A National Demonstration Project for Watershed Management:

An Innovative Approach to Identifying Key Priorities for Improving Water Quality in the East Fork Little Miami River Watershed

FINAL GRANT REPORT

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Prepared by the
East Fork Little Miami River Watershed Collaborative

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EXECUTIVE SUMMARY

The East Fork Little Miami River (EFLMR) watershed covers approximately 500 square miles in southwestern Ohio, from its headwaters in rural Clinton, Highland, and Brown counties to its confluence with the Little Miami River in suburban western Clermont County. In 1975, the U.S. Army Corps of Engineers impounded the East Fork by constructing an earthen dam at River Mile 20.5, creating a 2,160 acre reservoir (Harsha Lake) stretching approximately ten miles upstream from the dam. Based on surveys conducted in 1982 and 1998, the Ohio Environmental Protection Agency (Ohio EPA) has determined that various waterbodies in the EFLMR watershed are not meeting their use attainment goals. As a result, the EFLMR was placed on the state's impaired waters list in 2006 and designated for Total Maximum Daily Load (TMDL) development. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. The process of formulating TMDLs is therefore a method by which impaired waters are identified and restoration solutions are developed and implemented to meet the goals of the Clean Water Act.

To address the water quality impairments identified in the EFLMR watershed, Clermont County, together with the other counties, villages and townships that comprise the East Fork Watershed Collaborative (the Collaborative), have undertaken this study to determine the primary reasons for non-attainment of water quality standards. One goal of the study was to determine whether a locally-led TMDL would be appropriate and in the best interests of the community. The thought was that developing a locally-led TMDL would provide the Collaborative an opportunity to build upon ongoing activities, to ensure that local concerns are adequately addressed during TMDL development, and to possibly secure additional funding for protecting and improving water resources.

Two parallel and related approaches were used to better understand the reasons for biological impairment in the EFLMR watershed. The Stressor Identification approach utilized a weight-of-evidence process that considered the universe of potential stressors and evaluated the relative probability of each one to contribute to the observed biological impairment. Alternatively, a biostatistical modeling approach relied upon statistical evaluations of the relationships between available biological, physical, and chemical water quality data. One of the significant findings of this analysis was that meeting the biological criteria in currently impaired streams will be more dependent on addressing habitat factors, such as improving instream QHEI cover and pool scores, than reducing pollutant loadings. Flashiness (or the frequency and rapidity of short term changes in streamflow) was also found to be strongly correlated to fish scores and therefore the control of stormwater runoff should be a high priority in the watershed. Another interesting finding of the biostatistical analysis was that there is only a weak relationship between biological impairment and nutrient concentrations in the watershed, even though nutrients have long been considered one of the primary reasons for non-attainment.

The finding that habitat and flashiness are among the most important variables in controlling biological health in the EFLMR poses some challenges with regard to TMDL development. This is because the U.S. EPA has made a determination that some categories of water quality impairment, including flow and habitat alterations, are best resolved through measures other than TMDLs. TMDLs instead are required to address impairments caused by discrete "pollutants," such as nutrients and sediment, which are thought to be less important causes of impairment in the EFLRM watershed. A traditional TMDL developed for the EFLMR watershed would therefore focus on controlling pollutant loads when the Collaborative believes the focus should instead be on addressing flow and habitat problems in the watershed. This focus on pollutant loads would also translate into revised permit limits for the point sources in the watershed which, in turn, would require that resources that otherwise could be devoted to improving flow and habitat conditions would need to focus on reducing pollutant loads.

For these reasons, the Collaborative eventually decided to not pursue a locally-led TMDL and will instead pursue the implementation of a phased watershed management plan. Phase 1 will consist of implementing projects and programs that are already in development or have already been committed to. Additional nonpoint source controls will also be identified and implemented during Phase 1 that focus on the tributaries to the EFLMR and the primary headwater areas that have been found to be in non-attainment of their aquatic life uses. During Phase 1, preference will be given to tributary nonpoint source controls that improve stream habitat, decrease stream flashiness, and control the loadings of high priority pollutants. The Collaborative believes that many currently impaired streams can be brought into attainment as a result of Phase 1 activities.

During Phase 2, an enhanced level of controls will be focused on tributaries to the EFLMR where habitat and flow improvements have already been made but biological attainment has still not yet been achieved. Phase 2 nonpoint source controls will likely include those that control high priority pollutants (even if they do not also improve habitat or address flashiness). Water quality trading might also begin to take place during Phase 2 or a watershed-based permit might be finalized, depending on the decisions made in Phase 1. The final phase of implementation will be the adoption of all controls necessary to fully meet water quality standards, whether those are currently existing standards or new standards identified during Phase 2. Phase 3 has been set up to coincide with Ohio EPA's schedule to re-assess the EFLMR in 2012 and, if the watershed is still impaired, to develop an agency-led TMDL by 2014. The overall schedule for the three phases are presented in Figure ES-1.

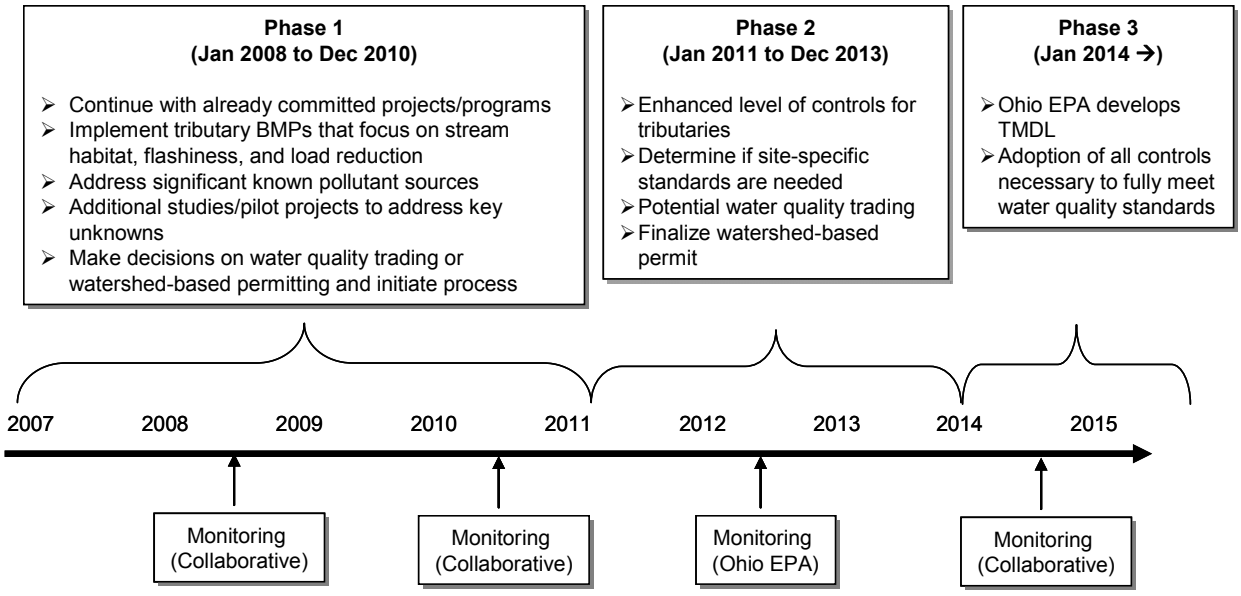


Figure ES-1. Implementation schedule for the EFLMR watershed.

1 INTRODUCTION

The East Fork Little Miami River (EFLMR) watershed covers approximately 500 square miles in southwestern Ohio, from its headwaters in rural Clinton, Highland, and Brown counties to its confluence with the Little Miami River in suburban western Clermont County (Figure 1-1). Information on the land use/land cover, soils, and population characteristics of the watershed can be found in Appendix A. In 1975, the U.S. Army Corps of Engineers impounded the East Fork by constructing an earthen dam at River Mile 20.5, creating a 2,160 acre reservoir (Harsha Lake) stretching approximately ten miles upstream from the dam. The reservoir was primarily intended to provide flood control, but is also used for recreation (boating and fishing) and is a source of drinking water for approximately 30,000 residents of Clermont County. Based on surveys conducted in 1982 and 1998, the Ohio Environmental Protection Agency (Ohio EPA) has determined that various waterbodies in the EFLMR watershed are not meeting their use attainment goals. As a result, the EFLMR was placed on the state's impaired waters list in 2006 and designated for Total Maximum Daily Load (TMDL) development.

1.1 What is a TMDL?

The 1972 Clean Water Act Section 303(d) requires States, Territories, and authorized Tribes to list and prioritize waters for which technology-based treatment limits alone do not ensure attainment of water quality standards. The Section 303(d) list of impaired waters is made available to the public and submitted to the U.S. Environmental Protection Agency (U.S. EPA) in every even-numbered year.

The Clean Water Act and U.S. EPA regulations require that TMDLs be developed for all waters on the Section 303(d) lists. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. The process of formulating TMDLs is therefore a method by which impaired waters are identified and restoration solutions are developed and implemented to meet the goals of the Clean Water Act. Ultimately, the goal of Ohio's TMDL process is full attainment of biological and chemical water quality standards and, subsequently, delisting of waters from the Section 303(d) list.

The 2006 listings for the EFLMR watershed are summarized in Table 1-1. The listing information is organized by subwatershed (or Assessment Unit) because Ohio EPA believes that developing TMDLs on a watershed basis is an effective approach toward the goal of full attainment of water quality standards. An Assessment Unit is listed as being impaired if even one of the waterbody segments within its boundaries is not fully attaining water quality standards. The four Assessment Units that comprise the EFLMR watershed are shown in Figure 1-1.

Table 1-1 indicates that a variety of causes of impairment have been identified by Ohio EPA as impacting the EFLMR watershed, including siltation, organic enrichment, dissolved oxygen, and nutrients. The potential sources of these impairments include agricultural activities, municipal wastewater treatment plants, failing onsite disposal (e.g., septic) systems, and stormwater runoff. A detailed analysis conducted as part of this project confirmed many of the causes of impairment identified by Ohio EPA but also concluded that flow and habitat factors are more significant factors affecting aquatic community health than is water chemistry.

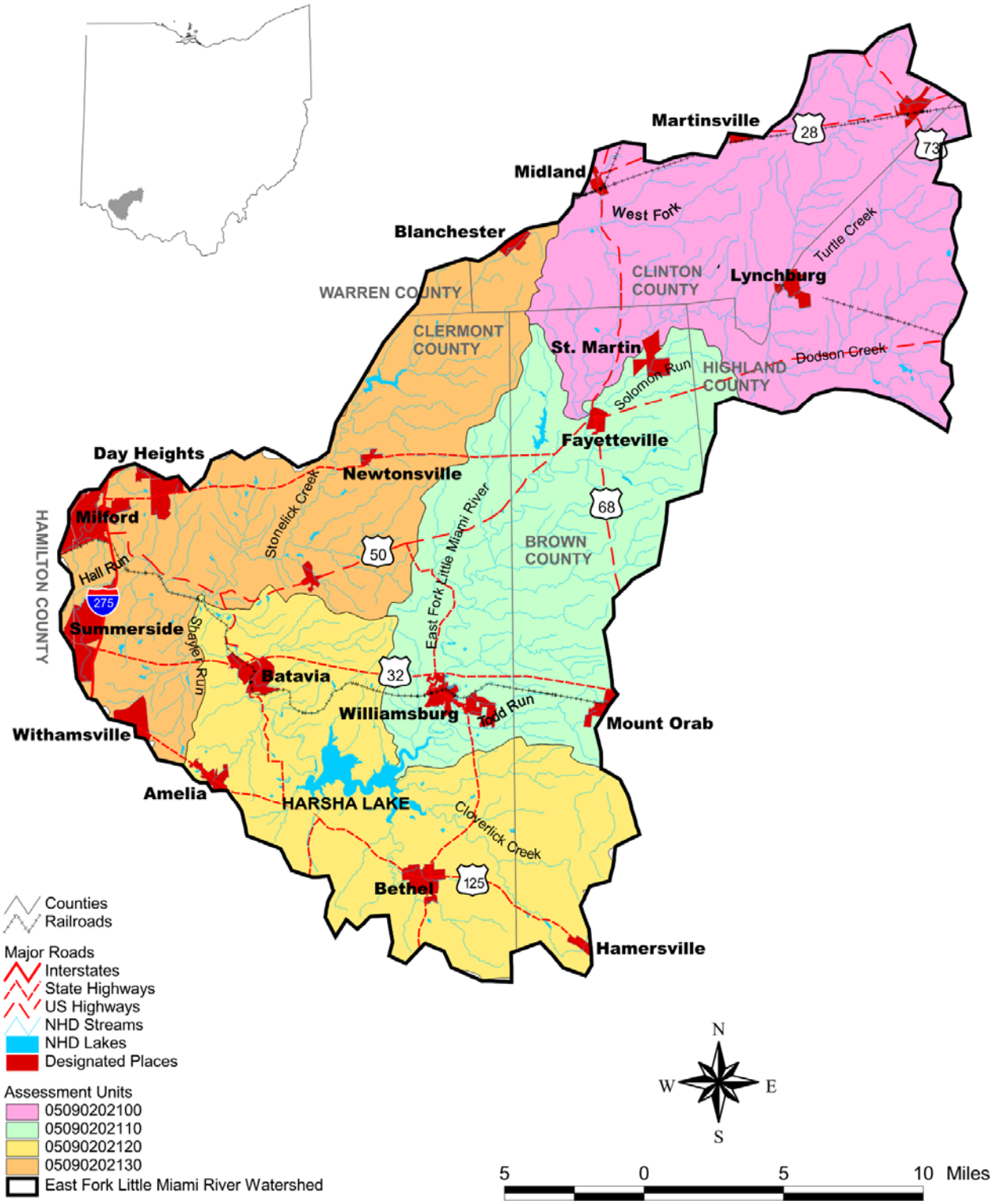


Figure 1-1. Location of the East Fork Little Miami River watershed.

Table 1-1. Ohio 2006 Section 303(d) listing information within the East Fork Little Miami River watershed.

AU	Description	Priority	High Magnitude Causes	Sources
05090202 100	East Fork Little Miami River (headwaters to upstream Solomon Run)	6	Cause Unknown, Nutrients, Siltation	Nonirrigated Crop Production, Surface Mining, Source Unknown
05090202 110	East Fork Little Miami River (upstream Solomon Run to upstream Cloverlick Creek)	2	Cause Unknown, Nutrients, Siltation, Organic Enrichment/DO	Nonirrigated Crop Production, Onsite Wastewater Systems (Septic Tanks), Source Unknown
05090202 120	East Fork Little Miami River (upstream Cloverlick Creek to upstream Stonelick Creek)	1	Nutrients, Siltation, Organic Enrichment/DO, Flow Alteration, Direct Habitat Alterations	Municipal Point Sources, Land Development/Suburbanization, Urban Runoff/Storm Sewers (NPS), Onsite Wastewater Systems (Septic Tanks), Channelization-Development, Flow Reg/Mod.- Dev.
05090202 130	East Fork Little Miami River (upstream Stonelick Creek to mouth)	6	Cause Unknown, Nutrients, Siltation, Organic Enrichment/DO, Flow Alteration, Direct Habitat Alterations, Pathogens	Major Municipal Point Source, Combined Sewer Overflows, Sanitary Sewer Overflows, Nonirrigated Crop Production, Sewer Line Construction, Urban Runoff/Storm Sewer (NPS), Dredging- Development, Dam Construction- Agriculture, Streambank Destabilization- Dev., Source Unknown

AU = Assessment Unit

1.2 Why Consider a Locally-Led TMDL?

To address the water quality impairments identified in the EFLMR watershed, Clermont County, together with the other counties, villages and townships that comprise the East Fork Watershed Collaborative, originally decided to undertake a study to determine the primary reasons for non-attainment of water quality standards and to determine whether a locally-led TMDL would be appropriate and in the best interests of the community. There are several reasons the East Fork Watershed Collaborative considered developing a TMDL:

- **Provide decision-making framework to focus management actions**. Because TMDLs address both point and nonpoint sources of pollution on a watershed (rather than jurisdictional) basis, they provide an effective framework for focusing implementation activities if the key causes of impairment are discrete pollutants. TMDLs help to prioritize management actions throughout a watershed by identifying the extent to which existing loads exceed allowable loads and determining the most significant pollutant sources (e.g., point sources versus nonpoint sources and specific categories of nonpoint sources).
- **Create opportunities to integrate point source and nonpoint source pollution controls**. Because there are both point and nonpoint sources of pollutants in the EFLMR watershed, an

approved TMDL would potentially allow for innovative controls such as watershed-based permitting and/or trading. To proceed with water quality trading or watershed-based permitting, U.S. EPA requires an analysis similar to a TMDL to determine the pollutant load contributions and develop appropriate caps (allocations) for the sources in the watersheds.

- **Consistent with Project XL.** Roughly the lower one-half of the EFLMR watershed is located in Clermont County. The county is experiencing rapid growth, and hopes to manage this growth in a responsible and sustainable manner, so as to maintain the quality of life that the county's residents have come to expect. In recognition of its effort, U.S. EPA has named Clermont County a Project XL community. U.S. EPA created Project XL, which stands for *eXcellence and Leadership*, to give proactive communities such as Clermont County the opportunity to propose more effective ways of protecting the environment. Project XL encourages sponsors to propose new approaches to demonstrate community-designed and directed strategies for achieving greater environmental quality consistent with community economic viability. To this end, Clermont County has taken the lead role in studying the primary reasons for non-attainment and evaluating the possibilities of a locally-led TMDL with the hope that the TMDL would lead to opportunities for water quality trading, watershed-based permitting, and other innovative strategies backed by the Project XL agreement.
- **Encourage public participation in protecting water resources.** The TMDL process provides an additional opportunity for the public to participate in protecting water resources within the EFLMR watershed. This cooperative approach to TMDL development, with the communities leading the process and the state providing technical assistance as needed, enabled the communities to create an implementation plan that best suits local needs, while at the same time meeting the requirements of the Clean Water Act.
- **Local control.** Ohio EPA is required to develop TMDLs for all impaired waterbodies in the state and the EFLMR is currently scheduled to have a TMDL study completed in 2014. If Ohio EPA would not develop a TMDL for some reason, U.S. EPA is required to do so. The Collaborative therefore wanted to take control of the process to ensure that local concerns and knowledge were adequately addressed.

1.3 Concerns with TMDL Development

For a variety of reasons the Collaborative eventually decided to not pursue a locally-led TMDL and will instead pursue a phased watershed management plan. These reasons include:

- One of the significant findings of this analysis was that meeting the biological criteria in currently impaired streams will be more dependent on addressing habitat factors, such as improving instream QHEI cover and pool scores, than reducing pollutant loadings. This finding poses some challenges with regard to TMDL development because TMDLs are required to address impairments caused by discrete "pollutants," such as nutrients and sediment, which are thought to be less important causes of impairment in the EFLRM watershed. A traditional TMDL developed for the EFLMR watershed would therefore focus on controlling pollutant loads when the Collaborative believes the focus should instead be on addressing flow and habitat problems in the watershed.
- A traditional TMDL focused on pollutant loads would also translate into revised permit limits for the point sources which, in turn, could divert resources that otherwise could be devoted to improving flow and habitat conditions.

Despite the decision to not develop a TMDL it is believed that this project still serves as an important case study demonstrating how a local community can use an innovative approach to address water quality issues.

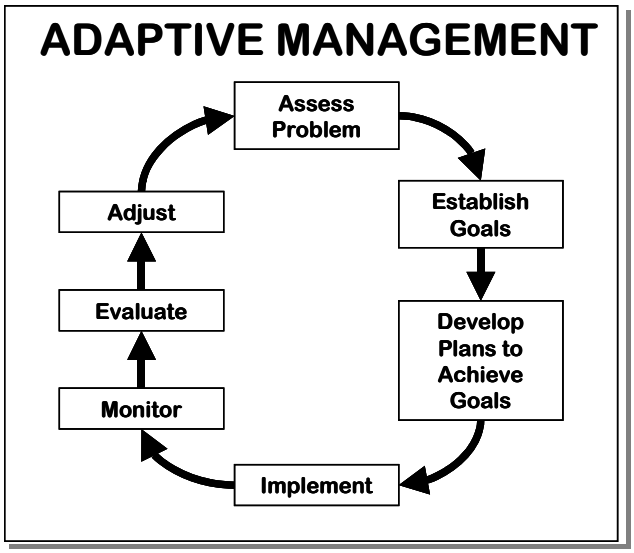
1.4 Strategy for Implementation and Adaptive Management

A tremendous amount of progress has already been made over the past few years to protect and restore water quality in the EFLMR watershed. Activities have included:

- Clermont County has conducted annual chemical and biological sampling in the watershed continuously since 1996.
- The East Fork Watershed Collaborative has already developed Watershed Action Plans for three subwatersheds within the larger EFLMR basin and is working on two others. The Watershed Action Plans focus on concerns unique to each subwatershed, providing a detailed description of subwatershed characteristics and stream conditions, causes and sources of water quality impairment, and specific recommendations on how those impairments might be addressed.
- The East Fork Watershed Collaborative has established a close working relationship with many of the major stakeholders in the area, including local sewer districts, health districts, soil and water conservation districts, and major landowners.
- A Watershed Coordinator has been in place since 2000 to help coordinate activities throughout the watershed and disseminate information to the general public and local officials.
- Clermont County has made a variety of collection system and wastewater treatment plant improvements over the past few years and is exploring the need to establish a regional Storm Water Management District to address drainage and water quality problems.
- The Water Resource Restoration Sponsor Program (WRRSP) is purchasing property or conservation easements along the mainstem of the lower East Fork Little Miami River and tributaries to protect the riparian zone from development and use.

