December 2010

Ohio Environmental Protection Agency

Total Maximum Daily Loads for the Lower Little Miami River Watershed

Final Report
December 8, 2010

Ted Strickland, Governor
Lee Fisher, Lt. Governor
Chris Korleski, Director

Photo caption: Lower Little Miami River downstream of State Route 126 and adjacent to the Kelly Nature Preserve in Clermont County.

Ohio EPA received financial assistance for this work from U.S. EPA and the American Recovery and Reinvestment Act of 2009.

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BIT	Bacteria Indicator Tool
BMP	best management practice
cm	centimeter
CNMP	Comprehensive Nutrient Management Plan
cnt/seas	counts per season
CO	consent agreement
Corps	U.S. Army Corps of Engineers
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSO	combined sewer overflow
CSS	combined sewer system
CWA	Clean Water Act
CWH	Cold Water Habitat
DA	drainage area
DEFA	Division of Environmental and Financial Assistance
DFFOs	Directors Final Findings and Orders
DNAP	Division of Natural Areas and Preserves
DSW	Division of Surface Water
DSWC	Division of Soil and Water Conservation
ECBP	Eastern Corn Belt Plains
EQIP	Environmental Quality Incentives Program
EWH	Exceptional Warmwater Habitat
FC	Fecal Coliform
FSA	Farm Service Agency
gpd	gallons per day
GPS	geographic positioning system
GW	ground water
HSTS	household sewage treatment system
HUC	hydrologic unit code
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
LA	load allocations
lb/yr	pounds per year
LEAP	Livestock Environmental Assurance Program
LID	low impact development
LTCP	Long term Control Plan
mg/L	milligrams per liter
MGD	million gallons per day
MHP	Mobile Home Park
MIWB	Modified Index of Well-Being
mi^2	square mile
ml	milliliter
MOR	monthly operating reports
MORPC	Mid-Ohio Regional Planning Commission
MOS	margin of safety
MS4	municipal separate storm sewer system
MWH	Modified Warmwater Habitat
NACD	National Association of Conservation Districts
NEMO	Nonpoint Education for Municipal Official

NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	Natural Resource Conservation Service
OAC	Ohio Administrative Code
OAEA	Ohio Agricultural Environmental Assurance
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OFAER	On Farm Assessment and Environmental Review
OFBF	Ohio Farm Bureau Federation
OLC	Ohio Livestock Coalition
ORC	Ohio Revised Code
PCR	Primary Contact Recreation
PIR	Pollution Investigation Report
PTI	Permit to Install
QHEI	Qualitative Habitat Evaluative Index
RC&D	Resource Conservation and Development
RI	return interval
RM	river mile
SCR	Secondary Contact Recreation
SCS	Soil Conservation Service
SSO	sanitary sewer overflow
SSO	separate sewer overflow
SSS	sanitary sewer system
SWCD	Soil and Water Conservation District
TMDL	total maximum daily load
tn/yr	tons per year
TP	total phosphorus
TSS	total suspended solids
U.S. EPA	U.S. Environmental Protection Agency
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
USGS	U.S. Geologic Survey
WHC	Wildlife Habitat Council
WLA	wasteload allocations
WPCLF	Water Pollution Control Loan Fund
WQC	Water Quality Certification
WQMP	Water Quality Management Plan
WQS	water quality standards
WRP	Wetland Reserve Program
WRRSP	Water Resource Restoration Sponsor Program
WTP	water treatment plant
WWH	Warmwater Habitat
WWTP	wastewater treatment plant

ACKNOWLEDGEMENTS

The following Ohio EPA staff provided technical expertise on this project:

- Biological and habitat assessment – Holly Tucker (fish) and Angela Dripps (macroinvertebrates)
- Water quality/sediment sampling – Louise Snyder and Diana Zimmerman
- Water quality modeling -- Paul Gledhill
- Permits (NPDES) – Mike Zimmerman, Ron Ware, Marianne Piekutowski and Gary Stuhfaulth
- Storm water – Chris Cotton, Jason Fyffe , and John Morrison
- Nonpoint sources – Hugh Trimble
- Fish Consumption – Mylynda Shaskus
- TMDL Coordination and Team Leader – Gregg Sablak

Other full- and part-time staff also participated in field monitoring.

The Ohio EPA appreciates the cooperation of the property owners who allowed access to lower Little Miami River and its tributaries.

Our gratitude extends to all of the groups and individuals who have participated in this TMDL. The following are particularly noteworthy:

Little Miami River Partnership
Little Miami Inc. (LMI)
County soil and water conservation districts
County health departments

EXECUTIVE SUMMARY

The lower Little Miami River watershed is located in southwest Ohio extending from Lebanon and Wilmington in the north and northwest to Cincinnati in the south. This 602 square mile watershed area is home to approximately 370,000 people and encompasses all or part of 43 municipalities in Clinton, Warren, Clermont, Hamilton and Butler counties.

The Little Miami River is one of Ohio' prized surface water resources. The Little Miami River has been a state scenic river since 1969 and it flows through Clifton Gorge State Nature Preserve and John Bryan State Park. Consequently, this water resource is enjoyed by many Ohioans.

In 2007, Ohio EPA staff sampled 82 sites on streams in the lower portion of this watershed which includes the entire area draining to the river starting just south of Waynesville with the exception of the East Fork of the Little Miami River. Through this survey, the usability of the stream resources for recreation and suitability for aquatic wildlife were evaluated. This evaluation was based on whether data collected were consistent with minimum criteria established in Ohio's Water Quality Standards (WQS) to protect those stream uses.

Details regarding this water quality survey are published in the Biological and Water Quality Study of the Lower Little Miami River and Selected Tributaries including the Todd Fork Subwatershed, 2007 (Ohio EPA, 2009) (available at http://www.epa.state.oh.us/portals/35/documents/LowerLittleMiamiRiverTSD2007.pdf). An interactive map showing sampling site locations in this watershed is available at http://wwwapp.epa.ohio.gov/dsw/gis/bio/index.php.

In terms of supporting aquatic life, the Little Miami River mainstem demonstrated exceptional water quality at all of the sites surveyed but one, which is located near the mouth of the river and impacted by sewer overflows. The tributaries that were surveyed however, showed a mix of water quality where stressors precluded the attainment of water quality standards at several locations. Failure to meet standards at nearly half of the impaired locations was due exclusively to low stream flow caused by an unusually dry year.

Of the fourteen sites where human induced stressors were problematic, fine sediment loading was the most widespread water quality problem. Also, tributary streams to Todd Fork, namely Lytle, First and Second Creeks suffered from elevated nutrients from point and nonpoint sources. Organic substances and oxygen demanding chemicals impacted Lytle and Cowan Creeks in the upper portion of the project area. Organic material from sewer overflows affects Duck and Clough Creeks near the lower portion of the study area.

Recreational uses were impaired due to the elevated risk for water-borne illness from pathogen contamination. This is evidenced by high concentrations of bacteria associated with fecal matter. Reasons for these failures include poorly treated human waste coming from home septic systems, bacteria associated with urban runoff, and ineffective waste water treatment and system overflows.

Total maximum daily loads (TMDLs) were calculated for *E coli* bacteria, nutrients, oxygen demanding substances, total suspended solids, sediment, and habitat quality. Watershed hydrology and estimates of pollutant loading from all sources were approximated using simple modeling methods based on mathematical equations and watershed characteristics. The sediment and habitat TMDLs were generated through a direct comparison of scores from a habitat evaluation index to target scores for that index.

Some of the watershed's point sources will require an increase in the quality of their effluent. Waste water treatment facilities serving Wilmington and Blanchester are recommended to have stricter limits on phosphorus discharges. Additionally, storm water discharges associated with the former ABX Airport will need to limit the discharge of oxygen demanding substances. The fulfillment of existing long term control plans to reduce impacts from combined sewage overflows and eliminate sanitary sewer overflows will abate the degraded conditions observed in Duck and Clough Creeks.

Addressing the nonpoint sources can be accomplished through system upgrades or better management of home septic systems. Sediment loading, in part, originates from the cropland surrounding some of the problem areas. Cover crops, conservation crop rotation, improvements in tillage methods, and sediment capture areas such as filter areas or wetlands would alleviate a large proportion of the problem. Storm water impacts from existing urbanized areas should be minimized by retrofitting storm water infrastructure as opportunities arise, and using a proactive storm water management approach for new development. In particular, impervious surfaces should be minimized, sensitive or critical areas protected, and localized storm water management (as opposed to larger centralized systems) could be used to better mimic a natural hydrology.

1 INTRODUCTION

The lower Little Miami River watershed is located in southwest Ohio extending from Lebanon and Wilmington in the north and northwest to Cincinnati in the south. This 602 square mile watershed area is home to more than 370,000 people and encompasses all or part of 43 municipalities in Clinton, Warren, Clermont, Hamilton and Butler counties.

Ohio EPA conducted a comprehensive physical, chemical and biological survey in the lower Little Miami River watershed excluding the East Fork of the Little Miami River in 2007. The water quality survey included monitoring of lower Little Miami River and several tributary streams. There were stream segments identified during the survey as not meeting Ohio's water quality standards. These findings and other information regarding water quality and habitat conditions are summarized in this report.

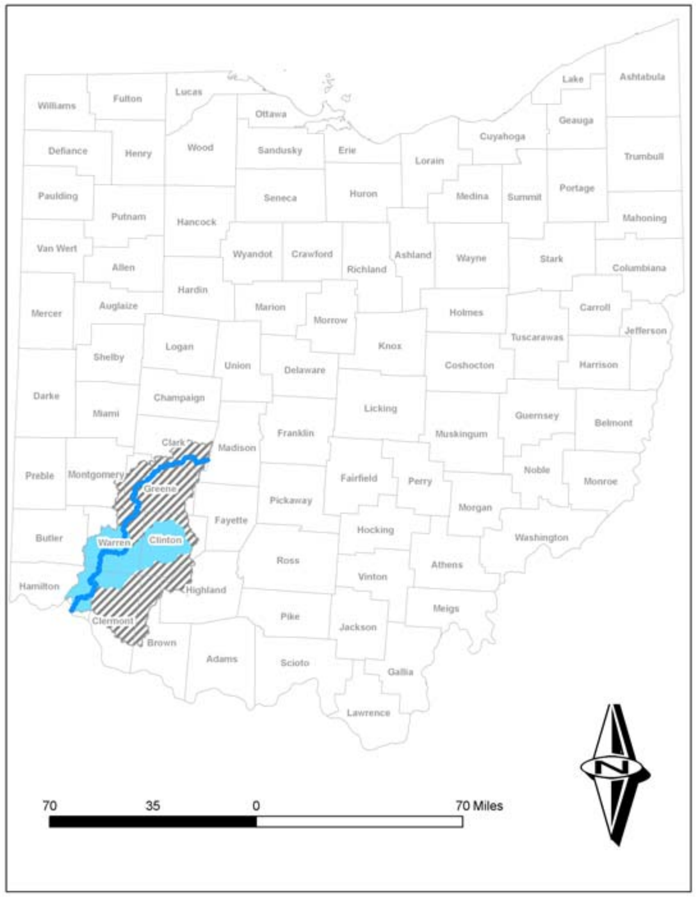


Figure 1.1 State wide map of the Little Miami River watershed with the TMDL project area highlighted.

Total Maximum Daily Loads (TMDL) have been developed for pollutants and stressors that have impaired water uses and precluded attainment of applicable water quality standards. This report summarizes the approach taken and results for these TMDL analyses. This report also includes a discussion about actions and land management that can abate the identified water resource problems.

Specific TMDLs that have been developed and are described in this report include:

- Pathogens (using *E coli* as an indicator of contamination)
- Nutrients (using total phosphorus as the indicator)
- Oxygen demand (using chemical oxygen demand as the indicator)
- Sediment (using a qualitative index to assess the degree of in-stream sedimentation)
- Habitat (using a qualitative index to assess the quality of habitat features)

Chapter five in this report provides strategies for restoring the full uses of surface waters in the lower Little Miami River watershed. Strategies for control of point sources and some nonpoint sources involve use of regulatory wastewater and storm water permits to control pollutant discharge in the watershed. Corrective measures have already been initiated to address use impairment caused by some regulated entities while others have yet to be addressed.

1.1 The Clean Water Act Requirement to Address Impaired Waters

The Clean Water Act (CWA) Section 303(d) requires States, Territories, and authorized Tribes to list and prioritize waters for which technology-based limits alone do not ensure attainment of water quality standards. Lists of these impaired waters (the Section 303(d) lists) are made available to the public for comment then submitted to the U.S. Environmental Protection Agency (U.S. EPA) for approval in even-numbered years. Further, the CWA and U.S. EPA regulations require that Total Maximum Daily Loads (TMDLs) be developed for all waters on the Section 303(d) lists. The Ohio EPA identified several subwatersheds (12-digit Hydrologic Unit Code) as impaired on the 2010 303(d) list (contained in the 2010 Integrated Report (Ohio EPA, 2010), available at http://www.epa.ohio.gov/dsw/tmdl/2010IntReport/index.aspx.

In the simplest terms, a TMDL can be thought of as a cleanup plan for a watershed that is not meeting water quality standards. A TMDL is defined as 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 quantity among the sources of the pollutant. Ultimately, the goal of Ohio's TMDL process is full attainment of Water Quality Standards (WQS), which would subsequently lead to the removal of the waterbodies from the 303(d) list.

Tables 1.1 and 1.2 list the assessment units (AUs) and how those AUs are dealt with regarding TMDL development for aquatic life and recreation uses respectively. No other beneficial use impairments within the lower Little Miami River watershed are addressed in this TMDL.

Table 1.1 Summary of causes of impairment to aquatic life and recreation uses for the lower Little Miami River watershed and actions taken to address them.

Assessment units		**Narrative description**	**Drainage area (square miles)**	**Cause of use impairment**	**Action taken**
HUC-10	**HUC-12 (or large river unit)**				
Large River	90-01	Little Miami River		E coli	TMDL for E coli
	90-02	Little Miami River		E coli	TMDL for E coli
05090202-06	06-01	Dutch Creek	14.8	***Not impaired***	NA
	06-02	Headwaters Todd Fork	33.4	***Not impaired***	NA
	06-03	Lytle Creek	20.4	E coli	TMDL for E coli
				nutrient/eutrophication biological indicators	TMDL for nutrients
				sedimentation/siltation	TMDL for sediment (habitat)
				organic enrichment (sewage) biological indicators	TMDL for dissolved oxygen/chemical oxygen demand
	06-04	Headwaters Cowan Creek	31.5	natural conditions (flow or habitat)	NA

Assessment units: HUC-10	Assessment units: HUC-12 (or large river unit)	Narrative description	Drainage area (square miles)	Cause of use impairment	Action taken
				nutrient/eutrophication biological indicators	TMDL for dissolved oxygen/chemical oxygen demand
				sedimentation/siltation	TMDL for sediment (habitat)
				oxygen, dissolved	TMDL for dissolved oxygen/chemical oxygen demand
	06-05	Wilson Creek-Cowan Creek	22.1	natural conditions (flow or habitat)	NA
	06-06	Little Creek-Todd Fork	24.4	***Not impaired***	NA
05090202-07	07-01	East Fork Todd Fork	39.6	E coli	TMDL for E coli
				natural conditions (flow or habitat)	NA
	07-02	Second Creek	20.0	E coli	TMDL for E coli
				nutrient/eutrophication biological indicators	TMDL for nutrients
				sedimentation/siltation	TMDL for sediment (habitat)
				organic enrichment (sewage) biological indicators	TMDL for nutrients
				Atrazine (public water supply)[1]	Not addressed
	07-03	First Creek	19.5	impairment unknown	NA
	07-04	Lick Run-Todd Fork	35.7	E coli	TMDL for E coli
				Not impaired	NA
05090202-08	08-01	Ferris Run-Little Miami River	30.2	***Not impaired***	NA
	08-02	Little Muddy Creek	20.6	sedimentation/siltation	TMDL for sediment (habitat)
	08-03	Turtle Creek	44.9	E coli	TMDL for E coli
				natural conditions (flow or habitat)	NA
	08-04	Halls Creek-Little Miami River	20.5	***Not impaired***	NA

Assessment units		Narrative description	Drainage area (square miles)	Cause of use impairment	Action taken
HUC-10	HUC-12 (or large river unit)				
05090202-09	09-01	Muddy Creek	15.9	E coli	TMDL for E coli
				natural conditions (flow or habitat)	NA
				nutrient/eutrophication biological indicators	Not addressed (SSOs causing impairment have been shut down since assessment)
				organic enrichment (sewage) biological indicators	
				sedimentation/siltation	TMDL for sediment (habitat)
	09-02	O'Bannon Creek	59.3	natural conditions (flow or habitat)	NA
	09-03	Salt Run-Little Miami River	35.3	***Not impaired***	NA
05090202-14	14-01	Sycamore Creek	23.4	organic enrichment (sewage) biological indicators	Not addressed
	14-02	Polk Run-Little Miami River	17.0	unknown toxicity	Not addressed
				siltation	Not addressed
				organic enrichment/DO	Not addressed
				flow alteration	Not addressed
				direct habitat alterations	Not addressed
	14-03	Horner Run-Little Miami River	21.5	unknown toxicity	Not addressed
				siltation	Not addressed
				organic enrichment/DO	Not addressed
				flow alteration	Not addressed
				direct habitat alterations	Not addressed
	14-04	Duck Creek	15.5	direct habitat alterations	TMDL for sediment (habitat)
				organic enrichment (sewage) biological indicators	TMDLs for TSS and CBOD 5-day (CSO)
				sedimentation/siltation	TMDL for sediment (habitat)

Assessment units		Narrative description	Drainage area (square miles)	Cause of use impairment	Action taken
HUC-10	HUC-12 (or large river unit)				
	14-05	Dry Run-Little Miami River	17.8	unknown toxicity	Not addressed
				siltation	Not addressed
				organic enrichment/DO	Covered by the Duck Creek TMDLs for TSS and CBOD 5-day (source of impairment is CSO)
				flow alteration	Not addressed
				direct habitat alterations	Not addressed
	14-06	Clough Creek-Little Miami River	18.7	sedimentation/siltation	TMDL for sediment (habitat) TMDLs for TSS and CBOD 5-day (source of impairment is CSO)

[A] Priority points as assigned in Ohio EPA, 2008.
1 Atrazine impairment to public water supply will be addressed in TMDL efforts in the East Fork Little Miami River set to begin in 2012.

1.2 Public Involvement

Public involvement is key to the success of water restoration projects, including TMDL efforts. From the beginning, Ohio EPA has invited participation in all aspects of the TMDL program. The Ohio EPA convened an external advisory group in 1998 to assist the Agency with the development of the TMDL program in Ohio. The advisory group issued a report in July 2000 to the Director of Ohio EPA on their findings and recommendations. The lower Little Miami River watershed TMDL project has been completed using the process endorsed by the advisory group.

Consistent with Ohio's current Continuous Planning Process (CPP), the draft TMDL report was available for public review from July 6 through August 16, 2010 A summary of the three sets of comments that were received and the associated responses is included in Appendix D to this final report.

Ohio EPA has been in contact with interested parties in the watershed throughout the TMDL process. Organizations external to the agency (representatives for waste water plants, watershed groups, and other state and county agencies) have been invited to study planning meetings and have had survey results presented at several different times and locations. Additionally, Ohio EPA has worked with the Little Miami River Partnership regarding information sharing and education efforts with the public and other interested parties. The following is a summary of some of the events where external parties have been involved with the process:

- January 13, 2007: Presentation to Greenacres Foundation Saturday Stream Snapshot monitoring volunteers about upcoming watershed survey.
- February 12, 2007 – Study planning meeting with several watershed stakeholder in attendance
- November 16, 2007: Presentation to Little Miami River Symposium sponsored by Little Miami River Partnership (LMRP).
- May 15, 2008: Presentation about the TSD process at public meeting sponsored by LMRP.
- June 26, 2008: Presentation about the TMDL process at public meeting sponsored by LMRP.
- July 22, 2008 – Discussion regarding the proposed Little Miami River CREP (involving LMRP and Ohio EPA)
- December 8, 2009 – Two public meetings regarding the results of the biological and water quality surveys

Continued public involvement is critical to the success of any TMDL project. Ohio EPA will continue to support the implementation process and will facilitate, to the fullest extent possible, restoration actions that are acceptable to the communities and stakeholders in the study area and to Ohio EPA. Ohio EPA is reluctant to rely solely on regulatory actions and strongly advocates voluntary actions facilitated by the local stakeholders, watershed organization, and agency partners to restore the lower Little Miami River watershed.

2 PROJECT OVERVIEW

The purpose of this chapter is to summarize the existing conditions within the TMDL project area. This includes physical and demographic attributes of the watershed as well as the most recent water quality information.

2.1 Description of Project Area

The following four subsections provide background information regarding the TMDL project area. Here the project area is clearly defined including an overview of the stream system. Also, important physical attributes such as land cover types, soils, and topography is discussed along with demographic information since human land use and development patterns impact water quality.

2.1.1 Project Delineation and Water Resources

The project area is comprised of five hydrologic units or watersheds (based on 10-digit hydrologic unit codes or HUCs). Each of these HUCs begins with the numbers 05090202 which indicate the 8-digit HUC to which they belong, namely the entire Little Miami River watershed. The 10-digit HUCs that constitute the project area, the lower Little Miami River watershed except for the East Fork of the Little Miami River watershed, are the following:

- Headwaters to Todd Fork (05090202 - 06)
- East Fork Todd Fork – Todd Fork (05090202 - 07)
- Turtle Creek – Little Miami River (05090202 - 08)
- O'Bannon Creek – Little Miami River (05090202 - 09)
- Sycamore Creek – Little Miami River (05090202 - 14)

Table 2.1 lists the 12-digit HUCs (assessment unit) in the lower Little Miami River watershed as well as the respective 10-digit HUC to which they belong (i.e., the first 10 of the 12 digits). Figure 2.1 is a map of the lower Little Miami River watershed with the respective 12-digit HUCs labeled with the last two of the 12 digits and identified by color.

The Little Miami River, nearly 108 miles long, flows for almost 51 miles through the TMDL project area. The Little Miami River joins the Ohio River on the east side of Cincinnati, Ohio. Figure 2.2 is a map showing some of the named tributaries in the watershed.

Principle tributaries to lower Little Miami River include:

- Todd Fork
- East Fork of Todd Fork
- Cowan Creek
- First Creek
- Second Creek
- O'Bannon Creek
- Turtle Creek
- Little Muddy Creek
- Muddy Creek
- Sycamore Creek

The TMDL project area is generally a high relief portion of the Little Miami River watershed and consequently most of the streams have a gradient that is greater than the average stream in Ohio. For most of its length the Little Miami flows atop a buried valley aquifer composed of highly permeable sands and gravel from past glacial events. Smaller tributaries in this area are known to disappear into the ground during dry periods due to high infiltration rates associated with the sand and gravel aquifer. This aquifer was designated a Sole Source Aquifer by U.S.

EPA. This designation requires extra review for any federally funded projects proposed for the surface above the aquifer.

There are two surface water intakes for public drinking water supplies in the project area; however, most of the communities in the watershed rely on groundwater. These surface water sources are Cowan Creek, which supplies the City of Wilmington and Whitakers Run which supplies Blanchester. Cowan Creek is impounded to form the nearly 700 acre Cowan Lake which was used to facilitate surface water withdrawals; however, this intake has been substituted by Wilmington with an intake on Caesar Creek Reservoir. Other lakes in the lower Little Miami River TMDL project area are far smaller in size.

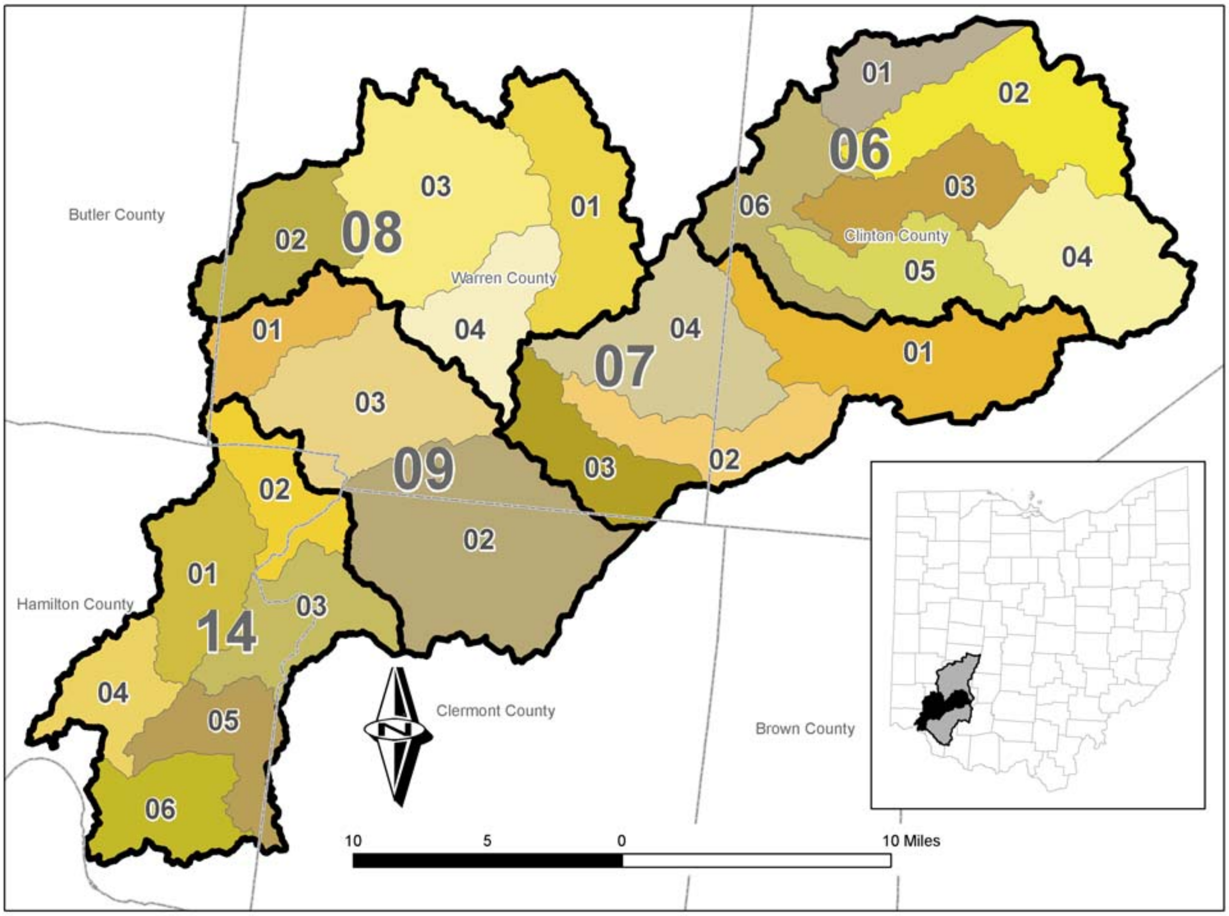


Figure 2.1 Lower Little Miami River's12-digit HUC assessment units.

Table 2.1 Twelve-digit HUC watersheds within the lower Little Miami project area.

10-digit HUC	12-digit HUC	Watershed description	Drainage area (square miles)	Drainage area (acres)
05090202 -				
06 -	01	Dutch Creek	14.8	9,503
	02	Headwaters Todd Fork	33.5	21,420
	03	Lytle Creek	20.4	13,075
	04	Headwaters Cowan Creek	31.5	20,178
	05	Wilson Creek-Cowan Creek	22.1	14,144
	06	Little Creek-Todd Fork	24.4	15,623

10-digit HUC	12-digit HUC	Watershed description	Drainage area (square miles)	Drainage area (acres)
05090202 -				
	HUC 10	**Headwaters Todd Fork**	***146.8***	***93,943***
07 -	01	East Fork Todd Fork	39.7	25,389
	02	Second Creek	20.0	12,786
	03	First Creek	19.5	12,494
	04	Lick Run-Todd Fork	35.7	22,867
	HUC 10	**East Fork Todd Fork-Todd Fork**	***114.9***	***73,535***
08 -	01	Ferris Run-Little Miami River	30.2	19,332
	02	Little Muddy Creek	20.6	13,187
	03	Turtle Creek	45.0	28,774
	04	Halls Creek-Little Miami River	20.5	13,116
	HUC 10	**Turtle Creek-Little Miami River**	***116.3***	***74,409***
09 -	01	Muddy Creek	15.9	10,162
	02	O'Bannon Creek	59.4	38,019
	03	Salt Run-Little Miami River	35.3	22,620
	HUC 10	**O'Bannon Creek-Little Miami River**	***110.6***	***70,802***
14 -	01	Sycamore Creek	23.4	14,967
	02	Polk Run-Little Miami River	17.0	10,872
	03	Horner Run-Little Miami River	21.5	13,759
	04	Duck Creek	15.5	9,904
	05	Dry Run-Little Miami River	17.8	11,392
	06	Clough Creek-Little Miami River	18.7	11,987
	HUC 10	**Sycamore Creek-Little Miami River**	***113.9***	***72,881***

2.1.2 Land Cover

While agriculture is the predominant land use with cultivated crop and pasture/hay respectively accounting for 40% and 11% of the total lower Little Miami River watershed area, a significant portion of the land is forested (30%) or developed (17%). Most of the agricultural and forested land use is found in the Todd Fork subwatershed while the majority of development occurs in the lower Little Miami River watershed downstream from O'Bannon Creek. Figure 2.3 is a map of the land cover found in the TMDL project area while Table 2.2 lists the area and proportion associated with these types of cover and Figure 2.4 is a pie chart showing the same.

2.1.3 Soils, Geology and Topography

The topography of the Little Miami River Watershed has been influenced by glaciations which left distinctive land forms and thick deposits of silt, sand, and gravel. The northwest part of the watershed is within the Eastern Corn Belt Plains ecoregion, which is characterized by level to gently sloping land and relatively low gradient streams. The majority of the watershed lies within the Interior Plateau ecoregion which has greater relief and tributaries tend to have steeper gradients before entering the Little Miami flood plain. The valley of the mainstem through the study area is relatively narrow with steep sides.

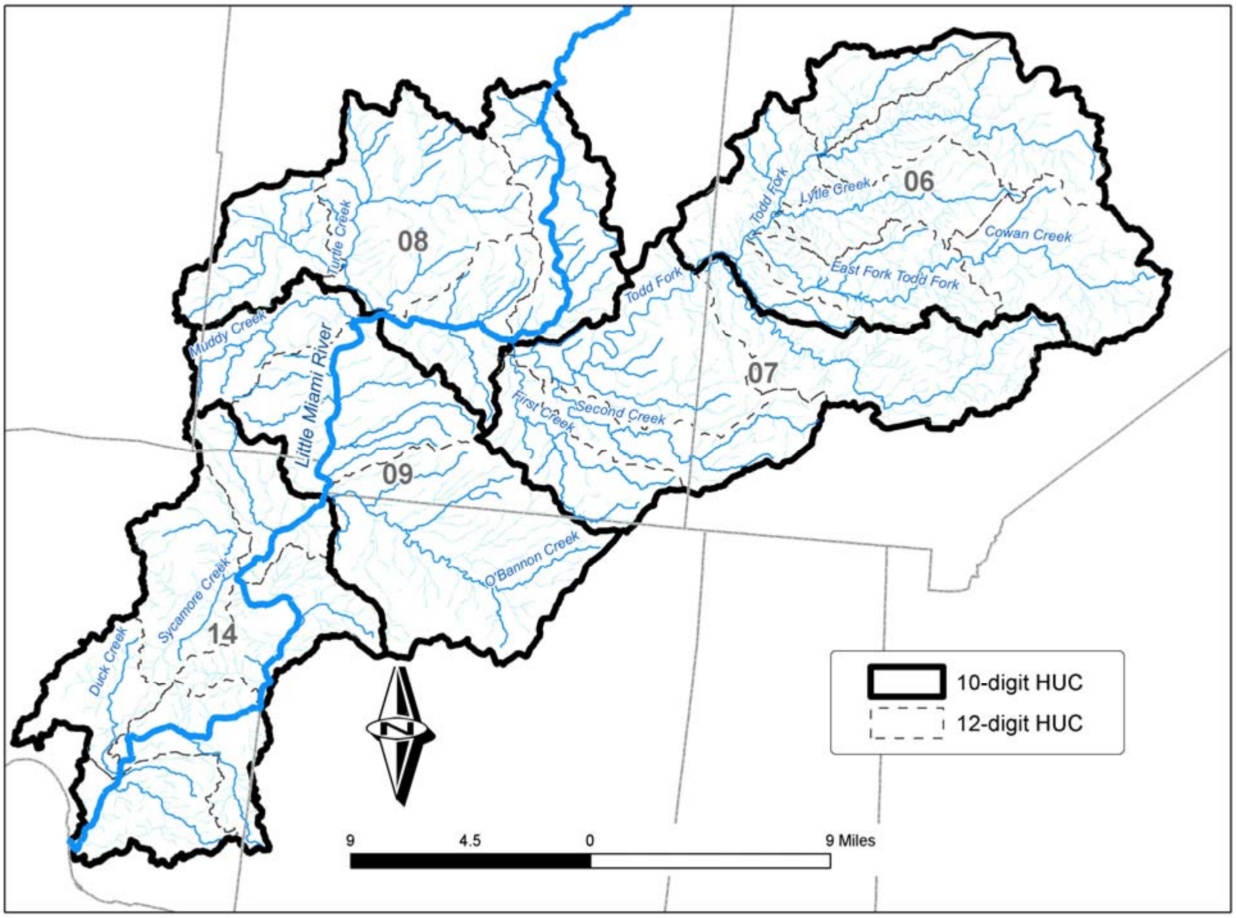


Figure 2.2 Map of streams in the lower Little Miami River watershed.

The majority of the soils are silt loams (nearly 80%) while clay loams and silty clay loams also occur in appreciable proportions. Among the most commonly found soils are the Xenia, Avonsburg, Clermont, and Rossmoyne silt loams. Over sixty percent of the soils are either well drained or moderately well drained leaving only seventeen percent either poorly drained or very poorly drained. The implications for this are related to the need for enhanced land drainage particularly for row crop production. Less than one percent of the soils are listed as all hydric which is an indication of the likelihood for wetland to be present or the potential to develop naturally (if land is left unmanaged). Flooding frequently occurs on less than two percent of the soils while ninety-two percent typically experience no flooding.

2.1.4 Population and Growth Trends and Economic Development

Communities in the watershed include Lebanon, South Lebanon, Mason, Loveland, Maineville, Milford, and portions of eastern Cincinnati. Comparing the 1990 and 2000 census figures shows that significant population increase has happened and probably continues. Total population in the watershed grew from 314,065 to 360,392 or 14.7%. Warren County tracts increased from a population of 62,660 in 1990 to 97,269 in 2000, an increase of 34,609 or 55% over the previous population. Clermont County increased by 9,955 or 21%. Hamilton County's watershed population only grew by 419 persons, which reflects the already well-developed nature of the area.

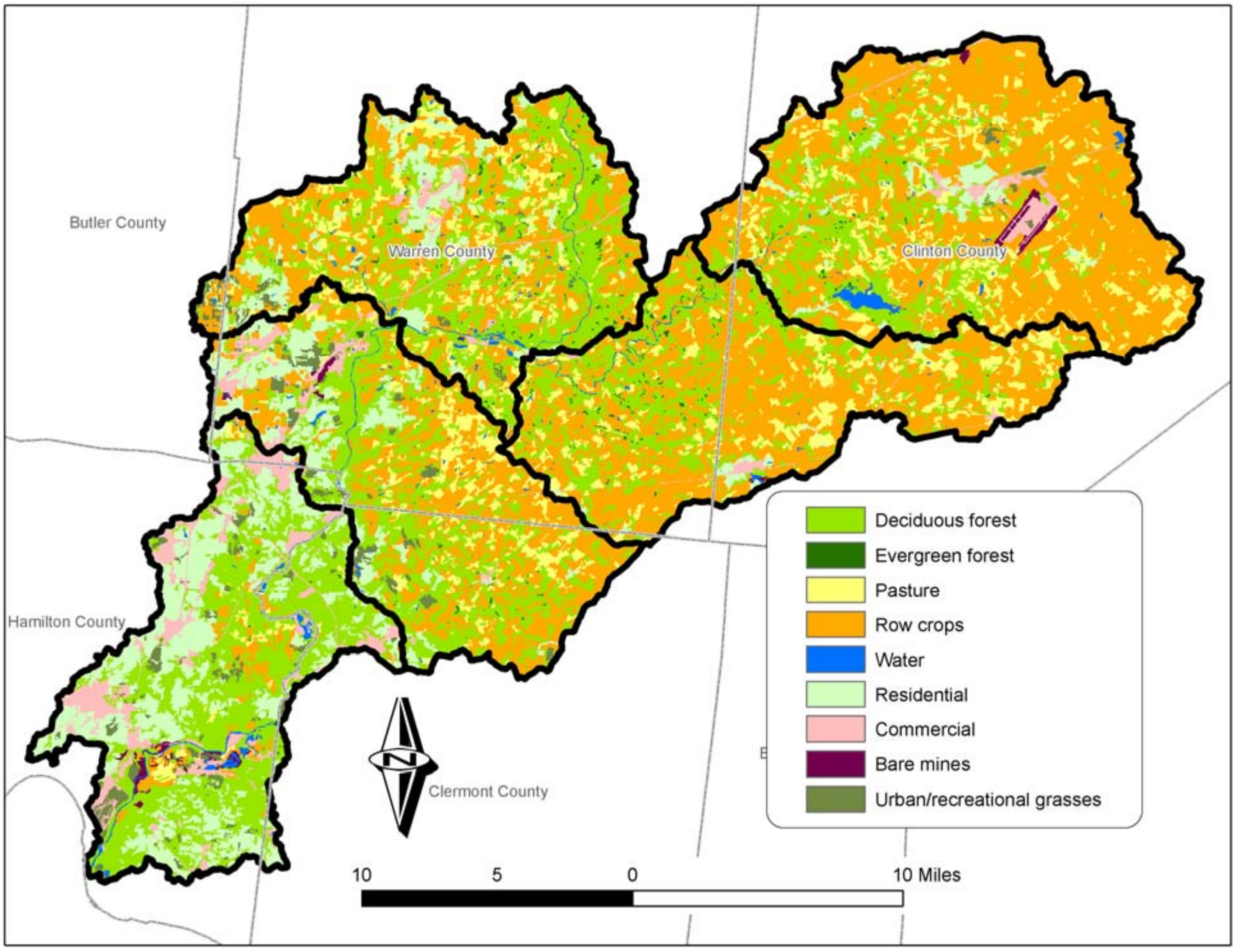


Figure 2.3 Map of land cover classes. Land cover is based on Landsat 7 imagery taken around 2001 and compiled in 2006 by the Multi-Resolution Land Characteristics (MRLC) consortium.

