt Creek watershed (HUC 0512020808). The main concern is E. coli and in 2018, the Indiana Department of Environmental Management published a Total Maximum Daily Load (TMDL) for the Lower Salt Creek watershed for E. coli. The TMDL report did not identify Lake Monroe as a source of E. coli. However, there may be opportunities for the Lake Monroe group and the Lower Salt Creek group to partner on education, outreach, and other joint ventures related to water quality issues.

2.5.4 Lake Monroe Studies

Several additional studies have been conducted looking at Lake Monroe.

Lake Monroe Diagnostics and Feasibility Study (Jones Study) 1997

This study of the Lake Monroe Watershed included sampling of five tributaries that feed into Lake Monroe – North Fork Salt Creek, Middle Fork Salt Creek, South Fork Salt Creek, Brummett Creek, and Stephens Creek – as well as sampling within the lake. The authors also developed a sediment budget for the lake and estimated sediment accumulation rate of 0.03 inches per year (32,825 tons per year). Sediment and phosphorus were identified as two major concerns as well as lakeshore erosion, turbidity, overrecreation, urbanization of the watershed, algal blooms, and the lack of a comprehensive watershed management plan.

IU SPEA Capstone Course 2018 – Sediment Budget for Lake Monroe

A class of Indiana University graduate students in the School of Public and Environmental Affairs developed a rough sediment model for Lake Monroe to quantify sources of sediment in the lake. Using the RUSLE soil loss model with a number of assumptions, the model indicated a total soil loss of 38,726 tons/year in the Lake Monroe Watershed, which translates to a watershed soil loss rate of 0.14 tons/acre/year. This was believed to be an underestimate due to the assumptions made and the lack of data around shoreline erosion. The group also estimated that Lake Monroe has a trap efficiency of 90.77% and a lake lifetime of 347,917 years.

IU SPEA Capstone Course 2019 – Economic Value of Lake Monroe
A class of Indiana University graduate students in the School of Public and Environmental Affairs gathered data in order to calculate the economic value of Lake Monroe. They considered the economic value of drinking water, property, and business income from recreational use. They considered the effect of water quality on treatment costs and property values, the economic impact of recreational activities on local businesses, the value of ecosystem service provided by the lake, and the general valuation of the lake by local residents and businesses.

IU SPEA Capstone Course 2020 – Shoreline Erosion Modeling for Lake Monroe
A class of Indiana University graduate students in the School of Public and Environmental Affairs worked on quantifying shoreline erosion at Lake Monroe. They developed a mathematical model to extrapolate an erosion rate of 0.01 cubic feet of soil per foot of shoreline per year. This translates to roughly 649 tons of sediment loss per year, or 1.7% of the annual soil loss calculated by the 2018 capstone class. This model considers erosion due to wave action at normal pool and does not account for shoreline erosion caused by prolonged high water levels in the lake. The project included guidelines for collecting future measurements that could be used to refine the model.

2.5.5 Other Planning Efforts in the Watershed

Brown County Regional Sewer District
Several sewer districts have formed in Brown County to address wastewater treatment needs. Nashville built a wastewater treatment plant in the early 1960's that has been rebuilt and expanded several times. Around 1997, the Helmsburg Sewer District (outside the Lake Monroe watershed) was formed and eventually constructed its own plant. In 2000, the Gnaw Bone Sewer District began operating. In 2006, the Bean Blossom Sewer District was formed by order of the Indiana Department of Environmental Management to address concerns about failing septic systems.

In 2015, the group changed its name to the Brown County Regional Sewer District and broadened its focus to encompass all areas of Brown County not already being serviced by other sewer districts. This group initially continued research on the Bean Blossom area but is currently conducting an evaluation of all the unserved areas of the county to identify potential solutions. This strategic wastewater management plan is expected to be published in 2022 and will include reports of E. coli concentrations in streams around the county as well as an analysis of the source (human vs. animal). Preliminary data are included in the water quality section of this report.

Brown County Septic Ordinance Updates
In May 2021, Brown County adopted a newly revised septic ordinance to replace the ordinance that had been in place since 1997. The goal was to clarify requirements, standardize enforcement, and provide an appeals process for enforcement situations.

Monroe County Drainage Ordinance

The Monroe County Stormwater Board is currently considering a drainage ordinance for the county that would clarify requirements and responsibilities for stormwater conveyance.

2.6 Endangered and Threatened Species

According to the Indiana Heritage Database, the Lake Monroe watershed contains four high quality natural areas – Mesic Floodplain Forest, Highland Rim Dry-Mesic Upland Forest, Highland Rim Dry Upland Forest, and Highland Rim Mesic Upland Forest. Brown County and Jackson County are well known for their forestland, much of which is managed by either the Indiana Department of Natural Resources or the United States Forest Service. These forests provide crucial habitat for a variety of species including songbirds, bats, salamanders, snakes, and turtles.

The Indiana Heritage Database also identified 41 animal species and 16 plant species within the Lake Monroe watershed that are being monitored as rare, threatened or endangered. Perhaps the most easily recognized, the Bald Eagle, is closely associated with Lake Monroe since its reintroduction in the late 1980's. Other species are more commonly found in the forests of the watershed or in nearby caves.

Table 2-12 Rare, Threatened, and Endangered Animal Species in the Lake Monroe Watershed

Scientific Name	Common Name	Type	State Status	Federal Status
Acris blanchardi	Blanchard's Frog	Amphibian	SSC	--
Hemidactylium scutatum	Four-toed Salamander	Amphibian	SSC	--
Accipiter striatus	Sharp-shinned Hawk	Bird	SSC	--
Aimophila aestivalis	Bachman's Sparrow	Bird	--	--
Ammodramus henslowii	Henslow's Sparrow	Bird	SE	--
Buteo platypterus	Broad-winged Hawk	Bird	SSC	--
Dendroica virens	Black-throated Green Warbler	Bird	--	--
Haliaeetus leucocephalus	Bald Eagle	Bird	SSC	--
Helmitheros vermivorus	Worm-eating Warbler	Bird	SSC	--
Ixobrychus exilis	Least Bittern	Bird	SE	--
Lanius ludovicianus	Loggerhead Shrike	Bird	SE	--
Mniotilta varia	Black-and-white Warbler	Bird	SSC	--
Setophaga cerulea	Cerulean Warbler	Bird	SE	--
Setophaga citrina	Hooded Warbler	Bird	SSC	--
Pseudocandona jeanneli	An Ostracod	Crustacean	SE	--

Scientific Name	Common Name	Type	State Status	Federal Status
Conotyla bollmani	Bollman's Cave Milliped	Millipede	WL	--
Hypogastrura gibbosus	Humped Springtail	Springtail	WL	--
Isotoma anglicana	A Springtail	Springtail	WL	--
Pseudosinella argentea	A Springtail	Springtail	SE	--
Pseudosinella collina	Hilly Springtail	Springtail	SR	--
Pseudosinella fonsa	Fountain Cave Springtail	Springtail	ST	--
Sinella alata	A Springtail	Springtail	WL	--
Atheta annexa	Rove beetle	Insect	WL	--
Cicindela patruela	A Tiger Beetle	Insect	SR	--
Autochton cellus	Gold-banded Skipper	Insect	SE	--
Hyperaeschra georgica	A Prominent Moth	Insect	ST	--
Pieris virginiensis	West Virginia white butterfly	Insect	ST	--
Rhionaeschna mutata	Spatterdock Darner	Insect	ST	--
Mustela nivalis	Least Weasel	Mammal	SSC	--
Myotis septentrionalis	Northern Long Eared Bat	Mammal	SE	LT
Myotis sodalis	Indiana Bat	Mammal	SE	LE
Sorex fumeus	Smoky Shrew	Mammal	SSC	--
Sorex hoyi	Pygmy Shrew	Mammal	SSC	--
Villosa lienosa	Little Spectaclecase	Mollusk	SSC	--
Punctum minutissimum	Small Spot	Mollusk	--	--
Paracapnia angulata	Angulate Snowfly	Insect	SE	--
Clonophis kirtlandii	Kirtland's Snake	Reptile	SE	--
Crotalus horridus	Timber Rattlesnake	Reptile	SE	--
Opheodrys aestivus	Rough Green Snake	Reptile	SSC	--
Opheodrys vernalis	Smooth Green Snake	Reptile	SE	--
Terrapene carolina carolina	Eastern Box Turtle	Reptile	SSC	--

State: SE = State endangered; ST= State threatened; SR = State rare; SSC = State species of special concern; SG = State significant; WL = watch list; no rank - not ranked but tracked to monitor status. **Federal**: LE= Listed Federal endangered; LT = Listed Federal threatened

Table 2-13 Rare, Threatened and Endangered Plant Species in Lake Monroe Watershed

Scientific Name	Common Name	State Status	Federal Status
Castanea dentata	American chestnut	SE	--
Cladrastis kentukea	yellowwood	SE	--
Cypripedium parviflorum var. pubescens	large yellow lady's-slipper	WL	--
Dichanthelium bicknellii	panic-grass	SE	--
Dichanthelium mattamuskeetense	panic-grass	SX	--
Epigaea repens	trailing arbutus	ST	--
Hydrastis canadensis	golden seal	WL	--
Hypericum pyramidatum	great St. John's-wort	ST	--
Juglans cinerea	butternut	ST	--
Oenothera perennis	small sundrops	ST	--
Oxalis illinoensis	Illinois woodsorrel	WL	--
Panax quinquefolius	American ginseng	WL	--
Rubus odoratus	purple flowering raspberry	ST	--
Spiranthes ochroleuca	yellow nodding ladies'-tresses	ST	--
Stachys clingmanii	Clingman's hedge-nettle	WL	--
Tsuga canadensis	eastern hemlock	WL	--

State: SE = State endangered; ST= State threatened; SR = State rare; SSC = State species of special concern; SG = State significant; SX = state extirpated; WL = watch list

2.7 Watershed Overview Summary

The Lake Monroe watershed is characterized by a hilly terrain with shallow erodible soils. The steepest slopes are generally forested, which helps to keep soils stable. Agriculture is generally found in the flatter valley lands surrounding the main tributaries to the lake (South Fork, Middle Fork, and North Fork).

Septic systems are prevalent throughout the watershed despite the lack of suitable soils. Wastewater treatment plants serve most of the more heavily populated areas such as the town of Nashville, the community of Gnaw Bone, and several dense developments located near Lake Monroe. One notable area lacking sewage treatment is the Sweetwater-Cordry Conservancy community though they require regular inspection of all septic systems in order to catch and address any issues.

Brown County and Jackson County lack MS4 entities and staff to inspect construction sites for erosion despite an abundance of highly erodible soils. Monroe County does have an MS4 program that provides site inspection and contractor education. Monroe County also has implemented tighter development restrictions in the watershed through their ECO Zone overlay.

Community concerns center largely around protecting Lake Monroe and its tributaries from sediment, nutrients, and E. coli.

3 Watershed Inventory: Environmental and Water Quality Data

3.1 Water Quality Targets

Water quality targets for each parameter have been selected based on applicable Indiana Administrative Code, the Lower Salt Creek Total Maximum Daily Load (TMDL), and other standards accepted by the Indiana Department of Environmental Management. Table 3-1 Water Quality Parameters and Target Levels are used for the Lake Monroe Watershed to assess the water quality throughout the drainage area. The chosen targets for nutrients in particular are very conservative in order to minimize the likelihood of algal blooms in Lake Monroe.

Table 3-1 Water Quality Parameters and Target Levels for Lake Monroe Watershed

Parameter	Target Level	Source
pH	> 6 and < 9	Indiana Administrative Code Article 2 327-IAC
Temperature	Monthly Standard	Indiana Administrative Code Article 2 327-IAC
Dissolved Oxygen	> 4 mg/L and < 12 mg/L	Indiana Administrative Code Article 2 327-IAC
E. coli	< 235 colony forming units (cfu) per 100 mL sample < 125 cfu per 100 mL for geometric mean of 5 samples in 30 days	Indiana Administrative Code Indiana Administrative Code
Total Phosphorus	0.02 mg/L in lakes and streams	USEPA Ecoregion IX Nutrient Guidance for Lakes and Reservoirs (minimizes HABs)
Ortho-phosphate	Max: 0.005 mg/L	Wawassee Area Conservancy Foundation recommendation for lake systems, NESWP344
Total Nitrogen	0.36 mg/L in lakes 0.69 mg/L in streams	USEPA Ecoregion IX Nutrient Guidance for Lakes USEPA Ecoregion IX Nutrient Guidance for Streams and Rivers
Nitrate-nitrogen (NO3)	0.633 mg/L in lakes and streams	USEPA Ecoregion Nutrient Guidance for Streams and Rivers
TSS	< 30.0 mg/L	IDEM draft TMDL target
Chlorophyll-a	4.93 ug/L for lakes	EPA Ecoregion IX Nutrient Guidance
Atrazine	3.0 ppb	Indiana Administrative Code (and USEPA Drinking Water Limit)
Citizen Qualitative Habitat Evaluation Index (CQHEI)	> 60 (Generally Healthy)	Hoosier River Watch/ Ohio EPA

Parameter	Target Level	Source
Qualitative Habitat Evaluation Index (QHEI)	>= 45 (Fair), >= 60 (Good)	Ohio EPA QHEI Manual minimum "Fair" score for large streams (>= 20 sq mile drainage area)
Macroinvertebrate Index of Biotic Integrity (mIBI)	>= 36 (Unimpaired)	IDEM 2017 Performance Measures Monitoring Work Plan for Selected Indiana Subwatersheds
Fish-based Index of Biotic Integrity (IBI)	>= 45 (Good)	IDEM 2017 Performance Measures Monitoring Work Plan for Selected Indiana Subwatersheds

Table 3-2 QHEI Interpretation per Ohio EPA Manual

QHEI Score Headwaters Stream (<= 20 square miles drainage area)	QHEI Score Larger Stream (<= 20 square miles drainage area)	Narrative Description
>= 70	>= 75	Excellent
55-69	60-74	Good
43-54	45-59	Fair
30-42	30-44	Poor
<30	<30	Very Poor

Table 3-3 IBI Interpretation per IDEM 2017 Performance Measures Monitoring Work Plan

Fish-Based IBI Score	Integrity Class	Attributes
53-60	Excellent	Comparable to "least impacted" conditions, exceptional assemblage of species.
45-52	Good	Decreased species richness (intolerant species in particular), sensitive species present.
36-44	Fair	Intolerant and sensitive species absent, skewed trophic structure.
23-35	Poor	Top carnivores and many expected species absent or rare, omnivores and tolerant species dominant.
12-22	Very Poor	Few species and individuals present, tolerant species dominant, diseased fish frequent.
< 12	No Fish	No fish captured during sampling.

Table 3-4 mIBI Interpretation per IDEM 2017 Performance Measures Monitoring Work Plan

mIBI Score	Integrity Class
>= 36	Unimpaired
< 36	Impaired

3.2 Historical Water Quality Data

Several historical sets of water quality data were reviewed and are summarized here. Further details are provided in the subwatershed analysis presented in Appendix K.

Lake Monroe Diagnostics and Feasibility Study (Jones Study) 1997
This study of the Lake Monroe Watershed identified sediment and phosphorus as two major concerns as well as lakeshore erosion, turbidity, over-recreation, urbanization of the watershed, algal blooms, and the lack of a comprehensive watershed management plan. The study included sampling of five tributaries that feed into Lake Monroe – North Fork Salt Creek, Middle Fork Salt Creek, South Fork Salt Creek, Brummett Creek, and Stephens Creek – as well as sampling within the lake. Sampling was conducted monthly from April 1992 to May 1993. The authors developed a hydrologic model for the lake which was used to calculate sediment and phosphorus budgets.

Cordry-Sweetwater Watershed Management Plan 2006
The Cordry-Sweetwater Conservancy District developed a watershed management plan to address concerns about Sweetwater Lake and its residential development. Sweetwater Lake flows into Sweetwater Creek and then North Fork Salt Creek, which flows into Lake Monroe. Initial concerns were failing septic systems, erosion and sedimentation, geese, and lawn chemicals. Sampling conducted in the summer of 2005 did not identify any parameters exceeding the Indiana surface water quality standards. The watershed team focused on educating the community about best management practices.

Yellowwood Lake Watershed Management Plan 2006
A watershed management plan was developed for Yellowwood Lake, which is part of Jackson Creek and drains into North Fork Salt Creek which drains into Lake Monroe. The main concerns were sediment, invasive species, E. coli, and potential chemical contamination. Water testing did not detect any chemical contamination but did detect elevated levels of E. coli in some samples which were believed to come from failing septic systems in the watershed.

Source Water Assessment for the City of Bloomington Utilities' Public Water Supply From Monroe Reservoir 2006
The Indiana Department of Environmental Management in cooperation with the U.S. Geological Survey prepared source water assessments for water supplies in Indiana that utilize surface water. The assessment describes the watershed, identifies contaminants of concern and their potential sources, and gives a brief overview of selected water quality data (primarily from CBU). Ninety-one potential point sources associated with sixty-one different contaminants of concern were identified. Examples include gas stations, quarries, scrapyards, and historic landfills. A review of water quality data from IDEM, IDNR, and USGS revealed no contaminant concentrations at or above a maximum contaminant level. A review of water quality data from City of Bloomington Utilities between 1993 and 2002 showed that none of the sampled

contaminants were detected above their respective maximum contaminant levels (MCL). Beryllium and thallium were the only constituents of concern detected at a concentration equal to their MCLs and those samples were collected in the 1990's.

Lake Monroe Water Quality Summary 1990-2017 (2018)
Prepared by the Indiana University School of Public and Environmental Affairs for The Nature Conservancy, this report summarized water quality data in Lake Monroe based on annual sampling activities conducted by the Indiana Clean Lakes Program and the United States Army Corps of Engineers between 1990 and 2017. The data were used to calculate the trophic state index (TSI) based on different sampling parameters. The study concluded that Lake Monroe appears to be mildly eutrophic and that algal blooms could be affecting water quality.

DNR Blue-Green Algae Beach Advisories (annually)
The Indiana Department of Natural Resources works with the Indiana Department of Environmental Management and the Indiana State Department of Health to monitor the presence of blue-green algae in lakes during the summer recreation season (Memorial Day-Labor Day). Water samples are collected and analyzed weekly at select swimming areas around the state. Samples are collected from Paynetown and Fairfax on Lake Monroe every other week except when the beaches are closed due to high water levels. Beach Advisory Alerts were issued annually 2011-2021 at both beaches based on algal counts over 100,000 cells/ml. These recreational advisories were typically issued in July and stayed in effect through the end of sampling (Labor Day). During a beach advisory alert, swimming and boating is permitted but visitors are advised to avoid contact with algae and take a bath after coming in contact with the water. No cyanotoxins were detected at levels that would trigger elevated recreational advisories.

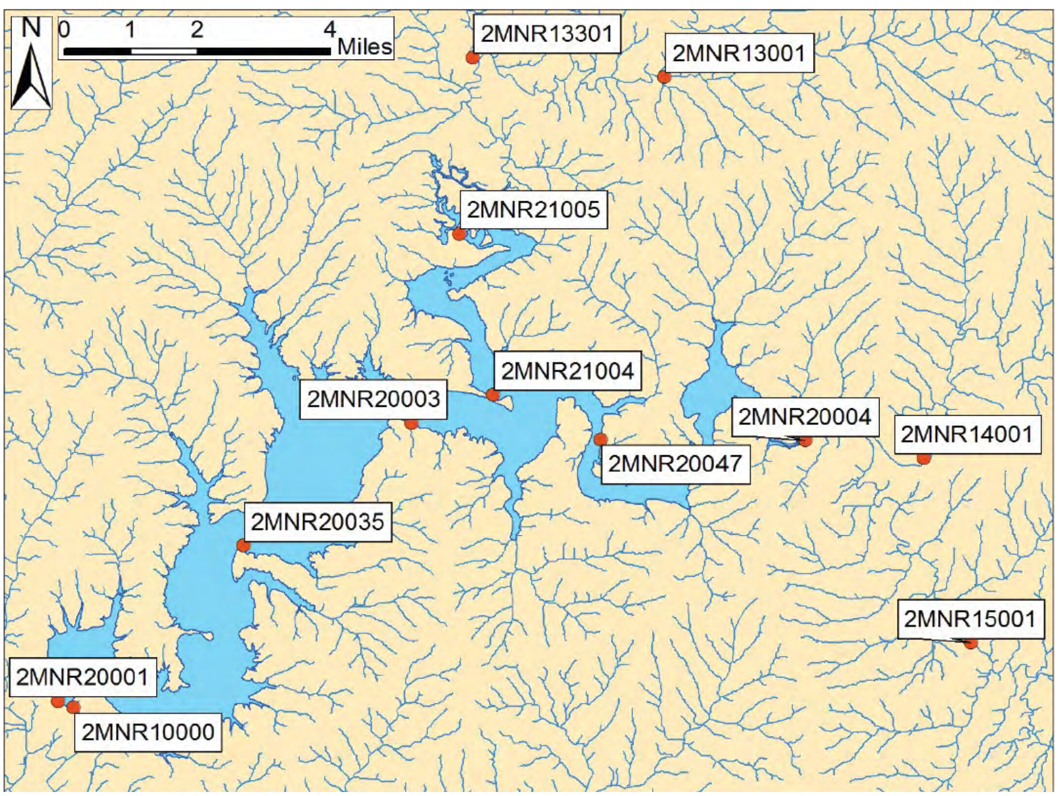
USFS Beach Advisories (annually)
The United States Forest Service monitors E. coli concentrations at the Hardin Ridge beach weekly from Memorial Day to Labor Day. Data reviewed from 2015-2020 revealed four exceedances (of the 235 CFU/100 ml standard) out of fifty-four total samples. Two occurred in August 2015, one in July 2016, and one in August 2016. No exceedances occurred in 2017-2020 and the highest recorded concentration in those years was 28 CFU/100 ml.

City of Bloomington Utilities Sampling (ongoing)
The City of Bloomington Utilities Department conducts multiple types of regular sampling events at the Monroe Water Treatment Plant located on the north side of the lake near the middle of the lower basin. Raw lake water at the intake to the water treatment plant is monitored hourly but digital records are maintained for samples collected once monthly. Those parameters include total organic carbon, dissolved organic carbon, and UV254. CBU also conducts periodic sampling for a wide variety of constituents at different frequency intervals. Every five years CBU samples in accordance with EPA's Unregulated Contaminant Monitoring Rule program, and those samples were most recently collected in 2020.

U.S. Army Corps of Engineers Lake Monroe Monitoring (annually)

The U.S. Army Corps of Engineers generally conducts ambient sampling events at Lake Monroe every summer and conducts an intensive three-season sampling program approximately once every twelve years. Sampling locations and frequencies have changed slightly over the years but generally samples are collected from the lower basin of the lake just above the dam, the middle of the center basin, the edge of the upper basin (just downstream of the causeway), the confluence with North Fork Salt Creek, and the confluence with Middle/South Fork Salt Creek. Additional samples have been collected certain years in North Fork Salt Creek in the waterfowl resting area, North Fork Salt Creek at Belmont, Brummett Creek where it enters North Fork Salt Creek, Middle Fork Salt Creek where it combines with South Fork, and South Fork Salt Creek at Maumee. Lake samples are collected at three depths – epilimnion, metalimnion, and hypolimnion. A wide variety of parameters are analyzed that have included (in various years) alkalinity, aluminum, ammonia, calcium, chloride, dissolved organic carbon, hardness, iron, magnesium, nitrate + nitrite, Kjeldahl nitrogen, orthophosphate, phosphorus, potassium, sodium, sulfate, total dissolved solids, total solids, total suspended solids, total organic carbon, atrazine, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, silver, and zinc. Samples within the lake area also analyzed for chlorophyll-α and phytoplankton. At the dam, zooplankton are investigated using a 20 foot vertical pull.

Figure 3-1 USACE Sampling Locations in Lake Monroe



IDEM 303d Assessment Sampling (2013)

(references: 2018 integrated report and appendices found at https://www.in.gov/idem/nps/watershed-assessment/water-quality-assessments-and-reporting/integrated-water-monitoring-and-assessment-report/)

The Indiana Department of Environmental Management (IDEM) operates a number of monitoring programs throughout the state. Probabilistic monitoring is conducted in one basin per year on a nine-year rotating cycle. The Lake Monroe watershed is located within the East Fork White River Basin which was monitored in 2013 (used to develop the 2016 303(d) impairment list) and is scheduled to be monitored again in 2022. Additionally, IDEM contracts with the Indiana University SPEA Clean Lakes Program to conduct trophic status monitoring on approximately 80 lakes annually out of 401 public lakes (see section above).

Hoosier National Forest Stream Monitoring for Biological Integrity in South Fork Watershed (2017-2019)

Hoosier National Forest staff periodically conduct fish sampling to evaluate water quality in streams within the forest. Data were provided for South Fork Salt Creek and several of its tributaries from 2017, 2018, and 2019 showing generally healthy biological integrity for fish.

3.3 New Water Quality Data

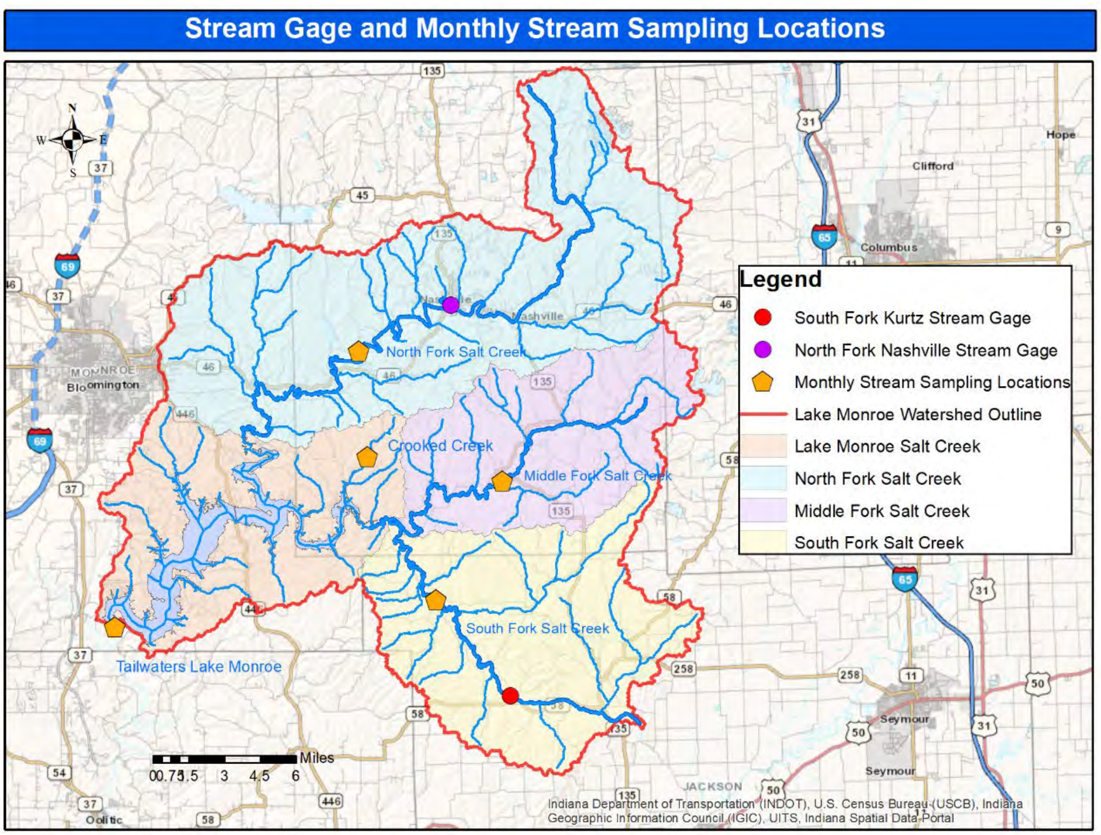
<u>Stream Monitoring Program (April 2020 – March 2021)</u>

The Indiana University Limnology Lab collected samples monthly for one year from four streams flowing into Lake Monroe as well as the tailwaters exiting the lake.

- North Fork Salt Creek
- Middle Fork Salt Creek
- South Fork Salt Creek
- Crooked Creek
- Lake Monroe Tailwaters

Samples were analyzed for pH, temperature, dissolved oxygen, nitrate+nitrite, total nitrogen, ammonia nitrogen, total and dissolved phosphorus, turbidity, conductivity, total suspended solids, discharge, and E. coli. The lab also conducted stream macroinvertebrate sampling once to calculate Indiana's macroinvertebrate Index of Biotic Integrity (mIBI) for each stream and conducted a habitat assessment using Indiana's Qualitative Habitat Evaluation Index (QHEI) for each stream. Data are provided in Appendices C and D.

Figure 3-2 Stream Gage and Monthly Stream Sampling Locations in Lake Monroe Watershed



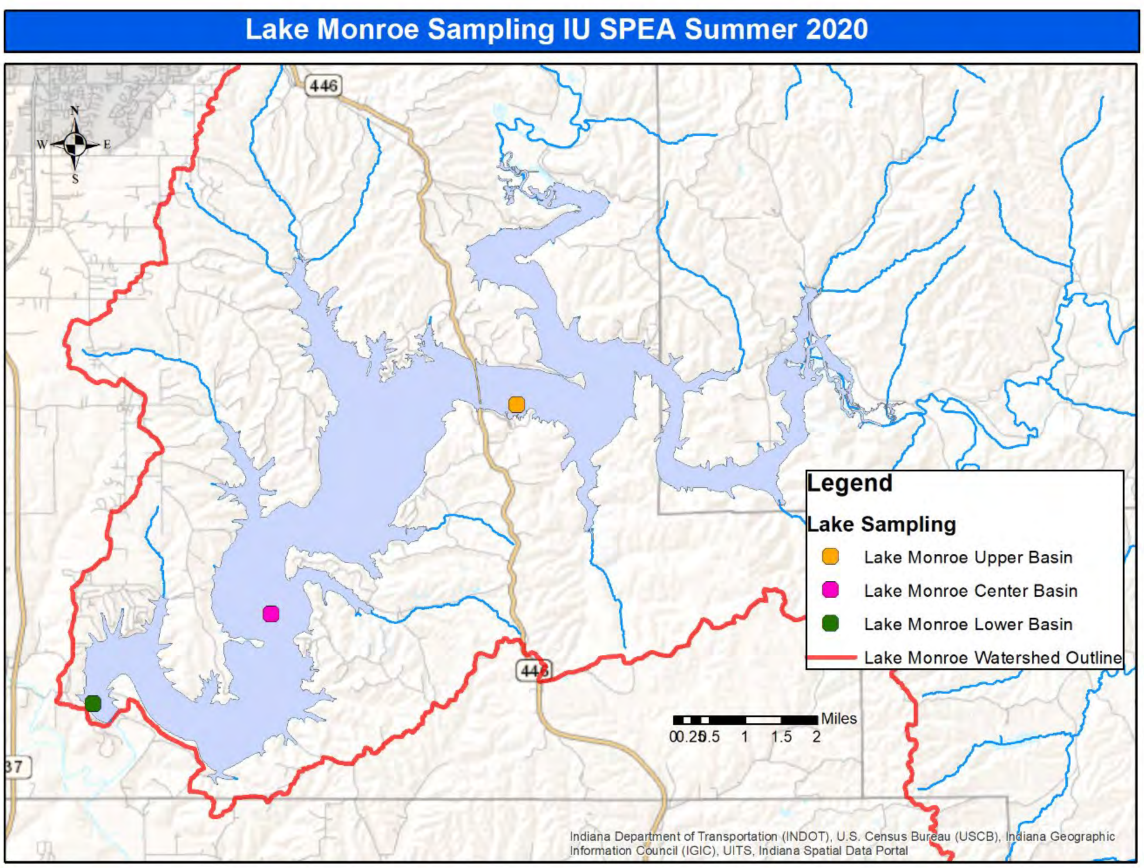
Lake Monitoring Program (May – October 2020)

The Indiana University Limnology Lab collected samples monthly during the summer season at three locations within Lake Monroe at two depths (epilimnetic and hypolimnetic) when the lake was stratified and one depth when the lake was not stratified.

- Upper Basin
- Center of Lake
- Lower Basin Near Dam

Samples were analyzed for temperature, dissolved oxygen, soluble reactive phosphorus, total phosphorus, total nitrogen, ammonia, nitrate nitrogen, alkalinity, conductivity, and chlorophyll-α (epilimnetic sample only). The lab also tested temperature and dissolved oxygen at one-meter levels as well as measuring Secchi disk transparency, number of meters at one percent light level, phytoplankton species distribution with 2-meter integrated sampler, and zooplankton species distributed through the full water column with a 50 micron tow net. Data are provided in Appendices C and D.

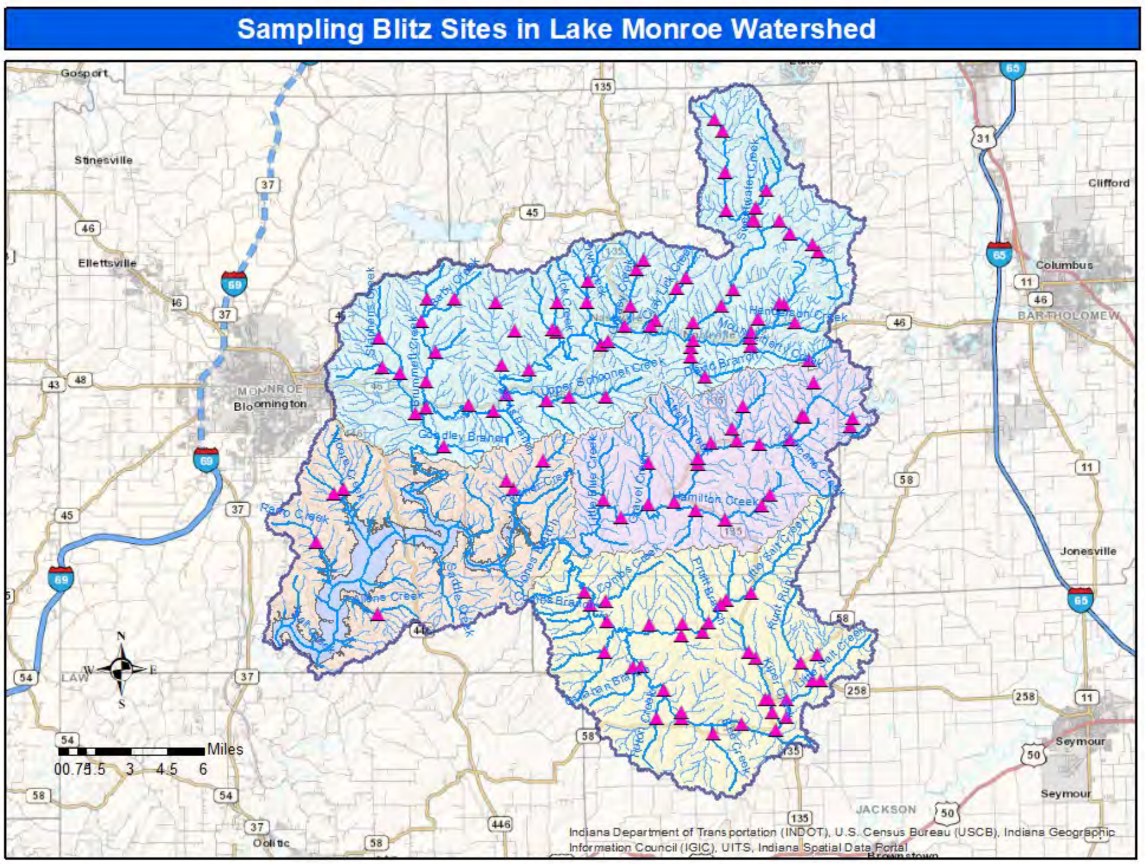
Figure 3-3 Lake Monroe Sampling Locations IU SPEA Summer 2020



Volunteer Monitoring Program aka Sampling Blitz (September 2020 and April 2021)

The Indiana University Limnology Lab worked with the Friends of Lake Monroe to conduct two volunteer monitoring events collecting water samples at 125 sites in the watershed. The fall blitz was held on September 18, 2020 with samples collected from 88 sites (the remaining stream sites were dry). The spring blitz was held on April 2, 2021 with samples collected from 122 sites (three sites were missed due to volunteer cancellations). Samples were analyzed for soluble reactive phosphorus, nitrate, hardness, pH, total phosphorus, ammonia, total nitrogen, and E. coli. Data are provided in Appendix E.

Figure 3-4 Sampling Blitz Sites in Lake Monroe Watershed



Brown County Regional Sewer District Sampling (May 2020)

The Brown County Regional Sewer District (BCRSD) collected and analyzed samples from various streams in Brown County for E. coli as part of a larger project developing a wastewater strategic management plan for the county. Samples were initially collected weekly for five weeks (5/5/20-6/2/20) to calculate the E. coli geometric mean. Data are provided in Appendix F.

Fecal Contamination Source Analysis (April 2021)

The Indiana University Limnology Lab partnered with BCRSD to determine whether fecal contamination is coming from human or animal sources. BCRSD used their sampling data to select 18 sites for source analysis, of which 7 were within the Lake Monroe watershed. The Lake Monroe watershed coordinator used the BCRSD data in combination with the data from the sampling blitz events to identify an additional 10 sites in the Lake Monroe watershed. Samples were collected on April 27, 2021 and sent to Scientific Methods for source analysis using genotyping of male-specific RNA coliphages to determine whether the fecal contamination is coming from humans or animals. Data are provided in Appendix G.

3.4 Windshield Surveys

Windshield surveys were conducted February – June 2020 using standardized field sheets as shown in Table 3-5 and Table 3-6. The surveys were conducted by the watershed coordinator and community volunteers at 243 of 540 identified road sections that cross a stream. The relevant concerns noted were:

1. Water odor, color, or algae
2. Stream buffer width by quadrant (upstream left, upstream right, downstream left, downstream right)
3. Areas of active streambank erosion
4. Areas where livestock were present and whether or not they had access to waterways
5. Evidence of channelization

Figure 3-5 Recording observations at a stream site.