The analysis conducted in support of the potential TMDL provided an opportunity to build upon these and other ongoing activities. For example, an important conclusion of the study was that flow and habitat are more significant factors affecting aquatic community health than is water chemistry. This conclusion can now be used to devote limited resources to where they are expected to have the most benefit. In addition, water quality targets and load reductions needed to meet those targets were identified as part of this project. This information can also be used to help to prioritize areas in need of storm water management or sources of pollution that need to be addressed (e.g., dense areas of failing onsite disposal systems).

Adaptive management will be a key component of implementing the EFLMR phased watershed management plan. Adaptive management is an iterative implementation process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities. Given the complexity and scale of water quality issues in the EFLMR watershed, it has not been possible to answer every question and address each detail in this document. Conclusions reached and decisions made/documented are based on the best information and data currently available. As new information becomes available in the future and/or conditions change, a strategy to evaluate the new information, react to it, and adjust components of the plan must be in place. The proposed adaptive management approach will allow the Collaborative to move forward with water quality improvement activities at the same time that additional data gathering occurs. These data will then be used to confirm or adjust some of the plan's technical assumptions, to fill remaining data limitations, and to evaluate the effectiveness of restoration measures on an individual and collective basis. Specifically, the Watershed Collaborative proposes to implement the EFLMR watershed management plan in three separate phases as follows:



Phase 1. The first phase will consist of implementing projects and programs that are already in development or have already been committed to. Additional BMPs will also be identified and implemented during Phase 1 that focus on the tributaries to the EFLMR and the primary headwater areas that have been found to be in non-attainment of their aquatic life uses; these areas are identified in Section 3. The tributaries and primary headwater areas will be targeted first because:

- The health of the EFLMR main stem depends upon an intact and healthy tributary and primary headwater stream network, and
- The cost effectiveness of controls for the tributaries and primary headwater areas (e.g., adoption of ordinances, establishment of riparian buffers) is anticipated to be much better than the cost effectiveness of controls for the main stem (e.g., costly upgrades to WWTPs).

During Phase 1, preference will be given to tributary BMPs that improve stream habitat, decrease stream flashiness, and control the loadings of high priority pollutants. Significant known pollutant sources (such as areas of high density failing onsite wastewater systems or problem semi-public wastewater treatment plants) will also be addressed during Phase 1, regardless of their location. The Collaborative believes that many currently impaired streams can be brought into attainment as a result of Phase 1 activities. Streams that are currently meeting water quality standards can also be protected. Other activities to be carried out during Phase 1 include:

- Ongoing collection of biological data to assess progress towards attainment of water quality standards.
- Additional studies to learn more about issues still not fully understood, such as the condition of Harsha Lake and its role in transporting pollutant loads downstream.
- Continue to evaluate current WWTP operations to optimize the level of treatment that can be attained with the current infrastructure, and conduct an alternatives analysis/feasibility study to determine the cost and technological requirements for further reducing nutrient concentrations.
- Pilot projects to measure the effectiveness of various BMPs, with the intent of identifying those BMPs that are most cost effective.
- Further explore and make decisions about innovative control opportunities, such as water quality trading and watershed-based permitting.

Phase 1 is expected to last from 2008 through 2010 (Figure 1-2).

Phase 2. During Phase 2, an enhanced level of controls will be focused on tributaries to the EFLMR where habitat and flow improvements have already been made but biological attainment has still not yet been achieved. Phase 2 BMPs will likely include those that control high priority pollutants (even if they do not also improve habitat or address flashiness). Water quality trading might also begin to take place during Phase 2 or a watershed-based permit might be finalized, depending on the decisions made in Phase 1.

Phase 2 will also include a re-assessment of the load reductions contained in this report to take advantage of any new information or understanding of key issues that result from the Phase 1 studies. For example, the load reduction targets for Municipal Separate Storm Sewer Systems (MS4s) might be revised (or

eliminated) if certain stream segments end up attaining the biological water quality standards even though the pollutant load reductions have not been achieved. This would be done to remove any undue burden on communities that might arise from trying to meet load reductions that turn out to be unnecessary.

Phase 2 might also include an analysis to determine if site-specific water quality standards are needed in the EFLMR because natural conditions preclude the attainment of certain statewide criteria (e.g., Ohio's propose nutrient criteria, which are expected to be adopted within the next several years).

Phase 2 is expected to last from 2011 through 2013 (Figure 1-2).

Phase 3. The final phase of implementation will be the adoption of all controls necessary to fully meet water quality standards, whether those are currently existing standards or new standards identified during Phase 2. Phase 3 controls might include new nutrient limits on the WWTPs that discharge directly to the EFLMR, if the EFLMR is still in non-attainment and all other potential remedies have been exhausted. Phase 3 has been set up to coincide with Ohio EPA's schedule to re-assess the EFLMR in 2012 and, if the watershed is still impaired, to develop an agency-led TMDL by 2014. Phase 3 controls are not expected to be in place until 2015 at the earliest.

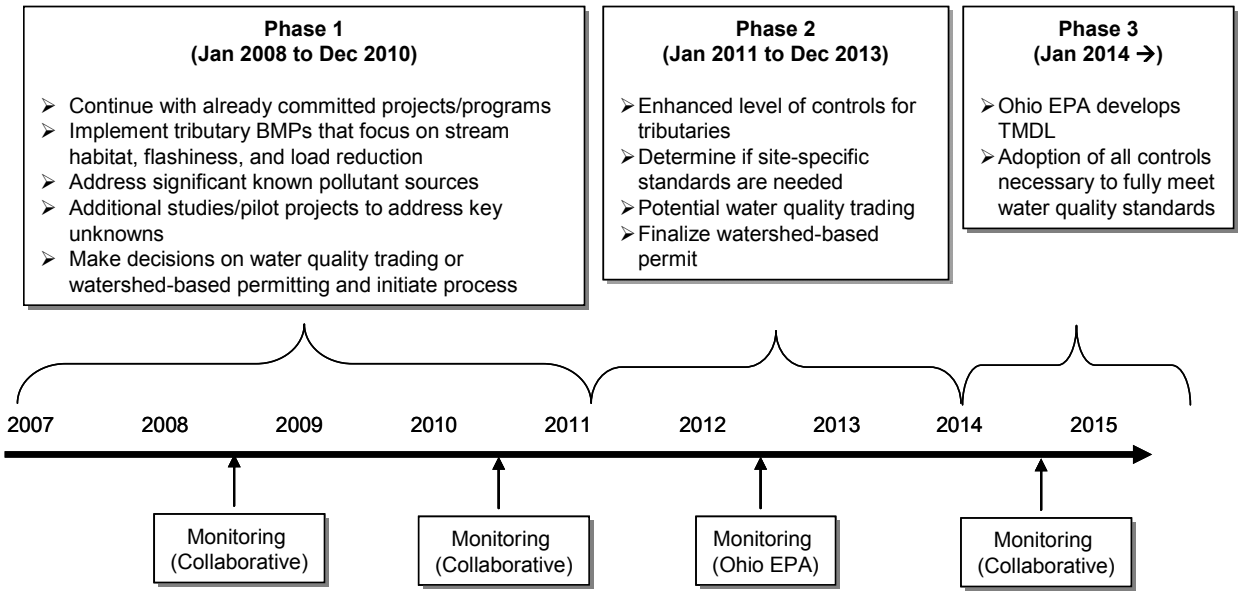


Figure 1-2. Implementation schedule for the EFLMR watershed.

1.5 Description of Report

This report documents the results of the water quality and loading analysis for the EFLMR conducted by the East Fork Watershed Collaborative. Section 2 describes the two methodologies used to identify the most significant factors affecting aquatic community health and discusses the findings, Section 3 describes the approach used to estimate the current and allowable pollutant loads and the resulting load reduction targets. Section 4 presents recommendations for implementation activities. A variety of supporting information is provided in the appendices (Appendix A: Watershed Characteristics; Appendix B: Water Quality Standards; Appendix C: Stressor Identification Results; Appendix D: Biostatistical Modeling; Appendix E: LSPC Modeling; Appendix F: Load Duration Curves; Appendix G: BATHTUB Modeling; and Appendix H: Description of Best Management Practices).

2 APPROACH TO IDENTIFYING THE MOST SIGNIFICANT FACTORS AFFECTING AQUATIC COMMUNITY HEALTH

This section of the document provides a summary of the approach that was used to identify the most significant factors affecting aquatic community health in the EFLMR watershed. It begins with an explanation of Ohio's water quality standards followed by a description of two methodologies used to assess biological conditions in the EFLMR and a discussion of the findings.

2.1 Ohio's Water Quality Standards

Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the Clean Water Act's goal of "swimmable" and "fishable" waters. To determine the status of waters relative to the "swimmable" and "fishable" goals, Ohio EPA first assigns each waterbody in the state to an aquatic life use designation. Aquatic life use categories include Coldwater Habitat, Exceptional Warm Water Habitat (EWH), Seasonal Salmonid Habitat, Warm Water Habitat (WWH), Modified Warmwater Habitat, and Limited Resource Waters. (Each water body may also be assigned a water supply and/or one recreational use designation.) Bioassessments are then performed in these waters to determine if they meet their assigned designations. The ability of a waterbody to meet its aquatic life use designation is based primarily on the scores it receives on two community indices: the Index of Biological Integrity (IBI) and the Invertebrate Community Index (ICI). The IBI is based on the composition of the fish community and the ICI is based on the composition of the macroinvertebrate community. Additional information on the water quality standards that apply to the EFLMR are provided in Appendix B.

As part of evaluating fish IBI scores Ohio EPA also evaluated the frequency of DELT anomalies (deformities, eroded fins, lesions, and tumors). High frequencies of these anomalies have been found to be an accurate indication of pollution stress usually caused by multiple sublethal stresses as the result of degraded water quality (i.e. often a combination of toxic impacts combined with marginal dissolved oxygen concentrations) (Ohio EPA, 2003).

Ohio EPA also uses the Qualitative Habitat Evaluation Index (QHEI) to assess stream habitat conditions. The QHEI is a quantitative composite of six physical habitat variables used to "score" a stream's habitat. The variables are: substrate, instream cover, riparian characteristics, channel characteristics, pool/riffle quality, and gradient and drainage area. The QHEI can be used to assess and evaluate a stream's aquatic habitat, and determine which of the six habitat components need to be improved to reach the QHEI target score. It is important to note that while there are QHEI target values for aquatic life use attainment, Ohio EPA does not have any criteria for QHEI scores or other habitat measures.

The use of bioassessments is a highly effective means of evaluating the cumulative impacts of nonpoint and point source pollution and determining whether biological water quality standards are being met. However, when water quality standards are not met, the bioassessment process does not identify the cause of the impairment. A further analysis is required to obtain a thorough understanding of the reasons for the impairment so that an effective restoration strategy can be identified.

Two parallel and related approaches were used to better understand the reasons for biological impairment in the EFLMR watershed. The Stressor Identification approach utilized a weight-of-evidence process that considered the universe of potential stressors and evaluated the relative probability of each one to contribute to the observed biological impairment. Alternatively, a biostatistical modeling approach relied upon statistical evaluations of the relationships between available biological, physical, and chemical water quality data. These two approaches are described further below.

2.2 Description of the Stressor Identification Process

Biological assessments are useful in detecting impairment, but they do not necessarily identify the cause(s) of impairment. U.S. EPA developed the *Stressor Identification Guidance Document* (Cormier et al., 2000) to assist water resource managers in identifying stressors or combinations of stressors that cause biological impairment. Elements of the stressor identification process were used to evaluate and identify the primary stressors of the fish and benthic macroinvertebrate communities in the biologically impaired streams of the EFLMR.

2.2.1 Methodology

Stressor identification (SI) is a formal and rigorous method that identifies stressors causing biological impairment and provides a structure for organizing the scientific evidence supporting the conclusions. The general Stressor Identification process entails reviewing available information, forming possible stressor scenarios that might explain the impairment, analyzing those scenarios, and producing conclusions about which stressor or stressors are causing the impairment.

Figure 2-1 provides an overview of the Stressor Identification process. The process consists of three main steps:

1) Listing candidate causes of impairment;
2) Analyzing new and previously existing data to generate evidence for each candidate cause; and,
3) Producing a causal characterization using the evidence generated in Step 2 to draw conclusions about the stressors that are most likely to have caused the impairment.

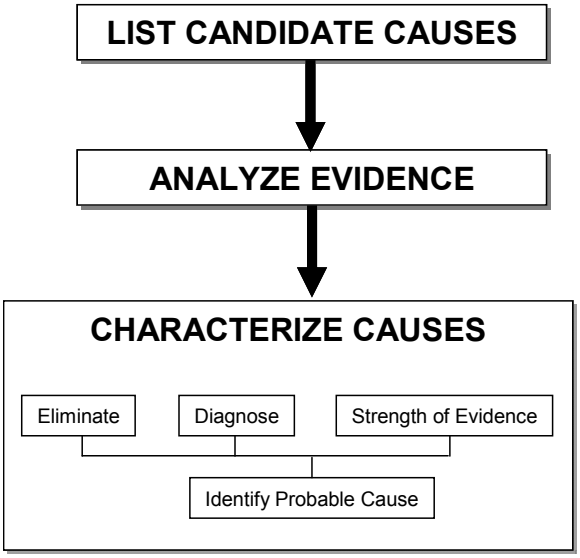


Figure 2-1. Overview of the Stressor Identification process (Cormier et al. 2000).

The first step in the Stressor Identification process for the EFLMR watershed was to develop a list of candidate causes, or stressors, to be evaluated (Table 2-1). A conceptual model was also developed that shows the cause and effect relationships between the stressors (Appendix C). The conceptual model graphically presents the process by which each candidate cause potentially affects the biological community, including any pertinent intermediate steps. In some cases, biological impairment can be linked to a single stressor; in other situations multiple stressors may be responsible for the listed

impairment. The purpose of this conceptual model is to presents all potential causes and their sources that may be present in the watershed.

Table 2-1. List of candidate causes, or stressors, evaluated for the EFLMR watershed.

Water Quality Parameters	
Phosphorus, Total	Arsenic, Dissolved and Total Recoverable
Nitrate and Nitrite	Cadmium, Dissolved and Total Recoverable
Dissolved Oxygen	Chromium, Dissolved and Total Recoverable
Chlorophyll a	Nickel, Dissolved and Total Recoverable
Ammonia	Selenium, Dissolved and Total Recoverable
Ammonia (Un-ionized)	Iron, Dissolved and Total Recoverable
pH	Atrazine
Biochemical Oxygen Demand	Chlorine (Total residual)
CBOD5	Cyanide
Chemical Oxygen Demand (low level)	Phenolic Compounds
Fecal Coliform	Oil & Grease, Total, Hexane Extractable
Total Suspended Solids	Oil and Grease (freon extraction)
Turbidity	Water Temperature
Copper, Dissolved and Total Recoverable	Conductivity
Lead, Dissolved and Total Recoverable	Chlorides
Zinc, Dissolved and Total Recoverable	Sulfate Dissolved
Aluminum, Total Recoverable	
Habitat and Flow Parameters	
QHEI total score	▪ Riparian
▪ QHEI Individual Scores	▪ Pool
▪ Substrate	▪ Riffle
▪ Siltcover	▪ Gradient_S (Score)
▪ Embedded	▪ Gradient_V (Feet/Mile)
▪ Cover	Richards-Baker Flashiness Index
▪ Channel	

The second step in the Stressor Identification process, analyzing evidence, involved gathering and evaluating available information related to each of the potential causes. All information that was known about each waterbody in the watershed was used during this step, including available water chemistry, flow, and habitat data collected by Ohio EPA and others. (It should be noted that data for all of the candidate causes shown in Table 2-1 were not available for every stream that was analyzed. For example, only limited metals data were available in the watershed). Anecdotal information was also compiled for each stream based on discussions with various individuals with local knowledge of the streams.

In the third Stressor Identification step, all of the available information was analyzed and organized to characterize the candidate causes. The available data were used to eliminate, diagnose, and to compare the strength of evidence for each potential stressor in Table 2-1 to identify the primary cause(s) of impairment. The resulting list of high priority stressors for each stream that was evaluated is shown in Table 2-2 (along with a comparison to causes of impairment previously identified by Ohio EPA) and additional details of the Stressor Identification process are included in Appendix C.

2.2.2 Nutrients and the Stressor Identification Process

Nutrient (i.e., phosphorus and nitrogen) concentrations received special attention during the SI process because they have long been considered a primary stressor in the EFLMR watershed. An original goal of the biostatistical modeling was to identify site-specific nutrient targets that could be applied to the EFLMR watershed. However, such targets could not be identified because no strong correlation was found between nutrient concentrations and IBI and ICI scores (see Section 2.3 and Appendix D for details). Despite this finding, phosphorus and nitrogen concentrations were still considered during the SI process and, in the absence of any site-specific targets, Ohio EPA's proposed nutrient criteria (Appendix

B) were applied. As shown in Table 2-2, this resulted in nutrients being identified as high priority stressors in a number of streams, a conclusion which conflicts with the findings of the biostatistical modeling results. The implications of this finding, in contrast to the results of the biostatistical modeling, are further discussed in Section 2.4.

Table 2-2. Summary of high priority stressors for impaired streams in the EFLMR watershed.

Stream	*SI High Priority Stressors*	*Ohio EPA 305(b) Causes of Impairment*
Assessment Unit 100		
East Fork, headwaters to Dodson Creek	Nutrients	Nutrients, Siltation
East Fork, Dodson Creek to Solomon Run	Nutrients	Cause Unknown
West Fork of East Fork	Not Impaired	Not Impaired
Dodson Creek	Nutrients; Sediment, Habitat	Cause Unknown
Turtle Creek	Habitat	Siltation, Cause Unknown
Assessment Unit 110		
East Fork, Howard Run to Todd Run	Nutrients	Siltation, Nutrients
East Fork, Solomon Run to Howard Run	Nutrients; Sediment	Siltation, Nutrients
East Fork, Todd Run to Harsha Lake	Nutrients	Siltation, Nutrients (Howard to Todd and Solomon to Howard)
Kain Run	Nutrients; Organic Enrichment/DO, Habitat	Nutrients
Todd Run	Habitat	Cause Unknown
Pleasant Run	Nutrients, Habitat	Organic enrichment/DO, Flow alteration, Unionized Ammonia
Fivemile Creek	Nutrients, Habitat	Organic enrichment/DO
Assessment Unit 120		
East Fork, below dam to Stonelick	Nutrients	Flow alteration, Nutrients
Lucy Run	Habitat	Other habitat alterations, Nutrients, Pathogens
Fourmile Run	Sediment	Siltation, Other habitat alterations
Ulrey Run	Sediment, Habitat	Organic enrichment/DO, Pathogens
Slabcamp Run	Sediment, Habitat	Organic enrichment/DO, Flow alteration
Barnes Run	Organic; Sediment	Organic enrichment/DO, Siltation
Poplar Creek	Sediment, Habitat	Organic enrichment/DO, Pathogens
Cabin Run	Not Impaired	NA
Assessment Unit 130		
East Fork, mouth to Wolfpen Run	Nutrients; Ammonia; Sediment	Nutrients
Hall Run	Organic Enrichment/Do; Sediment, Habitat	Other habitat alterations, Priority organics, Other Metal
Wolfpen Run	Nutrients, Habitat	Organic enrichment/DO, Pathogens, Other habitat alterations
East Fork, Stonelick Cr to upst Wolfpen Run	Nutrients	Nutrients
Salt Run	Sediment, Habitat	Siltation, Nutrients
Sugarcamp Run	Not Impaired	Nutrients, Thermal modifications, Siltation
Shayler Run	Nutrients; Organic; Sediment, Habitat	Nutrients, Other habitat alterations, Flow alterations
Stonelick Creek	Nutrients	Organic enrichment/DO, Nutrients, Cause Unknown, Flow alteration
Lick Fork	Not Impaired	Organic enrichment/DO, Pathogens
Brushy Fork	Ionic Stress, Habitat	
Newtonsville Creek	Nutrients; Organic Enrichment	

Notes: DO = Organic Enrichment

2.3 Description of Biostatistical Modeling

A biostatistical modeling analysis was also conducted within the EFLMR watershed to further understand the complex relationships among water chemistry, flow, habitat, and biological condition. Whereas the Stressor Identification analysis focused on individual streams, the biostatistical modeling attempted to evaluate stressors for their overall importance throughout the watershed. Specifically, the objectives were to identify environmental factors that are directly and indirectly contributing to biological degradation in the EFLMR; to build empirical models to establish linkages between environmental stressors and the biological community; to develop biological indicators for environmental impairment; and to diagnose stressors that impact biological integrity.

Three statistical approaches were performed to implement the proposed objectives:

- Correlation analyses identify the apparent linkage between biological conditions and environmental variables. They may or may not indicate the real relationship between biological condition (biological indices) and environmental characteristics.
- Canonical Correspondence Analysis (CCA) is a direct gradient analysis, which is designed to detect the patterns of variation in the species data that can be "best" explained by the observed environmental variables. The resulting ordination diagram expresses not only a pattern of variation in species composition but also the main relationships between the species and each of the environmental variables.
- Weighted averaging regression is a method to estimate a taxon's optimal condition for growth and survival, and is used to infer the environmental condition based on all taxa present in the sample.