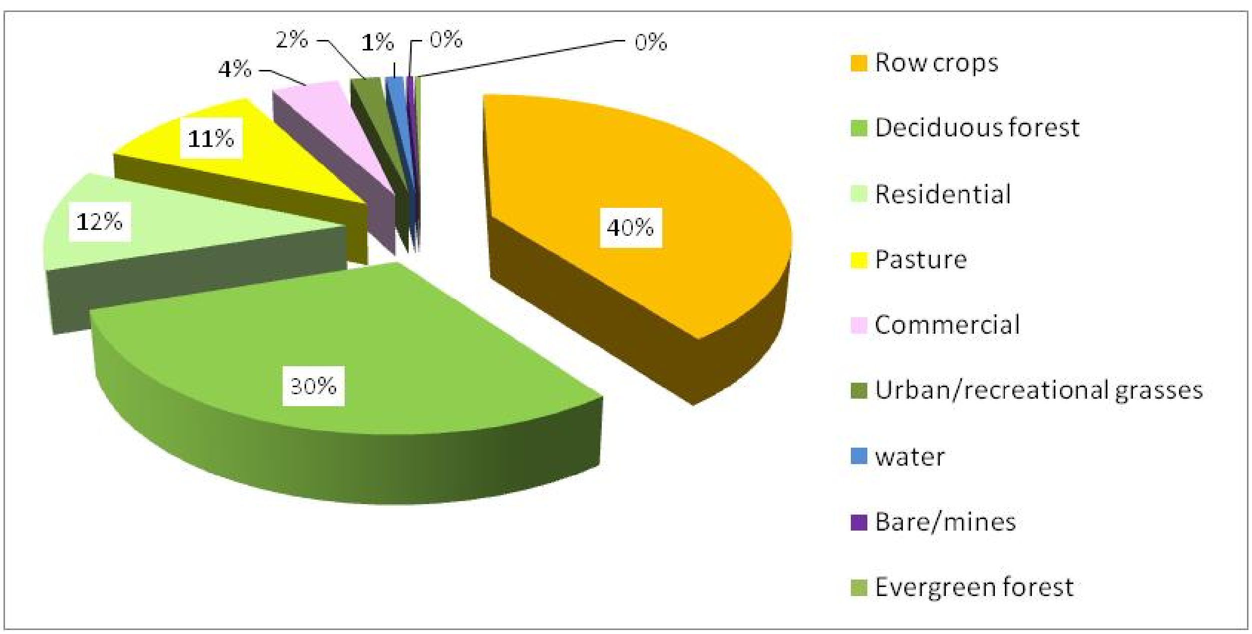


Figure 2.4 Pie chart of the distribution of land cover types.

Table 2.2 Cumulative acres of various land cover types.

Land cover type	Percent of area	Area (acres)	Area (square miles)
Row crops	40%	153,360	239.6
Deciduous forest	30%	116,532	182.1
Residential	11%	44,253	69.1
Pasture	11%	40,760	63.7
Commercial	4%	16,388	25.6
Urban/recreational grasses	2%	7,083	11.1
water	1%	4,190	6.5
Bare/mines	0%	1,599	2.5
Evergreen forest	0%	1,407	2.2

While most developing areas in the Little Miami watershed are not immediately adjacent to the river, the impacts of development are still a potential problem. However; waste water treatment capacity should be adequate to handle the new growth since several facilities have undergone expansions designed to accommodate upcoming growth for the next 20 years. Numerous residential, industrial, and commercial developments are recently completed, underway, or proposed within the watershed. Some local programs and the NPDES general permit for construction sites attempt to control sediment-laden runoff from these sites during construction. Enforcement of these regulations has not kept pace with the development, however, and a significant amount of sediment enters streams in the watershed as a result. This increased amount of sediment is eventually transported to the Little Miami via tributaries. Already developed areas contribute different types of pollutants to the watershed (oil & grease, lawn chemicals, PAHs). Problems have been reported from combined sewer overflows along Duck Creek.

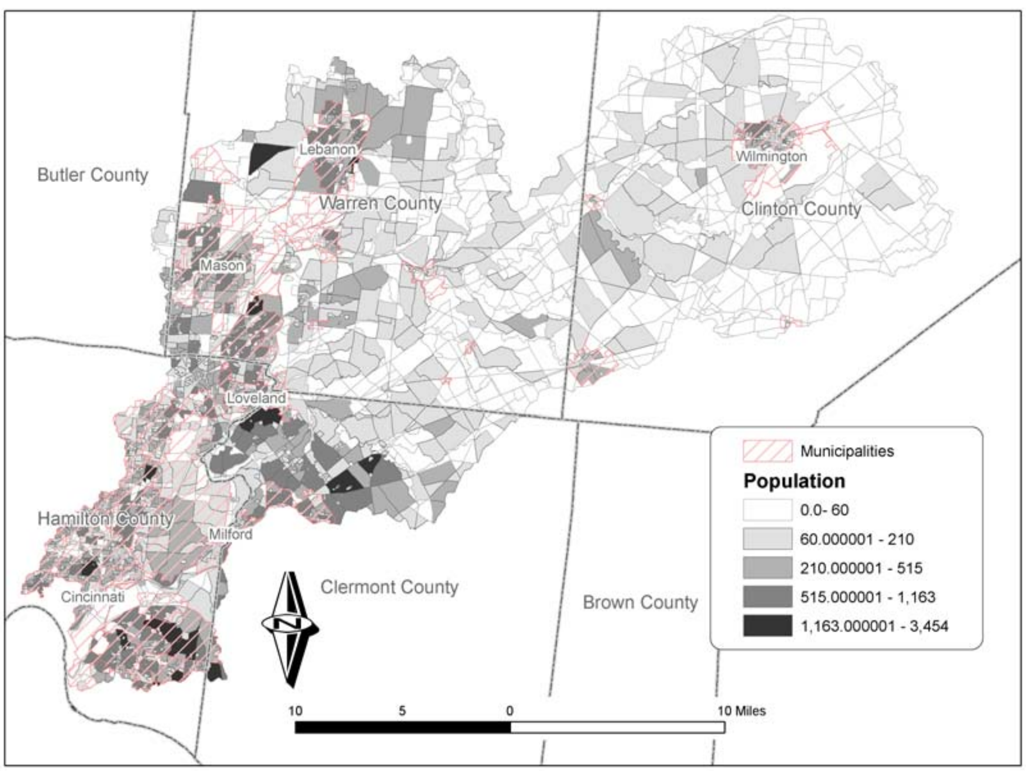


Figure 2.5 Map of population density. Based on the 2000 census provided by the Ohio Department of Development in a spatially referenced database.

2.2 Water Quality Assessment Results

This section of the report summarizes the results of the most recent water quality surveys completed within the project area. The criteria used to establish the level of water quality (i.e., whether or not minimum standards are being met) is discussed in the next chapter along with the other water quality based targets that are needed for developing TMDLs.

2.2.1 Recreation Use Attainment

Data collected by the Ohio EPA during the 2007 and 2008 recreation seasons were used to assess the status of recreation use attainment. A summary of the data is provided in Table 2.3.

Bacteria samples (*E. coli*) were collected by Ohio EPA at 37 sites on five occasions in 2007 and at eleven sites in 2008. Overall 11 of the 37 sites failed to meet the standards for recreation uses (30 percent). The distribution of this impairment is as follows:

- HUC 06 accounts for 27 percent of the total impairment
- HUC 07 accounts for 27 percent of the total impairment
- HUC 08 accounts for 9 percent of the total impairment
- HUC 09 accounts for 9 percent of the total impairment
- Mainstem accounts for 18 percent of the total impairment
- One site on the East Fork of the Little Miami River accounts for 9 percent of the total impairment

Table 2.3 summarizes the data collected at all of the sites across the 2007 and 2008 field seasons and Figure 2.6 is a bar chart showing the distribution of recreation use impairment across the mainstem of the river and the five 10-digit HUCs. The unconfirmed but suspected major sources of the bacteria are also listed in Table 2.3.

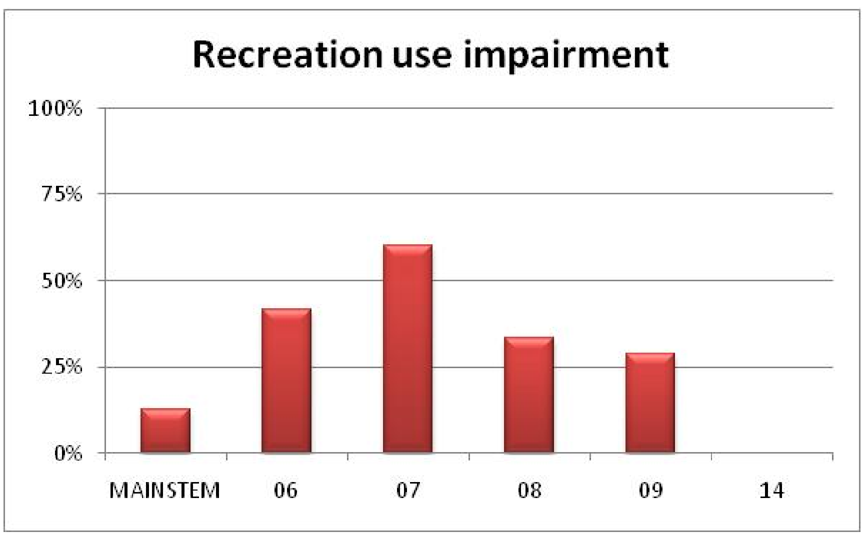


Figure 2.6 Percent of the assessed sites in each assessment unit that are impaired for their recreation uses.

Table 2.3 Sample results for E coli bacteria during the 2007 and 2008 recreation seasons.

12-Digit WAU	River mile	Location description	Sampling year	*E. coli (counts per 100 ml)*[1] Geo[2] mean	Max value	Attainment Status	Suspected Sources of Bacteria [3]
***Little Miami River** - PCR - A*							
-	53.84	SR 73, (Upst Waynesville WWTP)	2007	83	220	FULL	
-	53.15	Upst Newman Run, Dst Waynesville WWTP	2007	93	260	FULL	
-	50.25	Dst Caesar Cr (Shaw property)	2007	59	110	FULL	
			2008	**237**	**2300**	**NON**	H,J
-	43.76	SR 350- Near Fort Ancient	2007	40	70	FULL	
-	35.98	Stubbs Mill Rd	2007	40	230	FULL	
-	32.9	SR 48 (Upstream Lebanon WWTP)	2007	53	190	FULL	
-	31.96	Upst Muddy Cr., Dst Lebanon WWTP	2007	97	140	FULL	
-	29	Upst Simpson Cr	2007	105	**500**	FULL	
-	27.9	Dst SR 22/3 (Little Miami State Park)	2007	82	**640**	FULL	
-	22.3	Upst Polk Run (Isaac Walton Park)	2007	67	180	FULL	
-	21.45	Hopewell Rd (Bridge St)	2007	49	140	FULL	
-	20.6	Adjacent Lake Isabella	2007	62	210	FULL	
-	17.73	Dst SR 126 (Kelly Nature Preserve)	2007	28	100	FULL	
-	13.07	Wooster Pike (Milford gage)	2007	71	130	FULL	
			2008	**127**	**520**	**NON**	E,G,H,J
***East Fork Little Miami River** - PCR - A*							
13-05	0.77	S. Milford Rd	2007	45	170	FULL	
			2008	**195**	**1200**	**NON**	C,G
***Todd Fork** - PCR - B*							
06-06	19.5	SR 22, Upst Lytle Cr	2007	91	**2100**	FULL	
06-06	17.1	Adjacent Creek Rd, Dst Cowan Cr	2007	103	320	FULL	
06-06	15.1	Spring Hill Rd, Dst Clarksville WWTP	2007	78	**760**	FULL	
07-04	0.14	SR 22/3 (Morrow)	2007	46	400	FULL	
			2008	**209**	**1300**	**NON**	H,J
***Lytle Creek**- PCR - B*							
06-03	7.01	Nelson Rd, Upst Wilmington WWTP	2007	**455**	**1200**	**NON**	F,G
			2008	**783**	**8400**	**NON**	F,G
06-03	5.95	Dst Wilmington WWTP and landfill at ford	2007	**1570**	**2800**	**NON**	C,F,G,H
06-03	0.65	Clarksville Rd	2007	**304**	**2000**	**NON**	A,C,F,G,H
			2008	**701**	**7800**	**NON**	A,C,F,G,H
***Cowan Creek** - PCR - B*							

12-Digit WAU	River mile	Location description	Sampling year	*E. coli (counts per 100 ml)*[1]		Attainment Status	Suspected Sources of Bacteria [3]
				Geo[2] mean	Max value		
06-05	0.6	Clarksville Rd	2007	46	100	FULL	
			2008	84	250	FULL	
***East Fork Todd Fork** - PCR - B*							
07-01	7.12	SR 730	2007	106	**1000**	FULL	
07-01	1.6	SR 132 (Clarksville)	2007	145	**750**	FULL	
			2008	**233**	310	**NON**	G,H
***Second Creek**- PCR - B*							
07-02	10.94	Columbus Ave (Upst Blanchester WWTP)	2007	34	370	FULL	
07-02	9.45	SR 123 (Dst Blanchester WWTP)	2007	**228**	430	**NON**	C,F,H
***Turtle Creek**- PCR - B*							
08-03	6.23	Glosser Rd	2007	66	370	FULL	
08-03	0.52	SR 48	2007	85	140	FULL	
			2008	**166**	**595**	**NON**	G,H,J
***Muddy Creek** – PCR - B*							
09-01	2.5	Mason-Morrow Rd (Upst Mason WWTP)	2007	52	**900**	FULL	
09-01	0.54	Mason-Morrow Rd (Dst Mason WWTP)	2007	**279**	**3200**	**NON**	C,G
			2008	**441**	**10000**	**NON**	C,G
***O'Bannon Creek** – PCR - B*							
09-02	4.37	Gibson Rd (Upst O'Bannon WWTP)	2007	56	120	FULL	
09-02	1.84	O'Bannonville Rd (Dst O'Bannon WWTP)	2007	87	220	FULL	
09-02	0.26	SR 48 (Loveland)	2007	55	240	FULL	
			2008	138	**3900**	FULL	
***Sycamore Creek** - PCR - B*							
14-01	0.5	Upst Sycamore Creek WWTP	2007	21	50	FULL	
14-01	0.1	Dst Sycamore Creek WWTP	2007	107	**1200**	FULL	
***Dry Run** –SCR*							
14-05	1.79	Snook Rd	2007	71	540	FULL	

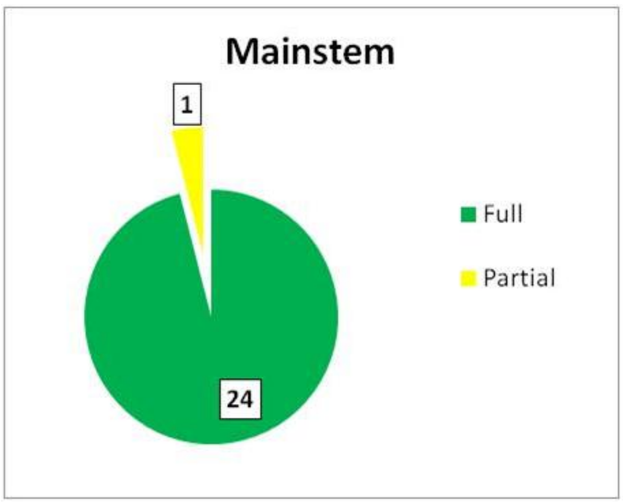
1 Statistics mostly based on five samples collected at each site per year; however, this ranged from two to five samples.
2 "Geo" refers to the geometric mean.
3 Recreation use attainment status based on the following criteria and evaluated as the geometric mean of the data from each site (expressed as colony forming units per 100 ml of sample): PCR-A = 126; PCR-B = 161; SCR = 1030
4 Suspected Sources of Bacteria:

A - Failing home sewage treatment systems
B - Livestock access to stream
C - Wastewater treatment plant
D - Unsewered community
E - Combined sewer overflow (CSOs)
F - Sanitary sewer overflows (SSOs)
G -Urban runoff (city, village, etc.)
H - Agricultural runoff
I - Wildlife (geese, etc.)
J - Unknown

2.2.2 Aquatic Life Use Attainment

Aquatic life use (ALU) attainment was assessed at eighty-two sites in the lower Little Miami River watershed. Twenty-four of the 25 sites sampled on the Little Miami River mainstem fully met criteria for EWH while one site was in partial attainment. The tributaries saw more ALU impairment as only 53% of the 57 tributary sites fully met their applicable criteria and 35% and 12% were in partial and non attainment respectively. Figure 2.7 shows a graph of aquatic life use attainment status for the Little Miami River mainstem and the tributaries with the TMDL project area.

The biology and water quality of the lower Little Miami River watershed revealed positive changes over previous studies. Earlier surveys consistently revealed less than 50 percent full attainment of EWH criteria on the mainstem. In 2007, this percentage leaped to 96 percent full attainment. Only the lowermost site, located near Beechmont Road at River Mile (RM) 3.5, was partially meeting EWH expectations due to a subpar Index of Biotic Integrity (IBI) score of 36. The underperformance at this location was attributed primarily to the continuing influence of urban runoff, Combined Sewer Overflows (CSOs), Sanitary Sewer Overflows (SSOs), and industrial discharges from Duck Creek. Secondarily, as the most downstream site on the mainstem, RM 3.5 was also subjected to the cumulative effect of upstream wastewater loadings.



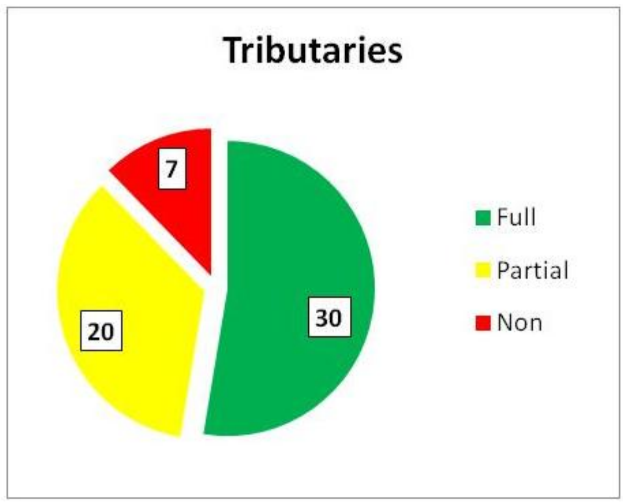


Figure 2.7 Summary of the aquatic life use attainment status.

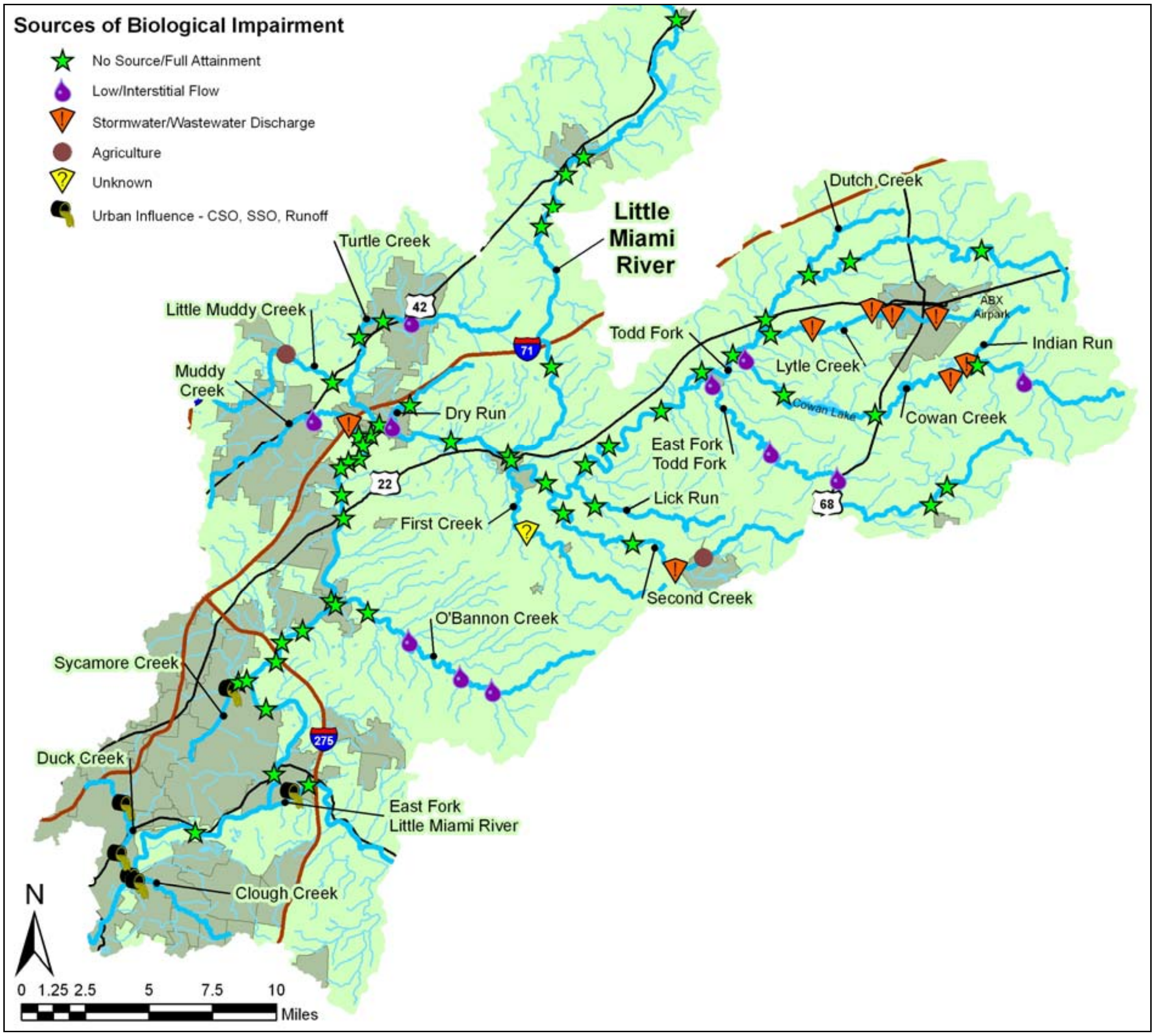


Figure 2.8 Map of sources of impairment to aquatic life uses at the survey sites. Map includes sites surveyed on the mainstem of the Little Miami River outside of the five 10-digit HUCs defining the TMDL project area.

Table 2.4 Results of the biological assessment.

Location	STORET (RM)	Drain. (mi²)^	IBI	MIwb[1]	ICI[2]	QHEI	Status[3, 4]	Causes	Sources
HUC 05090202 01 04 Yellow Springs Creek – Little Miami River									
Little Miami River @ Jacoby Road, dst. Yellow Springs Cr.	M01S09 (83.14)	118.0[W]	48[ns]	9.8	42[ns]	77.5	FULL [EWH]		
HUC 05090202 05 04 Newman Run – Little Miami River									
Little Miami River @ Spring Valley roadside park	M01W45 (63.3)	360.0[B]	56	10.2	48	83.0	FULL [EWH]		
Little Miami River @ Corwin Rd. upstream Waynesville WWTP	M01P29 (54.3)	395.0[B]	54	11.0	44[ns]	82.0	FULL [EWH]		
Little Miami River adj. Corwin Rd. dst. Waynesville WWTP	M01S29 (53.15)	402.0[B]	51	10.8	50	80.5	FULL [EWH]		
Little Miami River upstream Middletown Road	M01W55 (51.2)	413.0[B]	54	10.6	48	90.0	FULL [EWH]		
Large River Assessment Unit 05090202 9001 – Caesar Creek to O'Bannon Creek									
Little Miami River dst. Caesar Creek @ Shaw property	M05K01 (50.25)	658.0[B]	52	11.3	52	85.0	FULL [EWH]		
Little Miami River @ SR 350	M05S12 (43.76)	680.0[B]	53	10.8	E	87.0	FULL [EWH]		
Little Miami River dst .Todd Fork & SR 123	300361 (38.50)	949.0[B]	54	11.4	46	82.5	FULL [EWH]		
Little Miami River @ Stubbs Mill Road	610520 (35.98)	964.0[B]	57	10.8	50	91.5	FULL [EWH]		
Little Miami River @ US 48	M05P03 (32.9)	1035.0[B]	52	10.1	54	--	FULL [EWH]		
Little Miami River @ Lebanon WWTP mix zone	M05S36 (32.1)	1036.0[B]	42	9.9	--	N/A	Mix Zone		
Little Miami River ust. Muddy Creek, N of King's Mill	M05W15 (31.96)	1036.0[B]	--	--	48	--	(FULL) [EWH]		
Little Miami River ust. Peter's Cartridge	M05W19 (31.5)	1050.0[B]	51	11.3	52	89.5	FULL [EWH]		

Location	STORET (RM)	Drain. (mi²)^	IBI	MIwb[1]	ICI[2]	QHEI	Status[3, 4]	Causes	Sources
Little Miami River @ King's Mill Road	M05S09 (30.9)	1054.0 B	--	--	52	--	(FULL) EWH		
Little Miami River adj. Peter's Cartridge	200516 (30.5)	1054.0 B	54	11.5	50	85.5	FULL EWH		
Little Miami River dst. Grandin Road	M05W20 (30.0)	1055.0 B	--	--	52	--	(FULL) EWH		
Little Miami River dst. Peter's Cartridge	M05W24 (29.0)	1059.0 B	54	11.0	54	85.0	FULL EWH		
Little Miami River dst. Simpson Creek	M05S07 (27.9)	1069.0 B	54	11.3	54	91.0	FULL EWH		
Little Miami River ust. O'Bannon Creek	M05W34 (24.10)	1085.0 B	50	10.2	48	81.0	FULL EWH		
Large River Assessment Unit 05090202 9002 – O'Bannon Creek to Ohio River									
Little Miami River adj. Loveland-Kemper Road	M05S39 (22.30)	1150.0 B	53	9.8	54	79.5	FULL EWH		
Little Miami River @ Polk Run WWTP mixing zone	300364 (21.7)	1150.0 B	--	--	14*	--	Mix Zone		
Little Miami River @ Branch Hill New Guinea Road	600540 (21.5)	1161.0 B	50	11.2	--	89.5	(FULL) EWH		
Little Miami River adj. Lake Isabella	M05S05 (20.6)	1161.0 B	56	10.4	52	88.5	FULL EWH		
Little Miami River @ canoe access area dst. SR 126	M05W47 (17.7)	1187.0 B	52	11.2	E	86.5	FULL EWH		
Little Miami River @ Wooster Pike Milford gage	M05P11 (13.07)	1203.0 B	51	10.2	52	90.5	FULL EWH		
Little Miami River @ Newtown Road	M05P12 (8.14)	1713.0 B	52	10.2	50	85.5	FULL EWH		
Little Miami River @ Beechmont Road	600580 (3.5)	1744.0 B	36*	9.7	VG ns	73.5	**PART.** EWH	Sedimentation/Siltation Nutrient/Organic enrichment (sewage) biological indicators	Combined sewer overflows Municipal point source discharges
HUC 05090202 06 02 Headwaters Todd Fork (***Tributary to Little Miami River at RM 38.54)***									

Location	STORET (RM)	Drain. (mi²)^	IBI	MIwb[1]	ICI[2]	QHEI	Status[3, 4]	Causes	Sources
Todd Fork @ Starbuck Rd.	300325 (32.72)	14.4 H	36 ns	N/A	G	44.0	FULL WWH		
Todd Fork @ SR 73	200528 (25.2)	29.1 W	50	10.1	32 ns	84.0	FULL WWH		
HUC 05090202 06 06 Little Creek – Todd Fork									
Todd Fork @ SR 22, ust. Lytle Creek	M03S06 (19.5)	56.0 W	55	9.5	34 ns	74.5	FULL WWH		
Todd Fork adj. Creek Rd. dst. Cowan Creek	300326 (17.1)	135.0 W	48	9.3	44	70.5	FULL WWH		
Todd Fork @ Spring Hill Rd. dst. Clarksville WWTP	M03S20 (15.1)	142.0 W	56	10.0	40	69.0	FULL WWH		
HUC 05090202 07 04 Lick Run (*Tributary to Todd Fork at RM 4.52*) - Todd Fork									
Todd Fork @ Gum Grove Road	300314 (12.2)	192.0 W	54	10.6	46	72.5	FULL WWH		
Todd Fork @ Middleboro Road	M03S19 (8.53)	198.0 W	51	10.1	42	66.5	FULL WWH		
Todd Fork @ Roachester-Osceola Road	M99Q16 (5.6)	200.0 W	52	10.1	44	80.5	FULL WWH		
Todd Fork @ Achterman Road	M03S18 (2.65)	239.0 W	51	10.2	VG	77.5	FULL WWH		
Todd Fork @ SR 22/3	600530 (0.14)	261.0 W	50	9.2	42	57.5	FULL WWH		
Lick Run @ SR 132	M03P01 (1.28)	12.3 H	42	N/A	G	39.0	FULL WWH		
HUC 05090202 06 01 Dutch Creek (*Tributary to Todd Fork at RM 22.10*)									
Dutch Creek @ Todd Fork Road	M03P23 (0.28)	14.7 H	54	N/A	G	51.5	FULL WWH		
HUC 05090202 06 03 Lytle Creek (*Tributary to Todd Fork at RM 18.57*)									
Lytle Creek adj. Townsend Field	M03S26 (9.3)	3.0 H	<u>26*</u>	N/A	LF*	59.5	**NON** WWH	Sedimentation/Siltation Nutrient/Eutrophication Biological Indicators	Highways, Roads, Bridges, Infrastructure (New Construction) Industrial/Commercial Storm water Discharge (Permitted)

Location	STORET (RM)	Drain. (mi²)^	IBI	MIwb[1]	ICI[2]	QHEI	Status[3, 4]	Causes	Sources
Lytle Creek @ Nelson Road	M03P07 (7.01)	8.1 H	38 ns	N/A	LF*	66.5	**PART.** WWH	Sedimentation/Siltation Nutrient/Eutrophication Biological Indicators	Industrial/Commercial Storm water Discharge (Permitted)
Lytle Creek dst. Wilmington WWTP	M03W03 (5.95)	9.3 H	48	N/A	LF*	77.0	**PART.** WWH	Sedimentation/Siltation Nutrient/Eutrophication & Organic Enrichment (Sewage) Biological Indicators	Municipal point source discharges Industrial/Commercial Storm water Discharge (Permitted)
Lytle Creek @ Ogden Road	M03P08 (2.76)	15.9 H	56	N/A	F*	67.0	**PART.** WWH	Nutrient/Eutrophication & Organic Enrichment (Sewage) Biological Indicators	Municipal point source discharges Industrial/Commercial Storm water Discharge (Permitted)
Lytle Creek @Clarksville Road	M03P09 (0.65)	19.8 H	55	N/A	32 ns	77.0	FULL WWH		
HUC 05090202 06 04 Headwaters Cowan Creek (*Tributary to Todd Fork at RM 17.15)*									
Cowan Creek @ School Road	300330 (16.62)	15.1 H	46	N/A	F*	65.0	**PART.** WWH	Natural conditions (Flow)	Natural
Cowan Creek @ Jenkins Road	M03S24 (13.2)	26.0 W	43	7.9	MG ns	60.5	FULL WWH		
Cowan Creek adj. Jenkins Road, dst. Indian Run	M03S23 (12.45)	32.0 W	38 ns	7.2*	LF*	58.0	**PART.** WWH	Sedimentation/Siltation Nutrient/Eutrophication Biological Indicators	Streambank Modification/Destabilization Industrial/Commercial Storm water Discharge (Permitted)
Indian Run – Tributary to Cowan Creek at RM 13.06									
Indian Run @ Jenkins Road, ust. ABX outfalls	200524 (0.7)	2.3 H	--	--	LF*	--	Macro qual only-no status	Nutrient/Eutrophication Biological Indicators	Channelization
Indian Run @ Jenkins Road, dst. ABX outfalls	M03S25 (0.2)	4.1 H	42	N/A	P*	57.0	**NON** WWH	Low dissolved oxygen	Industrial/Commercial Storm water Discharge (Permitted)
HUC 05090202 06 05 Wilson Creek – Cowan Creek									
Cowan Creek @ Champlin Road	M03P21 (6.8)	40.0 W	47	9.3	MG ns	67.0	FULL WWH		
Cowan Creek @ Old State Road	300331 (2.82)	51.0 W	49	9.2	MG ns	68.0	FULL WWH		
Cowan Creek @ Clarksville Road	M03P12 (0.6)	54.0 W	52	9.2	F*	78.0	**PART.** WWH	Natural conditions (Flow)	Natural

Location	STORET (RM)	Drain. (mi²)^	IBI	MIwb[1]	ICI[2]	QHEI	Status[3, 4]	Causes	Sources
HUC 05090202 07 01 East Fork Todd Fork (*Tributary to Todd Fork at RM 14.07)*									
East Fork Todd Fork @ Greene Road	300316 (18.29)	7.8^H	50	N/A	G	42.5	FULL ^WWH		
East Fork Todd Fork @ Gibson Road	300317 (17.28)	14.6^H	52	N/A	MG^ns	66.0	FULL ^WWH		
East Fork Todd Fork @ US 68	300318 (11.46)	27.9 ^W	50	8.7	F*	64.0	**PART.^WWH**	Natural conditions (Flow)	Natural
East Fork Todd Fork @ Reeder Road	300319 (7.12)	35.0 ^W	49	10.0	F*	68.5	**PART.^WWH**	Natural conditions (Flow)	Natural
East Fork Todd Fork @ SR 132	M03P19 (1.6)	37.3 ^W	54	9.6	F*	73.0	**PART.^WWH**	Natural conditions (Flow)	Natural
HUC 05090202 07 02 Second Creek (*Tributary to Todd Fork at RM 3.02)*									
Second Creek @ Columbus Street	M03S16 (10.94)	6.8^H	32*	N/A	LF*	60.5	**NON ^WWH**	Nutrient/Eutrophication Biological Indicators	Agriculture
Second Creek dst. Blanchester WWTP	M03S14 (9.45)	11.0^H	36^ns	N/A	F*	56.5	**PART.^WWH**	Organic Enrichment (Sewage) Biological Indicators Sedimentation/Siltation	Municipal point source discharges Unpermitted Discharge (Domestic Wastes) Sanitary Sewer Overflows
Second Creek @ Gustin-Rider Road	M03S13 (6.55)	13.2^H	38^ns	N/A	MG^ns	77.0	FULL ^WWH		
Second Creek @ Cozaddale Road, near Butlerville	M03P14 (1.53)	19.0^H	42	N/A	G	65.5	FULL ^WWH		
Whitakers Run – Tributary to Second Creek at RM 10.20									
Whitakers Run dst. Blanchester PWS	300320 (1.15)	1.5^H	--	--	VP*	--	Macro qual only-no status	Intermittent flow Low Dissolved oxygen	Natural conditions Dam/Impoundment
HUC 05090202 07 03 First Creek (*Tributary to Todd Fork at RM 0.54)*									
First Creek @ Volkerding Rd.	300322 (3.83)	13.8^H	30*	N/A	MG^ns	58.5	**PART.^WWH**	Unknown	Unknown
HUC 05090202 08 03 Turtle Creek (*Tributary to Little Miami River at RM 33.19)*									
Turtle Creek @ East Street	300327 (7.43)	12.3^H	40	N/A	F*	47.5	**PART.^WWH**	Natural conditions (Flow)	Natural

Location	STORET (RM)	Drain. (mi²)[^]	IBI	MIwb[1]	ICI[2]	QHEI	Status[3, 4]	Causes	Sources
Turtle Creek @ Glosser Rd.	M05S17 (6.23)	21.3[W]	44	8.5	34	70.0	FULL[WWH]		
Turtle Creek @ McClure Rd.	M05S21 (4.85)	30.0[W]	41	8.6	28[ns]	65.0	FULL[WWH]		
Turtle Creek @ US 48	M05S14 (0.52)	58.0[W]	48	8.2	VG	61.0	FULL[WWH]		
Dry Run – Tributary to Turtle Creek at RM 0.9									
Dry Run @ Snook Road	M05S19 (1.79)	4.2[H]	45	N/A	38	55.0	FULL[CWH]		
Dry Run @ Main St., S. Lebanon	M05S18 (0.18)	7.3[H]	26*	N/A	--	50.0	**(NON)[WWH]**	Natural conditions (Flow)	Natural
HUC 05090202 08 02 Little Muddy Creek (*Tributary to Turtle Creek at RM 2.73)*									
Little Muddy Creek @ Hamilton Road	300328 (3.22)	11.7[H]	48	N/A	LF*	44.0	**PART.[WWH]**	Sedimentation/Siltation	Channelization
Little Muddy Creek @ SR 42	300329 (1.02)	20.2[W]	44	7.6	40	52.0	FULL[WWH]		
HUC 05090202 09 01 Muddy Creek (*Tributary to Little Miami River at RM 31.95)*									
Muddy Creek ust. Mason WWTP	M05S02 (2.5)	10.2[H]	52	N/A	F*	62.5	**PART.[WWH]**	Natural conditions (Flow)	Natural
Muddy Creek dst. Mason WWTP	M05P06 (0.54)	15.2[H]	54	N/A	F*	74.0	**PART.[WWH]**	Sedimentation/Siltation Nutrient/Organic Enrichment (Sewage) Biological Indicators	Municipal point source discharges
HUC 05090202 09 02 O'Bannon Creek (*Tributary to Little Miami River at RM 24.00)*									
O'Bannon Creek @ Linton Road	300323 (10.14)	8.1[H]	32*	N/A	LF*	48.5	**NON[WWH]**	Natural conditions (Flow)	Natural
O'Bannon Creek @ SR 132	300324 (8.27)	14.3[H]	44	N/A	F*	56.0	**PART.[WWH]**	Natural conditions (Flow)	Natural
O'Bannon Creek @ Gibson Road	M05W60 (4.37)	28.1[W]	51	9.2	LF*	54.0	**PART.[WWH]**	Natural conditions (Flow)	Natural
O'Bannon Creek @ O'Bannonville Road	M05P19 (1.84)	55.6[W]	55	10.4	40	75.5	FULL[WWH]		
O'Bannon Creek @ SR 48	M05P18 (0.26)	59.0[W]	51	10.3	34	60.0	FULL[WWH]		
HUC 05090202 14 01 Sycamore Creek (*Tributary to Little Miami River at RM 19.22)*									

Location	STORET (RM)	Drain. (mi²)^	IBI	MIwb[1]	ICI[2]	QHEI	Status[3, 4]	Causes	Sources
Sycamore Creek adj. Loveland Rd, dst. tributary	M05P17 (1.10)	10.4[H]	40	N/A	F*	63.5	**PART.**[WWH]	Organic Enrichment (Sewage) Biological Indicators	Urban Runoff/Storm Sewers
Sycamore Creek dst. North Fork Sycamore Creek	M05S41 (0.50)	20.7[W]	54	8.9	44	69.5	FULL[WWH]		
Sycamore Creek at mouth, dst. Sycamore Creek WWTP	M05S37 (0.1)	23.3[W]	54	9.4	32	76.5	FULL[WWH]		
HUC 05090202 13 05 Salt Run – East Fork Little Miami River (*Tributary to Little Miami River at RM 11.50)*									
East Fork Little Miami River @ Milford Parkway	M04S29 (2.3)	494.0[B]	52	10.4	52	73.5	FULL[EWH]		
East Fork Little Miami River @ curve dst. Milford WWTP	M04W44 (1.2)	498.0[B]	43*	9.7	50	66.0	**PART.**[EWH]	Sedimentation/Siltation	Streambank modification/destabilization
HUC 05090202 14 04 Duck Creek (*Tributary to Little Miami River at RM 3.87)*									
Duck Creek @ Rosslyn Drive	300311 (3.36)	7.3[H]	<u>12*</u>	N/A	<u>VP*</u>	24.5	**NON**[LRW]	Direct habitat alteration	Channelization (CSO conveyance)
Duck Creek @ park at the end of Hutton Road	M05S24 (0.95)	15.1[H]	<u>20*</u>	N/A	<u>VP*</u>	36.0	**NON**[WWH]	Sedimentation/Siltation Organic Enrichment (Sewage) Biological Indicators	Combined Sewer Overflows Urban Runoff/Storm Sewers
HUC 05090202 14 06 Clough Creek (*Tributary to Little Miami River at RM 3.36)* – Little Miami River									
Clough Creek @ SR 125	300313 (0.42)	8.3[H]	38[ns]	N/A	F*	55.0	**PART.**[WWH]	Sedimentation/Siltation	Combined Sewer Overflows Urban Runoff/Storm Sewers

1 MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.

2 An evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional

3 Attainment is given for the proposed aquatic life use when a change is recommended. Aquatic life use in superscript.EWH = Exceptional Warmwater Habitat; WWH = Warmwater Habitat; LRW = Limited Resource Water.