Figure 3-6 Windshield Survey Observations in Lake Monroe Watershed

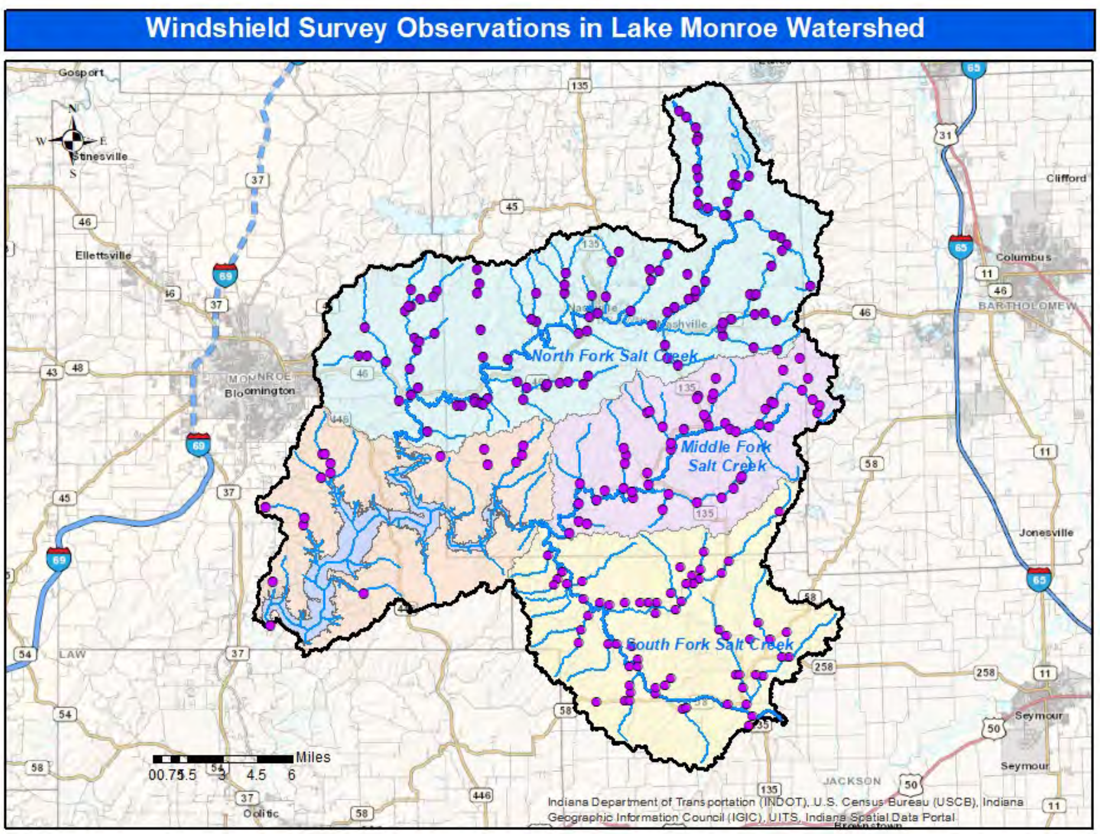


Table 3-5 Windshield Survey Field Sheet Page 1

Windshield Survey Field Sheet

Site ID ______________ Sub-Watershed ______________

Date ______________ Cross Street ______________

Time ______________ Investigator(s) ______________

Weather (past 24 hours)

- ☐ Rain ☐ Snow
  - ☐ Heavy
  - ☐ Steady
  - ☐ Intermittent
- ☐ Overcast
- ☐ Partly cloudy
- ☐ Clear

Weather (now)

- ☐ Rain ☐ Snow
  - ☐ Heavy
  - ☐ Steady
  - ☐ Intermittent
- ☐ Overcast
- ☐ Partly cloudy
- ☐ Clear

Observations

- ☐ Pipes flowing into stream
  How many? ______________
- ☐ Wildlife observed
  ____
- ☐ Hanging culvert?

Land Use - *Check land uses that best apply*

- ☐ Residential
  - ☐ Single Family
  - ☐ Multi-family
  - ☐ Stormdrain marking present
  - ☐ Stormwater management practices
    - ☐ curb and gutter
    - ☐ retention basins
    - ☐ naturalized drainage systems
- ☐ Industrial
- ☐ Commercial (Strip malls, restaurants, etc)
- ☐ Forestry
  - ☐ Ruts or gullies
  - ☐ Noticeable drainage issues
  - ☐ Logging debris in streams
  - ☐ Logging debris adjacent to streams
  - ☐ Unstabilized Soil
- ☐ Mining
- ☐ Wetlands
- ☐ Agricultural
  - ☐ Row Crop
    - ☐ no-till
    - ☐ reduced till (50% residue)
    - ☐ conventional
  - ☐ Pasture
    - ☐ Stream access
    - ☐ Fenced from stream
    - ☐ Cattle
    - ☐ Hogs
    - ☐ Horses
    - ☐ Other ______________
  - ☐ Feedlot
    - ☐ Cattle (dairy)
    - ☐ Cattle (other)
    - ☐ Hogs
    - ☐ Other ______________
    Estimated # of animals
    ____

Available Shade/Stream Cover

- ☐ 0% Cover
- ☐ 1-25% Cover
- ☐ 25-75% Cover
- ☐ 75-100% Cover

In-Stream Habitat
check all that apply

- ☐ Underwater tree roots
- ☐ Boulders
- ☐ Downed Trees
- ☐ Deep Areas
- ☐ Shallow Areas
- ☐ Undercut Banks

Table 3-6 Windshield Survey Field Sheet Page 2

Windshield Survey Field Sheet (cont.)

Site ID ____________ Sub-Watershed ____________ Date ____________

Water Odors
check all that apply
- ☐ Normal
- ☐ Sewage
- ☐ Petroleum
- ☐ Chemical
- ☐ Other ____________

Water Color/Appearance
check all that apply
- ☐ Clear
- ☐ Green
- ☐ Brown
- ☐ Murky
- ☐ Oily Sheen
- ☐ Other ____________

Algae
check all that apply
- ☐ Floating
- ☐ Attached to Substrate
- ☐ Thick mats
- ☐ Limited growth
- ☐ Moderate growth
- ☐ Excessive growth

Stream Buffer

	up	down
left		
right		

Buffer Type
check all that apply
- ☐ Trees
- ☐ Shrubs
- ☐ Grasses

Estimated Width of Buffer
- ☐ < 10'
- ☐ 10-25'
- ☐ 25-50'
- ☐ >50'

Stream Erosion
- ☐ Absent
- ☐ Stabilized (rip-rap, coir log, etc.)
- ☐ Present

Estimated Height of Erosion
- ☐ < 1'
- ☐ 1-3'
- ☐ > 3'

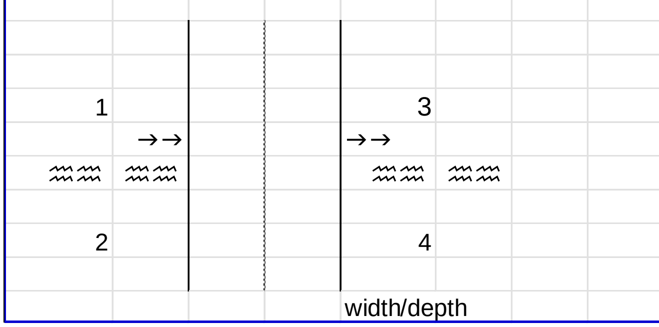
In-Stream Debris
check all that apply
- ☐ Trash
- ☐ Deposits
- ☐ Beaver Dam
- ☐ Log Jam
- ☐ Logging Debris
- ☐ Other

Sampling Blitz Site Assessment

Safe Place to Park?
- ☐ Yes Where: ____________
- ☐ No

Safely Accessible?
- ☐ Yes
- ☐ No

Where: ____________



Fences or Blockages?
- ☐ Yes
- ☐ No

Excessive Erosion or Dangerous Loose Rocks?
- ☐ Yes
- ☐ No

Deep muck, silt, or sand at entry point?
- ☐ Yes
- ☐ No

Steepness at Entry Point ____________

Water Depth at Entry Point ____________

Recommended Sampling Site?
- ☐ Yes
- ☐ No

Photographs were taken of each site and sites were evaluated to determine suitability for volunteer water quality monitoring. A brief summary is presented below with additional discussion presented in Section 4.

Table 3-7 Windshield Survey Summary for Lake Monroe

HUC 10 Windshield Survey Summary	North Fork Salt Creek	Middle Fork Salt Creek	South Fork Salt Creek	Lake Monroe Basin	Entire Watershed
Number Sites Observed	111	51	64	17	243
% Sites with No Buffer (<5 feet)	27%	20%	9%	12%	20%
% Sites with Minimal Riparian Buffer (5-19 feet)	43%	43%	33%	29%	40%
% Sites with Moderate Riparian Buffer (20-100 feet)	18%	20%	38%	24%	24%
% Sites with Healthy Riparian Buffer (>100 feet)	12%	18%	20%	35%	17%
% Sites with Active Erosion	89%	90%	88%	53%	86%
% Sites with Minimal Erosion (~1 feet)	16%	16%	14%	6%	15%
% Sites with Moderate Erosion (~2 feet)	46%	41%	45%	35%	44%
% Sites with Severe Erosion (3+ feet)	27%	33%	28%	12%	28%
% Sites with Livestock Present	23%	25%	23%	12%	19%
% Sites with Livestock Stream Access	7%	4%	13%	0%	7%
% Sites with Obvious Channelization	0%	0%	2%	0%	0%

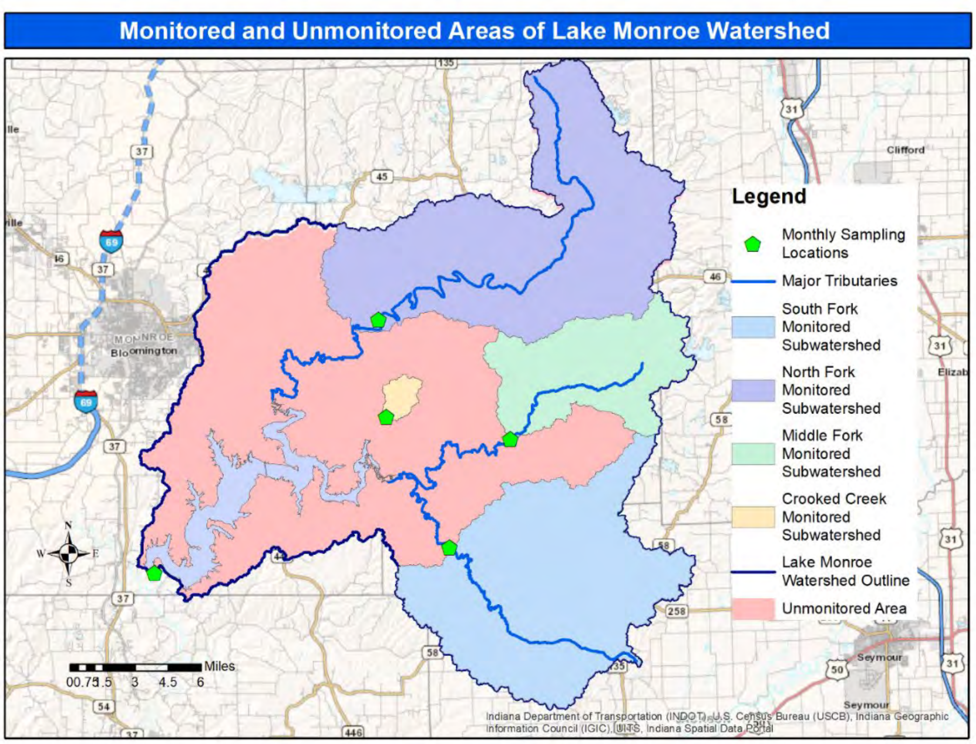
4 Analysis of Available Data

The water quality monitoring program was developed to both understand what is happening within the lake and how activities in the watershed impact water quality in the lake. Both components provide increased understanding of the challenges facing Lake Monroe and the best strategies for improvement.

4.1 Nutrient and Sediment Budgets

Nutrient and sediment budgets were developed for Lake Monroe to calculate the amount of phosphorus, sediment, and nitrogen entering and exiting the lake annually. The hydrologic year used was 04/01/2020 – 03/31/2021. Regression models were developed for the four monitored tributaries (South Fork, Middle Fork, North Fork, and Crooked Creek). These represent approximately 45% of the watershed (Figure 4-1). Inputs from the remaining unmonitored area were estimated by multiplying the unmonitored drainage area (excluding the lake) by the areal loads (lbs/acre) for the North Fork subwatershed. North Fork was chosen because the land cover in the unmonitored area most closely resembles the land cover in the North Fork subwatershed. These loads were added together to calculate the total loads coming into Lake Monroe.

Figure 4-1 Monitored and Unmonitored Areas of Lake Monroe Watershed



Nutrient and sediment loads leaving Lake Monroe were calculated using a regression model based on monthly monitoring data from the outlet and flow data out the dam provided by the USACE. Based on these calculations, Lake Monroe retains 48% of the incoming phosphorus load, 92% of the incoming sediment load and 15% of the incoming nitrogen load.

Table 4-1 Nutrient and Sediment Budgets for Lake Monroe

	Phosphorus Load (lbs/yr)	Percent of Inflow	Sediment Load (tons/yr)	Percent of Inflow	Nitrogen Load (lbs/yr)	Percent of Inflow
South Fork above Maumee	7,652		2,273		181,750	
Middle Fork above Story	1,048		489		24,013	
North Fork above Yellowwood	13,427		13,393		142,929	
Crooked Creek above Tecumseh	35		5		886	
Unmonitored Area	22,630		22,573		240,897	
Lake Monroe Inflow	44,792		38,733		590,474	
Lake Monroe Outflow	23,229		3,037		501,996	
Lake Storage	21,563	48%	35,696	92%	88,478	15%

As shown in the table above, the models show that North Fork is the largest contributor of phosphorus and sediment while South Fork is the largest contributor of nitrogen. This is true even when the drainage areas are taken into account and areal loads (lbs/acre-year) are calculated as shown in Table 4-2 below.

Table 4-2 Areal Pollutant Loads into Lake Monroe

Sub-Watershed	Drainage Area (acres)	Areal Load Phosphorus (lbs/ acre-yr)	Drainage Area (acres)	Areal Load Sediment (tons/ acre-yr)	Drainage Area (acres)	Areal Load Nitrogen (lbs/ acre-yr)
South Fork above Maumee	56,825	**0.13**	56,825	**0.04**	56,825	**3.20**
Middle Fork above Story	24,400	**0.04**	24,400	**0.02**	24,400	**0.98**
North Fork above Yellowwood	68,100	**0.20**	68,100	**0.20**	68,100	**2.10**
Crooked Creek above Tecumseh	1,700	**0.02**	1,700	**0.00**	1,700	**0.52**
Unmonitored Area	114,778	**0.20**	114,778	**0.05**	114,778	**2.10**

Based on land use analysis, the South Fork subwatershed was expected to be the largest contributor of all three parameters due to it having the highest concentration of agricultural land. One possible explanation for the high loads in the North Fork is that nonpoint source pollution could be coming primarily from non-agricultural sources such as leakage from septic systems or fertilizer use on commercial and residential properties.

Another possible explanation is that the difference in flows captured during the sampling events caused a difference in the models. The highest discharge recorded during a monthly sampling event occurred on 2/25/21 for both streams. Daily flow at the South Fork Kurtz gage was 168 cfs, the 20th highest daily flow for the hydrologic year. Daily flow at the North Fork Kurtz gage was 571 cfs, the 10th highest daily flow for the hydrologic year. Since the data set for the North Fork model included a higher flow event, it better predicts loads during larger flow events and therefore generates higher annual load estimates than the South Fork model.

4.2 Flow Frequency Analysis

When evaluating nutrient and sediment models, it is important to understand if the captured stream flow events are representative of typical stream flow. If the sampling events only captured low flow conditions, the models would likely underestimate nutrient and sediment loads. It is also useful to know if the hydrologic year is typical of the stream over time or if it was an unusually wet or dry year. The full flow frequency analysis is provided in Appendix L.

Peak discharge for the monitored hydrologic year (4/1/2020-3/31/2021) was compared to historical records of peak discharge for both the Kurtz stream gage and the Nashville stream gage. For the South Fork at the Kurtz gage, the probability of a peak discharge exceeding the monitored hydrologic year peak discharge is 38%, corresponding to a 3-year return period. For the North Fork gage, the probability of a peak discharge exceeding the monitored hydrologic year peak discharge is 53%, corresponding to a 2-year return period. These values indicate that the study year was not unusually wet or dry.

The highest discharge recorded during a monthly sampling event for each stream was also compared to the historical records of peak discharge. Both streams had the highest discharge recorded during the 2/25/21 sampling event. Daily flow at the Kurtz gage on 2/25/21 was 168 cfs, corresponding to less than a 1-year return period. Daily flow at the Nashville gage on 2/25/21 was 571 cfs, corresponding to less than a 1-year return period. These very low return periods mean that the 2/25/21 sampling event was not during a particularly high flow event for either stream.

This information indicates that our nutrient and sediment load calculations are based on regression models that do not contain representative peak flows. Therefore, the models likely underestimate the nutrient and sediment load to the lake.

4.3 Water Budget for Lake Monroe

Water budget calculations provide insight into the balance between water coming into the lake and water leaving the lake. The water budget also helps to evaluate the reliability of the hydrologic measurements used to calculate nutrient and sediment loads. Annual streamflow into Lake Monroe from the four monitored tributaries (South Fork, Middle Fork, North Fork, and Crooked Creek) was calculated using regression models based on sampling data and stream gage data. These streamflow calculations account for approximately 55% of the watershed. Streamflow from the remaining unmonitored area was calculated using the areal flow rate for North Fork because land cover is the most similar. These flows were combined to get the annual streamflow into Lake Monroe.

Table 4-3 Annual Total and Areal Flow in Tributaries to Lake Monroe

Sub-watershed	Annual Flow From Regression Models 8-17-2021 (cubic feet/yr)	Catchment Area (acres)	Areal Flow (cubic feet/acre-yr)
South Fork - Maumee	3,987,393,636	56,825	70,170
Middle Fork - Story	665,491,732	24,400	27,274
North Fork - Yellowwood	3,673,311,759	68,100	53,940
Crooked Creek - Tecumseh	57,152,217	1,700	33,619
Unmonitored – Excluding Lake Monroe	6,191,121,543	114,778	53,940
Total Inflow Via Tributaries	**14,574,470,887**	**265,803**	**54,832**

The total input of water coming into Lake Monroe is streamflow + precipitation. Streamflow accounts for 90% of inputs and precipitation accounts for the remaining 10%. Outputs include drinking water withdrawals, evaporation, and outlet flow through the dam. Outlet flow accounts for 88% of outputs. Drinking water withdrawals by the City of Bloomington account for 5% of outputs, while evaporation from the lake surface accounts for 7% of outputs. (See Appendix L for the detailed water budget and data sources.)

The water budget is balanced when the difference between inflow and outflow is equal to the change in water stored in the lake. By comparing storage to the difference between inflow and outflow we can estimate the accuracy of our calculations. Calculations used to estimate streamflow, precipitation, evaporation and changes in storage are prone to error. The reliability of our calculations can be judged by the relative significance of this error. Error is expressed in the table below as a percentage of the total inputs to the lake.

Table 4-4 Monthly Water Budget for Lake Monroe 4/1/20-3/31/21

Month	Inflow	Outflow	Storage	In-Out-Storage	% Error
Apr-20	1397251288	4693361171	-2861148290	-434961592	-31.13%
May-20	3,377,286,254	2202127146	1032813390	142345718	4.21%
Jun-20	396,007,328	2,591,922,052	-2369099941	173185217	43.73%
Jul-20	448,329,344	288,530,924	224801710	-65003289	-14.50%
Aug-20	556,210,201	972,393,550	-246022649	-170160699	-30.59%
Sep-20	23,659,418	226,490,745	-332202228	1,293,709,00	546.81%
Oct-20	232,975,719	224,374,741	194814936	-186213958	-79.93%
Nov-20	907,889,896	393,208,251	806769218	-292087573	-32.17%
Dec-20	459,973,932	826,777,351	-455838595	89035176	19.36%
Jan-20	1,630,558,036	1,542,918,328	134879501	-47239794	-2.90%
Feb-20	3,195,459,649	2,245,576,345	375909437	573973866	17.96%
Mar-20	3,149,066,163	1,821,861,581	2622607851	-1,295,403,270	-41.14%
Annual Total	**15,774,667,227**	**18,029,542,186**	**-871,715,661**	**-1,383,159,298**	**-8.77%**

On a monthly basis, errors are large, but on an annual basis, the 8.77% error is very good. A cursory comparison of streamflow discharge and reported outflows suggests a tendency to underestimate outflow during periods of small releases to Salt Creek. High errors occurring in September 2020 are likely due to underestimation of outflow. Additionally, the lake level-volume and lake level-area curves most likely originate from the 1960’s. No lake-wide bathymetric surveys have been conducted since the lake was constructed in the early 1960’s and so the changes in the lake level-volume and lake level-area tables are unknown.

4.4 Water Quality in Lake Monroe

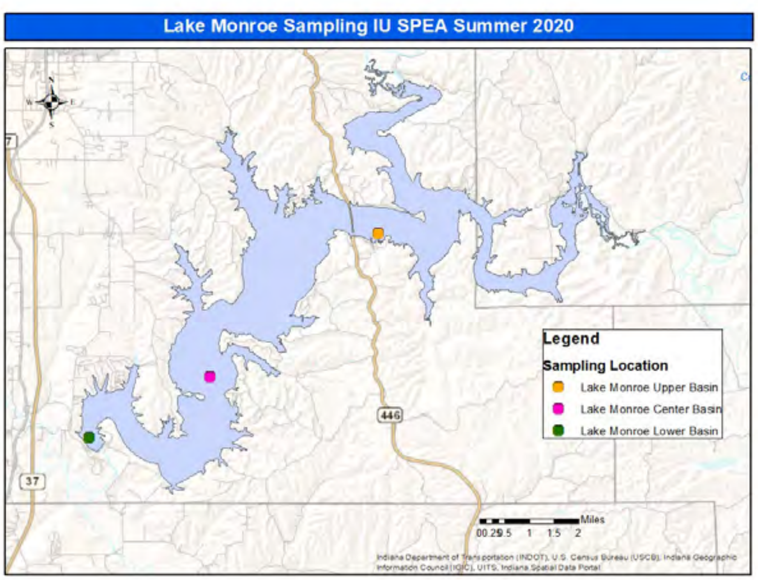
Historical Information

Historical data indicates that Lake Monroe is mildly eutrophic, resulting in periodic algal blooms. The 2018 report "Lake Monroe Water Quality Summary 1990-2017" determined that total phosphorus, Secchi disk transparency, and chlorophyll-a met or exceeded the eutrophic threshold in more than 40% of the samples collected by USACE and the Indiana Clean Lakes Program during the summer stratification period from 1990 to 2017. The 1997 "Lake Monroe Diagnostic and Feasibility Study" also reported total phosphorus concentrations and soluble reactive phosphorus concentrations regularly exceeding the eutrophic threshold. Mean total phosphorus concentrations in each basin ranged from 0.02 to 0.07 mg/L. TP concentrations were generally low in early summer, rising throughout the summer, and falling throughout the winter months. TP concentrations were highest and most consistently above the threshold in the upper basin which tends to be shallowest.

Current Study

Indiana University conducted water quality monitoring in Lake Monroe during the summer and fall of 2020 to evaluate current chemical and biological conditions. Nutrient concentrations were measured in the upper, center and lower basins as shown in Figure 4-2. During the summer months, many lakes become stratified which means the top layer of water (epilimnion) does not mix with the bottom layer of water (hypolimnion). Samples were collected from both the epilimnion and hypolimnion during periods of stratification as determined based on temperature and dissolved oxygen profiles for each basin.

Figure 4-2 Lake Monroe Sampling Locations IU SPEA Summer 2020

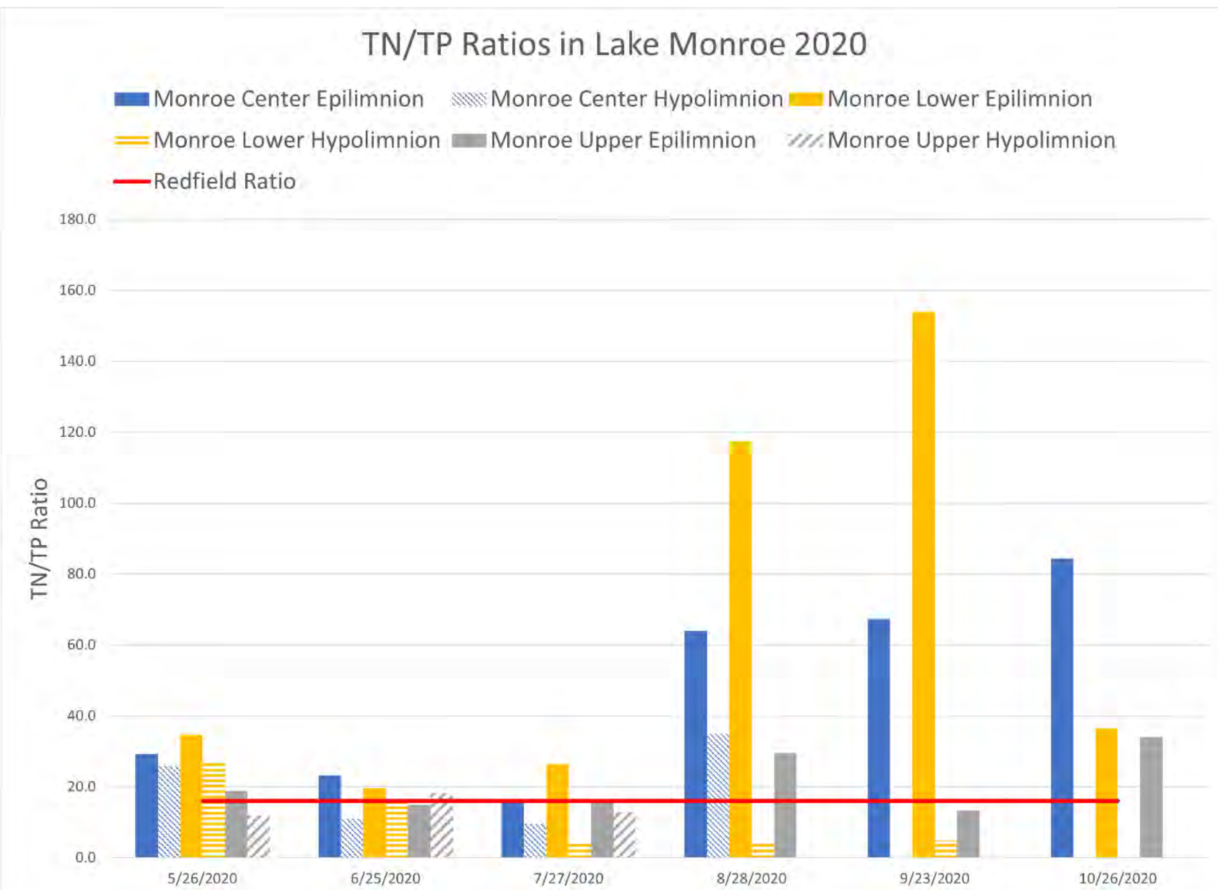


4.4.1 Limiting Nutrient (Nitrogen-Phosphorus Ratio)

Lakes in Indiana are generally presumed to be phosphorus limited, meaning that an increase in phosphorus will cause an increase in algal growth and that reducing the concentration of phosphorus will reduce algal growth. The total nitrogen to total phosphorus ratio (TN/TP) is an indicator of nutrient limitation in Lake Monroe. A ratio of TN/TP of 16 or higher is generally considered to indicate phosphorus limitation (Redfield, 1934). Below the threshold, algal growth is limited by the availability of nitrogen. Recent researchers have suggested using a slightly higher ratio, such as 20 or 30, due to variability in phytoplankton and in freshwater systems.

TN/TP ratios are generally above 16 in both the epilimnion and the hypolimnion in May and June, indicating phosphorus limitation, as shown in Figure 4-3. However, in July the TN/TP ratio drops below 16 in the hypolimnion of all three basins, indicating nitrogen limitation in the hypolimnion. This is believed to occur because the hypolimnion has become anoxic, allowing phosphorus release from the sediments. The drop is the most pronounced and sustained in the lower basin, which is the deepest.

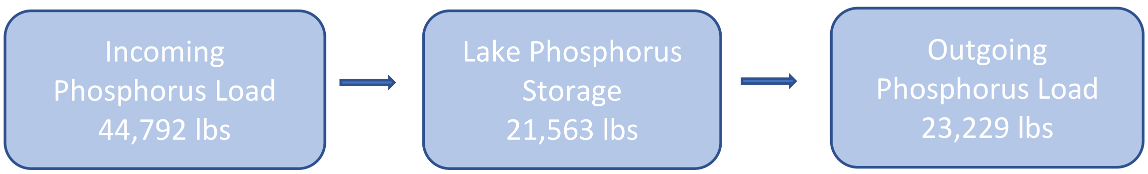
Figure 4-3 Total Nitrogen to Total Phosphorus Ratio in Lake Monroe 2020



4.4.2 Phosphorus in Lake Monroe

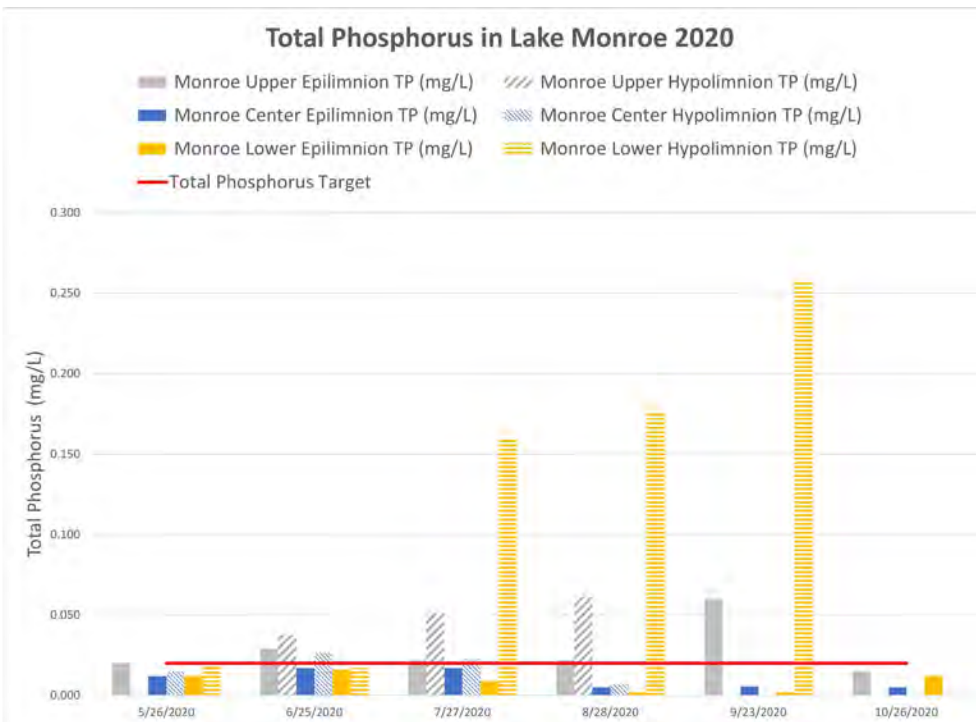
Lake Monroe acts as a phosphorus sink, as shown in Figure 4-4. 44,792 pounds of phosphorus enter the lake annually and 23,229 pounds leave the lake, leaving 21,563 pounds stored in the lake. Storage of phosphorus in the lake can be dissolved in the water column, bound to sediment or, tied up in fish, algae and other life forms.

Figure 4-4 Phosphorus Movement Through Lake Monroe



Elevated phosphorus levels increase the likelihood of algal blooms. Total phosphorus was measured at levels above the water quality target of 0.020 mg/L in 86% of the hypolimnion samples, with 100% of upper basin hypolimnion, 50% of center basin hypolimnion, and 67% of lower basin hypolimnion samples exceeding the water quality target. Total phosphorus concentrations were highest in the lower basin hypolimnion, where concentrations exceeded 0.150 in July, August, and September. This is three times the concentrations seen in the upper basin.

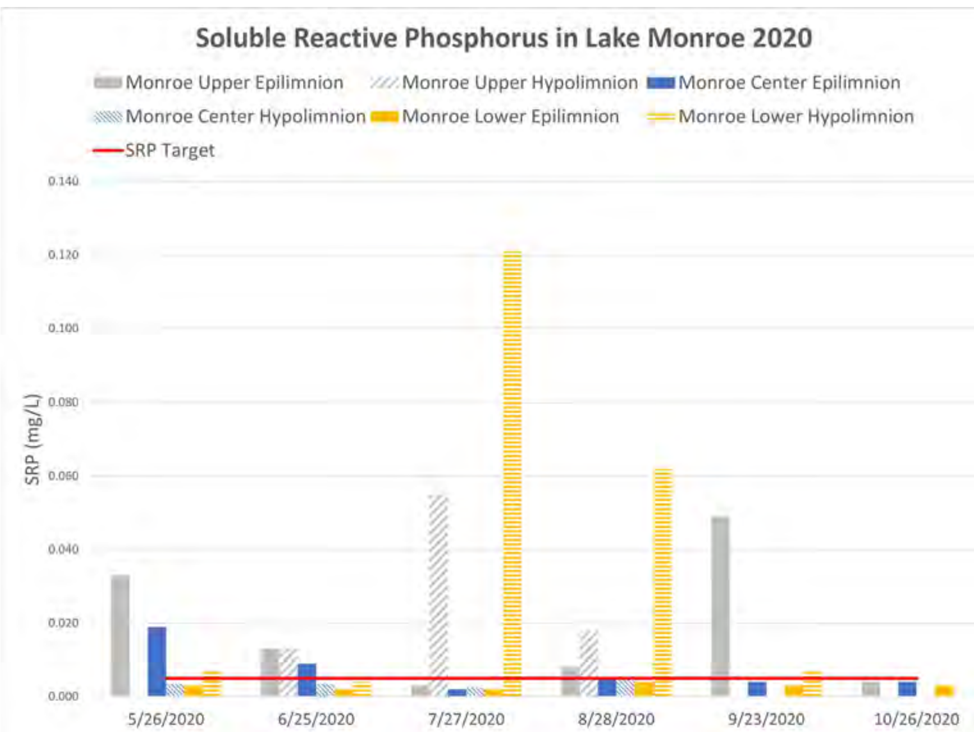
Figure 4-5 Total Phosphorus Concentrations in Lake Monroe Summer 2020



The high concentrations in the lower basin most likely occur because the lower basin is the deepest portion of the lake and stratification causes dissolved oxygen levels to drop to zero, as discussed in section 4.4.3. These anoxic conditions allow for phosphorus release from the sediments and in turn that phosphorus is taken up by algae. No total phosphorus exceedances were reported in the center and lower basin epilimnions. Concentrations in the upper basin epilimnion were slightly over the target in June, July, and August before jumping to 0.060 mg/L in September. The elevated concentration in September may reflect the mixing of the epilimnion and hypolimnion as the lake began to turn over.

While total phosphorus increased in the upper and lower basin hypolimnion through the summer months, Soluble Reactive Phosphorus (SRP) concentrations decreased (Figure 4-6). SRP is the form of phosphorus that is available to fuel algae growth. SRP is highest in the lower and upper basin hypolimnions where stratification occurs and SRP is released from bottom sediments.

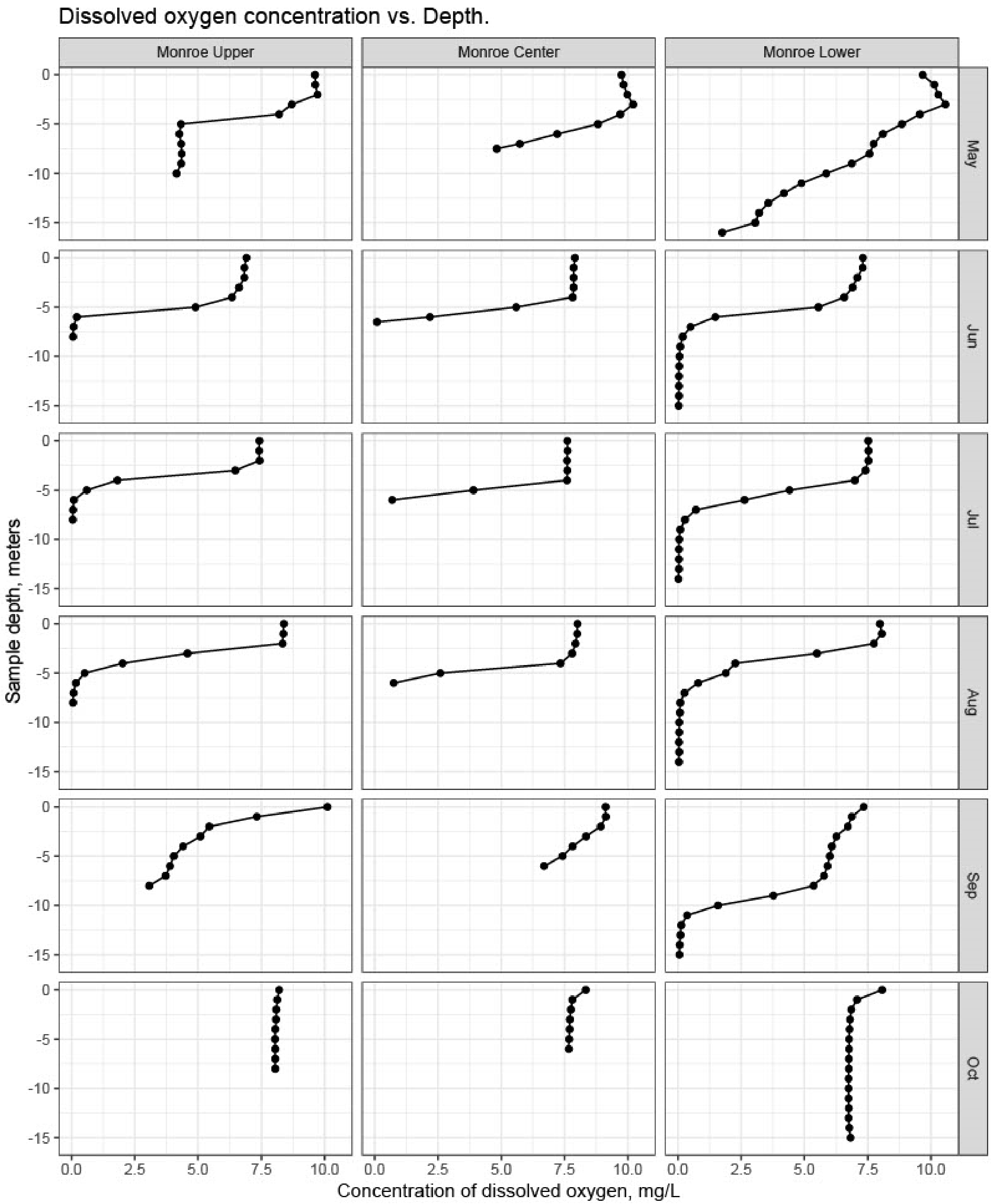
Figure 4-6 Soluble Reactive Phosphorus in Lake Monroe 2020



4.4.3 Stratification and Anoxia

During stratification, the epilimnion has higher temperatures and more dissolved oxygen due to exposure to sunlight and mixing with air. In contrast, the hypolimnion will have lower temperatures and less dissolved oxygen because it is not mixing with the surface water. Dissolved oxygen in the hypolimnion is at or near zero from June-August in the upper basin and June-September in the lower basin, as shown in Figure 4-7. In the center basin, low oxygen concentrations occurred in June-August but only at the bottom, likely because this sampling point was shallow, allowing mixing to occur in most of the water column.