An initial evaluation of the EFLMR database indicated that there were very few exact matches (less than 60 samples) of macroinvertebrates, fish, and environmental characteristics by site and date. The following procedures were therefore taken to increase the sample size and establish a more statistically-valid database:

- The "window" of water quality samples that were associated with biological samples was expanded to three months before the biological sample;
- The definition of a "site" was expanded to be a contiguous stream reach with no intervening mapped tributaries or discharges. All sites within such a defined contiguous stream reach were then considered multiple observations of the same reach.

In addition to all the regular environmental variables (e.g., water chemistry, QHEI metrics) directly measured by Clermont County and Ohio EPA, a list of other variables were also made available for statistical modeling. For example, hydrology metrics (e.g., percentage over base flow, frequency of high flows, etc.) were calculated from the watershed model and used during the multiple regression analysis as were additional candidate predictor variables obtained from an analysis of subwatershed characteristics (e.g., percent imperviousness, percent forest).

Additional details of the biostatistical modeling process are provided in Appendix D. Among the most significant findings were the following:

- Percent imperviousness was strongly correlated with total nitrogen, nitrate/nitrite, and total phosphorus concentrations.
- A number of ion-related variables were negatively correlated with macroinvertebrate ICI scores. Conductivity is generally an excellent predictor of biological condition of streams because many invertebrate taxa responded strongly to ion gradients.

- Unlike macroinvertebrates, fish were not significantly associated with total ionic strength and most individual ions.
- Ammonia and TKN were significantly negatively correlated with ICI. The negative correlation with ammonia is likely due to ammonia toxicity (especially when ammonia concentrations are greater than one mg/L). The negative correlation with TKN could be due to the fact TKN is a measure of organic enrichment (as well as nitrogen enrichment). For example, BOD also showed a negative correlation with ICI scores.
- Changes in habitat were surprisingly not associated with strong changes in ICI scores. This might have been due to the sampling protocol for macroinvertebrates which relies on artificial substrates. For example, the qualitative sampling of macroinvertebrates (which does not rely on artificial substrates) indicated that they respond strongly to habitat related parameters, especially cover, pool, and gradient.
- Fish IBI scores were highly significantly correlated with habitat scores, especially cover and pool.
- Surprisingly, macroinvertebrate ICI scores were positively correlated with flashiness, the number of falls in flow, and high pulse count and negatively correlated with the number of flow rises and high pulse duration. All of these finding suggest that healthy macroinvertebrate communities prefer low water levels. (The positive correlation with flashiness may again be due to the fact the samples were taken from artificial substrates.)
- Fish were strongly negatively associated with flashiness and strongly positively correlated with high pulse duration and number of flow rises. This suggests that fish prefer high water levels and fewer changes in flow.
- The CCA ordination supports the notion that macroinvertebrates are very sensitive to conductivity, nitrate/nitrite, and total QHEI scores.
- The relationship between nutrient concentrations and fish and macroinvertebrate data were relatively weak compared to some of the flow and habitat factors and were not strong enough to develop site-specific criteria.

Several management recommendations emerged from the findings of the biostatistical modeling effort. First, the following should be prioritized to improve fish IBI scores:

1) decrease flashiness
2) increase instream QHEI cover scores
3) increase QHEI pool scores
4) decrease organic enrichment
5) decrease ammonia

Secondly, the following should be prioritized to improve macroinvertebrate ICI scores:

1) increase instream QHEI pool scores
2) increase QHEI cover scores
3) decrease conductivity
4) decrease organic enrichment
5) decrease ammonia

The implications of these findings for watershed management and TMDL development are discussed in the next section.

2.4 Implications for Watershed Management and TMDL Development

The results of the Stressor Identification and biostatistical modeling analyses have a variety of important implications for water resource management and TMDL development in the EFLMR watershed. One interesting conclusion of the biostatistical modeling is that there is only a weak relationship between nutrient concentrations and biological conditions in the watershed. This conclusion is supported by the fact that several streams have demonstrated attainment of the biocriteria despite nutrient concentrations that exceed Ohio EPA's proposed criteria (Table 2-3). One possible explanation for this may be that some other factor (such as light availability, flow levels, substrate, grazing, or bedrock type) is limiting algal growth in these streams.

Nutrients and Aquatic Life

Nutrients rarely approach concentrations in the ambient environment that are toxic to aquatic life; in fact, nutrients are essential in minute amounts for the proper functioning of healthy aquatic ecosystems. However, nutrient concentrations in excess of these minute needs can exert negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al., 1994). Increased plant production increases turbidity, decreases minimum dissolved oxygen concentrations, and increases fluctuations in diurnal dissolved oxygen and pH levels. Such changes shift aquatic species composition away from functional assemblages comprised of intolerant species, benthic insectivores, and top carnivores that are typical of high quality streams towards less desirable assemblages of tolerant species, generalists, omnivores, and detrivores that are typical of degraded streams (OEPA, 1999). Such a shift in community structure lowers the diversity of the system.

Perhaps even more significantly, the biostatistical modeling suggests that meeting the biological criteria in currently impaired streams will be more dependent on addressing habitat factors, such as improving instream QHEI cover and pool scores, than reducing pollutant loadings. This can be done by establishing riparian setbacks to allow natural vegetation to occur and to restrict activities that might affect stream channel development, as well as various other measures designed to promote a natural stream corridor (see Section 4 for more details). Flashiness (or the frequency and rapidity of short term changes in streamflow) was also found to be strongly correlated to fish scores and therefore the control of stormwater runoff should be a high priority in the watershed. Controlling stormwater runoff also has the added benefits of mitigating the damage caused by flooding and indirectly reduces sediment and nutrient loading. By trying to maintain or mimic the existing hydrology as new development occurs, the existing stream morphology is protected, bank and channel erosion is minimized, and, as a result, loads of sediment and nutrients are reduced. A variety of storm water best management practices are identified in Section 4.

The finding that habitat and flashiness are among the most important variables in controlling biological health in the EFLMR posed some challenges with regard to TMDL development and eventually resulted in the Collaborative deciding to not pursue a locally-led TMDL. This is because the U.S. EPA has made a determination that some categories of water quality impairment, including flow and habitat alterations, are best resolved through measures other than TMDLs[1]. On the other hand, TMDLs are required to address impairments caused by discrete "pollutants," such as nutrients and sediment. The Collaborative factored these considerations into its adoption of a phased approach to implementation that is described in Section 1.4. Other considerations in deciding to not pursue a locally-led TMDL included the following:

- Because the biostatistical modeling did not find a strong correlation between nutrients and biological condition, it was not possible to develop site-specific nutrient targets for the EFLMR watershed. Ohio EPA's statewide values (Ohio EPA, 1999) were therefore the only ones available for estimating needed nutrient load reductions. Application of these values to many streams in the EFLMR watershed resulted in very high, potentially unrealistic, load reduction recommendations. The Collaborative was concerned with "formalizing" these load reduction

[1] The reason that U.S. EPA has made this determination is that stressors such as flow and habitat and other categories of "pollution" do not lend themselves well to calculating daily loads.

recommendations through the development of a TMDL, especially those associated with wastewater and MS4 stormwater sources and subject to the NPDES Program, especially given the fact that some streams have attained biological criteria despite nutrient concentrations that exceed Ohio EPA's target levels.

- The presence of Harsha Lake in the middle of the EFLMR watershed complicated development of a TMDL. For example, Ohio EPA has not yet established lake water quality standards and therefore it was unclear what in-lake targets should be used to develop the TMDL. Secondly, there is currently a lack of information concerning how loads into the lake impact lake water quality, as well as how lake water quality impacts downstream conditions.
- Many of the advantages typically associated with the TMDL Program (e.g., science-based, quantifiable goals, increased awareness of water quality issues) have already been addressed in the EFLMR watershed through other efforts associated with watershed management.
- Other advantages associated with development of a TMDL (e.g., framework for watershed-based trading or permitting) are considered to still be possible using the information contained in this report and the associated Watershed Action Plans.

Table 2-3. Streams in the EFLMR that have attained biological criteria despite nutrient concentrations that exceed the state's proposed criteria.

Stream	*IBI Score*	*ICI Score*	*Total Phosphorus (mg/L)*				*Nitrate (mg/L)*			
			Criterion	*25th Perctile.*	*Median*	*75th Perctile.*	*Criterion*	*25th Perctile.*	*Median*	*75th Perctile.*
Poplar Creek[1]	38	N/A	0.08	0.07	0.09	0.13	1.0	0.10	0.16	0.71
Ulrey Run[2]	40	N/A	0.08	0.13	0.19	0.25	1.0	1.14	1.74	2.15
EFLMR Below Harsha Lake[3]	48.6	38.2	0.10	0.14	0.23	0.32	1.0	0.65	1.26	1.75

Notes: N/A = Not Available; Perctile = Percentile

[1] Poplar Creek IBI score is from 1997 and phosphorus and nitrate data collected between 1996 and 2002; more than 60 samples of each parameter.

[2] Ulrey Run IBI score is from 1997 and phosphorus and nitrate data collected between 1996 and 2002; more than 100 samples of each parameter.

[3] EFLMR Below Harsha Lake IBI and ICI scores are average from multiple stations from 2000 to 2005; phosphorus and nitrate data collected between 1996 and 2002; more than 1,000 samples of each parameter.

3 EXISTING CONDITIONS AND RECOMMENDATIONS BY WATERBODY

A summary of existing conditions and the recommended BMPs for the various waterbodies in the EFLMR watershed is presented in this section of the report. The approaches used to estimate existing and allowable loads and to estimate the most significant sources are described first, followed by the individual results for each waterbody.

Estimates of existing and recommended pollutant loads are presented in this section of the report even though, throughout the watershed, flow and habitat factors are considered more significant factors affecting aquatic community health than is water chemistry. The estimated load reductions are based on the results of the Stressor Identification analysis which, as explained previously, are not necessarily the same conclusions reached through the biostatistical modeling efforts. Therefore the load reductions presented here must be interpreted carefully and *are primarily for information purposes only to help guide implementation efforts*. This is because pollutant loads are still an important contributor to water quality impairment (especially in certain streams) and the loading analysis provides important insight into implementation priorities. For example, it suggests which locations are in need of the most attention and the critical time periods during which water quality is poorest.

3.1 Approach to Estimating Current and Recommended Loads and Identifying Probable Sources

Existing and recommended loads for each waterbody in the EFLMR were determined through the use of load duration curves. The load duration curve approach is widely used for this type of analysis and is especially appropriate when a large amount of water quality data are available (such is the case for many of the EFLMR streams). The approach involves calculating the allowable loadings over the range of flow conditions expected to occur in the impaired stream by taking the following steps:

1. A flow duration curve for the stream is developed by generating a flow frequency table and plotting the data points to form a curve. The data reflect a range of natural occurrences from extremely high flows to extremely low flows.

2. The flow curve is translated into a load duration curve by multiplying each flow value by the water quality standard/target for a particular contaminant, then multiplying by a conversion factor. The targets used for this analysis are presented in Appendix B. The resulting points are plotted to create a load duration curve.

3. Each water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was collected. Then, the individual loads are plotted as points on the graph and can be compared to the water quality standard/target.

4. Points plotting above the curve represent deviations from the water quality standard/target and the daily recommended load. Those plotting below the curve represent compliance with standards and the daily recommended load. Further, it can be determined which locations contribute loads above or below the water quality standard/target.

5. The area beneath the curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards/targets.

An example load duration curve is presented in Figure 3-1 and illustrates that observed total suspended solids loads exceed the recommended loads primarily during high flows zones (left portion of graph) and

are usually below allowable loads during low flow zones. The figure also indicates that excessive loads primarily occur during periods when surface runoff exceeds subsurface flows. The detailed results of the load duration analysis for the EFLMR watershed are presented in Appendix F.

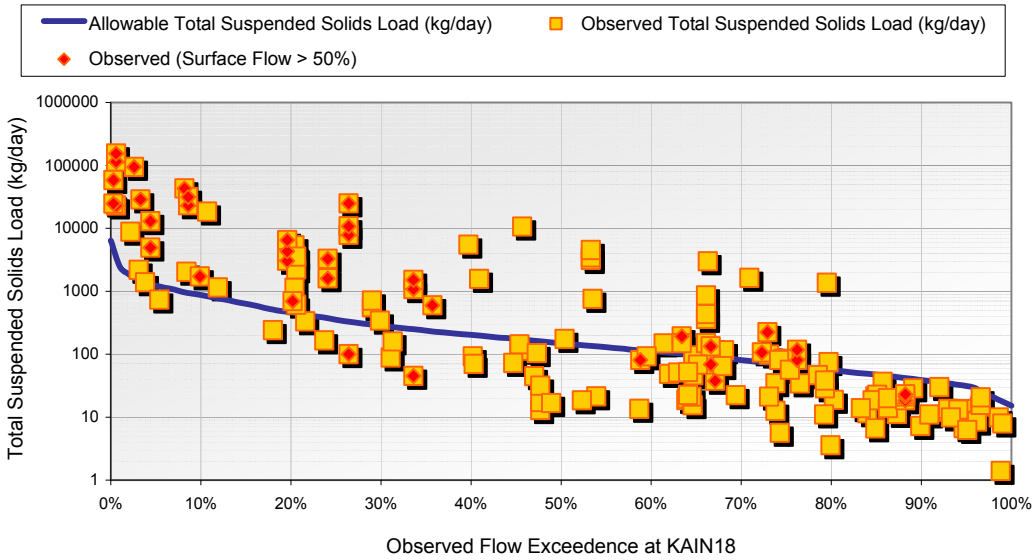


Figure 3-1. Total suspended solids load duration curve example for monitoring station KAIN18 located on Kain Run.

The stream flows displayed on a load duration curve may be grouped into various flow regimes to aid with interpretation of the load duration curves. The flow regimes are typically divided into 10 groups which can be further categorized into the following five "hydrologic zones" (Cleland, 2005):

- High flow zone: stream flows that plot in the 0 to 10 percentile range, related to flood flows.
- Moist zone: flows in the 10 to 40 percentile range, related to wet weather conditions.
- Mid-range zone: flows in the 40 to 60 percentile range, median stream flow conditions;
- Dry zone: flows in the 60 to 90 percentile range, related to dry weather flows.
- Low flow zone: flows in the 90 to 100 percentile range, related to drought conditions.

The Loading Simulation in C++ Program (LSPC) watershed model was used to further assess the significance of various pollutant sources in the EFLMR watershed. A watershed model is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate naturally occurring land-based processes over an extended period of time, including hydrology and pollutant transport. LSPC is a version of the Hydrologic Simulation Program Fortran (HSPF) model that has been ported to the C++ programming language to improve efficiency and flexibility. It is currently maintained by the EPA Office of Research and Development in Athens, Georgia and has been used to support TMDL development in numerous studies throughout the country.

Configuration of the EFLMR LSPC model involved consideration of five major components: channel configuration, subwatershed segmentation, meteorological data, land use representation, and point sources. The model was configured to simulate the watershed as a series of 249 hydrologically connected subwatersheds. Details of the model setup and calibration results are presented in Appendix E.

3.2 Recommendations by Waterbody

This section of the report provides recommendations for the individual waterbodies in the EFLMR watershed, starting with those located upstream of Harsha Lake. This section of the report provides recommendations for pollutants identified as primary causes of impairment by the Stressor Identification approach. Findings of the biostatistical modeling are not taken into account.

3.2.1 Upstream of Harsha Lake

Recommendations for the following waterbodies are presented in this section of the report (Figure 3-2):

- East Fork Little Miami River Upstream of Harsha Lake
- Barnes Run
- Cabin Run
- Cloverlick Creek
- Dodson Creek
- Fivemile Creek
- Glady Run
- Kain Run
- Grassy Fork
- Pleasant Run
- Poplar Creek
- Slabcamp Run
- Turtle Creek
- Ulrey Run
- West Fork East Fork

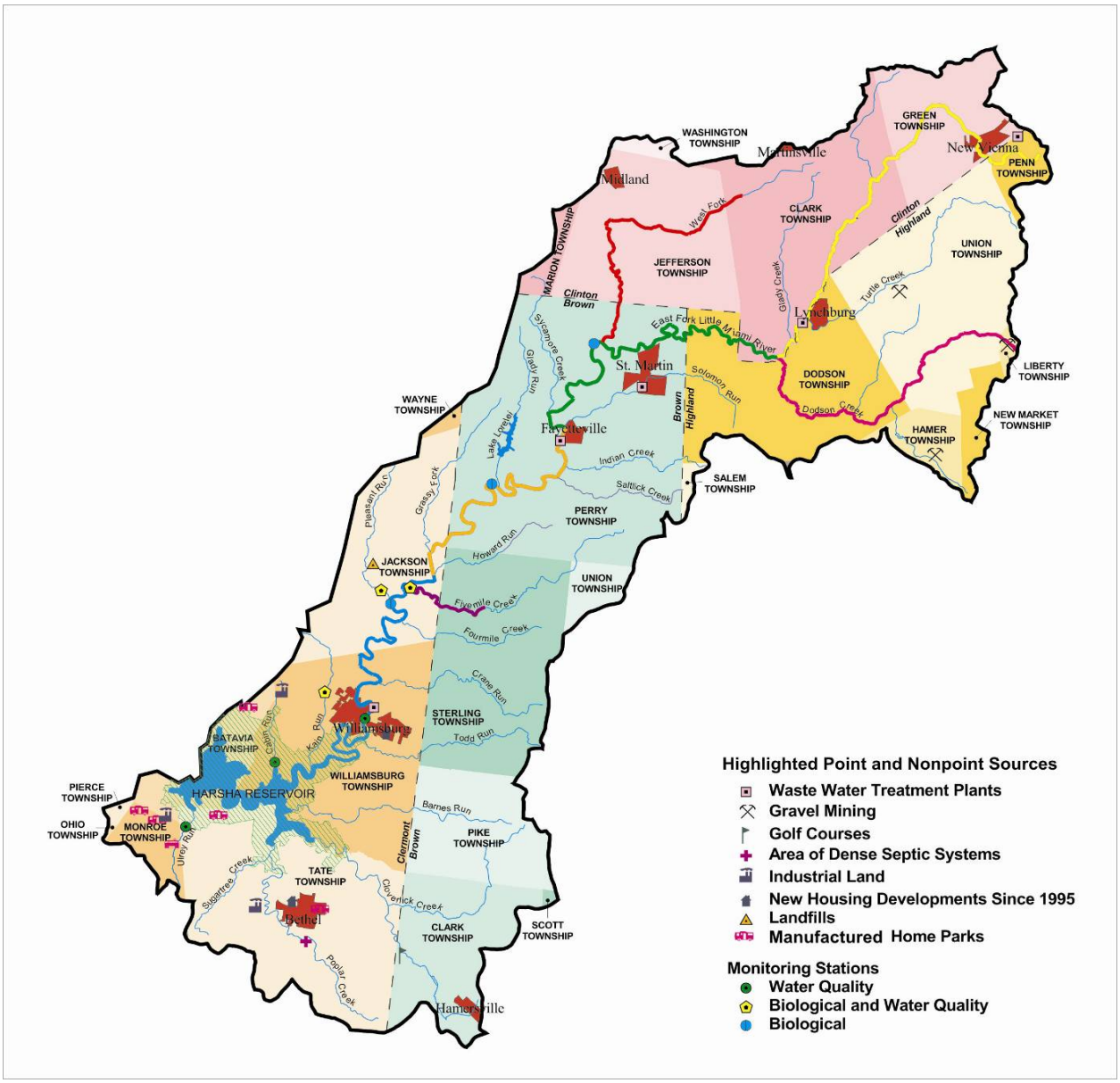


Figure 3-2. The EFLMR watershed upstream of Harsha Lake.

3.2.1.1 East Fork Little Miami River Upstream of Harsha Lake

In 1998 the EFLMR from Dodson Creek to Solomon Run was listed as being impaired due to siltation, organic enrichment and dissolved oxygen; the rest of the EFLMR downstream to Harsha Lake was listed as being impaired due to organic enrichment and dissolved oxygen. Biological sampling conducted since 1998 indicates that the average IBI score is 48.5 (nonsignficant departure from criterion) and the average ICI score is 37 (which does not meet the criterion). Both scores represent improved conditions compared to historical sampling.

Because of the improving conditions, and because flow and habitat impairments are believed to be the primary stressors in the EFLMR upstream of Harsha Lake, no Phase 1 load reductions are presented here. The Collaborative believes that Phase 1 and Phase 2 activities will be enough to bring the EFLMR into full attainment prior to Phase 3.

3.2.1.2 Barnes Run

Barnes Run, a tributary to Harsha Lake, is in non-attainment of its warmwater habitat (WWH) aquatic life use designation. This assessment unit is dominated by row crop agriculture with some livestock production; however, land use changes due to population growth and development are expected within the next twenty years.

Ohio EPA conducted a biological survey at River Mile 1.9 of Barnes Run in 1997. The survey resulted in an IBI score of 24, well below the criteria value of 40 for warmwater habitat (WWH). The DELT score was 5, indicating that the species of fish present did not appear to be overly stressed. Ohio EPA suggested in their 2000 report that this poor performance indicated an impact beyond siltation from agricultural land use and narrow riparian corridors. Bacterial problems associated with land use and failing household sewage treatment systems (HSTS) might be causing the observed impairment.

The Stressor Identification process concluded that the primary pollutants stressing aquatic life in Barnes Run are organic enrichment (fecal coliform) and sediment (TSS). The load reductions are presented in Table 3-1 and the LSPC modeling analysis suggests the primary source or sediment is row crops (94%). The most likely sources of fecal coliform are failing HSTS, agricultural runoff, livestock, and wildlife. Potential activities to address these sources can be found in Section 4 of this report and the *East Fork Lake Tributaries Watershed Management Plan*.

Table 3-1. Load reduction recommendations for Barnes Run (BARNS1.9).