4 Aquatic life use attainment status based on biological criteria listed in Table 3.3 on page 33.

ns - Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).

* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

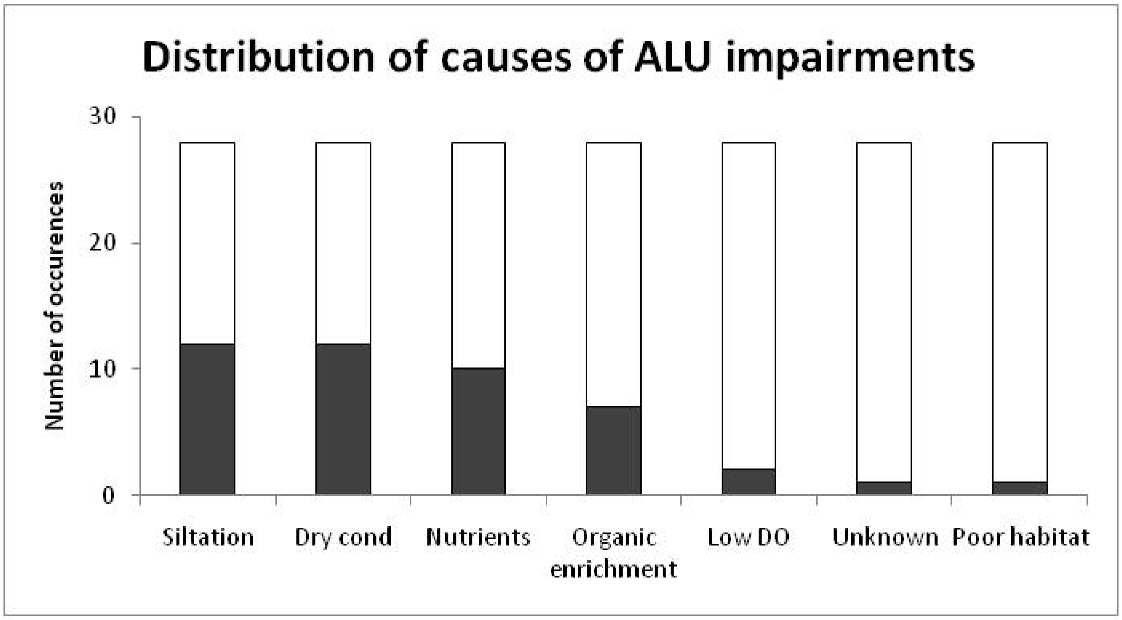


Figure 2.9 Distribution of causes of impairment to aquatic life uses. The dark area represents the number of occurrences of that cause of impairment while the open bar represents the number of impaired sites that do not have that cause of impairment.

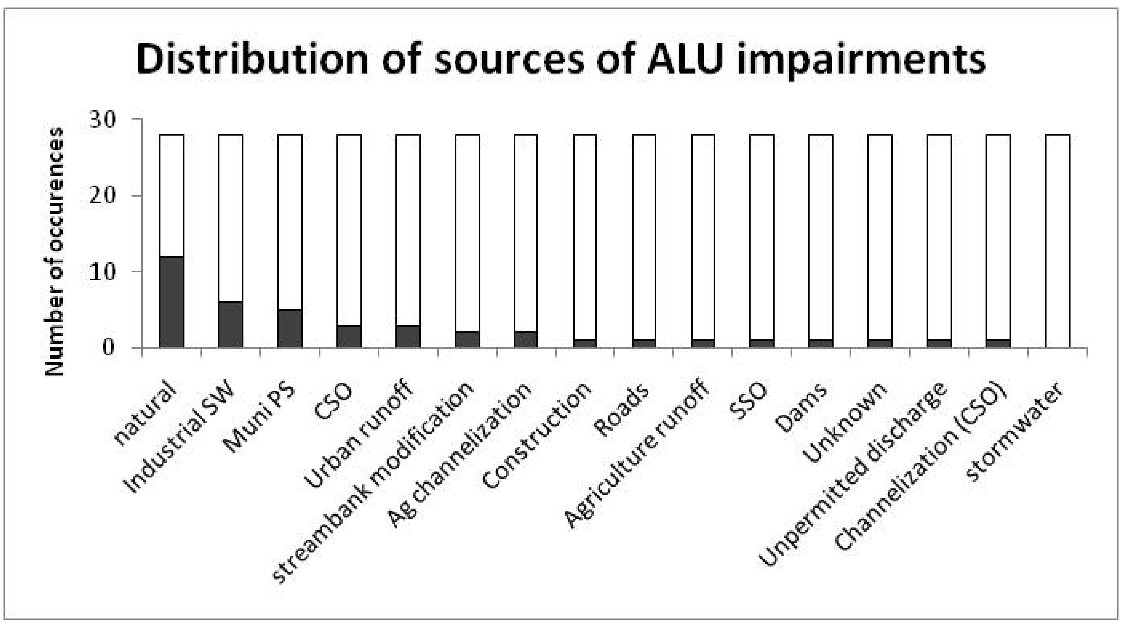


Figure 2.10 Bar graph of distribution of sources of impairment to aquatic life uses. The dark area represents the number of occurrences of that source of impairment while the open bar represents the number of impaired sites that do not have that source of impairment.

2.2.3 Public Drinking Water Use Attainment

One of the two Public Water Supplies (PWS) in the watershed (serving the cities of Wilmington and Blanchester) has impairments detected in their raw water. Elevated atrazine concentrations in Whitakers Run (a tributary to Second Creek) impaired Blanchester's PWS. Impairments to this PWS are not addressed in this TMDL; however, a watershed survey and subsequent TMDL development will begin in 2012 for the East Fork Little Miami River (EFLMR). Stonelick Creek is a water source for Blanchester and a tributary stream within the EFLMR and was shown to be impaired along with Whitakers Run (in the Todd Fork watershed). Impairments to both of these streams will be addressed under the East Fork Little Miami River TMDL project.

2.2.4 Human Health Use (Fish Tissue)

In May 2006, a mercury shipment leaked at the Airborne Express Airpark in Wilmington. A portion of the mercury was spilled in the hazmat sort area which drains to Indian Run and subsequently Cowan Creek. Inorganic mercury is converted by bacteria in the water and sediments into the more toxic and bioavailable methyl mercury. This process occurs much more quickly in anaerobic conditions such as those found in the wetland areas in the upper portion of Cowan Lake. Methyl mercury can accumulate in microorganisms, aquatic plants, and eventually fish tissue. While water quality criteria are devised to be protective of fish consumers, the criteria are based on bioaccumulation factors that can be highly variable from system to system. Fish tissue sample results for mercury collected in Cowan Lake in 2004, 2006, and 2007 are presented in Table 2.5.

Table 2.5 Mercury concentration in fish tissue taken from Cowan Lake in 2004, 2006, and 2007.

Species	Date Collected	Number of Samples	Ave Length (inches)	Ave Conc. (ppb)	Max Conc. (ppb)
Bluegill Sunfish	9/24/2004	4	6	47	50
	11/14/2006	ns	ns	ns	ns
	7/12/2007	2	7	67	70
Channel Catfish	9/24/2004	ns	ns	ns	ns
	11/14/2006	4	14	91	117
	7/12/2007	ns	ns	ns	ns
Common Carp	9/24/2004	4	23	84	102
	11/14/2006	ns	ns	ns	ns
	7/12/2007	2	22	68	69
Largemouth Bass	9/24/2004	ns	ns	ns	ns
	11/14/2006	ns	ns	ns	ns
	7/12/2007	2	11	149	172
Saugeye	9/24/2004	4	12	47	56
	11/14/2006	4	18	143	210
	7/12/2007	ns	ns	ns	ns
ns – no sample					

Given these levels, no more stringent advisories for mercury beyond the statewide advisory (1 meal per week) were recommended. Average mercury levels in a species must be greater than 220 ppb to issue a one meal per month advisory. The lake was re-sampled in 2009; however, at the time of the writing of this report, the results are not available.

Mercury is a ubiquitous contaminant in streams throughout the U.S. and its primary source is thought to be mercury deposited from the atmosphere. Mercury as a surface water pollutant is being addressed in a variety of ways outside of the traditional TMDL process, including limits on mercury emissions from air sources, mercury take-back programs, and legislation prohibiting the sale of most mercury-containing products. Unless there are known or suspected local surface water sources of mercury, mercury is best addressed outside of the individual watershed TMDL framework.

Additional information regarding fish consumption can be found at: http://www.epa.ohio.gov/dsw/fishadvisory/index.aspx.

2.2.5 Total Phosphorus Trends

Total phosphorus concentrations have been a significant concern in the Little Miami River watershed, particularly along the mainstem of the Little Miami River. Several waste water treatment facilities have expanded treatment capacity in terms of flow rate as well as improved effluent quality which has likely been a very important factor in the healthier aquatic life communities that are now being observed (see Biological and Water Quality Study of the Lower Little Miami River and Selected Tributaries including the Todd Fork Subwatershed, 2007 (Ohio EPA, 2009)).

Despite the improved biological performance, statistical analyses show that the total phosphorus concentrations in the mainstem of the river within this particular TMDL study area has not changed significantly across the last three Ohio EPA surveys on this part of the river (specifically, 1993, 1998, and 2007). However, flow conditions were considerably different between these surveys and perhaps with higher flow in 2007 the nutrient concentrations would have been lower (i.e., more dilution). The confounding factor in determining if in-stream improvements in total phosphorus concentrations have occurred is that there are two major differences between 1993 and 1998 surveys and the 2007 survey. Specifically, waste water treatment improved, but also the flows were low for 2007. Perhaps the only way to really know the response in terms of nutrients is another survey when flows are comparable.

The statistical analyses performed were comparisons of the sites across 3 surveys years (1993, 1998, 2007) with paired t-tests to see if there has been a change in TP concentrations across time and an analysis of variance was performed to see if the group means for any of the respective sampling years were different from one another. The results of these tests shown in Tables 2.6 and 2.7, respectively, demonstrate that there is little difference in the ambient TP concentrations.

Table 2.6 Results of a paired T-test in comparing annual mean total phosphorus concentrations in the Little Miami River (from approximately river miles 54 to 8) at the same site locations but across the different survey years, 1993, 1998, and 2007.

Type of Statistic	1993	2007	1998	2007	1993	1998
Mean	**0.390214**	**0.331429**	**0.398**	**0.331429**	**0.390214**	**0.398**
Variance	0.017561	0.022475	0.001956	0.022475	0.017561	0.001956
Number of Observations	14	14	14	14	14	14
Pearson Correlation	0.570943646		-0.497677679		-0.445711161	
Hypothesized Mean Difference	0		0		0	
Degrees of Freedom (df)	13		13		13	
t Statistic	1.6698596		1.414014224		-0.185199917	
P(T<=t) one-tail	**0.059417637**		**0.090428607**		**0.427965214**	
t Critical one-tail	1.770933383		1.770933383		1.770933383	
P(T<=t) two-tail	0.118835275		0.180857215		0.855930427	
t Critical two-tail	2.160368652		2.160368652		2.160368652	

Table 2.7 Results of an analysis of variance (ANOVA) in comparing annual mean total phosphorus concentrations in the Little Miami River (from approximately river miles 54 to 8) across the years 1993, 1998, and 2007.

Source of Variation	Sum of Squares	Degrees of freedom	MS	F- statistic	P-value	F critical
Between Groups	0.037091	2	0.018546	1.324932	**0.27752**	3.238096
Within Groups	0.5459	39	0.013997			
Total	0.582991	41				

3 BACKGROUND FOR TMDL DEVELOPMENT: WATER QUALITY STANDARDS AND TARGETS, LINKAGE ANALYSES AND METHODS

This chapter of the report shows how decisions were made regarding TMDL development. Namely, the water quality standards that are not being met are discussed and related to TMDL development.

This chapter will provide the following information:

- Which impairments are to be addressed (also summarized in Table 1.1)
- How each impairment will be addressed
- Justification for linking parameters that are not codified in the water quality standards to the water quality standards not being met
- Target values used to develop the TMDLs
- Summary of the methods used to estimate the appropriate loads

3.1 Water Quality Standards and Targets

TMDLs are required when a waterbody fails to meet water quality standards (WQS). Ohio's WQS, set forth in Chapter 3745-1 of the Ohio Administrative Code (OAC), include three major components: beneficial use designations, quality criteria, and anti-degradation provisions.

Beneficial use designations describe the existing or potential uses of a waterbody. Uses established in the WQS include: public water supply; protection and propagation of aquatic life; recreation in and on the water; and agricultural, industrial or other purposes. Ohio EPA assigns use designations to each waterbody in the state. Use designations are defined in paragraph (B) of rule 3745-1-07 of the OAC and are assigned in rules 3745-1-08 to 3745-1-32. Attainment of uses is based on specific numeric and narrative criteria.

Numeric criteria are estimations of chemical concentrations, degree of aquatic life toxicity, and physical conditions allowable in a waterbody without adversely impacting its beneficial uses. Narrative criteria, located in rule 3745-1-04 of the OAC, describe general water quality goals that apply to all surface waters. These criteria state that all waters shall be free from sludge, floating debris, oil, scum, color and odor-producing materials; substances that are harmful to human or animal health; and nutrients in concentrations that may cause excessive algal growth.

Antidegradation provisions describe the conditions under which water quality may be lowered in surface waters. Under such conditions water quality may not be lowered below criteria protective of existing beneficial uses unless lower quality is deemed necessary to allow important economic or social development. Antidegradation provisions are in Sections 3745-1-05 and 3745-1-54 of the OAC.

3.1.1 Recreation Uses

Recreational use designations are defined in Section 3745-1-07 of the OAC. Water quality criteria are established to protect recreational water uses by limiting risk for human illness due to exposure to pathogenic microorganisms. Pathogenic organisms include bacteria, viruses, and protozoa. Criteria are set for concentrations of E coli in surface waters. E coli bacteria typically are not pathogenic organisms; however, if their numbers exceed a threshold value it becomes increasingly probable that pathogenic organisms are present in sufficient numbers to threaten public health.

Two recreational use designations applicable to stream segments in the lower Little Miami River watershed are Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR). SCR is applied to waters suitable for partial-body contact recreation such as wading. PCR is applied to waters suitable for full-body contact such as swimming and canoeing. Ohio EPA assigns the PCR use designation to a stream unless it is demonstrated through use attainment analysis that the combination of remoteness, accessibility, and depth makes full-body contact recreation by adults or children unlikely. In those cases, the SCR designation is assigned.

PCR is divided in to three subcategories, classes A, B and C. Waterbodies in each of these classes are able to support the same types of water activities; however, distinctions are made based on the frequency or intensity of such activities. Class A PCR reflects the greatest use of the waterbody for recreation while B to C reflects progressively less frequent recreation activities. For waterbodies throughout Ohio, PCR class B is the most prevalent use assigned.

Attainment of the recreation use designation is evaluated by comparison to bacteriological numeric and narrative criteria. Ohio currently has bacteriological criteria for *E. coli*. Bacteriological criteria apply outside the mixing zone of permitted discharges and during the defined recreation season (May 1^{st} through October 30^{th}). The concentration values of E coli are based on the geometric mean of at least two samples collected at a single site within the same recreational season. If only one sample is available, the single sample maximum concentration can be used to determine if water quality standards are met, otherwise when more than one sample is available attainment is exclusively predicated on the geometric mean value. Table 3.1 shows the E coli water quality criteria for recreation uses.

There are 437 stream miles designated as PCR while 5.6 miles are designated SCR accounting for one percent of all the stream miles given a recreation use designation. There are no other recreation use designations in the lower Little Miami River watershed. Figure 3.1 is a map of the respective recreation use designations in the TMDL project area.

Table 3.1 Quality criteria for recreation use designations.

Recreation use	E coli (colony counts per 100 ml)	
	Seasonal geometric mean	Single sample maximum
Bathing water	126	235
Class A primary contact recreation	126	298
Class B primary contact recreation	161	523
Class C primary contact recreation	206	940
Secondary contact	1030	1030

TMDL targets for recreation use impairments

The water quality targets used for development of TMDLs and allocations are based directly on the applicable criteria described in Table 3.1. Target loading is determined based on the product of the applicable E coli concentrations and the appropriate stream flow volume or flow rate.

3.1.2 Aquatic Life Uses

Aquatic life use designations are defined in Section 3745-1-07 of the OAC. Four aquatic life beneficial use designations are applicable in the lower Little Miami River watershed:

- Warmwater Habitat (WWH)
- Exceptional Warmwater Habitat (EWH)
- Coldwater Habitat (CWH)
- Limited Resource Waters (LRW)

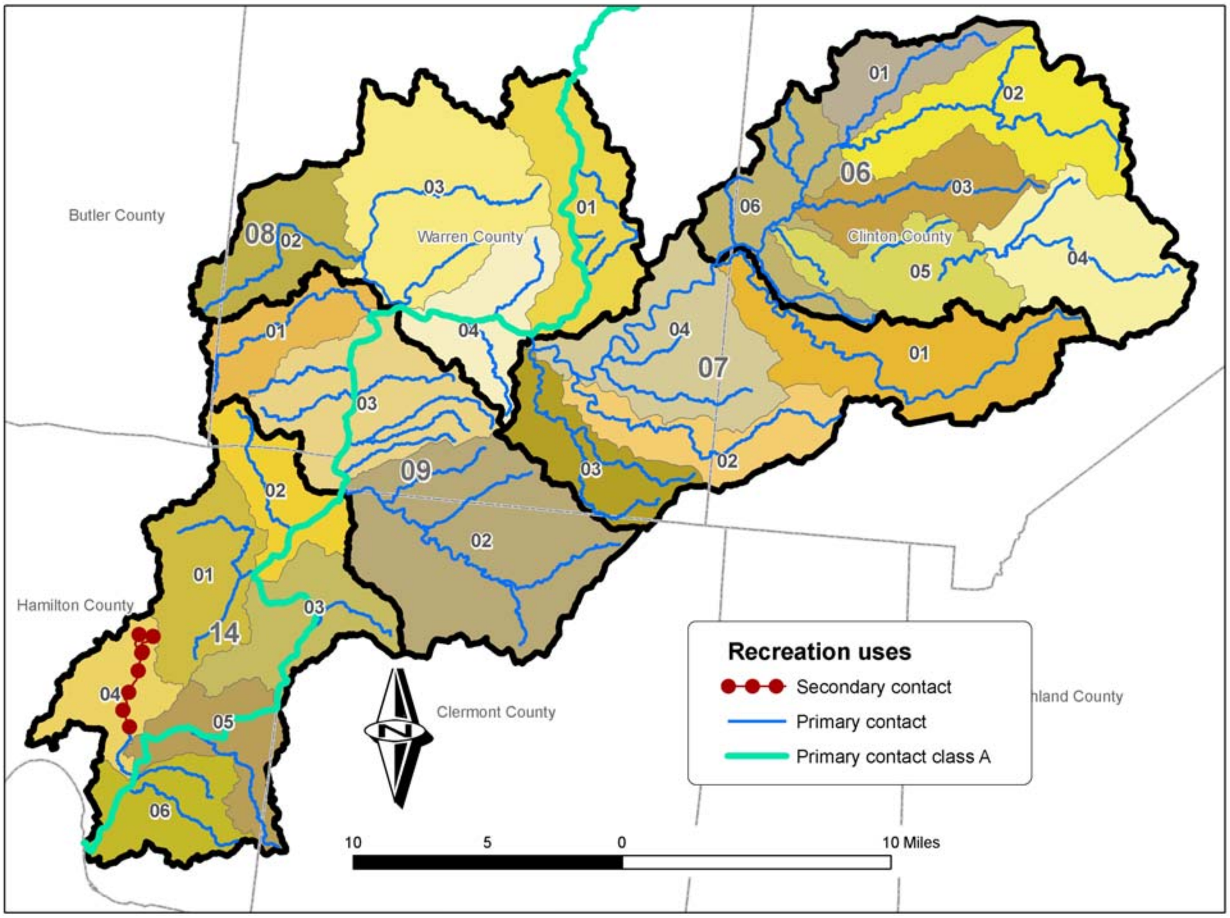


Figure 3.1 Map of recreation use designations.

Warmwater Habitat (WWH) waters are capable of supporting and maintaining a balanced integrated community of warm water aquatic organisms. WWH represents the principal restoration target for the majority of water resource management efforts in Ohio and is in line with the Clean Water Act goal of fishable waters.

Exceptional Warmwater Habitat (EWH) represents a protection goal for the management of Ohio's best water resources. Waters designated as EWH are capable of supporting exceptional or unusual assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly pollutant intolerant and/or are rare, threatened, or endangered (i.e., declining species).

Coldwater Habitat (CWH) is applied to waters that support native communities of cold-water organisms, and/or those that support trout stocking and management under the auspices of the Ohio Department of Natural Resources.

Limited Resource Waters (LRW) are assigned to waters where there are conditions in which only a degraded aquatic community can persist (e.g., restricted to pollution tolerant species). These stressful conditions are viewed as irretrievable due to either natural background or persistent human-induced conditions.

Attainment of aquatic life uses is determined by directly measuring fish and aquatic macroinvertebrate populations, and comparing results to expectations derived from least impacted reference sites. Attainment benchmarks (i.e., expectations) drawn from the least impacted reference population are established in the WQS in the form of biocriteria. If measurements of an aquatic community do not achieve any one of the three biocriterion (fish: Index of Biotic Integrity (IBI) and Modified Index of Well-being (MIwb)); aquatic macroinvertebrates: Invertebrate Community Index (ICI)) the stream is considered in non attainment. If the aquatic communities achieve at least one of the biological criteria and none of the other criteria are rated as poor, the stream is said to be in partial attainment. A stream that is in partial attainment is not achieving its designated aquatic life use, whereas a stream that meets all of the biocriteria benchmarks is in full attainment.

Table 3.2 and Figure 3.2 show the distribution of aquatic life use designations in the watershed. Table 3.3 presents biocriteria applicable in the lower Little Miami River watershed. Biocriteria do not currently exist for CWH; attainment is determined on a case-by-case basis.

Table 3.2 Distribution of aquatic life use designations.

Aquatic life use designation	Stream miles	Percent of total
Warmwater habitat (WWH)	337.7	76%
Exceptional warmwater habitat (EWH)	95.8	22%
Limited resource waters (LRW)	5.6	1%
Coldwater habitat (CWH)	3.9	1%
Total designated streams	**448.5**	**100%**

TMDL targets for aquatic life use impairments
TMDL target are determined for most of the water quality stressors identified as impairing aquatic life uses (See Tables 1.1 and 2.4 for lists of these stressors). None of these stressors have quality criteria established in Ohio's Water Quality Standards therefore these targets are developed using a science-based approach. Section 3.2 discusses the link between the stressors identified and meeting the minimum biocriteria which are established in Ohio's Water Quality Standards.

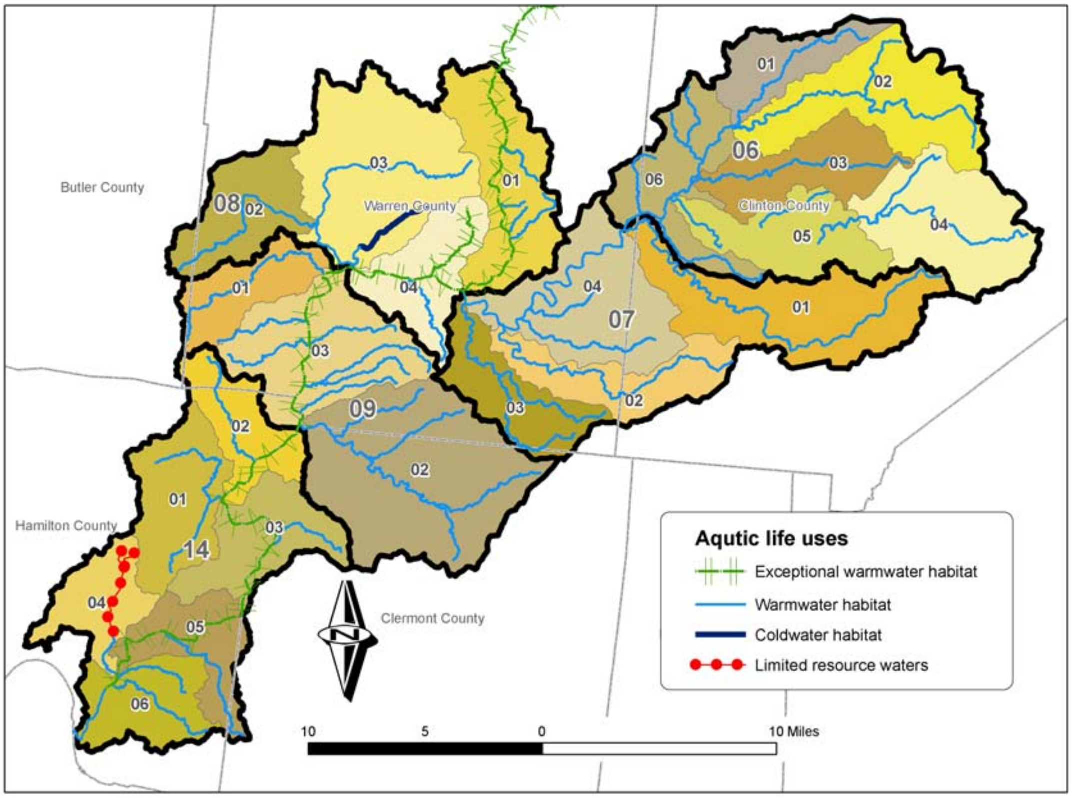


Figure 3.2 Map of aquatic life use designations.

Table 3.3 Biocriteria applicable for the Interior Plateau (IP) and the Eastern Corn Belt Plains (ECBP) ecoregions.

Eco-region[1]	Biological Index	Assessment Method	WWH	EWH	MWH
IP	Index of Biotic Integrity (IBI)	Headwater	40	50	24
		Wading	40	50	24
		Boat	38	48	24
	Modified Index of Well Being (MIwb)	Headwater	NA[2]	NA[2]	NA[2]
		Wading	8.1	9.4	6.2
		Boat	8.7	9.6	5.8
	Invertebrate Community Index (ICI)	All[3]	30	46	22
ECBP	Index of Biotic Integrity (IBI)	Headwater	40	50	24
		Wading	40	50	24
		Boat	42	48	24
	Modified Index of Well Being (MIwb)	Headwater	NA[1]	NA[1]	NA[1]
		Wading	8.3	9.4	4
		Boat	8.5	9.6	4
	Invertebrate Community Index (ICI)	All[3]	36	46	22

1 Ecoregion abbreviations are IP = Interior Plateau and ECBP = Easter Cornbelt Plains.
2 Not applicable to drainage areas less than 20 mi^2
3 Limited to sites with appropriate conditions for artificial-substrate placement

3.1.3 Public Drinking Water Supply Use

The public drinking water supply (PWS) use includes surface waters from which public drinking water is supplied. This beneficial use provides an opportunity to strengthen the connection between Clean Water Act and Safe Drinking Water Act (SDWA) activities by employing the authority of the CWA to meet SDWA objectives of source water protection and reduced risk to human health. Criteria associated with this use designation apply within five hundred yards of surface water intakes.

There are two surface water public drinking water supplies in the lower Little Miami River watershed project area serving people in the cities of Wilmington and Blanchester. Figure 3.3 is a map showing the locations of these public water supplies.

TMDL targets for Public Drinking Water Supply Use impairments
Although impairment to PWS has been found in source waters for Blanchester on Whitakers Run (Section 2.2.3), TMDLs are not developed to address this impairment at this time. This impairment is to be addressed with like impairments to Blanchester's PWS found in the East Fork Little Miami River basin when that project begins in 2012.

3.1.4 Human Health Use (Fish Tissue)

Ohio has adopted human health WQS criteria to protect the public from adverse impacts, both carcinogenic and non-carcinogenic, caused by exposure via drinking water (applicable at public water supply intakes) and by exposure in the contaminated flesh of sport fish (applicable in all surface waters). The latter criterion is called the non-drinking water human health criterion. The purpose of that criterion is to ensure levels of a chemical in water do not bioaccumulate in fish to levels harmful to people who catch and eat the fish.

TMDL targets for human Health Use impairments
No TMDLs are developed to address human health use impairments.

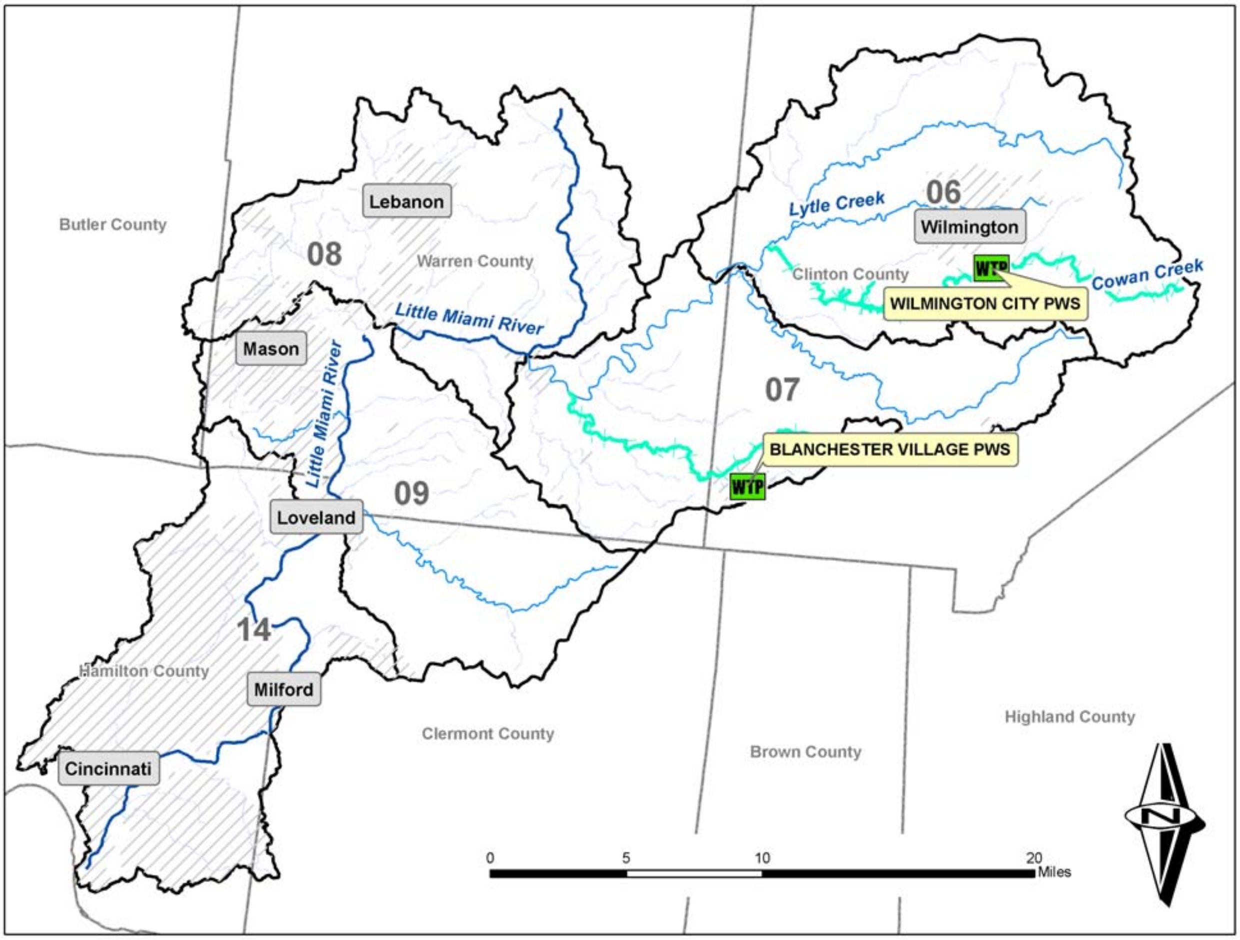


Figure 3.3 Public water supplies in the lower Little Miami River watershed project area.

3.2 Stressor Linkages to the Biocriteria and Water Quality Targets

A linkage analysis connects the observed water quality impairment to what has caused that impairment. The following sub-sections discuss how select stressors in the TMDL project area impair biological communities (and ultimately to failure in meeting the biocriteria). Appropriate water quality targets are also established. The following stressors are discussed: ***nutrients, oxygen demanding substances, suspended solids, habitat*** and ***sediment.*** The only remaining stressors, the dry conditions experienced that survey year, is identified as natural conditions and not addressed in this report.

3.2.1 Nutrients

Nutrients are identified as a cause of impairment at several assessment sites in the lower LMR basin. Nutrients rarely approach concentrations in the ambient environment that are toxic to aquatic life, and nutrients in small amounts are essential to the functioning of healthy aquatic ecosystems. However, nutrient concentrations in excess of the needs of a balanced ecosystem can exert negative effects by increasing algal and aquatic plant life production (Sharpely et al., 1994). This increases turbidity, decreases average dissolved oxygen concentrations and increases fluctuations in diel dissolved oxygen and pH levels. Such changes shift species composition away from functional assemblages comprised of intolerant species, benthic insectivores and top carnivores typical of high quality streams towards less desirable assemblages of tolerant species, niche generalists, omnivores and detritivores typical of degraded streams (Ohio EPA, 1999). Such a shift in community structure lowers the diversity of the system; the IBI and ICI scores reflect this shift and a stream may be precluded from achieving its aquatic-life use designation.

Phosphorus is selected as the nutrient to focus on because it is frequently the limiting nutrient to algal growth in the fresh water streams of Ohio. While the Ohio EPA does not currently have statewide numeric criteria for phosphorus, potential targets have been identified in a technical report titled *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA, 1999). This document provides the results of a study analyzing the effects of nutrients and other parameters on the biological communities of Ohio streams. It recommends total phosphorus (TP) target concentrations based on observed concentrations associated with acceptable ranges of biological community performance. The targets applicable to the lower LMR watershed are shown in Table 3.4. These targets are not codified in Ohio's water quality standards, so there is flexibility in how they can be used in a TMDL.