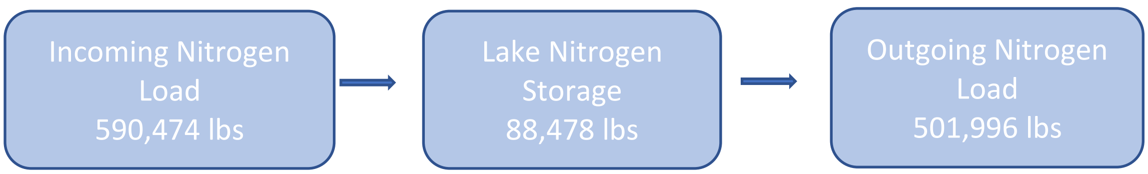
Figure 4-7 Dissolved Oxygen Concentration vs. Depth



4.4.4 Nitrogen in Lake Monroe

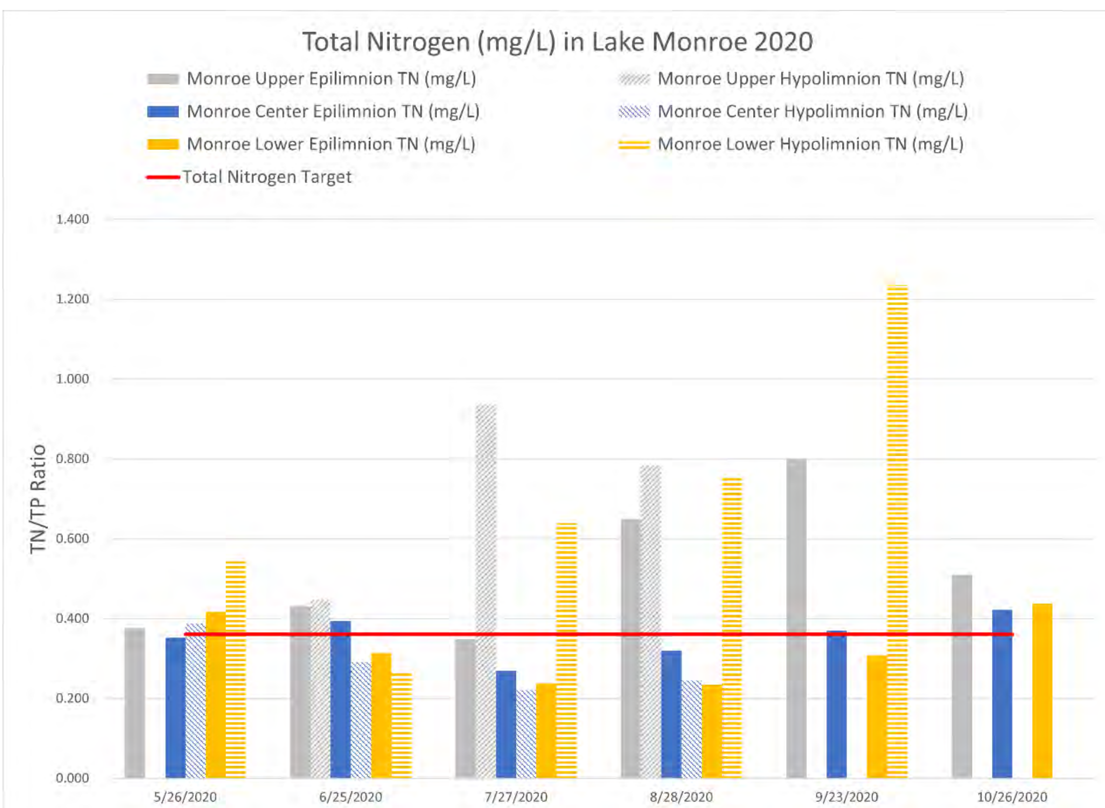
Lake Monroe retains about 15% of its incoming nitrogen load, as shown in Figure 4-8. 590,474 pounds of nitrogen enter the lake annually and 501,996 pounds leave the lake, leaving 88,478 pounds stored in the lake.

Figure 4-8 Nitrogen Movement Through Lake Monroe



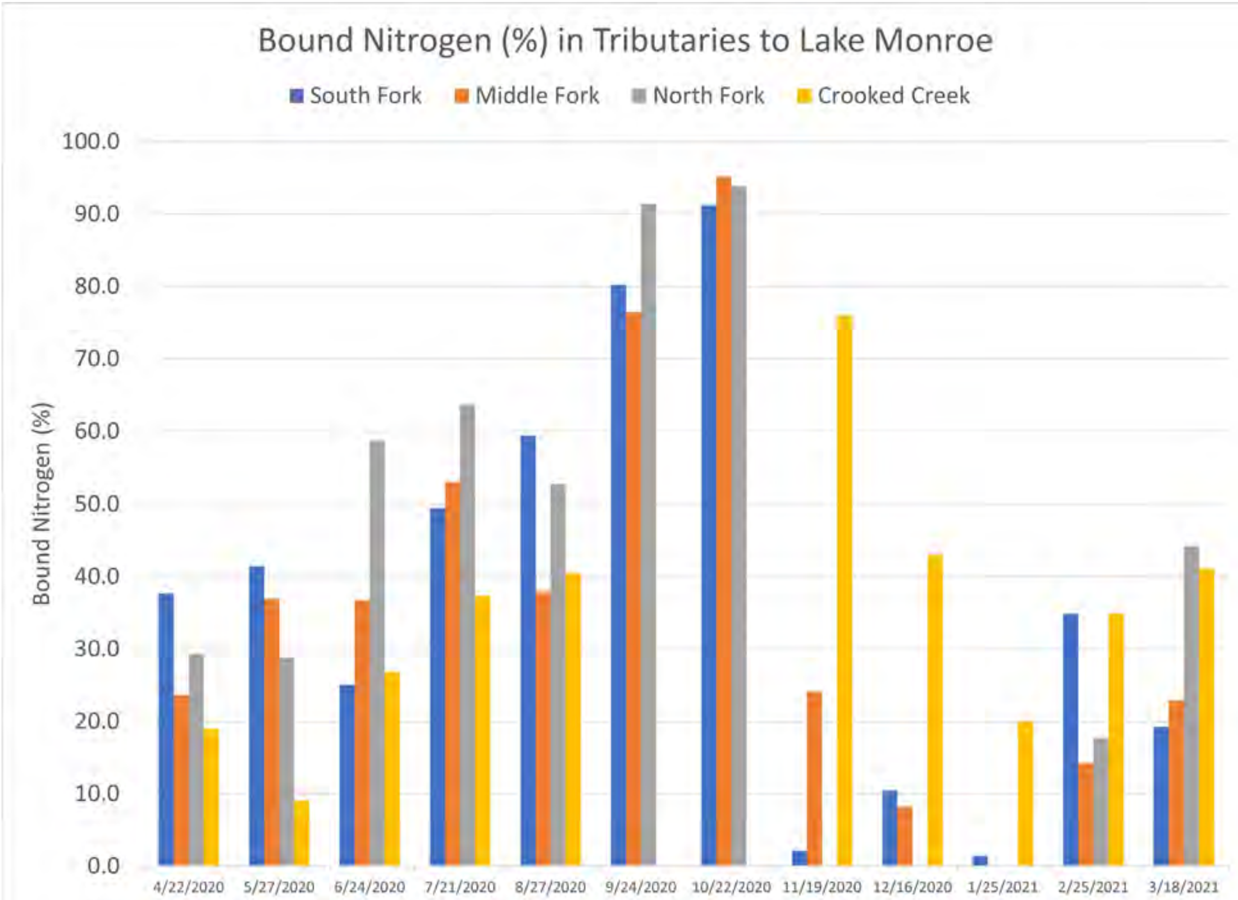
Total nitrogen was detected in Lake Monroe at levels above the target water quality goal of 0.69 mg/L in 17% of Upper Basin epilimnion samples, 67% of Upper Basin hypolimnion samples, and 40% of Lower Basin hypolimnion samples. No total nitrogen exceedances were detected in the Center Basin samples.

Figure 4-9 Total Nitrogen in Lake Monroe 2020



A significant portion of the nitrogen loads to Lake Monroe are in the form of sediment bound nitrogen. Bound nitrogen was calculated by subtracting nitrate and ammonia from the total nitrogen concentration. Bound nitrogen was divided by total nitrogen to get the percent of bound nitrogen as shown in Figure 4-10. Four data points were excluded because the reported ammonia concentrations were higher than the reported total nitrogen concentrations.

Figure 4-10 Percent Bound and Organic Nitrogen in Tributaries to Lake Monroe



4.4.5 Chlorophyll-a in Lake Monroe

Samples were collected from the epilimnion at each lake sampling site and analyzed in the lab for Chlorophyll-a concentrations. Chlorophyll-a concentration is an indicator of algal growth. According to Carlson (Carlson 1977), concentrations over 7.3 ug/L indicate eutrophic conditions. 83% of upper basin samples, 50% of center basin samples, and 33% of lower basin samples exceed that threshold.

Chlorophyll-a was reported at levels above the water quality target of 4.93 ug/L in 100% of upper basin epilimnion samples, 83% of center basin epilimnion samples, and 67% of lower basin epilimnion samples. The average concentration, maximum concentration, and percent of samples exceeding the water quality target were all highest in the upper basin with the center basin second and the lower basin third. These results indicate decreasing algal concentration as water moves through the lake, presumably due to the depletion of incoming nutrients as water flows through the lake and nutrient-laden sediments are deposited on the lake bottom.

Chlorophyll-a concentrations were highest in the upper and center basin during the late September sampling event. These high concentrations are likely due to coincident warm temperatures, destratification and mixing of nutrient rich hypolimnetic water with the epilimnion.

Table 4-5 Chlorophyll-a in Epilimnion of Lake Monroe 2020

Sample Date	Monroe Upper Chlorophyll-a (ug/L)	Monroe Center Chlorophyll-a (ug/L)	Monroe Lower Chlorophyll-a (ug/L)
5/26/2020	8.59	6.81	6.76
6/25/2020	6.19	4.42	2.97
7/27/2020	19.32	6.07	2.50
8/28/2020	26.49	11.34	7.96
9/23/2020	31.00	16.97	6.15
10/26/2020	18.57	13.78	7.73
Average	18.36	9.90	5.68
Max	31.00	16.97	7.96
Min	6.19	4.42	2.50
% > 4.93	100%	83%	67%

4.4.6 Blue-Green Algae in Lake Monroe

Blue-green algae monitoring by IDEM and ISDH led to Beach Advisory Alerts being issued annually 2011-2021 at Fairfax and Paynetown Beaches based on algal counts over 100,000 cells/ml. These recreational advisories were typically issued in July and stayed in effect through the end of sampling (Labor Day). During a beach advisory alert, swimming and boating is permitted but visitors are advised to avoid contact with algae and take a bath after coming in contact with the water. Cyanotoxins are also measured as part of the monitoring program. However, no cyanotoxins were detected at levels to trigger elevated recreational advisories in Lake Monroe.

Table 4-6 Historical Algal Counts at Paynetown per IDEM/IDNR/ISDH Beach Monitoring Program

Historical Algal Counts (cells/ml) at Paynetown							
	Mid June	**Late June**	**Early/Mid July**	**Mid/Late July**	**Early August**	**Mid August**	**Late August**
2011	—	46,960	—	110,240	604,400	599,160	541,800
2012	—	19,680	—	298,153	—	1,114,200	422,800
2013	—	52,800	—	77,093	—	161,019	148,284
2014	15,952	—	77,763	—	189,919	391,463	—
2015	2,083	—	61,589	—	147,960	87,385	—
2016	—	21,601	—	122,060	798,760	394,318	—
2017	13,078	—	42,699	—	222,759	242,444	—
2018	13,600	—	138,036	235,616	185,624	254,214	—
2019	84,519	—	—	—	508,684	586,131	—
2020	—	30,188	—	—	543,604	656,807	550,698

Chlorophyll-a measurements collected by the Indiana Limnology Lab from April showed peak concentrations during the late September (9/23/2020) sampling event. This indicates that algal counts likely continue to increase in the early fall after the IDEM beach monitoring program ends (Labor Day – late August). Peak algal counts likely occur in September or possibly October. While recreational use decreases significantly after Labor Day, there are still plenty of swimmers and boaters in September and October.

4.4.7 Legacy Nutrients in Lake Monroe

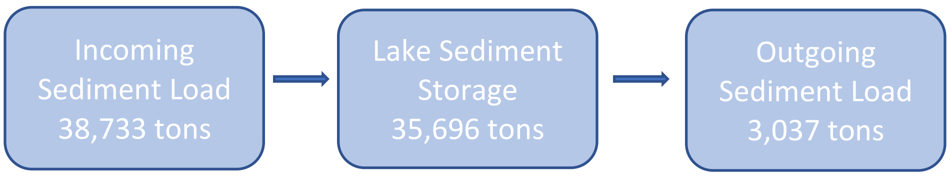
One challenge to understanding nutrient loads in Lake Monroe is evaluating the impact of legacy nutrients in lake sediments. Our data point to a process in which nutrients are transported to the lake primarily as sediment but also in dissolved form. The sediment is then deposited on the lake bottom and released to the hypolimnion during periods when stratification creates anoxic conditions. Under anoxic conditions SRP is available to feed algal growth and SRP is incorporated into the algae, causing an increase in TP. The nutrient loads entering from the streams are external loads while the nutrient loads released from the lake bottom sediments are internal loads. Even if all of the incoming nutrient load were eliminated, there would still be internal nutrient loads. These are called legacy nutrients.

Additional study is needed to quantify legacy nutrients in Lake Monroe. However, phosphorus release from the sediment under anoxic conditions was observed as described in section 4.4.2.

4.4.8 Sediment in Lake Monroe

Lake Monroe acts as a sediment sink, as shown in Figure 4-11. 38,733 tons of sediment enter the lake annually and 3,037 tons exit the lake, leaving 35,696 tons stored in the lake. Sediment accumulates at the bottom of the lake.

Figure 4-11 Sediment Movement Through Lake Monroe



Total suspended solids (TSS) concentrations in the lake were generally well below the water quality target of 30 mg/L. The single exceedance was the June sample from the Upper Basin hypolimnion, with a concentration of 36.4 mg/L. This elevated concentration may have been related to elevated sediment and nutrient levels in the South Fork stream samples collected on June 22, though TSS levels in the upper basin epilimnion were low.

Figure 4-12 Total Suspended Solids in Lake Monroe 2020

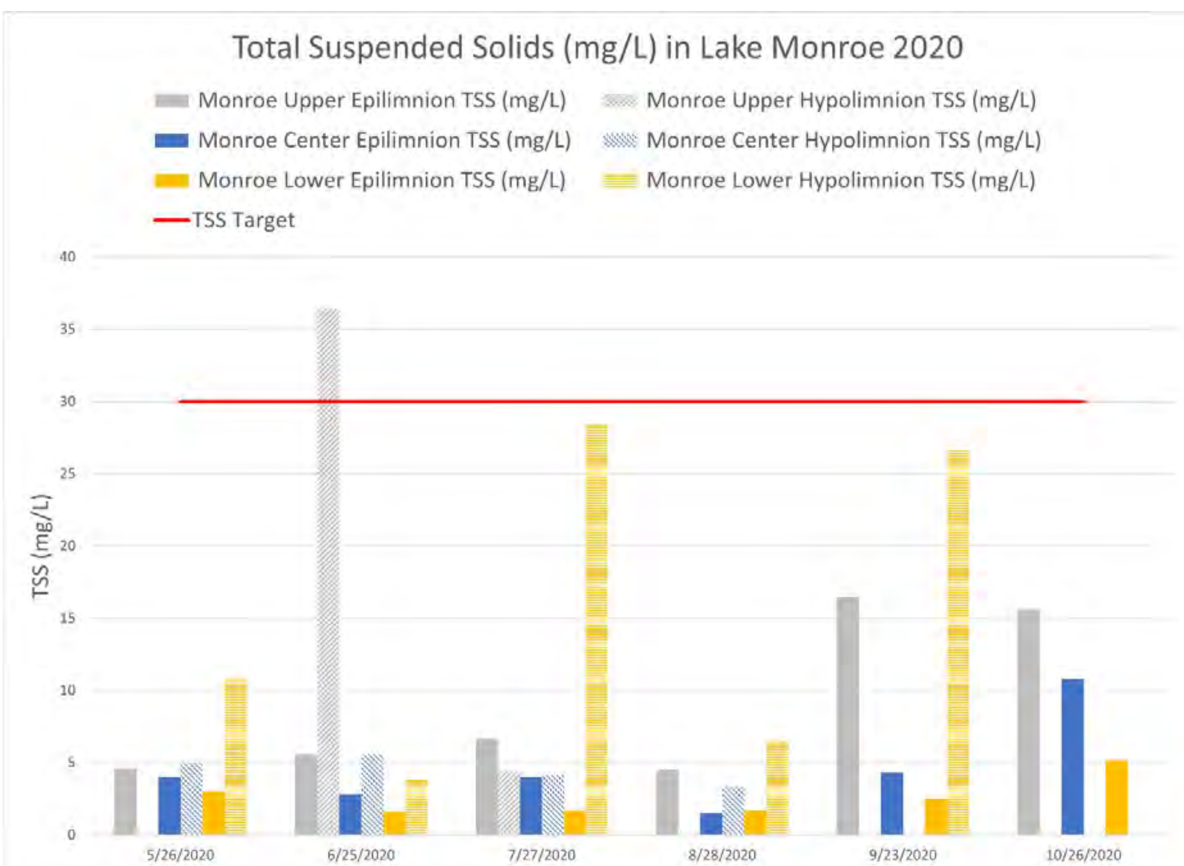


Table 4-7 Total Suspended Solids in Lake Monroe 2020

Sample Date	Monroe Upper Epilimnion TSS (mg/L)	Monroe Upper Hypolimnion TSS (mg/L)	Monroe Center Epilimnion TSS (mg/L)	Monroe Center Hypolimnion TSS (mg/L)	Monroe Lower Epilimnion TSS (mg/L)	Monroe Lower Hypolimnion TSS (mg/L)
5/26/2020	4.6		4	5	3	10.9
6/25/2020	5.6	36.4	2.8	5.6	1.6	3.8
7/27/2020	6.7	4.4	4	4.15	1.7	28.4
8/28/2020	4.5		1.5	3.3	1.7	6.5
9/23/2020	16.5		4.3		2.5	26.7
10/26/2020	15.6		10.8		5.2	

4.4.9 E. coli in Lake Monroe

The CBU Lab analyzed the monthly 2020 Lake Monroe samples for E. coli. All samples were well below the state E. coli standard of 235 CFU/100 ml. Furthermore, all samples were below 15 CFU/100 ml and 64% were below the detection limit of 1 CFU/ml.

Table 4-8 E. coli in Lake Monroe Epilimnion 2020

Sample Date	Monroe Upper Epilimnion E. coli (CFU/100 ml)	Monroe Center Epilimnion E. coli (CFU /100 ml)	Monroe Lower Epilimnion E. coli (CFU/100 ml)
5/26/2020	1.0	1.0	10.9
6/25/2020	1.0	1.0	1.0
7/27/2020	1.0	1.0	1.0
8/28/2020	1.0	1.0	1.0
9/23/2020	1.0	1.0	1.0
10/26/2020	1.0	1.5	2.0

Based on these data, E. coli does not appear to be an active concern in Lake Monroe. However, historical beach sampling data shows there have been E. coli exceedances in the past. Samples collected by USFS at the Hardin Ridge beach from 2015-2020 revealed four exceedances of the 235 CFU/100 ml standard out of fifty-four total samples. Two occurred in August 2015 (>2,400 and 727), one in July 2016 (>2,400), and one in August 2016 (632). All other samples had reported levels below 50 CFU/100 ml. No exceedances occurred in 2017-2020 and the highest recorded concentration in those years was 28 CFU/100 ml.

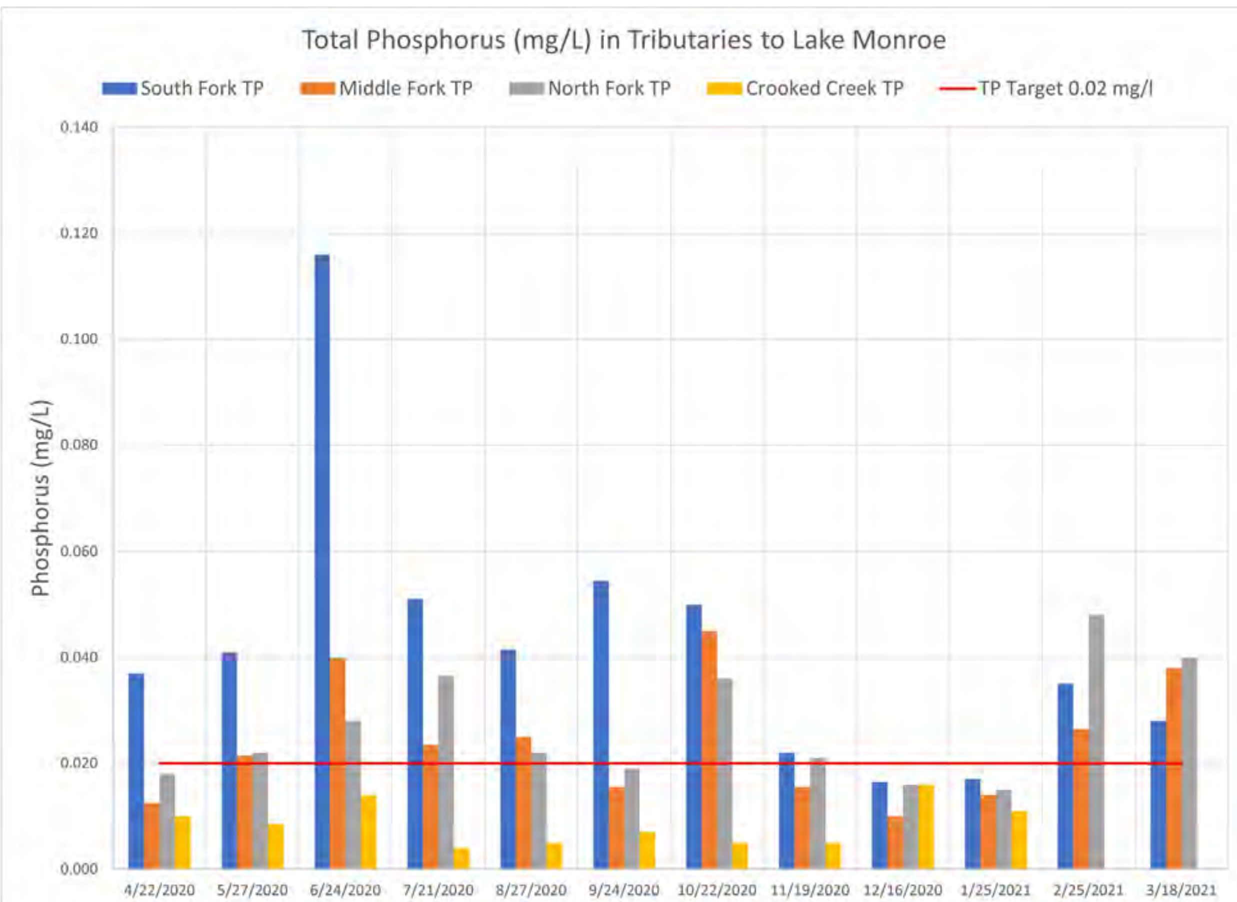
E. coli exceedances were reported in streams throughout the watershed, as discussed in section 4.8, and will need to be addressed. In the meantime, levels of E. coli in the lake should continue to be monitored to ensure that they stay well below levels of concern.

4.5 Potential Phosphorus Sources

Data from the nutrient budgets, tributary monitoring, and sampling blitz events were reviewed to evaluate the geographic distribution of phosphorus sources in the watershed.

While the nutrient budget indicates that the North Fork subwatershed generates the highest phosphorus load, monthly tributary monitoring shows the most phosphorus exceedances in the South Fork. Total phosphorus was reported at levels above the water quality target of 0.020 mg/L in 83% of South Fork samples, 58% of Middle Fork samples, and 67% of North Fork samples (Figure 4-13). Only one sample exceeded 0.060 mg/L, the June 2020 sample from South Fork Salt Creek which measured 0.116 mg/L.

Figure 4-13 Total Phosphorus in Lake Monroe Tributaries

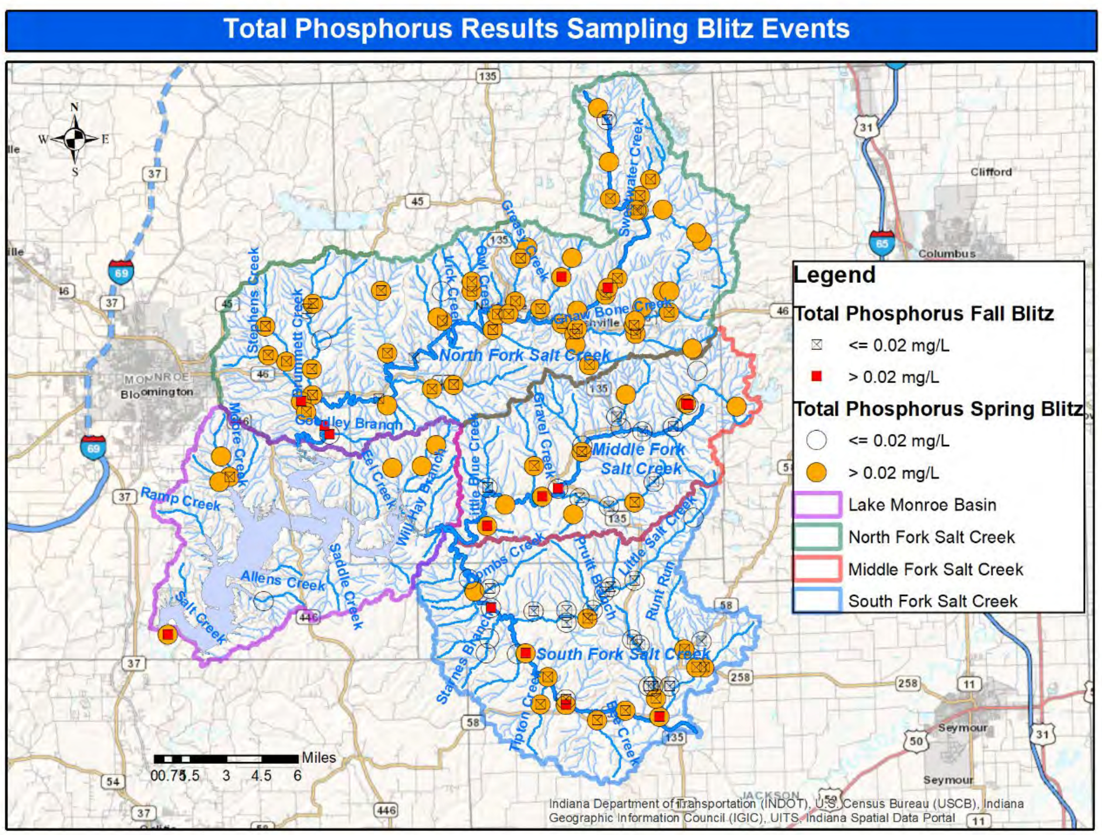


The sample collected from South Fork Salt Creek on June 24th is notable for its exceptionally high levels of E. coli, total phosphorus, and total nitrogen. This data point was reviewed to determine if it should be excluded from the data set as an outlier or mismeasurement. A review of flow data revealed that stream flows were elevated at the site in the three days preceding sampling, which could mean that the elevated levels were due to increased runoff from the watershed. Average daily stream flow measured in South Fork Salt Creek at Kurtz was 79.7 cubic feet per second (cfs) the day before sampling, dropping to 19.0 cfs the day of sampling. (Measured flow in North Fork at Nashville remained fairly constant during the same period, dropping from 9.6 to 8.7 cfs.)

Data collected from South Fork Salt Creek at Kurtz by the CBU Storm Team during flows between 20 cfs and 100 cfs was reviewed for comparison. This data indicated that the June values were within the expected range for elevated flow conditions with the exception of total nitrogen, which was considerably higher than the CBU data range. Ultimately the data point was kept in the report and analysis.

Data from the sampling blitz events reveal total phosphorus exceedances throughout the watershed, particularly during the spring blitz.

Figure 4-14 Total Phosphorus Results Sampling Blitz Events



Results were very different between the two blitz events. During the fall blitz, only 17% of samples were above the phosphorus target while during the spring blitz, 68% were above the target. During the fall blitz, Lake Monroe Basin had the highest percentage of phosphorus exceedances, followed by Middle Fork. During the spring blitz, Lake Monroe basin had the highest percentage of phosphorus exceedances, followed by North Fork. However, it should be noted that only 2 samples were collected in the Lake Monroe Basin during the fall blitz and only

8 samples during the spring blitz, meaning that each sample strongly influenced the overall percentage of exceedances.

Only four sites had total phosphorus exceedances during both the spring and fall blitz events. Two were in Middle Fork, one in South Fork, and one in North Fork. Site 488 in the North Fork subwatershed had the highest total phosphorus concentration (of these four sites) during both events.

Table 4-9 Sites With Phosphorus Exceedances During Both Blitz Events

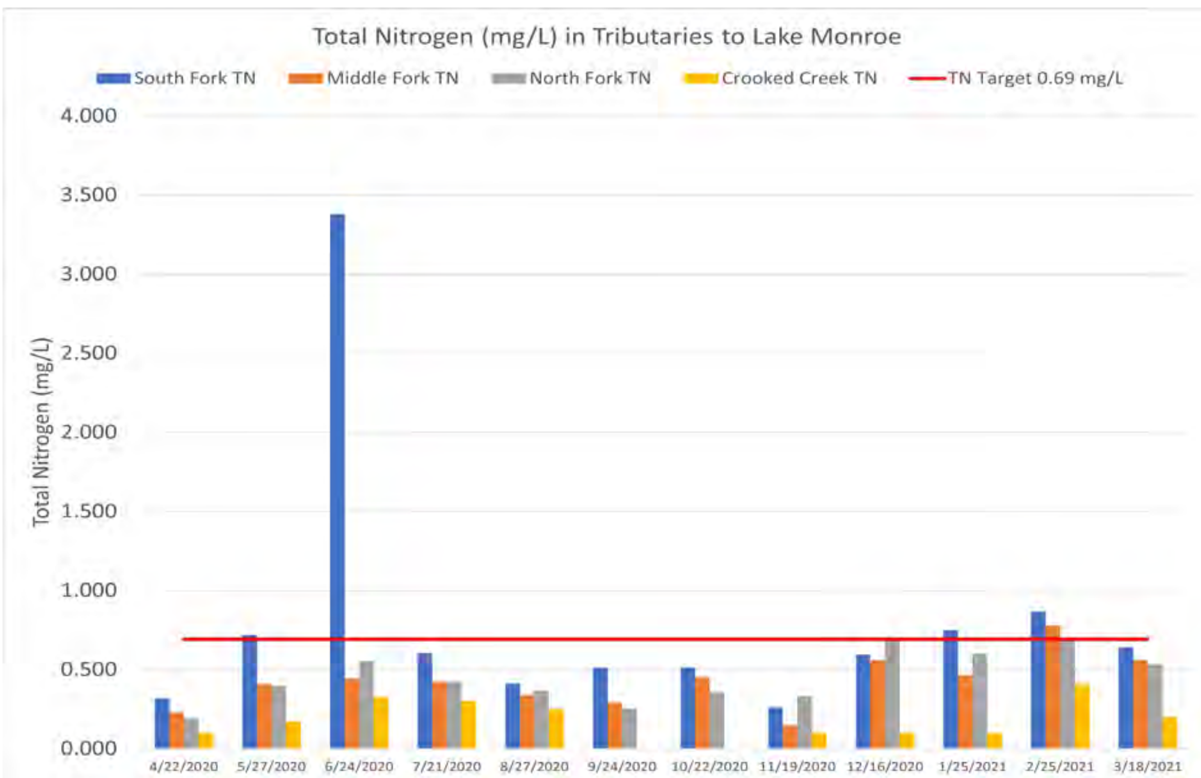
Blitz ID	Stream Name	HUC12 Subwatershed	Fall TP (mg/L)	Spring TP (mg/L)
814	South Fork Salt Creek	Tipton Creek (SF)	0.037	0.026
644	Unnamed tributary of South Branch Salt	Headwaters (MF)	0.033	0.022
662	Middle Fork Salt Creek	Gravel Creek (MF)	0.101	0.022
488	Unnamed tributary of NF Salt	East Fork Salt (NF)	0.235	0.031

4.6 Potential Nitrogen Sources

Data from the nutrient budgets, tributary monitoring, and sampling blitz events were reviewed to evaluate the geographic distribution of nitrogen sources in the watershed. All three data sets indicate that South Fork is the primary source of nitrogen, followed by North Fork.

Total nitrogen was detected at levels above the target water quality goal of 0.69 mg/L in 33% of South Fork samples, 8% of Middle Fork samples, and 8% of North Fork samples. Only one sample exceeded 1 mg/L, the June 2020 sample from South Fork Salt Creek which measured 3.379 mg/L.

Figure 4-15 Total Nitrogen in Tributaries to Lake Monroe

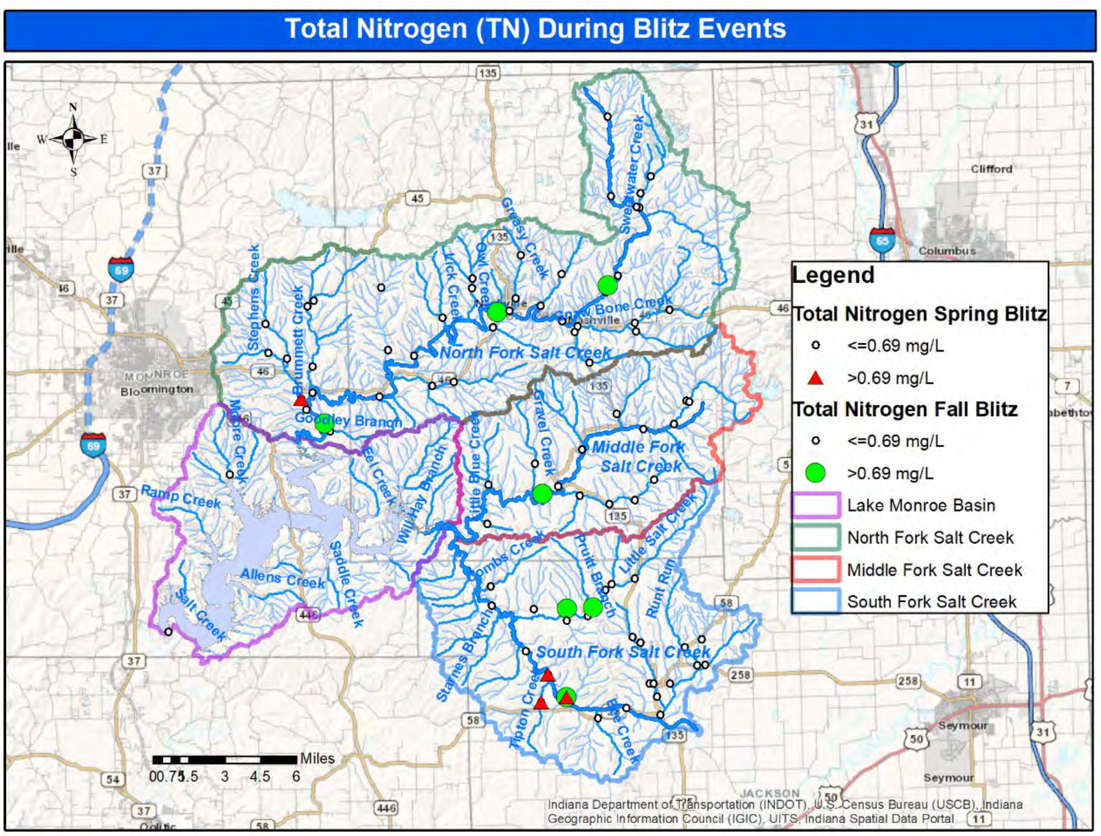


Total nitrogen was detected at levels above the target water quality goal of 0.69 mg/L in 7 of 88 fall samples (8%) and 4 of 122 spring samples (5%). The South Fork subwatershed had the highest percentage of total nitrogen exceedances during both blitz events, corresponding well with the nutrient budget. Only one site, #855 in an unnamed tributary of South Fork Salt Creek, had exceedances in both the spring and fall blitz events.