Barnes Run Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**Loading Component**	0-10	10-40	40-60	60-90	90-100
Total Suspended Solids (kg/day)	Current Load	4,387	154	134	16	18
	Recommended Load	2,358	679	288	131	60
	Non-MS4 Stormwater	2,358	679	288	131	60
	MS4 Stormwater	N/A	N/A	N/A	N/A	N/A
	Load Reduction (%)	-46%	0%	0%	0%	0%
Fecal Coliform (Million/day)	Current Load	1,722,003	54,909	38,675	1,113	2,681
	Recommended Load	862,126	179,944	74,227	37,756	21,722
	Non-MS4 Stormwater	862,126	179,944	74,227	37,756	21,722
	MS4 Stormwater	N/A	N/A	N/A	N/A	N/A
	Load Reduction (%)	-50%	0%	0%	0%	-50%

3.2.1.3 Cabin Run

Cabin Run, a tributary to Harsha Lake, is in full attainment of its warmwater habitat (WWH) aquatic life use designation. This watershed lies in a steep valley consisting of mostly forested land and residential land use. The headwaters of Cabin Run are located in a commercial and residential developed landscape and begin at a large manufacturing facility.

Ohio EPA conducted a biological survey at River Mile 1.3 of Cabin Run in 1998. The survey resulted in an IBI score of 47. The DELT score was 5, indicating that the species of fish present did not appear to be overly stressed. Since the aquatic life use support is being met, no TMDL for nutrients, sediments, etc. has been developed.

The Ohio EPA 2000 report stated that some bacterial spikes suggest sewage inputs, probably from residential HSTS. However, the load duration curve analysis (Appendix F) suggests that fecal coliform load reductions are not required.

3.2.1.4 Cloverlick Creek

Cloverlick Creek, a tributary to Harsha Lake, is in partial attainment of its warmwater habitat (WWH) aquatic life use designation. This assessment unit is dominated by row crop agriculture and some livestock production and horse farms; however, land use changes due to population growth and development are expected within the next twenty years.

Only two miles of Cloverlick Creek have been surveyed; until the remaining 8.6 miles of Cloverlick are assessed the status of the whole creek is unknown. Ohio EPA indicated in their 2000 report that siltation from non-irrigated row crop production was the cause and source of impairment. The Stressor Identification process also concluded that sediment is a primary stressor in Cloverlick Creek, along with total phosphorus; the available data also suggest that fecal coliform load reductions are needed. The recommended load reductions are presented in Table 3-2 and the LSPC modeling analysis suggests the primary sources of nutrients are row crops (86% nitrogen, 77% phosphorus) and pasture/hay/grasslands (9% nitrogen, 19% phosphorus), while the primary source of sediment is row crops (94%). The most likely sources of fecal coliform are failing HSTS, agricultural runoff, livestock, and wildlife. Potential activities to address these sources can be found in Section 4 of this report and the *East Fork Lake Tributaries Watershed Management Plan*. Additional sampling (biology, habitat, and water chemistry) should be performed and additional controls identified as a result of those findings.

Table 3-2. Load reduction recommendations for Cloverlick Creek (CLOVER5.1).

Cloverlick Creek Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	Loading Component	0-10	10-40	40-60	60-90	90-100
Total Phosphorus (kg/day)	Current Load	82.70	24.32	No Data	1.18	0.74
	Recommended Load	26.14	7.53	3.20	1.46	0.67
	Non-MS4 Stormwater	26.14	7.53	3.20	1.46	0.67
	MS4 Stormwater	0.00	0.00	0.00	0.00	0.00
	Load Reduction (%)	-68%	-69%	No Data	0%	-10%
Total Suspended Solids (kg/day)	Current Load	10,431	332	No Data	45	25
	Recommended Load	6,536	1,882	799	364	167
	Non-MS4 Stormwater	6,536	1,882	799	364	167
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-37%	0%	No Data	0%	0%
Fecal Coliform (Million/day)	Current Load	13,720,579	66,006	19,133	6,069	1,833
	Recommended Load	2,389,944	498,833	205,769	104,666	60,216
	Non-MS4 Stormwater	2,389,944	498,833	205,769	104,666	60,216
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-83%	0%	0%	0%	0%

3.2.1.5 Dodson Creek

Dodson Creek, a tributary to the EFLMR, is in non-attainment of its exceptional warmwater habitat (EWH) aquatic life use designation. Potential contributors to the water quality impairment include two surface mining operations, unfenced livestock pasture in riparian areas, as well as nutrient and sediment runoff from row crop agriculture.

Ohio EPA has only conducted a biological survey along one mile of the 11.5 miles of Dodson Creek at River mile 0.2 in 1982 and 1998. Early surveys conducted in 1982 resulted in an average IBI score of 44.7, short of meeting the exceptional warmwater habitat (EWH) criterion of 50. Two additional fish surveys were conducted in 1998, and there was a large discrepancy between the July fish sample (IBI of 30) and the August sample (IBI of 44). The macroinvertebrate community rated good in 1998. Ohio EPA's 2000 report noted that habitat quality dropped considerably between 1982 and 1998 as the result of heavy erosion in the watershed, increased embeddedness and reduced riffle habitat.

The LSPC modeling analysis suggests the primary sources of nutrients are row crops (74% nitrogen, 80% phosphorus) and pasture/hay/grasslands (17% nitrogen, 13% phosphorus), while the primary source of sediment is row crops (97%) with an unknown contribution from the surface mining operations and bank channel erosion associated with unrestricted livestock operations. The most likely sources of fecal coliform are failing HSTS, agricultural runoff, livestock, and wildlife.

The Stressor Identification process concluded that the primary aquatic life stressors in Dodson Creek are nutrients (both phosphorus and nitrate), sediment, and habitat alteration. However, there was not enough recent data to identify load reduction recommendations in Dodson Creek. Instead, it is recommended that BMPs be put in place to address the known problems associated with livestock having direct access to the stream and failing HSTS. This should result in improved habitat and reduced sediment, nutrient, and pathogen loadings. Additional sampling (biology, habitat, and water chemistry) should be performed and additional controls identified as a result of those findings.

3.2.1.6 Fivemile Creek

Fivemile Creek, a tributary to the EFLMR, is partially meeting its warmwater habitat (WWH) aquatic life use designation. This assessment unit is dominated by row crop agriculture with some livestock production; however, land use changes due to population growth and development are expected within the next twenty years.

Ohio EPA conducted a biological survey of Fivemile Creek at River Mile 0.4 in 1982 and River Mile 0.5 in 1998. The 1982 survey resulted in an IBI score of 36, just below the criteria value of 40 for warmwater habitat (WWH). The 1998 study resulted in a failing IBI score of 32; this may have been affected by low flow conditions. The DELT score in both surveys was 5, indicating that the species of fish present did not appear to be overly stressed. Bacterial exceedences suggested inputs of sewage from failing HSTS or, possibly, animal waste from poorly managed agricultural concerns in this rural watershed.

The LSPC modeling analysis suggests the primary sources of nutrients are row crops (68% nitrogen, 69% phosphorus) and pasture/hay/grasslands (27% nitrogen, 22% phosphorus), while the primary source of sediment is row crops (96%). The most likely sources of fecal coliform are failing HSTS, agricultural runoff, livestock, and wildlife.

The Stressor Identification process concluded that the primary aquatic life stressors in Fivemile Creek are nutrients and habitat alteration. However, there was not enough recent data to identify load reduction recommendations in Fivemile Creek. Instead, it is recommended that BMPs be put in place to improve riparian habitat conditions and to fix failing HSTS. Additional sampling (biology, habitat, and water chemistry) should be performed and additional controls identified as a result of those findings.

3.2.1.7 Glady Run

Glady Run, a tributary of the EFLMR, has not been assessed. It is unknown whether Glady Run is meeting its warmwater habitat (WWH) use designation. Glady Run is impounded to form Lake Lorelei.

There were not enough current data to estimate loadings to Glady Run. The LSPC modeling analysis suggests the primary sources of nutrients are row crops (61% nitrogen, 60% phosphorus), and pasture/hay/grasslands (29% nitrogen, 23% phosphorus), while the primary source of sediment is row crops (94%). Potential activities to address these sources can be found in Section 4 of this report and the *East Fork Lake Tributaries Watershed Management Plan*. Additional sampling (biology, habitat, and water chemistry) should be performed to determine the biological condition of Glady Run.

3.2.1.8 Kain Run

Kain Run, a tributary to Harsha Lake, is in non-attainment of its warmwater habitat (WWH) aquatic life use designation. This assessment unit is dominated by row crop agriculture with some livestock production; however, land use changes due to population growth and development are expected within the next twenty years.

Ohio EPA conducted biological surveys at River Mile 0.3 of Kain Run in 1997. The survey resulted in an IBI score of 30, well below the criteria value of 40 for warmwater habitat (WWH). The DELT score was 3, indicating some level of stress in the fish collected. Ohio EPA suggested that this poor performance might be due to low flow conditions, citing that few fish were collected given the high quality of the physical habitat of the stream. They did observe significant growths of in-stream algae, indicative of organic enrichment or excessive nutrient loading from agricultural land use. Kain Run was also surveyed by Clermont County in 2000 (RM 0.3) and 2001 (RM 0.3, RM 1.8 and RM 3.0). All of the county's fish

surveys resulted in failing IBI scores, ranging from 30 to 35, with the highest scores reported at the most downstream site (RM0.3). Recreational uses are also not supported due to high fecal coliform counts. The Stressor Identification process concluded that the primary aquatic life stressors in Kain Run are nutrients (phosphorus), organic enrichment/DO (fecal coliform and CBOD5), and habitat. The load reduction recommendations are presented in Table 3-3 and the LSPC modeling analysis suggests the primary sources of nutrients are runoff from row crops (85% nitrogen, 78% phosphorus) and pasture/hay/grassland (9% nitrogen, 18% phosphorus), while the primary source of sediment is row crops (95%). The most likely sources of fecal coliform are failing HSTS, agricultural runoff, livestock, and wildlife. Potential activities to address these sources can be found in Section 4 of this report and the *East Fork Lake Tributaries Watershed Management Plan*.

Table 3-3. Load reduction recommendations for Kain Run (KAIN18).

Kain Run Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**Loading Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Total Phosphorus (kg/day)	Current Load	32.0	6.9	1.3	0.5	0.2
	Recommended Load	3.9	1.1	0.5	0.2	0.1
	Non-MS4 Stormwater	3.9	1.1	0.5	0.2	0.1
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-88%	-84%	-64%	-58%	-38%
Total Suspended Solids (kg/day)	Current Load	23,138	1,144	92	42	11
	Recommended Load	1,224	352	150	68	31
	Non-MS4 Stormwater	1,224	352	150	68	31
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-95%	-69%	0%	0%	0%
Fecal Coliform (Million/day)	Current Load	1,235,776	68,182	7,304	579	73
	Recommended Load	447,432	93,389	38,523	19,595	11,273
	Non-MS4 Stormwater	447,432	93,389	38,523	19,595	11,273
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-64%	0%	0%	0%	0%

3.2.1.9 Grassy Fork

Grassy Fork, a tributary to EFLMR, has not been assessed, so it is unknown if it meets its WWH use designation. This assessment unit is primarily an agricultural watershed.

The Stressor Identification process concluded that the primary aquatic life stressors in Grassy Fork are nutrients (nitrogen and phosphorus). However, there was not enough recent data to calculate load reduction recommendations. Therefore BMPs should be put in place to improve riparian habitat conditions and to address any significant known pollutant sources, such as failing residential HSTS. Additional sampling (biology, habitat, and water chemistry) should be performed and additional controls identified as a result of those findings.

3.2.1.10 Pleasant Run

Pleasant Run, a tributary to the EFLMR, is not fully meeting its WWH water quality use designation. This assessment unit is dominated by row crop agriculture with some livestock production.

Ohio EPA surveyed Pleasant Run at River Mile 1.3 in 1997. The survey resulted in an IBI score of 38, not significantly different from the criteria value of 40. In 1998, Ohio EPA sampled the stream at RM 0.5 (IBI = 35), RM 1.3 (IBI = 40), RM 2.5 (IBI = 35), and RM 4.0 (IBI = 12). The poor scores upstream of the hazardous waste landfill were attributed to a combination of intermittent stream flows, high bacteria and ammonia levels, and low dissolved oxygen levels. The DELT score at RM 4.0 was 1, indicating that a

high percentage of the fish collected exhibited some form of anomaly. Conditions gradually improved in the lower reaches of the stream, with IBI scores ranging from 35 to 40 and DELT scores of 3 to 5. Clermont County has also monitored conditions in Pleasant Run extensively, beginning in 1996 and most recently in 2003. All of the county's sampling has been done at RM 0.2, just upstream of the confluence of Pleasant Run with the EFLMR. IBI scores have ranged from a low of 30 in 2000 to a high of 44 in 1997, with no apparent temporal trend.

The Stressor Identification process concluded that the primary aquatic life stressors in Pleasant Run are nutrients (TP and NO2NO3) and habitat alterations. The load reduction recommendations are presented in and the LSPC modeling analysis suggests the primary sources of nutrients are row crops (77% nitrogen, 72% phosphorus) and forested lands (18% phosphorus). The most likely sources of fecal coliform are failing HSTS, agricultural runoff, livestock, and wildlife. Potential activities to address these sources can be found in Section 4 of this report and the *East Fork Lake Tributaries Watershed Management Plan*.

Table 3-4. Load reduction recommendations for Pleasant Run (PLEAS02).

Pleasant Run Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**Loading Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Total Phosphorus (kg/day)	Current Load	31.2	8.9	2.0	0.8	0.4
	Recommended Load	7.8	2.3	1.0	0.4	0.2
	Non-MS4 Stormwater	7.8	2.3	1.0	0.4	0.2
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-75%	-75%	-51%	-48%	-55%
Nitrite Plus Nitrate as Nitrogen (kg/day)	Current Load	102.6	17.9	3.9	1.1	0.3
	Recommended Load	97.9	28.2	12.0	5.5	2.5
	Non-MS4 Stormwater	97.9	28.2	12.0	5.5	2.5
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-5%	0%	0%	0%	0%

3.2.1.11 Poplar Creek

Poplar Creek, a tributary to the EFLMR, is meeting its WWH water quality use designation. This assessment unit is comprised of mixed land uses including residential, industrial, commercial, and agricultural.

Ohio EPA surveyed Poplar Creek at River Mile 3.8 in 1997. The survey resulted in an IBI score of 38, not significantly different from the criteria value of 40. The DELT score was 3. Qualitative macroinvertebrate data indicated a marginally good biological community. No nutrient or sediment load reduction recommendations were developed for Poplar Creek because the biological water quality standards are being met.

Fecal coliform load reduction recommendations were developed for Poplar Creek because of sampling that indicates water quality standards are exceeded during high flows. Because loads only appear to be a problem at high flows, the most likely sources of fecal coliform are failing HSTS and runoff from manured agricultural fields. Re-suspension of fecal coliform in the sediment is also a possibility. Potential activities to address these sources can be found in Section 4 of this report and the *East Fork Lake Tributaries Watershed Management Plan*.

Table 3-5. Load reduction recommendations for Poplar Creek (POPLAR21).

POPLAR21 Load Reductions		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	Loading Component	0-10	10-40	40-60	60-90	90-100
Fecal Coliform (Million/day)	Current Load	8,698,649	84,936	15,119	2,122	208
	Recommended Load	1,909,773	398,611	164,427	83,637	48,118
	Non-MS4 Stormwater	1,909,773	398,611	164,427	83,637	48,118
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-80%	0%	0%	0%	0%

3.2.1.12 Slabcamp Run

Slabcamp Run, a tributary to Harsha Lake, is not meeting its WWH water quality use designation. The dominant land uses are forest and residential/other land use. The headwaters of Slabcamp Run are influenced by a large industrial manufacturing facility, rail lines, and multi-lane roads. Slabcamp Run enters Harsha Lake directly above the Bob McEwen Water Treatment Plant intake.

Ohio EPA surveyed Slabcamp Run at River Mile 2.6 in 1998. The survey resulted in an extremely low IBI score of 23. The DELT score was 3. Both of these ratings are poor. Ohio EPA, in its 2000 report, stated that Slabcamp Run had intermittent flow conditions. Additional stress and degradation were suggested by elevated nutrients and high bacterial counts most likely caused by failing residential HSTS.

The LSPC modeling analysis suggests the primary sources of nutrients are row crops (45% nitrogen, 36% phosphorus), pasture/hay/grasslands (23% nitrogen, 42% phosphorus), and forested lands (23% nitrogen, 15% phosphorus), while the primary sources of sediment are row crops (68%) and forested land (21%). The most likely sources of fecal coliform are failing HSTS, agricultural runoff, livestock, and wildlife.

The Stressor Identification process concluded that the primary aquatic life stressors in Pleasant Run are sediment (TSS) and habitat alterations. However, there were insufficient data in Slabcamp Run to calculate load reduction recommendations. Instead, it is recommended that BMPs be put in place to improve riparian habitat conditions and to address the known failing residential HSTS. Additional sampling (biology, habitat, and water chemistry) should be performed and additional controls identified as a result of those findings.

3.2.1.13 Turtle Creek

Turtle Creek, a tributary to the EFLMR, is only partially meeting its WWH aquatic life use designation. This assessment unit is dominated by row crop agriculture with some livestock production. Part of the Village of Lynchburg is in the assessment unit. Two active quarries drain to Turtle Creek.

Ohio EPA conducted biological surveys at River Miles 1.7 and 4.4 of Turtle Creek in 1998. River Mile 1.7 had an average IBI score of 35, which is fair, but does not meet the WWH standard. River mile 4.4 scored slightly lower with and IBI score of 32. Qualitative samples of macroinvertebrates were collected at stream mile 1.7, and received a rating of very good. Both sites exhibit moderately good habitat with some siltation problems. Ohio EPA specifically noted in their 1998 assessment that there was heavy siltation downstream of the surface mining operation on Sharpsville Rd.

The Stressor Identification process concluded that the primary aquatic life stressor in Turtle Creek was habitat alterations. As such, remedial activities should focus on improving habitat rather than reducing pollutant loads; no load allocations were therefore developed.

3.2.1.14 Ulrey Run

Ulrey Run, a tributary to Harsha Lake, is in full but threatened attainment of its WWH water quality use designation. This assessment unit is primarily forested and residential/commercial and includes the Forest Creek Manufactured Home Park.

Ohio EPA surveyed Ulrey Run at River Mile 1.9 in 1997. The survey resulted in an IBI score of 40 and a DELT score of 5 which were both good. The "Full, But Threatened" designation was due to marginal qualitative macroinvertebrate scores. No load reduction recommendations were developed for Ulrey Run because the biological water quality standards are being met.

Clermont County data indicate occasional exceedances of the fecal coliform criteria; however, the load duration curve analysis (Appendix F) suggests that fecal coliform load reductions are not required.

3.2.1.15 West Fork East Fork

The West Fork of the East Fork Little Miami River is meeting its WWH aquatic life use designation in the 1 mile that has been assessed. However, visual inspection of the stream below its confluence with A.E. Patton County Ditch suggests that organic enrichment and high nutrients from failing HSTS are causing impairment of the West Fork upstream of the Westboro Reservoir. Also, the West Fork is notable for having the longest channelized segment of any major tributary of the East Fork, adjacent to Jonesboro Road near Frazier Road.

Ohio EPA conducted biological surveys near the mouth of West Fork East Fork. IBI scores from 1982 and 1998 surveys were similar, with average IBI scores of 38.7 and 38, respectively. The stream just barely met its WWH use designation both years. A qualitative survey of macroinvertebrates at this same location in 1998 yielded "very good" results. Habitat scores were good in both 1982 and 1998, although the QHEI score dropped in 1998 from 78.5 in 1982 to 71. This drop in 1998 habitat was due to increased siltation and embeddedness.

No load reduction recommendations for nutrients, sediments, etc. were developed for West Fork because the biological water quality standards are being met. Insufficient data are available to determine if fecal coliform load reductions are needed. However, efforts to improve riparian habitat conditions and failing HSTS should be made and additional sampling should be conducted to confirm that water quality standards are being met.

3.2.2 William H. Harsha Lake

William H. Harsha Lake (Harsha Lake), also known as East Fork Lake, is an integral part of the EFLMR watershed. Created in 1978 for flood control, Harsha Lake provides drinking water for residents of Clermont County and is a major recreational area for people who live in the region. The Bob McEwen Treatment Plant, opened in 1995, can process up to 10 million gallons of water from Harsha Lake per day. Harsha Lake is not only valued for its use as a drinking water supply, but also as a place to enjoy the outdoors. East Fork State Park has two swimming beaches and five boat launches, along with natural and stocked fish populations.

The presence of Harsha Lake in the middle of the EFLMR watershed presents several challenges to effective watershed management. For example, Ohio EPA has not yet established lake water quality standards and therefore it is unclear what in-lake targets should be used to develop load reduction recommendations. Secondly, there is currently a lack of information concerning how loads into the lake impact lake water quality, as well as how lake water quality impacts downstream conditions. The lake may serve as a sink during certain parts of the year, sequestering sediment and associated nutrients (particularly sediment-bound phosphorus), while during other periods serving as a net source of sediments and nutrients. Finally, following significant rain events in the watershed, the USACE discharges high volumes of water from the lake for extended periods to maintain the desired water level in the lake. The impacts of these extended high flow events on water quality (particularly in terms of turbidity) and the biological communities inhabiting the waters of the lower EFLMR have not been studied in any detail, but very likely have an impact that should be considered in any approach to improving the biological integrity of the aquatic communities in this section of the watershed.