Table 3.4 Total phosphorus targets applicable to the lower LMR watershed

Watershed size	EWH	WWH
Headwaters (drainage area < 20 mi^2)	-	0.08
Wadable (drainage area ≥ 20 mi^2 < 200 mi^2)	-	0.10
Small Rivers drainage area ≥ 200 mi^2 < 1000 mi^2)	0.10	-
Large Rivers (drainage area ≥ 1000 mi^2)	0.15	-

3.2.2 Oxygen Demand from Deicing Agents

Two watersheds are impacted by glycol based discharges from the Airborne Express (ABX) airport east of Wilmington. The airport has an NPDES permit for discharge of treated glycol-laden storm water to Lytle Creek and Indian Run (permit number 1II00031). The areas impacted by this discharge consist of Lytle Creek downstream of this discharge at RM 10.65 and Cowan Creek's tributary Indian Run at RM 0.42 and Cowan Creek downstream of Indian Run.

Due to the oxygen demanding nature of the pollutants discharged from the ABX storm water treatment systems and the observed low dissolved oxygen (D.O.) levels in Indian Run and Cowan Creek, D.O. is an appropriate parameter for TMDL development. The State of Ohio has codified D.O. water quality criteria for the protection of aquatic life (Chapter 3745-1 Ohio Administrative Code table 7-1). These criteria stipulate that instantaneous instream D.O. outside of any effluent mixing zone cannot be below 4.0 mg/l and an average D.O. sample cannot be below 5.0 mg/l for warmwater habitat streams. All streams being considered for these TMDLs based on oxygen demands are designated warmwater habitat.

3.2.3 Suspended Sediment and Biological Oxygen Demand

TMDLs are calculated for two watersheds to address combined sewer overflows (CSOs); both are direct tributaries to the Little Miami River. The CSOs on both of these streams are owned by the Metropolitan Sewer District of Greater Cincinnati, Hamilton County, Ohio (MSD). Duck Creek drains 15.5 mi^2 and has 43 CSOs, some of which are no longer active. In addition to aquatic life use impairment throughout Duck Creek, this tributary is also causing impairment in the mainstem Little Miami River. Clough Creek drains 8.31 mi^2 and has two active CSOs discharging to it. Total suspended solids (TSS) and CBOD 5-day were determined to be used as parameters requiring control due to the cause and source assessment of impairment.

The State of Ohio does not have numeric water quality criteria for TSS or CBOD 5-day. The target for these TMDLs is based on U.S. EPA guidance, Combined Sewer Overflows Guidance For Long-Term Control Plan (U.S. EPA, 1995). This document outlines, "demonstrative and presumptive" approaches to successful control of CSOs. One of these approaches is described as 85% control of volume of annual average total CSO discharges (US EPA, 1995, page 3-7). While MSD indicates various existing proportions of CSOs are already under control, this TMDL assumes that 85% of existing CSO flow requires control in order to mitigate aquatic life use impairment. This provides an implicit margin of safety since in this situation controls will be greater than those recommended in the federal guidance (i.e., more than 85 percent). Furthermore, it should be noted that Ohio EPA and MSD are involved in a consent decree requiring MSD to create an acceptable long term control plan in accordance with US EPA guidelines (http://www.msdgc.org/consent_decree/). The final long term control plan will include much more detail and will outline and regulatory oversight of the CSOs.

3.2.4 Sediment and Habitat (QHEI)

In order for an aquatic community to be healthy it must have adequate habitat. The absence or low quality of stream habitat hampers the ability of aquatic organisms to successfully reproduce, acquire food, or find protection from other species and stressful environmental conditions leading to reduced or absent populations of aquatic species. A compounding effect of wide-spread degraded habitat is that source populations of sensitive aquatic species dwindle and migrate to areas that do have suitable habitat quality.

The qualitative habitat evaluation index (QHEI) was developed by the Ohio EPA (Rankin, 1989) with one of the objectives being to create a means for distinguishing impacts to the aquatic community from pollutant loading versus poor stream habitat. The design of the QHEI in conjunction with its statistically strong correlation to the bio-criteria makes it an appropriate tool for developing habitat TMDLs.

The QHEI assigns a numeric value to an individual stream segment (typically 150-200 meters in length) based on the quality of its habitat. The actual number values of the QHEI scores do not represent the quantity of any physical properties of the system but provide a means for comparing the relative quality of stream habitat. However, even though the numeric value is derived qualitatively, subjectivity is minimized because scores are based on the presence and absence and relative abundance of unambiguous habitat features. Reduced subjectivity was an important consideration in developing the QHEI and has since been evidenced through minimal variation between scores from various trained investigators at a given site as well as consistency with repeated evaluations (Rankin, 1989).

The QHEI evaluates six general aspects of physical habitat that include channel substrate, instream cover, riparian characteristics, channel condition, pool/riffle quality, and gradient. Within each of these categories or metrics, points are assigned based on the ecological utility of specific stream features as well as their relative abundance in the system. Demerits (i.e., negative points) are also assigned if certain features or conditions are present which reduce the overall utility of the habitat (e.g., heavy siltation and embedded substrate). These points are summed within each of the six metrics to give a score for that particular aspect of stream habitat. The overall QHEI score is the sum of all of the metric scores.

In terms of sediment, although in of itself it can be damaging to the aquatic community, its negative impact is typically restricted to the fact that it degrades stream habitat. Specifically, sediment fills in void spaces that occur between larger substrates such as cobbles and gravels, rendering those spaces inaccessible to organisms. The function of the substrate also decreases because flow of water through these spaces is limited, and with it dissolved oxygen and nutrition sources. The QHEI captures these deleterious results of excessive fine sediment loading therefore, it is appropriate to use in developing sediment TMDLs.

Sediment TMDL targets and the qualitative habitat evaluation index (QHEI)
Numeric targets for sediment are based upon metrics of the QHEI, specifically those that consider particular aspects of stream habitat closely related to and/or impacted by the sediment delivery and transport processes occurring in the system.

The QHEI metrics used in the sediment TMDL are the substrate, channel morphology, and bank erosion and riparian zone. Table 3.6 lists targets for each of these metrics.

- The substrate metric evaluates the dominant substrate materials (i.e., based on texture size and origin) and the functionality of coarser substrate materials in light of the amount of silt cover and degree of embeddedness. This is a qualitative evaluation of the amount of excess fine material in the system and the degree to which the channel has assimilated (i.e., sorts) the loading. Higher levels of mud/muck/silt, that cover the substrate have significant negative impacts on the fish community, impacting the reproduction, feeding, and overall health of the biotic community.
- The channel morphology metric considers sinuosity, riffle, and pool development, channelization, and channel stability. Except for stability each of these aspects are directly related to channel form and consequently how sediment is transported, eroded, and deposited within the channel itself (i.e., this is related to both the system's assimilative capacity and loading rate). Stability reflects the degree of channel erosion which indicates the potential of the stream as being a significant source for the sediment loading. Excessive sedimentation fills in the pools and covers up the riffles, resulting in a more uniform, flat stream bed, severely impacting the feeding and reproductive habitat in the stream.
- The bank erosion and riparian zone metric also reflects the likely degree of instream sediment sources. The evaluation of floodplain quality is included in this metric which is related to the capacity of the system to assimilate sediment loads. Specifically, floodplains sort the sediment load during floods where heavier, coarse substrates tend to remain in the main channel whereas fine grained, lighter sediment can occupy the floodplain areas and subsequently be deposited as the flow recedes after the storm event. If the floodplain is inaccessible, then removal of this sediment from main channel is hindered which will likely degrade habitat and water quality.

Each of these factors (substrate, channel, riparian) influences the degree to which siltation affect a stream, and cumulatively serves as its numeric target.

Analysis of Lower LMR Watershed QHEI Data to Develop Targets
Only WWH stream segment data are used for analysis of QHEI data for this TMDL. The minimum statewide QHEI target is 60 for WWH sites (Ohio EPA, 1999). However, when analyzed on a watershed scale, it has been determined that basin specific goals of QHEI and its subcategories are appropriate for TMDL development.

QHEI data are collected at every site assessed for biological attainment. Within the lower LMR watershed, these data are collected in multiple locations in streams of varying drainage areas. Figure 3.4 represents the QHEI score for each WWH sampling location vs. drainage area of the watershed up to the sampling location. The biological attainment of individual sites is shown by color shading of the data points.

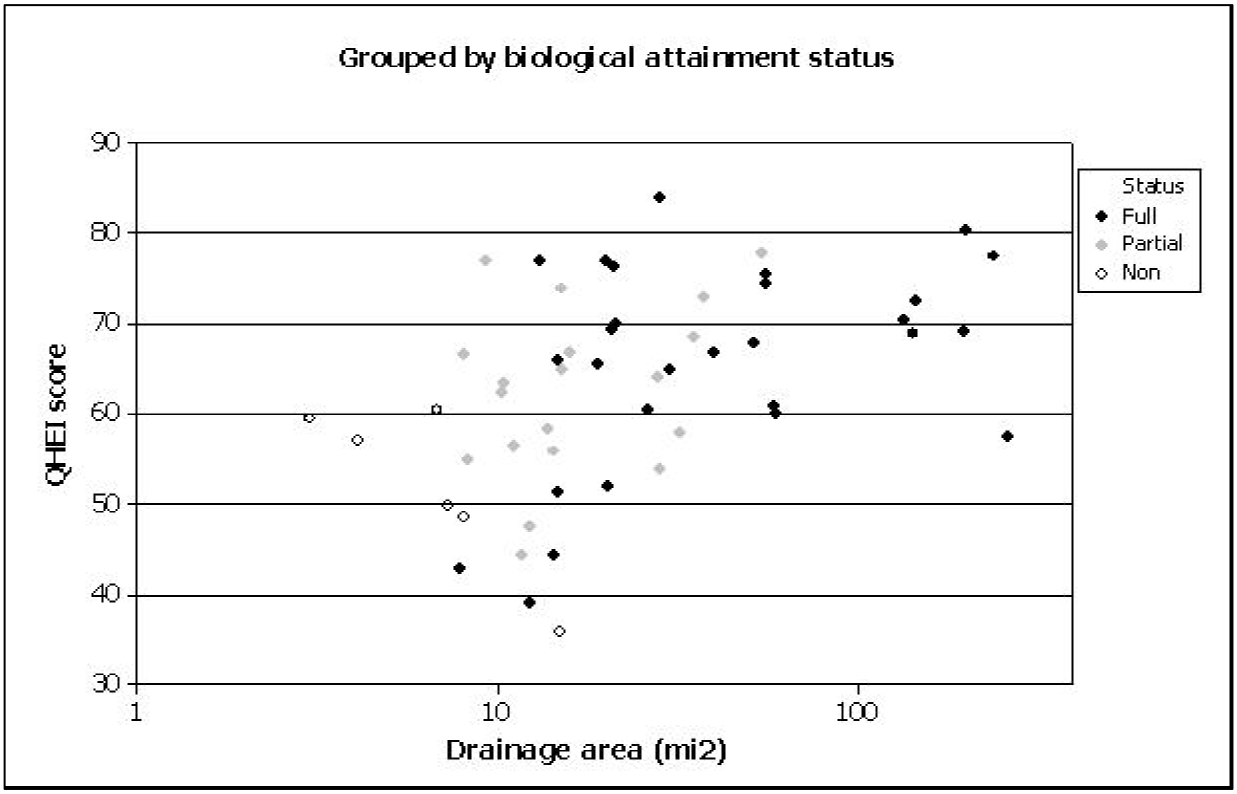


Figure 3.4 Lower LMR watershed WWH QHEI score vs. site drainage area

To determine if the QHEI values indicate habitat issues with respect to biological attainment groups, box plots of QHEI scores are generated for each attainment group (Figure 3.5).

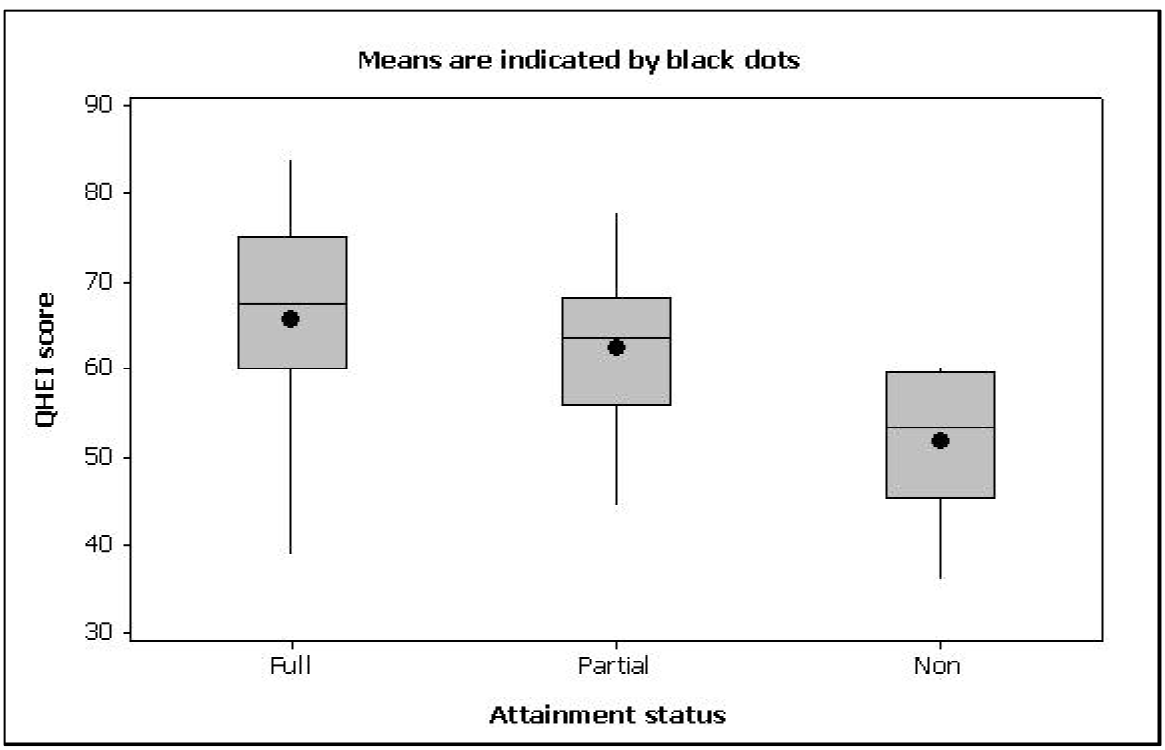


Figure 3.5 Lower LMR watershed WWH QHEI scores by biological attainment status

As can be observed from the box plots in Figure 3.5, it appears the non attainment group QHEI data set is significantly lower than the other datasets. To assure that a statistical difference in the QHEI score data sets for the LMR watershed does exist, a statistical hypothesis test is completed. Anderson-Darling normality test indicate all three data sets are normal [full (P=0.085), partial (P= 0.914), non (P=0.329)]; where P ≥ 0.05 indicates a normal distribution.

Because of the normality of the data sets, a one way analysis of variance (ANOVA) is utilized to determine if a significant difference exists in any one of three (full, partial and non attainment) data set means when compared to the other data set means. The null hypothesis is that all data set means are equal. The alternative hypothesis is that at least one of the means is not equal to the others. A five percent level of significance is chosen for the test.

Details of the ANOVA are presented in Table 3.5. The P value for the analysis is 0.018 indicating a statistically significant difference between the group means. This analysis assures within 95% certainty that at least one of the attainment group QHEI means does not equal the others, and suggesting based on visual inspection that the “Non” and the Full” groups are different. Additional statistical analysis is not warranted for this determination.

Table 3.5 One-way ANOVA of QHEI versus Attainment Status

Source	**DF**	**SS**	**MS**	**F**	**P**
Status	2	967	484	4.33	0.018
Error	50	5580	112		
Total	52	6547			

```
                         Individual 95% CIs For Mean      Based on
Pooled StDev
Level      N   Mean  StDev  --------+---------+---------+---------+-
Full      28  65.85  11.53                          (-----*-----)
Partial   19  62.58   9.33                    (------*------)
Non        6  51.92   9.23  (-----------*------------)
                            --------+---------+---------+---------+-
                                 49.0      56.0      63.0      70.0
Pooled StDev = 10.56
```

Because the non attainment group has significantly lower QHEI values than the full attainment group, an increase in habitat quality is needed to increase the non attainment deficit. Therefore, a TMDL for QHEI and the individual subcategories can be developed from the full attainment group values. A target value for QHEI and for each subcategory is chosen to be the lowest value of the 95th percent confidence interval of the full attainment group median. This value is chosen to reduce the effects of skewed data sets and to assure the full data set values for the most part achieve the TMDL goal. In addition, this value statistically assures with 95 percent confidence that the population median of the QHEI or subcategory is at least greater than this value. This goal provides assurance that an acceptable intrinsic safety factor for the TMDL is provided.

Because the QHEI total score is comprised of seven subcategories of habitat, the value of this index can be significantly affected by a large depletion in one category as well as small depletion in multiple categories. Therefore, TMDL goals are created individually for the QHEI and its subcategories. This technique insures that proper subcategory of the QHEI which is causing the impairment at a particular site is slated for mitigation. In addition, this procedure provides an estimate of effort required to eliminate the impairment cause.

The lowest value of the 95th percent confidence interval of the median for each of the QHEI subcategories is the TMDL value for that subcategory. Table 3.5 summarizes the TMDL value for the total QHEI score and each of the subcategories. Note that the total QHEI score TMDL value is the sum of the subcategories, 58.4, and not the lowest value of the 95^{th} percent confidence interval of the median for the grouped total QHEI values. This is done to offset the skewness within the individual subcategories. With the Table 3.6 TMDL targets, each of the biological sampling sites within the watershed can be compared for habitat and bedload attainment.

Table 3.6 TMDL targets for QHEI subcategory scores for lower LMR WWH streams

Applicable TMDLs		QHEI metric	TMDL target score
Metrics used for the habitat TMDLs		Total QHEI score	**58.4**
	Metrics used for the sediment TMDLs	Substrate	**13.7**
		Riparian	**5.5**
		Channel	**13.0**
		Cover	**10.5**
		Pool	**7.0**
		Riffle	**2.7**
		Gradient	**6.0**

3.3 Summary of Coverage for TMDL Development

With the exception of the naturally occurring dry stream flow conditions and where causes are unknown, nearly all causes of impairment have been addressed through TMDL development. Other exceptions include the deference of the atrazine impairment to Blanchester's PWS to the future TMDL effort in the East Fork Little Miami River (scheduled to begin in 2012). This decision was made because two similar impairments to Blanchester's PWS were noted on Stonelick Creek which is a tributary within the East Fork Little Miami River. Several causes of impairment related to ongoing CSO discharges in the Sycamore Creek watershed (HUC 05090202-14) have been tangentially addressed by the TMDL development that centers on abatement through reductions in CSO discharges. Tables 3.7 through 3.9 indicate how the applicable causes of impairment are addressed in each of the assessment units.

Table 3.7 Summary of causes of impairment and actions taken to address them in assessment units within the 06 and 07 ten digit HUCs. (Blank spaces indicate that the listed cause of impairment does not apply in that assessment unit.)

Causes of Impairment	Watershed Assessment Units									
	05090202 - 06 -						05090202 - 07 -			
	01	02	03	04	05	06	01	02	03	04
Aquatic Life Uses										
Direct habitat alterations										
Flow alteration										
Sedimentation/siltation			S	S				S		
Nutrient/eutrophication biological indicators			S	S				S		
Organic enrichment (sewage) biological indicators								O[1]		
Organic enrichment/DO										
Oxygen, dissolved			T*	T*						
Siltation										
Natural conditions (flow or habitat)				na	na		na			
Unknown toxicity										
Impairment unknown									na	
Recreation Use										
E coli			T				T	T		T
Public Water Supply Use										
Atrazine									N	

1 Nutrient enrichment will address organic enrichment due to similarity of sources
"T" means TMDL developed using WQS numeric criteria.
"T" means TMDL developed using WQS numeric criteria to address some other cause of impairment (e.g., pathogens used to address organic enrichment).*
"S" means a surrogate measure is used to calculate a TMDL.
"O" means that other causes being addressed will adequately deal with this cause.
"N" means TMDL not developed.
"na" means a TMDL cannot be developed for this.

Table 3.8 Summary of causes of impairment and actions taken to address them in assessment units within the 08 and 09 ten digit HUCs. (Blank spaces indicate that the listed cause of impairment does not apply in that assessment unit.)

Causes of Impairment	Watershed Assessment U`nits						
	05090202 - 08 -				05090202 - 09 -		
	01	02	03	04	01	02	03
Aquatic Life Uses							
Direct habitat alterations							
Flow alteration							
Sedimentation/siltation		S			S		
Nutrient/eutrophication biological indicators					N[2]		
Organic enrichment (sewage) biological indicators					N[2]		
Organic enrichment/DO							
Oxygen, dissolved							

Causes of Impairment	**Watershed Assessment U`nits**						
	05090202 - 08 -				**05090202 - 09 -**		
	01	**02**	**03**	**04**	**01**	**02**	**03**
Siltation							
Natural conditions (flow or habitat)			na			na	
Unknown toxicity							
Impairment unknown							
Recreational Uses							
E coli			T		T		

2 Source has been eliminated since the initial survey and impairments no longer present
"T" means TMDL developed using WQS numeric criteria.
"T" means TMDL developed using WQS numeric criteria to address some other cause of impairment (e.g., pathogens used to address organic enrichment).*
"S" means a surrogate measure is used to calculate a TMDL.
"O" means that other causes being addressed will adequately deal with this cause.
"N" means TMDL <u>not</u> developed.
"na" means a TMDL cannot be developed for this.

Table 3.9 Summary of causes of impairment and actions taken to address them in assessment units within the 14 ten digit HUCs and 9001 and 9002 large river assessment units. (Blank spaces indicate that the listed cause of impairment does not apply in that assessment unit.)

Causes of Impairment	**Watershed and Large River Assessment Units**							
	05090202 - 14 -						**05090202 -**	
	01	**02**	**03**	**04**	**05**	**06**	**upper**	**lower**
Aquatic Life Uses								
Direct habitat alterations		S	N	S	N			
Flow alteration		N	N		N			
Sedimentation/siltation		S		S		S[4]		O[3]
Nutrient/eutrophication biological indicators								O[3]
Organic enrichment (sewage) biological indicators	N			S	O[3]			O[3]
Organic enrichment/DO		N	N					
Oxygen, dissolved								
Siltation			N		N			
Natural conditions (flow or habitat)								
Unknown toxicity		na	na		na			
Impairment unknown								
Recreational Uses								
E coli							T	T

3 Impairment addressed with CSO based TMDLs in other AUs
4 ALU impairment addressed with multiple parameters (QHEI, TSS, and CBOD-5)
"T" means TMDL developed using WQS numeric criteria.
"T" means TMDL developed using WQS numeric criteria to address some other cause of impairment (e.g., pathogens used to address organic enrichment).*
"S" means a surrogate measure is used to calculate a TMDL.
"O" means that other causes being addressed will adequately deal with this cause.
"N" means TMDL <u>not</u> developed.
"na" means a TMDL cannot be developed for this.

3.4 Summary of Methods Used to Calculate Loads

This section of the report provides a summary of the technical methods used in estimating existing loads and calculating the TMDLs and respective wasteload and load allocations.

3.4.1 Nutrients

Lytle Creek

Lytle Creek drains 20 square miles and is a tributary to Todd Fork. Nutrients are causing aquatic life use impairment at sites in the upper portion of the stream where breakdown constituents of deicing chemicals in the ABX storm water runoff is a primary source (A separate TMDL for COD has been created for the pollutants from this facility). The lower portion of Lytle Creek is impacted by nutrients from the Wilmington WWTP (discharging at RM 7.01).

In order to determine what modeling approach is applicable to address the nutrient enrichment for Lytle Creek a critical condition, or a time when the nutrient loading is most damaging to water quality, must be set. Aquatic life is most sensitive to nutrient enrichment when dissolved oxygen swings and nighttime lows are most severe. This occurs when algae production is highest and temperatures are the warmest, corresponding to the summer low flow period (also, dilution of nutrients is minimal from a steady point source loading). The only appreciable nutrient loading at this time is that from the Wilmington WWTP since loading from the ABX storm water system discharges only seasonally and not during the summer low conditions. Likewise, runoff is minimal at this time so nonpoint source loading is very low. The result is that the majority of the TMDL and allocations are based on a summer low flow with the Wilmington WWTP as the only point source contribution and primary source of nutrients.

The standard low flow statistic used by Ohio EPA for modeling TMDLs relating to dissolved oxygen, a parameter impacted by nutrient enrichment, is the 7-consecutive day 10-year recurrence interval, or 7Q10. Since the Wilmington WWTP is the only known point source of total phosphorus (TP) to Lytle Creek at low flow conditions in the summertime, a **simple mass balance approach** for determining the TP TMDL downstream of the Wilmington WWTP can be used.

The TP target to be used in Lytle Creek is 0.08 mg/l (Table 3.3). Because the contribution of summer TP upstream of Wilmington WWTP is greater than the target concentration, some nonpoint source reduction will be required and the WWTP is assigned a concentration equal to the target (0.08 mg/l). Table 3.10 shows the pertinent information regarding this TMDL.

A margin of safety for this TMDL is implicitly incorporated. This is due to the fact that no account is made for decaying ambient phosphorus concentrations when in fact assimilation and sorption of this material can decrease its concentration in the water column (House, 2003, Bowes et al., 2003, Newbold et al., 1983). Additionally, most nutrient TMDLs developed in Ohio have implicit margins of safety because the water quality targets used are conservative in nature. Specifically, the median statistic is used to represent the phosphorus target that corresponds to an unimpaired biological community. Since Ohio EPA's evaluation of phosphorus data for generating target values is based on measured performance of aquatic life and since full attainment can be observed at concentrations above this target (reinforcing the concept that habitat and other factors play an important role in supporting fully functioning biological communities), water quality attainment can occur at levels higher than the target. The difference between the pollutant concentrations where attainment has been observed and the selected target is an implicit margin of safety.

Table 3.10 Parameters and calculations considered for mass balance modeling on Lytle Creek at the Wilmington WWTP outfall

Row	Parameter	Value	Unit	Justification/calculation
A	Area upstream Wilmington WWTP	8.97	mi^2	GIS delineated
B	Yield of 7Q10 flow/square mile	3.37 E^{-3}	cfs/mi^2	Nearby USGS low flow gage 03243400 “Cowan Ck at Clinton Co. AFB”
C	Lytle Creek upstream Wilmington WWTP 7Q10 flow	3.02 E^{-2}	cfs	A * B
D	Upstream flow TP concentration	0.08	mg/l	After a load allocation addressing NPS pollution (see next table)
E	Target TP concentration	0.08	mg/l	See targets in Table 3.3
F	Wilmington WWTP design flow	3.00 → 4.64 →	MGD cfs	NPDES permit
G	Load allocation for NPS upstream of Wilmington WWTP	5.91 E^{-3}	Kg/day	C*D*conversion factor
H	Total TP load downstream the WWTP	0.914	Kg/day	G + F*E* conversion factor
I	Concentration limit for Wilmington WWTP	0.08	mg/l	Mass balance: ((E*(C+F))/F) - ((C*D)/F)
J	Wasteload allocation for Wilmington WWTP	0.908	Kg/day	F*I* conversion factor

Indian Run and Cowan Creek

Indian Run and Cowan Creek both have nutrient/eutrophication listed as causes of aquatic life use impairment. The source of this impairment is from ABX and a separate TMDL for COD has been developed to address this.

Second Creek

Four sites were assessed on Second Creek, a 19.96 square mile tributary to Todd Fork downstream of Clarksville. The upper (eastern) section of Second Creek’s watershed drains an area primarily in agricultural land use. Downstream of this area Second Creek flows through the Village of Blanchester and then on to drain a mix of forested and agricultural land uses.

At all sites on Second Creek, each of the samples exceeded the 0.08 mg/l TP target for WWH headwater streams. The average TP of the six samples taken at the most upstream site (RM 10.94) in the summer of 2007 was 0.35 mg/l with little variation (standard deviation of 0.09). This site represents the watershed upstream of Blanchester and is impacted by upstream agricultural uses. Poor nutrient management, especially from row crops, is believed to be the source of the excessive nutrients.

A site downstream of the Blanchester WWTP is also impaired by nutrients and 2007 monitoring records indicate that the WWTP’s effluent TP concentration averaged 0.97 mg/l TP. Furthermore, a sewage system leak was found draining to Second Creek during the 2007 survey. The Village of Blanchester has corrected this leak, and it is not believed to be contributing to existing aquatic life use impairment. As expected, the site at river mile 9.45 has an average TP greater than the most upstream site. The remaining two sites downstream show elevated TP being assimilated from the two upstream sources discussed here (see Table 3.11).

Because upstream agriculture and the Blanchester WWTP are both contributing to the nutrient load impacting Second Creek, both are important to consider in developing the TMDLs. Again the most critical condition is the summertime low flow period; however, significant algae growth occurs at higher flows affected by nonpoint source nutrient loading. For this reason a stream flow that is generally representative of the 2007 assessment season is used to capture the nonpoint source loading. The flow condition selected is greater than the 7Q10 flow statistic used in this report for watersheds with point source dominated sources (e.g., Lytle Creek) and can be used to model the TP loading in an empirical manner with actual TP data.

Table 3.11 TP values at Second Creek assessment sites.

River mile	Site location on Second Creek	Mean (mg/l)*	Standard deviation
10.94	Columbus St. (upstream Blanchester WWTP)	0.35	0.09
9.45	State Route 123 (downstream Blanchester WWTP)	0.63	0.12
6.55	Gustin-Rider Rd	0.47	0.07
1.53	Cozaddale RD (near Butlerville)	0.27	0.12

* Six samples taken at each site on the same day throughout the summer of 2007

Flow was not measured at the Second Creek assessment sites during the 2007 survey. However, stage measurements were made at four frequently monitored sentinel sites in the Todd Fork watershed throughout this survey and stage to flow relationships were produced to determine loadings at these sentinel sites. The sentinel site on Todd Fork at US 22/SR 3 was observed to have the most closely corresponding flow conditions as those in Second Creek. The flows in Second Creek are estimated as a proportion of the corresponding flows at the Todd Fork site where the ratio of the respective drainage areas (19.96 versus 261 square miles) is used as the proportion. Table 3.12 shows the flow values.

Table 3.12 Flow values on sampling days for the Todd Fork at US 22/SR 3 sentinel site and calculated for the Second Creek watershed.

Date (in 2007)	Sentinel site (cfs)	Calculated for Second Ck flow (cfs)
July 11	118.03	9.03
July 25	15.52	1.19
August 8	7.28	0.56
August 22	7.70	0.59
September 5	1.16	0.09
September 12	6.48	0.50

A flow for the Blanchester WWTP during the selected flow condition needs to be determined. In checking the discharge monitoring reports (DMR), an average effluent flow of 0.59 cfs was reported for the six days that sampling took place. A TP mass balance is also used to determine the average effluent flow during the sampling days. Using the TP monitoring data from the river mile 10.54 and 9.45 sites (data are shown in Table 3.12) and the DMR of 0.96 mg/l TP throughout the summer of 2007 a flow of 0.52 cfs is calculated for the WWTP for this flow condition. This flow is very similar to the DMR flow (12 % difference) and 0.52 cfs will be used to calculate the TMDL. With the total watershed flow and WWTP flow determined, the difference between the two is 1.43 cfs, which is the nonpoint source flow.

A margin of safety for this TMDL is implicitly incorporated. This is due to the fact that no account is made for decaying ambient phosphorus concentrations when in fact assimilation and sorption of this material can decrease its concentration in the water column (House, 2003, Bowes et al., 2003, Newbold et al., 1983). Additionally, instream TP decay is evidenced downstream of the Blanchester WWTP where there is less intensive agriculture land uses, a more intact wooded riparian buffer, and better instream habitat. This demonstrates that decay is occurring in this system. Again, selection of a conservative target is another source of a margin of safety as discussed in reference to the TP TMDL for Lytle Creek.

Concentration allocations for all sources of flow are made in order to meet the TP target concentration of 0.08 mg/l. Table 3.13 shows the concentration based allocations made for the nonpoint source flow. Because of the most upstream sampling site's elevated TP (average of 0.35 mg/l) and the nearly total agricultural land use, it is assumed that agriculture contributes the highest amount of TP from non point sources. Because of this, agricultural land is allotted the highest allocation. The average TP concentration of all the nonpoint source flow is 0.06 mg/l. With this information a mass balance equation is used to determine what the WWTP's TP limit is for this critical condition. This TP limit is 0.13 mg/l. Table 3.14 shows the data used for this calculation.

Table 3.13 Nonpoint source TP concentration allocations by land use.

Land use	Area (mi^2)	Allocated TP concentration (mg/l)
Agriculture	13.04	0.08
Forested	4.90	0.02
Developed non agriculture	2.02	0.05
Total land use	19.96	0.06

Table 3.14 Values used to determine the Blanchester WWTP TP limit at critical condition flow.

Pollutant source	Flow (cfs)	TP concentration (mg/l)
Nonpoint sources land uses	1.47	0.06
Point sources: Blanchester WWTP	0.52	0.13
Total	1.99	0.08*

* This value is based on the flow weighted average of the two sources listed above.

3.4.2 Oxygen Demand from Deicing Agents

The seven consecutive day low flow calculated over a ten-year recurrence interval (7Q10) upstream flow is used to represent the stream flow for this critical condition per Ohio EPA rules [3745-2-11 (B)].

Existing limits for ABX's NPDES permit are for chemical oxygen demand (COD). The reason for this is because COD water quality values are relatively easy and fast to determine compared to carbonaceous biochemical oxygen demand (CBOD). Since propylene glycol, the main deicing component in the ABX discharge, is highly biodegradable, it is assumed for this TMDL that there is little to no difference between COD and CBOD ultimate. A ratio of CBOD ultimate to CBOD 5-day concentrations has been created for the treated discharge of ABX by consultants hired by the facility. This ratio is employed to determine CBOD 5-day for D.O. modeling in this TMDL; the equation for this is CBOD 5-day = 0.609 * COD - 21.2. Table 3.15 shows the concentration of COD in the effluent at the 031 and 032 storm water outfalls.

Table 3.15 ABX Discharge monitoring reports submitted to Ohio EPA for the period of 4/23-5/6/08 for chemical oxygen demand (mg/l).

Date	31 Lytle Creek	32 Indian Run
4/23/2008	32	212
4/24/2008	5	119
4/25/2008	No discharge[1]	140
5/6/2008	No discharge[1]	346

1 No flow data is submitted for these days at this outfall therefore it is assumed that no discharge occurred

In order to model instream D.O. for various loads discharged from the two ABX treatment facilities, a flow for the facility is assumed based on the statistics of the monitoring reporting data. The analyses of the data distribution show non-normal and positively skewed distributions for both outfalls therefore, a flow value greater than the median is picked to represent the critical condition flow. The flow of 0.5 MGD is a practical choice for both outfalls because it is greater than the median and it falls within the histogram's bin with the highest frequency for each outfall's data. Furthermore, using this flow in order to determine TMDL values is an implicit margin of safety since it overestimates the storm water discharge and consequently a higher COD loading for these particular stream flow conditions.

Modeling for this TMDL was carried out as a multi-segment version of EPA's Simplified Method (U.S. EPA, 1980). This model utilizes mass balance loading rates and decay coefficients to determine instream D.O. in a steady flow condition. In addition to the May 7-9, 2008, survey described above, an additional 3-day survey was conducted in June, 2008. Water quality data, time of travel information and some general stream cross-sections were measured during this survey to be utilized for this D.O. modeling.

Since D.O. and decay rate differences due to seasonal temperature cycles are critical in assessing pollutants from ABX, modeling for several time periods is necessary. To determine these time periods, an analysis of the 75^{th} percentile of stream temperature for each month of all Ohio EPA STORET data collected in Clinton County occurred. Based on this analysis, the following time periods are grouped together to each be considered for a TMDL: 1) November through February, 2) March through April and 3) May.

Due to the nature of the ABX treatment facilities, glycol laden storm water can be held and treated, and re-treated, as storage space is available. May is not grouped with other months due to its higher temperatures and the unlikelihood that future deicing events would occur for the season. After discussions with permits staff at Ohio EPA it was determined that an additional time period of June through October, thus covering all of the year, be modeled. This was deemed necessary to allow a permit limit to be developed for these warm months if, in a given year, the facility is still treating glycol from the winter. The stream temperature used in modeling for each of these time periods is the 75^{th} percentile value determined for each time period from the same data population described herein (Table 3.16).

Lytle Creek has zero upstream flow during 7Q10 flow conditions for all times of the year, and therefore no upstream flow is considered. Cowan Creek does have some upstream flow during 7Q10 conditions for some periods of the year. The flows are calculated from USGS published

7Q10 flows for a representative gage applied to a drainage area ratio of the gage and upstream Cowan Creek watershed. Water quality values for these upstream flows are based on data observed in Cowan Creek upstream of Indian Run. These values are within the normal range of unpolluted waters for warmwater habitat streams.

Table 3.16 Time periods and corresponding temperatures used in modeling COD from ABX storm water in Lytle and Cowan Creeks.

Time period	Stream temp (°C) used in modeling
November - February	8
March - April	10.5
May	17.25
June - October	22

3.4.3 Suspended Sediment and Biological Oxygen Demand

Data supplied to Ohio EPA from MSD explain the CSOs total volume of overflow discharge and the number of occurrences over a multiple year period. From these data an average volume per overflow event is determined for each CSO and a total average volume per overflow for Duck and Clough Creeks is determined (Table 3.17). For modeling purposes it is assumed that these volumes are the daily CSO flow for days with a typical CSO event.