Table 4-10 Total Nitrogen at Select Blitz Sites (Concentrations >0.69 mg/L)

Site ID	Stream Name	Subwatershed	Fall TN (mg/L)	Spring TN (mg/L)
903	Pruitt Branch	Little Salt Creek (SF)	1.87	0.58
915	Unnamed tributary of Little Salt	Little Salt Creek (SF)	1.17	0.31
836	Tipton Creek	Tipton Creek (SF)	0.10	0.98
855	Unnamed tributary of SF Salt	Tipton Creek (SF)	1.04	1.17
857	South Fork Salt Creek	Tipton Creek (SF)	0.27	0.72
662	Middle Fork Salt Creek	Gravel Creek (MF)	1.21	0.36
488	Unnamed tributary of NF Salt	East Fork Salt Creek (NF)	2.15	0.15
385	North Fork Salt Creek	Clay Lick Creek (NF)	6.79	0.41
258	Stephens Creek	Stephens Creek (NF)	0.16	0.83
499	North Fork Salt Creek	Stephens Creek (NF)	2.42	--

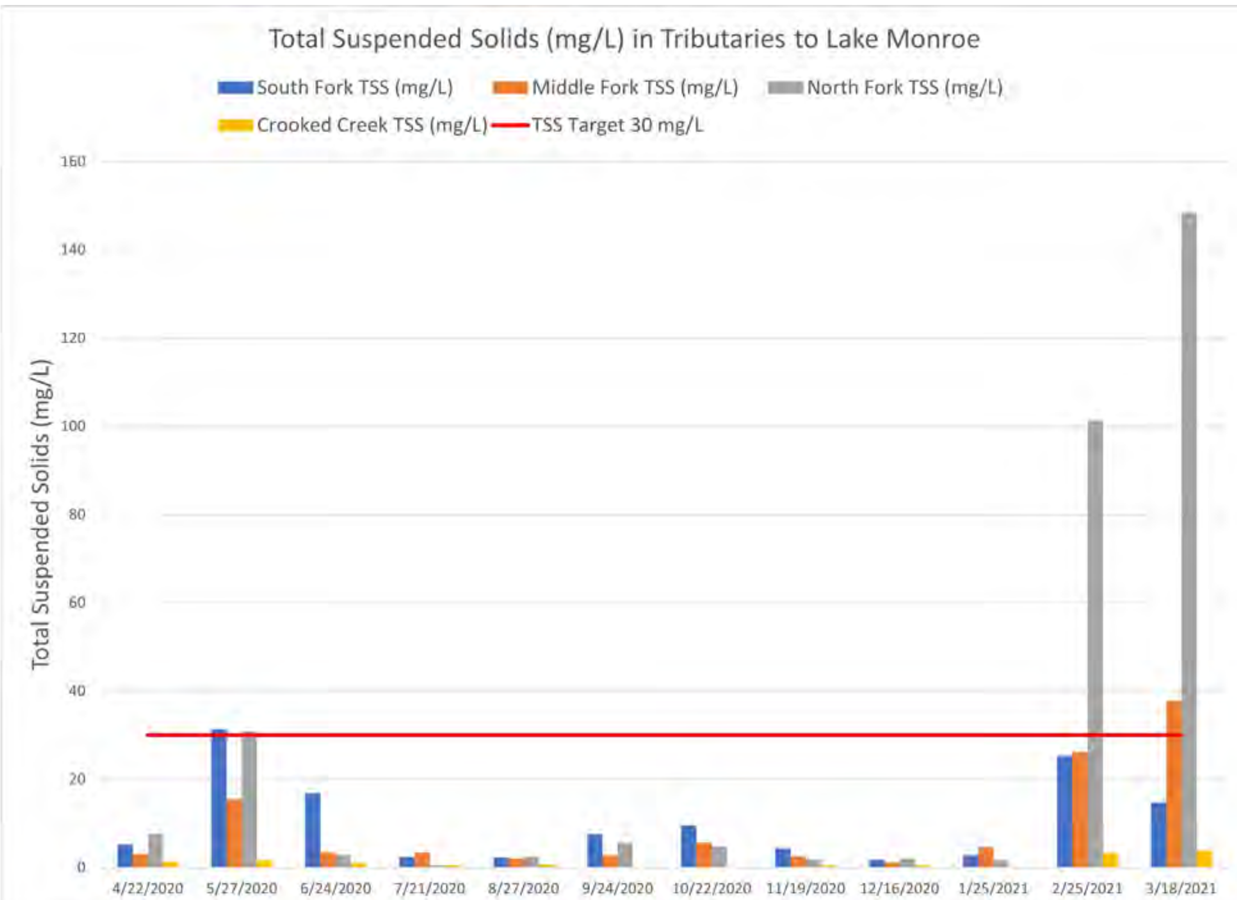
Figure 4-16 Total Nitrogen in Sampling Blitz Events



4.7 Potential Sediment Sources

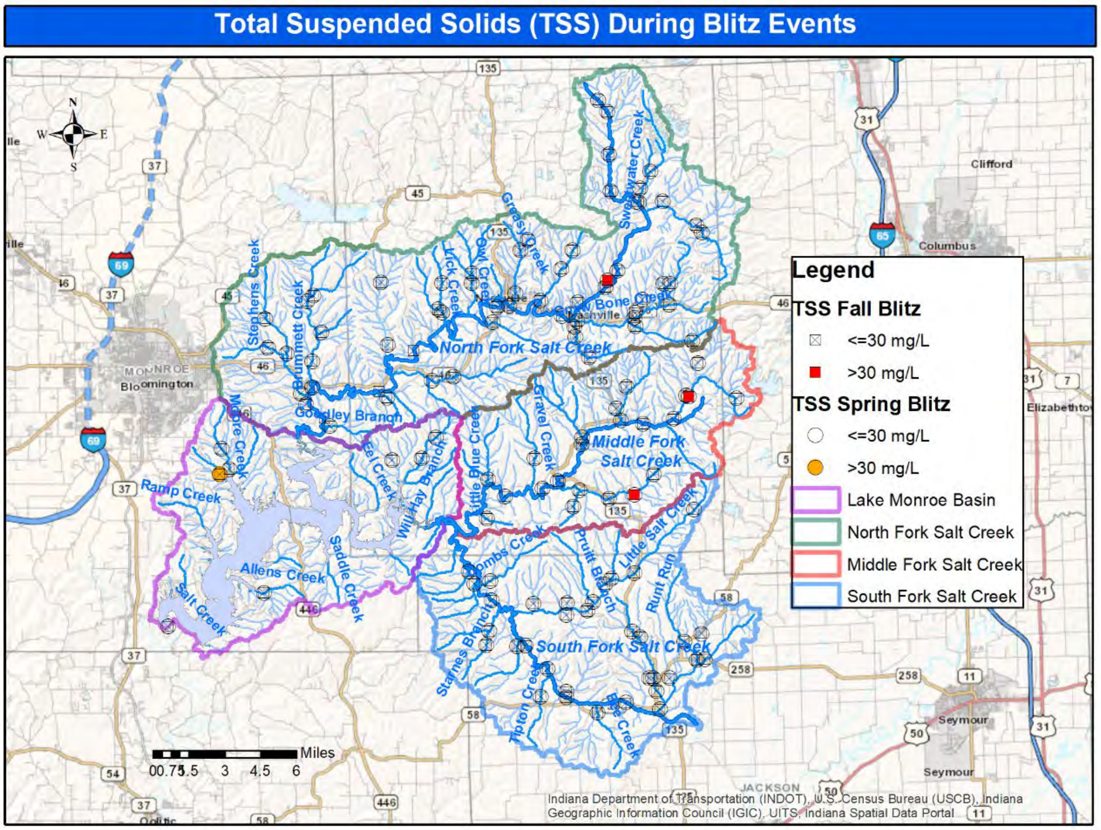
Based on the sediment budget developed using monthly tributary sampling, the primary source of sediment appears to be the North Fork followed by the South Fork. This was also reflected in the tributary sampling. Total suspended solids were reported at levels above the water quality target of 30 mg/L in 8% of South Fork samples, 8% of Middle Fork samples, and 25% of North Fork samples. North Fork had the two highest results, of 101.3 and 148.6 in February and March, respectively. Although there was not a strong correlation of total suspended solids concentration with total phosphorus concentration, evidence presented in sections 4.4.2 and 4.4.4 indicates that sediment is the primary source of nutrients entering the lake from streams.

Figure 4-17 Total Suspended Solids (TSS) in Lake Monroe Tributaries



Very few sediment exceedances were reported during the sampling blitz events. Total suspended solids concentrations were extremely low during the spring blitz with only one sample (of 122) exceeding the target concentration of 30 mg/L. This sample was collected in the Lake Monroe Basin subwatershed from a stream just before it enters Lake Monroe. During the fall blitz, three samples (of 88) exceeded the target concentration. Two were relatively small streams in the Middle Fork subwatershed and the third was from a very small stream in the North Fork subwatershed.

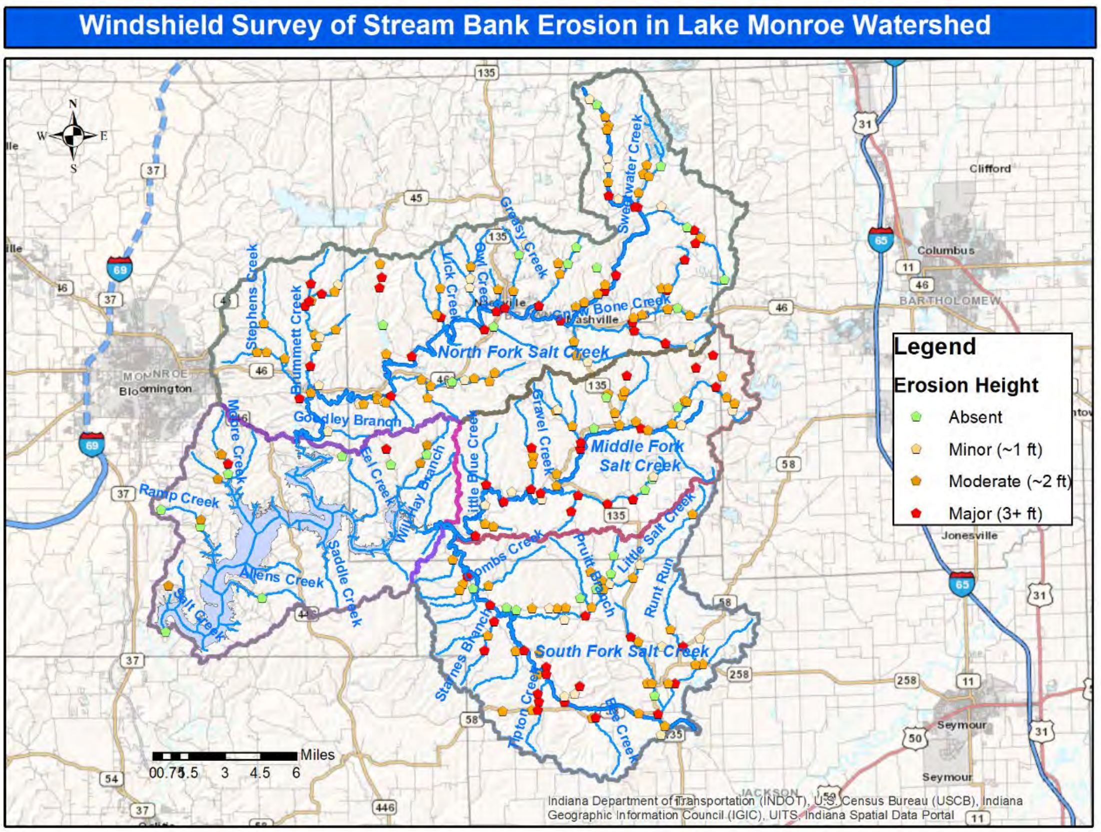
Figure 4-18 Total Suspended Solids (TSS) During Blitz Events



Streambank Erosion

Streambank erosion was identified as one potential source of sediment. During the windshield survey, 243 stream sites were evaluated. Erosion was observed at 209 sites throughout the watershed (86% of observed sites) ranging from minimal (1 foot) to severe (3 or more feet). Severe erosion was observed on both small and large streams.

Figure 4-19 Windshield Survey of Stream Bank Erosion in Lake Monroe Watershed



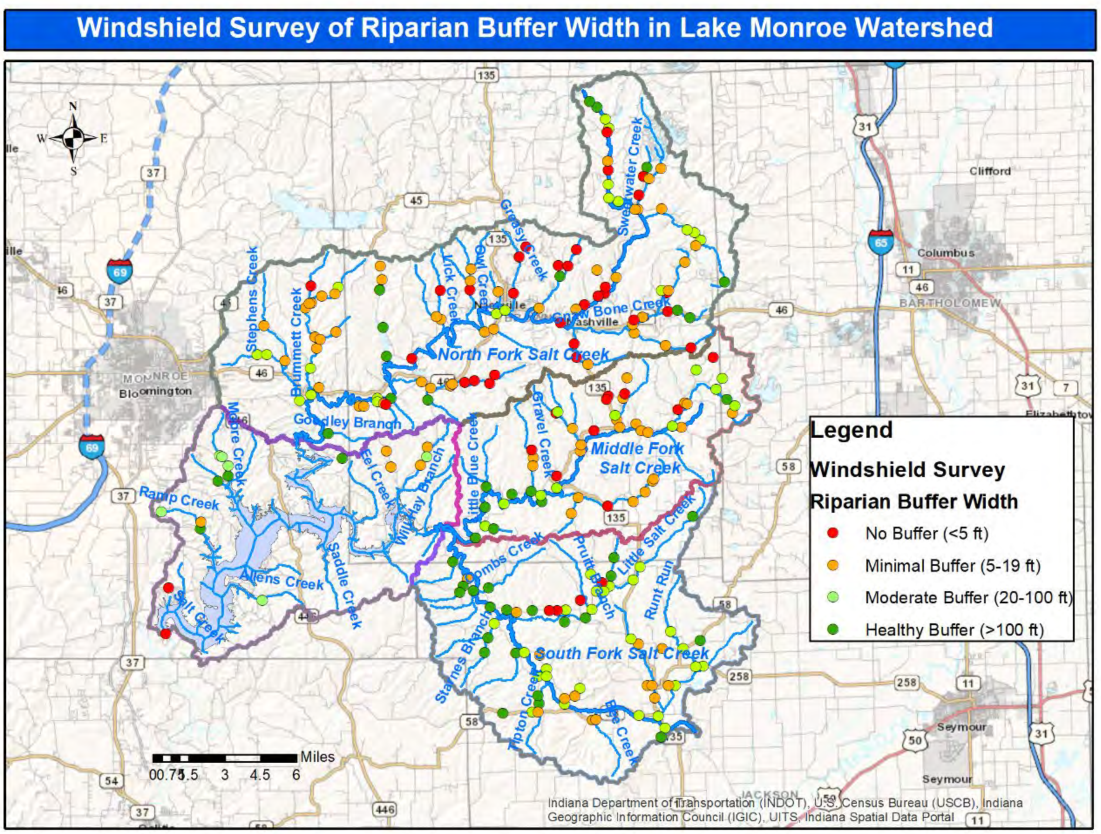
It is difficult to determine if streambank erosion has occurred recently or is historic in nature. Much of the watershed was deforested in the early twentieth century and it is possible that some of the observed streambank erosion occurred at that time. Streambanks may also be eroding due to hydrologic changes caused by the fluctuating water levels in Lake Monroe.

Riparian Buffer

Despite the large amount of forest in the watershed, sites lacking riparian buffer were prevalent and were distributed throughout the watershed. This includes sites where there is insufficient riparian buffer adjacent to agricultural land and also residential and commercial sites that are mowed to the edge of the stream. While mowed grass is clearly a better alternative than tilled ground, its root system is much shallower than most native flowers and grasses and it does not provide shade or other habitat benefits.

Of the 243 stream sites evaluated, 48 (20% of observed sites) had less than five feet of buffer and 97 (40% of observed sites) had between five and nineteen feet of buffer. Lack of buffer was most common for small and medium sized streams. The North Fork sub-watershed had the highest percentage of stream sites lacking sufficient riparian buffer, followed closely by the Middel Fork sub-watershed.

Figure 4-20 Windshield Survey of Riparian Buffer Width in Lake Monroe Watershed



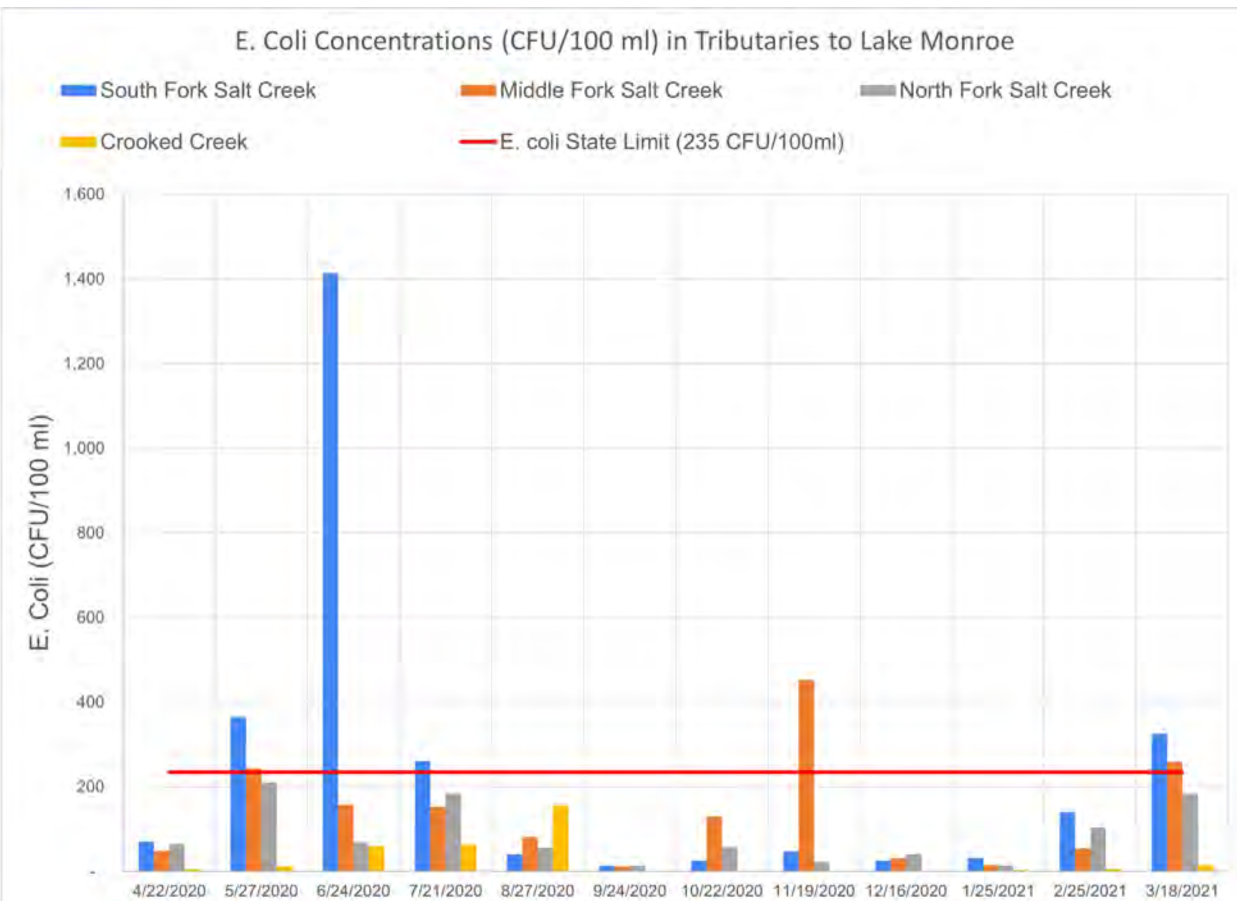
There was not as strong of a correlation between erosion and lack of riparian buffer as expected. This could be an indicator that streambank erosion happened in the early twentieth century when deforestation was widespread. Another possibility is that riparian buffer helps reduce lateral (sideways) movement of streams but is not as effective in combatting channel incision downward which could be caused by fluctuation of water levels in Lake Monroe.

Regardless, riparian buffer still plays an important role in both streambank stabilization and in filtering runoff from adjacent land, trapping sediment before it arrives in the stream. Forested buffer also provides shade and in-stream habitat.

4.8 Potential E. coli Sources

While E. coli does not appear to be a current concern in Lake Monroe, it was detected at levels above the state standard of 235 CFU/100 mL in 33% of monthly samples of South Fork Salt Creek and 25% of monthly samples of Middle Fork Salt Creek. No exceedances were measured in monthly samples of North Fork, Crooked Creek, or the Lake Monroe Outlet.

Figure 4-21 E. Coli Results from Monthly Sampling of Tributaries



E. coli exceedances were also reported in 16 of 88 samples during the fall blitz and 1 of 123 samples during the spring blitz. Tabulating exceedances from the fall blitz by subwatershed, 19% of Middle Fork subwatershed samples, 13% of North Fork subwatershed samples, 12% of South Fork subwatershed samples, and no Lake Monroe Basin subwatershed samples exceeded the E. coli threshold. The single spring blitz exceedance was in the South Fork subwatershed. Most of the E. coli exceedances were in relatively small streams. All exceedances were upstream of another sample location where E. coli concentrations were reported below the target level, suggesting that bacterial loads were diluted as water moved downstream.

Figure 4-22 Sites with E. Coli Exceedances During Either Sampling Blitz Event

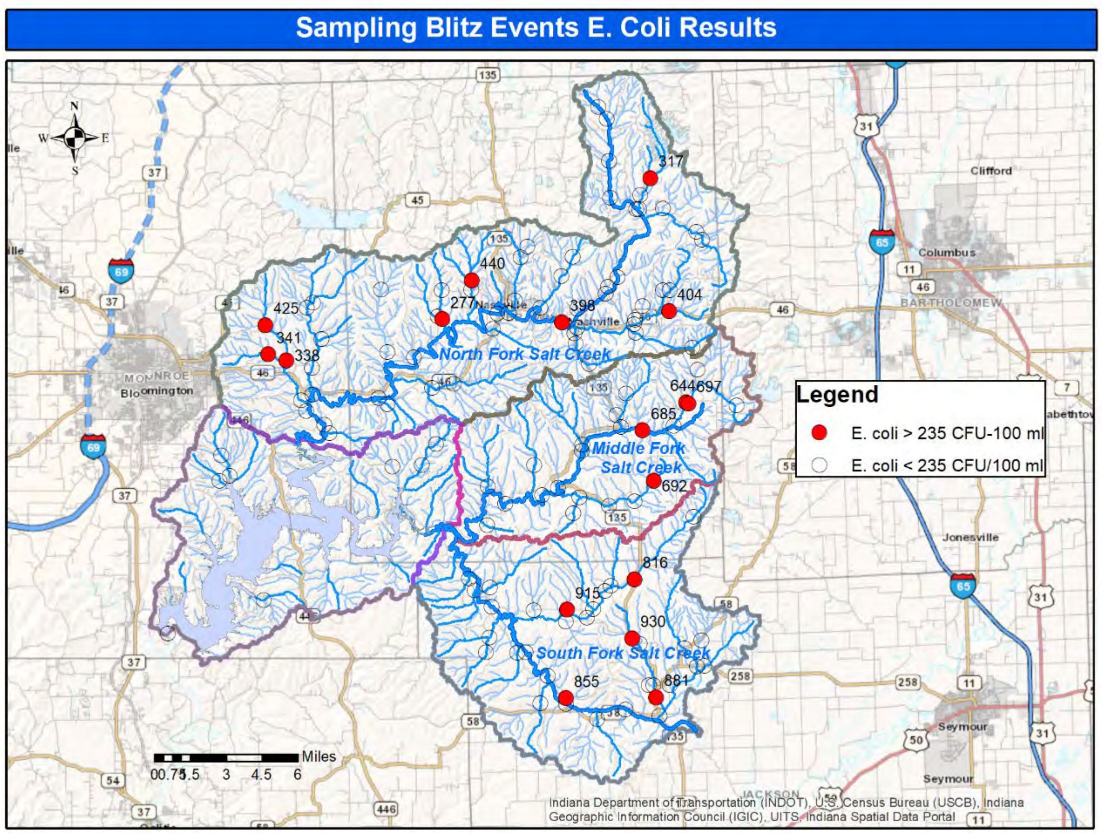


Table 4-11 E. Coli Exceedances During Sampling Blitz Events

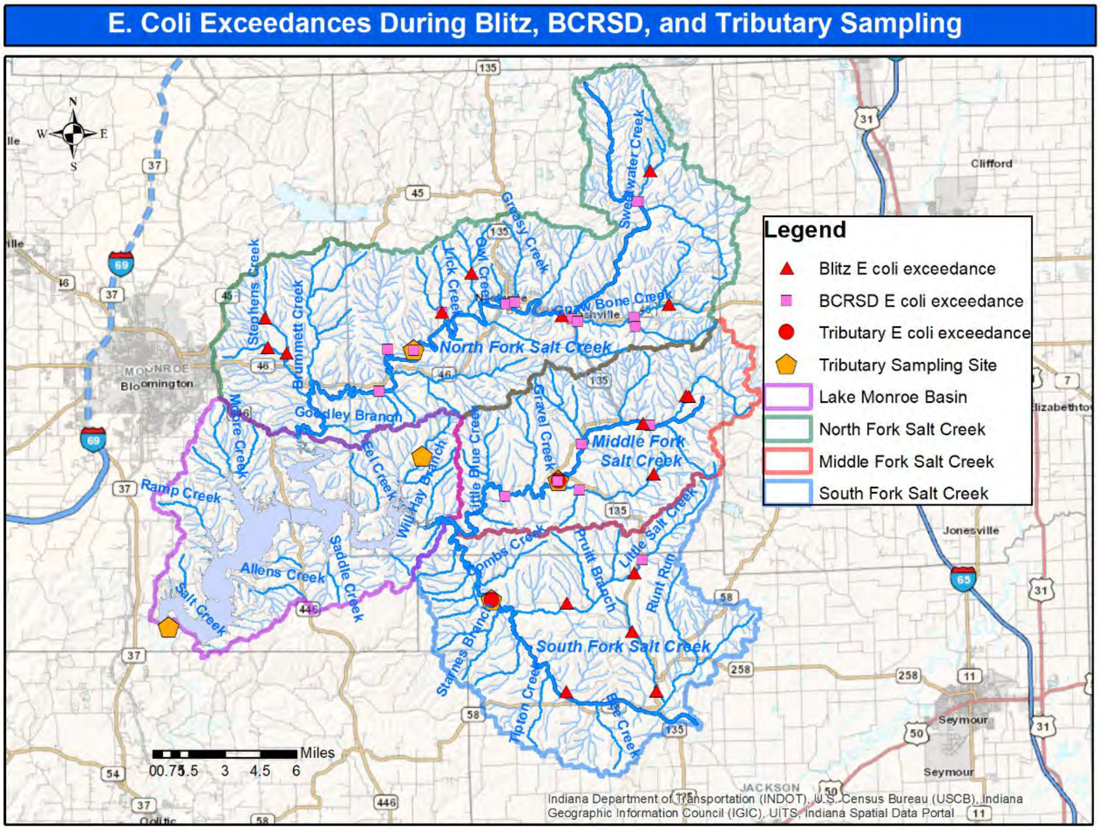
Blitz ID	Stream Name	Sub-watershed	Fall Blitz E. Coli (MPN/100 ml)	Spring Blitz E. Coli (MPN/100mL)
930	Kiper Creek	Kiper Creek (SF)	435.2	4.1
915	Unnamed tributary of Little Salt	Little Salt Creek (SF)	613.1	4
881	Kiper Creek	Kiper Creek (SF)	145.5	488.4
855	Unnamed tributary of SF Salt	Tipton Creek (SF)	>2419.6	3.1
816	Little Salt Creek	Little Salt Creek (SF)	>2419.6	11
697	South Branch Salt Creek	Headwaters (MF)	2419.6	6.3
692	Unnamed tributary of Hamilton Creek	Pleasant Valley (MF)	488.4	0
685	Middle Fork Salt Creek	Headwaters (MF)	648.8	18.9
644	Unnamed tributary of South Branch Salt	Headwaters (MF)	>2419.6	0
440	Owl Creek	Clay Lick Creek (NF)	298.7	8.6
425	Stephens Creek	Stephens Creek (NF)	1986.3	5.2
404	Henderson Creek	Gnaw Bone Creek (NF)	727	14.2
398	North Fork Salt Creek	Clay Lick Creek (NF)	1986.3	14.5
341	Kerr Creek	Stephens Creek (NF)	410.6	4.1
338	Stephens Creek	Stephens Creek (NF)	920.8	3.1
317	East Branch Sweetwater Creek	Sweetwater Creek (NF)	920.8	17.1
277	Lick Creek	Clay Lick Creek (NF)	378	20.3

Data from the BCRSD sampling efforts was also reviewed (Table 4-13). A map of the combined data sets (Fig 4-22) shows E. coli exceedances throughout the North Fork, Middle Fork, and South Fork subwatershed. While none of the monthly samples collected from North Fork Salt Creek at Yellowwood had levels of E. coli above the target level, samples collected by BCRSD in North Fork Salt Creek both upstream and downstream of the site had E. coli levels well above the target.

Table 4-12 Brown County Regional Sewer District E. Coli Sampling 2020

Site ID	Stream	Sub-watershed	5/5/2020	5/12/2020	5/19/2020	5/26/2020	6/2/2020	Geo. Mean
EF01	Sweetwater Creek	Sweetwater (NF)	115	12	379	365	82	109
EF02	North Fork Salt Creek	Sweetwater (NF)	338	9	219	61	77	80
EF03	Outlet Sweetwater Lake	Sweetwater (NF)	75	--	--	--	--	
EF04	North Fork Salt Creek	Brummett (NF)	338	112	1,630	365	128	310
EF05	Outlet Yellow-wood Lake	Clay Lick (NF)	87	33	87	461	13	69
EF06	North Fork Salt Creek	Clay Lick (NF)	705	310	1,170	32	126	253
EF07	Lick Creek	Clay Lick (NF)	449	22	401	93	59	117
EF08	North Fork Salt Creek	Clay Lick (NF)	1,440	58	811	1,990	122	439
EF09	Clay Lick	Clay Lick (NF)	85	36	171	187	25	76
EF10	North Fork Salt Creek	Gnaw Bone (NF)	424	195	661	345	96	283
EF11	Gnaw Bone	Gnaw Bone (NF)	449	78	620	186	141	224
EF12	Gnaw Bone	Gnaw Bone (NF)	338	21	276	172	84	122
EF13	Mount Liberty	Gnaw Bone (NF)	401	61	449	228	118	197
EF14	Middle Fork Salt Creek	Gravel Creek (MF)	705	63	1,220	548	144	336
EF15	Middle Fork Salt Creek	Pleasant Valley (MF)	310	115	925	866	122	322
EF16	Hamilton Creek	Pleasant Valley (MF)	1,020	43	705	548	166	309
EF17	Middle Fork Salt Creek	Pleasant Valley (MF)	755	31	755	861	192	310
EF18	Middle Fork Salt Creek	Headwaters (MF)	1,440	89	1,170	461	122	385
EF20	Greasy Creek	Clay Lick (NF)	755	83	276	365	228	270
EF21	Little Salt Creek	Little Salt Creek (SF)	136	4	190	461	93	85

Figure 4-23 E. Coli Exceedances During Blitz, BCRD, and Tributary Sampling

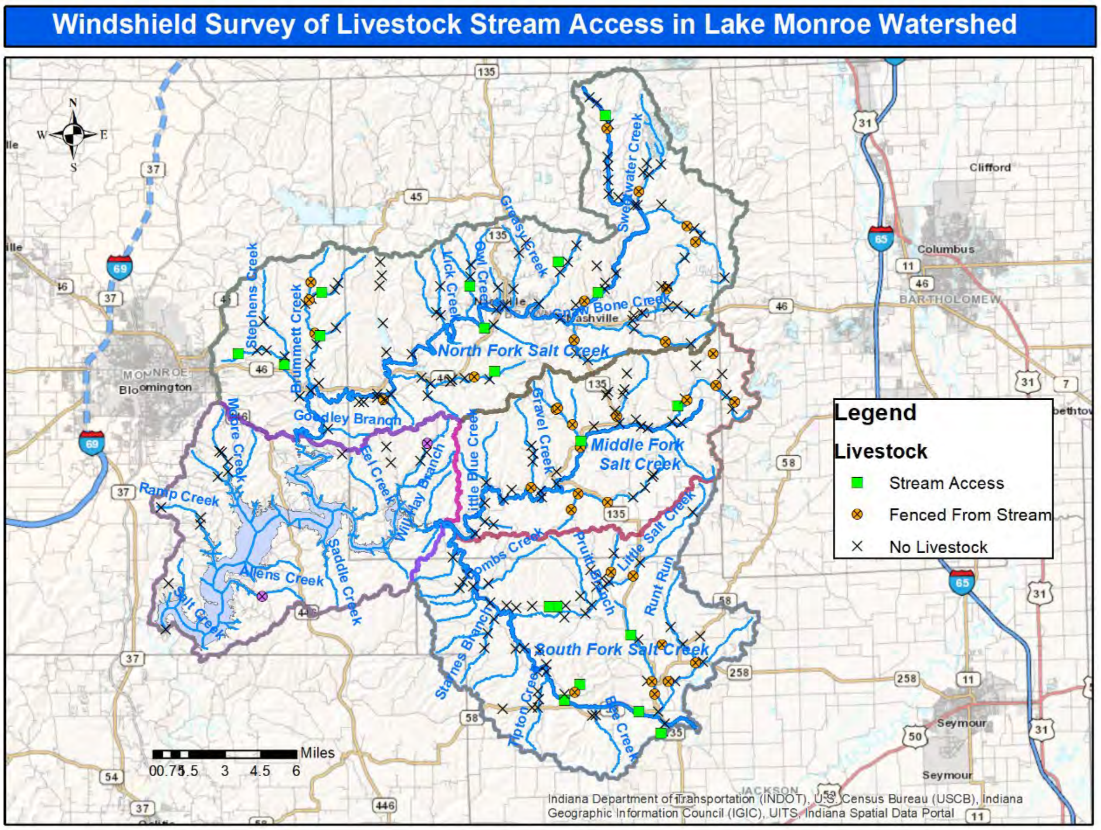


Interestingly, Crooked Creek had no E. coli exceedances despite appearing on the 303(d) impaired water bodies list as impaired for E. coli. The highest reported E. coli concentration in Crooked Creek was 157 CFU/100 mL and 70% of samples were below 20 CFU/100 mL.

Livestock in Streams

Livestock were observed at 44 sites, 19% of total observed sites (Fig 4-23). Livestock with free access to streams were observed at 17 sites, a little over a third of the livestock sites and 7% of total observed sites. Livestock operations tend to be small with a variety of animals observed including cows, horses, goats, and donkeys. There are also at least two exotic animal farms in the watershed. Livestock operations tend to be somewhat larger in the Middle Fork and South Fork subwatersheds.

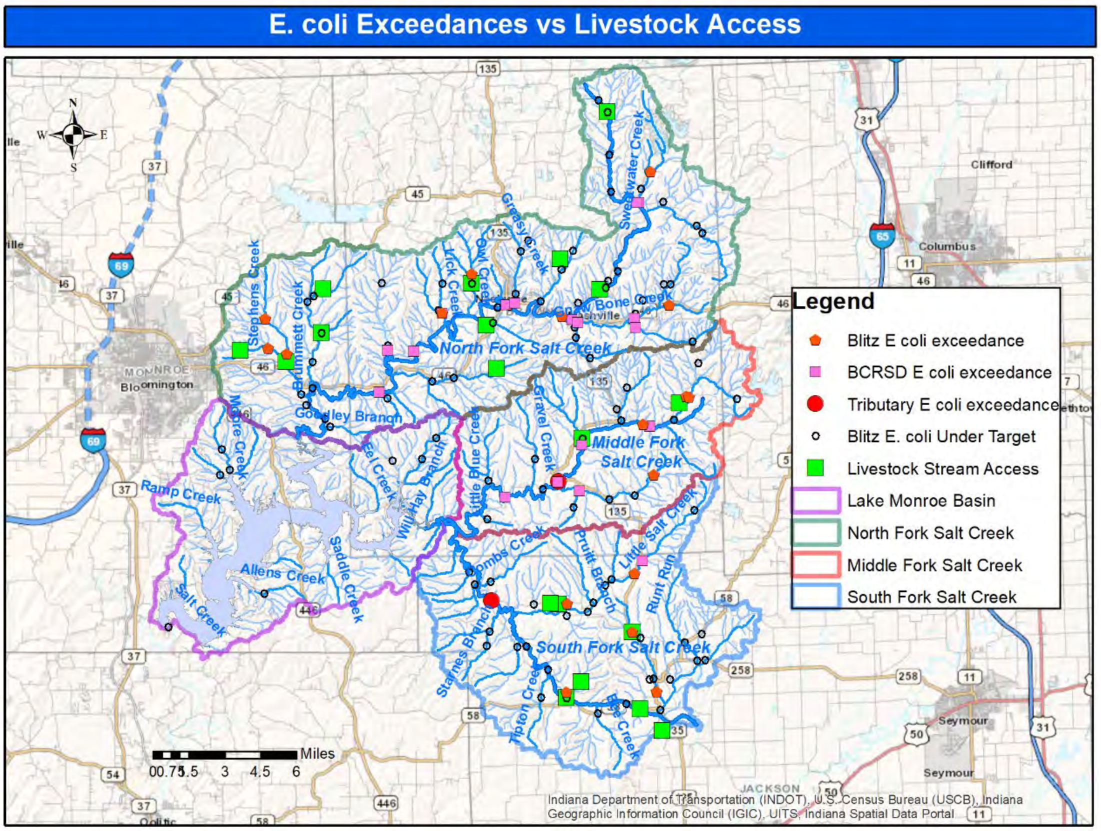
Figure 4-24 Windshield Survey of Livestock Stream Access in Lake Monroe Watershed



E. coli and Livestock

All E. coli exceedances were mapped and compared to sites where livestock have free access to streams, as observed during the windshield survey.

Figure 4-25 E. Coli Exceedances vs Livestock Access



There was not a strong correlation observed between livestock access to streams and E. coli. Some sites at or downstream from livestock access points showed elevated E. coli concentrations and others showed concentrations below the target level.

Failing Septic Systems

The Lake Monroe watershed has an estimated 9,096 septic systems. Limited data are available to quantify the number that are inadequate or failing. The Indiana State Department of Health estimates that 200,000 of the 800,000 on-site wastewater systems statewide are failing, a failure rate of 25% (Purdue Extension HENV-1-W). That failure rate would indicate 2,274 failing septic systems in the Lake Monroe watershed.

The Monroe County Health Department had 17 sewage discharge complaints on file within the Lake Monroe watershed. Given an estimated 3,754 households in the Monroe County portion of the watershed, the failure rate would be 0.5%. However, this is likely a gross underestimate as the Health Department relies on complaints to identify failing systems. Additional failing systems may be undetected because they have not caused ponding or odor issues that impact neighbors.

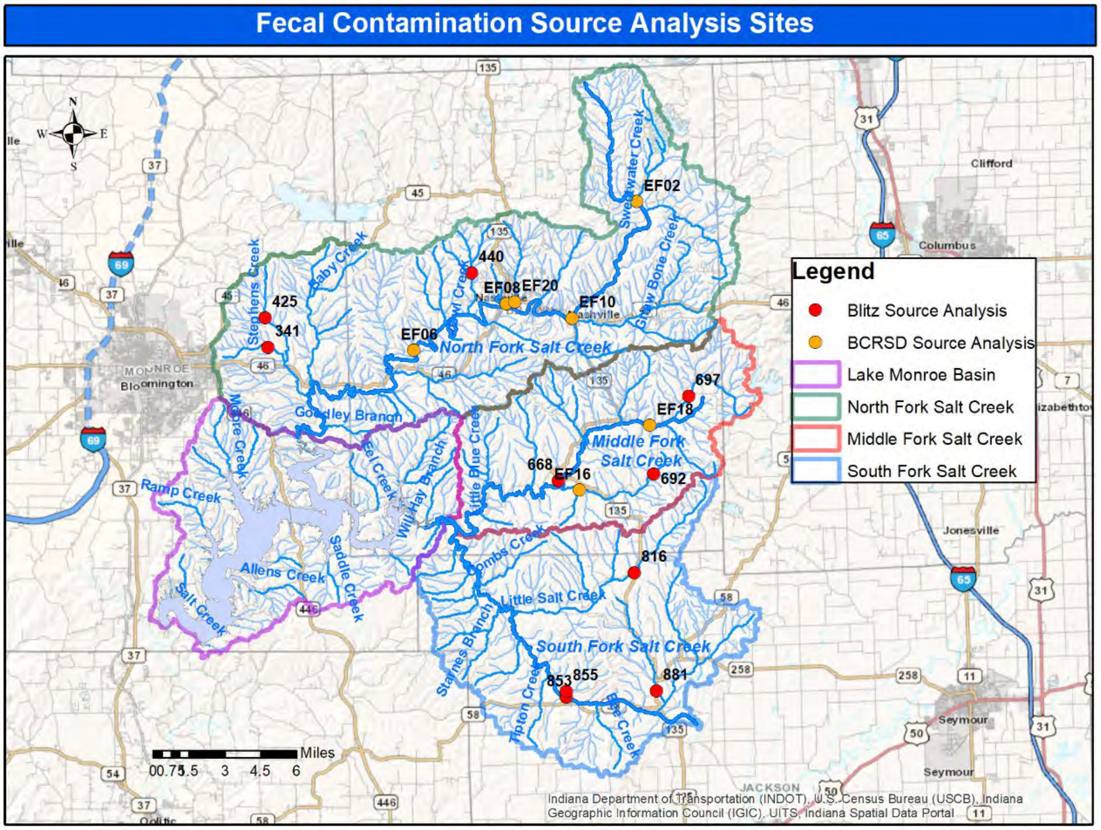
Septic system failure is likely to increase in frequency as systems age. BCRSD reviewed septic system records in Brown County and estimated that 50% of the 7,700 septic systems in Brown County were installed prior to 1990. Assuming this is true throughout the watershed, 4,548 septic systems in the watershed are over 30 years old and the average septic system life expectancy is 25 years. Proactive education and outreach can help households and businesses identify and address septic system issues promptly, protecting water quality in streams and waterbodies throughout the watershed.

Fecal Contamination Source Analysis

The Brown County Regional Sewer District (BCRSD) has been studying E. coli as part of a larger effort to develop a wastewater strategic plan for Brown County. They collected 5 samples weekly in May and early June of 2020 at twenty sites in the Lake Monroe watershed (as well as twelve sites in the adjacent Bean Blossom watershed) and analyzed for E. coli. For water to meet the recreation standards in Indiana, the geometric mean of 5 samples over a 30-day period is required to be less than 125 CFU/100 mL, with no sample testing higher than 235 CFU/100 mL.

Based on the sampling results and land use data for each site, seven sites in the Lake Monroe watershed were selected by BCRSD for source analysis. Friends of Lake Monroe reviewed their data in conjunction with data from the sampling blitz events and identified an additional ten sites to sample. Water was collected from the seventeen sites and sent to Scientific Methods where it was analyzed using coliphage serotyping. This method studies residue from coliphages, which are viruses that infect coliform bacteria such as E. coli. Certain species of coliphages can be directly linked to human sources and others to animal sources. Other coliphage species cannot be linked to a particular source.