The U.S. Army Corps of Engineers has developed a detailed lake model (CE-QUAL-W2) of Harsha Lake but unfortunately a lack of resources precluded the use of this model for this study. A simple screening level BATHTUB model was instead used to assess the potential impacts to the lake from reduced upstream loadings. The details of the BATHTUB modeling application are presented in Appendix G and the results suggest the following:

- The BATHTUB model was developed for Harsha Lake to simulate algal response from 1996 through 2006. Calibration factors for phosphorus, nitrogen, and chlorophyll *a* were left at default values because of the relative lack of data to better calibrate the model. Though the model does not currently predict the year to year variability of chlorophyll *a* observed in the summers of 2005 and 2006, it does reflect the average eutrophication response fairly well.
- Continuous monitoring of the lake over the next couple of summers is necessary to determine whether typical summer concentrations were best represented by the 2005 data or the 2006 data. Once more data are available, the model could be better calibrated to represent existing conditions in the lake. For now, the model should be used to assess general trends in water quality rather than to predict exact inlake concentrations of nutrients or chlorophyll *a*.
- Based on the current model, upstream load reductions of approximately 78 percent for total phosphorus and 12 percent for nitrate/nitrite may result in an average reduction of total phosphorus concentration of 59 percent, an average reduction of total nitrogen concentration of 12 percent, an average reduction of chlorophyll *a* concentration of 59 percent, and an average increase in the Secchi depth of 67 percent (see Appendix G for details).
- A review of the lake water quality samples collected in 2005 and 2006 over the entire depth of the lake reveals that, at depths greater than approximately 35 feet, the concentrations of phosphorus and nitrogen show a significant increase with depth, likely due to settling and re-suspension near the lake bottom. Therefore nutrient concentrations below the dam are probably strongly correlated to the depth at which the release occurs, perhaps even more so than they are to average in-lake nutrient concentrations. This phenomenon makes it even more difficult to predict how loads into the lake impact downstream conditions.

Because of these difficulties, no specific load reductions for Harsha Lake have been identified for the Phase 1 watershed management efforts. Further study of the lake and its role on downstream conditions are being conducted under Phase 1 of the management plan.

3.2.3 Downstream of Harsha Lake

Recommendations for the following waterbodies are presented in this section of the report (Figure 3-3):

- East Fork Little Miami River Downstream of Harsha Lake
- Backbone Creek
- Fourmile Run
- Hall Run
- Lick Run
- Lucy Run
- Salt Run
- Shayler Run
- Stonelick Creek
- Brushy Fork
- Wolfpen Run

Figure 3-3. The EFLMR watershed downstream of Harsha Lake.

3.2.3.1 East Fork Little Miami River Downstream of Harsha Lake

No load reduction recommendations are being developed for the East Fork Little Miami River downstream of Harsha Lake due to the following considerations:

Improving Conditions: An assessment of fish IBI scores for the EFLMR downstream of Harsha Lake indicates that there was a considerable improvement in scores between 1997 and 2005 (Figure 3-4). In fact, the most recent sampling for locations downstream of the lake indicates a nonsignficant departure from the EWH criteria. Although the ICI scores do not exhibit the same level of performance (Figure 3-5), the more recent data are believed to be skewed due to extremely high flows that occurred just prior to the samples being collected.

Other Efforts Underway to Improve Biology: As explained in Section 1.4, there are many activities ongoing to improve water quality in the EFLMR watershed. Many of these, especially ongoing improvements to the Clermont County collection system and wastewater treatment plants and the WRRSP purchase of conservation easements, are already focused on the EFLMR downstream of Harsha Lake. The Collaborative therefore believes that it will be more cost effective to focus implementation activities on the tributaries to the EFLMR.

Significance of Lake and Upstream Loadings: An examination of water quality data at the outlet of Harsha Lake indicates that total phosphorus concentrations from the lake routinely exceed Ohio's proposed criterion of 0.10 mg/L (Figure 3-6). In fact, more than 75 percent of the samples at this location exceed the target, making it unlikely that the target can be achieved downstream of the lake without some control of loads from the lake. An additional study to further characterize lake loading issues is being proposed as part of Phase 1.

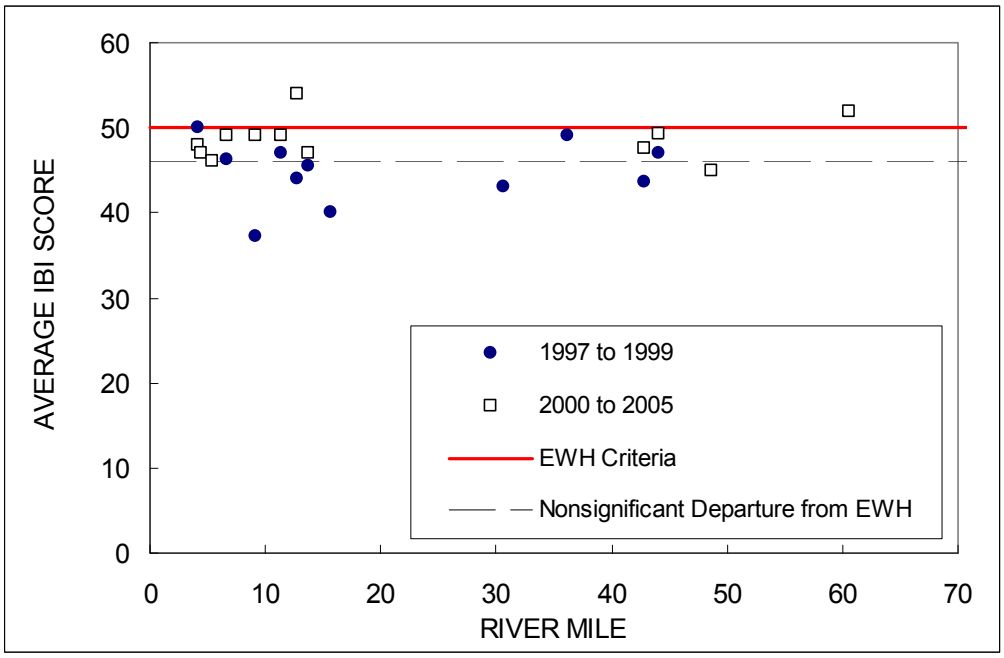


Figure 3-4. Results of fish sampling in the main stem of the EFLMR. Harsha Lake is between approximately river mile 20 and 30.

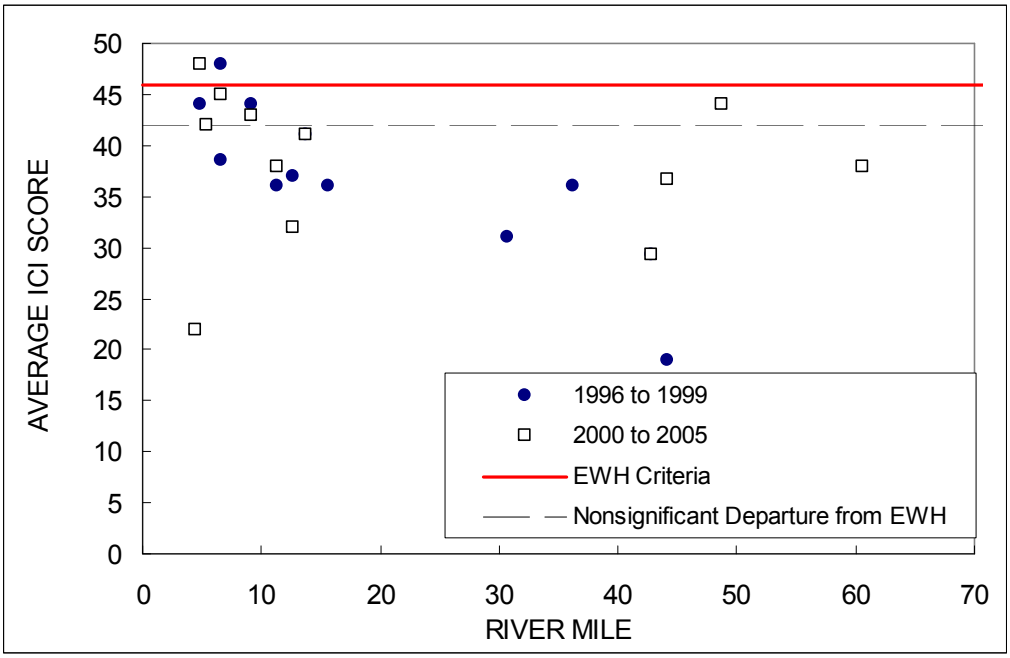


Figure 3-5. Results of macroinvertebrate sampling in the main stem of the EFLMR. Harsha Lake is between approximately river mile 20 and 30.

Lack of Knowledge Concerning Impact of Harsha Lake on Downstream Loads: Another consideration in postponing load reduction recommendations for the EFLMR downstream of Harsha Lake is that the role of the lake in transporting loads downstream is unknown. Although a detailed lake model is available (CE-QUAL-W2) a lack of resources precluded the use of this model for this project. As such, it is difficult to predict how potential reductions to future loads upstream of the lake (and from tributaries to the lake) will impact downstream water quality.

Costly Implications to NPDES Facilities: WWTP discharges to the EFLMR are a significant portion of nutrient loads to the EFLMR downstream of Harsha Lake during low flow conditions. Load reductions for the lower EFLMR could therefore potentially require expensive upgrades to the treatment plants, and still not result in the proposed instream targets of 0.10 mg/L total phosphorus and 1.0 mg/L nitrate being met due to background concentrations above these limits. Given the considerations previously discussed, the Collaborative believes that resources would be better devoted to addressing nonpoint sources and other factors affecting water quality in the EFLMR. During Phase 1 current WWTP operations will continue to be optimized within the current infrastructure, and an alternatives analysis/feasibility study will be conducted to determine the cost and technological requirements for further reducing nutrient concentrations.

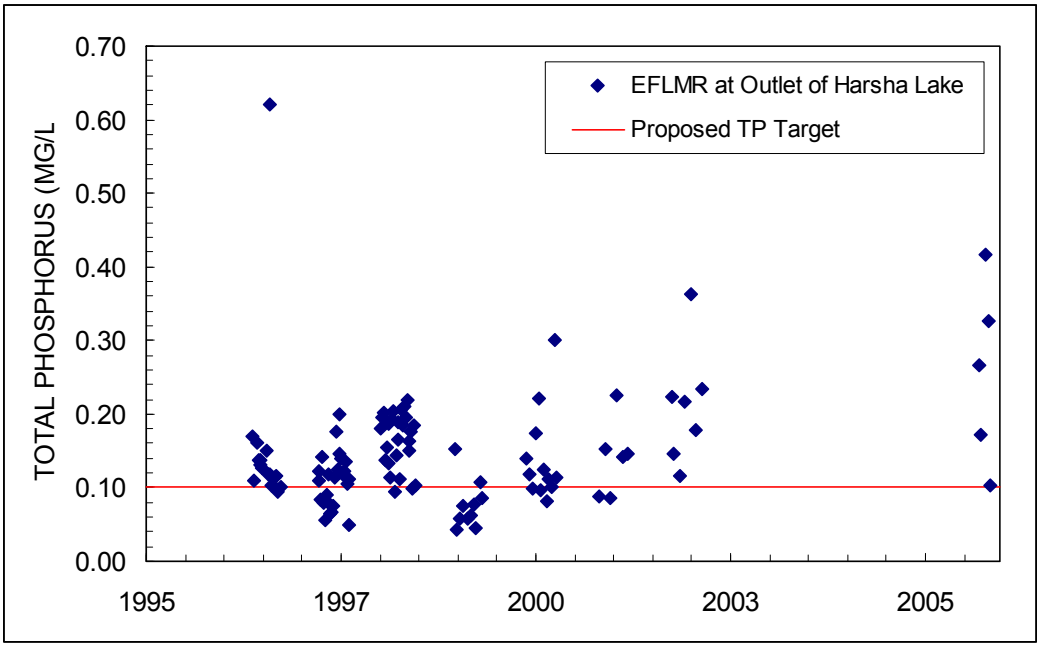


Figure 3-6. Total phosphorus at East Fork Little Miami River immediately downstream of Harsha Lake.

3.2.3.2 Backbone Creek

Backbone Creek has not been sampled by Ohio EPA or Clermont County and therefore no data exists with which to perform the Stressor Identification analysis or develop TMDLs.

3.2.3.3 Fourmile Run

The Stressor Identification process concluded that the primary aquatic life stressor in Fourmile Run is sediment (TSS). However, the load duration analysis suggests that no TSS load reductions are required . Therefore it is recommended that Phase 1 activities focus on improving riparian habitat conditions and additional sampling be conducted to determine if water quality standards have been attained.

3.2.3.4 Hall Run

Hall Run, a tributary to the EFLMR, is only partially meeting its WWH aquatic life use designation. This assessment unit is dominated by developed space.

Ohio EPA conducted biological surveys on Hall Run at three locations near Roundbottom Road. IBI scores in 1999 met water quality standards while they fell below standards in 2000. In 1998 there was a sewage spill that lowered the previous IBI score of 32 down to the lowest possible IBI score of 12. Sites upstream of the spill recovered back to 32 while sites downstream remained closer to 12. Clermont County also sampled Hall Run downstream of the spill and had identical results. Macroinvertebrate scores along Hall Run were consistently better than fish scores, ranging from moderately good to good. Results from the most recent fish survey conducted in 2004 show that the IBI has rebounded to 37.

The Stressor Identification process concluded that the primary aquatic life stressors in Hall Run are organic enrichment/DO (fecal coliform and CBOD5), sediment, and habitat. There are two stations with enough data for a load duration analysis along Hall Run but the only reductions that were identified were for fecal coliform at the most downstream station (Hall 0.3). The load reduction recommendations are presented in Table 3-6.

No TSS load reductions were identified by the use of load duration curves, even though the Stressor Identification analysis suggested sediment impairments. This may be due to the existing TSS concentrations not adequately characterizing stream embeddedness. A 2001 study concluded that Hall Run headwaters were dominated by unstable, habitat-poor Rosgen F stream type and streambank erosion is considered a significant contributor of sediment loads in Hall Run. The most likely sources of fecal coliform are a large number of failing HSTS (estimated 150) and excessive sewer inflow and infiltration (I/I).

Recommended Phase 1 controls in Hall Run should focus on improving riparian habitat conditions, controlling storm water runoff, and addressing the known HSTS and I/I problems. Other potential controls are described in Section 4 of this report and the *Lower East Fork Watershed Management Plan*.

Table 3-6. Load reduction recommendations for Hall Run (HALL03).

Hall Run Load Reduction Recommendations		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**Loading Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Fecal Coliform (Million/day)	Current Load	2,527,826	80,221	8,538	376	191
	Recommended Load	720,257	150,333	62,012	31,543	18,147
	Non-MS4 Stormwater	140,450	29,315	12,092	6,151	3,539
	MS4 Stormwater	579,807	121,018	49,920	25,392	14,609
	Load Reduction (%)	-72%	0%	0%	0%	0%

3.2.3.5 Lick Run

Lick Run, a tributary to Stonelick Creek, is dominated by row crop agriculture with some livestock production. Analysis of the available IBI and ICI scores indicated that Lick Run is impaired and the Stressor Identification process concluded that the primary aquatic life stressors in Lick Run are total phosphorus and habitat. The load reduction recommendations are presented in Table 3-7 and the LSPC modeling analysis suggests the primary sources of phosphorus are runoff from row crops (35%) and pasture/hay/grassland (54% phosphorus). Potential activities to address these sources can be found in Section 4.

Table 3-7. Load reduction recommendations for Lick Run (LICK01).

Lick Run Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**Loading Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Total Phosphorus (kg/day)	Current Load	3.37	0.71	0.22	0.10	0.05
	Recommended Load	1.91	0.55	0.23	0.11	0.05
	Non-MS4 Stormwater	1.78	0.51	0.22	0.10	0.05
	MS4 Stormwater	0.13	0.04	0.02	0.01	0.00
	Load Reduction (%)	-43%	-22%	0%	0%	0%

3.2.3.6 Lucy Run

Lucy Run, a tributary to the EFLMR, is dominated by row crop agriculture with some livestock production; however, land use changes due to population growth and development are expected within the next twenty years.

Analysis of the available IBI and ICI scores indicated that Lick Run is impaired and the Stressor Identification process concluded that the primary aquatic life stressor in Lucy Run is poor upstream habitat. Therefore no load reduction recommendations are being presented and implementation should focus on improving instream habitat.

3.2.3.7 Salt Run

Salt Run, a tributary to the EFLMR, is in partial attainment of its WWH aquatic life use designation. This assessment unit is dominated by developed areas in the headwaters and forested lands near the mouth.

Ohio EPA conducted a biological study on Salt Run near Roundbottom Road in 1997. The survey resulted in a QHEI score of 56 which is fair while the fish survey was in compliance with water quality standards and the macroinvertebrate study resulted in a "fair" collection of the aquatic insects. There has been heavy commercial development in the headwaters which significantly increased the amount of impervious land in the watershed. Stormwater runoff peaks and volume as well as nutrient loads have increased significantly.

The Stressor Identification process concluded that the primary aquatic life stressors in Salt Run are sediment (TSS) and habitat. However, the load duration analysis suggests that no reductions in TSS are required, potentially due to the TSS concentrations not adequately characterizing stream embeddedness. Phase 1 activities in Salt Run should include efforts to improve riparian habitat conditions, control stormwater runoff, and address known pollutant sources such as failing HSTS. Other potential activities are described in Section 4 of this report and the *Lower East Fork Watershed Management Plan*.

3.2.3.8 Shayler Run

Shayler Run, a tributary to the EFLMR, is in non-attainment of its WWH aquatic life use designation. This assessment unit is dominated by row crop agriculture with some livestock production, as well as developed lands.

Ohio EPA has conducted 14 habitat surveys on Shayler Run with QHEI scores ranging from 38 to 56.5 between Shayler miles 5.2 and 2.3; reaches upstream and downstream of this scored much better (QHEI score from 56.5 to 73). A 2001 study of the physical characteristics of streams in the lower East Fork watershed determined that Shayler Run headwaters are dominated by the unstable, habitat poor Rosgen F stream type. Stream instability, stormwater peak flows and volume have increased due to locating and installing the sanitary sewer infrastructure as well as increased development.

The Stressor Identification process concluded that the primary aquatic life stressors in Shayler Run are nutrients (phosphorus), organic enrichment/DO (*E. coli* and CBOD5), sediment (TSS), and habitat. The load reduction recommendations are presented in Table 3-8 and the LSPC modeling analysis suggests the primary sources of nutrients are runoff from grasslands (44% nitrogen, 65% phosphorus) and row crops (41% nitrogen, 20% phosphorus), while the primary source of sediment is row crops (64%) and unquantified streambank erosion. Phase 1 activities in Shayler Run should include efforts to improve riparian habitat conditions, control stormwater runoff, and address known pollutant sources such as failing HSTS. Other potential activities are described in Section 4 of this report and the *Lower East Fork Watershed Management Plan*.

Table 3-8. Load reduction recommendations for Shayler Run (SHYLR17).

Shayler Run Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	Loading Component	0-10	10-40	40-60	60-90	90-100
Total Phosphorus (kg/day)	Current Load	78.12	8.95	3.24	1.61	0.19
	Recommended Load	11.36	3.27	1.39	0.63	0.29
	Non-MS4 Stormwater	2.86	0.82	0.35	0.16	0.07
	MS4 Stormwater	8.50	2.45	1.04	0.47	0.22
	Load Reduction (%)	-85%	-63%	-57%	-61%	0%
Total Suspended Solids (kg/day)	Current Load	33,849	3,566	1,309	345	18
	Recommended Load	3,552	1,023	434	198	91
	Non-MS4 Stormwater	895	258	109	50	23
	MS4 Stormwater	2,657	765	325	148	68
	Load Reduction (%)	-90%	-71%	-67%	-43%	0%

3.2.3.9 Stonelick Creek

Stonelick Creek, the largest tributary to the EFLMR, is dominated by row crop agriculture with some livestock production; however, land use changes due to population growth and development are expected within the next twenty years.

Analysis of the available IBI and ICI scores indicated that Stonelick Creek is impaired upstream from river mile 8. The Stressor Identification process concluded that the primary aquatic life stressors in Stonelick Creek are nutrients (phosphorus, nitrate) and upstream habitat.

There are three stations located on Stonelick Creek with enough data to make load reduction recommendations, which are presented in Table 3-9, Table 3-10, and Table 3-11. The LSPC modeling analysis suggests the primary sources of nutrients are runoff from row crops (84% nitrogen, 75% phosphorus) and pasture/hay/grasslands (10% nitrogen, 20% phosphorus), while the primary source of sediment is row crops (94%) and unquantified streambank erosion. The most likely sources of fecal coliform are failing HSTS, agricultural runoff, livestock, and wildlife. Phase 1 activities in Stonelick Creek should include efforts to improve riparian habitat conditions, control stormwater runoff, and address known pollutant sources such as failing HSTS. Other potential activities are described in Section 4.

Table 3-9. Load reduction recommendations for Stonelick Creek (ST0100).