Table 3.17 Average volume of CSO discharges per event from MSD's system.

Receiving stream	Number of CSOs	Average volume per event from all CSOs (MG)*
Duck Creek	43	19.39
Clough Creek	2	2.94

* MG = million gallons; Data includes events from Metropolitan Sewer District of Greater Cincinnati, 2006

More complete data for two of the CSOs draining Duck Creek (#549 and #136) were provided to Ohio EPA. These data contain effluent quality, amount of discharge and amount of rainfall (from the closest gage and an average of gages used by MSD). Taken as daily data, these included 65 and 57 CSO events for CSO #549 and #136 respectively between June, 2001 and July, 2003. Table 3.18 shows the median values of these parameters for the two CSOs. Averages of these medians were calculated to be 294 mg/l and 32.5 mg/l TSS and CBOD 5-day respectively. These values are used to represent CSO effluent quality for all of the CSOs in the two watersheds being modeled. These values fall within the range provided by US EPA as expected CSO effluent quality (US EPA, 2001).

Table 3.18 Median effluent quality values for MSD's CSO discharges on Duck and Clough Creeks.

CSO	TSS mg/l	CBOD 5-day
#136	320	22
#549	268	43
Average of medians	294	32.5

Efforts to determine the critical condition storm to apply to all CSOs in the Duck and Clough Creeks' watersheds were carried out. The average of the medians of the daily rainfall on event days is 0.51 inches. This was determined too low of a rainfall value to use to apply to all CSOs. This is because in applying the runoff model TR-55 (USDA, 1986) for these two watersheds given a storm of this rainfall yields 9.67 MG and 2.54 MG in Duck and Clough creeks respectively. Table 3.19 shows that this storm does not produce enough storm water to equal the amount of flow in the CSOs (i.e., 19.39 and 2.94 MGD respectively). If this storm were the typical storm in which the typical CSO flow is observed it would mean a very large portion of the storm water is captured in the CSO or that a great amount of sanitary sewer water is included in the CSO flow relative to the storm water runoff. Since the effluent quality observed for the two Duck Creek CSOs, Table 3.18, does not fall on either of the extremes (highly diluted with storm water or highly concentrated with sewage) of the range of concentrations expected (US EPA, 2001), these possibilities can be ruled out.

In order to consider a storm with more rainfall for the critical condition the 75th percentile rainfall from the data provided was evaluated. The average of the gages' 75th percentile is a storm of 0.835 inches. Again employing the runoff model TR-55, a storm of this size yields 44.69 and 17.04 MG in Duck and Clough creeks respectively. These runoff values are more reasonable when compared to the average CSO flow from all Duck and Clough creeks, and this storm will be used as the CSO critical condition. Table 3.19shows the rainfall values and calculated runoff. This method of TMDL calculation is implicitly conservative. Therefore no explicit margin of safety is necessary.

Table 3.19 Rainfall values and calculated runoff.

Stream	Rainfall (in)	Runoff/storm water (MG)
Duck Creek	0.510	9.67
	0.835*	44.69*
Clough Creek	0.510	2.54
	0.835*	17.04*

* Critical condition

3.4.4 Sediment and Habitat (QHEI)

The bedload and habitat QHEI components for each assessment site are compared to the watershed specific targets developed above. This method of TMDL calculation is implicitly conservative. Therefore no explicit margin of safety is necessary.

3.4.5 Pathogens (E. coli)

An empirical method of determining TMDL loading and reductions is utilized for bacteria with load duration curves (LDCs).

In order to make LDCs the flow duration for each recreation use impaired site on the lower LMR is determined. This involves calculating the flow (cfs) expected for the full range of exceedance percentile. This normalizes the flows to a range of natural occurrences from extremely high flows (0 exceedance percentile) to extremely low flows (100). The flow curve is converted into a load duration curve by taking the product of all flow values, the water quality geometric mean standard and a conversion factor. These values, in *E. coli* colony forming units (or counts) per day are the TMDL for each flow condition. The resulting points are plotted to create a LDC.

The water quality samples for each impaired site are converted into loads by taking the product of the *E. coli* sample result, the flow at the time the sample was collected and a conversion factor. Each calculated load is plotted as a point on the LDC plot and is then compared to the water quality TMDL load. Points that plot above the LDC represent deviations from the water quality standard and the daily allowable load. Points that plot below the curve represent samples in compliance with standards and the daily allowable load.

All of the area beneath the TMDL curve is considered the *E. coli* 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. The final step to create an LDC, is to determine where reductions need to occur. Those exceedances at the right side of the graph occur during low flow conditions, and significant sources might include wastewater treatment plants, malfunctioning home sewage treatment systems, illicit sewer connections and/or animals depositing waste directly to the stream. The exceedances on the left side of the graph occur during higher flow events and potential sources are land uses or management practices such as manure spreading or livestock production, which supply bacteria that is washed off with runoff. The LDC approach helps determine which implementation practices are most effective for reducing loads.

Figure 3.6 shows an example of a LDC where some of the observed *E. coli* loads exceed allowable loads in some flow zones sampled. Samples that were taken when storm flow was greater than 50% of the flow are noted with the diamond filled in red. This flow condition is determined using the sliding-interval method for streamflow hydrograph separation contained in the USGS HYSEP program (Sloto and Crouse, 1996). Note that flows are grouped into five flow regimes. These regimes are defined as the following:

- High flow zone: Stream flows in the 0 to 10 exceedance percentile range; these are related to flood flows.
- Moist zone: Flows in the 10 to 40 exceedance percentile range; these are flows in wet weather conditions.
- Mid-range zone: Flows in the 40 to 60 exceedance percentile range; this are the median stream flow conditions.
- Dry zone: Flows in the 60 to 90 exceedance percentile range; these are related to dry weather flows.
- Low flow zone: Flows in the 90 to 100 exceedance percentile range; related to drought conditions.

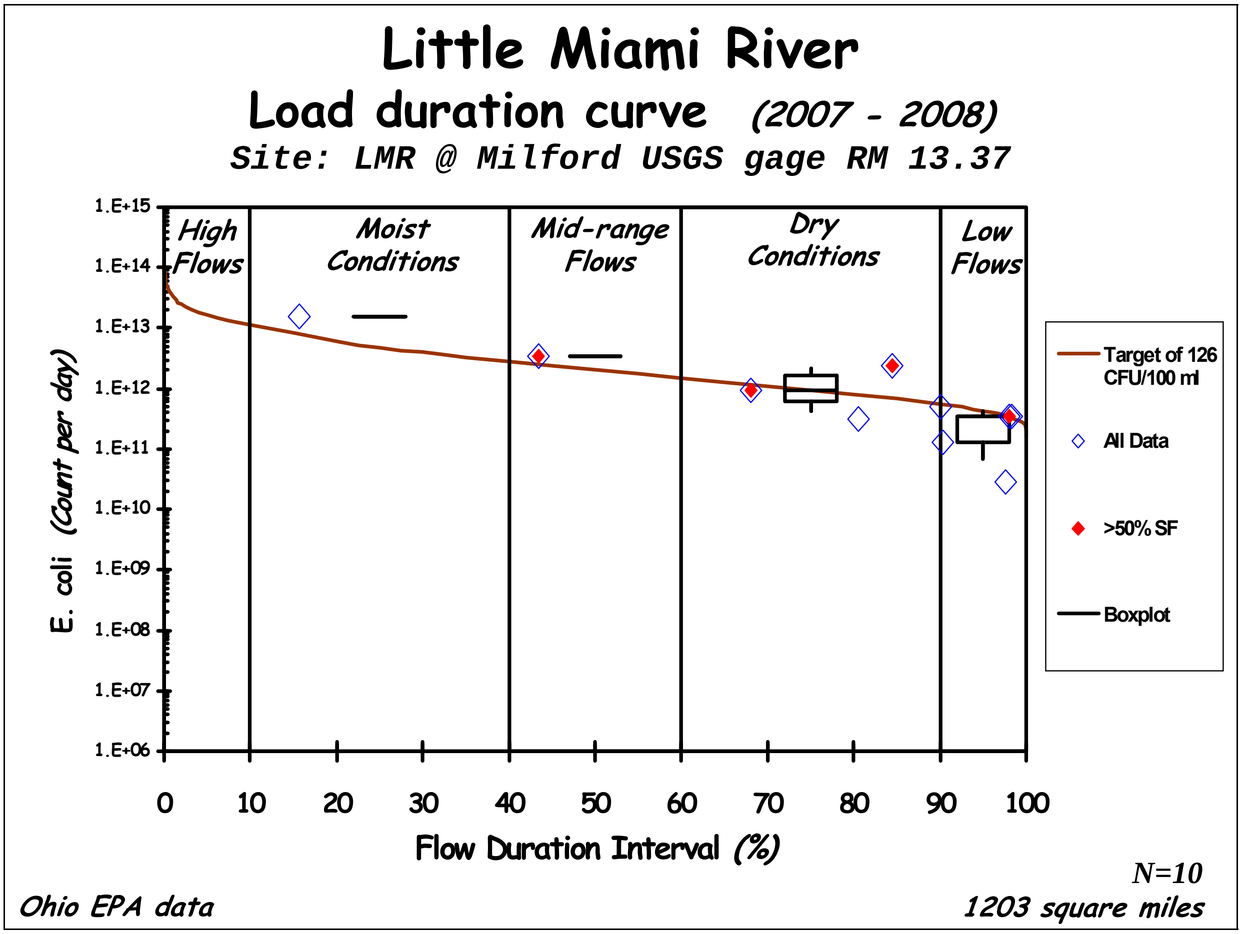


Figure 3.6 Example load duration curve (LDC) for E coli bacteria taken at the USGS gage in Milford, Ohio.

In order to calculate the load duration curve and the load for each *E. coli* sample, each site's flow duration interval must be calculated. In order to determine the load duration curve for each LDC site, stream flows are extrapolated using a USGS gage (station # 03245500 Little Miami River at Milford OH). For most sites a simple drainage area ratio of the LDC site to the USGS gage is applied to the gage flows to determine the LDC site's flows.

The flow duration curve for the Little Miami River mainstem site downstream of Caesar Creek (Shaw property) is created using a different method than described above. At this site, like most recreational use impaired sites, a stage to flow relationship has been made for a nearby bridge. However, unlike most other sites with this relationship this site has been sampled far greater amount of times due to monitoring being carried out by dischargers in the upper Little Miami River watershed. Because of this, the stream flows known at this site can be compared to the flows at the Little Miami River at Milford USGS gage flows for the same day and the next day. Analyses are applied to find the best fit predictor regression equation for this site by using the USGS gage flow data. A linear relationship of the same day's USGS gage flow found the best fit (R2 value of 0.9616). This equation is used to determine the entire flow duration curve for the downstream Caesar Creek site. The USGS gage station that is used for flow estimations has a drainage area of approximately 1203 mi2, and most of the LDC sites included in this TMDL drain less than 100 mi2. Such a size discrepancy can introduce uncertainty to the flow estimates using the unit-area approach. Due to a high amount of wastewater treatment plant effluent making up the low flow of the mainstem, this uncertainty is likely to be greater in low flows.

However, this uncertainty is deemed acceptable as this gage is in the same watershed, and in fact all sites drain to it. Table 3.20 shows the drainage area and ratios used for each LDC site.

The LDC that is created for the Little Miami River at the USGS gage site in Milford needs no flow relationship calculations. The daily stream flow data from the gage is used.

The methods described above for calculating flow duration intervals are only used for calculating the LDC's loading capacity. At all sites except for the Second Creek site the flow used to calculate the load for each sampling event is determined via the flow determined at the exact time of sampling. These flows are determined by using a stage to flow curves made for each site at a nearby bridge. However, the flows used to calculate the existing sample loads for the Second Creek LDC are determined using the same drainage area ratio to the USGS gage that is used to determine the flow duration interval.

Table 3.20 Drainage areas for each LDC site and the drainage area ratio used to calculate stream flow for the *E. coli* loading capacity (TMDL).

12-Digit HUC	Stream Name	Location	River Mile	Drainage Area (Sq. mi.)	Drainage Area Ratio
Mainstem/ 050902020801	Little Miami R.	Dst Caesar Cr (Shaw property)	50.25	658	na[1]
Mainstem/ 050902021403	Little Miami R.	Wooster Pike (Milford gage)	13.07	1203	1.00
050902020704	Todd Fork	SR 22/3 (Morrow)	0.14	261	0.217
050902020603	Lytle Creek	Clarksville Rd	0.65	19.8	0.016
050902020701	East Fork Todd Fork	SR 132 (Clarksville)	1.60	37.3	0.031
050902020702	Second Creek	SR 123 (Dst Blanchester WWTP)	9.42	11.0	0.009
050902020803	Turtle Creek	SR 48	0.52	58.0	0.048
050902020901	Muddy Creek	Mason-Morrow Rd (Dst Mason WWTP)	0.54	15.2	0.013

1 The flow duration interval for this site was calculated a different manner than the drainage area ratio method. See the above section.

Using load duration curves takes advantage of the principle that loads often vary depending on flow and that different sources may contribute loads at different flow conditions. An advantage to the load duration curve approach is that the analysis can directly assist in determining implementation practices that are most effective for reducing loads based on flow magnitude. For example, if loads exceed allowable LDC mostly during storm and winter snow melt events, then implementation efforts can be targeted to best management practices that most effectively reduce loads associated with that type of runoff. Table 3.21 shows various pollutant sources and the loads they are associated with.

Table 3.21 Load duration curve flow zones and typical contributing sources.

Contributing Source Area	Duration Curve Zone				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
Point source				M	H
Livestock direct access to streams				M	H
Home sewage treatment systems	M	M-H	H	H	H
Riparian areas		H	H	M	
Storm water: Impervious		H	H	H	
Combined sewer overflow (CSO)	H	H	H		
Storm water: Upland	H	H	M		
Field drainage: Natural condition	H	M			
Field drainage: Tile system	H	H	M-H	L-M	
Bank erosion	H	M			

To account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality an explicit MOS is applied for this watershed’s bacteria TMDLs. This MOS is calculated as 10% of the allowable load that is calculated for each flow zone. The ten percent MOS was selected based on the use of load duration curves, which minimize potential uncertainties associated with calculating the allowable loads (i.e., the allowable loads are based on observed data rather than modeling simulations).

The critical condition for pathogens is the summer dry period when flows are lowest, and thus the potential for dilution is the lowest. Summer is also the period when the probability of recreational contact is the highest. For these reasons recreational use designations are only applicable in the period May 1 to October 31. Pathogen TMDLs are developed for the same May to October 31 time-periods in consideration of the critical condition, and for agreement with Ohio WQS.

4 RESULTS OF TMDL DEVELOPMENT

This section of the report provides the results of the TMDL analyses. These results indicate the needed pollution and/or stressor abatement needed in the watershed in order to meet the applicable water quality standards. Section 5.0 of the report focuses on strategies that might best achieve the needed water quality improvements.

Figure 4.1 is a map of the watershed illustrating the areas where TMDLs were developed for total phosphorus (TP), chemical oxygen demand (COD), and total suspended solids (TSS). Figure 4.2 is a map of the recreation use attainment status and locations where load duration curves were developed to calculate TMDLs and various allocations of the E coli loading.

The remainder of the this section is organized based on the specific TMDLs, namely TP and COD constitute Section 4.1, TSS and CBOD constitute Section 4.2, habitat and sediment constitute Section 4.3, and E coli bacteria constitutes Section 4.4.

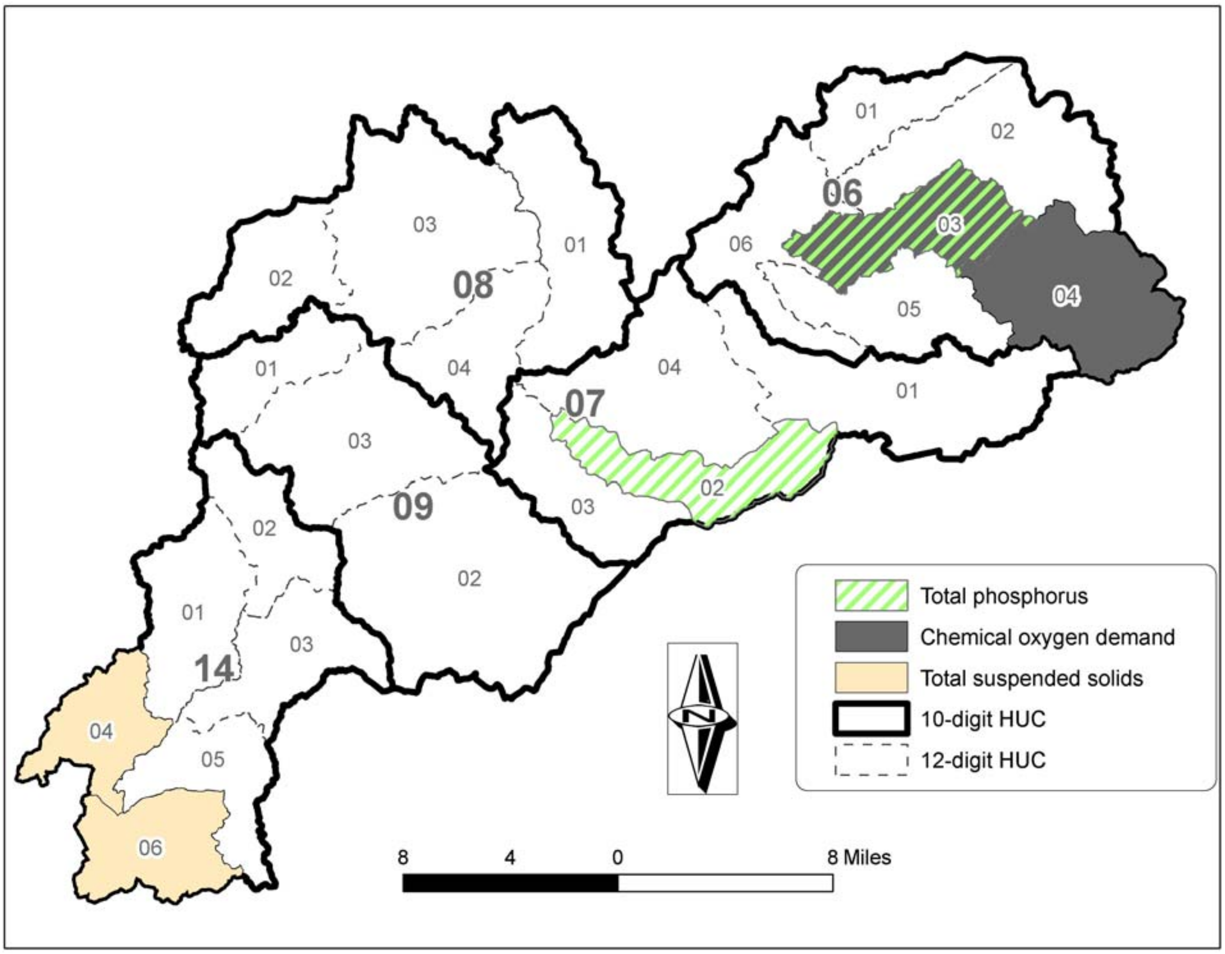


Figure 4.1 Areas analyzed for TMDL development. Areas without shading or diagonal lines were not subject to TMDL analysis.

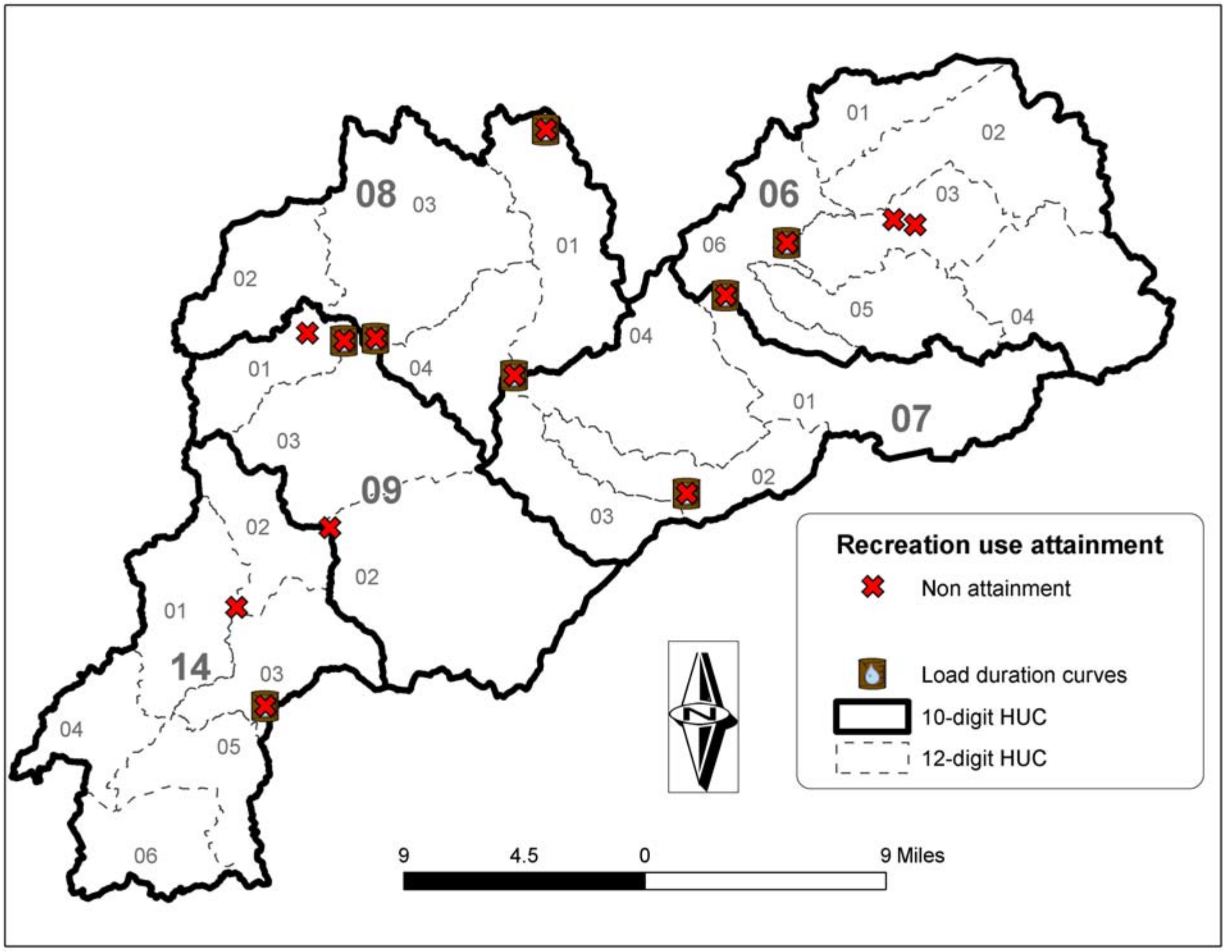


Figure 4.2 Map of sites showing impaired recreation use and locations where load duration curves were developed to calculate TMDLs and various allocations of the E coli loading.

4.1 Nutrients

Lytle Creek

Table 4.1 shows the critical condition existing, allocation and TMDL values for the Lytle Creek TP TMDL. These values are based on the calculations shown above in the methods section's Tables 3.1 and 3.2. The vast majority of existing TP in Lytle Creek is from the Wilmington WWTP. Based on these modeling results, implementation to mitigate this stream's impairment due to nutrients should focus on the WWTP's contribution as a priority.

Table 4.1 Total phosphorus TMDLs and allocations for Lytle Creek

	Loading	
	Existing (kg/day)	**Allocated (kg/day)[1]**
Load (nonpoint source)	**0.021[2]**	**0.013**
Wasteload Wilmington WWTP	34.21[3]	0.913
Wasteload ABX	- [4]	0
TMDL	-	0.922[5]

1 Margin of safety is implicit
2 Load allocation is based on the calculated full 20 mi^2 7Q10 flow (see Table 3.10). Existing load is based on the average of the two non-WWTP impacted sampling sites monitoring data (TP= 0.13 mg/l).
3 Existing WWTP load based on projected effluent quality of discharger monitoring reports and median discharged flow from a period of record (2003-2007)
4 ABX has closed all storm water discharges to Lytle Creek
5 Value does not sum exactly due to rounding for the table

Second Creek

The Blanchester WWTP's current average design flow discharge of 0.99 million gallons a day is regularly exceeded by the plant. However, this is not an indication of a need for plant expansion, but rather illustrates the current difficulties the village has with sewage collection and treatment. Blanchester is currently in the process of making improvements to their WWTP and associated collection system. The first phase of this process involves the installation of an equalization basin and wet-weather pump station. Construction began on phase one in March of 2009 and currently is nearly complete to the point that the new equalization basin is useable. Work on the automatic control system should end by June of 2010. The existing design flow will be used for the wasteload allocation because the facility design flow is not expected to go up and, once the first phase of improvements are made, plant discharges should be less variable. The TP concentration limit calculated for the TMDL critical condition is applied to the design flow. Table 4.2 shows the existing, allocation and TMDL values.

Table 4.2 Total phosphorus TMDLs and allocations for Second Creek

	Loading	
	Existing (kg/day)	**Allocated (kg/day)[1]**
Load (nonpoint source)	1.29[2]	0.22
Wasteload (point source) Blanchester WWTP	4.33[3]	0.49
TMDL	-	0.71

1 Margin of safety is implicit
2 Existing load based on an assumed TP concentration of 0.35 mg/l from all existing nonpoint sources
3 Existing WWTP load based on projected effluent quality of discharger monitoring reports and median discharged flow for the period of record 2004-2008

4.2 Oxygen Demand from Deicing Agents

Modeling scenarios are carried out in both streams examining progressively lower discharge concentrations. The pollutant value that is protective of the D.O. TMDL target (the average D.O. criterion) is determined for each stream for each of the time periods defined in Section 3.4.

Figures 4.3 and 4.4 show the instream D.O. longitudinal profile for Lytle Creek and the Indian Run/Cowan Creek complex respectively.

Lytle Creek's D.O. modeling results, Figure 4.3, show relatively the same pattern of D.O. depletion for all four conditions considered. This is also the same pattern observed during the May 2008 D.O. for the reach below ABX to Wilmington WWTP. In all of these scenarios the oxygen demanding pollutant continues to deplete D.O. as the stream flows downstream throughout the modeling reach. Modeling is not carried out past the Wilmington WWTP because it is assumed the flow from this plant significantly raises the D.O. of the stream. This is because, 1) Wilmington's permit limits require low BOD and relatively high D.O. discharges and 2) observations of Lytle Creek downstream of the Wilmington WWTP show a nutrient enriched environment very different from the oxygen depleted conditions upstream. The Lytle Creek D.O. results and COD values calculated from this modeling are as expected in that the colder the water, the more pollutant load the stream can accept without excessive D.O. depletion.

The Indian Run and Cowan Creek modeling results, Figure 4.4, show that in two of the time periods the D.O. bottoms out in Indian Run and in the other two the lowest D.O. occurs further downstream in Cowan Creek. The primary reason for this is because of the different stream temperatures in each condition play a part in the differences in the lowest D.O. river mile. Also the varying amount of upstream flow changes instream velocity and thereby D.O. reaeration. Despite these differences, the same pattern is seen as modeled in Lytle Creek in that the colder the water temperature, the greater the COD load the stream can receive without D.O. criterion violation. It can also be noted the same pattern of longitudinal average instream D.O. is predicted as was observed in the field (Figure 3.13). The main difference from the predicted and observed however is that the pollutant load was greater during the latter resulting in D.O. standard violations and a fish kill.

Table 4.3 shows the allocations and TMDL for each time period for both Lytle and Cowan Creek's watersheds. For Lytle Creek the point of compliance for this TMDL is just upstream the Wilmington WWTP (river mile 6.83). The Wilmington WWTP is a source of aquatic life use impairment to Lytle Creek further downstream; however, this impairment is caused by a different type of pollutant (nutrients). It is therefore dealt with in a different TMDL. The point of compliance for the Cowan Creek watershed is upstream of the Cowan Creek Lake at river mile 6.75. As noted in Section 3.4, the margin of safety for this TMDL is implicit.

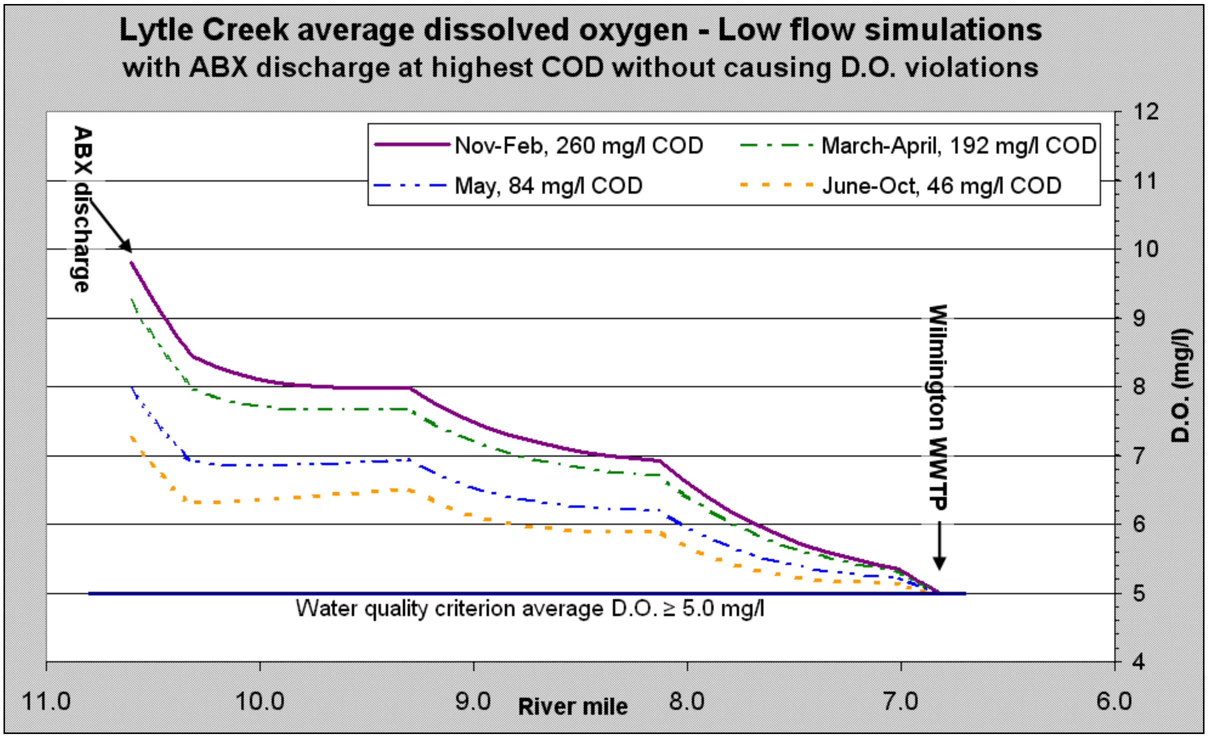


Figure 4.3 Graph of the profile of Lytle Creek with the model output for the maximum allowable COD concentrations for meeting DO criteria under low flow conditions.

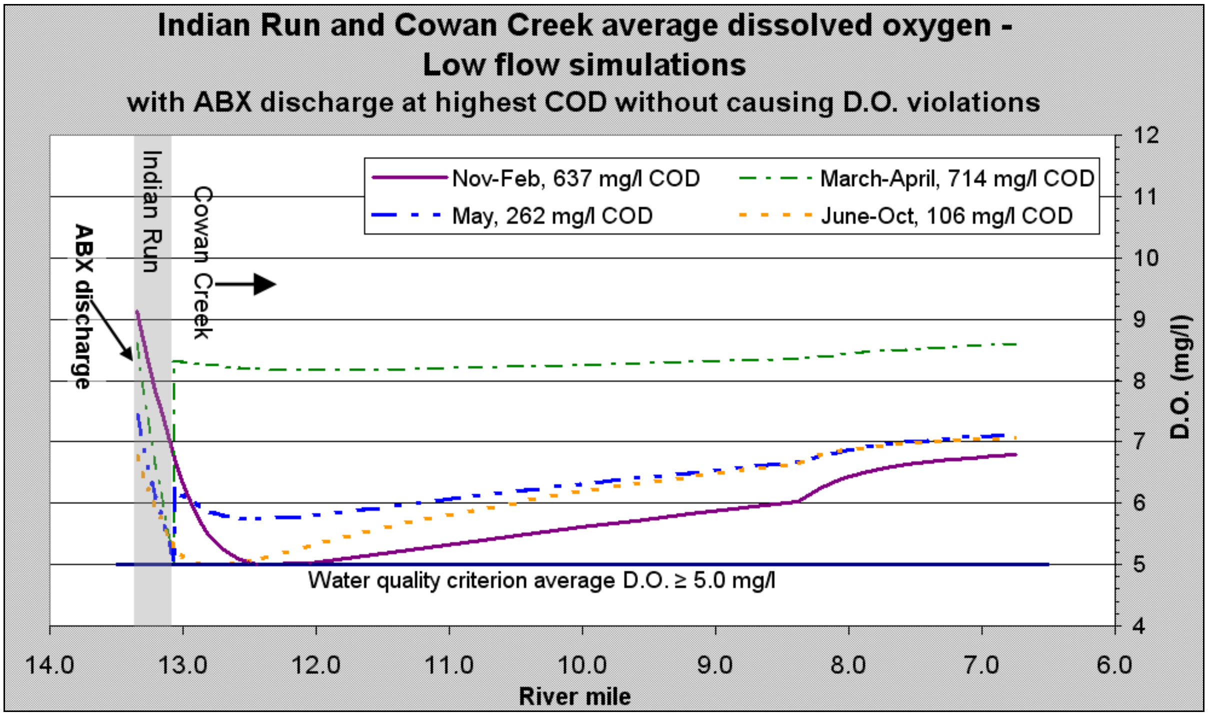


Figure 4.4 Graph of the profile of Indian Run and Cowan Creek with the model output for the maximum allowable COD concentrations for meeting DO criteria under low flow conditions

Table 4.3 COD TMDLs for Lytle and Cowan Creeks based on 7Q10 stream flow conditions

Stream	Allocation	Nov - Feb		March - April		May		June - October	
		Load[1]	Conc[2]	Load[1]	Conc[2]	Load[1]	Conc[2]	Load[1]	Conc[2]
Lytle Ck at sources	WLA for ABX	492.10	260	363.40	192	158.99	84	87.06	46
	LA Upstream	0	No flow	0	No flow	0	No flow	0	No flow
	TMDL	492.10	-	363.40	-	158.99	-	87.06	-
Cowan Ck at sources	WLA for ABX	1205.65	637	1351.39	714	495.89	262	200.63	106
	LA Upstream	0	No flow	35.65	Back-ground	6.90	Back-ground	0	No flow
	TMDL	1205.65	-	1387.04	-	502.79	-	200.63	-

1 Loads are in kg/day
2 Concentrations are in mg/l

4.3 Suspended Sediment and Biological Oxygen Demand

The existing load for the TSS and CBOD 5-day is calculated for Duck and Clough Creek's watershed using the typical CSO effluent water quality (see Table 3.18) and calculated runoff for a storm of 0.835 inches (see Table 3.17). A percentage of sanitary sewer and storm water making up the CSO flow is calculated based on the typical observed effluent quality of CSOs (see Table 3.18) and reference values for these parameters in urban storm water runoff and sanitary sewers (US EPA 2001). This generalization results in a typical Duck and Clough creeks' CSO flow that is made up of 45% sanitary sewer (8.82 and 1.34 million gallons Duck and Clough creeks respectively) and 55% storm water (10.57 and 1.60 million gallons Duck and Clough creeks respectively). Based on this assumption, Tables 4.4 and 4.6 show the TSS and CBOD 5-day loads respectively for the existing critical condition while Tables 4.5 and 4.7 show the respective TMDLs and allocations.

In order to reach the target of 85% existing CSO volume control, total CSO loads are reduced 85%. For the purposes of this TMDL, the percentages of sanitary sewer and storm water in CSOs are assumed to be held the same as in the existing conditions calculations. The same 0.835 inches storm is considered for this loading capacity calculation, and therefore the same amount of total storm water is considered. Because of CSO reductions, much more storm water is considered to be non-CSO storm water. Figures 4.5 and 4.7 show the load reductions from existing to TMDL for TSS in Duck and Clough creeks respectively. Figures 4.6 and 4.8 show the load reductions from existing to TMDL for CBOD 5-day in Duck and Clough creeks respectively.