Figure 4-26 Fecal Contamination Source Analysis



While coliphage residue does not correlate directly with E. coli concentration, both indicate the presence of fecal contamination. Many of the samples did not contain enough coliphage residue (plaque forming units or pfu/100 ml) to provide probable source results (see Table 4-13). Of the five samples that produced results, four were very close to having a 50%/50% split between coliphage strains connected to human sources and coliphage strains connected to animal sources.

One sample, collected from Greasy Creek at site EF20, showed 94% coliphage strains connected to human sources and 6% coliphage strains connected to animal sources. However, these percentages do not reflect the true source probability as there are species of coliphage that cannot be traced to a particular source. The primary conclusion to be drawn from these results is that both human and animal fecal contamination were present in the five samples where results were obtained.

Table 4-13 Fecal Contamination (Coliphage) Source Analysis Results April 2021

BC_ID	LM_ID	Subwatershed	Stream	pfu/100ml	% probability human source	% probability animal source
	425	Stephens (NF)	Stephens Creek	< 1	NA	NA
	341	Stephens (NF)	Kerr Creek	< 1	NA	NA
	440	Clay Lick (NF)	Owl Creek	< 1	NA	NA
EF06	256	Clay Lick (NF)	North Fork Salt Creek	0.6	54	46
EF08	near 389	Clay Lick (NF)	North Fork Salt Creek	< 1	NA	NA
EF20	near 309	Clay Lick (NF)	Greasy Creek	0.4	94	6
EF10	near 398	Gnaw Bone (NF)	North Fork Salt Creek	< 1	NA	NA
EF02	332	Sweetwater (NF)	North Fork Salt Creek	0.1	NA	NA
EF18	near 685	Headwaters (MF)	Middle Fork Salt Creek	0.4	50.5	49.5
	697	Headwaters (MF)	South Branch Salt Creek	< 1	NA	NA
EF16	623	Pleasant Valley (MF)	Hamilton Creek	0.3	NA	NA
EF15	668	Pleasant Valley (MF)	Middle Fork Salt Creek	< 1	NA	NA
	692	Pleasant Valley (MF)	unnamed tributary to Hamilton Creek	< 1	NA	NA
	816	Little Salt Creek (SF)	Little Salt Creek	< 1	NA	NA
	853	Tipton Creek (SF)	South Fork Salt Creek	0.1	50.5	49.5
	855	Tipton Creek (SF)	unnamed tributary to South Fork Salt Creek	< 1	NA	NA
	881	Kiper Creek (SF)	Kiper Creek	0.1	50.5	49.5

4.9 Metals, Inorganic Compounds, and Other Parameters in Lake Monroe

While the water quality monitoring for this study focused on nutrients and sediment, historical data was reviewed to evaluate other parameters in Lake Monroe.

USACE Historic Sampling

USACE evaluates a wide variety of parameters in its annual sampling events includes atrazine, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, silver, and zinc. Most parameters consistently measure below levels of concern. However, copper was flagged in the tailwaters sample of the USACE 2019 annual report (based on 2018 sampling) and iron was flagged in the USACE 2020 annual report (based on 2019 sampling).

Reported copper levels in Lake Monroe from 2007-2020 were generally extremely low with almost all samples below 5 ug/L (0.005 mg/L). The exception was the 2018 tailwaters sample with a concentration of 11.4 ug/L which exceeded the acute aquatic criterion of 7.79 ug/L. This is a very conservative threshold. For comparison, the drinking water limit for copper is 1300 ug/L, or 1.3 mg/L. Ultimately copper was not selected as a contaminant of concern for this study.

Reported iron levels in Lake Monroe from 2007-2020 have ranged from below the detection limit to 6.6 mg/L with a median of 1.1 mg/L. Iron cycling in lakes and streams is complex and it is normal for concentrations to vary considerably over both time and space. The EPA acute aquatic criterion is hardness dependent and must be calculated for each sampling event. The 2019 tailwater sample had an iron level of 4.28 mg/L, exceeding the acute aquatic criterion of 2.744 mg/L. While any exceedance is concerning, the concentrations of iron in Lake Monroe appear to be within normal variations for the state. Iron concentrations in samples from all the Louisville District ACOE lakes ranged from below the detection limit to 20.8 mg/L. Due to the limited data availability and the lack of obvious potential sources of iron within the watershed, iron has been excluded from this watershed plan.

City of Bloomington Utilities (CBU)

CBU routinely analyzes drinking water samples for a variety of parameters at different frequencies. A full list of contaminants monitored in 2019 is provided as Appendix H. Although this is treated drinking water, the presence of a constituent in drinking water would likely indicate its presence in the raw lake water, with the exception of chloramine, disinfection by-products, and fluoride.

- Tests are run quarterly for a list of twenty-one Synthetic Organic Carbons (SOCs) and a much longer parameter list is run every three years.
- Tests are run annually for eighteen Inorganic Compounds (IOCs), twenty-one regulated Volatile Organic Compounds (VOCs), and nineteen unregulated Volatile Organic Compounds.

- Tests are run every six years for radioactive contaminants (most recently in 2015).
- Chloramine, a chemical used for water treatment, is regularly monitored throughout the treatment plant and water distribution system.
- Disinfection By-Products (DBPs), chlorine by-products formed during disinfection, are monitored monthly.
- EPA's Unregulated Contaminant Monitoring Rule program requires sampling for additional parameters every five years (currently underway in 2020).

Based on the 2020 Annual Drinking Water Report (using 2019 data), the two detected constituents that are likely to come from raw lake water are barium and atrazine. Barium was detected at 0.012 ppm, well below EPA's maximum contaminant level of 2 ppm, and is attributed to the erosion of natural deposits. Atrazine was detected at 0.2 ppb, well below EPA's maximum contaminant level of 3.0 ppb, and is attributed to runoff from herbicide used on row crops. Barium has been present at consistent levels for the last ten years. Atrazine was reported at levels between 0.2 and 0.3 ppb in the 2013, 2014, 2015, 2018, 2019, and 2020 annual water quality reports.

Hexachlorocyclopentadiene was detected in 2018, 2016, and 2015 at 0.1 ppb, well below the EPA maximum contaminant level of 50 ppb. Di(2-ethylhexyl)phthalate was detected in 2016 at 1.6 ppb compared to the EPA maximum contaminant level of 6 ppb. Both constituents are associated with chemical manufacturing. Nitrate was detected in 2011 at 0.02 ppm and in 2012 at 3.7 ppb compared to the action level of 15 ppb and was attributed to nonpoint source pollution (fertilizer, septic systems, sewage, or erosion of natural deposits).

Lead and copper were also detected in the drinking water in all years. Copper levels ranged from 0.017 ppm to 0.037 ppm, well below the EPA regulatory limit for drinking water of 1.3 ppm. Lead levels ranged from 4.9 to 7.0 ppb with an EPA action level of 15 ppb and a target of 0 ppb. Lead and copper were both attributed in the annual report to a combination of corrosion of household plumbing and erosion of natural deposits. For comparison, USACE lake sampling data from 2007-2016 show copper levels ranging from under detection limits to 4.4 ug/L (0.0044 mg/L). Lead levels in thirty-five of thirty-seven samples were below 3.0 ppb. The two elevated results were 4.5 and 6.9 ppb, comparable to the CBU samples.

In 2020, samples of raw lake water collected by CBU via a pipe from the raw water intake tower showed elevated copper levels of 0.32 ppm, an order of magnitude higher than the typical drinking water results. The elevated copper levels were due to a new pilot program where copper sulfate is introduced at the intake tower to fight algae. This will likely be adopted as a standard operating procedure during the summer months. CBU will change their sampling point to a spot in the intake tower prior to the copper sulfate addition.

4.10 Habitat Evaluation (QHEI and CQHEI)

Habitat data was gathered by the IU Limnology Lab once at each of the five monthly sampling locations using the Qualitative Habitat Evaluation Index (QHEI) guidelines. While this data set is inadequate for studying trends in the watershed, it was analyzed to see if there was a connection between low water quality results and low habitat results. North Fork Salt Creek had the highest QHEI score, at 60, meriting the “good” classification according to the Ohio EPA QHEI handbook. This was also the only score to meet or exceed the IDEM recommended minimum score of 51. In Indiana streams with a QHEI score less than 51, “habitat is likely having a negative impact on aquatic communities” according to IDEM’s Procedures for Completing the Qualitative Habitat Evaluation Index.

Crooked Creek, a headwaters stream, would be classified as “fair” based on Ohio EPA criteria with a score of 49 but would be considered impaired per IDEM criteria. Middle Fork, South Fork, and the Lake Monroe Outlet would all be considered “poor.” The Lake Monroe Outlet scored the lowest which is unsurprising given it is a highly modified channel lined with riprap that receives highly variable flow from the Lake Monroe Dam.

Table 4-14 QHEI Evaluation of Main Tributaries by IU Limnology Lab

Site Name	**Substrate**	**Instream cover**	**Channel Morphology**	**Bank Erosion and Riparian Zone**	**Pool/glide and Riffle/run quality**	**Riffle**	**Gradient**	**QHEI TOTAL**
South Fork (Site 914)	1	6	9	7	7	0	4	**34**
Middle Fork (Site 668)	2	8	11	6.5	9	0	4	**40.5**
North Fork (Site 256)	8.5	16	15	5.5	8	3	4	**60**
Crooked Creek (Site 123)	13	4	16	10	2	0	4	**49**
Monroe Outlet (Site 111)	0	6	6	6	9	0	4	**31**

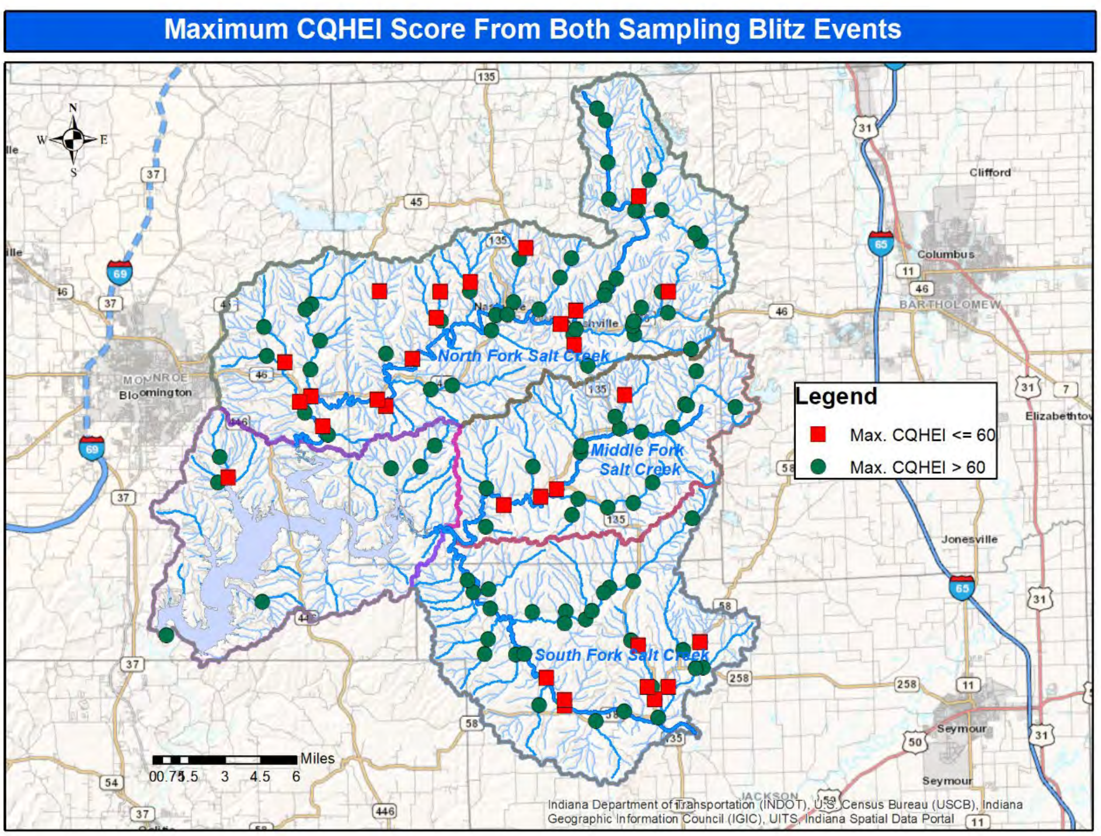
Volunteers gathered habitat data at our 125 Blitz locations twice, once in fall 2020 (during drought conditions) and once in spring 2021 (after a recent rainfall), using the Citizen’s Qualitative Habitat Evaluation Index (CQHEI). This index is a simplified version of QHEI that is easier to evaluate but generally considered less accurate. While there is no established rating scale for CQHEI, Hoosier Riverwatch suggests that scores above 60 indicate good habitat.

Table 4-15 Average CQHEI Scores From Blitz Events

Subwatershed	Spring CQHEI Average	Fall CQHEI Average	Spring CQHEI % Sites > 60	Fall CQHEI % Sites > 60
South Fork	67.3	58.1	71%	29%
Middle Fork	66.9	57.9	76%	41%
North Fork	68.1	57.4	73%	36%
Lake Monroe Basin	70.7	60.7	88%	75%

CQHEI scores tabulated during the spring sampling blitz were on average ten points higher than scores tabulated during the fall sampling event. This is largely attributable to the drought conditions in the fall that eliminated stream flow in many places. However, the range in differences was substantial with some scores differing as much as 33 points between the two sampling events, indicating some inconsistency in scoring between volunteers. Figure 4-27 shows sites with scores at or below 60 during both blitz events in red, indicating poor habitat.

Figure 4-27 Maximum CQHEI Score From Both Sampling Blitz Events



4.11 Biological Evaluation (mIBI)

A macroinvertebrate assessment was conducted once at each of the five monthly sampling locations by the IU Limnology Lab. Specimens were collected on August 27, 2020 and tabulated to calculate the macroinvertebrate index of biotic integrity (mIBI). Results indicate that all sampling locations are impaired (scores below 36). The highest score was for Crooked Creek.

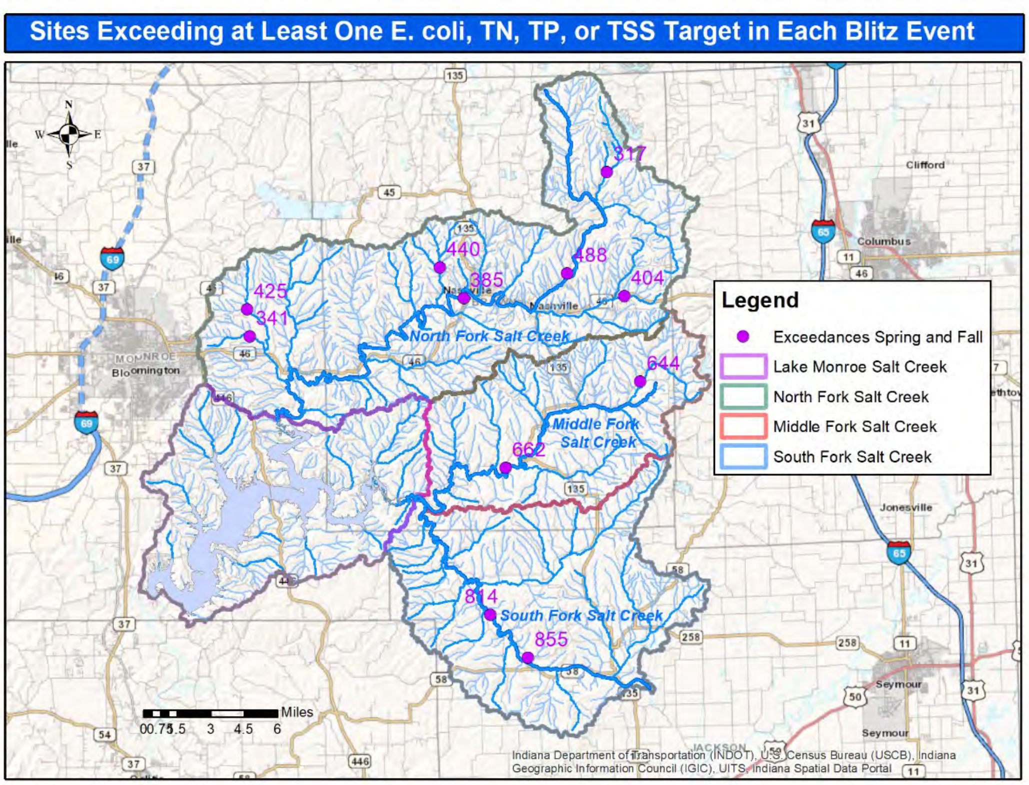
Table 4-16 Macroinvertebrate Assessment (mIBI) of Tributaries by IU Limnology Lab

Site ID	Site Name	Date	mIBI	Description
914	South Fork	8/27/2020	20.0	Impaired
668	Middle Fork	8/27/2020	24.0	Impaired
256	North Fork	8/27/2020	20.0	Impaired
123	Crooked Creek	8/27/2020	28.0	Impaired
111	Monroe Outlet	8/27/2020	20.0	Impaired

4.12 Sites of Concern

Of the 85 sites that were sampled during both the spring and fall blitz events, 11 sites had at least one E. coli, TP, TN, or TSS exceedance in each event.

Figure 4-28 Sites Exceeding at Least One E. coli, TN, TP, or TSS Target in Each Blitz Event



Seven sites are located in the North Fork subwatershed, two in the Middle Fork subwatershed, and two in the South Fork subwatershed.

Table 4-17 Sites of Concern Based on Sampling Blitz Exceedances

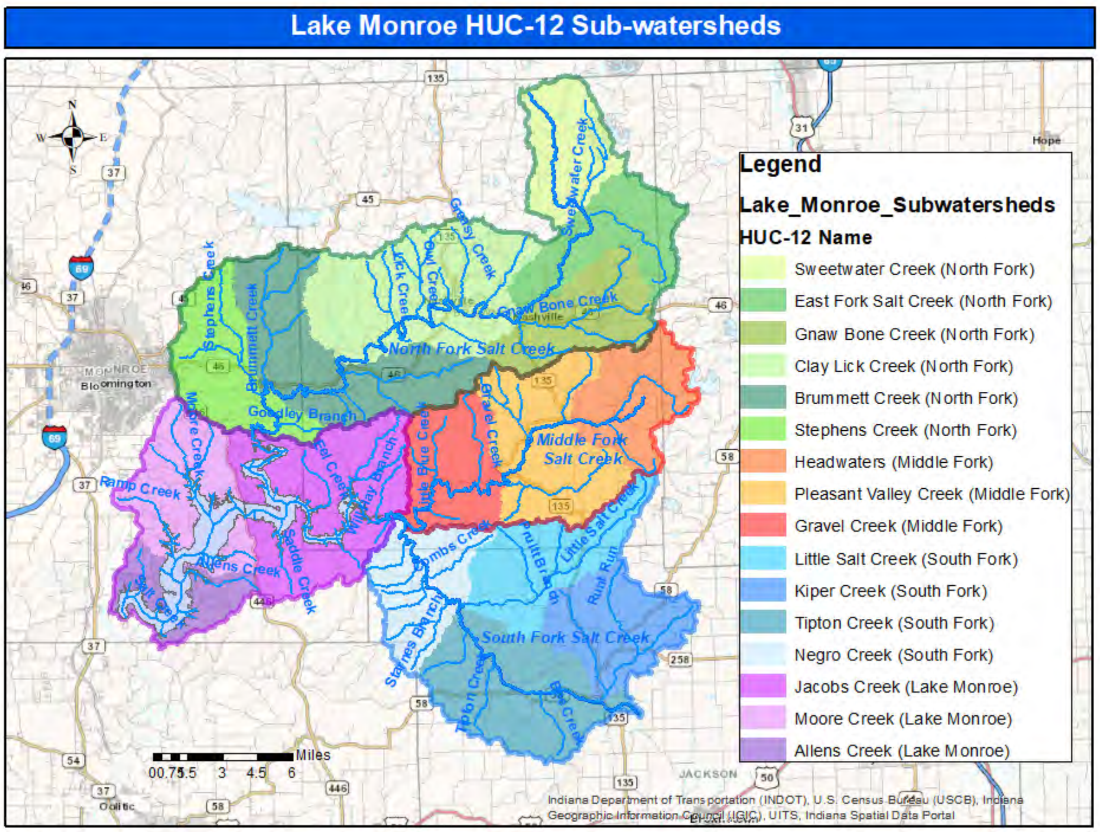
Blitz ID	Creek Name	Fall E. Coli (MPN/ 100 mL)	Spring E. coli (MPN/ 100mL)	Fall TN (mg/L)	Spring TN (mg/L)	Fall TSS (mg/L)	Spring TSS (mg/L)	Fall TP (mg/L)	Spring TP (mg/L)
317	East Branch Sweetwater Creek	920.8	17.1	0.136	0.198	2.3	1	0.002	0.024
341	Kerr Creek	410.6	4.1	0.1	0.342	2	0.5	0.002	0.029
385	North Fork Salt Creek	9.7	27.2	6.792	0.406	2.8	1.6	0.002	0.026
404	Henderson Creek	727	14.2	0.1	0.169	0.5	0.5	0.002	0.026
425	Stephens Creek	1986.3	5.2	0.269	0.271	3	0.5	0.002	0.032
440	Owl Creek	298.7	8.6	0.402	0.267	17.2	0.5	0.006	0.032
488	Unnamed tributary of NF Salt	180.7	3.1	2.154	0.1515	639.2	0.5	0.235	0.0305
644	Unnamed tributary of South Branch Salt	2419.6	0	0.446	0.374	10	1.6	0.033	0.022
662	Middle Fork Salt Creek	1	13.5	1.208	0.361	28.5	1.8	0.101	0.0215
814	South Fork Salt Creek	156.5	14.5	0.258	0.6885	5.5	3.6	0.037	0.026
855	Unnamed tributary of SF Salt	2419.6	3.1	1.0365	1.169	1.8	0.5	0.0175	0.014

These sites are discussed further in the detailed HUC-12 subwatershed analysis in Appendix J as areas to target during the implementation phase of the project.

4.13 HUC-12 Subwatershed Assessment

Data from the desktop survey, windshield survey, monthly tributary sampling, spring sampling blitz, fall sampling blitz, and the Brown County Regional Sewer District E. coli study were analyzed at the HUC-12 subwatershed level (dividing the watershed into sixteen subwatersheds). Underlying data and calculations is provided in Appendix I and detailed maps of each HUC-12 subwatershed with further discussion are provided in Appendix J.

Figure 4-29 Lake Monroe HUC-12 Subwatershed Map



In order to make comparisons across variable data sets, a ranking system was used where the highest value represents the highest impact (worst water quality) and the lowest value represents the lowest impact (best water quality).

The following data sets were evaluated:

- IDEM's 303(d) Impaired Waterbodies List
- Point Source Assessment
- Land Cover Assessment
- Nutrient, Suspended Sediment, and E. coli Load Assessment
- Watershed Visual Assessments
    - Streambank Erosion Assessment

- Adequate Buffer Zone Assessment
- Livestock Access Assessment

- Fall Sampling Blitz Water Quality Assessment
- Spring Sampling Blitz Water Quality Assessment
- Habitat Assessment
- Brown County RSD E. Coli Assessment

Methodology

For each data set, a value was calculated for each subwatershed in order to evaluate relative prioritization. In some cases, the value was a simple count (e.g. number of impaired waterbodies). For data sets like visual assessments, the value was a percentage of total sites in that subwatershed (e.g. percent of stream sites with severe erosion) in order to account for differences in the number of sites per subwatershed. For water quality data, results were compared to water quality targets in order to determine the percentage of samples in a subwatershed that exceeded the water quality target (e.g. percentage of samples exceeding E. coli target of 235 CFU/100 ml).

In all cases, subwatersheds were compared to evaluate relative prioritization. Each subwatershed was assigned a rank for each parameter with "1" indicating the highest water quality (least exceedances) and "16" indicating the lowest water quality (most exceedances). Detailed methodology and the full data analysis is available in Appendix I.

Once all subwatersheds were ranked for all parameters, parameters were divided into two major categories:

1. Level of Degradation based on water quality parameters
2. Level of Vulnerability based on land usage assessments

With all parameters equally weighted, the average for each category was calculated and the subwatersheds were ranked according to their Level of Degradation (Category 1) and Vulnerability (Category 2). The ranks of these two categories were then averaged to give an overall Rank Score. As with the individual parameter rankings, the most impacted subwatershed received the highest rank (most concerns) and the least impacted received the lowest rank (least concerns).

4.13.1 HUC-12 Water Quality Degradation Assessment

Parameters used to calculate Water Quality Degradation Rank were the number of 303(d) impaired water bodies and the percentage of exceedances for E. coli, Total Nitrogen, Nitrates, Total Phosphorus, Soluble Reactive Phosphorus, and Total Suspended Solids from the monthly tributary monitoring, fall blitz monitoring, spring blitz monitoring, and BCRSD monitoring (E. coli only).

Impaired Water Bodies

Impairments listed in the IDEM 303(d) list of impaired water bodies were tabulated for each sub-watershed. Based on the 303(d) list of impaired water bodies, Jacobs Creek had the most impairments, followed by Moore Creek, Allens Creek, Negro Creek, and Little Salt Creek.

Table 4-18 HUC-12 Sub-watershed Comparison of 303(d) Impairments

HUC-12-Subwatershed	303(d) Waterbodies and Impairments	Number of Impairments	303(d) Rank
Kiper Creek (SF)	None	0	1
Little Salt Creek (SF)	Little Salt Creek (E. Coli)	1	12
Tipton Creek (SF)	None	0	1
Negro Creek (SF)	South Fork Salt Creek (Dissolved Oxygen, Biological Integrity)	2	13
Headwaters Middle Fork (MF)	None	0	1
Pleasant Valley Creek (MF)	None	0	1
Gravel Creek (MF)	None	0	1
Sweetwater Creek (NF)	None	0	1
East Fork Salt Creek (NF)	None	0	1
Gnaw Bone Creek (NF)	None	0	1
Clay Lick Creek (NF)	None	0	1
Brummett Creek (NF)	None	0	1
Stephens Creek (NF)	None	0	1
Jacobs Creek (LM)	Crooked Creek (E. Coli), Lake Monroe Upper Basin (Algae, Mercury in Fish, and Taste and Odor)	4	16
Moore Creek (LM)	Lake Monroe Lower Basin (Algae, Mercury in Fish, and Taste and Odor)	3	14
Allens Creek (LM)	Lake Monroe Lower Basin (Algae, Mercury in Fish, and Taste and Odor)	3	14

E. coli

Three data sets were reviewed to evaluate E. coli impact – the fall sampling blitz, the spring sampling blitz, and the Brown County Regional Sewer District sampling.

The two subwatersheds with the greatest E. coli concerns are Kiper Creek (SF) and Headwaters Middle Fork (MF). The following four subwatersheds of concern are Clay Lick Creek (NF), Little Salt Creek (SF), Gnaw Bone Creek (NF), and Stephens Creek (NF).

Table 4-19 HUC-12 Sub-watershed Comparison of E. coli Impairments

Site Name	**Fall Blitz E Coli Rank**	**Spring Blitz E Coli Rank**	**BCRSD E Coli Rank**	**Average E Coli Rank**
Kiper Creek (SF)	8	16		**12.0**
Little Salt Creek (SF)	14	1	9	**8.0**
Tipton Creek (SF)	9	1		**5.0**
Negro Creek (SF)	1	1		**1.0**
Headwaters Middle Fork (MF)	16	1	13	**10.0**
Pleasant Valley Creek (MF)	9	1	13	**7.7**
Gravel Creek (MF)	1	1	13	**5.0**
Sweetwater Creek (NF)	11	1	10	**7.3**
East Fork Salt Creek (NF)	1	1		**1.0**
Gnaw Bone Creek (NF)	11	1	12	**8.0**
Clay Lick Creek (NF)	13	1	11	**8.3**
Brummett Creek (NF)	1	1	13	**5.0**
Stephens Creek (NF)	15	1		**8.0**
Jacobs Creek (LM)	1	1		**1.0**
Moore Creek (LM)	1	1		**1.0**
Allens Creek (LM)	1	1		**1.0**

Phosphorus
Phosphorus scores varied considerably across blitz events and between total phosphorus and soluble reactive phosphorus. Although Allens Creek scored the worst during the fall blitz, this is somewhat of a sampling artifact as there was only one sample collected and it exceeded the target, meaning 100% of the samples in the subwatershed exceeded the target. However, Allens Creek was the only subwatershed to score poorly during both blitz events, indicating that there is a phosphorus concern present.

The subwatershed with the highest (worst) ranking for phosphorus is Allens Creek in the Lake Monroe subwatershed. The second through fourth ranked (worst) for phosphorus were East Fork Salt Creek (NF), Stephens Creek (NF), and Tipton Creek (SF).

Table 4-20 HUC-12 Sub-watershed Comparison of Phosphorus Impairments

Site Name	Fall Blitz TP Rank	Fall Blitz SRP Rank	Spring Blitz TP Rank	Spring Blitz SRP Rank	Average Phosphorus Rank
Kiper Creek (SF)	8	13	5	4	**7.5**
Little Salt Creek (SF)	1	8	1	1	**2.8**
Tipton Creek (SF)	10	15	9	6	**10.0**
Negro Creek (SF)	13	14	2	1	**7.5**
Headwaters Middle Fork (MF)	13	1	5	5	**6.0**
Pleasant Valley Creek (MF)	9	4	4	10	**6.8**
Gravel Creek (MF)	13	8	9	1	**7.8**
Sweetwater Creek (NF)	1	11	11	11	**8.5**
East Fork Salt Creek (NF)	11	11	16	12	**12.5**
Gnaw Bone Creek (NF)	1	7	16	15	**9.8**
Clay Lick Creek (NF)	7	4	12	9	**8.0**
Brummett Creek (NF)	1	4	9	6	**5.0**
Stephens Creek (NF)	12	10	10	13	**11.3**
Jacobs Creek (LM)	1	1	16	16	**8.5**
Moore Creek (LM)	1	1	16	8	**6.5**
Allens Creek (LM)	16	16	6	13	**12.8**

Nitrogen

There were relatively few total nitrogen and nitrate exceedances during both blitz events. However, nitrogen scores were consistently poor in the Tipton Creek (SF) watershed. Of the four following subwatersheds of concern, Little Salt Creek is also in the South Fork subwatershed while East Fork, Clay Lick, and Stephens Creek are in the North Fork subwatershed.

Table 4-21 HUC-12 Sub-watershed Comparison of Nitrogen Impairments

Site Name	Fall Blitz TN Rank	Fall Blitz NO3 Rank	Spring Blitz TN Rank	Spring Blitz NO3 Rank	Average Nitrogen Rank
Kiper Creek (SF)	1	1	1	1	**1.0**
Little Salt Creek (SF)	14	15	1	1	**7.8**
Tipton Creek (SF)	12	14	16	16	**14.5**
Negro Creek (SF)	1	1	1	1	**1.0**
Headwaters Middle Fork (MF)	1	1	1	1	**1.0**
Pleasant Valley Creek (MF)	1	1	1	1	**1.0**
Gravel Creek (MF)	14	1	1	1	**4.3**
Sweetwater Creek (NF)	1	1	1	1	**1.0**
East Fork Salt Creek (NF)	16	16	1	1	**8.5**
Gnaw Bone Creek (NF)	1	1	1	1	**1.0**
Clay Lick Creek (NF)	11	13	1	1	**6.5**
Brummett Creek (NF)	1	1	1	1	**1.0**
Stephens Creek (NF)	12	1	15	1	**7.3**
Jacobs Creek (LM)	1	1	1	1	**1.0**
Moore Creek (LM)	1	1	1	1	**1.0**
Allens Creek (LM)	1	1	1	1	**1.0**

Sediment
Total suspended solids concentrations were low during both blitz events, generating few exceedances. During the fall blitz only three samples (of 88) exceeded the target concentration. During the spring blitz only one sample (of 122) exceeded the target concentration of 30 mg/L.

Based on these data, the four subwatersheds of concern for sediment are Headwaters (MF), Pleasant Valley (MF), East Fork Salt (NF), and Moore Creek (LM).

Table 4-22 HUC-12 Sub-watershed Comparison of Sediment Impairments

Site Name	Fall Blitz TSS Rank	Spring Blitz TSS Rank	Average Sediment Rank
Kiper Creek (SF)	1	1	**1.0**
Little Salt Creek (SF)	1	1	**1.0**
Tipton Creek (SF)	1	1	**1.0**
Negro Creek (SF)	1	1	**1.0**
Headwaters Middle Fork (MF)	15	1	**8.0**
Pleasant Valley Creek (MF)	14	1	**7.5**
Gravel Creek (MF)	1	1	**1.0**
Sweetwater Creek (NF)	1	1	**1.0**
East Fork Salt Creek (NF)	16	1	**8.5**
Gnaw Bone Creek (NF)	1	1	**1.0**
Clay Lick Creek (NF)	1	1	**1.0**
Brummett Creek (NF)	1	1	**1.0**
Stephens Creek (NF)	1	1	**1.0**
Jacobs Creek (LM)	1	1	**1.0**
Moore Creek (LM)	1	16	**8.5**
Allens Creek (LM)	1	1	**1.0**

Water Quality Degradation Summary

Overall, the Tipton Creek subwatershed (South Fork) scored the highest (worst) for water quality degradation, followed by East Fork Salt Creek (North Fork), Stephens Creek (North Fork), Clay Lick Creek (North Fork), and Little Salt Creek (South Fork). This indicates that these five subwatersheds have the poorest water quality. These subwatersheds match fairly well with the tributary monitoring data suggesting that the South Fork is the primary source of E. coli and nitrogen while the North Fork as the primary source of phosphorus and sediment.

Table 4-23 HUC-12 Subwatershed Water Quality Degradation Ranking

HUC-12 Subwatershed	# Parameters	Sum of Scores	Level of Degradation
Kiper Creek (SF)	14	66	5
Little Salt Creek (SF)	15	81	12 – High
Tipton Creek (SF)	14	120	16 – High
Negro Creek (SF)	14	53	2
Headwaters Middle Fork (MF)	15	80	10 - Medium
Pleasant Valley Creek (MF)	15	74	8 - Medium
Gravel Creek (MF)	15	75	5
Sweetwater Creek (NF)	15	74	3
East Fork Salt Creek (NF)	14	120	15 - High
Gnaw Bone Creek (NF)	15	86	8
Clay Lick Creek (NF)	15	98	13 - High
Brummett Creek (NF)	15	51	1
Stephens Creek (NF)	14	103	14 - High
Jacobs Creek (LM)	14	74	3
Moore Creek (LM)	14	79	7 - Medium
Allens Creek (LM)	14	79	11 - Medium

0-6 Low, 7-11 Medium, 12-16 High

The full set of parameter scores are presented in Table 4-25 on the next page.

Table 4-24 HUC-12 Subwatershed Water Quality Degradation Calculations

HUC-12 Sub-watershed	# Parameters	303(d) Rank	Fall Blitz E Coli Rank	Fall Blitz TSS Rank	Fall Blitz TP Rank	Fall Blitz SRP Rank	Fall Blitz TN Rank	Fall Blitz NO3 Rank	Spring Blitz E Coli Rank	Spring Blitz TSS Rank	Spring Blitz TP Rank	Spring Blitz SRP Rank	Spring Blitz TN Rank	Spring Blitz NO3 Rank	BCRSD E Coli Rank
Kiper Creek (SF)	14	1	8	1	8	13	1	1	16	1	5	4	1	1	
Little Salt Creek (SF)	15	12	14	1	1	8	14	15	1	1	1	1	1	1	9
Tipton Creek (SF)	14	1	9	1	10	15	12	14	1	1	9	6	16	16	
Negro Creek (SF)	14	13	1	1	13	14	1	1	1	1	2	1	1	1	
Headwaters Middle Fork (MF)	15	1	16	15	13	1	1	1	1	1	5	5	1	1	13
Pleasant Valley Creek (MF)	15	1	9	14	9	4	1	1	1	1	4	10	1	1	13
Gravel Creek (MF)	15	1	1	1	13	8	14	1	1	1	9	1	1	1	13
Sweetwater Creek (NF)	15	1	11	1	1	11	1	1	1	1	11	11	1	1	10
East Fork Salt Creek (NF)	14	1	1	16	11	11	16	16	1	1	16	12	1	1	
Gnaw Bone Creek (NF)	15	1	11	1	1	7	1	1	1	1	16	15	1	1	12
Clay Lick Creek (NF)	15	1	13	1	7	4	11	13	1	1	12	9	1	1	11
Brummett Creek (NF)	15	1	1	1	1	4	1	1	1	1	9	6	1	1	13
Stephens Creek (NF)	14	1	15	1	12	10	12	1	1	1	10	13	15	1	
Jacobs Creek (LM)	14	16	1	1	1	1	1	1	1	1	16	16	1	1	
Moore Creek (LM)	14	14	1	1	1	1	1	1	1	16	16	8	1	1	
Allens Creek (LM)	14	14	1	1	16	16	1	1	1	1	6	13	1	1	

4.13.2 HUC-12 Vulnerability Assessment

The level of vulnerability represents observed sources of pollutants in the watershed and utilizes all windshield survey data – erosion, riparian buffer, livestock access – as well as NPDES facilities, land cover, and habitat data. Individual rankings are averaged and compared between watersheds to calculate a vulnerability rank.

Point Source Pollution (NPDES)
The number of facilities with point discharge permits (NPDES) was tabulated for each sub-watershed to evaluate relative prioritization. Based on NPDES permits, the largest impact is from the Clay Lick Creek sub-watershed followed by Moore Creek. Additional areas of concern include the Kiper Creek, Gnaw Bone Creek, Brummett Creek, Allens Creek, and Jacobs Creek sub-watersheds.

Table 4-25 HUC-12 Subwatershed Comparison of Point Discharge Facilities

HUC-12 Subwatershed	NPDES Permits	# Permits	Rank
Kiper Creek (SF)	Jackson County Regional Sewer District WWTP, Springhill Camps WWTP	2	11
Little Salt Creek (SF)	None	0	1
Tipton Creek (SF)	None	0	1
Negro Creek (SF)	None	0	1
Headwaters Middle Fork (MF)	None	0	1
Pleasant Valley Creek (MF)	None	0	1
Gravel Creek (MF)	None	0	1
Sweetwater Creek (NF)	None	0	1
East Fork Salt Creek (NF)	None	0	1
Gnaw Bone Creek (NF)	Gnaw Bone WWTP, Camp Moneto WWTP	2	11
Clay Lick Creek (NF)	Nashville WWTP, Greg Rose Properties WWTP, Wrights Auto Parts, Shelby Materials	4	16
Brummett Creek (NF)	Brown County State Park WWTP, Unionville Elementary WWTP	2	11
Stephens Creek (NF)	None	0	1
Jacobs Creek (LM)	Salt Creek Services WWTP	1	10
Moore Creek (LM)	Paynetown SRA WWTP, SCI RSD WWTP, CBU Drinking Water Plant	3	15
Allens Creek (LM)	USFS Hardin Ridge WWTP, Hardin-Monroe WWTP	2	11

Land Cover Assessment
Nonpoint source pollution is most likely to come from agricultural land or developed land (as opposed to forest, water/wetlands, or scrub/shrub). The percentage of agricultural and developed land was tabulated for each sub-watershed to evaluate relative prioritization.