Stonelick Creek ST0100 Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	Loading Component	0-10	10-40	40-60	60-90	90-100
Total Phosphorus (kg/day)	Current Load	78.12	8.95	3.24	1.61	0.19
	Recommended Load	11.36	3.27	1.39	0.63	0.29
	Non-MS4 Stormwater	11.36	3.27	1.39	0.63	0.29
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-85%	-63%	-57%	-61%	0%
Nitrate (kg/day)	Current Load	1,352	152	49	8	2
	Recommended Load	955	275	117	53	24
	Non-MS4 Stormwater	955	275	117	53	24
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-29%	0%	0%	0%	0%
Fecal Coliform (Million/day)	Current Load	25,402,084	197,312	56,930	26,846	7,717
	Recommended Load	8,730,390	1,822,221	751,666	382,341	219,968
	Non-MS4 Stormwater	8,730,390	1,822,221	751,666	382,341	219,968
	MS4 Stormwater	NA	NA	NA	NA	NA
	Load Reduction (%)	-66%	0%	0%	0%	0%

Table 3-10. Load reduction recommendations for Stonelick Creek (ST0570).

Stonelick Creek ST0570 Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	Loading Component	0-10	10-40	40-60	60-90	90-100
Total Phosphorus (kg/day)	Current Load	194.21	44.83	5.58	2.06	1.06
	Recommended Load	51.33	14.78	6.28	2.86	1.31
	Non-MS4 Stormwater	50.62	14.47	6.06	2.68	1.15
	MS4 Stormwater	0.56	0.16	0.07	0.03	0.01
	Clermont NE School District WWTP	0.15	0.15	0.15	0.15	0.15
	Load Reduction (%)	-74%	-67%	0%	0%	0%
Fecal Coliform (Million/day)	Current Load	7,645,782	86,864	15,898	4,691	3,077
	Recommended Load	4,692,584	979,444	404,021	205,508	118,233
	Non-MS4 Stormwater	4,637,938	965,642	396,548	200,220	113,904
	MS4 Stormwater	51618	10774	4444	2261	1301
	Clermont NE School District WWTP	3028	3028	3028	3028	3028
	Load Reduction (%)	-39%	0%	0%	0%	0%

Table 3-11. Load reduction recommendations for Stonelick Creek (ST1430).

Stonelick Creek ST1430 Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	Loading Component	0-10	10-40	40-60	60-90	90-100
Total Phosphorus (kg/day)	Current Load	79.75	19.54	6.15	2.39	1.35
	Recommended Load	27.82	8.01	3.40	1.55	0.71
	Non-MS4 Stormwater	27.67	7.86	3.25	1.40	0.56
	MS4 Stormwater	0.00	0.00	0.00	0.00	0.00
	Clermont NE School District WWTP	0.15	0.15	0.15	0.15	0.15
	Load Reduction (%)	-65%	-59%	-45%	-35%	-47%
Total Suspended Solids (kg/day)	Current Load	10,278	2,294	323	197	99
	Recommended Load	6,954	2,002	851	387	178
	Non-MS4 Stormwater	6,954	2,002	851	387	178
	MS4 Stormwater	0.0	0.0	0.0	0.0	0.0
	Clermont NE School District WWTP	3.0	3.0	3.0	3.0	3.0
	Load Reduction (%)	-32%	-13%	0%	0%	0%

3.2.3.10 Brushy Fork

Brushy Fork, a tributary to Stonelick Creek, is located in AU 130, which was listed in 2002 and 2004 as being impaired due to unknown causes, nutrients, siltation, organic enrichment/DO, flow alterations, other habitat alterations, and pathogens. This subwatershed is dominated by row crop agriculture with some livestock production; however, land use changes due to population growth and development are expected within the next twenty years.

Analysis of available ICI and IBI scores indicated that Brushy Fork is impaired. The Stressor Identification process concluded that the primary aquatic life stressors in Brushy Fork are habitat and possibly ionic stress caused by high salinity. Phase 1 controls should therefore focus on improving riparian habitat and controlling stormwater runoff and collecting additional information on potential sources of salinity.

3.2.3.11 Wolfpen Run

Wolfpen Run, a tributary to the EFLMR, is in non-attainment of its WWH aquatic life use designation. This assessment unit is dominated by row crop agriculture with some livestock production; however, land use changes due to population growth and development are expected within the next twenty years.

Ohio EPA conducted one survey on Wolfpen Run in 1997. The resulting QHEI score was fair (52), with poor instream cover and below average pool and riffle quality. Despite the less than ideal habitat the fish community scored well (IBI=42), the macroinvertebrate community was only rated as “fair.”

The Stressor Identification process concluded that the primary aquatic life stressors in Wolfpen Run are nutrients (phosphorus, nitrate) and habitat. The nutrient load reduction recommendations are presented in Table 3-12 and the LSPC modeling analysis suggests the primary sources of nutrients are runoff from pasture/hay/grasslands (47% nitrogen, 68% phosphorus), forested lands (26% nitrogen, 14% phosphorus) and row crops (21% nitrogen, 13% phosphorus), while the primary sources of sediment are row crops (46%) and forested lands (33%). The most likely sources of fecal coliform are failing HSTS, agricultural runoff, livestock, and wildlife. Wolfpen Run is considered to have the greatest concentration of failing HSTS systems in the Lower East Fork watershed. Phase 1 controls should therefore focus on addressing

the failing HSTS and improving riparian habitat conditions. Potential activities to address these sources can be found in Section 4 of this report and the *Lower East Fork Watershed Management Plan*.

Table 3-12. Load reduction recommendations for Wolfpen Run (WLFP010).

Wolfpen Run (WLFP010) Loading Analysis		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**Loading Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Total Phosphorus (kg/day)	Current Load	3.30	1.45	0.35	0.17	0.04
	Recommended Load	1.15	0.33	0.14	0.06	0.03
	Non-MS4 Stormwater	0.61	0.18	0.07	0.03	0.02
	MS4 Stormwater	0.54	0.15	0.07	0.03	0.01
	Load Reduction (%)	-65%	-77%	-60%	-63%	-31%
Nitrate+Nitrite (kg/day)	Current Load	10.83	5.64	1.54	0.51	0.09
	Recommended Load	14.33	4.12	1.75	0.80	0.37
	Non-MS4 Stormwater	7.61	2.19	0.93	0.42	0.19
	MS4 Stormwater	6.72	1.93	0.82	0.37	0.17
	Load Reduction (%)	0%	-27%	0%	0%	0%
Fecal Coliform (Million/day)	Current Load	138,067	19,504	10,113	7,300	No Data
	Recommended Load	130,956	27,333	11,275	5,735	3,300
	Non-MS4 Stormwater	69,538	14,514	5,987	3,045	1,752
	MS4 Stormwater	61,418	12,819	5,288	2,690	1,547
	Load Reduction (%)	-5%	0%	0%	-21%	No Data

4 IMPLEMENTATION STRATEGY

The biostatistical analysis conducted for this study concluded that decreasing stream flashiness, increasing QHEI cover and pool scores, and decreasing organic enrichment, ammonia, and conductivity were the top priorities for improving biological conditions across the watershed. The Stressor Identification analysis also identified load reductions that are needed for various streams for nutrients, sediments, and/or fecal coliform. Consistent with the goals of Phase 1 of the watershed management effort, this section of the report describes BMPs and management strategies that reduce conventional pollutant loading and/or result in improved habitat conditions. BMPs are generally grouped by pollutant source (agriculture, wastewater, etc.) though some BMPs are capable of treating multiple sources (e.g., vegetated filter strips, grass swales).

4.1 Agricultural Sources

Agricultural operations in the EFLMR watershed include crop production, pasture/hay, and animal operations. Agricultural land uses comprise 58 percent of the watershed area (41 percent in row crop and 17 percent in pasture/hay). Pollutant loading from agriculture, simulated by the LSPC model, contributes 41 to 95 percent of the nitrogen loading to each TMDL segment with an average contribution of 81 percent of the total load. The total phosphorus loading from agriculture ranges from 20 to 96 percent across the subwatersheds with an average of 80 percent. Sediment loads are consistently high with contributions ranging from 46 to 97 percent with an average rate of 83 percent from agricultural lands. Relative contributions to the fecal coliform loading were not simulated with the model though contributions from livestock are assumed a significant portion of the loading.

In addition to delivering pollutants to streams in the watershed, agricultural operations significantly alter the soil profile. Soil compaction from animals and farm equipment reduces infiltration and increases surface runoff. Lack of vegetative cover decreases surface roughness, exposes soil particles to erosive forces, and allows for faster transport of water and pollutants to the stream system. Some farmers use tile drainage systems to lower the water table, which increases the fraction of subsurface flow but delivers higher concentrations of dissolved pollutants such as nitrate.

Several structural and non-structural BMPs have been developed and studied for use in agricultural areas and the following are recommended for use in the EFLMR watershed:

- Nutrient Management Planning
- Manure Handling and Storage
- Manure Composting and Soil Amendment
- Feeding Strategies
- Cattle Exclusion from Streams
- Alternative Drinking Sources for Cattle
- Grazing Land Protection
- Controlled Drainage
- Conservation Tillage
- Cover Crop
- Filter Strip
- Grass Swale
- Riparian Area Improvements
- Land Acquisition

Appendix H describes these BMPs in terms of removal mechanisms, effectiveness, and cost. Though the BMPs are presented individually, they typically must be used in combinations to mitigate hydrologic and water quality impacts.

Agricultural BMPs can be highly efficient in reducing pollutant loading and protecting stream ecosystems, particularly when used in combinations. Table 4-1 presents the removal efficiencies for sediment, nitrogen, phosphorus, and fecal coliform for each agricultural BMP, and Table 4-2 lists the initial and maintenance cost for each option.

Table 4-1. Agricultural BMP removal efficiencies and impacts on flow and habitat.

BMP	TSS Reduction (%)	TN Reduction (%)	TP Reduction (%)	Fecal Coliform Reduction (%)	Impact on Flow Conditions	Impact on Habitat
Nutrient Management Planning	Minimal	Assume 15 percent reduction of total nitrogen (USEPA, 2003)	Assume 35 percent reduction of total phosphorus (USEPA, 2003)	Minimal	L	L
Manure Handling and Storage	No data	No data	No data	No data	L	L
Manure Composting and Soil Amendment	Reduces sediment loss by 68 percent on treated fields (HRWCI, 2005)	30 to 70 percent loss of total nitrogen (USEPA, 2003)	Minimal reduction in phosphorus	Reductions up to 99% in fecal coliform concentrations (Larney et. al., 2003)	M	M
Feeding Strategies	Minimal	20 to 30 percent (USEPA, 2003)	30 to 50 percent (USEPA, 2003)	Minimal	L	L
Cattle Exclusion from Streams	Theoretically, 100 percent reduction in direct deposition of fecal matter	Reduction in total nitrogen loading of 15 percent (USEPA, 2003)	Reduction in total phosphorus loading of 15 to 49 percent (USEPA, 2003)	29 to 46 percent reduction in fecal coliform counts	L	H
Alternative Drinking Sources for Cattle	90 percent reduction in direct deposition of fecal matter (USEPA, 2003)	90 percent reduction in direct deposition of fecal matter (USEPA, 2003)	90 percent reduction in direct deposition of fecal matter (USEPA, 2003)	90 percent reduction in direct deposition of fecal matter (USEPA, 2003)	L	H
Grazing Land Protection	88 percent reduction in sediment loading assuming increased ground cover from 60 percent to 95 percent (Haith et al., 1992)	60 percent reduction in nitrogen loading (USEPA, 2003)	49 to 60 percent reduction in phosphorus loading (USEPA, 2003)	29 to 46 percent reduction in fecal coliform loading (USEPA, 2003)	M	H
Controlled Drainage	Minimal	40 to 50 percent compared to conventionally drained fields	No data	No data	M	L
Conservation Tillage	75 to 88 percent reduction in soil loss rates (USEPA, 2003; USDA, 2004, respectively)	55 percent reduction in total nitrogen (USEPA, 2003)	45 percent reduction in total phosphorus (USEPA, 2003)	Minimal	M	M
Cover Crop	88 percent reduction in soil erosion (HRWCI, 2005)	30 percent reduction in nitrogen loading rates (Haith et al, 1992)	70 to 85 percent removal of total phosphorus (HRWCI, 2005)	Variable	M	M
Filter Strip	60 to 65 percent reduction in sediment (USEPA, 2003)	70 percent reduction in total nitrogen (USEPA, 2003; Kalita, 2000)	~ 65 percent removal of total phosphorus (Winer, 2000; Kalita, 2000)	55 percent reduction in fecal coliform (USEPA, 2003)	M	M

BMP	TSS Reduction (%)	TN Reduction (%)	TP Reduction (%)	Fecal Coliform Reduction (%)	Impact on Flow Conditions	Impact on Habitat
Grass Swale	93 percent reduction of TSS (Winer, 2000)	92 percent removal of total nitrogen (Winer, 2000)	83 percent removal of total phosphorus (Winer, 2000)	Minimal	M	M
Riparian Area Improvements	97 percent removal of sediment from treated area, assuming a 90 ft buffer width (NCSU, 2002)	80 percent removal of total nitrogen from treated area, assuming a 90 ft buffer width (NCSU, 2002)	78 percent removal of total phosphorus from treated area, assuming a 90 ft buffer width (NCSU, 2002)	Variable impacts depending on presence of cattle and wildlife in the area.	M	H
Land Acquisition	98 percent reduction in sediment loading rates (Haith et al, 1992)	92 percent reduction in nitrogen loading rates (Haith et al, 1992)	90 percent reduction in phosphorus loading rates (Haith et al, 1992)	Variable impacts depending on presence of cattle and wildlife in the area.	M	H

Impacts on flow and habitat are based on engineering judgment: L = low; M = medium; H = high.

Table 4-2. Estimated 2006 costs of agricultural BMPs.

BMP	Construction Costs	Annual Maintenance Costs
Nutrient Management Planning	No construction costs associated with this management practice	$5 to $10/ac every 3 to 5 years. May result in net savings due to savings on operating expenses
Manure Handling and Storage	Variable depending on size of operation	Variable depending on size of operation
Manure Composting	Variable depending on size of operation	Variable depending on size of operation
Feeding Strategies	No construction costs associated with this management practice	May result in net savings
Cattle Exclusion from Streams	Ranges from $0.70 to $1.32/ft. for fencing, depending on material	Ranges from $0.04 to $0.11/ft., depending on material
Alternative Drinking Sources for Cattle	Pipeline costs range from $0.30 per ft. to $2.50 per ft. Pump plus tank costs range from $400 to $1400.	Annual operating costs range from $10 to $25 per year, not including costs of water.
Grazing Land Protection	$42/ac to $73/ac to establish vegetation	$6/ac to $11/ac
Controlled Drainage	No data available	No data available
Conservation Tillage	No construction costs associated with this management practice. May require purchase of additional farm equipment.	Compared to conventional tillage, costs approximately $21/ac/yr more for soybean production and saves approximately $17/ac/yr for corn production.
Cover Crop	No construction costs associated with this management practice	$15/ac for seeding and removing cover crop
Filter Strip	Seeded filter strips cost $0.34 per sq. ft. to construct; use of level spreader to disperse flow is $13 per linear ft.	Filter strips cost approximately $0.01 per sq. ft. per year to maintain; level spreaders cost approximately $0.39 per linear ft. per year to maintain.
Grass Swale	Cost $0.56 per sq. ft. to construct	$0.02 per sq. ft. per year to maintain
Riparian Area Improvements	Cost $106/ac to construct	$10 per ac to maintain
Land Acquisition	Seeding cost for initial vegetation is $98/ac, if not previously established	$0 - $10 per ac to maintain

4.2 Residential and Urban Land Uses

Several of the subwatersheds in the EFLMR watershed are expected to undergo land use changes over the next 20 years. The primary transition will likely be from agricultural to urban/residential uses. Relative to row crop agriculture, urban land uses typically have more vegetative cover on pervious surfaces (e.g., lawns, parks, etc.), so the transition from agriculture to urban land uses sometimes results in a decrease in sediment loading once the development is complete. During the construction phase, however, sediment loading can exceed that of row crop agriculture. In addition, increases in the amount of impervious surface through the construction of roads, parking lots, and building footprints significantly alters site hydrology by decreasing infiltration, increasing surface runoff, and decreasing travel times such that peak and total flow volumes are substantially increased. The altered hydrology can also impact stream morphology, leading to unstable streams, bank and channel erosion, siltation, habitat modification, etc. Urbanization also tends to lead to a loss of riparian corridor vegetation, which can increase stream temperatures, reduce filtering capacity, and destabilize streambank soils. Impacts on loading of phosphorus, nitrogen, and fecal coliform will depend on rates of fertilization before and after the transition, performance of onsite wastewater treatment systems, and the presence of wildlife and pets in the area.

Biostatistical analysis has shown that habitat and flow conditions, particularly stream flashiness, canopy cover, and pool quality, are primary factors of the biological impairment in the EFLMR watershed. The Collaborative feels that implementation of Phase 1 BMPs will bring the majority of the stream segments in the watershed into compliance with the biological criteria. Subsequent development to urban land uses could quickly undo much of the progress if not managed appropriately. This section of the report presents structural BMPs and management strategies proven effective in mitigating the impacts of urban development.

Watershed management and the protection of water quality require a combination of strategies, generally grouped as regulatory and non-regulatory options. Regulatory options are those that involve government action and include approaches such as zoning, subdivision, and construction regulations. Nonregulatory options may involve government action, but not in the form of a development regulation. For example local governments or other organizations may acquire land, conduct monitoring, and encourage better site design using low impact development or conservation design principles, and educate homeowners about good stewardship and good housekeeping practices.

4.2.1 Regulatory Tools

Local planners can utilize regulatory tools to guide development and control its impact on water quality and habitat.

4.2.1.1 Zoning Ordinance

A zoning ordinance establishes districts and specifies allowable uses of land within each district. In addition to segregating incompatible uses of land, zoning ordinances often prescribe standards for each use. For example, there can be intensity regulations (controls of housing density and number of dwelling units, minimum setbacks and lot widths, frontage requirements, height limitations, and limits on impervious cover). As a legal tool for implementing the local government's land use plan, a zoning ordinance can shape where growth occurs in the jurisdiction, as well as governing the type and intensity of development and the mitigation of its impacts.

4.2.1.2 Subdivision Regulations

Subdivision regulations are adopted to control the division of land into lots or parcels suitable for building. The purposes of local subdivision ordinances include issues related to promoting health, safety, and general welfare; promoting orderly, economic, efficient and coordinated development; conforming to public improvement plans; and ensuring an equitable handling of subdivision plans. Regulations may stipulate a variety of requirements, including but not limited to lot sizes, number of dwelling units allowed per lot, minimum lot size for use of a septic tank; water supply systems; utility easements; street design and right-of-way; building lines and setbacks; and storm drainage facilities.

4.2.1.3 Sediment and Erosion Control Plans

Local governments enact sedimentation and erosion control ordinances to minimize the impacts from construction activities on downstream water quality, particularly impacts from erosion and the discharge of sediment during construction. Construction BMPs include structural controls such as sediment basins, sediment fences, rock riprap, and level spreaders, as well as nonstructural controls such as tree preservation and protection, topsoiling, mulching, and grading and seeding activities according to weather conditions. Adequate local inspections and enforcement are critical to the effectiveness of sedimentation and erosion control ordinances.

4.2.1.4 Stormwater Management Ordinances

Stormwater management ordinances typically stipulate the purposes and objectives of the ordinance; applicability; administrative procedures (e.g., application requirements, schedule, and fees); approval procedures; stormwater management performance standards; BMP maintenance; and inspections. Some recent stormwater management ordinances have included stream buffer and open space requirements in addition to water quality and hydrologic performance standards.

4.2.2 Nonregulatory Tools

4.2.2.1 Land Acquisition Tools

Local governments rely on a range of land acquisition techniques for permanent protection resulting from land disturbance; the following is a review of three commonly used approaches – donations, land purchases, and conservation easements.

Donations: Landowners are sometimes in the position to donate a piece of land (as part of a development project or an entire developable parcel) either to the local government or a non-profit organization like a land conservancy. Often the entire value of the donation can be deducted over time from federal and/or state income taxes. In addition, real estate taxes, insurance, and maintenance costs can be avoided. While land donations can be attractive to the owner and to the local government, this approach alone cannot meet the needs of a coordinated land acquisition strategy.

Outright (or Fee Simple) Land Purchases: Sometimes local governments are so committed to the acquisition of selected parcels deemed so significant to their future that they are willing to purchase them outright. The local government may choose to purchase the land at its market value or may negotiate a bargain sale with the landowner. With a bargain sale, the difference between fair market value and the reduced price may qualify for a deduction from state and/or federal income taxes.

Conservation Easements: An easement is a tool used by many local governments and land trusts to protect sensitive environmental resources at relatively little cost. An easement limits the right to use or restricts land owned by someone else. Easements presume that various land rights may be sold separately. An easement can assist in protecting land from development by restricting all or a portion of the property to open space or limited development uses.

4.2.2.2 Encouraging Low Impact Design

Through the process of development, field and forest land is made suitable for various human uses (e.g., residences, industry, transportation, and commerce). Typically, as land is developed, natural grass and forest cover is replaced by impervious surfaces such as streets, parking areas, driveways, and roofs, and less pervious cover such as residential and commercial lawns. Due to the decrease in perviousness, precipitation events more readily produce stormwater runoff from developed land unless adequate management techniques are implemented. The greater volumes of stormwater runoff typically transport elevated levels of nonpoint source pollutants over land (and, when used, even through conventional stormwater management devices) to receiving streams and lakes – impacting both their ecologic function and quality. Low impact design (LID) is an alternative approach toward development that combines time-proven site design methods for minimizing stormwater runoff in a way that enhances protection of ecologic functions, water quality, and frequently the aesthetics of the site. The LID approach is flexible in that it includes a range of design components that can be implemented at a development site, depending on both the physical characteristics of the site as well as its planned use.