Table 4.4 Existing conditions for TSS loading

Stream	Existing CSO			Existing non-CSO storm water			Total
	Flow MG	Conc. mg/l	Load kg/day	Flow MG	Conc mg/l	Load kg/day	Load kg/day
Duck Ck	19.39	294.00	21580.89	34.11	70.00	9039.43	30620.32
Clough Ck	2.94	294.00	3270.91	15.44	70.00	4090.22	7361.13

Table 4.5 TMDL TSS loads

Stream	TMDL CSO			TMDL non-CSO storm water			Total
	Flow MG	Conc. mg/l	CSO Wasteload allocation kg/day	Flow MG	Conc. mg/l	MS4 Wasteload allocation kg/day	TMDL kg/day
Duck Ck	2.91	294.00	3237.13	43.10	70.00	11421.12	14658.25
Clough Ck	0.44	294.00	490.64	16.80	70.00	4451.20	4941.83

Table 4.6 Existing conditions for CBOD 5-day loading

Stream	Existing CSO			Existing non-CSO storm water			Total
	Flow MG	Conc. mg/l	Load kg/day	Flow MG	Conc. mg/l	Load kg/day	Load kg/day
Duck Ck	19.39	32.50	2385.64	34.11	15.50	2001.59	4387.23
Clough Ck	2.94	32.50	361.58	15.44	15.50	905.69	1267.27

Table 4.7 TMDL CBOD 5-day loads

Stream	TMDL CSO			TMDL non-CSO storm water			Total
	Flow MG	Conc. mg/l	CSO Wasteload allocation kg/day	Flow MG	Conc. mg/l	MS4 Wasteload allocation kg/day	TMDL kg/day
Duck Ck	2.91	32.50	357.85	43.10	15.50	2528.96	2886.81
Clough Ck	0.44	32.50	54.24	16.80	15.50	985.62	1039.86

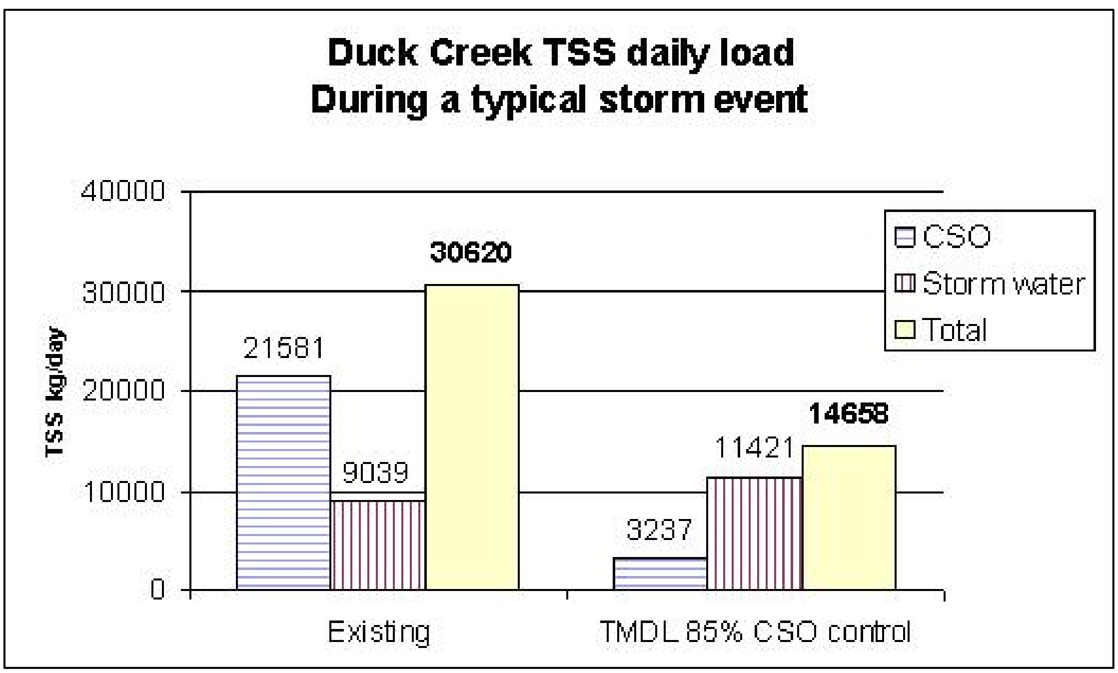


Figure 4.5 Graph of TSS existing and allocated loading on Duck Creek.

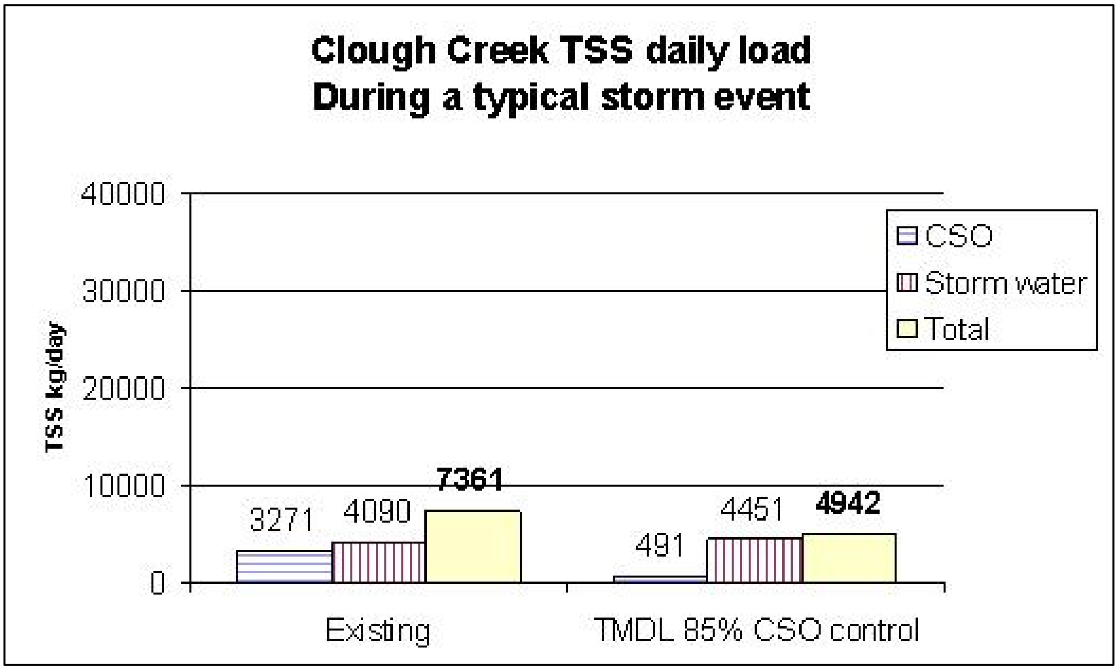


Figure 4.6 Graph of TSS existing and allocated loading on Clough Creek

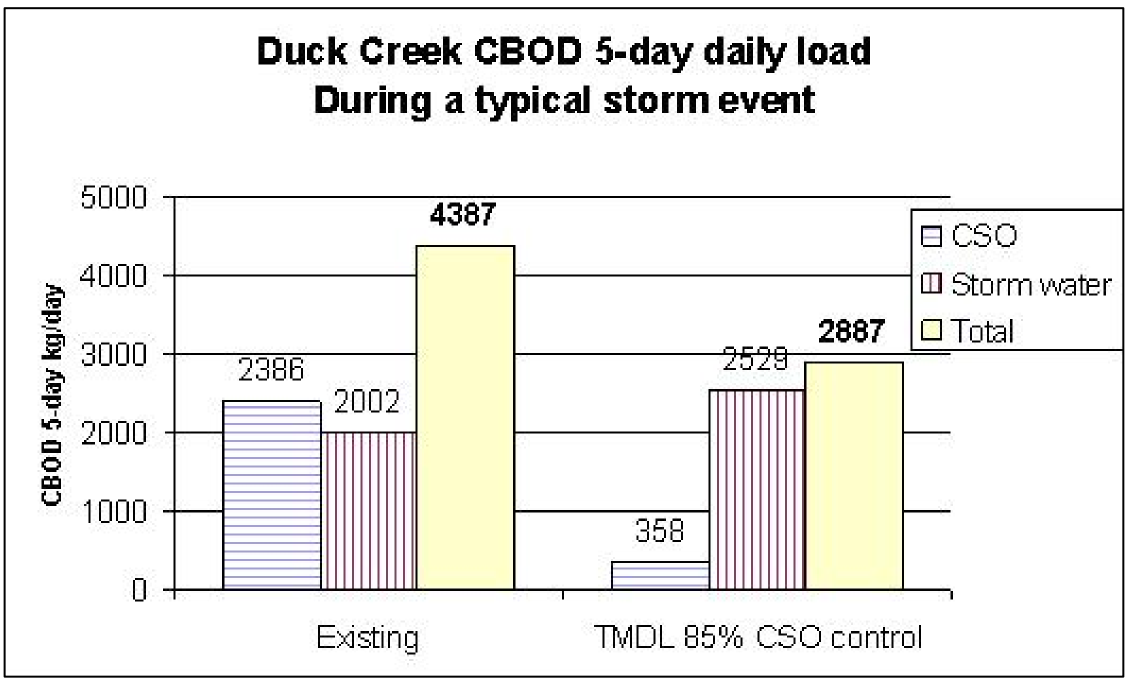


Figure 4.7 Graph of CBOD-5 existing and allocated loading on Duck Creek

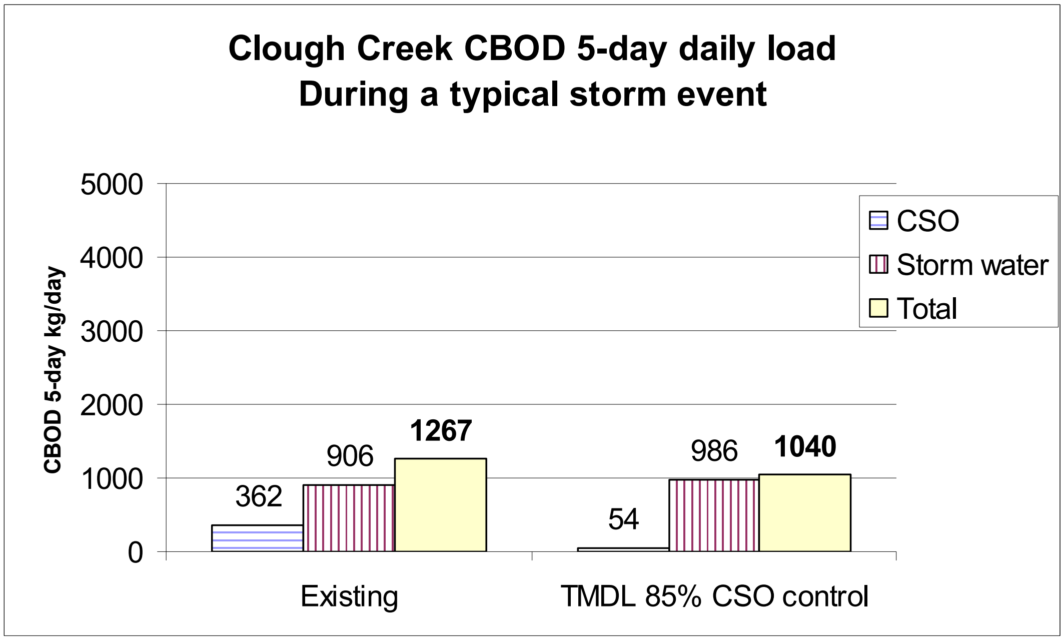


Figure 4.8 Graph of CBOD-5 existing and allocated loading on Clough Creek

4.4 Sediment and Habitat (QHEI)

The bedload and habitat QHEI components comparison to TMDL results are summarized in Tables 4.8 and 4.9. Sites are organized by HUC12. Allocations in the table are specific to the QHEI categories (e.g., substrate metric) and the 12-digit HUC watersheds. The target values are listed at the top of each column. The TMDL values are valid for WWH streams in the lower LMR watershed only. These TMDL targets are not applicable to the mainstem LMR because it is designated as exceptional warmwater habitat, so the mainstem QHEI scores are not shown. The non attaining Duck Creek stream section that is designated limited resource waters habitat and the Dry Run site designated cold water habitat also do not have established QHEI targets. However these two sites are listed on the table for completeness since each have another stream segment that is WWH. Sites listed as impaired by sediment are indicated in Tables 4.8 and 4.9 as bold italics and the one site listed as impaired by habitat (it is not listed as impaired by sediment) is indicated as bold underline. The percent deviation of the actual QHEI and QHEI subcategory scores from the allowable TMDL is provided in the table. Sites are in non-attainment exclusively due to the failure to meet the minimum criteria of the biological indices described in Section 3.1.2 (i.e., the QHEI score have no bearing in determining the aquatic life use attainment status).

Table 4.8 Sediment and Habitat TMDLs for lower LMR watershed based on QHEI metrics (total score and substrate, riparian, and channel scores).

Stream/River name (use)		River mile	Aquatic Life Attainment	QHEI Score		QHEI category					
						Substrate score		Riparian score		Channel score	
				TMDL ≥ 58.4		TMDL ≥ 13.7		TMDL ≥ 5.5		TMDL ≥ 13.0	
				Actual	% Deficit	Actual	% Deficit	Actual	% Deficit	Actual	% Deficit
509020206-01	Dutch Creek	0.28^H	Full	**51.5**	**---**	**13**	**---**	**4**	**---**	13	---
509020206-02	Todd Fork	32.72^H	Full	**44.5**	**---**	**9**	**---**	**4.5**	**---**	12	---
		25.2^W	Full	84	---	**18**	**---**	**5.5**	**---**	17	---
509020206-03	Lytle Creek	***9.3^H***	***Non***	59.5	5	10.5	23	3.5	36	***15.5***	**---**
		7.01^H	***Partial***	***66.5***	**---**	***12***	***12***	***4***	***27***	***14.5***	**---**
		5.95^H	***Partial***	***77***	**---**	***12***	***12***	***7***	**---**	***18***	**---**
		2.76^H	Partial	***67***	**---**	***14.5***	**---**	***7.5***	**---**	16.5	---
		0.65^H	Full	**77**	**---**	**16.5**	**---**	**6.5**	**---**	16.5	---
509020206-04	Cowan Creek	16.62^H	Partial	***65***	**---**	***16***	**---**	***3.5***	***36***	14.5	---
		13.2^W	Full	60.5	---	**15**	**---**	**4.5**	**---**	14	---
	Indian Run	0.2^H	Non	**57**	**9**	17	---	3.5	36	10.5	19
	Cowan Creek	***12.45^W***	***Partial***	*58*	*8*	***1***	***93***	***6.5***	---	***14***	**---**
509020206-05	Cowan Creek	6.8^W	Full	**67**	**---**	**11**	**---**	**10**	**---**	14	---
		2.82^W	Full	68	---	**16.5**	**---**	**7.5**	**---**	13	---
		0.6^W	Full	78	---	**18**	**---**	**7**	**---**	16.5	---
509020206-06	Todd Fork	19.5^W	Full	**74.5**	**---**	**17.5**	**---**	**8.5**	**---**	14.5	---
		17.1^W	Full	70.5	---	**15**	**---**	**6.5**	**---**	14	---
		15.1^W	Full	69	---	**17**	**---**	**8.5**	**---**	14	---
509020207-01	East Fork Todd Fork	18.29^H	Full	**43**	**---**	**5.5**	**---**	**5.5**	**---**	12	---
		17.28^H	Full	**66**	**---**	**13.5**	**---**	**6.5**	**---**	16	---
		11.46^W	Partial	***64***	**---**	***11***	***20***	***5.5***	**---**	13	---

Stream/River name (use)		River mile	Aquatic Life Attainment	QHEI Score		QHEI category					
						Substrate score		Riparian score		Channel score	
				TMDL ≥ 58.4		TMDL ≥ 13.7		TMDL ≥ 5.5		TMDL ≥ 13.0	
				Actual	% Deficit	Actual	% Deficit	Actual	% Deficit	Actual	% Deficit
		7.12[W]	Partial	***68.5***	**---**	***16.5***	**---**	***5***	***9***	13	---
		1.6[W]	Partial	***73***	**---**	***16***	**---**	***6***	**---**	13	---
509020207 -02	Second Creek	10.94[H]	Non	60.5	4	18.5	---	5.5	---	12.5	4
		9.45[H]	***Partial***	*56.5*	***10***	***13.5***	***1***	***4.5***	***18***	***14.5***	***---***
		6.55[H]	Full	77	---	**18**	**---**	**7**	**---**	17	---
		1.53[H]	Full	65.5	---	**11**	**---**	**8.5**	**---**	17	---
509020207 -03	First Creek	3.83[H]	Partial	***58.5***	***7***	***20***	---	***6.5***	---	13	---
509020207 -04	Todd Fork	12.2[W]	Full	**72.5**	**---**	**16**	**---**	**7**	**---**	15	---
		8.53[W]	Full	69.25	---	**18.5**	**---**	**7.25**	**---**	11	---
		5.6[W]	Full	80.5	---	**17.5**	**---**	**8.5**	**---**	16.5	---
		2.65[W]	Full	77.5	---	**16**	**---**	**9**	**---**	16	---
		0.14[W]	Full	57.5	---	**16**	**---**	**4.5**	**---**	13	---
509020208-02	Little Muddy Creek	***3.22[H]***	***Partial***	***44.5***	***29***	***8***	***42***	***5***	***9***	***7.5***	***42***
		1.02[W]	Full	52	---	**11.5**	**---**	**4.5**	**---**	12	---
509020208 -03	Turtle Creek	7.43[H]	Partial	***47.5***	***24***	***17.5***	---	***5***	***9***	12	8
		6.23[W]	Full	70	---	**14**	**---**	**5.5**	**---**	13.5	---
		4.85[W]	Full	65	---	**11.5**	**---**	**5.5**	**---**	12	---
		0.52[W]	Full	61	---	**17.5**	**---**	**6**	**---**	13.5	---
	Dry Run **CWH**	1.79[H]	Full	55	---	**14**	**---**	**6**	**---**	12	---
	Dry Run	0.18[H]	Non	**50**	20	17	---	5	9	11	15

Stream/River name (use)		River mile	Aquatic Life Attainment	QHEI Score		QHEI category					
						Substrate score		Riparian score		Channel score	
				TMDL ≥ 58.4		TMDL ≥ 13.7		TMDL ≥ 5.5		TMDL ≥ 13.0	
				Actual	% Deficit	Actual	% Deficit	Actual	% Deficit	Actual	% Deficit
509020209 -01	Muddy Creek	2.5 H	Partial	***62.5***	***0.5***	***13.5***	***1***	***4.5***	***18***	13.5	---
		0.54 H	***Partial***	*74*	---	**15**	**---**	**7**	**---**	**18**	**---**
509020209 -02	O'Bannon Creek	10.14 H	Non	48.5	23	13.5	1	7	---	13	---
		8.27 H	Partial	*56*	*11*	***18***	***---***	***5***	***9***	12	8
		4.37 W	Partial	*54*	*14*	***12***	***12***	***4***	***27***	11	15
		1.84 W	Full	75.5	---	**15**	**---**	**6**	**---**	17	---
		0.26 W	Full	60	---	**14**	**---**	**5**	**---**	12	---
509020214- 01	Sycamore Creek	1.1 H	Partial	***63.5***	***---***	***15.5***	***---***	***6***	***---***	13	---
		0.5 W	Full	69.5	---	**19**	**---**	**4.5**	**---**	11	---
		0.1 W	Full	76.5	---	**18**	**---**	**6**	**---**	11.5	---
509020214- 04	Duck Creek *LRW*	**3.3 H** (underlined)	**Non** (underlined)	24.5	61	-1	107	3.5	36	**6** (underlined)	**54** (underlined)
	Duck Creek	***0.95 H***	***Non***	**36**	**43**	-1.5	111	4	27	***8.5***	***35***
509020214- 06	Clough Creek	***0.42 H***	***Partial***	***55***	***12***	***16.5***	***---***	***5***	***9***	***13.5***	***---***

H – Headwater site, W – Wading site, B – Boat site **Bold – Non Biological Attainment**, ***Bold & Italic – Partial Biological Attainment***

Bold italics indicates sites that are impaired by sediment only therefore only the substrate, riparian and channel QHEI metrics are used as the TMDL surrogates for sediment.

Bold underline indicates the site that is impaired for habitat only therefore all QHEI metrics (including the total score) are used as the TMDL surrogates for habitat.

Table 4.9 Habitat TMDLs based on QHEI metrics (cover, pool, riffle, and gradient scores) for lower LMR watershed.

Stream/River name (use)		River mile	Aquatic Life Attainment	QHEI category: Cover Score TMDL ≥ 10.5 Actual	% Deficit	Pool score TMDL ≥ 7.0 Actual	% Deficit	Riffle score TMDL ≥ 2.7 Actual	% Deficit	Gradient score TMDL ≥ 6.0 Actual	% Deficit
509020206-01	Dutch Creek	0.28[H]	Full	5	---	6	---	2.5	---	8	---
509020206-02	Todd Fork	32.72[H]	Full	7	---	6	---	0	---	6	---
		25.2[W]	Full	17	---	10	---	6.5	---	10	---
509020206-03	Lytle Creek	***9.3[H]***	***Non***	***12***	---	7	---	1	63	10	---
		7.01[H]	***Partial***	***15***	---	9	---	2	26	10	---
		5.95[H]	***Partial***	***14***	---	12	---	4	---	10	---
		2.76[H]	Partial	7	33	7	---	4.5	---	10	---
		0.65[H]	Full	16	---	11	---	4.5	---	6	---
509020206-04	Cowan Creek	16.62[H]	Partial	11	---	6	14	4	---	10	---
		13.2[W]	Full	16	---	5	---	0	---	6	---
	Indian Run	0.2[H]	Non	14	---	5	29	3	---	4	33
	Cowan Creek	***12.45[W]***	***Partial***	***15***	---	10	---	1.5	44	10	---
509020206-05	Cowan Creek	6.8[W]	Full	16	---	9	---	1	---	6	---
		2.82[W]	Full	12	---	9	---	6	---	4	---
		0.6[W]	Full	14	---	11	---	5.5	---	6	---
509020206-06	Todd Fork	19.5[W]	Full	14	---	8	---	6	---	6	---
		17.1[W]	Full	12	---	9	---	6	---	8	---
		15.1[W]	Full	8	---	7	---	6.5	---	8	---
509020207-01	East Fork Todd Fork	18.29[H]	Full	8	---	4	---	0	---	8	---
		17.28[H]	Full	14	---	5	---	3	---	8	---
		11.46[W]	Partial	14	---	9	---	1.5	44	10	---
		7.12[W]	Partial	13	---	6	14	5	---	10	---

Stream/River name (use)		River mile	Aquatic Life Attainment	QHEI category: Cover Score TMDL ≥ 10.5		Pool score TMDL ≥ 7.0		Riffle score TMDL ≥ 2.7		Gradient score TMDL ≥ 6.0	
				Actual	% Deficit	Actual	% Deficit	Actual	% Deficit	Actual	% Deficit
		1.6[W]	Partial	14	14	---	---	6	---	8	---
509020207-02	Second Creek	10.94[H]	Non	12	---	4	43	0	100	8	---
		9.45[H]	***Partial***	***8***	24	4	43	2	26	10	---
		6.55[H]	Full	14	---	8	---	5	---	8	---
		1.53[H]	Full	12	---	8	---	5	---	4	---
509020207-03	First Creek	3.83[H]	Partial	8	24	1	86	0	100	10	---
509020207-04	Todd Fork	12.2[W]	Full	10	---	9	---	5.5	---	10	---
		8.53[W]	Full	8	---	9	---	5.5	---	10	---
		5.6[W]	Full	12	---	11	---	7	---	8	---
		2.65[W]	Full	13	---	10	---	5.5	---	8	---
		0.14[W]	Full	5	---	6	---	5	---	8	---
509020208-02	Little Muddy Creek	***3.22[H]***	***Partial***	***9***	14	5	29	0	100	10	---
		1.02[W]	Full	11	---	6	---	1	---	6	---
509020208-03	Turtle Creek	7.43[H]	Partial	3	71	2	71	0	100	8	---
		6.23[W]	Full	15	---	10	---	2	---	10	---
		4.85[W]	Full	15	---	10	---	1	---	10	---
		0.52[W]	Full	7	---	7	---	4	---	6	---
	Dry Run **CWH**	1.79[H]	Full	8	---	4	---	1	---	10	---
	Dry Run	0.18[H]	Non	5	52	2	71	0	100	10	---
509020209-01	Muddy Creek	2.5[H]	Partial	12	---	10	---	3	---	6	---
		0.54[H]	***Partial***	***13***	---	9	---	4	---	8	---
509020209-02	O'Bannon Creek	10.14[H]	Non	5	52	2	71	0	100	8	---
		8.27[H]	Partial	10	5	3	57	0	100	8	---

	Stream/River name (use)	River mile	Aquatic Life Attainment	QHEI category: Cover Score TMDL ≥ 10.5		Pool score TMDL ≥ 7.0		Riffle score TMDL ≥ 2.7		Gradient score TMDL ≥ 6.0	
				Actual	% Deficit	Actual	% Deficit	Actual	% Deficit	Actual	% Deficit
		4.37^W	Partial	12	---	7	---	0	100	8	---
		1.84^W	Full	15	---	12	---	6.5	---	4	---
		0.26^W	Full	12	---	7	---	4	---	6	---
509020214-01	Sycamore Creek	1.1^H	Partial	11	---	7	---	5	---	6	---
		0.5^W	Full	13	---	11	---	5	---	6	---
		0.1^W	Full	13	---	11	---	7	---	10	---
509020214-04	**Duck Creek *LRW***	**3.3^H**	**Non**	**3**	**71**	**3**	**57**	**0**	**100**	**10**	**---**
	Duck Creek	***0.95^H***	***Non***	***5***	52	7	---	3	---	10	---
509020214-06	Clough Creek	***0.42^H***	***Partial***	***6***	43	6	14	4	---	4	33

H – Headwater site, W – Wading site, B – Boat site, **Bold – Non Biological Attainment*, Bold & Italic – Partial Biological Attainment***

Bold italics indicates sites that are impaired by sediment only therefore only the substrate, riparian and channel QHEI metrics are used as the TMDL surrogates for sediment.

Bold underline indicates the site that is impaired for habitat only therefore all QHEI metrics (including the total score) are used as the TMDL surrogates for habitat.

4.5 Pathogens (E. coli)

For each sampling site that has recreational use impairment an LDC has been created. These LDCs represent the entire watershed draining to the sampling site. TMDLs have been developed for each of the five flow regimes examined in each LDC. The load at the middle of each flow regime is used for the TMDL. For example, the median flow load is used for the mid-range flow regime. Load and wasteload allocations (LA and WLA respectively) have been determined for each of these flow regimes in each LDC.

Margin of Safety
The first step of load allocation takes 10% from the TMDL load and sets this aside as the margin of safety. The ten percent MOS was selected based on the use of load duration curves, which minimize potential uncertainties associated with calculating the allowable loads (i.e., the allowable loads are based on observed data rather than modeling simulations).

Permitted dischargers with NPDES permits that currently require disinfection of their final effluent (mostly wastewater treatment plants, WWTPs), are given a WLA of the product of their design flow, the target E. coli concentration and a conversion factor. Since these facilities operate no matter what the stream flow, their WLA is the same for all five flow regimes. In a few of the LDC watersheds, this WLA is greater than the calculated TMDL load for the low flow regime. This is reflective of two aspects of the LDC method. The first reason is that most WWTPs are not currently at their design flow, and therefore the flow duration interval calculated is not high enough in the low flow regime. The second reason can be attributed to error in the calculation of the flow duration curve. This issue is compensated for by raising the TMDL when this occurs to the NPDES WLA. Since no runoff/non point source loads are expected at this flow regime this adjustment has no impact on LAs. This issue is more problematic in the Muddy Creek TMDL. This is because the main effluent from the Mason WWTP No. 2 plant is discharged in this watershed. This facility has an extremely high design flow, 13 million gallon per day that discharges to a relatively small sized watershed 15.2 square miles. Because of this the WLA for the WWTP is greater than the calculated TMDL for not just the low flow regime, but also the dry conditions and mid-range flows. As in the other cases where this occurs the TMDL is raised to the WLA for these additional flow regimes. This however allows for no LA from runoff sources in these regimes.

Once margin of safety and NPDES WLAs are determined for each flow condition’s TMDL, the remaining load is assigned to runoff loads. Any home sewage treatment systems or direct livestock existing loads of E. coli are not allocated, hence they are assigned no load. The runoff loads are divided between runoff from MS4 areas and non-MS4 areas. Since runoff from MS4s is regulated by Ohio EPA, this allocation is considered a WLA. The non-MS4 runoff is an LA. This division is carried out simply by applying the land area ratio of each type (MS4 and non-MS4) to the remaining E. coli load allowed for each TMDL. Specific MS4s are subdivided and identified.

Figures 4.10, 4.12, 4.14, 4.16, 4.18, 4.20, and 4.22 show the LDCs, while Figures 4.9, 4.11, 4.13, 4.15, and 4.17 are maps of the areas covered by the respective LDCs. Tables 4.10 through 4.18 (with the exception of Table 4.15) show the TMDL and allocation loads for each recreational use impaired watershed. The geometric mean of existing data for each flow regime is included in these tables. The percent load reduction required to meet the TMDL is also provided for each flow regime, where data has been collected.

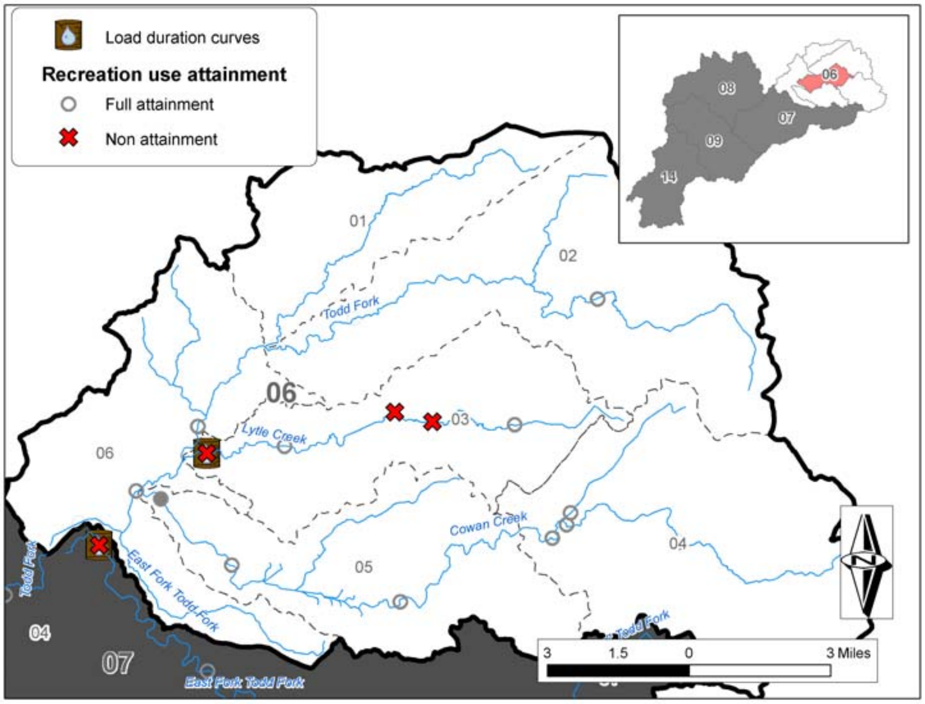


Figure 4.9 Map of recreation use impairments and location of LDC for E coli in the 06 ten digit HUC.

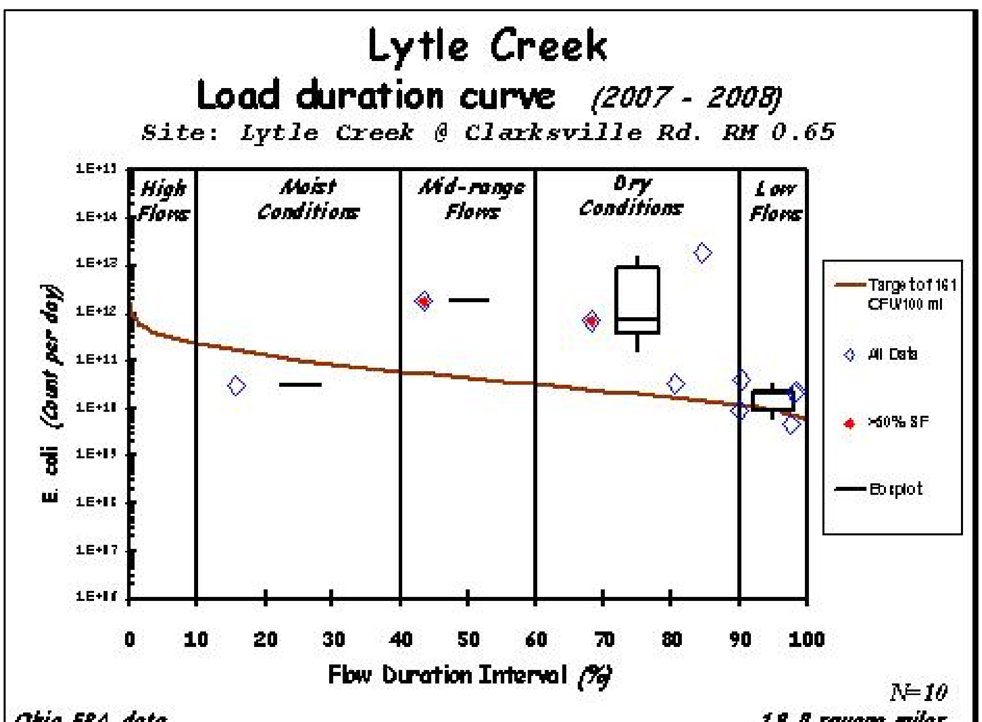


Figure 4.10 Load duration curve for the E coli bacteria TMDLs on Lytle Creek (06 ten digit HUC).

Table 4.10 Bacteria existing loads and TMDL for Lytle Creek RM 0.65. Units for *E. coli* concentrations are count/day.

Flow exceedance percentile	High Flows 0-10	Moist Conditions 10-40	Mid-Range Flows 40-60	Dry Conditions 60-90	Low Flows 90-100
Current Load (geometric mean)	No Data	3.08E+10	1.72E+12	7.36E+11	1.49E+10
TMDL= LA+WLA+MOS	3.51E+11	1.01E+11	4.34E+10	1.99E+10	1.57E+10*
LA	2.37E+11	6.01E+10	1.94E+10	2.82E+09	0
WLA: Wilmington WWTP	1.43E+10	1.43E+10	1.43E+10	1.43E+10	1.43E+10
WLA: MS4 Wilmington	6.53E+10	1.66E+10	5.35E+09	7.80E+08	0
MOS (10%)	3.51E+10	1.01E+10	4.34E+09	1.99E+09	1.43E+09
TMDL Reduction (%)	No Data	0%	97.47%	97.29%	0%

* The TMDL in this category is greater than calculated for the LDC because the curve reflects current flows, and the TMDL include flows from future expansion of waste water treatment plants (permitted design flows).

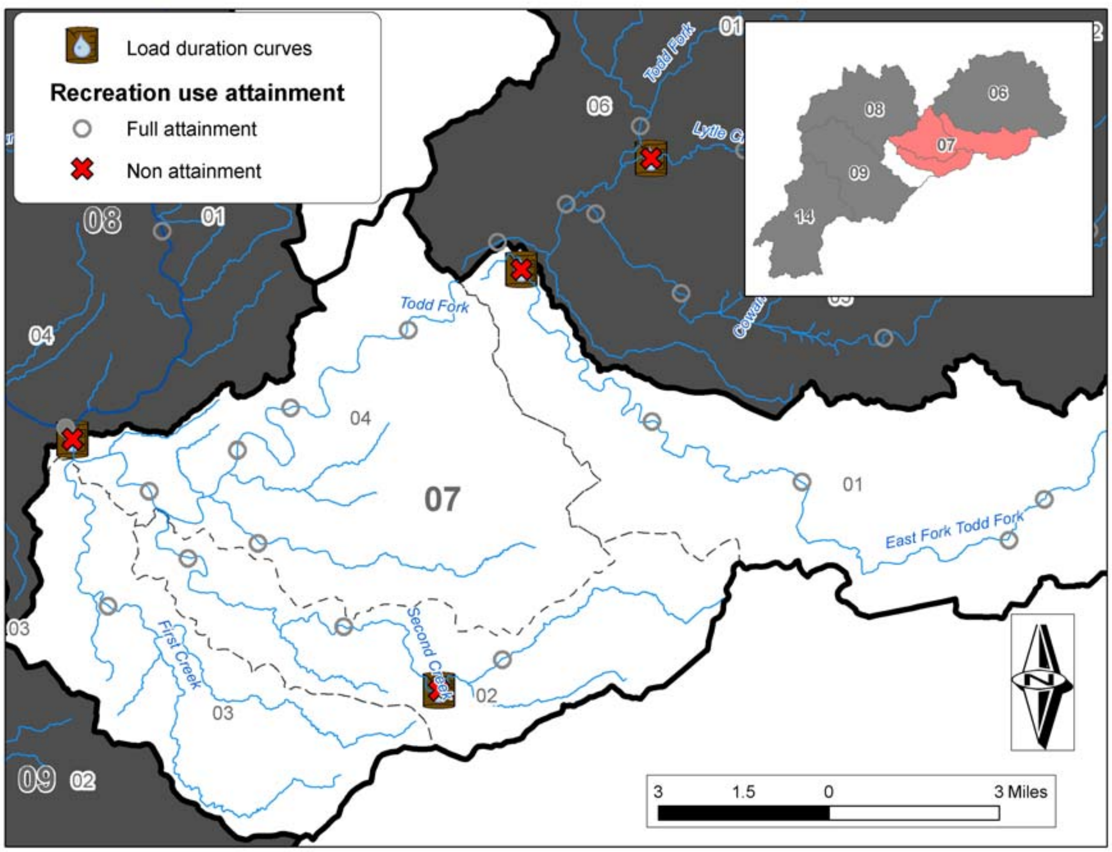


Figure 4.11 Map of recreation use impairments and location of LDC for E coli in the 07 ten digit HUC.