The four sub-watersheds with the highest percentage of combined agricultural and developed land were Kiper Creek, Tipton Creek, Allens Creek, and Stephens Creek. The five sub-watersheds with moderate percentage of combined agricultural and developed land were Little Salt Creek, Pleasant Valley Creek, Sweetwater Creek, Brummett Creek, and Moore Creek.

Table 4-26 HUC-12 Subwatershed Comparison of Land Cover

HUC-12 Sub-watershed	% Agricultural	% Developed	% Agricultural or Developed	Land Cover Rank
Kiper Creek (SF)	24.6%	4.8%	29.4%	16
Little Salt Creek (SF)	8.0%	1.7%	9.8%	10
Tipton Creek (SF)	21.5%	2.6%	24.1%	15
Negro Creek (SF)	1.8%	1.0%	2.7%	2
Headwaters Middle Fork (MF)	5.8%	1.7%	7.5%	6
Pleasant Valley Creek (MF)	8.7%	1.8%	10.5%	10
Gravel Creek (MF)	2.4%	0.7%	3.0%	2
Sweetwater Creek (NF)	5.8%	2.8%	8.6%	8
East Fork Salt Creek (NF)	5.1%	1.2%	6.3%	4
Gnaw Bone Creek (NF)	4.2%	2.1%	6.4%	4
Clay Lick Creek (NF)	5.2%	2.6%	7.8%	7
Brummett Creek (NF)	6.8%	2.2%	8.9%	8
Stephens Creek (NF)	7.1%	4.1%	11.2%	13
Jacobs Creek (LM)	0.4%	0.8%	1.2%	1
Moore Creek (LM)	7.4%	2.4%	9.8%	10
Allens Creek (LM)	9%	3%	12%	14

Windshield Survey

The windshield survey evaluated streambank erosion, riparian buffer, and where livestock have free access to streams. Results were variable across the different parameters, with no obvious correlation between erosion and riparian buffer or between erosion and livestock access.

Three subwatersheds tied for having the highest percentage of streambank erosion – Tipton Creek (SF), Gravel Creek (MF), and Stephens Creek (NF). The fourth was Brummetts Creek (NF). The subwatershed with the highest percentage of sites lacking riparian buffer (less than twenty feet on each side of the stream), was Pleasant Valley Creek (MF), Gnaw Bone Creek (NF), and a tie between Clay Lick Creek (NF) and Brummett Creek (NF). Two subwatersheds tied for having the highest percentage of sites with livestock access to streams – Tipton Creek (SF) and Stephens Creek (NF). Third place was Little Salt Creek (SF).

Table 4-27 HUC-12 Subwatershed Comparison of Windshield Survey Observations

Subwatershed	Erosion Rank	Riparian Buffer Rank	Livestock Access Rank
Kiper Creek (SF)	10	12	10
Little Salt Creek (SF)	6	5	14
Tipton Creek (SF)	14	6	15
Negro Creek (SF)	4	1	1
Headwaters Middle Fork (MF)	10	8	10
Pleasant Valley Creek (MF)	8	16	7
Gravel Creek (MF)	14	3	1
Sweetwater Creek (NF)	9	7	8
East Fork Salt Creek (NF)	4	9	12
Gnaw Bone Creek (NF)	12	15	1
Clay Lick Creek (NF)	7	13	12
Brummett Creek (NF)	13	13	8
Stephens Creek (NF)	14	4	15
Jacobs Creek (LM)	2	9	1
Moore Creek (LM)	3	2	1
Allens Creek (LM)	1	9	1

Habitat

Habitat assessments were conducted during both blitz events using the CQHEI methodology. The average CQHEI score was calculated for each subwatershed and ranks were assigned. Rankings vary somewhat between blitz events but the two worst subwatersheds had consistently low scores during both events.

The three subwatersheds with the lowest average CQHEI scores were Kiper Creek (SF), Gravel Creek (MF), and East Fork Salt Creek (NF). Four subwatersheds tied for fourth place – Tipton Creek (SF), Pleasant Valley Creek (MF), Clay Lick Creek (NF), and Moore Creek (LM).

Table 4-28 HUC-12 Subwatershed Comparison of Habitat (CQHEI)

Subwatershed	Fall Blitz CQHEI Rank	Spring Blitz CQHEI Rank	Average CQHEI Rank
Kiper Creek (SF)	15	15	15.0
Little Salt Creek (SF)	2	1	1.5
Tipton Creek (SF)	7	13	10.0
Negro Creek (SF)	11	6	8.5
Headwaters Middle Fork (MF)	3	3	3.0
Pleasant Valley Creek (MF)	11	9	10.0
Gravel Creek (MF)	13	16	14.5
Sweetwater Creek (NF)	3	4	3.5
East Fork Salt Creek (NF)	15	10	12.5
Gnaw Bone Creek (NF)	9	8	8.5
Clay Lick Creek (NF)	9	11	10.0
Brummett Creek (NF)	14	5	9.5
Stephens Creek (NF)	6	13	9.5
Jacobs Creek (LM)	5	7	6.0
Moore Creek (LM)	8	12	10.0
Allens Creek (LM)	1	2	1.5

Water Quality Vulnerability Summary

The Kiper Creek subwatershed (South Fork) scored the highest (worst) for vulnerability, followed by Clay Lick Creek (North Fork), Brummett Creek (North Fork), Tipton Creek (South Fork), and Stephens Creek (North Fork). This indicates that these five subwatersheds have the highest concentration of documented pollution sources.

Sub-watershed	# Parameters	Sum of Scores	Level of Vulnerability
Kiper Creek (SF)	7	89	16 - High
Little Salt Creek (SF)	7	39	3
Tipton Creek (SF)	7	71	13 - High
Negro Creek (SF)	7	26	1
Headwaters Middle Fork (MF)	7	41	6
Pleasant Valley Creek (MF)	7	62	11
Gravel Creek (MF)	7	50	7
Sweetwater Creek (NF)	7	40	5
East Fork Salt Creek (NF)	7	55	9
Gnaw Bone Creek (NF)	7	60	10
Clay Lick Creek (NF)	7	75	15 - High
Brummett Creek (NF)	7	72	14 - High
Stephens Creek (NF)	7	66	12 - High
Jacobs Creek (LM)	7	35	2
Moore Creek (LM)	7	51	8
Allens Creek (LM)	7	39	3

0-6 Low, 7-11 Medium, 12-16 High

4.13.3 HUC-12 Overall Assessment

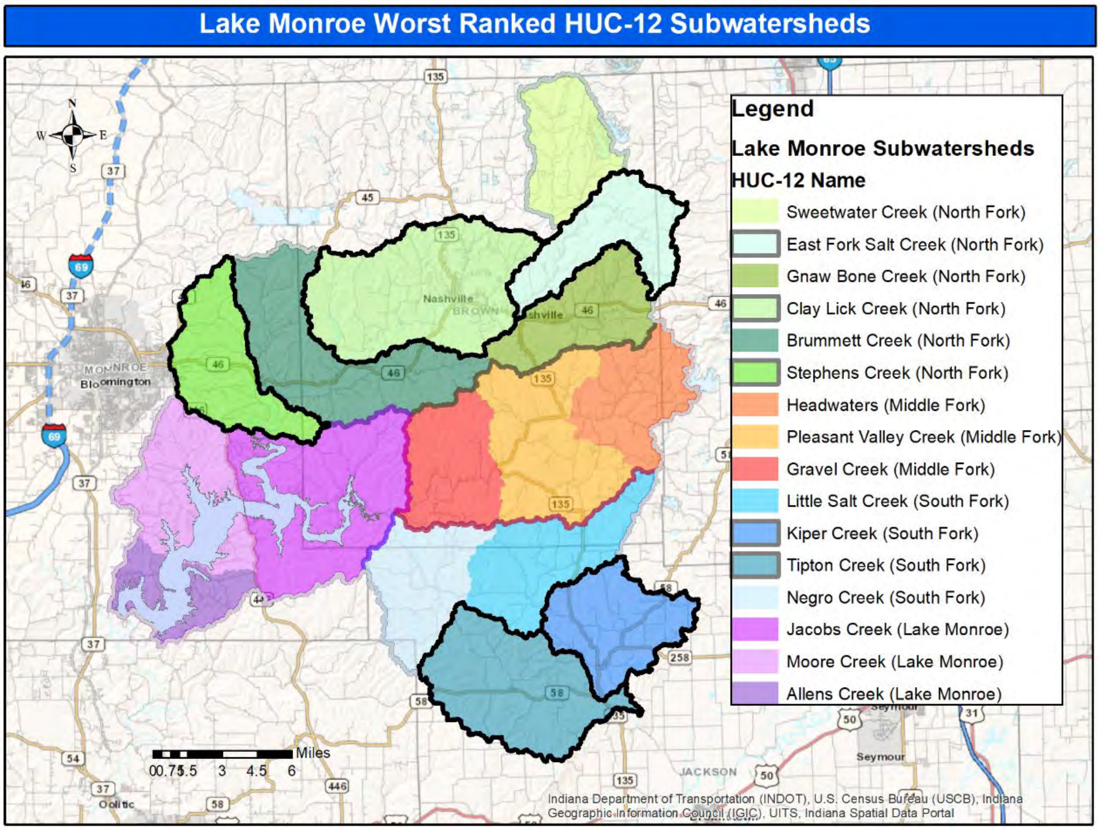
Combining the two sets of rankings, the five highest priority HUC-12 subwatersheds are Kiper Creek and Tipton Creek in the South Fork subwatershed; and East Fork Salt Creek, Clay Lick Creek, and Stephens Creek in the North Fork subwatershed as shown in Table 4-30. These subwatersheds are mapped on Figure 4-30.

Table 4-29 HUC-12 Subwatershed Combined Ranking

HUC-12 Subwatershed	Level of Degradation	Level of Vulnerability	Sum	Overall Rank
Kiper Creek (SF)	5	16 - High	24	12 - High
Little Salt Creek (SF)	12 – High	3	15	6
Tipton Creek (SF)	16 – High	13 - High	29	16 - High
Negro Creek (SF)	2	1	3	1
Headwaters Middle Fork (MF)	10 - Medium	6	16	9 - Medium
Pleasant Valley Creek (MF)	8 - Medium	11 - Medium	19	11 - Medium
Gravel Creek (MF)	5	7 - Medium	12	4
Sweetwater Creek (NF)	3	5	8	3
East Fork Salt Creek (NF)	15 - High	9 - Medium	24	13 - High
Gnaw Bone Creek (NF)	8 - Medium	10 - Medium	18	10 - Medium
Clay Lick Creek (NF)	13 - High	15 - High	28	15 - High
Brummett Creek (NF)	1	14 - High	15	6
Stephens Creek (NF)	14 - High	12 - High	26	14 - High
Jacobs Creek (LM)	3	2	5	2
Moore Creek (LM)	7 - Medium	8 - Medium	15	6
Allens Creek (LM)	11 - Medium	3	14	5

0-6 Low, 7-11 Medium, 12-16 High

Figure 4-30 Lake Monroe Worst Ranked HUC-12 Subwatersheds



4.14 HUC-12 Subwatershed Detailed Assessment

All available data was compiled and reviewed at the HUC-12 subwatershed level in order to identify specific areas of concern. Maps of each subwatershed and accompanying data are available in Appendix J.

5 Identifying Problems and Causes

Results from the analysis were used to determine which community concerns were supported by data, to craft problem statements, and to identify the potential causes and sources of each problem.

5.1 Key Findings of Watershed Assessment

Several water quality impairments were identified during the watershed inventory process, based on data collected 2020-2021 by the IU Limnology Lab and the Brown County Regional Sewer District as well as historic data collected by IDEM, CBU, USFS, and USACE. These include elevated total phosphorus, elevated total nitrogen, elevated E. coli concentrations, poor macroinvertebrate communities, and poor habitat. Field observations identified streambank erosion, insufficient riparian buffer, and livestock access to streams in most subwatersheds.

Total phosphorus concentrations above the water quality target were reported in all subwatersheds during the spring blitz and more than half the subwatersheds during the fall blitz. Total phosphorus exceedances were also regularly reported in monthly samples collected from South Fork Salt Creek, Middle Fork Salt Creek, North Fork Salt Creek, and the Lake Monroe Outlet. The one exception was Crooked Creek, which did not have elevated total phosphorus during the monthly sampling events.

Total nitrogen concentrations above the water quality target were reported in two of sixteen subwatersheds during the fall blitz and six of sixteen subwatersheds during the spring blitz. The two subwatersheds with exceedances in both events were Tipton Creek (SF) and Brummett Creek (NF).

E. coli concentrations above the water quality target were reported in nine of sixteen subwatersheds during the fall blitz and one subwatershed during the spring blitz. The subwatershed with exceedances in both events was Kiper Creek (SF). Additionally, E. coli concentrations above the water quality target were reported in all eight subwatersheds sampled by BCRSD.

Stream sections with CQHEI habitat scores below 60 were reported in eleven of sixteen subwatersheds during the spring blitz.

Water quality impairments were also identified in Lake Monroe. Samples collected in 2020 confirm elevated total phosphorus concentrations with over 50% of hypolimnion samples and upper basin epilimnion samples exceeding the water quality target of 0.02 mg/L. This correlates well with historical data indicating that Lake Monroe is mildly eutrophic and that concentrations of phosphorus and total organic carbon appear to be trending upward. Chlorophyll-a levels were also well above water quality targets, which is unsurprising given that harmful algal blooms are becoming more common, with recreational advisories issued annually from 2011 through 2021.

Table 5-1 Summary of Subwatershed Concerns

Subwatershed (HUC12)	Total Phosphorus Exceedance (Fall or Spring Blitz)	Total Nitrogen Exceedance (Fall or Spring Blitz)	E. coli Exceedance (Fall or Spring Blitz)	E. coli Exceedance (BCRSD)	CQHEI < 60 (Spring Blitz)
Kiper Creek (SF)	X		X		X
Little Salt Creek (SF)	X	X	X	X	
Tipton Creek (SF)	X	X	X		X
Negro Creek (SF)	X				
Headwaters Middle (MF)	X		X	X	
Pleasant Valley Creek (MF)	X		X	X	X
Gravel Creek (MF)	X	X		X	X
Sweetwater Creek (NF)	X		X	X	X
East Fork Salt Creek (NF)	X	X			X
Gnaw Bone Creek (NF)	X		X	X	X
Clay Lick Creek (NF)	X	X	X	X	X
Brummett Creek (NF)	X			X	X
Stephens Creek (NF)	X	X	X		X
Jacobs Creek (LM)	X				
Moore Creek (LM)	X				X
Allens Creek (LM)	X				

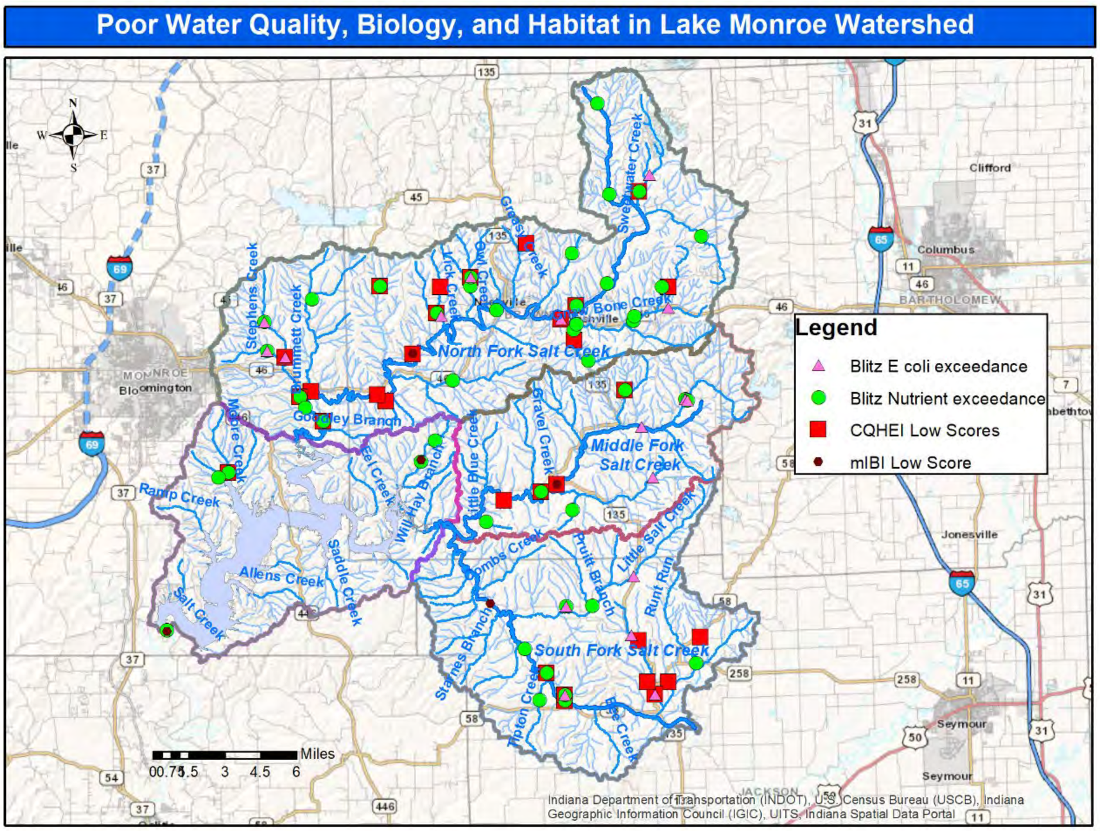
Tributary monitoring data indicate that the South Fork Salt Creek subwatershed is the largest contributor of nitrogen and E. coli. This is not unexpected since the subwatershed contains the largest acreage of agricultural land and two impaired streams. However, the North Fork subwatershed appears to be the largest contributor of phosphorus and sediment.

The HUC-12 subwatershed assessment indicates that there are priority subwatersheds in both the South Fork and North Fork areas – Kiper Creek and Tipton Creek in the South Fork subwatershed; and East Fork Salt Creek, Clay Lick Creek, and Stephens Creek in the North Fork subwatershed. These areas have a higher percentage of agricultural land, including both row crop agriculture and livestock, while Kiper, Clay Lick, and Stephens also have high concentrations of developed land. Projects within these subwatersheds should be prioritized for funding and implementation.

Source analysis for fecal contamination suggests that both human and animal sources are present. While it is still unclear which source is the largest contributor, both livestock and failing septic systems should be addressed throughout the watershed.

Sites with nutrient, E. coli, habitat, and biological concerns are shown in Figure 5.1.

Figure 5-1 Poor Water Quality, Biology, and Habitat in Lake Monroe Watershed



5.2 Analysis of Stakeholder Concerns

Two community forums were held at the beginning of the project with support from local chapters of the League of Women Voters. The first forum was held in Bloomington (Monroe County) in November 2019 and the second forum was held in Nashville (Brown County) in January 2020. Participants worked in small groups of 6-8 to brainstorm concerns about the lake. Each group identified their top three concerns and reported back to the entire forum. The top three concerns from each group were compiled and duplicates were eliminated. Then the steering committee reviewed the concerns to determine which were within the project's scope and what data were available to evaluate each concern.

While most concerns were selected for further exploration, a few fell outside of the project's scope and/or focus. The following concerns were outside the scope of the watershed management plan.

- Several community members raised concerns about drinking water costs to homeowners and potential loss of access to Lake Monroe as a drinking water source for Bloomington, since the water is ultimately owned and controlled by the US Army Corps of Engineers. While lake water quality does affect drinking water treatment costs, it is beyond the scope of this project to directly address drinking water cost or community concerns related to future allocations of Lake Monroe water. These concerns are not directly connected to nonpoint source pollution.
- Likewise, the issue of uneven distribution of economic return from the lake was raised and is a concern in this and many other watersheds. It is important to be aware that the communities that receive the most economic benefits from Lake Monroe are different from the communities whose activities most directly impact water quality in the lake. While this issue will not be directly addressed as a problem statement, uneven distribution of economic benefits will be considered when determining how best to implement the plan and prioritize projects.
- Prescription pharmaceuticals were mentioned as a concern, particularly in the context of failed septic systems. Very limited data are available and there are no established water quality standards in Indiana. The steering committee determined that pharmaceuticals are outside the scope of this project.
- Drinking water quality was mentioned several times. It is important to note that this watershed management plan will only address watershed and lake management and will not address drinking water treatment. While drinking water treatment processes can change depending on the quality of raw lake water, this project will not proscribe changes to drinking water treatment.

Several concerns were identified that are not supported by existing data.

- Improper management of boat toilets was mentioned as a concern. Conversations with Indiana DNR staff on Lake Monroe indicate that there have been no complaints related to illicit dumping of boat toilets or other evidence that indicates this is an issue at the lake.

- Asian Carp were mentioned as a potential concern. According to reports from Indiana DNR, Asian carp have been observed in Salt Creek downstream from Lake Monroe but have not yet been found within the lake or its tributaries.
- One concern raised was that lake water will become so polluted/undrinkable that it is no longer available as our water supply. Current data show Lake Monroe is far from this extreme scenario.
- Pesticide usage (including herbicides) was mentioned multiple times in conjunction with forest management, terrestrial invasive species management, and agricultural production. Atrazine was reported in drinking water at levels between 0.2 and 0.3 ppb in six of the last ten years and was detected in lake samples at levels up to 0.5 ppb in samples collected by the Army Corps of Engineers over the last ten years. All are well below EPA's maximum contaminant level of 3.0 ppb. No other herbicide data are available. Because the available data show levels well below regulatory thresholds, pesticide usage will be addressed only as a component of public education.
- Copper was identified as a potential concern based on a water sample collected by the US Army Corps of Engineers from the Lake Monroe tailwaters in 2018. This sample had a reported copper concentration of 11.4 ug/L. The acute aquatic criterion for copper (calculated based on hardness measured during the sampling event) is 7.79 ug/L, and therefore an exceedance occurred. However, there were no exceedances in any other Lake Monroe samples analyzed by the USACE from 1999 through 2019. Over 70% of the reported copper concentrations from USACE were less than 2 ug/L and all but one were less than 10 ug/L. The acute aquatic criterion is also a very conservative value – in comparison, the drinking water action limit for copper is 1300 ug/L (1.3 ppm). Based on this data, copper does not appear to be a significant concern.

Additional concerns were raised that have not been chosen by the steering committee for further investigation as part of this watershed management plan.

- Iron was identified as a potential concern based on water samples collected by the USACE. Over 20% of the 87 samples analyzed for total iron between 1999 and 2017 exceeded the acute aquatic criterion for iron of 2.744 mg/L. The maximum reported value was 6.6 mg/L and the median was 1.1 mg/L. Iron cycling in lakes and streams is complex and it is normal for concentrations to vary considerably over both time and space. Iron concentrations in samples from all the Louisville District ACOE lakes ranged from below the detection limit to 20.8 mg/L. The concentrations of iron in Lake Monroe appear to be within normal variations for the state. Due to the limited data availability and the lack of obvious potential sources of iron within the watershed, iron has been excluded from this watershed plan.

Table 5-2 Stakeholder Concern Analysis

Concern	Supported by Data?	Evidence for Concern	Quantifiable?	Within Project Scope?	Focusing on?
Algae blooms caused by nutrient loading make the lake unswimmable	Yes	IDEM/IDNR sampling data leading to recreational advisories (for algae) at Paynetown and Fairfax beaches 2011-2021	Yes	Yes	Yes
Nutrient loading (urban lawns, agriculture, septic systems)	Yes	Sampling data - 11% of monthly stream samples exceed total nitrogen target; 55% of monthly stream samples exceed total phosphorus target	Yes	Yes	Yes
Inappropriate agricultural practices	Yes	Livestock with stream access observed at 24% of the sites where livestock were present; tillage transect indicates low cover crop usage for corn fields (17% Brown, 0% Monroe, 23% Jackson); lack of riparian buffer observed throughout watershed	Estimates	Yes	Yes
Lawn maintenance (and its downstream effects)	Yes	Anecdotal observations of lawn care at residential and commercial properties throughout the watershed	Estimates	Yes	Yes
Effects of septic systems on nutrient loading	Yes	Monroe County Health Department and Brown County Health Department both maintain lists of failing septic systems within the watershed	Estimates	Yes	Yes
Waterways are not up to standards; clean up E coli	Yes	IDEM 303d list (Crooked Creek), sampling data - 33% of monthly samples from South Fork, 25% of monthly samples from Middle Fork,	Yes	Yes	Yes

Concern	Supported by Data?	Evidence for Concern	Quantifiable?	Within Project Scope?	Focusing on?
		18% of samples from fall blitz, and 45% of BCRSD samples exceeded the state standard of 235 CFU/100 ml.			
Pathogens from humans and animals	Yes	IDEM 303d list (Crooked Creek), sampling data – source sampling suggests both human and animal sources of fecal contamination	Yes	Yes	Yes
Failed septic systems	Yes	Monroe County Health Department and Brown County Health Department both maintain lists of failing septic systems within the watershed	Estimates	Yes	Yes
Ensure that boat toilets are properly managed	No	Anecdotal; DNR reports no boat toilet incidents in recent years	No	Yes	No
Need to quantify what chemicals/pollutants are entering lake	Maybe	Lake sampling data; CBU data; Brown County Health Department data	Yes	Yes	Yes
Trash and plastic pollution	Yes	Shoreline Cleanups, Microplastics sampling by Bloomington Utilities	Yes	Yes	Yes
Metals	Maybe	ACOE 2018-2019 lake sampling	Yes	Yes	No
Use of herbicides/pesticides in residential/commercial	No	Finished water sampling by Bloomington Utilities; ACOE sampling	Yes	Yes	No
Toilet flush of prescription pharmaceuticals	No	Insufficient data and standards available.	Yes	No	No

Concern	Supported by Data?	Evidence for Concern	Quantifiable?	Within Project Scope?	Focusing on?
Drinking water treatment costs as a homeowner	Yes	Steadily increasing rates	Yes	No	No
Taste and odor issues with drinking water	Yes	IDEM 303d list; Bloomington Utilities concerns record	Yes	Yes	Yes
Actual ownership of water; ensure water stays here	Yes	Newspaper articles about Indianapolis exploring drinking water options	No	No	No
Drinking water quality (nitrates, phosphates, dangerous bacteria, E. coli, toxic blue-green algae)	Yes	Monitored by CBU; outside scope of this project	Yes	No	No
Algae blooms affect drinking water treatment	Yes	CBU data show increased treatment cost based on raw water quality	Yes	Yes	Yes
Fear that lake water would be so undrinkable so it is no longer available as our water supply	No	Current data show Lake Monroe is far from extreme scenarios	Estimates	No	No
Silting in of lake – can we stop it	Yes	Anecdotal reports of siltation near boat ramps; USGS Reservoir Sedimentation Database (silting in is inevitable but rate can be slowed)	Yes	Yes	Yes
Lake getting more shallow due to sedimentation	Yes	Anecdotal reports of siltation near boat ramps; Jones 1997	Yes	Yes	Yes
Shoreline erosion	Yes	Visual observation 2020-2021; limited shoreline documentation 2020; documentation Jones 1997	Yes	Yes	Yes
Sedimentation/erosion - entire watershed	Yes	Visual observation 2020-2021 – 85% of stream sites showed signs of erosion; Jones 1997	Yes	Yes	Yes

Concern	Supported by Data?	Evidence for Concern	Quantifiable?	Within Project Scope?	Focusing on?
Need to quantify siltation rate and identify source(s)	Yes	Jones 1997	Yes	Yes	Yes
Development on and around the lake	Yes	Anecdotal reports of development causing erosion; Monroe County Comprehensive Plan; Monroe County ECO Overlay	Estimates	Yes	Yes
Effects of logging/forest management (herbicides – amphibians, heavy equipment – road damage)	Yes	Visual observation of sediment from some logging sites; insufficient data about herbicides	Estimates	Yes	Yes
Keep forests as forests	No	Land use trends	Yes	Yes	Yes
Unregulated forest management	Yes	Anecdotal reports of buyers offering owners cash for timber and not developing forest management plan; controversial timber harvest on public land in Brown County where expectations were not clear	Yes	Yes	Yes
Log jams	Yes	Multiple log jams observed on North Fork Salt Creek, Brummett Creek	Yes	Yes	Yes
Flooding	Yes	Monroe County Long-Term Stormwater Plan, Newspaper articles about flooding of North Fork Salt Creek	Yes	Yes	Yes
Invasive plants	Yes	Garlic mustard, Asian bush honeysuckle, and Japanese honeysuckle vine were documented at more than 10% of blitz sampling sites.	Yes	Yes	Yes
Asian Carp	No	USACE data show Asian Carp are not yet in lake	Yes	No	No

Concern	Supported by Data?	Evidence for Concern	Quantifiable?	Within Project Scope?	Focusing on?
Effects of invasive species control	No	Insufficient data are available to quantify impacts from herbicide use or other invasive species control efforts.	No	No	No
Poor public understanding of how lakes/watersheds function	Yes	Survey data from other communities	Yes	Yes	Yes
Educate public and school children	Yes	Survey data from other communities	Yes	Yes	Yes
Need more data about water quality and trends	Yes	Existing data are primarily from annual sampling in the lake (INCLP, ACOE) and does not consider the larger watershed; minimal analysis done on ACOE data	Yes	Yes	Yes
Lack of oversight/enforcement of polluters, landowners	Uncertain	Anecdotal	Estimates	Yes	Yes
Uneven distribution of economic return from the lake	Uncertain	Anecdotal	Yes	No	No
Long-term management plan implementation, monitoring, and funding	Yes	Other WMPs that were not implemented	Yes	Yes	Yes
No drainage ordinance	Yes	No consistent drainage ordinance exists across the watershed	Yes	Yes	Yes
Deregulation of environmental protection	Uncertain	Proposals to Indiana legislature limiting local ordinances	Yes	Yes	Yes
Collaboration between multiple governments required for implementation; unclear who is in charge	Yes	Watershed crosses multiple counties and towns	Yes	Yes	Yes
Maintain recreational value	Yes	303d listing; IDEM recreational advisories (algae)	Yes	Yes	Yes

Concern	Supported by Data?	Evidence for Concern	Quantifiable?	Within Project Scope?	Focusing on?
Recreational pollution - how to limit effects, dispel myths	Yes	Jones 1997	Estimates	Yes	Yes
Recreation - boating impacts; responsible use	Yes	Jones 1997	Yes	Yes	Yes
Large boat engines contribute to erosion, turbidity	Yes	Jones 1997	Yes	Yes	Yes

The steering committee further reviewed the list of public concerns and used them to craft problem statements. These problem statements combine overlapping issues in order to identify root issues to be addressed.

Table 5-3 Problem Statements

Public Concern	Problem Statement
Silting in of lake – can we stop it Lake getting more shallow due to sedimentation Shoreline erosion Sedimentation/erosion - entire watershed Effects of logging Inappropriate agricultural practices Large boat engines contribute to erosion, turbidity Need to quantify siltation rate and identify source(s)	Sediment accumulation in the lake decreases its lifespan, reduces recreational capability, and increases turbidity of the water. Sediment carries nutrients and total organic carbon, which can contribute to algal blooms.
Algae blooms affect drinking water treatment Taste and odor issues with drinking water Drinking water quality (nitrates, phosphates, dangerous bacteria, E. coli, toxic blue-green algae) Algae blooms caused by nutrient loading make the lake unswimmable Need to quantify what chemicals/pollutants are entering lake Need more data about water quality and trends Nutrient loading (urban lawns, agriculture, septic systems) Inappropriate agricultural practices Lawn maintenance (and its downstream effects) Effects of septic systems on nutrient loading	Elevated nutrient loads lead to excessive growth of aquatic plants and algae. Harmful algal blooms (HAB) can limit recreational use, harm pets and, in extreme cases, cause lakes to become unswimmable. Each year HAB recreational advisories are issued for Lake Monroe. The US EPA lists Lake Monroe as impaired for algae as well as taste and odor, which is often linked to algal blooms.

Public Concern	Problem Statement
Waterways are not up to standards; clean up E coli	Elevated levels of E. coli in some waterways within the watershed indicate the likely presence of fecal matter that may be associated with pathogens making it unsafe to swim and recreate. Two streams are listed as impaired for E. coli on the IDEM 303d list of impaired water bodies. The source of E. coli is unclear, but could be due to livestock, failing septic systems, boat discharge, or wildlife.
Need to quantify what chemicals/pollutants are entering lake	
Need more data about water quality and trends	
Pathogens from humans and animals	
Failed septic systems	
Maintain recreational value	Boating is a popular activity on Lake Monroe. Recreational value of the lake must be preserved while minimizing recreational pollution through education and enforcement.
Recreational pollution - how to limit effects, dispel myths	
Lack of oversight/enforcement of polluters	
Recreation - boating impacts; responsible use	
Effects of logging/forest management (herbicides – amphibians, heavy equipment – road damage)	Over 82% of the watershed is forested and forestry management activities such as logging, burning or herbicide application may have a negative impact on water quality.
Keep forests as forests	
Unregulated forest management	
Invasive plants	
Waterways are not up to standards	The downstream section of South Fork Salt Creek is listed as impaired for “biological integrity” on the IDEM 303d list, meaning that the stream does not provide good habitat for aquatic wildlife.
Impact of stream flooding	Periodic flooding of streams causes property damage, increased stream bank erosion, and lateral stream movement. Log jams and lack of healthy floodplains may exacerbate the issue.
Sedimentation/erosion - entire watershed	
Impact of log jams	
Collaboration between multiple governments required for implementation; unclear who is in charge	Lack of cohesive regulations and governance across the watershed makes funding and implementation of a watershed plan challenging. There is no uniform drainage ordinance for the watershed. There is no single government body that oversees the watershed.
Long-term management plan implementation, monitoring, and funding	
Need more data about water quality and trends	

Public Concern	Problem Statement
No drainage ordinance Lack of oversight/enforcement of polluters, landowners	
Poor public understanding of how lakes/watersheds function Recreation - boating impacts; responsible use Educate public and school children	Education of the public, both adults and children, is needed to increase awareness of water quality protection needs and solutions.
Trash and plastic pollution	Trash and plastic pollution are negatively impacting the lake and its tributaries.
Invasive plants	Invasive plant species displace native plant species, which may disrupt food chains and decrease biodiversity. Invasive plant species may also be less effective at stabilizing stream banks and may alter nutrient cycling in the soil.
Deregulation of environmental protection Development on and around the lake	Local regulations are key to minimizing impacts from development in the watershed. Deregulation, including proposed state regulations that would take away local control, poses a threat to the watershed.

5.3 Potential Causes and Sources of Each Problem

Each problem statement can be tied to one or more causes (a particular pollutant, a lack of awareness) and one or more sources (a location or activity where the cause came from). Additional discussion is provided to review data limitations and key considerations.