The principle components of LID are:

- Using simple, non-structural stormwater control methods where possible.
- Using runoff hydrology as the integrating framework for site design.
- Focusing on micromanagement of stormwater.
- Controlling stormwater at the source.
- Preserving (and creating) a multifunctional landscape.

A range of planning, design, and implementation techniques can be pursued to address these components, including:

- Minimizing land disturbances to preserve sensitive natural areas (e.g., wetlands, mature forests, and stream corridors).
- Designing and using smaller parking lots and parking stalls and shared parking agreements.
- Designing narrower streets integrated with open drainage (e.g., grass swales).
- Using conservation design with clustered buildings and preserved open space.
- Preserving vegetated buffers along stream corridors.
- Disconnecting impervious surfaces and associated runoff (e.g., rooftop runoff) from the stormwater sewer system.
- Managing and treating stormwater through the use of conditioned soil bed and planting materials (e.g., bioretention cells and wetlands).

4.2.2.3 Education

Education programs can be used effectively to increase stakeholders' (e.g., property owners, residents, farmers, developers) awareness of and participation in watershed management efforts. Examples of potentially useful education programs include:

- Impacts of agricultural BMPs on water quality, crop yield, and profits
- Better site design for new development or redevelopment
- Fertilizer application rates for homeowners
- Onsite wastewater system operation and maintenance
- Animal/pet waste cleanup
- Impacts of illicit dumping

Education in the EFLMR watershed will be conducted jointly by the East Fork watershed coordinator, the local Soil and Water Conservation Districts, OSU Extension, Farm Bureau, County Health Departments, local sewer departments, Clermont County Office of Environmental Quality, and other EFWC partners (EFWC, 2006a).

4.2.3 Structural BMPs

Both regulatory and non-regulatory options employ development BMPs for stormwater management on lands disturbed by human activities (e.g., agriculture, forestry, and urban and suburban development). Structural practices require construction, installation, and maintenance. The types of practices recommended for a given area will depend on several factors including watershed characteristics, physical site constraints, maintenance requirements, administrative resources, and cost. The following is a list of commonly used structural BMPs, with additional details presented in Appendix H:

- Bioretention Cell
- Rainwater Harvesting
- Water Quality Swale
- Underground Storage

- Conventional Dry Detention
- Extended Dry Detention
- Grass Swale
- Green Roof
- Infiltration Trench
- Permeable Pavement
- Sand Filter
- Stormwater Wetland
- Vegetated Filter Strip
- Wet Pond

Table 4-3 and Table 4-4 compare the removal efficiencies and costs to construct the urban BMPs described in this section. Annual maintenance costs vary widely from site to site based on site design, topography, soil type, and choice of vegetation, but may be assumed 10 percent of construction costs for planning purposes.

Table 4-3. Pollutant removal efficiencies and hydrologic impacts of urban BMPs.

BMP	TSS Reduction (%)	TN Reduction (%)	TP Reduction (%)	Fecal Coliform Reduction (%)	Impact on Flow Conditions	Impact on Habitat
Bioretention Cell	85[7,8]	55[4,5]	75[4,5,6,7]	90[11]	M	M
Rainwater Harvesting	Variable	Variable	Variable	Minimal	M	M
Conventional Dry Detention	Minimal[1]	5[1]	20[1]	80[1]	H	M
Extended Dry Detention	60[1]	30[1]	20[1]	80[1]	H	M
Grass Swale	70[1]	40[1]	30[1]	Minimal	L	L
Green Roof	Minimal	Minimal	Minimal	Minimal	L	L
Infiltration Trench	100[1]	80[1]	65[1]	90[3]	M	M
Water Quality Swale	90[1]	90[1]	80[1]	Variable	H	M
Underground Storage	Variable	Variable	Variable	Variable	H	M
Permeable Pavement	95[1]	80[1]	65[1]	No data	M	M
Sand Filter	85[1]	40[1]	60[1]	40[1]	M	L
Stormwater Wetland	75[1]	30[1]	50[1]	80[1]	H	H
Vegetated Filter Strip	60[9,10]	70[9,10]	65[9,10]	55[9,10]	L	L
Wet Pond	80[1,4]	30[1]	50[1]	70[1]	H	M

Impacts on flow and habitat are based on engineering judgment: L = low; M = medium; H = high.

[1] Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD. Note: fecal coliform removal rates for dry ponds were not defined separately for conventional versus extended dry detention.

[2] NC DENR, 1999. North Carolina Stormwater Best Management Practices Manual. Division of Water Quality.

[3] Schueler, T. 1987. Controlling urban runoff – a practical manual for planning and designing urban best management practices. Metropolitan Washington Council of Governments, Washington, DC.

[4] Davis, A.P., M. Shokouhian, H. Sharma, and C. Minami. 2001. Laboratory Study of Biological Retention for Urban Stormwater Management. Water Environment Research. 73(1): 5-14.

[5] Davis, A.P., M. Shokouhian, H. Sharma, and C. Minami. 1998. Optimization of Bioretention Design for Water Quality and Hydrologic Characteristics. Department of Civil Engineering, University of Maryland, College Park.

[6] Davis, A.P., and C. Minami. 1999. Evaluation of Pollutant Removal Characteristics at Bioretention Facilities at Peppercorn Place. Project No. 01-4-33173. Department of Civil Engineering. University of Maryland, College Park, MD.

[7] Davis, A.P. "Bioretention – Studies Completed by the University of Maryland" http://www.ence.umd.edu/~apdavis/Biodata.htm. Updated: August 27, 2002.

[8] Low Impact Development Center. "Watershed Benefits of Bioretention Techniques." http://www.lid-stormwater.net/bioretention/bio_benefits.htm. Accessed: December 13, 2002.
[9] USEPA. 2003. National Management Measures to Control Nonpoint Source Pollution from Agriculture. EPA 841-B-03-004, July 2003.
[10] Kalita, Prasanta. 2000. Vegetative Filter Strips to Reduce Pathogens and Nutrients in Runoff from Livestock Feedlots. Department of Crop Sciences College of Agriculture, Consumer and Environmental Sciences, University of Illinois Extension.
[11] Best Professional Judgment.

Table 4-4. Approximate cost ranges for urban stormwater BMPs in 2006 dollars.[1]

Stormwater BMP	Construction Cost	Reference	Notes
Bioretention Cell	$7 - $27 per square foot	Hunt, 2004	Cost depends on design and drainage area imperviousness.
Rainwater Harvesting	For Cisterns: $3-$14 per cubic foot of storage; For Rain Barrels: $14-$19 per cubic foot	LIDC, 2003; Rain Water Solutions, Inc., 2004	Cost depends on type of material and installation.
Conventional Dry Detention[2]	$12,000 - $40,000 for a 100,000 cubic foot facility; $20,000 - $70,000 for a 250,000 cubic foot facility	Rouge River, 2001; CWP, 2000	Cost depends on design; cost range is greater than for the extended facility due to uncertainty and lack of cost data.
Extended Dry Detention[2]	$20,000 - $30,000 for a 100,000 cubic foot facility; $40,000 - $50,000 for a 250,000 cubic foot facility	CWP, 2000	Cost depends on design.
Grass Swale	$0.30 - $0.60 per square foot	USEPA, 2002b	Cost depends on design.
Green Roof	$9 - $16 per square foot for extensive (no public access); $17 - $33 per square foot for intensive (with public access)	LIDC, 2003; Hunt, 2004	Cost depends on design.
Infiltration Trench	$2 - $10 per cubic foot of storage	CWP, 2000	Cost depends on design.
Water Quality Swale	$3 - $5 per square foot	Hunt, 2004	Cost depends on design.
Underground Storage	Variable		Cost depends on design and site conditions.
Permeable Pavement	$1 - $10 per square foot	LIDC, 2003	Cost depends on type of material and design.
Sand Filter[2]	$30,000 - $40,000 for a 500 square foot facility; $60,000 - $80,000 for a 1,000 square foot facility	Wossink and Hunt, 2003	Cost depends on design.
Stormwater Wetland[2]	$70,000 - $95,000 for a 100,000 cubic foot facility; $95,000 - $130,000 for a 250,000 cubic foot facility	Wossink and Hunt, 2003	Cost depends on design.
Vegetated Filter Strip	<$0.01 to $0.60 per square foot; $6 to $14 per square foot for level spreader	USEPA, 2002b; Hunt et al., 2001; Wossink and Osmond, 2001	Cost depends on type of vegetation used: natural vegetation is less expensive than managed grass.
Wet Pond[2]	$80,000 - $110,000 for a 100,000 cubic foot facility; $145,000 - $195,000 for a 250,000 cubic foot facility	Wossink and Hunt, 2003	Cost depends on design.

[1] See Tetra Tech, 2006b for more information on how cost ranges were estimated. The costs above do not include design and engineering, which is typically 25 percent of construction costs.
[2] These facilities tend to have economies of scale.

4.3 Wastewater Disposal

The transition to urban and residential land uses in the EFLRM watershed will require management of increased volumes of wastewater flow. There are currently 7 permitted municipal wastewater treatment plants, 6 permitted package treatment plants, and approximately 9,517 individual onsite systems in the watershed (EFWC, 2003; 2006a; 2006b). This section summarizes the treatment processes, pollutant loading rates, and management practices for each system type, with additional information provided in Appendix H.

4.3.1 Centralized Wastewater Treatment Plants

Centralized wastewater service is characterized by: 1) the system of piping which collects sewage at each home or facility and transports it to a central location, and 2) the central treatment facility, which typically discharges to a nearby body of water, but can discharge to the land (subsurface infiltration area, sprayfield) if conditions are favorable. Centralized and decentralized wastewater treatment both use similar biological, physical, and chemical technologies to process and treat sewage:

- Continuous flow, suspended growth aerobic treatment, usually in an open, aerated tank.
- Fixed film treatment, with wastewater distributed over rock, gravel, sand, fabric, peat, plastic, or other media.
- Sequencing batch reactors, sequential suspended growth treatment through an intermittent or continuous flow process.
- Ponds, lagoons, and wetlands, which combine suspended and attached growth biological treatment with physical and other processes.

Centralized treatment is often viewed as providing more reliable and superior treatment, but upon closer examination both approaches – centralized and decentralized – offer substantial pollutant removal capabilities for the full range of pollutant parameters, at somewhat comparable costs. Monthly usage fees for centralized treatment are sometimes considered to be more accepted by the public, but most users know little about their wastewater treatment system and may be willing to pay regular operation/maintenance fees if they can avoid responsibility for large capital costs.

Factors to consider other than costs when deciding whether it is beneficial to use decentralized/onsite systems, construct a new treatment plant, or extend service lines from a nearby system include the following:

- Age and operational history of existing onsite systems in the area.
- The management entity's capacity and authority to properly manage existing onsite systems.
- Future housing and other development trends.
- Proximity and capacity of existing centralized collection lines and treatment facilities.
- Potential for acquiring (or revising, in the case of plant expansion) an NPDES discharge permit.
- Suitable financing, land area, and site conditions for construction of facilities and collection lines.
- Hydrologic impacts and catastrophic risk potential due to failure of collection systems and/or the centralized treatment plant.
- Secondary impacts associated with higher density development expected with centralized waste treatment systems.

If additional centralized treatment is proposed for new or existing development in the EFLMR drainage area, a detailed study regarding cost, effluent discharge location, potential for sprawl development, and other factors should be conducted to examine these issues in greater depth.

The existing facilities in the watershed will be undergoing various plant upgrades and sewer system improvements over the next several years to address known problems (EFWC, 2003; 2006a; 2006b). Further improvements may be required if Phase 1 management strategies for nonpoint sources do not result in attainment of use designations.

4.3.2 Decentralized Wastewater Treatment

Decentralized wastewater treatment is often proposed for areas of scattered and mixed large/small lot development due to lower costs, acceptable treatment performance, and other reasons. Decentralized systems include onsite systems that treat wastewater from individual homes or buildings, and cluster (community) systems that treat wastewater from groups of two or more homes. When properly planned, designed, sited, installed, operated, and maintained, individual or cluster systems can effectively remove or treat contaminants such as nutrients, pathogens, and biochemical oxygen demand in human sewage (USEPA, 2005).

Typical individual onsite treatment systems consist of a septic tank and a subsurface soil absorption field. Buried in the ground, septic tanks are essentially watertight single or multiple chamber sedimentation and anaerobic digestion tanks. They are designed to receive and pretreat domestic wastewater, mediate peak flows, and keep settleable solids, oils, scum, and other floatable material out of the absorption field. Wastewater effluent is discharged from the tank and passes to the soil via a series of underground perforated pipes, perforated pipe wrapped in permeable synthetic materials, leaching chambers, pressure drip irrigation pipes or tubing, or other distribution systems. From there, the partially treated effluent flows onto and through the developing biomat located at the soil infiltrative surface, and finally into the soil itself. Treatment occurs in the septic tank, on and within the biomat, in the soil, and continues as the effluent moves through the underlying soil toward groundwater or nearby surface waters.

Cluster (community) systems typically serve fewer than a hundred homes, but they can serve more. Under this approach, septic tank effluent from each home is collected and routed to another site for further treatment. Other designs where primary treatment occurs at the treatment site instead of at individual home septic tanks are also possible, but most designers prefer individual tanks due to a greater ability to detect problems that may affect biological treatment processes (e.g., dumping of toxic wastes). Collection and movement of effluent to the final treatment site can be accomplished by gravity flow or pumps. The off-site treatment facility resembles a downsized sewage plant, using similar technologies such as trickling (media) filters, aerobic lagoons, constructed wetlands, etc. Final dispersal of treated effluent is usually to the soil, due to greater treatment advantages and avoidance of NPDES permitting, monitoring, reporting, and other requirements. However, cluster systems can be designed and permitted to discharge to the surface.

Package treatment plants are prefabricated treatment units serving one or more households. Wastewater from the septic tank is collected and routed to the treatment facility, treated, then discharged to the surface or subsurface. Developers using large cluster systems typically construct their own plants rather than using package treatment plants.

Alternative or innovative systems such as mound systems, fixed-film contact units, wetlands, aerobic treatment units ("package plants"), low-pressure drip applications, and cluster systems, are used in areas where conventional soil-based systems cannot provide adequate treatment of wastewater effluent. Areas that might not be suitable for conventional systems are those with nearby nutrient-sensitive waters, high densities of existing conventional systems, highly permeable or shallow soils, shallow water tables, large rocks or confining layers, and poorly drained soils.

Concerns over treatment system failure and malfunction over the past 30 years have led to significant improvements in system planning, design, and management. The result of these upgrades has been elevated performance both hydraulically and functionally, with a wider array of technologies capable of removing targeted pollutants. It should be noted that treatment occurring in the soil matrix – a characteristic of most onsite and cluster systems – is an important component of the overall pollutant removal/attenuation process, making soil type and depth a key consideration in siting these systems.

Onsite and cluster systems have malfunctioned due to system age, inappropriate design, hydraulic/ pollutant overloading, and poor maintenance (see Table 4-5). Detrimental impacts from onsite systems can occur when they are sited in sensitive ecological areas (such as wellhead protection zones, near nitrogen/phosphorus limited waters, or near beaches or shellfish habitat) or when they are installed at densities that exceed the hydraulic and hydrologic assimilative capacities of regional soils and aquifers. Failure rates in the ELFMR watershed range from 20 to 70 percent depending on soil type, system density, and system age (EFWC, 2003; 2006a; 2006b). Many of the high failure rates are associated with discharging aerobic systems in the lower EFLMR watershed that discharge treated effluent directly to surface water without contact with soil and are considered a major problem in the lower watershed.

Table 4-5. Common causes of onsite and cluster system malfunction (USEPA, 2005).

Type of Malfunction	Contributing Causes
Hydraulic	Excessive hydraulic loadings to undersized systems, low soil permeability, excessive ponding at the infiltrative surface, poor maintenance. Increases in water usage over a period of years can exceed the design capacity of the wastewater treatment system.
Organic	Excessive organic loading from unpumped or sludge-filled tanks resulting in reductions in biomat infiltrative surface permeability.
Soil Depth to Groundwater Table or Bedrock	Insufficient soil depths (i.e., soil thickness between the subsurface wastewater infiltration system and groundwater tables, impermeable strata, or bedrock is less than the recommended depth for soil texture and structure). High groundwater is deleterious to pathogen removal and hydraulic performance.
System Age	Systems more than 25 to 30 years old generally experience more failures if not operated and maintained properly. Failure rates can more than triple for poorly managed older systems. Regular tank pumping and use of alternating absorption fields can prolong system life indefinitely.
Design Failure	Inappropriate system design for the site; failure to adequately consider or characterize wastewater strength and flow (average daily and/or peak flows); failure to identify and consider restrictive soil/rock layers (e.g., fragipan) or regional geology (e.g., karst features, creviced bedrock); failure to assess landscape position.
System Density	Cumulative effluent load from all systems in watershed or groundwater recharge area exceeds the hydrologic capacity of the area to accept and/or properly treat effluent.

Nitrogen in domestic wastewater can be removed through effective linking of aerobic and anaerobic biochemical transformation processes, but in general, most conventional septic systems are not considered effective in removing nitrogen without additional treatment in the soil. Septic tanks remove approximately 30 percent of the nitrogen in raw domestic wastewater. Percolation through 3 to 5 feet of soil can remove 0 to 20 percent of the total nitrogen in septic tank effluent. Additional nitrogen removal is possible under optimum soil and denitrification (e.g., anaerobic and carbon-rich) conditions.

Phosphorus loading rates from properly functioning onsite wastewater systems are typically insignificant due to adsorption to soil particles in the drainfield. However, if systems are placed on unsuitable soils, not maintained properly, or are connected to subsurface drainage systems, loading rates to receiving waterbodies may be relatively high. Favorable phosphorus removal conditions exist for soil absorption systems in most soils of the United States, but some phosphorus loading problems might be encountered

in areas with older systems, highly permeable soils (e.g., sands), mineral-poor soils, nearby surface waters, and high system densities.

Pathogenic microorganisms found in domestic wastewater, including bacteria, viruses, protozoa, and parasites, are removed or attenuated through chemical, physical, and biological processes occurring in the septic tank, within the biomat, and in the soil. The main methods of bacterial retention in unsaturated soil are filtration, sedimentation, and adsorption. Normal operation of septic tank/subsurface infiltration systems results in retention and die-off of most, if not all, observed pathogenic bacterial indicators within 2 to 3 feet of the infiltrative surface (USEPA, 2002c). With a mature biomat at the infiltrative surface of coarser soils, most bacteria are removed within the first foot vertically or horizontally from the trench-soil interface. Removal rates for other pathogens, such as viruses and protozoa, vary significantly depending on soil, climate, and other factors. Table 4-6 summarizes wastewater constituents of concern and estimates of their effluent concentration from different treatment units.

Table 4-6. Wastewater constituents of concern and representative estimates of concentrations in the effluent of various treatment units (adapted from Siegrist et al., 2000).

Constituents of Concern	Direct or Indirect Measures	Tank-based Treatment Unit Effluent Concentrations					Following Percolation Through 3 to 5 ft of Soil Drain Field (Percent Removal)
		Domestic STE[1]	Domestic STE with N-removal Recycle[2]	Aerobic Unit Effluent	Recirculating Sand Filter Effluent[3]	Recirculating Foam or Textile Filter Effluent[4]	
Oxygen Demand	BOD_5 (mg/L)	140-200	80-120	5-50	2-15	5-15	>90
Particulate Solids	TSS (mg/L)	50-100	50-80	5-100	5-20	5-10	>90
Nitrogen	Total N (mg N/L)	40-100	10-30	25-60	10-50	30-60	10-20
Phosphorus[4]	Total P (mg P/L)	5-15	5-15	4-10	3-9	4-10	0-100
Bacteria (e.g., *Clostridium perfringens, Salmonella, Shigella*)	Fecal coliform (organisms per 100 mL)	10^6-10^8	10^6-10^8	10^3-10^6	10^1-10^3	10^1-10^3	>99.99
Virus[5] (e.g., hepatitis, polio, echo, coxsackie, coliphage)	Specific virus (pfu/mL)	0-10^5	0-10^4	0-10^4	0-10^3	0-10^3	>99.9
Organic Chemicals (e.g., solvents, petro-chemicals, pesticides)	Specific organics or totals (µg/L)	0 to trace	0 to trace	0 to trace	0 to trace	0 to trace	>99
Heavy Metals (e.g., Pb, Cu, Ag, Hg)	Individual metals (µg/L)	0 to trace	0 to trace	0 to trace	0 to trace	0 to trace	>99

1 Septic tank effluent (STE) concentrations given are for domestic wastewater. However, restaurant septic tank effluent (STE) is markedly higher, particularly in BOD_5, COD, and suspended solids, while concentrations in graywater STE are noticeably lower in total nitrogen.
2 N-removal accomplished by recycling STE through a packed bed for nitrification with discharge into the influent end of the septic tank for denitrification.
3 Operated in recirculating mode.
4 P-removal by adsorption or precipitation is highly dependent on media capacity, P loading, and system operation.
5 Episodically present at high levels.

Failing and poorly functioning decentralized wastewater treatment systems in the EFLMR watershed contribute nutrient and fecal coliform loading to the water bodies. Inspections of each onsite wastewater treatment system in the watershed should be performed to assess functionality and degree of maintenance. Systems older than 20 years and those located close to a lake or stream should be inspected first. A database containing the age and future maintenance records for each system in the watershed should be created and maintained. All tanks discharging to tile drainage systems should be disconnected immediately. Bacterial counts from systems directly connected to a subsurface drainage system have been reported at 90,000 per 100 mL (Bird, 2006). These systems pose a threat to water quality in the EFLMR watershed as well as a public health hazard. Repair or replacement of poorly functioning systems should be required and confirmed.