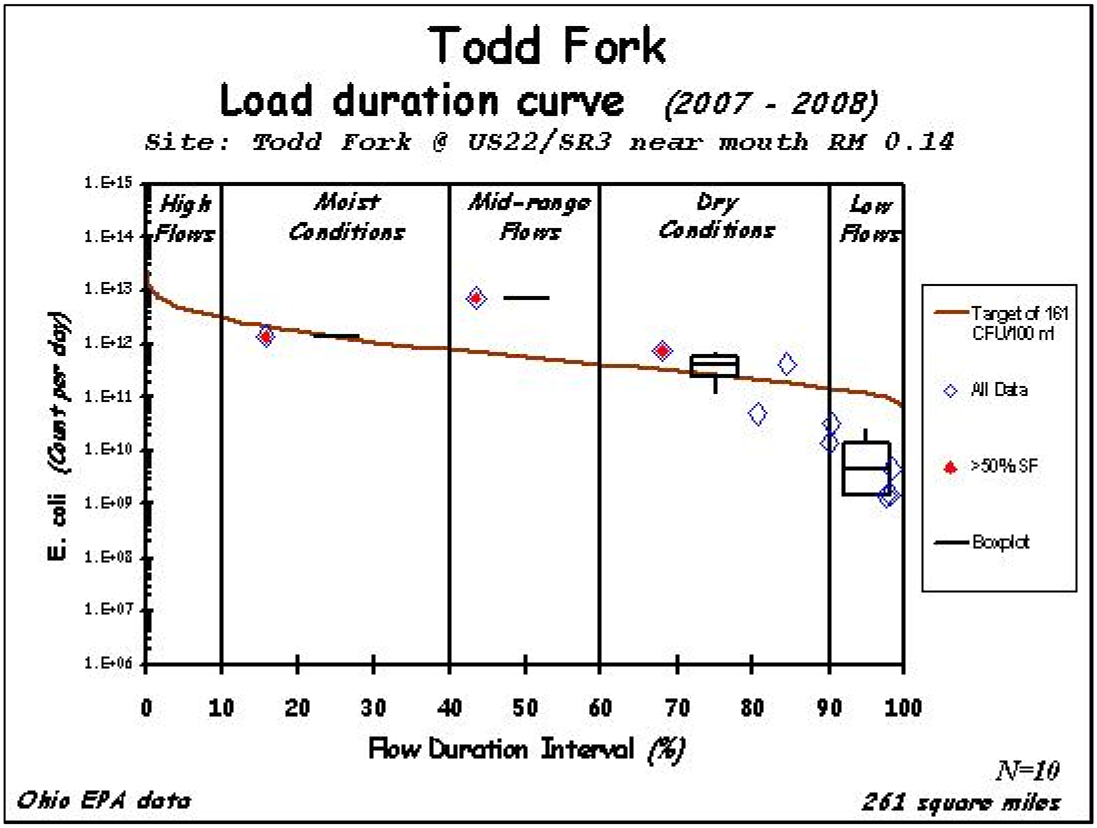


Figure 4.12 Load duration curve for the E coli bacteria TMDLs on Todd Fork (07 ten digit HUC).

Table 4.11 Bacteria existing loads and TMDL for Todd Fork at SR 22/3 (Morrow) RM 0.04 Units for *E. coli* concentrations are count/day.

Flow exceedance percentile	High Flows 0-10	Moist Conditions 10-40	Mid-Range Flows 40-60	Dry Conditions 60-90	Low Flows 90-100
Current Load (geometric mean)	No Data	1.43E+12	7.35E+12	2.55E+11	5.56E+09
TMDL= LA+WLA+MOS	4.63E+12	1.33E+12	5.72E+11	2.62E+11	1.21E+11
LA	4.07E+12	1.16E+12	4.85E+11	2.12E+11	8.73E+10
WLA: Wilmington WWTP	1.43E+10	1.43E+10	1.43E+10	1.43E+10	1.43E+10
WLA: Clarksville WWTP	4.29E+08	4.29E+08	4.29E+08	4.29E+08	4.29E+08
WLA: Caesar Creek Flea Market	4.77E+07	4.77E+07	4.77E+07	4.77E+07	4.77E+07
WLA: Thousand Trails Inc Wilmington Preserve WWTP	5.72E+07	5.72E+07	5.72E+07	5.72E+07	5.72E+07
WLA: Martinsville-Midland WWTP	7.25E+08	7.25E+08	7.25E+08	7.25E+08	7.25E+08
WLA: Blanchester WWTP	4.72E+09	4.72E+09	4.72E+09	4.72E+09	4.72E+09
WLA: Joy Outdoor Education Center	5.72E+07	5.72E+07	5.72E+07	5.72E+07	5.72E+07
WLA: MS4 Wilmington	7.42E+10	2.11E+10	8.83E+09	3.86E+09	1.59E+09
MOS (10%)	4.63E+11	1.33E+11	5.72E+10	2.62E+10	1.21E+10
TMDL Reduction (%)	No Data	7.01%	92.22%	0%	0%

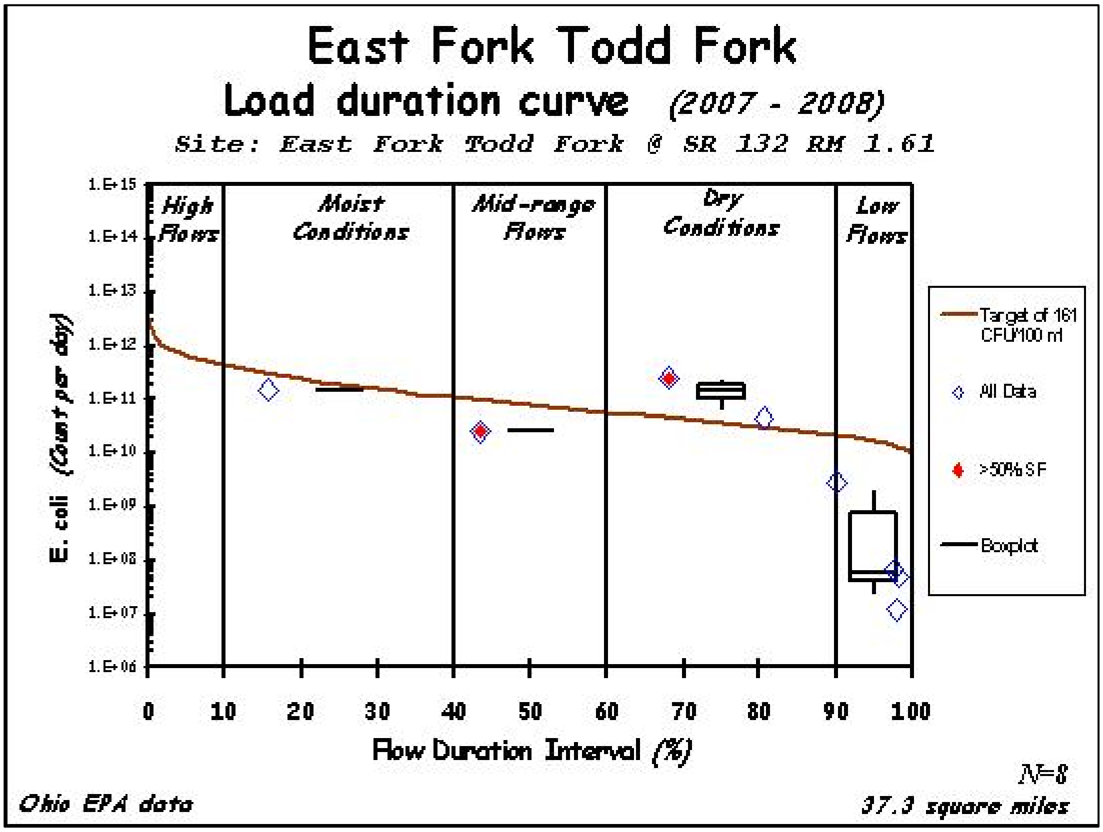


Figure 4.13 Load duration curve for the E coli bacteria TMDLs on EAST Fork Todd Fork (07 ten digit HUC).

Table 4.12 Bacteria existing loads and TMDL for East Fork Todd Fork at SR 132 (Clarksville) RM 1.6 Units for *E. coli* concentrations are count/day.

Flow exceedance percentile	High Flows 0-10	Moist Conditions 10-40	Mid-Range Flows 40-60	Dry Conditions 60-90	Low Flows 90-100
Current Load (geometric mean)	No Data	1.5E+11	2.57E+10	1.08E+11	1.04E+08
TMDL= LA+WLA+MOS	6.62E+11	1.91E+11	8.17E+10	3.75E+10	1.73E+10
LA	5.95E+11	1.71E+11	7.28E+10	3.30E+10	1.49E+10
WLA: Martinsville-Midland WWTP	7.25E+08	7.25E+08	7.25E+08	7.25E+08	7.25E+08
MOS (10%)	6.62E+10	1.91E+10	8.17E+09	3.75E+09	1.73E+09
TMDL Reduction (%)	No Data	0%	0%	65.26%	0%

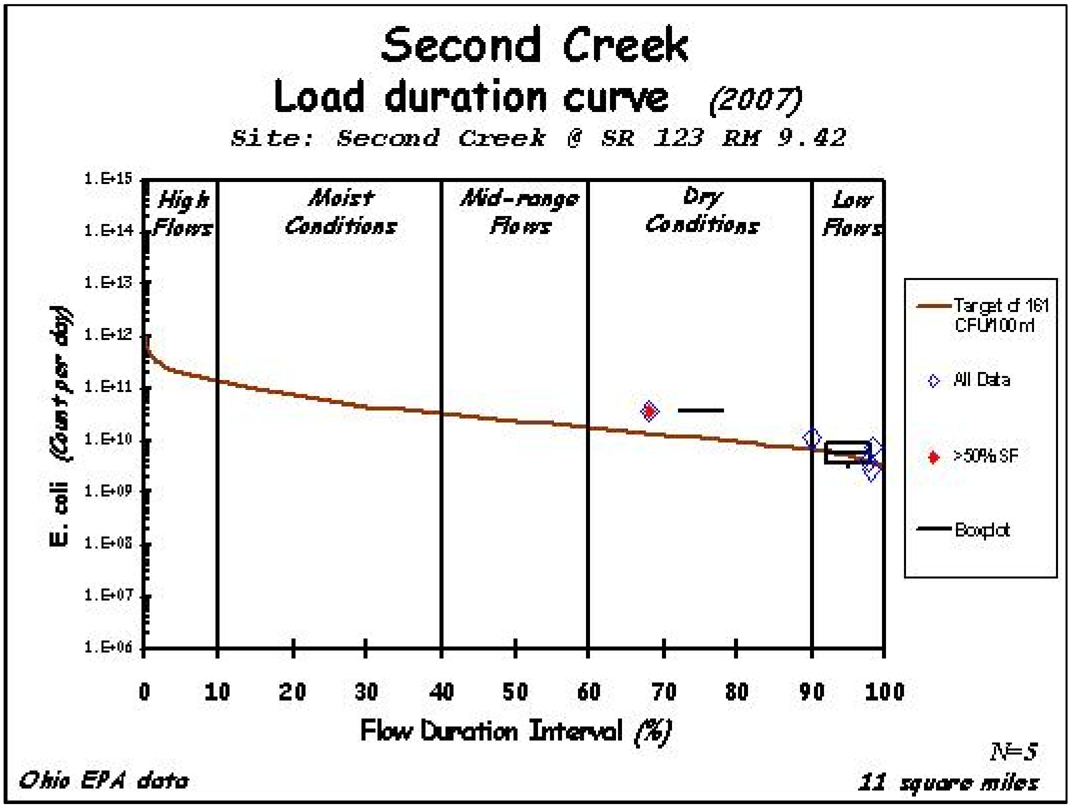


Figure 4.14 Load duration curve for the E coli bacteria TMDLs on Second Creek (07 ten digit HUC).

Table 4.13 Bacteria existing loads and TMDL for Second Creek at SR 123 (Dst Blanchester WWTP) RM 9.45. Units for *E. coli* concentrations are count/day.

Flow exceedance percentile	High Flows 0-10	Moist Conditions 10-40	Mid-Range Flows 40-60	Dry Conditions 60-90	Low Flows 90-100
Current Load (geometric mean)	No Data	No Data	No Data	3.70E+10	5.44E+09
TMDL= LA+WLA+MOS	1.95E+11	5.62E+10	2.41E+10	1.11E+10	5.19E+09
LA	1.71E+11	4.58E+10	1.70E+10	5.23E+09	0
WLA: Blanchester	4.72E+09	4.72E+09	4.722E+09	4.72E+09	4.722E+09
MOS (10%)	1.95E+10	5.62E+09	2.41E+09	1.11E+09	5.19E+08
TMDL Reduction (%)	No Data	No Data	No Data	70.14%	4.60%

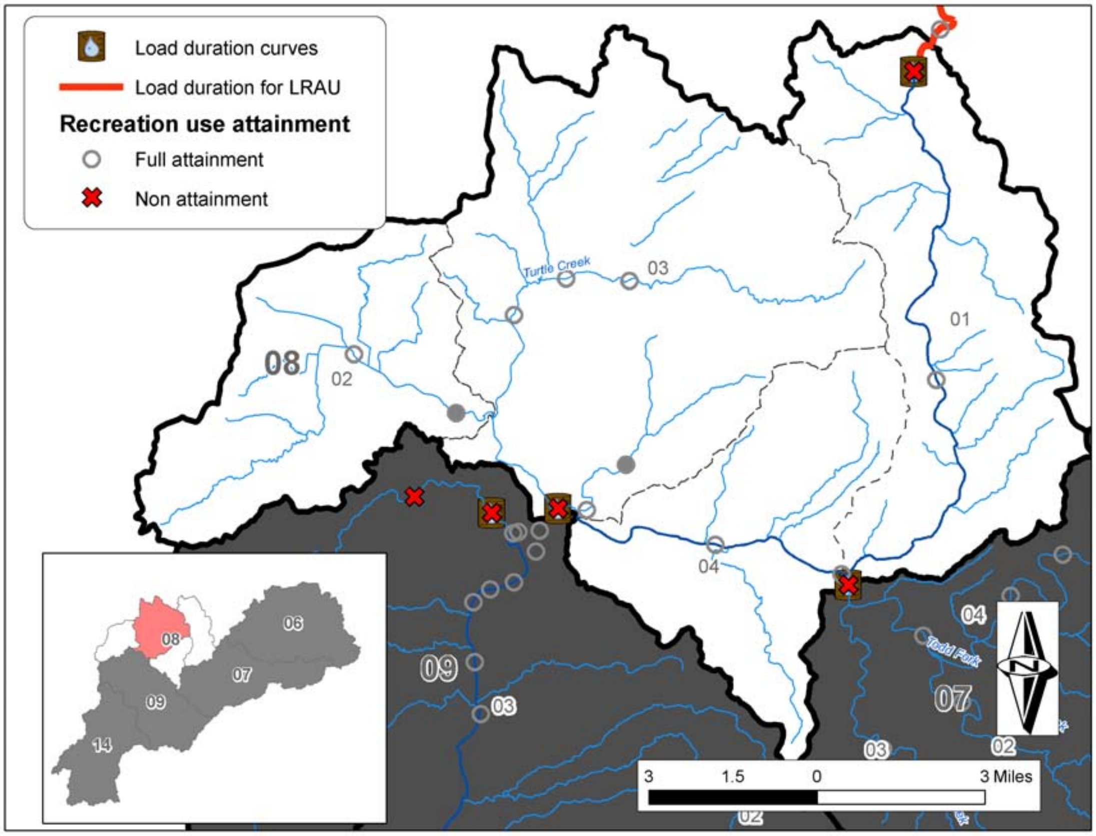


Figure 4.15 Map of recreation use impairments and location of LDC for E coli in the 08 ten digit HUC.

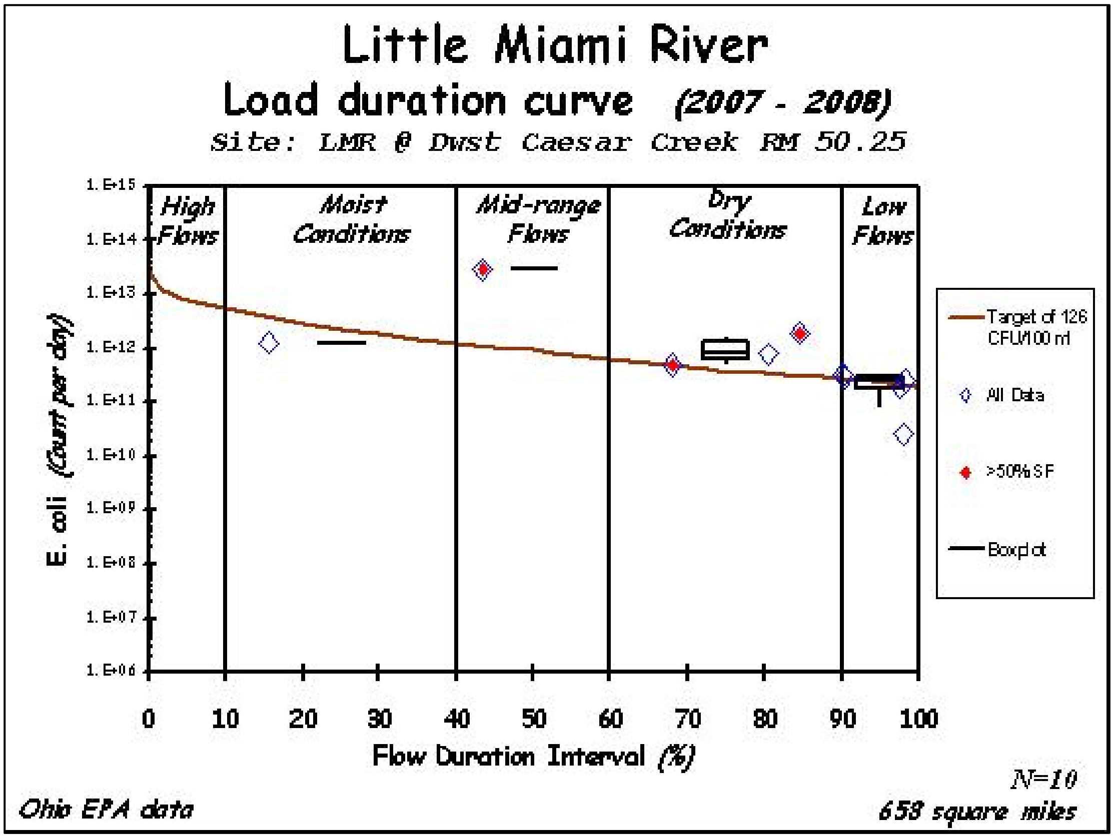


Figure 4.16 Load duration curve for the E coli bacteria TMDLs on Little Miami River (9002 large river assessment unit).

Table 4.14 Bacteria existing loads and TMDL for Little Miami River downstream of Caesar Creek (Shaw property) RM 50.25 Values in *E. coli* count/day

Flow exceedance percentile	High Flows 0-10	Moist Conditions 10-40	Mid-Range Flows 40-60	Dry Conditions 60-90	Low Flows 90-100
Current Load (geometric mean)	No Data	1.29E+12	2.87E+13	9.18E+11	1.63E+11
TMDL= LA+WLA+MOS	7.96E+12	2.23E+12	9.12E+11	3.75E+11	2.39E+11
LA	6.19E+12	1.81E+12	6.17E+11	1.34E+11	1.19E+10
WLA: WWTP See Table X.4 for details	2.03E+11	2.03E+11	2.03E+11	2.03E+11	2.03E+11
WLA: MS4 Springfield	1.26E+10	3.26E+09	1.11E+09	2.41E+08	2.16E+07
WLA: MS4 Dayton	7.56E+11	1.96E+11	6.70E+10	1.45E+10	1.30E+09
MOS (10%)	7.96E+11	2.23E+11	9.12E+10	3.75E+10	2.39E+10
TMDL Reduction (%)	No Data	0%	96.82%	59.18%	0%

Table 4.15 NPDES WWTPs and their TMDL WLA for Little Miami River downstream of Caesar Creek (Shaw property) RM 50.25

NPDES Facility	NPDES #	WLA at all flows
South Charleston WWTP	1PB00028	1.14E+09
Reid Primary Middle School	1PT00120	5.72E+07
Clifton WWTP	1PA00023	1.38E+08
Yellow Springs WWTP	1PC00013	2.86E+09
Cedarville WWTP	1PB00006	2.67E+09
Eastern Regional Water Reclamation Facility	1PL00001	6.20E+10
Beavercreek WRRF	1PK00003	4.05E+10
Xenia Ford Road WWTP	1PD00015	1.72E+10
East Clinton High School	1PT00085	4.77E+07
Budget Inn	1PX00054	1.18E+08
Pilot Travel Centers LLC No 016	1PZ00019	2.62E+07
McDonalds Restaurant	1PZ00041	4.77E+07
Roberts Development Commerce Park WWTP	1PZ00113	2.38E+09
Total		2.03E+11

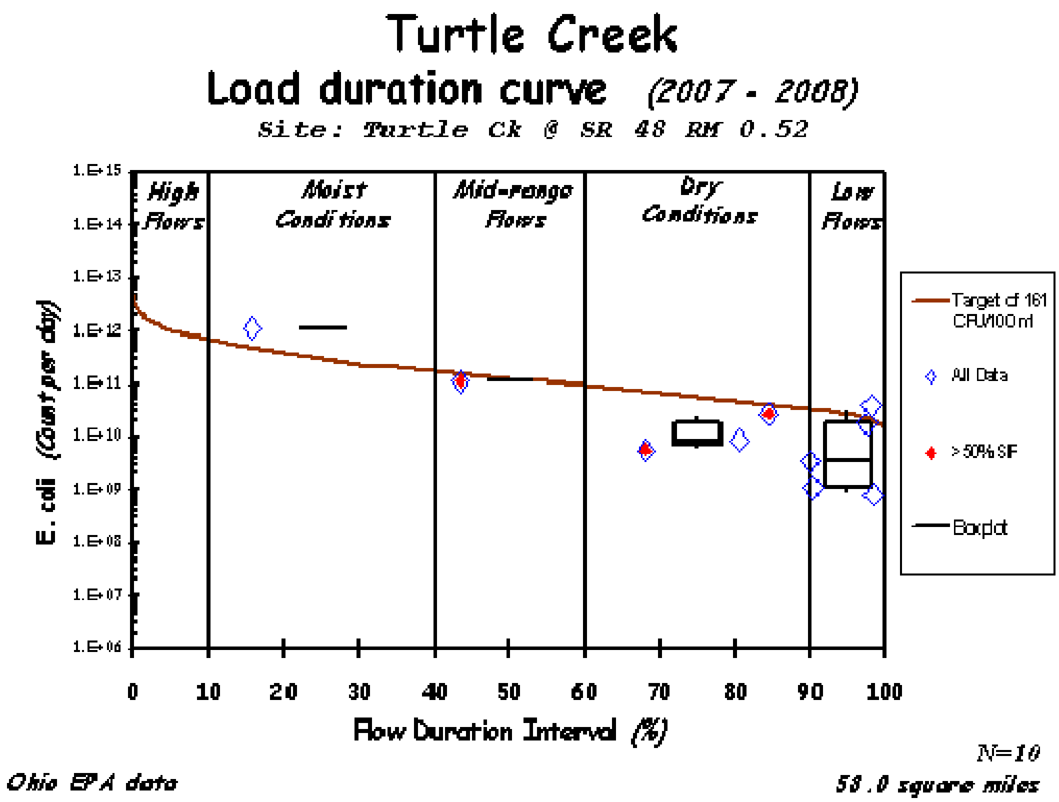


Figure 4.17 Load duration curve for the E coli bacteria TMDLs on Turtle Creek at SR 48 RM 0.52 (08 ten digit HUC).

Table 4.16 Bacteria existing loads and TMDL for Turtle Creek at SR 48 RM 0.52
Units for E. coli concentrations are count/day.

Flow exceedance percentile	High Flows 0-10	Moist Conditions 10-40	Mid-Range Flows 40-60	Dry Conditions 60-90	Low Flows 90-100
Current Load (geometric mean)	No Data	1.15E+12	1.08E+11	1.09E+10	4.63E+09
TMDL= LA+WLA+MOS	1.03E+12	2.96E+11	1.27E+11	5.83E+10	2.70E+10
LA	6.98E+11	1.99E+11	8.43E+10	3.76E+10	1.63E+10
WLA: Mason WWTP No 2 (outfall 002)	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09
WLA: Shadow Lake Village MHP	2.62E+08	2.62E+08	2.62E+08	2.62E+08	2.62E+08
WLA: Combs Inc Country Kitchen WWTP	9.54E+07	9.54E+07	9.54E+07	9.54E+07	9.54E+07
WLA: Warren Co Career Center	1.19E+08	1.19E+08	1.19E+08	1.19E+08	1.19E+08
ODOT Rest Area 08-38	1.91E+08	1.91E+08	1.91E+08	1.91E+08	1.91E+08
WLA: MS4 Wilmington	8.85E+10	2.53E+10	1.07E+10	4.77E+09	2.07E+09
WLA: MS4 Cincinnati	1.38E+11	3.93E+10	1.66E+10	7.42E+09	3.22E+09
MOS (10%)	1.03E+11	2.96E+10	1.27E+10	5.83E+09	2.70E+09
TMDL Reduction (%)	No Data	74.26%	0%	0%	0%

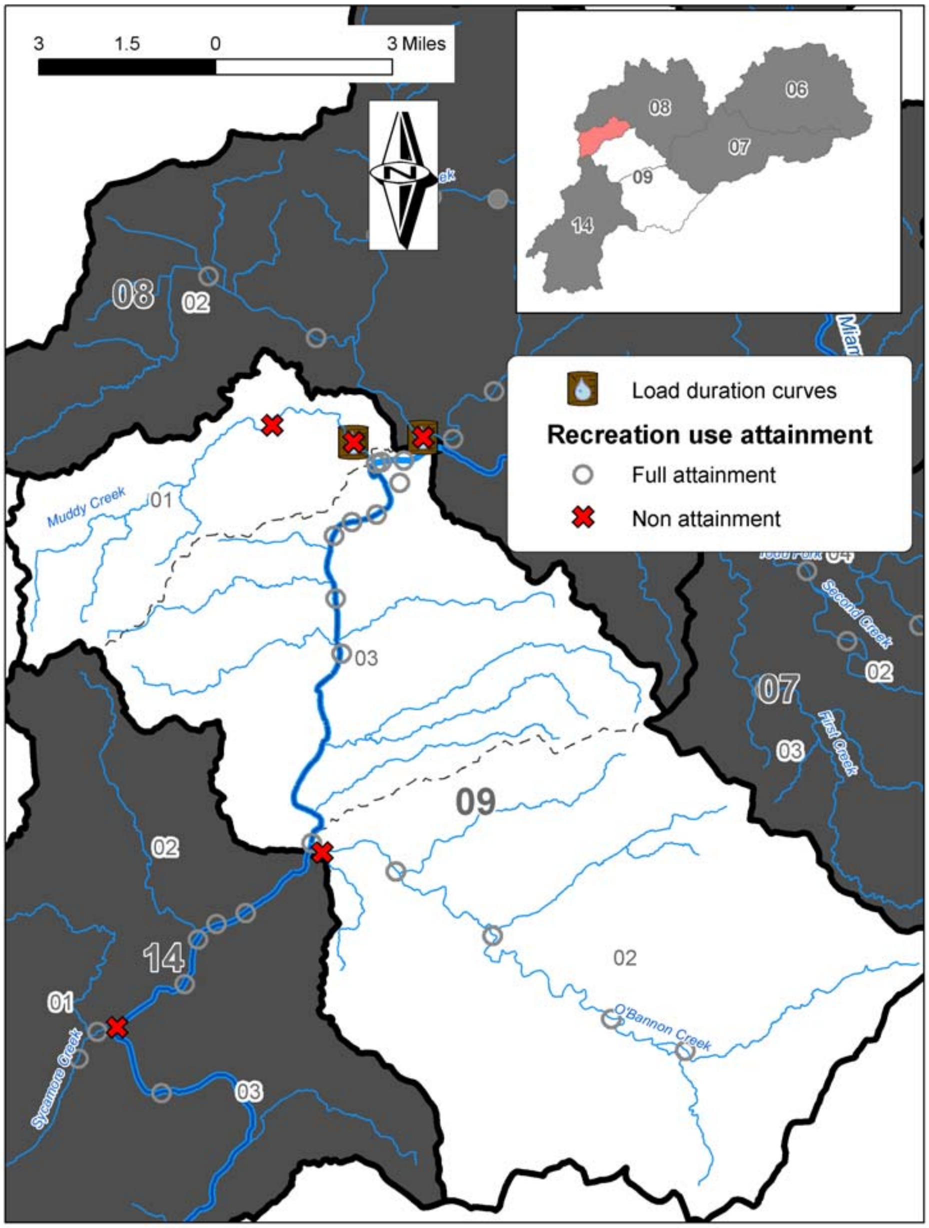


Figure 4.17 Map of recreation use impairments and location of LDC for E coli in the 09 ten digit HUC.

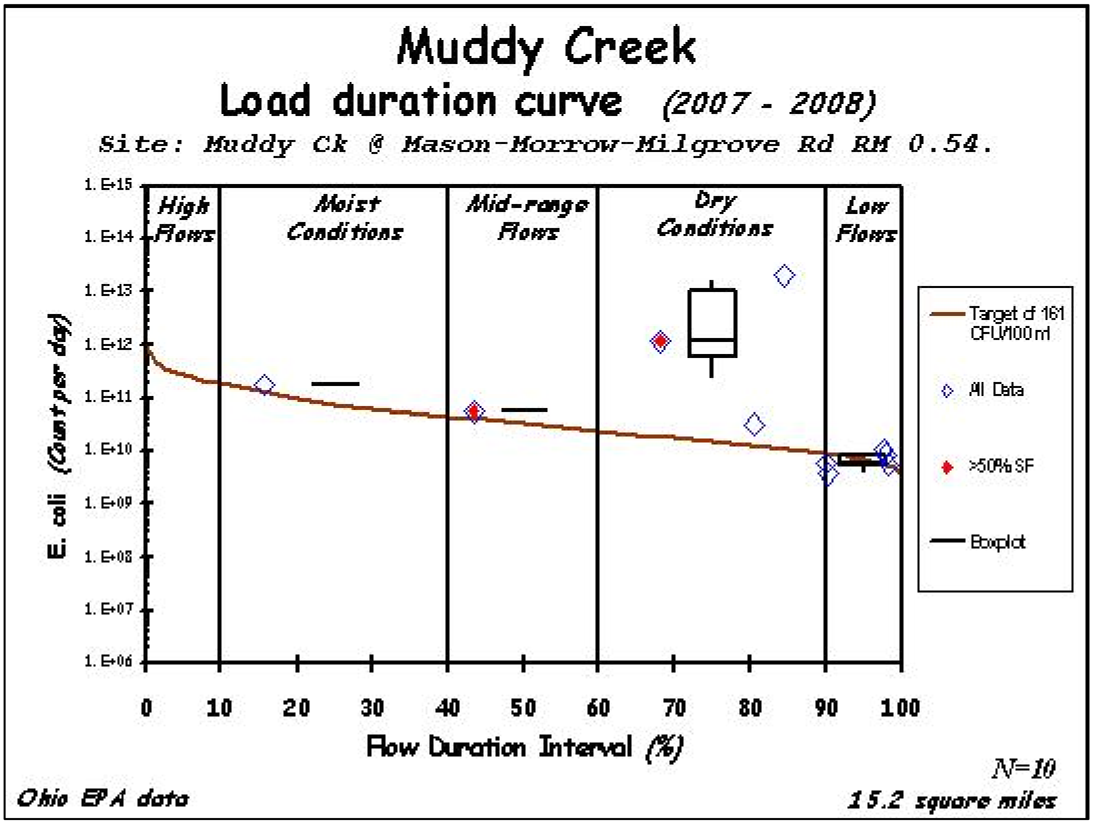


Figure 4.18 Load duration curve for the E coli bacteria TMDLs on Muddy Creek (09 ten digit HUC).

Table 4.17 Bacteria existing loads and TMDL for Muddy Creek at Mason-Morrow Rd (Dst Mason WWTP) RM 0.54. Units for E. coli concentrations are count/day.

Flow exceedance percentile	High Flows 0-10	Moist Conditions 10-40	Mid-Range Flows 40-60	Dry Conditions 60-90	Low Flows 90-100
Current Load (geometric mean)	No Data	1.76E+11	5.6E+10	9.14E+11	6.47E+09
TMDL= LA+WLA+MOS	2.70E+11	7.76E+10	6.82E+10*	6.82E+10*	6.82E+10*
LA	5.42E+10	2.36E+09	0	0	0
WLA: Mason WWTP No 2 (outfall 001)	6.20E+10	6.20E+10	6.20E+10	6.20E+10	6.20E+10
WLA: MS4 Cincinnati	1.27E+11	5.51E+09	0	0	0
MOS (10%)	2.70E+10	7.76E+09	6.20E+09	6.20E+09	6.20E+09
TMDL Reduction (%)	No Data	55.95%	0%	92.54%	0%

* The TMDL in this category is greater than calculated for the LDC because the curve reflects current flows, and the TMDL include flows from future expansion of NPDES waste water treatment plants (permitted design flows).

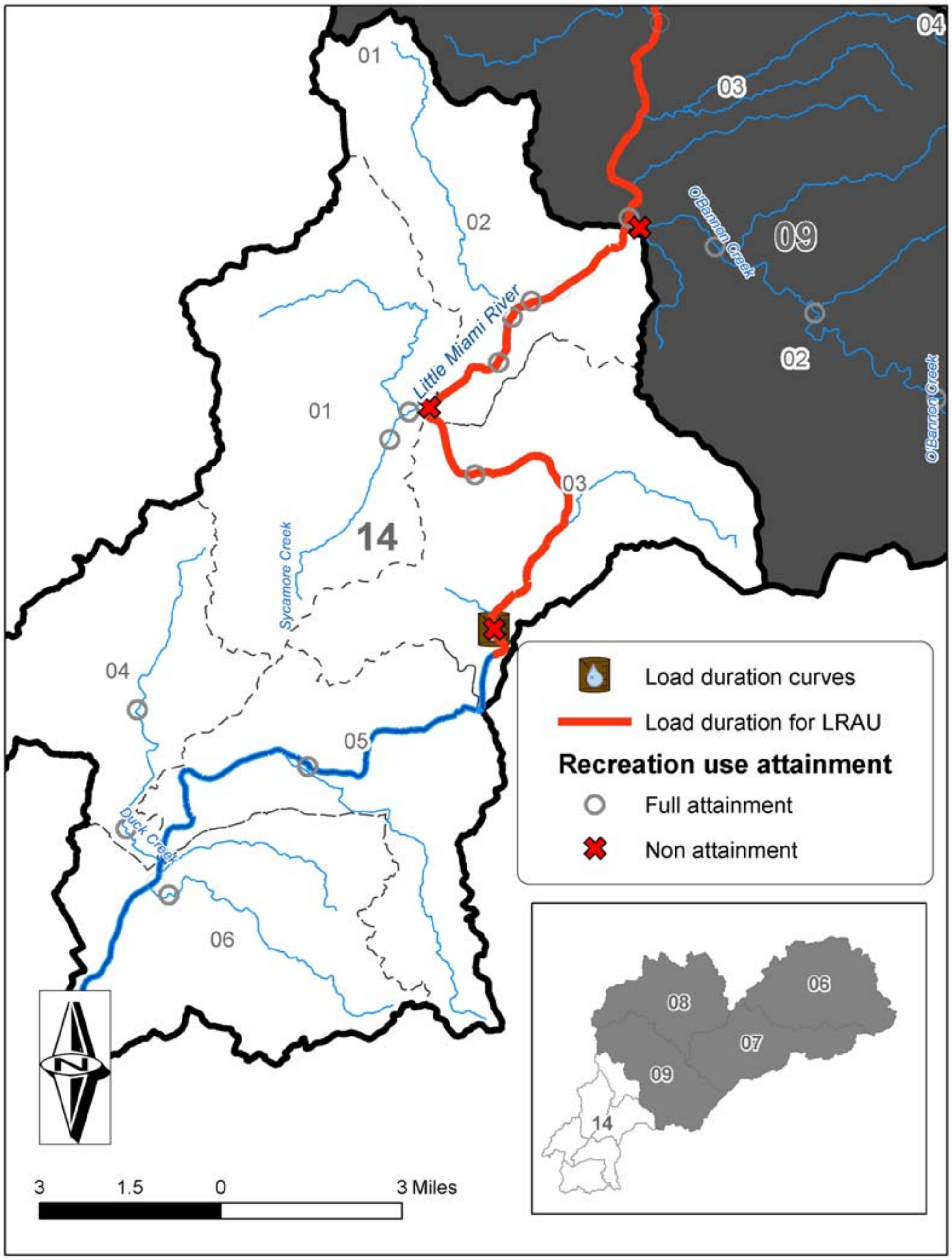


Figure 4.19 Map of recreation use impairments and location of LDC for E coli in the 14 ten digit HUC covering the 9001 large river assessment unit.

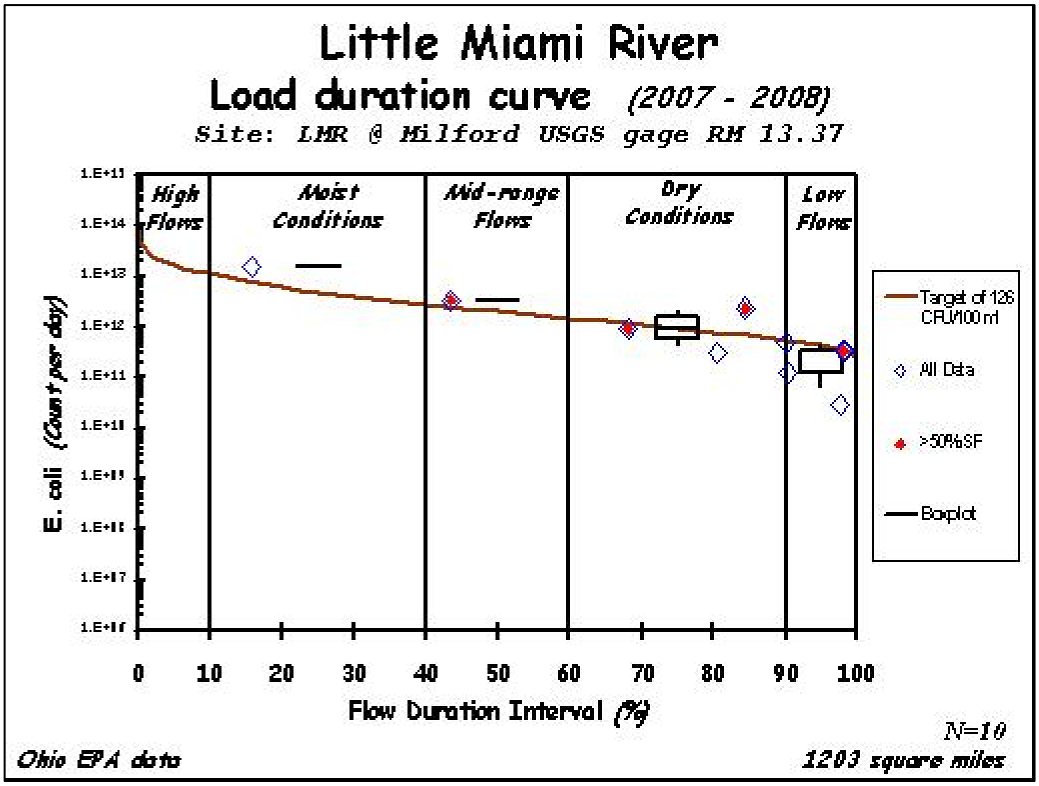


Figure 4.20 Load duration curve for the E coli bacteria TMDLs on Little Miami River (9001 large river assessment unit).