Table 5-4 Problems, Causes, Potential Sources, and Discussion

Problem:	**Elevated nutrient loads lead to excessive growth of aquatic plants and algae. Harmful algal blooms (HAB) can limit recreational use, harm pets and, in extreme cases, cause lakes to become unswimmable. Each year HAB recreational advisories are issued for Lake Monroe. The US EPA lists Lake Monroe as impaired for algae as well as taste and odor, which is often linked to algal blooms.**
Potential Causes:	Nitrogen and phosphorus concentrations exceed target levels.
Potential Sources:	• Application of fertilizers with phosphorus (agriculture, commercial, residential) – Almost 10,000 acres (3.5%) in the watershed are used for row crops with regular fertilizer application. Anecdotal reports indicate that fertilizer use is also prevalent on commercial and residential properties. • Overapplication of fertilizer for its specific use – Conversations with farmers in Jackson County indicate that many farmers apply fertilizer based on product recommendations rather than testing the soil and adjusting appropriately. • Inadequate riparian buffers – 60% of sites observed for the windshield survey had less than 20 feet of riparian buffer; 20% had less than 5 feet of riparian buffer • Livestock access to streams – 17 livestock stream access points were observed during the windshield survey (7% of sites) • Lack of manure management – Anecdotal reports indicate that few farms in the watershed have manure management plans; Brown County State Park struggles with horse manure management • Inadequately functioning septic systems – County Health Departments maintain list of failing septic systems that include sites in the watershed • Exceedances in NPDES permitted discharges – NPDES permit exceedances were documented for five facilities in the watershed • Legacy nutrients stored in lake sediment – Lake monitoring indicates that phosphorus is released from lake sediments during anoxic conditions when the lake is stratified. • Nutrients bound to sediment – Phosphorus and nitrogen are often carried with sediment

Discussion:	One of the biggest challenges facing Lake Monroe is algal blooms and the key to addressing algal blooms is to minimize nutrient levels, particularly phosphorus. Phosphorus was detected at concentrations above target levels in all three basins of Lake Monroe and all three major tributaries. Phosphorus may be arriving in the lake from fertilizers, manure, leaking septic systems, or bound to sediment. It is also important to consider phosphorus contained within sediment at the bottom of Lake Monroe that can be released during anoxic conditions. Reducing the level of phosphorus in the lake will require addressing both incoming sources of phosphorus and legacy phosphorus stored in lake sediment.
Problem:	**Sediment accumulation in the lake decreases its lifespan, reduces recreational capability, and increases turbidity of the water. Sediment carries nutrients and total organic carbon, which can contribute to algal blooms.**
Potential Causes:	Sediment concentrations exceed target levels
Potential Sources:	• Streambank erosion – 86% of observed stream sites exhibited streambank erosion; 28% of sites exhibited severe erosion (3+ feet) • Inadequate riparian buffers – 60% of sites observed for the windshield survey had less than 20 feet of riparian buffer; 20% had less than 5 feet of riparian buffer • Livestock access to streams – 17 livestock stream access points were observed during the windshield survey (7% of sites) • Farmed wetland areas – Farmland is concentrated in the floodplains of the major tributaries which is also where hydric soils are located • Lakeshore erosion – Visual observations 2020-2021 indicate widespread erosion; Jones 1997 study documented widespread lakeshore erosion • Crop tillage – 67% of corn fields in Brown County, 56% of corn fields in Monroe County, and 28% of corn fields in Jackson County are tilled per the 2019 tillage transects • Livestock heavy usage – Anecdotal reports indicate high density of livestock on some small farms leading to soil disturbance • Boat resuspension of sediment – Anecdotal reports indicate increased water turbidity in Lake Monroe during and immediately after periods of high boat traffic • Poorly designed driveways and stream crossings – Interviews with SWCD representatives and stakeholders indicate that roads through streams, steep driveways without water bars, and undersized culverts all contribute to sediment in streams during storm events

	• Logging without BMPs – Two active logging sites with sediment issues were observed during the windshield survey; anecdotal reports indicate timber buyers regularly offer owners cash for timber and do not develop forest management plans that suggest BMPs or timber sale contracts that require BMPs • Lack of temporary erosion control on construction sites – Anecdotal reports indicate construction sites lacking erosion control particularly where there is no MS4 jurisdiction • Lack of Rule 5 enforcement – Rule 5 enforcement is limited in the Brown County and Jackson County portions of the watershed due to the lack of MS4 jurisdiction
Discussion:	Sediment is a concern because it accumulates in the lake, decreasing the lake's lifespan, but it also is a concern because it can carry nutrients and other contaminants. While only a few samples collected during the 2020-2021 water quality monitoring revealed levels of total suspended solids above target levels, this is largely because samples were largely collected during periods of low or medium flow. Some studies estimate that 80% of annual sediment load is delivered during the 20% highest flow periods. Eroded stream banks, areas of bare soil in the watershed, and anecdotal reports of sediment accumulation in the lake all clearly indicate that sediment is an issue. Reducing sediment loads is key to reducing nutrient loads as well as lengthening the lifespan of Lake Monroe.
Problem:	**Elevated levels of E. coli in some waterways within the watershed indicate the likely presence of fecal matter that may be associated with pathogens making it unsafe to swim and recreate. Two streams are listed as impaired for E. coli on the IDEM 303d list of impaired water bodies. The source of E. coli is unclear, but could be due to livestock, failing septic systems, boat discharge, or wildlife.**
Potential Causes:	E. coli concentrations exceed target levels.
Potential Sources:	• Inadequately functioning septic systems – The local health departments maintain a list of known septic system issues that include sites in the watershed • Livestock access to streams – 17 livestock stream access points were observed during the windshield survey (7% of sites) • Lack of manure management – Anecdotal reports indicate that few farms in the watershed have manure management plans • Inadequate riparian buffers – 60% of sites observed for the windshield survey had less than 20 feet of riparian buffer; 20% had less than 5 feet of riparian buffer • Exceedances in NPDES permitted discharges – NPDES permit exceedances were documented for five facilities in the watershed

	• Wildlife manure deposits – While difficult to quantify, the watershed has large wildlife populations that produce large quantities of manure. • Boat toilet discharges – Anecdotal reports from DNR indicate this is not an issue in Lake Monroe
Discussion:	While E. coli does not currently appear to be an issue in Lake Monroe, it is an issue in certain streams in the watershed. Addressing E. coli in these streams will ensure that E. coli does not become an issue in Lake Monroe while also making the streams more suitable for recreation. Source sampling indicates that fecal contamination is likely coming from both human and animal sources. Both potential sources should be addressed. Educating the public about E. coli concerns is also a way to increase community engagement and awareness of water quality issues.
Problem:	**Trash and plastic pollution are negatively impacting the lake and its tributaries.**
Potential Causes:	Trash accumulates in streams and lake
Potential Sources:	• Littering – Friends of Lake Monroe sends volunteers to collect litter at Lake Monroe monthly and they always find litter to collect • Illegal dumping – Keep Brown County Beautiful reports that they frequently deal with trash that is illegally dumped, particularly in ravines in the Brown County portion of the watershed
Discussion:	While trash generally does not impact the commonly monitored water quality parameters like nutrient levels, dissolved oxygen, or pH, the presence of trash discourages recreational use. Trash can also negatively impact wildlife, a key attraction at Lake Monroe. One systemic challenge to addressing trash dumping in the watershed is the limited availability of trash disposal options in rural areas. This should be explored in addition to engaging volunteers in trash cleanups and organizing anti-litter educational campaigns.
Problem:	**Boating is a popular activity on Lake Monroe. Recreational value of the lake must be preserved while minimizing recreational pollution through education and enforcement.**
Potential Causes:	Sediment concentrations exceed target levels Trash accumulates in streams and lakes
Potential Sources:	• Boat resuspension of sediment – Anecdotal reports indicate increased water turbidity in Lake Monroe during and immediately after periods of high boat traffic • Lakeshore erosion – Visual observations 2020-2021 indicate widespread erosion; Jones 1997 study documented widespread lakeshore erosion • Littering – Friends of Lake Monroe sends volunteers to collect litter at Lake Monroe monthly and they always find litter to collect

Discussion:	There are limited data available to quantify the impact of boating on water quality in Lake Monroe or its tributaries. One anecdotal report states that sampling conducted by SPEA students during a high traffic weekend showed much higher turbidity levels than sampling during a quiet weekday. However, it is difficult to determine if boating increases rates of lakeshore erosion or merely stirs up sediment that had previously been deposited. Recent studies involving wakeboats suggest that they may be having a measurable impact on water quality but wakeboats have not yet become an issue at Lake Monroe. Ultimately, boats should follow no wake restrictions in shallow water to reduce the possibility of exacerbating shoreline erosion and increasing water turbidity. Boaters have also been identified as a potential source of trash and educational campaigns should specifically include recreational users of Lake Monroe.
Problem:	**Over 82% of the watershed is forested and forestry management activities such as logging, burning or herbicide application may have a negative impact on water quality.**
Potential Causes:	Sediment concentrations exceed target levels
Potential Sources:	• Logging without BMPs – Two active logging sites with sediment issues were observed during the windshield survey; anecdotal reports indicate timber buyers regularly offer owners cash for timber and do not develop forest management plans that would require BMPs
Discussion:	Over 82% of the watershed is forested. While intact forest is excellent at protecting water quality, forest management activities such as timber harvests have the potential to generate sediment that can impact nearby streams. Branches and logs dumped in streams can create log jams that exacerbate streambank erosion. These impacts can be minimized if best management practices are used, ideally with a forest management plan put in place prior to project implementation. Concerns were also raised about potential water quality impacts from burning and herbicide application. However, insufficient data were available to quantify impacts. Following best management practices for these activities is still recommended.
Problem:	**The downstream section of South Fork Salt Creek is listed as impaired for "biological integrity" on the IDEM 303d list, meaning that the stream does not fully support aquatic life use.**
Potential Causes:	Biological assessment scores, including the fish-based Index of Biotic Integrity (IBI) and the macroinvertebrate Index of Biotic Integrity (mIBI), are below the desired target
Potential Sources:	• Disconnect between stream channel and floodplain – Anecdotal information suggests that many streams in the watershed are incised; hydrologic studies indicate that reservoirs cause their tributaries to become incised due to changing water levels (see Section 2.2) • Modified stream channel – Interview with Len Kring (USFS Fisheries Biologist) suggests that portions of Tipton Creek and other tributaries to South Fork Salt Creek were channelized at some point

	• Lack of forested riparian buffer (provides shade and woody debris) – 60% of sites observed for the windshield survey had less than 20 feet of riparian buffer; 20% had less than 5 feet of riparian buffer
Discussion:	Biological impairment is determined by surveying fish and/or macroinvertebrate communities in a stream section. Poor biological integrity can be linked to poor habitat, poor water quality, or both. Increasing riparian buffer and decreasing the load of sediment and nutrients should theoretically improve biological integrity. In lower South Fork, mIBI scores were poor but fish-based IBI scores were fair. This portion of the stream is also known to be heavily influenced by operations in the lake, becoming stagnant when lake levels are high, which may contribute to the poor mIBI scores.
Problem:	**Periodic flooding of streams causes property damage, increased stream bank erosion, and lateral stream movement. Log jams and lack of healthy floodplains may exacerbate the issue.**
Potential Causes:	Damage from flooding observed
Potential Sources:	• Disconnect between stream channel and floodplain – Anecdotal information suggests that many streams in the watershed are incised; hydrologic studies indicate that reservoirs cause their tributaries to become incised due to changing water levels (see Section 2.2) • Modified stream channel – Interview with Len Kring (USFS Fisheries Biologist) suggests that portions of Tipton Creek and other tributaries to South Fork Salt Creek were channelized at some point • Log jams – Brown County SWCD identified multiple log jams in North Fork Salt Creek (see Section 4.11); other log jams in smaller streams were reported by stakeholders • Lack of wetlands – Many areas with hydric soil are currently farmland • Impoundment in the lake disrupting natural hydrology of streams and altering stream cross-sections – hydrologic studies indicate that reservoirs cause their tributaries to become incised due to changing water levels (see Section 2.2) • Lack of unified government strategy about watershed flooding – each county has different regulations about construction in flood zones and floodways
Discussion:	While flooding is in many cases a natural event, it can be exacerbated by log jams, poorly designed culverts, and even Lake Monroe itself (as an artificial reservoir). Rather than seeking to eliminate flooding, the focus should be on preventing property damage and minimizing stream bank erosion. Strategies include limiting construction in flood zones, removing structures that frequently flood, establishing conservation easements around riparian zones, restoring riparian zones by planting native vegetation, addressing log jams that pose a significant threat, and restoring wetlands.

Problem:	**Lack of cohesive regulations and governance across the watershed makes funding and implementation of a watershed plan challenging. There is no uniform drainage ordinance for the watershed. There is no single government body that oversees the watershed.**
Potential Causes:	Lack of unified approach Lack of perceived benefits/impacts Lack of interest Lack of time and commitment
Potential Sources:	• Not applicable for social issues.
Discussion:	Large scale efforts to improve water quality across the watershed will need to be coordinated across multiple counties, primarily Monroe County, Brown County, and Jackson County. Efforts should also include the City of Bloomington and the Town of Nashville as well as the state and federal agencies that manage land within the watershed – the United States Forest Service, the Indiana Department of Natural Resources Forestry Division, and the Indiana Department of Natural Resources State Parks Division.
Problem:	**Education of the public, both adults and children, is needed to increase awareness of water quality protection needs and solutions.**
Potential Causes:	Lack of perceived benefits/impacts Lack of interest
Potential Sources:	• Not applicable for social issues.
Discussion:	Education is key to encouraging community members to take direct action. Community members who feel connected to their local streams and lakes are much more likely to get involved. They also need information about how to improve and protect water quality. This could include activities like maintaining septic systems and using fertilizer appropriately or it could be larger engagement in citizen science projects. Education should be combined with opportunities for community members to spend time exploring lakes and streams so that they become local stewards and protectors.
Problem:	**Invasive plant species displace native plant species, which may disrupt food chains and decrease biodiversity. Invasive plant species may also be less effective at stabilizing stream banks and may alter nutrient cycling in the soil.**
Potential Causes:	Lack of native vegetation Presence of invasive non-native vegetation
Potential Sources:	• Public introducing non-native species in yards – MC IRIS and Brown County Native Woodlands Project have both documented the presence of invasive species throughout Monroe and Brown Counties

	• Seeds and starts transferred within streams – Garlic mustard, Asian bush honeysuckle, and Japanese honeysuckle vine were documented at more than 10% of blitz sampling sites (along streams). • Public transporting seeds when hiking – Educational signage at shoe cleaners have been installed at multiple nature preserves in the area
Discussion:	Invasive plant species were mentioned by multiple stakeholders as a major concern. They are also an area of focus for local conservationists due to their negative impact on local ecosystems. However, there are few studies that show a direct impact on water quality from invasive plants. Some studies suggest that invasive plants may be less effective at soil stabilization. Others clearly identify streams and floods as common ways that invasive plants spread. While addressing invasive plants may not directly improve water quality, it is a powerful way to educate and engage community members in stewardship of natural resources. Educating the public about invasive plants and engaging volunteers in weed wrangles can be an effective part of a larger strategy to engage the public in protection of the watershed while also increasing ecosystem resiliency.
Problem:	**Local regulations are key to minimizing impacts from development in the watershed. Deregulation, including proposed state regulations that would take away local control, poses a threat to the watershed.**
Potential Causes:	State legislature attempting to remove local control Lack of MS4 entity in Brown County
Potential Sources:	• Not applicable for social issues
Discussion:	Local regulations are a tool that can be used to protect water quality if carefully developed and implemented. Further investigation is needed to determine if there are opportunities to expand protection of water quality through regulations in any of the counties, cities, or towns included in the watershed. Two current possibilities include an upcoming update to the Monroe County Development Ordinance and an upcoming update to the Monroe County Stormwater Ordinance.

6 Current Loads and Targets

The four main pollutants of concern were identified as phosphorus, nitrogen, sediment, and E. coli. While E. coli does not appear to be a concern in the lake, samples from multiple streams exceeded the daily threshold of 235 CFU/100 mL. Phosphorus and sediment are concerns in Lake Monroe and in streams throughout the watershed due to their potential for causing harmful algal blooms (HABs). Nitrogen and nitrates are of secondary concern as it is phosphorus concentrations that tend to drive HABs (many blue-green algae are nitrogen fixers). However, load modeling indicates that nitrogen reductions are also needed to achieve water quality targets.

Two modeling approaches were used to calculate loads. The first was a regression analysis of water quality monitoring data in the main tributaries, which was used to model phosphorus, sediment, and E. coli loads. The second was the STEPL model, a spreadsheet tool based on land use in the watershed which was used to model phosphorus, nitrogen, and sediment. Sediment and phosphorus loads were also compared to loads developed as part of the Lake Monroe Diagnostics and Feasibility Study (Jones 1997).

6.1 Regression Model Loads and Needed Reductions

Phosphorus, sediment, nitrogen, and E. Coli loads were calculated using regression models, as discussed in section 4.4.1 with additional information provided in Appendix L. These models were developed using the monthly stream sampling data and continuous flow records from stream gages on North Fork Salt Creek at Nashville and South Fork Salt Creek at Kurtz. Loads in the unmonitored area were based on areal pollutant loads in the North Fork subwatershed as it had the most similar land cover. Target loads were calculated using modeled flow and target concentrations.

Table 6-1 Annual Phosphorus and Sediment Loads Based on Regression Models

	Total Phosphorus				Sediment			
Subwatershed	Current P Load (lbs/yr)	Target P Load (lbs/yr)	Load Reduction Required (lbs/yr)	Percent Reduction Needed	Current Sed. Load (tons/yr)	Target Sed. Load (tons/yr)	Load Reduction Required	Percent Reduction Required
South Fork above Maumee	7,652	4,978	2,674	35%	2,273	3,734	-	0%
Middle Fork above Story	1,048	831	217	21%	489	623	-	0%
North Fork above Yellowwood	13,427	4,586	8,841	66%	13,393	3,440	9,953	74%
Crooked Creek above Tecumseh	35	71	-	0%	5	54	-	0%
Unmonitored Area	22,630	7,730	14,900	66%	22,573	5,797	16,776	74%
Totals	**44,792**	**18,197**	**26,595**	**59%**	**38,733**	**13,648**	**25,085**	**65%**

Table 6-2 Annual Nitrogen and E. coli Loads Based on Regression Models

	Nitrogen				E. Coli			
Subwatershed	Current Nitrogen Load (lbs/yr)	Target N Load (lbs/yr) @ 0.69 mg/L	Load Reduction Required (lbs/yr)	Percent Reduction Needed	E. Coli Load (CFU/yr)	Target E. Coli Load (CFU/yr)	Load Reduction Required (CFU/yr)	Percent Reduction Needed
South Fork above Maumee	181,750	171,758	9,992	5%	9.21E+14	2.65E+14	6.56E+14	71%
Middle Fork above Story	24,013	28,666	-	0%	1.58E+13	3.82E+13	--	0%
North Fork above Yellowwood	142,929	157,781	-	0%	1.90E+14	2.44E+14	--	0%
Crooked Creek above Tecumseh	886	2,459	-	0%	1.27E+11	3.01E+12	--	0%
Unmonitored Area	240,897	266,684	-	0%	3.20E+14	4.11E+14	--	0%
Totals	**590,474**	**627,348**	-	0%	**1.447E+15**	**9.61E+14**	6.56E+14	45%

According to the regression models, the total current annual phosphorus load is 44,792 lbs/year, the annual sediment load is 38,733 tons per year, and the annual nitrogen load is 590,474 pounds per year. The North Fork subwatershed is the primary source of both phosphorus and sediment while the South Fork subwatershed is the primary source of nitrogen and E. coli.

Based on the target loads, significant reductions are required. Total phosphorus loads must be reduced by 59% overall, primarily in the North Fork and Unmonitored Area, to achieve the target phosphorus concentration of 0.02 mg/L. Total sediment loads must be reduced by 65% overall with no reduction needed in the South Fork, Middle Fork, and Lake Monroe Basin subwatersheds, 74% in North Fork and 74% in the Unmonitored Area. Total nitrogen loads overall are below target levels even though South Fork nitrogen loads should be reduced by 5%.

One limitation of the regression model is that it is based on monthly sampling results, which generated a small data set. There were also few samples collected during periods of high flow. Additional samples were collected from South Fork Salt Creek by the CBU Storm Team twice a month at the Kurtz stream gage starting in July 2020. These samples were collected primarily during high flow events. Because the samples were collected at a different location on the stream, the two data sets could not be directly combined. However, a regression model developed using that data suggest that the annual loads in South Fork Salt Creek may be 2-3 times higher than what is presented here.

The regression model results for E. Coli show that only the South Fork subwatershed requires reductions to meet the water quality target of 235 CFU/100 ml. These results seem consistent with data from monthly tributary monitoring, which showed E. coli exceedances in 4 of 12 South Fork samples (including one sample with a concentrations six times the target level) and minor E. coli exceedances in 3 of 12 Middle Fork samples.

6.2 STEPL Model Current Loads and Needed Load Reductions

The STEPL model is a spreadsheet tool developed for USEPA to model nutrient and sediment loads in a watershed based on various land uses and management practices. The model is highly dependent on land cover data which means that the South Fork subwatershed with 8% cropland is expected to have a significantly higher pollutant load than the Lake Monroe Basin subwatershed with 1% cropland.

Table 6-3 Phosphorus and Sediment Loads Based on STEPL Model

	Total Phosphorus				**Sediment**			
Sub-watershed	**Current Phos. Load (lbs/yr)**	**Target Phos. Load (lbs/yr)**	**P Load Reduction Required (lbs/yr)**	**Percent Reduction Needed**	**Current Sed. Load (tons/yr)**	**Target Sed. Load (tons/yr)**	**Sed. Load Reduction Required**	**Percent Reduction Needed**
South Fork	36,732	5,013	31,719	86%	9,463	3,760	5,704	60%
Middle Fork	14,082	3,292	10,790	77%	4,119	2,469	1,650	40%
North Fork	31,336	7,525	23,811	76%	8,282	5,644	2,638	32%
Lake Monroe Basin	11,051	3,273	7,778	70%	2,219	2,455	--	--
Totals	**93,201**	**19,103**	**74,098**	**80%**	**24,083**	**14,327**	**9,992**	**41%**

Table 6-4 Nitrogen Loads Based on STEPL Model

	Total Nitrogen			
Subwatershed	**Current Nitrogen Load (lbs/yr)**	**Target Nitrogen Load (lbs/yr)**	**Load Reduction Required (lbs/yr)**	**Percent Reduction Needed**
South Fork	170,437	90,233	80,204	47%
Middle Fork	56,683	59,253	--	--
North Fork	130,175	135,452	--	--
Lake Monroe Basin	47,302	58,915	--	--
Totals	**404,597**	**343,853**	**80,204**	**20%**

As anticipated, the South Fork Salt Creek subwatershed has the largest STEPL-modeled sediment, phosphorus, and nitrogen loads both by annual weight (lbs/year – see Tables 6-1 and 6-2) and by areal load (lbs/acre-year – see Tables 6-3 and 6-4). This indicates that the South Fork subwatershed is the most impaired and therefore has the most opportunity for improvement. The North Fork Salt Creek subwatershed has the second largest pollutant load by annual weight and is only about 15% smaller than the South Fork Salt Creek subwatershed while the Middle Fork Salt Creek subwatershed has a pollutant load about 55% smaller than the South Fork Salt-Creek subwatershed. However, North Fork's areal load is comparable to Middle Fork.

Table 6-5 Areal Phosphorus and Sediment Loads Based on STEPL Model

Subwatershed	**Areal Phosphorus Loads**			**Areal Sediment Loads**		
Subwatershed	**Current P Load (lbs/yr)**	**Size (acres)**	**Areal P Load (lbs/ acre-yr)**	**Current Sed. Load (tons/yr)**	**Size (acres)**	**Areal Sed. Load (lbs/ acre-yr)**
South Fork	36,732	65,599	0.56	9,463	65,599	0.14
Middle Fork	14,082	46,779	0.30	4,119	46,779	0.09
North Fork	31,336	106,937	0.29	8,282	106,937	0.08
Lake Monroe Basin	11,051	46,512	0.24	2,219	46,512	0.05

Table 6-6 Areal Nitrogen Loads Based on STEPL Model

Subwatershed	**Areal Nitrogen Loads**		
Subwatershed	**Current Nitrogen Load (lbs/yr)**	**Subwatershed Size (acres)**	**Areal Nitrogen Load (lbs/acre-yr)**
South Fork	170,437	65,599	2.60
Middle Fork	56,683	46,779	1.21
North Fork	130,175	106,937	1.22
Lake Monroe Basin	47,302	46,512	1.02

Target loads were calculated by multiplying water quality target concentrations by annual flow volume as determined using a ratio of drainage areas compared to stream gage data. Continuous flow measurements were available from USGS Stream Gage 03371650 on North Fork Salt Creek in Nashville and USGS Stream Gage 03371600 on South Fork Salt Creek in Kurtz. A proportional flow was calculated using the ratio between the catchment area of the gage and the subwatershed. For example, the catchment area above the North Fork Stream Gage in Nashville is 48,500 acres while the entire North Fork subwatershed is 65,600 acres so the annual flow for the entire North Fork subwatershed was estimated to be the annual flow volume measured at the Nashville stream gage x 65,600/48,500 or roughly 2.7 times the annual gaged flow. The Middle Fork and Lake Monroe Basin subwatershed flow estimates were also based on the Nashville stream gage while the South Fork subwatershed flow estimate was based on the Kurtz stream gage.

Based on these target loads, significant reductions are required. Total phosphorus loads must be reduced by 80% overall with subwatershed reductions ranging from 70% in the Lake Monroe Basin to 86% in the South Fork subwatershed to achieve the target phosphorus concentration of 0.02 mg/L. Total nitrogen loads must be reduced by 20% overall with no reduction needed in the North Fork, Middle Fork, or Lake Monroe Basin subwatersheds but 47% reduction needed in South Fork. Total sediment loads must be reduced by 41% with no reduction needed in the Lake Monroe Basin subwatershed, 32% in North Fork, 40% in Middle Fork, and 60% in South Fork.

6.3 Jones 1997 Model Loads and Needed Reductions

The 1997 Jones study was used as a point of comparison for reviewing load models and needed reductions. The study developed a sediment budget and phosphorus budget for Lake Monroe based on data collected in 1992 and 1993. Total estimated annual incoming sediment load is 29,779,000 kg/yr (32,825 tons/yr). About 5% (~1,500,000) passes through the outlet of the lake and the rest is retained. This can also be expressed as a sediment accumulation rate of 0.03 inches per year. However, it is known that sediment does not distribute evenly across the lake. Studies done by Bradbury in 1976 show that sedimentation during the 11 years since the reservoir was completed was about 1 inch thick in the middle and lower basins but 2-4 inches thick in the upper basin. Based on the stream modeling, Middle Fork Salt Creek has the highest contribution rate per acre followed by the unmonitored area and Brummett Creek. It is unclear why this is the case.

Total estimated phosphorus loading was 46,544 kg/yr (102,612 lbs/yr). The greatest contribution (kg/yr) was from the unmonitored areas followed by the North Fork Salt Creek. However, the greatest areal rate of loading (kg/ha-yr) was from the South Fork Salt Creek, which was somewhat expected since it has the most agricultural land use. The South Fork also had the highest measured mean total phosphorus concentration for the five stream sites at 0.0728 mg/L. In the report it was noted that South Fork discharge rates were likely underestimated.

The Jones study also ran the Reckhow (1980) phosphorus export model using land use and slope to predict phosphorus loads and came up with a load of 46,257 kg/year which is very close to the modeled phosphorus budget. Based on the Reckhow model, South Fork drainage area contributes a greater share of the total phosphorus loading – 32.8% in the Reckhow model compared to 16.8% in the Jones phosphorus budget. Overall, the Reckhow model calculates that agricultural land contributes 48.5% of the total P loading and forests contribute 47.2% due to the substantial amount of acreage in forested land use.

Jones calculated how much phosphorus reduction is needed to avoid eutrophic conditions. The current loading rate was determined to be 1.07 grams/square meter-year. Using the Richard Vollenweider (1975) model to relate areal phosphorus loading with mean lake depth and hydraulic flushing rate, the target in-lake summertime phosphorus concentration to avoid eutrophic conditions is 0.3 grams/square meter-year. This translates to a 72% reduction in phosphorus loading over current rates to achieve the target in-lake phosphorus concentration of 0.020 mg/L. If the target in-lake phosphorus concentration is 0.030 mg/L, then a 63% reduction is needed.

6.4 Current Loads and Needed Reductions

The three methods used for nutrient and sediment reductions (STEPL, new regression model, and Jones historic regression model) all generated differing results. The largest difference was for phosphorus, with the STEPL model and the Jones Study both indicating an annual load around 95,000 lbs/year while the regression model indicated an annual load of 44,752 lbs/year, less than half as much. The low estimates of the regression model are most likely due to the relatively low peak discharges of our study year and sampling dates.

Table 6-7 Comparison of Load Models for Lake Monroe Watershed

	Current Phosphorus Load (lbs/yr)	Current Sediment Load (tons/yr)	Current Nitrogen Load (lbs/yr)	Current E. coli Load (CFU/yr)
Regression Model 2021	44,792	38,733	590,474	1.447E+15
STEPL Model	93,201	24,083	404,597	Not Calculated
Jones Regression Model 1997	102,612	32,825	Not Calculated	Not Calculated

The STEPL Model was used to establish current loads and needed reductions for phosphorus, sediment, and nitrogen because it correlated reasonably well with the Jones study and is easy to replicate.

The regression model was used to establish current loads and needed reduction for E. coli.

Table 6-8 Needed Load Reductions for Nutrients, Sediment, and Bacteria

	Phosphorus Load (lbs/yr)	Sediment Load (tons/yr)	Nitrogen Load (lbs/yr)	E. coli Load (CFU/yr)
Current Load	93,201	24,083	404,597	1.447E+15
Target Load	19,103	14,327	343,853	9.61E+14
Needed Reduction	**74,098**	**9,992**	**80,204**	**6.56E+14**

One limitation of these models is that they do not address pollutant accumulation within Lake Monroe. As discussed in section 4, sediment and nutrients accumulate in the lake over time. Bound phosphorus can be released from the sediment under anoxic conditions, increasing phosphorus concentrations in the lake regardless of the amount of incoming phosphorus from the streams. Improving and restoring the lake's natural health will require more than just reducing inflows of nitrates, phosphorus, sediment, and E. coli. Legacy pollutants in the lake must be addressed to avoid increasing eutrophication and an increased frequency in algal blooms.

7 Goal Statements and Indicators for each Pollutant and Problem

A total of twelve problem statements were identified. Goal statements and indicators were identified for each.

7.1 Sediment Accumulation

Problem Statement: Sediment accumulation in the lake decreases its lifespan, reduces recreational capability, and increases turbidity of the water. Sediment carries nutrients and total organic carbon, which can contribute to algal blooms.

Vision Statement: Clear water and minimal sediment accumulation. While some sediment accumulation in a reservoir is inevitable, it is important to limit the rate of sedimentation.

Goal Statement: Reduce sediment loads to meet the IDEM statewide draft TMDL target of 30 mg/L for TSS within 20 years. The estimated reduction needed is 9,992 tons/year.

Indicators of Progress:

- Steady or downward trend in documented TSS values.
- Number of BMPs implemented.
- Number of farmers implementing conservation tillage and acreage involved.
- Number of farmers using cover crops and acreage involved.
- Number of farmers and land managers attending field days and workshops.
- Linear feet of stabilized streambank.
- Linear feet of stabilized lakeshore.
- Calculated load reductions from all BMPs and conservation practices.

7.2 Nutrient Accumulation

Problem Statement: Elevated nutrient loads lead to excessive growth of aquatic plants and algae. Harmful algal blooms (HAB) can limit recreational use, harm pets and, in extreme cases, cause lakes to become unswimmable. Each year HAB recreational advisories are issued for Lake Monroe. IDEM lists Lake Monroe as impaired for algae as well as taste and odor, which is often linked to algal blooms.

Vision Statement: A fishable and swimmable lake, raw lake water that is cost-effective to process into drinking water, and elimination of HAB.

Goal Statement: Reduce phosphorus loads by 74,098 lbs/year and nitrogen loads by 80,204 lbs/year within 20 years.

Indicators of Progress:

- Decrease in phosphorus concentrations over time.

- Decrease in nitrogen concentrations over time.
- Number of farmers implementing conservation tillage and acreage involved
- Number of farmers using cover crops and acreage involved
- Number of nutrient management plans completed
- Number of livestock stream access sites eliminated
- Number of BMPs implemented.
- Calculated load reductions from all BMPs and conservation practices.
- Decreased frequency of harmful blue-green algal blooms

7.3 Elevated E. Coli Levels

Problem Statement: Elevated levels of E. coli in some waterways within the watershed indicate the likely presence of fecal matter that may be associated with pathogens making it unsafe to swim and recreate. Two streams are listed as impaired for E. coli on the IDEM 303d list of impaired water bodies. The source of E. coli is unclear, but could be due to livestock, failing septic systems, boat discharge, or wildlife.

Vision Statement: Swimmable streams throughout the watershed. Reduction of E. coli and associated pathogens to safe levels.

Goal Statement: Reduce E.coli concentrations to meet the state standard of 235 CFU/100mL. This would entail an E. coli load reduction of 6.56E+14 CFU/year within 20 years.

Indicators of Progress:

- Sampling will show a continuing decline in E. coli counts
- Calculated load reductions for Best Management Practices installed
- Number of livestock restricted from stream access
- Improvement of agricultural waste management practices: number of practices implemented
- Improvements in septic system maintenance and care as a result of disseminated information and attendance at workshops

7.4 Boating

Problem Statement: Boating is a popular activity on Lake Monroe. Recreational value of the lake must be preserved while minimizing recreational pollution through education and enforcement.

Vision Statement: Sustainable recreational use of the lake and its tributaries while ensuring that water quality is preserved or improved. Negative impacts from recreation must be clearly identified and controlled.

Goal Statement: Develop and implement a responsible boating education and outreach program within the watershed that includes recommendations for policy changes (if identified) and increased enforcement within 10 years.

Indicators of Progress

- Number of boaters taking the Indiana Clean Boaters pledge
- Completion of responsible boating program
- Stakeholder participation in workshops, field days, and lake cleanups
- Improved water clarity

7.5 Forestry Management

Problem Statement: Over 82% of the watershed is forested and forestry management activities such as logging, burning or herbicide application may have a negative impact on water quality.

Vision Statement: Maintain forested land within the watershed as forested land. Minimize impacts to water quality from forest management.

Goal Statement: Develop and implement a responsible forest management education and outreach program within the watershed that includes recommendations for policy changes (if identified) within 10 years. Encourage and financially support the use of forestry best management practices as part of efforts to reduce sediment and nutrient loads to the lake within 20 years.

Indicators of Progress

- Number of forestry management plans in the watershed
- Number of forestry BMPs implemented in the watershed
- Stakeholder participation in forestry workshops and field days
- Number of workshops and field days held
- Number of educational materials developed and distributed

7.6 Biological Integrity

Problem Statement: The downstream section of South Fork Salt Creek is listed as impaired for “biological integrity” on the IDEM 303d list, meaning that the stream does not fully support aquatic life use.

Vision Statement: High biological integrity in all watershed streams.

Goal Statement: Improve stream quality so IBI (fish) and mIBI (macroinvertebrates) meet “fair” criteria (>42) in all stream reaches within 20 years.

Indicators of Progress

- Improved CQHEI scores (an indirect indicator of biological integrity)
- Improved fish survey scores (IBI)
- Improved macroinvertebrate survey scores (mIBI)
- Reduced nutrient and sediment concentrations meeting the goals set forth above

- Increase in linear feet of riparian buffer

7.7 Flooding

Problem Statement: Periodic flooding of streams causes property damage, increased stream bank erosion, and lateral stream movement. Log jams and lack of healthy floodplains may exacerbate the issue.

Vision Statement: Healthy streams that can carry floodwaters without excessive stream bank erosion in order to minimize property damage and sediment load to the lake.

Goal Statement: Identify and remove key log jams to reduce flooding and lateral stream movement in key areas within 20 years. Restore floodplains, riparian buffer, and wetlands where practical within 20 years.

Indicators of Progress

- Number of log jams removed
- Increase in linear feet of restored stream bank
- Increase in linear feet of stream buffer
- Acres of floodplain restored
- Acres of wetland restored/constructed
- Decrease in number of flooding events

7.8 Lack of Cohesive Regulations

Problem Statement: Lack of cohesive regulations and governance across the watershed makes funding and implementation of a watershed plan challenging. There is no uniform drainage ordinance for the watershed. There is no single government body that oversees the watershed.

Vision Statement: A comprehensive plan to address watershed concerns with committed participation from local communities and all government bodies across the watershed. A structure for funding and overseeing projects to improve and protect water quality.

Goal Statement: Obtain support of this watershed management plan from all affected government bodies within 5 years. Support the development of a water fund or other structure to financially support watershed improvements within 5 years.

Indicators of Progress

- Government participation in watershed management plan implementation at all levels (Brown County, Monroe County, Jackson County, Indiana, Town of Nashville)
- Permanent watershed coordinator position
- Organizational capacity of Friends of Lake Monroe to spearhead watershed management plan implementation into the future

- Organizational capacity of Lake Monroe Water Fund to financially support watershed improvement
- Increase in funds available for watershed improvement

7.9 Lack of Public Understanding

Problem Statement: Education of the public, both adults and children, is needed to increase awareness of water quality protection needs and solutions.

Vision Statement: Members of public who understand how watersheds work and embrace strategies to preserve and enhance the watershed.

Goal Statement: Develop and implement an education and outreach program within the Watershed within 5 years.

Indicators of Progress

- Number of educational materials developed and circulated
- Number of workshops, field days, recreational outings, and trash cleanups held
- Stakeholder participation in workshops and other events
- Exit surveys showing behavior change due to educational events

7.10 Trash and Plastic Pollution

Problem Statement: Trash and plastic pollution are negatively impacting the lake and its tributaries.

Vision Statement: No trash in the lake and its tributaries.

Goal Statement: Develop and implement a trash removal and education program within the Watershed within 10 years.

Indicators of Progress

- Number of educational materials developed about proper waste management
- Number of trash cleanup events held
- Number of stakeholders participating in cleanup events

7.11 Invasive Plant Species

Problem Statement: Invasive plant species displace native plant species, which may disrupt food chains and decrease biodiversity. Invasive plant species may also be less effective at stabilizing stream banks and may alter nutrient cycling in the soil.

Vision Statement: Remove invasive species and restore native species throughout the watershed.

Goal Statement: Develop and implement an invasive species removal and education program within the watershed within 10 years.

Indicators of Progress

- Number of invasive species removal events
- Monitoring data show a decrease in invasive species density

7.12 Local Regulations

Problem Statement: Local regulations are key to minimizing impacts from development in the watershed. Deregulation, including proposed state regulations that would take away local control, poses a threat to the watershed.

Vision Statement: Expanded local ordinances that ensure appropriate development within the watershed.

Goal Statement: Develop and implement local ordinances to protect the watershed within 20 years. Organize opposition to state regulations that would limit local control within 10 years.

Indicators of Progress

- Government participation in watershed management plan implementation
- Number of local ordinances created or modified to protect water quality

8 Critical Area Selection

Critical areas for watershed management planning purposes are places where implementing the management plan can reduce nonpoint source pollution and improve water quality (or protect future water quality). Critical areas also serve to narrow the focus to areas where implementation of BMPs or other projects will have the greatest impact on water quality. There are multiple ways to identify critical areas. One method is to rank the subwatersheds based on different parameters (number of impaired streams, number of exceedances for a particular parameter, percentage of sites lacking riparian buffer). The resulting prioritization specifies which geographic areas have the most need for improvement. A second method is to utilize source identification, where the data are reviewed to identify the most significant pollutant sources.

When defining critical areas based on subwatersheds, one concern is establishing an area that is too small for successful implementation of the management plan, particularly the adoption of best management practices. Since implementation is voluntary, program success rests upon attracting enough interested landowners. The smaller the designated critical area, the smaller the number of potential landowners. This is an especially important consideration when the intent is to implement agricultural BMPs and the amount of agricultural land is limited, which it is in the Lake Monroe watershed (8%). Marketing is also a consideration, as it can be difficult to explain subwatershed boundaries to landowners.

With those concerns in mind, the steering committee chose to define critical areas based on sources rather than subwatersheds. Focusing on sources also seems appropriate given that subwatershed analysis (see section 5) shows the presence of potential sources of pollution throughout the watershed.

8.1 Critical Area Definition

Critical areas were defined based on potential sources rather than geographical locations. As discussed in Section 5, there are multiple sources associated with each pollutant. The location and extent of some sources are better documented than others.

Table 8-1 Potential Sources of Pollution as Critical Areas

Pollutant	Source	Location	Documentation
Sediment Nutrients	Streambank Erosion	Throughout (most prominent in Middle Fork, North Fork)	Windshield Survey
Sediment Nutrients	Lakeshore Erosion	Lake Monroe (Paynetown, Branigan Peninsula, Deam Wilderness, other)	Informal Observations
Sediment Nutrients	Lack of Riparian Buffer	Throughout (most prominent in North Fork, Middle Fork)	Windshield Survey
Sediment Nutrients	Conventionally Tilled Cropland	Throughout (largest amount of cropland in South Fork)	Land Cover Map, Tillage Transect
Sediment Nutrients	Forestry Sites and Timber Harvests Without Adequate BMPs	Documented in North Fork; Potential Throughout	Documented During Windshield Survey
Sediment Nutrients	Site Construction Without Adequate BMPs	Documented in North Fork; Potential Throughout	Documented During Windshield Survey
Sediment Nutrients	Poorly Installed Roadside Ditches	Documented in North Fork; Potential Throughout	Documented During Windshield Survey
Nutrients	Fertilizer on Cropland	Throughout (largest amount of cropland in South Fork)	Land Cover Map
Nutrients	Fertilizer on Commercial/ Residential Land	Throughout (largest amount of developed land in North Fork and South Fork)	Land Cover Map
Nutrients E. Coli	Manure on Pasture	Throughout (largest amount of pasture in South Fork; largest percentage of stream sites with livestock access in South Fork)	Land Cover Map, Windshield Survey
Sediment	Livestock In Streams	Throughout (largest percentage in South Fork)	Windshield Survey
Nutrients E. Coli	Failed Septic Systems	Throughout (largest number of septic systems in North Fork, Lake Monroe Basin	GIS Building Layer, Brown and Monroe County Health Department Data

The primary potential sources of pollution appear to be agricultural land with resource concerns; eroding stream banks and lakeshores; lack of riparian buffer; and failing septic systems. Secondary sources include timber harvests with erosion concerns, site construction with insufficient erosion control, severely dredged roadside ditches, and fertilizer usage on commercial and residential land.

Most strategies for reducing sediment and nutrient loads focus on land management (cover crops, erosion control practices, reduced fertilizer usage, streambank stabilization) to limit the amount of sediment and nutrients that reach the streams. However, another strategy to consider is to reduce the frequency and intensity of high stream flows. High flow events are responsible for most of the sediment load which in turn delivers bound phosphorus and nitrogen into Lake Monroe. Peak flows can be reduced by restoring stream meanders, restoring wetlands, adding retention basins, and encouraging infiltration of storm water before it reaches streams.

Similarly, it is worth considering how water movement within Lake Monroe contributes to sediment and nutrient levels within the lake. High water levels and wave action result in soil saturation and slumping along vulnerable shoreline areas, which delivers sediment, bound phosphorus, and bound nitrogen into the lake. Wave action can be caused by wind or by motorboats generating wake near the shoreline. Water levels are controlled by USACE operation of the dam. While their primary goal is reducing flood events downstream, there may be opportunities to adjust operations with the goal of minimizing the duration of high water levels.