Education of owners concerning maintenance of onsite wastewater treatment systems is a crucial component of reducing pollution from these systems. Many owners are not familiar with USEPA recommendations concerning maintenance schedules. Septic systems, when not maintained properly, can cause the release of pathogens and excess nutrients into surface water. Good housekeeping measures relating to septic systems include (Goo, 2004; CWP, 2004):

- Inspect system annually and pump system every 3 to 5 years, depending on the tank size.
- Refrain from trampling the ground or using heavy equipment above a septic system (to prevent collapse of pipes).
- Prevent septic system overflow by conserving water, not diverting storm drains or basement pumps into septic systems, and not disposing of trash through drains or toilets.

Education of home and business owners that use onsite wastewater treatment systems should occur periodically. Public meetings, mass mailings, radio and TV announcements can all be used to remind and inform owners of their responsibility to maintain their systems.

The costs associated with education and inspection programs will vary depending on the level of effort required to communicate the importance of proper maintenance and the number of systems in the area.

4.4 Current Efforts in Watershed Management

The Collaborative is currently developing five watershed action plans to address water quality issues in the EFLMR watershed. As of September 2006, three of the plans have been completed: headwaters, lake tributaries, and Lower East Fork. Plans for the Stonelick Creek Watershed and Middle East Fork Watershed should be completed in the near future.

The plans are available for viewing at the Clermont County Office of Environmental Quality website: **http://www.oeq.net/default.php?section=wataction**. Each plan characterizes the watershed in detail and summarizes the causes and impairments of water quality. In addition, each plan recommends management strategies to address each impairment and improve water quality.

This section integrates the findings and recommendations of the Demonstration Project report with the three watershed action plans that have been developed. Information concerning the rural and urban BMPs were used to detail how the watershed action plans will achieve the required pollutant reductions and improvements to habitat. Once the final two watershed action plans are completed, that information should be incorporated as well.

In some cases, the loading analysis determined that no conventional pollutant reductions were required based on the load duration analysis and current water quality standards. However, as described in the watershed action plans and recommendations included in this report, loadings from poorly functioning onsite wastewater treatment systems should be reduced, and areas of known habitat disturbance should be mitigated.

In addition, though not all of the segments have been assessed quantitatively, visual inspections confirm that impairments are likely occurring in several segments where load reduction recommendations could not be calculated. The watershed action plans suggest management practices to improve conditions in these waterbodies, such as fencing cattle from streams, repairing or replacing failing onsite wastewater treatment systems, and extending the habitat and water quality assessments to these areas so that use attainment can be determined. The following tables summarize the goals and recommendations presented in the watershed action plans and this report, even for those segments where load reduction recommendations have not been made.

4.4.1 East Fork Headwaters Recommendations

The watershed action plan for the headwaters of the East Fork Little Miami River covers a drainage area of approximately 195 square miles and ends at the mouth of Fivemile Creek. The area is typically used for row crop production (61.4 percent of the land use area), with some livestock operations as well. Wastewater is mostly disposed via onsite wastewater treatment systems, but the Villages of New Vienna, Lynchburg, St. Martin, and Fayetteville-Perry operate centralized wastewater treatment plants. In addition, the Snow Hill Country Club operates a package treatment plant. It is estimated that 25 percent of onsite wastewater systems are poorly functioning, due to system age and/or soil conditions. Table 4-7 summarizes the goals and recommendations to reduce pollutant loading from the major contributors in the watershed and recommends BMPs and other management strategies that will likely result in improvements to water quality and habitat.

Table 4-7. Action items for improving habitat and water quality in the east fork headwaters.

Goals and Recommendations	Targeted Reaches (WAP Reduction)	Suggested BMPs and Potential Reductions
Reduce sediment loading from row crop agriculture by 25 to 50%	Turtle Creek (25) , East Fork Mainstem from headwaters to Turtle Creek (50) , East Fork Mainstem from Turtle Creek to above Solomon Run (50), East Fork Mainstem from Solomon Run to Fivemile Creek (50)	Conservation tillage reduces sediment loading by 75 to 88% Use of cover crop reduces sediment loading by 88% Filter strips reduce sediment loading by 60 to 65% Grass swales reduce sediment loading by 93%
Reduce mean nutrient loadings from row crop agriculture by 20%	East Fork Mainstem from headwaters to Turtle Creek, East Fork Mainstem from Turtle Creek to above Solomon Run, East Fork Mainstem from Solomon Run to Fivemile Creek	Conservation tillage may reduce N by 55% and P by 45% Use of cover crop may reduce N by 30% and P by 70 to 85% Filter strips may reduce N by 70% and P by 65% Grass swales may reduce N by 92% and P by 83% Manure composting may reduce N by 30 to 70% Nutrient management planning and proper manure application rates may reduce N by 15% and P by 35% Proper manure handling and storage will reduce contact with precipitation Riparian area improvements may reduce N by 80% and P by 78% Land acquisition may reduce N by 92% and P by 90%
Manage livestock to reduce impacts on streambanks and water quality	Dodson Creek	Exclude cattle from streams Provide alternative drinking water sources Manage grazing lands to optimize vegetative cover

Goals and Recommendations	Targeted Reaches (WAP Reduction)	Suggested BMPs and Potential Reductions
Maintain or reduce nutrients from livestock agriculture	East Fork Mainstem from headwaters to Turtle Creek, East Fork Mainstem from Turtle Creek to above Solomon Run, Glady Run, Sycamore Creek, Hales Branch, East Fork Mainstem from Solomon Run to Fivemile Creek (20), Dodson Creek, Turtle Creek, West Fork	Feeding strategies may reduce N and P by 20 to 30% Manure composting may reduce N by 30 to 70% and fecal coliform by 99% Nutrient management planning and proper manure application rates may reduce N by 15% and P by 35% Filter strips may reduce N by 70%, P by 65%, and fecal coliform by 55% Grass swales may reduce N by 92% and P by 83% Proper manure handling and storage will reduce contact with precipitation Exclude livestock from streams to reduce N by 15% and P by 15 to 49% Restoration of riparian corridors may reduce N by 80% and P by 78%
Reduce sediment loading from streambank erosion by 25 to 50%	Dodson Creek (25), Turtle Creek (25), East Fork Mainstem from headwaters to Turtle Creek (50) , East Fork Mainstem from Turtle Creek to above Solomon Run (50), East Fork Mainstem from Solomon Run to Fivemile Creek (50)	Riparian area improvements and streambank stabilization reduce sediment loading by 97% Land acquisition reduces sediment loading by 98% Removal of levees constructed adjacent to stream channels will allow access to the floodplain
Permanently protect 25% of the riparian corridor	East Fork Mainstem from headwaters to Turtle Creek, East Fork Mainstem from Turtle Creek to above Solomon Run, East Fork Mainstem from Solomon Run to Fivemile Creek	Land purchase or donation Conservation easements Setback requirements
Restore channelized segments	West Fork	Restore stream and riparian corridor to natural dimension, pattern, and profile and reconnect to floodplain
Inventory, assess, and improve where needed, riparian and streambank conditions, habitat, and use attainment of entire segment	Dodson Creek, Fivemile Creek, South Fork Dodson Creek, Crane Creek, Glady Run, Sycamore Creek, Grassy Fork, Turtle Creek, Anthony Run, West Fork, Hales Branch, A.E. Patton County Ditch, East Fork Mainstem from headwaters to Turtle Creek, East Fork Mainstem from Turtle Creek to above Solomon Run, East Fork Mainstem from Solomon Run to Fivemile Creek, Solomon Run, Murray Run, Little Indian Creek, Indian Creek, Saltlick Creek, Howard Run, Sixmile Creek	Evaluate each segment for habitat, stream stability, and riparian condition Determine use attainment of all non-assessed streams and rivers Conduct riparian area improvements where needed Utilize land acquisition strategies to permanently protect targeted areas
Address localized flooding	Dodson Creek	Remove log jams and debris Retrofit stormwater controls and storage (Section 4.2.3) Disconnect impervious surfaces Inspect and maintain storm sewer pipes if present

Goals and Recommendations	Targeted Reaches (WAP Reduction)	Suggested BMPs and Potential Reductions
Reduce bacterial, nutrient, and BOD loading from failing onsite wastewater treatment systems.	Dodson Creek (50), Fivemile Creek, Grassy Fork, West Fork, East Fork Mainstem from headwaters to Turtle Creek (50), East Fork Mainstem from Turtle Creek to above Solomon Run (50), East Fork Mainstem from Solomon Run to Fivemile Creek (50)	Inventory and assess functionality of all onsite systems Educate owners on maintenance and operating procedures Repair, replace, or connect to sewer all poorly functioning systems
Where feasible, connect homes served by onsite systems to municipal wastewater treatment plants	West Fork, A.E. Patton County Ditch	Connect all homes in Midland and Westboro with septic systems to the new Midland-Martinsville wastewater treatment plant
Reduce sediment loading from surface mining by 25 to 50%	Dodson Creek (25), Turtle Creek (50)	Develop and implement sediment control plans Ensure adequate storage of stormwater runoff onsite Prohibit discharge of stored water to waterbodies

4.4.2 Lake Tributaries Recommendations

The Lake Tributaries Watershed drains approximately 147 sq. mi. and contains the mainstem East Fork Little Miami River from Howard Run to Harsha Dam. Eight species of rare plants and seven species of rare animals have been located in the watershed. The area is typically used for row crop production (37 percent of the land use area), with some livestock operations as well. Wastewater is mostly disposed via onsite wastewater treatment systems, but Williamsburg operates a centralized wastewater treatment plant, and the Forest Creek Mobile Home Park (MHP), Holly Town MHP, and the US DOA at William H. Harsha Lake operate package treatment plants. Table 4-8 summarizes the goals and recommendations to reduce pollutant loading from the major contributors in the watershed and recommends BMPs and other management strategies that will likely result in improvements to water quality and habitat.

Table 4-8. Action items for improving habitat and water quality in the lake tributaries watershed.

Goals and Recommendations	Targeted Reaches (WAP Reduction)	Suggested BMPs and Potential Reductions
Reduce sediment loading from row crop agriculture by 25 to 50%	Barnes Run (50), Cloverlick Creek (50), Fivemile Creek (25), Kain Run (50), Poplar Creek (50), East Fork Mainstem from Howard Run to Todd Run (50)	Conservation tillage reduces sediment loading by 75 to 88% Use of cover crop reduces sediment loading by 88% Filter strips reduce sediment loading by 60 to 65% Grass swales reduce sediment loading by 93%
Reduce mean nutrient loadings from row crop agriculture by 20%	East Fork Mainstem from Howard Run to Todd Run, East Fork Mainstem from Todd Run to Harsha Dam	Conservation tillage may reduce N by 55% and P by 45% Use of cover crop may reduce N by 30% and P by 70 to 85% Filter strips may reduce N by 70% and P by 65% Grass swales may reduce N by 92% and P by 83% Manure composting may reduce N by 30 to 70% Nutrient management planning and proper manure application rates may reduce N by 15% and P by 35% Proper manure handling and storage will reduce contact with precipitation Riparian area improvements may reduce N by 80% and P by 78% Land acquisition may reduce N by 92% and P by 90%
Maintain or reduce nutrients from livestock agriculture Reduce contamination from manured agricultural fields, particularly in Poplar Creek Identify manure management practices at large horse farms in the Cloverlick watershed and reduce bacterial, nutrient, and BOD loading	East Fork Mainstem from Howard Run to Todd Run, East Fork Mainstem from Todd Run to Harsha Dam (20), Cloverlick Creek, Poplar Creek	Feeding strategies may reduce N and P by 20 to 30% Manure composting may reduce N by 30 to 70% and fecal coliform by 99% Nutrient management planning and proper manure application rates may reduce N by 15% and P by 35% Filter strips may reduce N by 70%, P by 65%, and fecal coliform by 55% Grass swales may reduce N by 92% and P by 83% Proper manure handling and storage will reduce contact with precipitation Exclude livestock from streams to reduce N by 15 % and P by 15 to 49% Restoration of riparian corridors may reduce N by 80% and P by 78%

Goals and Recommendations	Targeted Reaches (WAP Reduction)	Suggested BMPs and Potential Reductions
Inventory, assess, and improve where needed riparian and streambank conditions, habitat, and use attainment of entire segment	Barnes Run, Cloverlick Creek, Fivemile Creek, Kain Run, Pleasant Run, Poplar Creek, Slabcamp Run, Ulrey Run, Cabin Run, East Fork Mainstem from Howard Run to Todd Run, Todd Run, East Fork Mainstem from Todd Run to Harsha Dam, Sugartree Creek, Town Run, Guest Run, Back Run, Fourmile Run, Crane Run, Polecat Run, Trible Run, and Light Run	Evaluate each segment for habitat, stream stability, and riparian condition Determine use attainment of all non-assessed streams and rivers Conduct riparian area improvements where needed Utilize land acquisition strategies to permanently protect targeted areas
Reduce sediment loading from streambank erosion by 25 to 50%	Barnes Run (25), Cloverlick Creek (25), Fivemile Creek (25), Kain Run (25), Pleasant Run (25), Poplar Creek (25), East Fork Mainstem from Howard Run to Todd Run (50), East Fork Mainstem from Todd Run to Harsha Dam (50)	Riparian area improvements and streambank stabilization reduce sediment loading by 97% Land acquisition reduces sediment loading by 98% Removal of levees constructed adjacent to stream channels will allow access to the floodplain
Permanently protect 25% of the riparian corridor	East Fork Mainstem from Howard Run to Todd Run, East Fork Mainstem from Todd Run to Harsha Dam	Land purchase or donation Conservation easement Setback requirements
Reduce bacterial, nutrient, and BOD loading from failing onsite wastewater treatment systems	Barnes Run, Cloverlick Creek, Fivemile Creek, Kain Run (50), Pleasant Run (50), Poplar Creek, Slabcamp Run, Ulrey Run (50), Cabin Run, East Fork Mainstem from Howard Run to Todd Run (50), East Fork Mainstem from Todd Run to Harsha Dam (50)	Inventory and assess functionality of all onsite systems Educate owners of maintenance and operating procedures Repair, replace, or connect to sewer all poorly functioning systems
Monitor stormwater runoff from industrial areas and transportation corridors	Slabcamp Run (headwaters)	Assess impervious surface coverage Inventory stormwater conveyances
Control impacts of new development	Barnes Run, Cloverlick Creek, Fivemile Creek, Kain Run	Use zoning, subdivision, and construction regulations to reduce impacts of new development Encourage low impact design Use structural BMPs described in Section 4.2.3 to reduce stormwater peak and total volumes and to reduce loading of sediments, nitrogen, phosphorus, and fecal coliform

4.4.3 Lower East Fork Recommendations

The Lower East Fork Watershed drains approximately 42.4 sq. mi. and includes the reaches of the East Fork Little Miami River from Stonelick Creek to the mouth. Though no load reduction recommendations are currently being developed for the EFLMR below Harsha Lake, significant efforts in watershed planning are ongoing. Most of these improvements focus on municipal wastewater treatment plants and collection systems as well as the purchase of conservation easements (Table 4-9). The Collaborative believes that these strategies, along with the action items set forth for the headwater and lake tributary watersheds, will result in the lower EFLMR attaining all designated uses without further planning and resources. This assumption will be confirmed during Phases 2 and 3 when additional monitoring occurs.

Table 4-9. Action items for improving habitat and water quality in the lower east fork watershed.

Goals and Recommendations	Targeted Reaches (WAP Reduction)	Suggested BMPs and Potential Reductions
Reduce mean nutrient loadings from the two wastewater treatment plants by 20%	East Fork Mainstem from Stonelick Creek to mouth	Upgrade WWTPs and collection systems
Reduce pollutant loading from sanitary sewer overflows by 100%	Hall Run, Shayler Run, Sugarcamp Run, East Fork Mainstem from Stonelick Creek to mouth	Update sewer infrastructure to address I/I and sanitary sewer overflows
Reduce pollutant loadings from onsite wastewater systems by 40 to 60%	Hall Run (50), Wolfpen Run (60), East Fork Mainstem from Stonelick Creek to mouth (40)	Inventory and assess functionality of all onsite systems Educate owners on proper maintenance and operating procedures Repair, replace, or connect to sewer all poorly functioning systems
Eliminate failing onsite wastewater systems	Shayler Run, Sugarcamp Run	Extend central sewer to areas with older or failing onsite systems
Stabilize and restore stream segments degraded by excessive stormwater volumes, sewer infrastructure, and channelization	Hall Run, Salt Run, Shayler Run	Restore stream and riparian corridor to natural dimension, pattern, and profile and reconnect to floodplain Move sewer lines from channel and restore channel to natural morphology
Reduce sediment loadings from streambank erosion by 25%	Hall Run	Riparian area improvements and streambank stabilization reduce sediment loading by 97% Land acquisition reduces sediment loading by 98%
Inventory 100 percent of riparian corridor; provide recommendations for reestablishing riparian corridor	Hall Run, Wolfpen Run, East Fork Mainstem from Stonelick Creek to mouth	Evaluate each segment for habitat, stream stability, and riparian condition Riparian area improvements Land acquisition
Permanently protect 25% of the riparian corridor	East Fork Mainstem from Stonelick Creek to mouth	Land purchase or donation Conservation easement Setback requirements
Control stormwater runoff from new and existing urban areas Reduce nutrient loading from urban stormwater by 20% Reduce sediment loading from urban stormwater by 20%	Hall Run, Salt Run, East Fork Mainstem from Stonelick Creek to mouth, Wolfpen Run	Use zoning, subdivision, and construction regulations to reduce impacts of new development Encourage low impact design Use structural BMPs described in Section 4.2.3 to reduce stormwater peak and total volumes and to reduce loading of sediments, nitrogen, phosphorus, and fecal coliform

4.4.4 Middle East Fork and Stonelick Watershed Action Plans (WAP) and TMDL Recommendations

Several reaches discussed in this report are in the Middle East Fork and Stonelick watersheds. The Collaborative is in the process of developing the watershed action plans for these areas. Once the plans are completed, the goals, targeted reaches, and suggested management strategies (Table 4-10) will be updated. For now, the contents are based solely on the information contained in this report.

Table 4-10. Action items for improving habitat and water quality in the Middle East Fork and Stonelick Creek watersheds.

Goals and Recommendations	Targeted Reaches (WAP Reduction)	Suggested BMPs and Potential Reductions
Reduce sediment loading from row crop agriculture	Lick Run, Lucy Run, Stonelick Creek, Brushy Fork	Conservation tillage reduces sediment loading by 75 to 88% Use of cover crop reduces sediment loading by 88% Filter strips reduce sediment loading by 60 to 65% Grass swales reduce sediment loading by 93%
Reduce mean nutrient loadings from row crop agriculture	Lick Run, Lucy Run, Stonelick Creek, Brushy Fork	Conservation tillage may reduce N by 55% and P by 45% Use of cover crop may reduce N by 30% and P by 70 to 85% Filter strips may reduce N by 70% and P by 65% Grass swales may reduce N by 92% and P by 83% Manure composting may reduce N by 30 to 70% Nutrient management planning and proper manure application rates may reduce N by 15% and P by 35% Proper manure handling and storage will reduce contact with precipitation Riparian area improvements may reduce N by 80% and P by 78% Land acquisition may reduce N by 92% and P by 90%
Maintain or reduce nutrients from livestock agriculture	Lick Run, Lucy Run, Stonelick Creek, Brushy Fork	Feeding strategies may reduce N and P by 20 to 30% Manure composting may reduce N by 30 to 70% and fecal coliform by 99% Nutrient management planning and proper manure application rates may reduce N by 15% and P by 35% Filter strips may reduce N by 70%, P by 65%, and fecal coliform by 55% Grass swales may reduce N by 92% and P by 83% Proper manure handling and storage will reduce contact with precipitation Exclude livestock from streams to reduce N by 15% and P by 15 to 49% Restoration of riparian corridors may reduce N by 80% and P by 78%
Inventory, assess, and improve where needed, riparian and streambank conditions, habitat, and use attainment of entire segment	Lick Run, Lucy Run, Stonelick Creek, Brushy Fork, Backbone Creek, East Fork Mainstem from Harsha Dam to Stonelick Creek	Evaluate each segment for habitat, stream stability, and riparian condition Determine use attainment of all non-assessed streams and rivers Conduct riparian area improvements where needed Utilize land acquisition strategies to permanently protect targeted areas
Reduce sediment loading from streambank erosion	Stonelick Creek	Riparian area improvements and streambank stabilization reduce sediment loading by 97% Land acquisition reduces sediment loading by 98% Removal of levees constructed adjacent to stream channels will allow access to the floodplain

Goals and Recommendations	Targeted Reaches (WAP Reduction)	Suggested BMPs and Potential Reductions
Reduce bacterial, nutrient, and BOD loading from failing onsite wastewater treatment systems	Lick Run, Lucy Run, Stonelick Creek, Brushy Fork, Backbone Creek, East Fork Mainstem from Harsha Dam to Stonelick Creek	Inventory and assess functionality of all onsite systems Educate owners on maintenance and operating procedures Repair, replace, or connect to sewer all poorly functioning systems
Identify and control sources of salinity	Brushy Fork	Monitor instream water quality to detect changes in salinity Use data concerning point and nonpoint sources to identify source
Control impacts of new and existing development	Stonelick Creek, Brushy Fork, Lucy Run	Use zoning, subdivision, and construction regulations to reduce impacts of new development Encourage low impact design Use structural BMPs described in Section 4.2.3 to reduce stormwater peak and total volumes and to reduce loading of sediments, nitrogen, phosphorus, and fecal coliform

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