Table 8-2 Critical Areas in the Lake Monroe Watershed

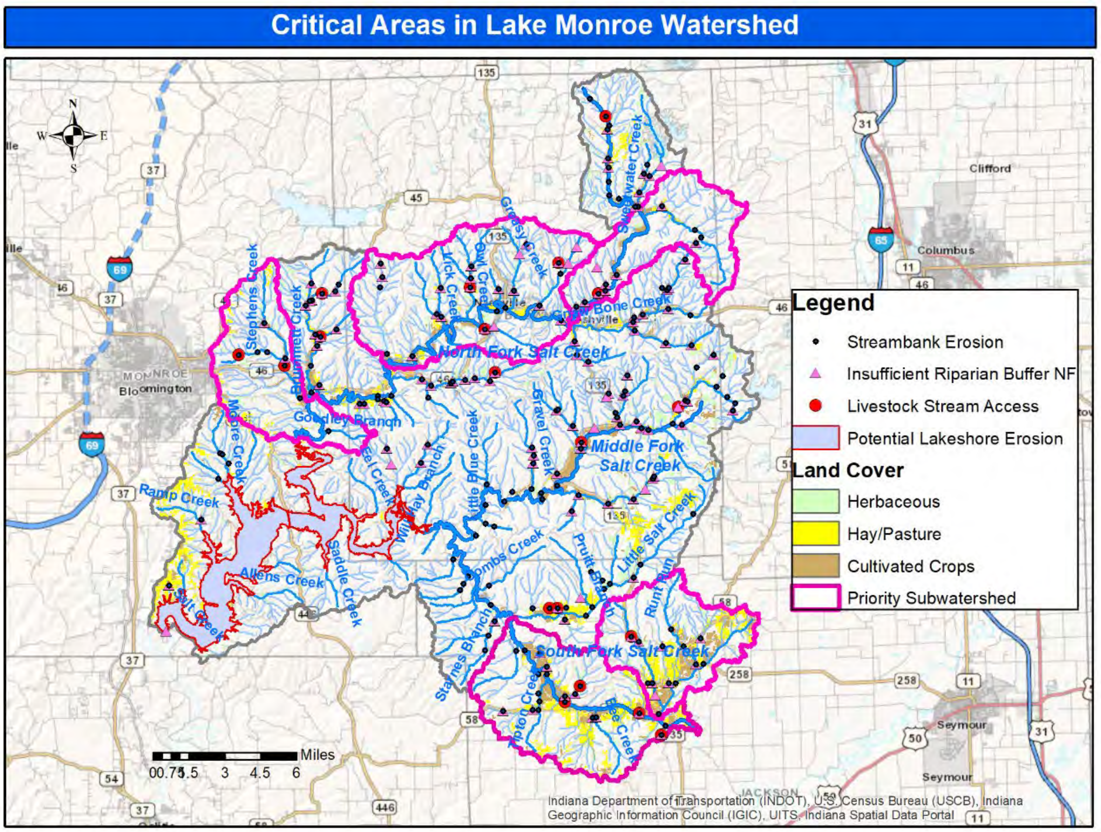
Critical Areas (Source-Based)
Areas with active agriculture and resource concerns
Forestry sites with active erosion
Eroding stream banks
Stream sections with insufficient riparian buffer (less than 20 feet)
Eroding lakeshore
Areas with failing septic systems

For the purposes of implementing land management practices, critical areas in the Lake Monroe watershed are defined as areas with active agriculture and resource concerns, forestry sites with active erosion, eroding stream banks, stream sections with insufficient riparian buffer (less than 20 feet), sections of eroding lakeshore, or areas with failing septic systems.

Contributions to water quality concerns from these lands will be evaluated through site reviews to determine whether they are considered as a significant contributor. Any land that has visibly notable problems, including but not limited to, highly erodible land, livestock with access to streams, conventional row cropping practices, poor pasture management, unprotected manure piles, and lack of riparian buffers will be considered a significant contributor.

Figure 8-1 shows the approximate locations of critical areas in the watershed. This figure should be used as a starting point rather than an exhaustive map of potential projects. Further investigation is needed to identify specific locations. Some specific sites are mapped based on observations of streambank erosion, insufficient riparian buffer, and livestock access to streams but there many stream sections in the watershed that were not inspected as part of the windshield survey. Agricultural land is shown as a starting point for identifying areas with active agriculture and resource concerns. The Lake Monroe shoreline is shown as a starting point for identifying sections of lakeshore erosion. No sites are mapped corresponding with active forestry sites or failing septic systems due to insufficient data availability.

Figure 8-1 Approximate Locations of Critical Areas in Lake Monroe Watershed



While critical areas were defined based on pollutant sources, the subwatershed analysis revealed that certain subwatersheds are at higher risk than others based on current water quality data and observed stream conditions. These five subwatersheds are shown on Figure 8-1 as priority subwatersheds. During the implementation phase, these areas should be given priority when there may be more interested landowners than available funds. A ranking system will be developed prior to implementing any cost-share programs that assigns a weighted score to each potential project based on its subwatershed.

9 Best Management Practices

There are many different best management practices (BMPs) available for on-the-ground implementation to address water quality concerns. A master list of BMPs was reviewed by the project steering committee and project partners. The following list of practices were deemed most likely to successfully meet load reduction targets, be feasible to implement, and address stakeholder concerns. No practice list is exhaustive and additional techniques may be both possible and necessary to reach water quality goals. Descriptions of each practice are available in Appendix K.

Table 9-1 Priority Best Management Practices

Critical Area/Source	Pollutant(s)	Suggested BMP
Agricultural Resource Concerns – Livestock Access to Streams	bacteria, sediment, nutrients	Livestock exclusion fencing
		Livestock watering systems
Agricultural Resource Concerns – Erosion of Pasture	sediment, nutrients	Heavy use area protection
		Critical area seeding
		Forage and biomass planting
Agricultural Resource Concerns – Conventional Tillage or Erosion of Cropland	sediment, nutrients	No till or reduced till agriculture
		Cover crops
		Field border or filter strip
		Riparian forested or herbaceous buffer
		Land retirement
		Tree or shrub establishment
Forestry sites with active erosion	sediment, nutrients	Forest management plan
		Training of foresters and loggers
		Critical area seeding
		Forest trails and landing improvement
Streambank Erosion	sediment, nutrients	Riparian forested or herbaceous buffer
		Streambank stabilization
		Logjam removal
		Wetland creation or restoration
		Improved stream crossing
		Land Retirement
Streams Lacking Riparian Buffer	sediment, nutrients	Riparian forested or herbaceous buffer
Failing Septic Systems	bacteria, nutrients	Septic system maintenance
		Septic system repair
		Septic system alternatives
		Education of homeowners

Critical Area/Source	Pollutant(s)	Suggested BMP
Lakeshore Erosion	sediment, nutrients	Lakeshore stabilization
		Boating restrictions
		Education of boaters
		Modifying dam operations

9.1 Proposed BMPs and Pollutant Reduction Values

The following table summarizes a potential combination of BMPs that could be put in place during our first round of implementation (3 years) along with their pollutant reduction value and financial cost to implement.

Table 9-2 BMP Load Reductions for Initial Implementation Phase (3 years)

Practice	Acres/ Ft Applied	Total E. coli Reduction CFU/yr	Reduction Sediment t/ac/yr	Total Sed. Reduction tons/yr	Reduction P lb/ac/yr	Total P Reduction lb/yr	Reduction N lb/ac/yr	Total N Reduction lb/yr	Cost per acre or lf	Total Cost
Cover Crops (x2 years)	600	-	6.9	4,140	7.2	4,320	14.5	8,700	$40	$48,000
No Till 60% or More	250	-	26	6,500	21	5,250	43	10,750	$15	$3,750
Field Border (15 ft)	50	-	9.1	455	10.7	535	21.3	1,065	$400	$20,000
Riparian Herbaceous Buffer - 35 feet	-	-	9.1	-	10.7	-	21.3	-	$350	-
Riparian Forested Buffer - 35 feet	-	-	7.6	-	9.2	-	17.9	-	$400	-
Land Retirement and Tree Establishment	10	1.03E+12	4.6	46	4.6	46	9.2	92	$450	$4,500
Exclusion Fencing	1,000	4.75E+12	0.057	57	0.0655	66	0.131	131	$3	$3,000
Forage and Biomass Planting	50	-	8.9	445	10.2	510	20.5	1,025	$200	$10,000
Critical Area Planting	-	-	8.9	-	10.2	-	20.5	-	$200	-
Heavy Use Area Protection	2	-	88	176	58	116	114	228	$15,000	$30,000
Streambank Stabilization	-	-	0.114	-	0.131	-	0.262	-	$1,000	-
Lakeshore Stabilization	-	-	0.107	-	0.123	-	0.246	-	$1,000	-
TOTAL		**5.77E+12**		**11,819**		**10,843**		**21,991**		**$119,250**
GOAL		**6.56E+14**		**9,992**		**74,098**		**80,204**		
REMAINING		**6.50E+14**		**(1,827)**		**63,255**		**58,213**		

While it should be possible to reduce sediment to target levels within the first round of implementation, additional work will be needed to achieve the phosphorus target. This table presents a series of BMPs to achieve the phosphorus target within 20 years. BMP installation was divided over 20 years to establish annual targets. Interim load reduction targets at 5-year intervals are presented in section 10.3.

Table 9-3 BMP Load Reductions for Over 20-Year Implementation Project

Practice	**Acres/ Ft Applied**	**Total E. coli Reduction CFU/yr**	**Reduction Sediment t/ac/yr**	**Total Sed. Reduction tons/yr**	**Reduction P lb/ac/yr**	**Total P Reduction lb/yr**	**Reduction N lb/ac/yr**	**Total N Reduction lb/yr**	**Cost per acre or lf**	**Total Cost**
Cover Crops (x2 years)	4000	-	6.9	27,600	7.2	28,800	14.5	58,000	$40.00	$320,000
No Till 60% or More	2000	-	26	52,000	21	42,000	43	86,000	$15.00	$30,000
Field Border (15 ft)	400	-	9.1	3,640	10.7	4,280	21.3	8,520	$400.00	$160,000
Riparian Herbaceous Buffer - 35 feet	50	3.96E+12	9.1	455	10.7	535	21.3	1,065	$350.00	$17,500
Riparian Forested Buffer - 35 feet	100	4.57E+12	7.6	760	9.2	920	17.9	1,790	$400.00	$40,000
Land Retirement and Tree Establishment	60	5.15E+12	4.6	276	4.6	276	9.2	552	$450.00	$27,000
Exclusion Fencing	2500	1.19E+14	0.057	143	0.0655	164	0.131	328	$3.00	$7,500
Forage and Biomass Planting	250	-	8.9	2,225	10.2	2,550	20.5	5,125	$200.00	$50,000
Critical Area Planting	350	-	8.9	3,115	10.2	3,570	20.5	7,175	$200.00	$70,000
Heavy Use Area Protection	10	-	88	880	58	580	114	1,140	$15,000.00	$150,000
Streambank Stabilization	200	-	0.114	23	0.131	26	0.262	52	$1,000.00	$200,000
Lakeshore Stabilization	200	-	0.107	21	0.123	25	0.246	49	$1,000.00	$200,000
TOTAL		**1.32E+14**		**90,693**		**83,216**		**168,771**		**$1,272,000**
GOAL		**6.56E+14**		**9,992**		**74,098**		**80,204**		
REMAINING		**5.24E+14**		**(80,701)**		**(9,118)**		**(88,567)**		

10 Action Plan

The following action plan outlines strategies for achieving each of our goals for improving Lake Monroe and its tributaries. Each identified objective (strategy) is associated with series of milestones (measurable achievements) to measure progress. Each milestone has an associated timeframe, target audience, possible partners, and estimated cost. This is the roadmap for meeting the target water quality goals as well as the less tangible watershed improvement goals.

10.1 Action Plan Milestones

Pollutant reduction from each quantifiable milestone is summarized in the previous section. Many milestones do not have easily quantifiable pollutant reduction benefits but are key to overall improvements in water quality. Based on the Region 5 model for pollutant load reduction, it is likely that the sediment goal will be achieved much sooner than the phosphorus and nitrogen goals. To achieve the phosphorus and nitrogen reduction goals, the model may demonstrate a reduction in sediment over the twenty-year period larger than the current estimated sediment load. While this is clearly incorrect, the action plan was developed using the phosphorus goal and Region 5 model calculations as a conservative method for achieving water quality improvements.

Table 10-1 Action Plan for Lake Monroe Watershed

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
Sediment Nutrients Bacteria	Implement a conservation education and cost-share program to encourage	Agricultural Producers, Landowners, Operators	By the end of the first quarter, develop cost-share program and application process	2023	$2,000	Steering committee (P), SWCDs (P/T), NRCS (P/T), ISDA (T),
			By the end of the first quarter, develop promotional strategy for cost-share program	2023	$2,000	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
	adoption of agricultural best management practices		By the end of the second quarter, create 2 brochures or fact sheets (one for agricultural producers and one for other landowners) and a page on the Friends of Lake Monroe website.	2023	$1,000 staff + $2,000 graphics = $3,000	Purdue Extension (P)
			Send targeted mailing promoting cost-share program	2023	Estimated 500 @ $2 = $1,000	
			Launch targeted social media campaign	2023	$1,000	
			By end of first year, identify alternate funding sources for BMPs to increase participation	2023	$2,000	
			Every year administer cost-share program including personal visits with prospective agricultural landowners and operators and tracking BMP installations	Annually	$20,000/yr	
Sediment Nutrient	Increase adoption of agricultural best management practices on cropland to	Crop Producers, Landowners, Operators	Increase cover crop acreage by 200 acres annually (1.75% of watershed cropland). 200 acres x $40/acre x 2 years	Annually	$16,000/year	NRCS (P/T), Purdue Extension (P), ISDA (T), IDNR (P), IDEM (P), Soil and Water
			Increase no-till acreage by 100 acres annually (0.88% of cropland). 100 acres x $15/acre	Annually	$1,500/year	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
	reduce nutrient and sediment runoff		Install 20 acres of filter strips or field borders annually (0.2% of cropland). 20 acres x $400/acre	Annually	$8,000/year	Conservation Districts (P/T)
			Install 2.5 acres of herbaceous riparian buffer (to treat 16 acres farmland) annually. 2.5 acres x $350/acre	Annually	$875/year	
			Install 5 acres of forested riparian buffer (to treat 31 acres of farmland) annually. 5 acres x $400/acre	Annually	$2,000/year	
Sediment Nutrient Bacteria	Increase adoption of agricultural best management practices on pasture to reduce nutrient, sediment, and bacteria runoff	Livestock Producers, Landowners, Operators	Install 12.5 acres of forage and biomass planting on pasture annually. 12.5 acres x $200/acre	Annually	$2,500/year	NRCS (P/T), Purdue Extension (P), ISDA (T), IDNR (P), IDEM (P), Soil and Water Conservation Districts (P/T)
			Install 17.5 acres of critical area planting on pasture annually. 17.5 acres x $200/acre	Annually	$3,500/year	
			Install 0.5 acres of heavy use area protection annually. 0.5 acre x $15,000/acre	Annually	$7,500/year	
			Install fencing to exclude livestock from 125 linear feet of stream and install alternate watering systems as needed. 125 feet x $3/foot	Annually	$375/year for fencing $1,000-$8,000 per watering system	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
Nutrient Bacteria	Reduce nutrient and bacteria contributions from malfunctioning septic systems	General Public (Owners of Septic Systems)	Host or actively participate in at least 1 regional workshop annually to promote septic system maintenance for water quality protection in partnership with local health departments and regional sewer districts	Annually	$2,000/year	SWCDs (P/T), Health Departments (P), Regional Sewer Districts (P), Monroe County Stormwater (P), Purdue Extension (P), Community Foundations (P)
			Develop an educational mailer for watershed residents about proper septic system care and maintenance	2023	$3,000	
			Identify funding source for septic system maintenance cost-share program	2023	$2,000	
			Identify funding source for septic system repair cost-share program	2024	$2,000	
			Work with local health departments and regional sewer districts to identify and replace straight pipe systems	2024	$4,000	
			Work with local health departments and regional sewer districts to explore alternatives to septic systems	2027	$4,000	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
			Work with local health departments and regional sewer districts to explore potential expansion of existing sewer systems	2028	$4,000	
Sediment Nutrient Bacteria Flooding Habitat	Protect and restore riparian floodplains in agricultural areas	Agricultural Owners and Operators	Convert 3 acres of floodplain farmland to forest annually. 3 acres x $1,350/acre	Annually	$1,350/year	NRCS (P/T), Purdue Extension (P), ISDA (T), IDNR (P), IDEM (P), Soil and Water Conservation Districts (P/T), Lake Monroe Water Fund (P)
			Identify and quantify farmland in the 100-year floodplain of North, Middle, and South Fork Salt Creek	2025	$4,000	
			Develop a strategy to encourage taking floodplain land out of production.	2028	$4,000	
			Contact and work with agricultural landowners to identify barriers to retiring farmland and track their responses annually beginning in 2030.	Annually	$2,000	
Sediment Nutrient Bacteria Flooding	Protect and restore riparian floodplains in	Local government, floodplain landowners	Identify and quantify non-agricultural land in the 100-year floodplain of North, Middle, and South Fork Salt Creek	2029	$4,000	Salt Creek Preservation Group (P), Brown County

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
Habitat	non-agricultural areas		Develop a strategy to encourage protection of non-agricultural floodplain land through easements, removal of structures, and installation of wetlands or bottomland forest	2031	$4,000	Redevelopment Commission (P), SWCDs (P), Sycamore Land Trust (P)
			Contact and work with landowners to explore floodplain land protection and track their responses annually beginning in 2030.	Annually	$2,000	
			Identify specific properties in floodplain that should be acquired and converted to forest or wetland	2031	$1,000	
Sediment Nutrient Forestry	Increase adoption of forest conservation plans on private lands to reduce sediment and nutrient contributions from forestland.	Private Forest Owners and Managers	Host or actively participate in one regional workshop annually to promote forestry best management practices.	Annually	$2,000	The Nature Conservancy (P), The Indiana Department of Natural Resources Forestry Division (P/T), Indiana Forestry and Woodlands Owners Association (P),
			Publish at least one article annually promoting forestry best management practices.	Annually	$100	
			Identify funding sources to introduce cost-share program for forest management plans and forestry best management practices.	2025	$2,000	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
			Increase adoption of forest management plans by 2 annually starting in 2026.	Annually	$1,000/year	NRCS (P/T), SWCD (P/T), National Wild Turkey Federation (P/T)
Sediment Nutrient Forestry	Increase logger and forester knowledge of forestry best management practices	Forestry practitioners – loggers, foresters, etc.	Host or actively participate in at least one regional training session annually on forestry best management practices for loggers and foresters	Annually	$2,000	The Nature Conservancy (P), The Indiana Department of Natural Resources Forestry Division (P/T), Indiana Forestry and Woodlands Owners Association (P), NRCS (P/T), SWCD (P/T)
	Increase use of forestry best management practices in the watershed		Explore possibility of introducing local ordinances to guide forestry management (e.g., require a certified forester)	2028	$4,000	
Sediment Nutrient	Reduce sediment contribution from streambank erosion	Landowners with streams	Identify streambank sections for stabilization	2026	$2,000	NRCS (P/T), SWCDs (P/T), LARE staff (T)
			Acquire funding for streambank stabilization projects	2028	$2,000	
			Stabilize 100 feet of streambank	2030	$108,000	
			Stabilize an additional 100 feet of streambank	2035	$108,000	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
			Develop system for tracking and addressing logjams	2024	$4,000	LARE staff (T)
Sediment Nutrient	Reduce sediment contribution from lakeshore erosion by stabilizing lakeshore	Lake Monroe – DNR State Parks Division and US Army Corps of Engineers	Acquire funding for adding vegetation to riprap using live stakes	2022	$1,000	DNR State Parks (P), US Army Corps of Engineers (P), Sycamore Land Trust (P), NRCS (P/T), LARE staff (T)
			Install live stake vegetation using community volunteers	2022	$2,000	
			Identify section of Lake Monroe shoreline for pilot stabilization project	2023	$2,000	
			Acquire funding for pilot lakeshore stabilization project	2025	$2,000	
			Stabilize 100 feet of lakeshore via shoreline stabilization project	2026	$104,000	
			Research alternative strategies for reducing shoreline erosion such as adding aquatic plants near the shoreline	2030	$500	
			Identify, acquire funding, and install an additional 100 feet of lakeshore stabilization	2031	$108,000	
Sediment Nutrient	Reduce sediment contribution from	U.S Army Corps of Engineers	Meet with U.S. Army Corps of Engineers to discuss modifications to water level management at the dam	2024	$4,000	U.S. Army Corps of Engineers (P), DNR Parks Division (P)

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
	lakeshore erosion by reducing water level fluctuations in the lake		Modify dam operation (if feasible) to reduce water level fluctuations in Lake Monroe in coordination with U.S. Army Corps of Engineers	2030	In-kind (ACOE)	
Sediment Nutrient Recreation	Reduce sediment contribution from lakeshore erosion exacerbated by boating activity	Boaters, DNR State Parks Division	Circulate 1,000 copies of existing "green boating" brochure developed by FLM	2024	$3,000	DNR Parks Division (P), Visit Bloomington (P), Local Marinas (P), US Army Corps of Engineers (P), Indiana Geological and Water Survey (T)
			Add educational signs at 4 recreational areas explaining water quality concerns and best practices for visitors	2026	$8,000 design, $16,000 print	
			Create or modify existing responsible boating program to address lakeshore erosion from boating and other potential impacts	2025	$4,000	
			Add 8 signs delineating no-wake zones	2028	$2,000 design, $8,000 print	
			Update map of Lake Monroe to more clearly show no-wake zones	2026	$8,000 design	
			Circulate new map	2027	In-kind (DNR)	
			Identify funding and/or legislation to increase boating regulation enforcement at Lake Monroe	2028	$2,000	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
			Work with DNR and state government to increase boating regulation enforcement at Lake Monroe	2030	$2,000	
Sediment Nutrient	Create sediment traps or wetlands to capture sediment before it reaches Lake Monroe.	IDNR State Parks Division, US Army Corps, private landowners with land suitable for wetland restoration	Conduct preliminary analysis to evaluate feasibility of using North Fork Waterfowl Resting Area as a sedimentation basin	2027	$4,000	LARE staff (T), DNR State Parks Division (P), US Army Corps of Engineers (P), NRCS (P/T)
			Acquire funding for design work to modify North Fork Waterfowl Resting Area to enhance effectiveness as a sedimentation basin	2027	$4,000	
			Modify North Fork Waterfowl Resting Area (if feasible) to enhance effectiveness as a sedimentation basin	2029	$104,000	
			Locate and review old proposal to use Crooked Creek area as a sedimentation basin	2030	$2,000	
			Identify funding for Crooked Creek sediment basin project	2031	$2,000	
			Install Crooked Creek sediment basin project (if feasible)	2032	$506,000	
			Identify areas for creating or restoring wetlands in floodplains	2030	$2,000	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
Sediment Nutrient Flooding			Conduct preliminary feasibility work to install one wetland project	2030	$2,000	
			Identify funding for wetland project	2031	$2,000	
			Install wetland project	2032	$52,000	
Nutrient	Reduce nutrient loading with in-lake treatment	U.S. Army Corps of Engineers, City of Bloomington Utilities, DNR State Parks	Conduct feasibility analysis of using in-lake aeration system to reduce phosphorus concentrations	2028	$5,000	U.S. Army Corps of Engineers (P), City of Bloomington Utilities (P), DNR State Parks (P)
			Conduct feasibility analysis of adding flocculant to lake to reduce phosphorus concentrations	2029	$5,000	
Sediment Nutrients Bacteria	Evaluate success of action plan and modify as needed	Steering committee, Friends of Lake Monroe	Annually evaluate watershed management goals, tasks, and indicators of success. This includes tabulating total load reductions using the Region 5 load model and Indiana E. coli calculator to determine if project goals have been satisfied.	Annually	Included in cost-share program administration	Steering committee (P)
			Modify action plan based on annual evaluation	Annually		
Sediment Nutrients	Monitor water quality to	General public	Collect and analyze water samples from Lake Monroe in late summer.	Annually	$7,500	IU Limnology Lab (P/T), City

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
Bacteria Education	evaluate watershed health		Summarize and report results of available water quality data in annual report.	Annually	$2,000/year	of Bloomington Utilities (P/T), US Army Corps of Engineers (P), US Forest Service (P), IDEM (P)
			By end of fourth year, identify funding sources for conducting an additional water quality monitoring event to evaluate program impacts	2026	$2,000	
			Explore options for integrated water quality monitoring	2026	$2,000	
			After two rounds of implementation projects, conduct an additional water quality monitoring event to evaluate program impacts	2029	IU Contract $75,000	
			Organize citizen scientist water sampling in conjunction with water quality monitoring	2029	$7,000	
Capacity	Acquire support of all affected local government bodies	Policymakers, government employees, elected officials	Organize a multi-county watershed summit to align policymakers around watershed issues	2022	$4,000	SWCDs (P), Purdue Extension (P), government bodies (P)
			Give presentations to all affected local government bodies at least once annually	Annually	$2,000	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
	Establish long-term capacity for watershed work	Steering Committee, Friends of Lake Monroe	Create a long-term strategic plan for funding watershed work and establishing a permanent watershed coordinator position	2023	$8,000	Lake Monroe Water Fund (P), SWCDs (P), Community Foundations (P)
			Implement strategic plan for funding watershed work (2024-2042)	2024	$1,000/year	
			Establish permanent watershed coordinator position	2030	See annual cost estimates	
Education	Conduct educational workshops for the public with the goal of changing behaviors to positively impact water quality	General Public	Host at least two community forums presenting watershed management plan	2022	$6,000	SWCDs (P/T), Health Departments (P/T), League of Women Voters (P), Brown County Regional Sewer District (P/T), Visit Bloomington (P)
			Conduct at least one public meeting (community forum) each year	Annually	$4,000	
			Host or actively participate in one regional workshop annually to promote septic system maintenance.	Annually	See Sediment and Nutrients Section	
			Develop an educational mailer for watershed residents about proper septic care and maintenance.	2023	See Sediment and Nutrients Section	
			Develop an educational mailer for watershed residents about streambank stewardship.	2023	$3,000	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
			Develop an educational mailer for watershed residents about landscaping for water quality.	2023	$3,000	
			Develop an educational mailer for watershed residents about soil protection.	2023	$3,000	
			Mail the newly developed educational brochures to 7,000+ stakeholders with information on how their actions have a positive or negative impact on water quality.	2023	$3 x 4 x 7,000 = $84,000	
			Develop an educational brochure about the watershed management plan to be used at events.	2023	$3,000	
Education	Activate community members as watershed stewards by connecting them with local waters	General public	Hold at least one large stream or lake cleanup annually	Annually	$500/year	Keep Brown County Beautiful (P), Salt Creek Preservation Group (P), local marinas (P), Indigo Birding
			Hold at least one boat tour annually	Annually	$500/year	
			Host at least one watershed tour annually	Annually	$500/year	
			Continue monthly trash cleanups at Lake Monroe	Annually	$200/year	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
	and hands-on activities		Coordinate citizen science project monitoring shoreline erosion within Lake Monroe.	2025	Summer intern = $5,000	(P), Brown County Parks and Rec (P), Monroe County Stormwater (P), IDNR State Parks (P), USFS (P)
Education	Engage community members through regular updates and information.	General Public	Post quarterly updates on FLM website	Annually	$200/year	Steering committee (P), SWCDs (P)
			Publish watershed-related articles in FLM newsletter at least quarterly	Annually	$200/year	
			Use social media to provide meeting notices/reminders, and informational updates on a monthly basis.	Annually	$100/year	
			Provide media releases to local newspaper(s) and/or radio and television stations about watershed protection at least twice a year.	Annually	$100/year	
			Share information at a minimum of four public events annually.	Annually	$500/year	

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
Trash Education	Increase awareness of the negative impacts of littering and trash dumping.	General Public	Develop and launch an anti-litter campaign	2026	$6,000	Keep Brown County Beautiful (P), SWCDs (P), local parks and rec departments (P)
	Increase availability of trash collection options in all counties	General Public	Identify funding sources to increase waste management options	2025	$2,000	Keep Brown County Beautiful (P/T), local waste management districts (P/T)
			Meet with county solid waste management districts to discuss expanding waste disposal options	2025	$2,000	
Invasives	Increase citizen action removing invasive species.	General Public	Host Indiana Weed Wrangle events within watershed	2025	$500	MC-IRIS (P/T), Brown County Native Woodlands Project (P/T), Southern Indiana Cooperative Invasives Management (SICIM) (P/T)
			Facilitate private landowner interactions with the local CISMA so citizens can learn invasive species on their properties and develop a management plan to deal with them	2023	N/A	
Governance	Explore the need for ordinance	Local governments	Organize a committee to review ordinances and meet quarterly for one year.	2028	$2,000	Monroe County (P), Brown County (P),

Goal	Objective	Target Audience	Milestone	Target Date	Estimated Cost	Potential Partner/ Technical Assistance
	updates or new ordinances to increase protection of Lake Monroe		Develop action plan based on ordinance review	2029	$1,000	Jackson County (P), City of Bloomington (P), Town of Nashville (P)
			Implement ordinance update action plan	2030	$5,000	

Many of the Action Plan objectives will be repeated annually, including administering a cost-share program to encourage BMP adoption (as funds allow) and hosting annual workshops on topics like septic system maintenance, agricultural BMPs, forestry BMPs, and general updates on the state of the watershed. Other objectives occur only once. Below is a breakdown of tasks by calendar year.

Table 10-2 Action Plan By Year

Year	Staff	BMP Install	Supplies	Services	Total	Area of Focus
Annually	$ 34,200	$ 47,600	$ 1,700	$ 7,500	$ 91,000	Annually administer cost-share program, hold 4 annual workshops, keep local government officials informed, conduct public education and outreach
2022	$ 22,100	$ 1,000	$ 1,700	$ -	$ 24,800	Community forums to present watershed management plan, developing educational materials, presenting at events, laying groundwork for implementation, live stake project
2023	$ 58,200	$ 47,600	$ 86,700	$ 19,500	$ 212,000	Initial round of implementation – launching cost-share program, develop and send educational mailers, summer sampling of Lake Monroe, groundwork for shoreline stabilization project, strategic planning for long-term funding
2024	$ 49,200	$ 47,600	$ 3,700	$ -	$ 108,000	Implement strategic plan for long-term funding, work with health departments of septic issues, develop logjam system, educate about green boating, summer sampling of Lake Monroe, initial conversations with Army Corps about modifying dam operation
2025	$ 50,700	$ 47,600	$ 1,700	$ 5,000	$ 110,500	Shoreline erosion project, responsible boating education, identifying waste management expansion options, quantifying floodplain farmland, monitoring shoreline erosion, acquiring funding for forestry work

Year	Staff	BMP Install	Supplies	Services	Total	Area of Focus
2026	$ 58,200	$ 147,600	$ 1,700	$ 24,000	$ 239,000	Lakeshore stabilization pilot, install educational signage at beaches, update boating map of Lake Monroe, launch anti-litter campaign, acquire funding for large water quality monitoring event, research integrated water monitoring options
2027	$ 53,200	$ 47,600	$ 1,700	$ -	$ 110,000	Preparation work for North Fork Waterfowl Resting Area project, circulate updated boating map
2028	$ 48,200	$ 47,600	$ 9,700	$ 5,000	$ 118,000	Develop strategy for taking agricultural floodplain land out of production, install 8 signs delineating no-wake zones, explore increasing boat regulation enforcement, conduct local ordinance review, continue work with health departments
2029	$ 47,200	$ 147,600	$ 1,700	$ 80,000	$ 283,000	Water quality monitoring event with citizen science component, install North Fork sediment trap (if feasible), develop action plan based on ordinance review, investigate floodplain protection options, conduct feasibility analysis of adding flocculant to lake
2030	$ 53,700	$ 147,600	$ 1,700	$ -	$ 210,200	Establish permanent watershed coordinator position, stabilize 100 feet of streambank, modify dam operation (if feasible), preliminary work for Crooked Creek sediment trap project, preliminary work for wetland project, begin contacting floodplain landowners about land protection
2031	$ 46,200	$ 147,600	$ 1,700	$ -	$ 203,000	Stabilize an additional 100 feet of lakeshore, continue preliminary work for Crooked Creek and wetlands
2032	$ 42,200	$ 597,600	$ 1,700	$ -	$ 649,000	Install Crooked Creek sediment trap, install new wetlands
2033	$ 34,200	$ 47,600	$ 1,700	$ -	$ 91,000	Continue with annual task list
2034	$ 34,200	$ 47,600	$ 1,700	$ -	$ 91,000	Continue with annual task list

Year	Staff	BMP Install	Supplies	Services	Total	Area of Focus
2035	$ 42,200	$ 147,600	$ 1,700	$ -	$ 198,000	Stabilize an additional 100 feet of streambank
2036 to 2042	$ 34,200	$ 47,600	$ 1,700	$ -	$ 91,000	Continue with annual task list

10.2 Potential Funding Sources

For successful implementation of the watershed management plan, multiple funding sources will need to be explored and accessed. Here is a starting list of potential funding sources to consider.

- Lake Monroe Water Fund
- Indiana Department of Environmental Management (IDEM) Nonpoint source 319 grant
- Natural Resource Conservation Services (NRCS) Farm Bill Conservation Programs including EQIP, CRP, CSP, WRP
- Indiana State Department of Agriculture (ISDA) Clean Water Indiana Grants
- Indiana Department of Natural Resources (IDNR) Lake and River Enhancement (LARE) grant
- IDNR Reservoir Habitat Enhancement Program
- Duke Energy Foundation
- Office of Rural Affairs
- Local Community Foundations (Monroe County, Brown County, Jackson County)
- National Fish and Wildlife Federation Five Star and Urban Waters Restoration Grant Program
- United States Department of Agriculture (USDA) Rural Development
- Regional Opportunity Investment
- Environmental Protection Agency (EPA) Clean Water Revolving Fund
- Indiana Department of Natural Resources (IDNR) Forestry BMP Cost-Share Program
- Indiana Forestry Educational Foundation
- United States Forest Service grants
- USACE Section 206 Aquatic Ecosystem Restoration and other USACE grants

10.3 Tracking Effectiveness

The effectiveness of implementation efforts will be tracked through load reduction models using Region 5 modeling and Indiana E. coli calculator for all installed BMPs. Load reductions will be calculated on an ongoing basis and BMP locations will also be tracked using GIS. These load reductions are likely to differ from year to year based on available funds and landowner interest. Substantial load reductions are expected from the proposed floodplain/wetland restoration projects in the North Fork Salt Creek and Crooked Creek areas. However, these projects will require feasibility studies and extensive design work before accurate load reductions can be calculated. Therefore, interim load reduction targets were developed for five-year intervals assuming a constant load reduction each year (see table 10-3). These interim milestones will provide a general metric for evaluating progress within the twenty-year timeframe.

Table 10-3 Load Reduction Targets Over 20-Year Timeline

	Phosphorus Load Reduction (lbs/yr)	**Sediment Load Reduction (tons/yr)**	**Nitrogen Load Reduction (lbs/yr)**	**E. coli Load Reduction (CFU/yr)**
Year 3 Reduction Goal	11,115	1,499	12,031	9.84E+13
Year 5 Reduction Goal	18,525	2,498	20,051	1.64E+14
Year 10 Reduction Goal	37,049	4,996	40,102	3.28E+14
Year 15 Reduction Goal	55,574	7,494	60,153	4.92E+14
Year 20 Reduction Goal (Total)	**74,098**	**9,992**	**80,204**	**6.56E+14**

Costs for installation will be borne on a cost-share basis with landowners when grant funding can be obtained by Friends of Lake Monroe and its partners. Friends of Lake Monroe will work closely with NRCS and local SWCD offices to identify additional funding sources when cost-share programs are not available or applicable. Technical assistance in either case will be provided by potential project partners NRCS and ISDA in coordination with the SWCDs.

Education and outreach will be tracked on an ongoing basis using social and administrative indicators such as databases of workshop/event participants, pre- and post- surveys collected at workshops, personal interviews at events, and testimonials. At the end of each year, the implementation plan and its strategies will be reviewed for effectiveness. All problems and concerns will be identified, evaluated, and used to adjust future strategies.

Watershed scale water quality monitoring will be reintroduced after two rounds of implementation projects (approximately 6 years). Data collection will utilize the same methodology used during the watershed planning phase and will be performed by our partners at the Indiana University Limnology Lab for an approximate cost of $75,000. Sampling results will be compared to data collected during the watershed planning phase to evaluate impacts from initial plan implementation. Additional water quality monitoring will be scheduled based on future implementation work with an anticipated frequency of once every 6-8 years.

Detailed information on milestones and costs related to tracking environmental, social, and administrative indicators are included in the Action Register.

10.4 Description of future WMP activity

The Lake Monroe Watershed Management Plan summarizes historical information about the watershed as well as newly collected data in order to analyze water quality concerns and present strategies for addressing those concerns. To make this information common knowledge, Friends of Lake Monroe will host two community forums upon plan completion to present the key findings of the plan and engage community member participation in implementation. Executive summaries will be presented to community leaders in all affected local governments. A full copy of the report and all water quality monitoring data will be available through the Friends of Lake Monroe website. A Story Map of water quality monitoring data developed by the IU Limnology Lab will also be available online and linked from the Friends of Lake Monroe website.

Friends of Lake Monroe has applied for a FFY 2022 Clean Water Act Section 319 grant that would fund an initial phase of implementation starting in November 2022. In the meantime, Friends of Lake Monroe is working to secure funding to continue project work through the gap period between grants (February-October 2022). The Monroe County Stormwater Board has pledged funds towards keeping the watershed coordinator on contract to continue education and outreach about the watershed and water quality issues while also laying the groundwork for the initial phase of implementation.

One long-term goal is to create a permanent watershed coordinator position to ensure continuity and maintain project momentum. Friends of Lake Monroe will develop a strategic plan for funding watershed work long-term and establishing a permanent watershed coordinator position.

Since watersheds are constantly evolving, the watershed management plan will need to be revisited and updated periodically. Friends of Lake Monroe along with its partners will meet at least annually to evaluate the plan for effectiveness then consider and adjust the plan as needed to make it more effective. If implementation efforts are on track and interim milestones are being met, no adjustments will be needed. However, if interim milestones or pollutant reduction goals are not being met, the steering committee will consider the following questions to determine if minor adjustments to the plan would increase its feasibility and effectiveness:

- Were there weather-related issues beyond our control that postponed or affected implementation?
- Was there a shortage of technical assistance?
- Are the practices taking longer to install than estimated in the watershed management plan?
- Are there socio-economic or other barriers to adoption that need to be overcome?
- Are the BMPs being installed correctly?
- Is it simply too soon to see measurable improvements?

In most cases, the action plan will be adjusted as needed and implementation will continue. However, Friends of Lake Monroe will contact IDEM to discuss rewriting or revising the plan if at least five years have passed and any of the following have occurred:

- Water quality impairments still persist after the plan has been implemented and there are no more viable BMP options in the original critical areas (necessitating a revised definition of critical areas)
- Land use has changed significantly
- Plan evaluation shows pollutant reduction goals are not being met and the group believes the plan is not effective in its current form
- A nonpoint source Total Maximum Daily Load (TMDL) has been developed for the Lake Monroe watershed which impacts water quality targets

This watershed management plan is meant to be a living document. Revisions and updates to the plan will be necessary as stakeholders begin to implement the plan and as stakeholders become more active in implementing the plan. Friends of Lake Monroe will be responsible for holding and revising the Lake Monroe Watershed Management Plan as appropriate based on stakeholder feedback. The primary contact is Maggie Sullivan, watershed coordinator (watershed@friendsoflakemonroe.org, 812-558-0217).