Table 4.18 Bacteria existing loads and TMDL for Little Miami River downstream Wooster Pike (Milford gage) RM 13.07. Units for E. coli concentrations are count/day.

Flow exceedance percentile	High Flows 0-10	Moist Conditions 10-40	Mid-Range Flows 40-60	Dry Conditions 60-90	Low Flows 90-100
Current Load (geometric mean)	No Data	1.54E+13	3.35E+12	8.93E+11	1.84E+11
TMDL= LA+WLA+MOS	1.67E+13	4.81E+12	2.06E+12	9.46E+11	6.15E+11*
LA	1.22E+13	3.19E+12	1.10E+12	2.48E+11	0
WLA: WWTP See Table X.6 for details	5.59E+11	5.59E+11	5.59E+11	5.59E+11	5.59E+11
WLA :MS4 Springfield	1.43E+10	3.72E+09	1.28E+09	2.89E+08	0
WLA: MS4 Dayton	8.60E+11	2.24E+11	7.70E+10	1.74E+10	0
WLA: MS4 Wilmington	5.61E+10	1.46E+10	5.03E+09	1.14E+09	0
WLA: MS4 Cincinnati	1.20E+12	3.11E+11	1.07E+11	2.42E+10	0
WLA: MS4 Lebanon	1.04E+11	2.71E+10	9.32E+09	2.10E+09	0
MOS (10%)	1.67E+12	4.81E+11	2.06E+11	9.46E+10	5.59E+10
TMDL Reduction (%)	No Data	68.80%	38.40%	0%	0%

* The TMDL in this category is greater than calculated for the LDC because the curve reflects current flows, and the TMDL include flows from future expansion of waste water treatment plants (permitted design flows).

Table 4.19 NPDES WWTPs and their TMDL WLA for Little Miami River downstream Wooster Pike (Milford gage) RM 13.07

NPDES Facility	NPDES #	WLA at all flows	NPDES Facility	NPDES #	WLA at all flows
South Charleston WWTP	1PB00028001	1.14E+09	Camp Swoneky	1PX00055001	1.67E+08
Reid Primary Middle School	1PT00120001	5.72E+07	Mason WWTP No 2	1PC00004002	2.00E+09
Clifton WWTP	1PA00023001	1.38E+08	Shadow Lake Village MHP	1PV00040001	2.62E+08
Yellow Springs WWTP	1PC00013001	2.86E+09	Combs Inc Country Kitchen WWTP	1PR00049001	9.54E+07
Cedarville WWTP	1PB00006001	2.67E+09	Warren Co Career Center	1PT00071001	1.19E+08
Eastern Regional Water Reclamation Facility	1PL00001001	6.20E+10	ODOT Rest Area 08-38	1PZ00073001	1.91E+08
Beavercreek WRRF	1PK00003001	4.05E+10	Joy Acres MHP	1PV00049001	1.67E+08
Xenia Ford Road WWTP	1PD00015001	1.72E+10	Mason WWTP No 2	1PC00004001	6.20E+10
East Clinton High School	1PT00085001	4.77E+07	Dale Acres WWTP	1PG00096001	7.15E+07
Budget Inn	1PX00054001	1.18E+08	O'Bannon Creek Regional WWTP	1PK00017001	2.10E+10
Pilot Travel Centers LLC No 016	1PZ00019001	2.62E+07	MidWestern Childrens Home	1PT00093001	7.63E+07
McDonalds Restaurant	1PZ00041001	4.77E+07	Lebanon WWTP	1PC00003001	2.86E+10
Roberts Development Commerce Park WWTP	1PZ00113001	2.38E+09	Lower Little Miami WWTP	1PK00018001	6.94E+10
Jamestown STP	1PB00015001	4.29E+09	Sycamore Creek WWTP	1PK00005001	2.86E+10
Glady Run WWTP	1PD00016001	1.91E+10	Sycamore Creek WWTP	1PK00005002	2.86E+10
Waynesville WWTP	1PB00032001	3.39E+09	Sycamore Creek WWTP	1PK00005003	4.29E+10
Sugarcreek WRF	1PK00014001	4.72E+10	Wards Corner Regional WWTP	1PK00021001	9.54E+09
Caesar Lake MHP	1PV00114001	2.30E+08	Arrowhead Park WWTP	1PH00014001	6.68E+08
Wilmington WWTP	1PD00013001	1.43E+10	Polk Run WWTP	1PK00019001	3.82E+10
Clarksville WWTP	1PA00024001	4.29E+08	Miami Trails WWTP	1PW00023001	1.91E+09
Caesar Creek Flea Market	1PX00003001	4.77E+07	Indian Lookout WWTP	1PG00041001	2.15E+08
Thousand Trails Inc Wilmington Preserve WWTP	1PX00010001	5.72E+07	Bramblewood WWTP	1PG00067001	2.00E+08
Martinsville-Midland WWTP	1PH00031001	7.25E+08	Lake Remington MHP	1PV00101001	1.22E+08
Blanchester WWTP	1PB00003001	4.72E+09	Total	-	5.59E+11
Joy Outdoor Education Center	1PZ00045001	5.72E+07			

5 WATER QUALITY IMPROVEMENT STRATEGY

This section of the report discusses options for abating the water quality problems in the lower Little Miami River watershed and achieving the goals established earlier in this report. Namely, what will be discussed are options for meeting the pollutant reductions as well as making improvements to the stream system such as habitat improvements and increasing capacity to assimilate pollutant loads.

A series of tables list actions appropriate for abating the water quality stressors at specific locations in the basin. The recommended actions are well established practices with proven effectiveness. Details regarding these practices are included in Appendix C of this report. Additionally, Appendix C compiles various programs and organizations that can be sources for assistance in carrying out the recommended actions.

The actions recommended herein are not the only means for making the needed water quality improvements but rather highlight the more common approaches. Additionally, there is some redundancy in these recommendations because certain stressors can be addressed by a variety of approaches (e.g., both naturalizing watershed hydrology and stream restoration improve habitat quality). The abatement options were selected considering effectiveness coupled with efficiency. In other words more costly actions may produce similar or greater levels of improvement but this may go beyond the minimum level of abatement needed in addressing the stressors causing impairments. Additionally, good land management practices are applicable everywhere so not specifically recommending a management practice does not necessarily suggest that a given management practice is inappropriate in that location. Instead, the recommendations are made to prioritize watershed restoration activities and not merely list what is beneficial. A primary objective of these recommendations is to assist watershed planning and/or provide guidance regarding investments that are made to improve water quality.

Table 5.1 lists the actions that are to be taken through regulatory controls and authority. These are relegated to the Ohio EPA and deal with NPDES permitting and compliance. This table is used separately and placed first in this section because these actions have the highest assurances of being implemented. Table 5.2 provides a basin-wide perspective on the general types of practices needed for each of the assessment areas (including the regulatory actions discussed in the first table). The subsequent tables provide more detail about the recommendations for each assessment area. A map of the assessment area with the subwatersheds delineated is shown before the table of recommendations.

5.1 Regulatory Measures for Abatement

This section summarizes recommendations from this TMDL that can be implemented using Ohio EPA's regulatory authority. This differs from other recommendations found in this plan regarding land management or other measures that currently have no associated regulations. The National Pollution Discharge Elimination System (NPDES) is the primary regulatory means for making improvements to restore water quality. Table 5.1 shows the recommendations for NPDES permit holders.

Table 5.1 NPDES permit limits for facilities in the lower Little Miami River watershed

Area of Assessment (last four HUC 12 digits)	**Facility name /** ***Ohio EPA permit number***	**Permit expiration date**	**Recommendation**
06 -03	Wilmington WWTP / **1PD00013**	7/31/2014	Weekly total phosphorus monitoring required
07 - 02	Blanchester WWTP / **1PB00003**	7/31/2010	Total phosphorus limit of 1.0 mg/l and monitoring required
06 - 03	ABX Air Inc / **1II00031**		Chemical oxygen demand limits of 637, 714, 262, and 106 mg / l for the respective time intervals: Nov. – Feb; Mar. – April; May; and June – Oct.

5.2 Recommended Actions

Table 5.2 in this section lists each impaired assessment unit and its constituent subwatersheds. The major cause/sources associations are listed (sources are listed with causes in parentheses) and an associated suite of potential abatement actions are marked. These abatement actions are grouped in general categories which are described in more detail in subsections for each assessment unit.

Table 5.2 Overview of the types of restoration actions that are recommended throughout the entire TMDL project area.

Water-shed	Coupled source/cause association	Bank & Riparian Restoration	Stream Restoration	Wetland Restoration	Conservation Easements	Home Sewage Planning and Improvement	Education and Outreach	Point Source Controls (Regulatory Programs)	Agricultural Best Management Practices
05090202 - 06 - Headwaters Todd Fork									
06-01 - Dutch Creek									
	Not impaired								
06-02 - Headwaters Todd Fork									
	Not impaired								
06-03 - Lytle Creek									
	HSTS, WWTP, SSOs, urban runoff, crop production (E coli)	x				x		x	x
	storm water discharge (nutrient/eutrophication biological indicators)							x	
	highways, storm water discharge (sedimentation/siltation)							x	
	storm water discharge, WWTP (organic enrichment (sewage) biological indicators)							x	
06-04 - Headwaters Cowan Creek									
	natural conditions (flow or habitat)								
	storm water discharge, channelization (nutrient/eutrophication biological indicators)							x	
	streambank erosion, (sedimentation/siltation)	x							
	storm water discharge (oxygen, dissolved)							x	
06-05 - Wilson Creek-Cowan Creek									
	natural conditions (flow or habitat)								
06-06 - Little Creek-Todd Fork									
	Not impaired								
05090202 - 07 - East Fork Todd Fork-Todd Fork									
07-01 - East Fork Todd Fork									
	urban runoff, crop production (E coli)								x

	natural conditions (flow or habitat)								
07-02 - Second Creek									
	WWTP, SSOs, crop production (E coli)			x				x	x
	crop production (nutrient/eutrophication biological indicators)	x		x					x
	crop production, SSOs (sedimentation/siltation)	x							x
	WWTP, SSOs (organic enrichment (sewage) biological indicators)							x	
	crop production (atrazine (public water supply)1)	x		x					x
07-03 - First Creek									
	impairment unknown								
07-04 Lick Run-Todd Fork									
	crop production (E coli)	x		x	x				x
05090202 - 08 - Turtle Creek-Little Miami River									
08-01 - Ferris Run-Little Miami River									
	Not impaired								
08-02 - Little Muddy Creek									
	channelization (sedimentation/siltation)	x	x						
08-03 - Turtle Creek									
	urban runoff, crop production (E coli)	x		x	x				x
	natural conditions (flow or habitat)								
08-04 - Halls Creek-Little Miami River									
	Not impaired								
05090202 - 09 - O'Bannon Creek-Little Miami River									
09-01 - Muddy Creek									
	WWTP, urban runoff (E coli)							x	
	natural conditions (flow or habitat)								
	WWTP (nutrient/eutrophication biological indicators)							x	
	WWTP (organic enrichment (sewage) biological indicators)							x	
	WWTP (sedimentation/siltation)							x	
09-02 - O'Bannon Creek									
	natural conditions (flow or habitat)								
09-03 - Salt Run-Little Miami River									

	Not impaired								
05090202 - 14 - Sycamore Creek-Little Miami River									
14-01 - Sycamore Creek									
	urban runoff (organic enrichment (sewage) biological indicators)							x	
14-02 - Polk Run-Little Miami River									
	unknown toxicity							x	
	siltation							x	
	organic enrichment/DO							x	
	flow alteration							x	
	direct habitat alterations							x	
14-03 - Horner Run-Little Miami River									
	unknown toxicity							x	
	siltation							x	
	organic enrichment/DO							x	
	flow alteration							x	
	direct habitat alterations							x	
14-04 - Duck Creek									
	channelization (direct habitat alterations)								
	CSOs, urban runoff (organic enrichment (sewage) biological indicators)							x	
	CSOs, urban runoff (sedimentation/siltation)							x	
14-05 - Dry Run-Little Miami River									
	unknown toxicity							x	
	siltation							x	
	flow alteration							x	
	direct habitat alterations							x	
	organic enrichment/DO							x	
14-06 - Clough Creek-Little Miami River									
	CSOs, urban runoff (sedimentation/siltation)							x	

5.2.1 Headwaters Todd Fork (05090202 – 06)

In terms of aquatic life uses the 06 ten-digit HUC watershed demonstrates the most impairment with a total of eight out of thirteen (61 percent) sites not fully meeting the biological criteria. It is Lytle and Cowan Creeks and Indian Run that are impaired (12 digit HUCs – 03, 04, and 05). Nutrient enrichment and organic chemicals are mostly responsible for stressing the aquatic communities leading to low dissolved oxygen and/or wide swings in its concentration. Primary sources of the pollutants are inadequately treated storm water and waste water from the ABX airpark and Wilmington's WWTP respectively. Other human sources include runoff and drainage from cropland where dissolved and particulate forms of phosphorus are being transported to streams. Three of the eight impaired sites were impacted primarily due to low flow conditions resulting from the below average rainfall that occurred the year of the survey.

Implementation will focus on addressing the storm water pollutant loading from the ABX airpark facility. Communications have been made between Ohio EPA and airpark officials regarding monitoring and treatment protocols that will ensure that dissolved oxygen issues will no longer impair aquatic communities in Lytle, Indian, and Cowan Creeks. It is recommended that the Wilmington WWTP treat total phosphorus to a monthly average effluent concentration of 1.0 mg/l. This will abate low oxygen concentration during summer low flow conditions and reduce an over-abundance of plant growth which causes a shift in the biological community away from a diverse assemblage that includes high quality, pollution sensitive species.

The concentration limits for the ABX storm water treatment facilities (Table 4.4) are protective of aquatic life use degradation during low flow periods. Current permit limits are acceptable for higher (runoff period) stream flows. Using the same D.O. model described here, Ohio EPA modeling staff is able to provide a flow cut-off at which the existing higher effluent limits are acceptable. Based on this work, the existing COD limits for both treatment facilities are recommended when flows in Cowan Creek upstream of Indian Run are at or exceed 7.1 cfs.

Nonpoint source of nutrients and sediment would be abated with additional stream-side buffering. There are small, first and second order streams passing through cropland that have little in the way of buffers. Buffers consisting of native grasses or trees are recommended to abate overland transport of sediment and nutrients and increase infiltration capacity due to the deep root structure associated with these types of vegetation. The lack of buffering is most apparent along tributaries to the southeast of Wilmington entering Lytle Creek at river miles 8.8 and 9.4.

Other field based management practices that minimize surface erosion, sequester nutrients, and promote more infiltration are recommended such as cover cropping and conservation tillage. Use of controlled drainage would likely abate some nutrient loading during the non-growing season, particularly the dissolved portion. Controlled drainage may also augment low flows during the dry summer periods if the systems are managed appropriately. Soil slopes and drainage classifications seem consistent with basic criteria for applying drainage water management through the use of controlled drainage structures (that is, low slopes and an indicated need for drainage based on the soil drainage classification).

Ohio EPA is unaware of a plan to address home septic system failures in this part of the watershed. Almost the entire ten-digit HUC is located in Clinton County and currently there are no county-wide plans posted on their website. However, failing septic systems are likely a source of bacteria leading to the impairment of recreation uses as well as pollutants that further add stress on the biological communities. Furthermore, estimated load reductions needed to meet the TMDLs are very large (well over 90%) and apply to the mid range to low flow conditions. This provides an indication that HSTS discharges are occurring through direct connections to the streams. Planning and inspection of private HSTS is recommended as well as public education and information sharing regarding proper maintenance of these systems.

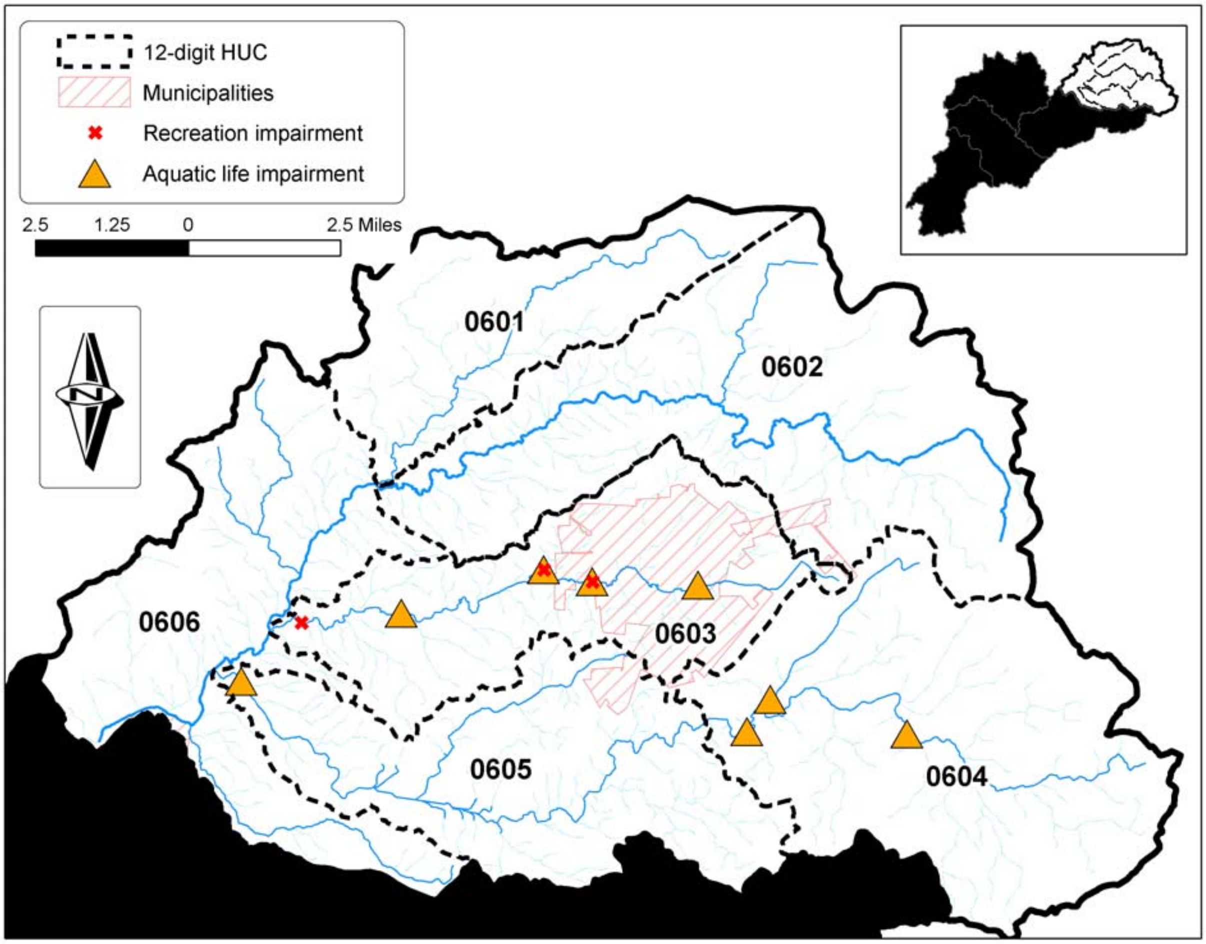


Figure 5.1 Map of the 06 ten-digit HUC with sites impaired for recreation and aquatic life uses and the respective 12-digit HUCs are shown.

Table 5.3 Restoration and abatement actions recommended for the 06 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	05090202-06	
			03	04
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering		
		Restore streambank by recontouring or regrading		
	planted	Plant grasses in riparian areas		
		Plant prairie grasses in riparian areas	x	

Restoration Categories		Specific Restoration Actions	05090202-06 03	05090202-06 04
		Remove/treat invasive species		
		Plant trees or shrubs in riparian areas	x	
Home Sewage Planning and Improvement		Develop HSTS plan	x	
		Inspect HSTS	x	
		Repair or replace traditional HSTS	x	
		Repair or replace alternative HSTS	x	
Point Source Controls (Regulatory Programs)	collection and new treatment	Install sewer systems in communities		
		Develop and/or implement long-term control plan (CSOs)		
		Eliminate SSOs/CSOs/by-passes		
	storm water	Implement an MS4 permit		
		Implement an industrial permit	x	x
		Implement a construction permit		
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)	x	
		Improve quality of effluent	x	
	monitoring	Establish ambient monitoring program		
		Increase effluent monitoring		
	alternatives	Establish water quality trading		
Agricultural Best Mgt Practices	farmland	Plant cover/manure crops	x	
		Implement conservation tillage practices	x	
		Implement grass/legume rotations	X	
		Convert to permanent hayland		

Restoration Categories		Specific Restoration Actions	05090202-06	
			03	04
		Install grassed waterways		
		Install vegetated buffer strips		
		Install / restore wetlands	x	
	nutrients / agro-chemicals	Conduct soil testing	x	
		Install nitrogen reduction practices	x	
		Develop nutrient management plans	x	
	drainage	Install sinkhole stabilization structures		
		Install controlled drainage system	x	
		Implement drainage water management	x	
		Construct overwide ditch		
		Construct 2-stage channel		

5.2.2 East Fork Todd Fork-Todd Fork (05090202 – 07)

In this watershed six out of sixteen sites (37.5 percent) do not fully meet the biological criteria for aquatic life uses. First Creek is affected by an unknown source and Second Creek is impacted by human activities (12 digit HUCs –04 and 03 respectively). East Fork of Todd Fork (three impaired sites) did not meet biological criteria due to low stream flow. Nutrient enrichment and organic chemicals are mostly responsible for stressing the aquatic communities leading to low dissolved oxygen and/or wide swings in its concentration.

Primary sources of the pollutants are inadequately treated waste water from the Blanchester's WWTP so an average monthly effluent concentration of 1.0 mg/l for total phosphorus is recommended. Additionally, Blanchester has received financial assistance through an American Recovery and Reinvestment Act (ARRA) grant and a low interest loan through the Water Pollution Control Loan Fund (WPCLF). These funds will offset costs incurred in the construction of a pump station and equalization basin for the city's water collection and treatment system. These improvements will abate bypass flows and sewer overflows of untreated sewage when the system is overburdened by storm water.

Other human sources of nutrients and organic materials include runoff and drainage from cropland where dissolved and particulate forms of phosphorus are being transported to streams.

Agriculture is by far the dominant land use in the 6.8 square mile area that drains to the uppermost impaired site on Second Creek (at river mile 10.94). There are few buffers along the small tributaries therefore native grasses and tree plantings should be considered in these riparian areas. Typical cool season grasses could also have a mitigating effect on pollutants leaving the fields in surface or shallow sub-surface flows. Cover cropping and conservation tillage are recommended to both sequester residual nutrients in the soil as well as reduce the potential for surface erosion and improve soil tilth. Wetlands would likely benefit stream quality by receiving and processing nutrient rich runoff and supplying slower sub-surface flow paths that may augment low flows in dry periods, providing both better flow and pollutant dilution. There are nearly one thousand acres classified as all hydric (meaning soils that were formerly wetlands) in this drainage area and the majority of the soils are either all or partially hydric. Controlled drainage is appropriate to reduce annual nutrient loading by retaining drainage water, at a minimum, during the non-growing season. More intense management of the drainage system could result in even higher annual nutrient reductions. The relatively flat slopes and the apparent wide-use of subsurface drainage in this area make this management practice a practical improvement to water quality.

Elevated bacteria on the East Fork of Todd Fork (12 digit HUC – 01) is likely emanating from poorly functioning home septic systems. This is based on the presence of several homes that are not likely to be on central sewers and the fact that no other significant sources of enteric bacteria are apparent in the vicinity. It is recommended that homes in this area of Clinton County be inspected and problems addressed appropriately. Homes and businesses in the Village of Butlerville were inspected in the spring of 2009 by staff from the Warren County Health Department and they found some indication of illicit connections between septic systems and the village's storm water system. Aquatic life was impaired at a sampling location on First Creek approximately two river miles down from Butlerville; however, recreation uses were not found to be impaired. Recreation uses were impaired down from Blanchester; however, improvements in the sewage collection and treatment system will likely abate these water quality problems.

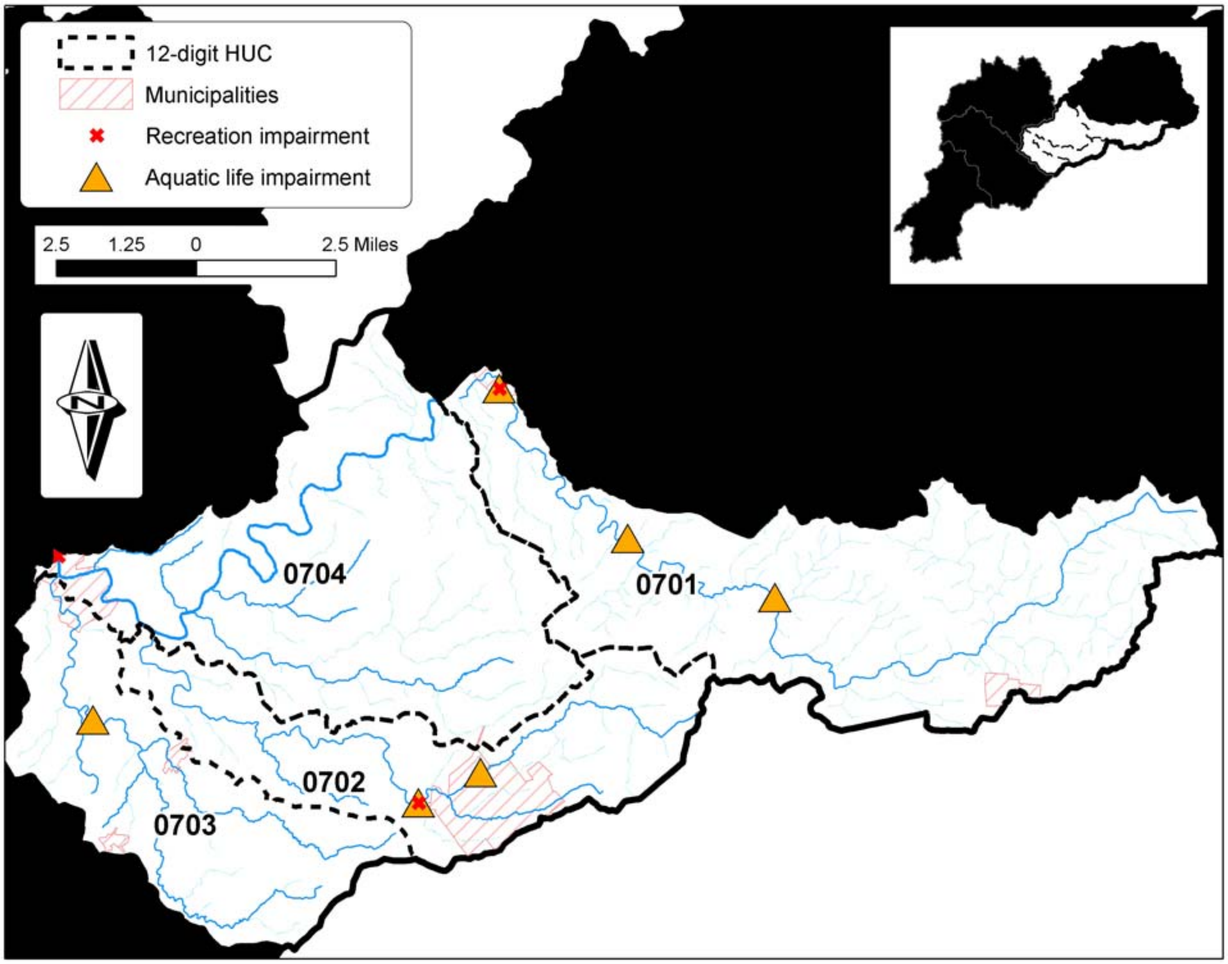


Figure 5.2 Map of the 07 ten-digit HUC with sites impaired for recreation and aquatic life uses and the respective 12-digit HUCs are shown.

Table 5.4 Restoration and abatement actions recommended for the 07 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	05090202-07		
			01	02	04
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering			
		Restore streambank by recontouring or regrading			
	planted	Plant grasses in riparian areas		x	
		Plant prairie grasses in riparian areas		x	
		Remove/treat invasive species			
		Plant trees or shrubs in riparian areas		x	x

Restoration Categories		Specific Restoration Actions	05090202-07		
			01	02	04
Home Sewage Planning and Improvement		Develop HSTS plan			
		Inspect HSTS	x		
		Repair or replace traditional HSTS	x		
		Repair or replace alternative HSTS	x		
Storm Water Best Mgt Practices	quantity controls	Post-construction BMPs: innovative BMPs			
		Post-construction BMPs: infiltration	x		x
		Post-construction BMPs: retention/detention	x		x
	quality controls	Post-construction BMPs: filtration	x		x
		Construction BMPs: erosion control			
		Construction BMPs: runoff control			
		Construction BMPs: sediment control			
Point Source Controls (Regulatory Programs)	collection and new treatment	Install sewer systems in communities			
		Develop and/or implement long-term control plan (CSOs)			
		Eliminate SSOs/CSOs/by-passes		x	
	storm water	Implement an MS4 permit			
		Implement an industrial permit			
		Implement a construction permit			
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)		x	
		Improve quality of effluent		x	
	monitoring	Establish ambient monitoring program			
		Increase effluent monitoring			

Restoration Categories		Specific Restoration Actions	05090202-07 01	05090202-07 02	05090202-07 04
	alternatives	Establish water quality trading			
Agricultural Best Mgt Practices	farmland	Plant cover/manure crops	x	x	x
		Implement conservation tillage practices	x	x	x
		Implement grass/legume rotations		x	
		Convert to permanent hayland		x	
		Install grassed waterways			
		Install vegetated buffer strips		x	
		Install / restore wetlands	x	x	x
	nutrients / agro-chemicals	Conduct soil testing		x	
		Install nitrogen reduction practices		x	
		Develop nutrient management plans		x	
	drainage	Install sinkhole stabilization structures			
		Install controlled drainage system		x	
		Implement drainage water management		x	
		Construct overwide ditch			
		Construct 2-stage channel			
	livestock	Implement prescribed & conservation grazing practices			
		Install livestock exclusion fencing			
		Install livestock crossings			
		Install alternative water supplies			
		Install livestock access lanes			

Restoration Categories		Specific Restoration Actions	05090202-07		
			01	02	04
	manure	Implement manure management practices			
		Construct animal waste storage structures			
		Implement manure transfer practices			
		Install grass manure spreading strips			
	misc. infra-structure and mgt	Install chemical mixing pads			
		Install heavy use feeding pads			
		Install erosion & sediment control structures			
		Install roof water management practices			
		Install milkhouse waste treatment practices			
		Develop whole farm management plans			

5.2.3 Turtle Creek-Little Miami River (05090202 – 08)

Three out of twelve sites (25 percent) are not fully meeting the biological criteria for aquatic life uses. Only one of these three sites (Little Muddy Creek – river mile 3.22) is impaired by land use and the other two (Dry Run – river mile 0.18 and Turtle Creek – river mile 7.43) were impacted by the dry summer and resulting low flow conditions. The cause of aquatic life use impairment at RM 3.22 on Little Muddy Creek is poor substrate quality largely due to coarse substrates being embedded by sand. The primary source is the channelized nature of the stream in this area of Little Muddy Creek. When a stream is channelized it loses its ability to export fine sediment outside of the main low flow channel as well as it undergoes increased bed and bank erosion.

The sandy soils adjacent to an unnamed tributary to Swamp Run (enters Little Muddy Creek at RM 3.4) and along the lower portion of Swamp Run are likely to be exacerbating the sediment issues on Little Muddy Creek. There is little buffering in this area and it is possible that a significant amount of sand originates from these soils. The bank erosion that is likely occurring due to the stream channelization can also be a significant source where the sandy soils of the banks are transported downstream following bank failure. Buffers, bank stabilization and surface erosion controls are of highest priority in this area of the HUC 12 watershed.

Only one site was impaired for recreation uses in this watershed (Turtle Creek at river mile 0.52). Suspected sources are urban runoff from Lebanon and South Lebanon, and upstream agricultural production. Land application of manure or sludge may be the source of bacteria from croplands. Streamside buffering and controls on subsurface drainage infrastructure can help prevent transport of manure and sludge in surface and subsurface flows. Additionally, an intact subsurface drainage system (one without blowout connections to the surface) can also help prevent spills of manure or other land applied pollutants.

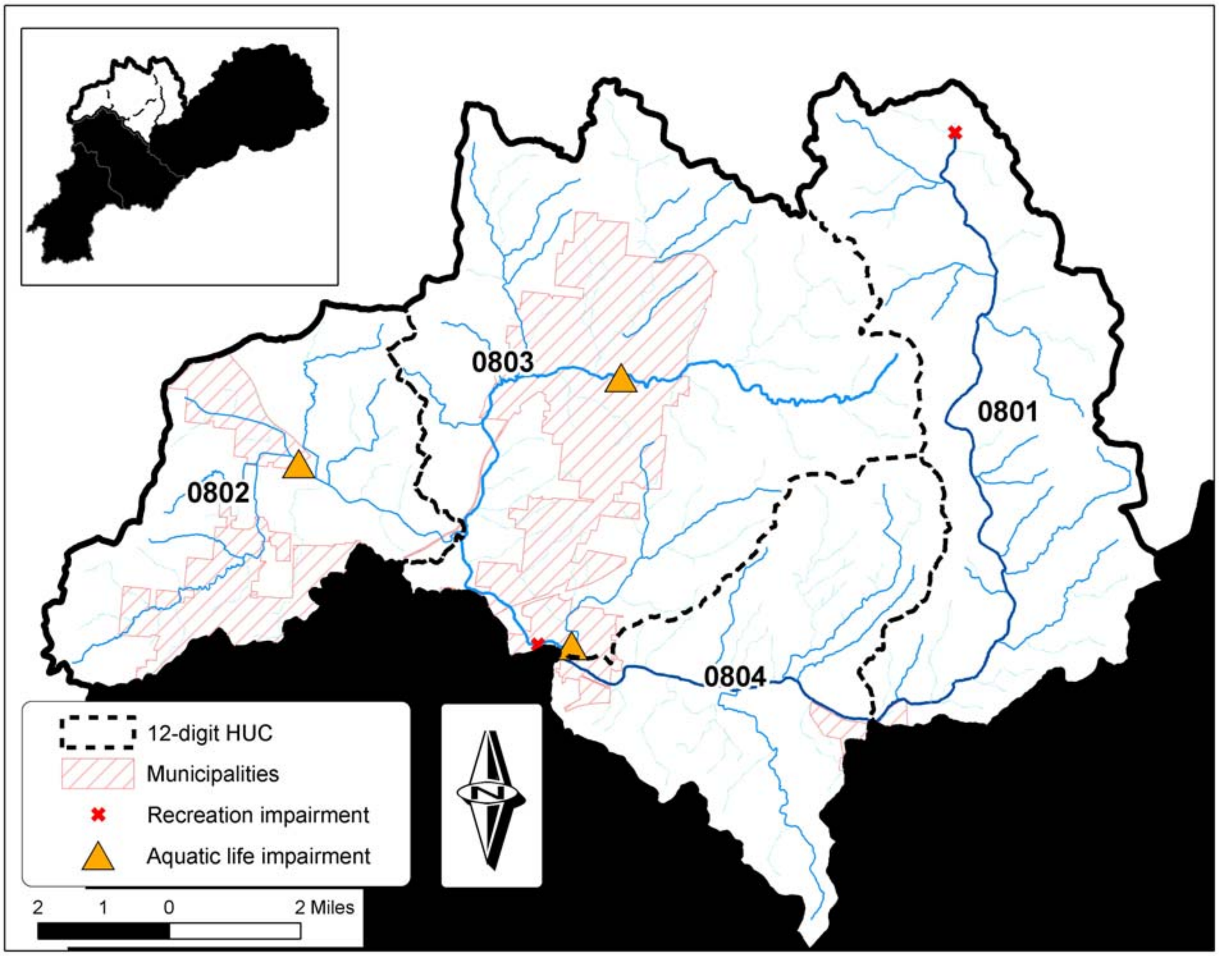


Figure 5.3 Map of the 08 ten-digit HUC with sites impaired for recreation and aquatic life uses and the respective 12-digit HUCs are shown.

Table 5.5 Restoration and abatement actions recommended for the 08 ten-digit HUC.

Restoration Categories		**Specific Restoration Actions**	**05090202-08**	
			02	**03**
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering	X	
		Restore streambank by recontouring or regrading	X	
	planted	Plant grasses in riparian areas		X

Restoration Categories		Specific Restoration Actions	05090202-08 02	05090202-08 03
		Plant prairie grasses in riparian areas	X	X
		Remove/treat invasive species		
		Plant trees or shrubs in riparian areas	X	X
Stream Restoration		Restore flood plain	X	
		Restore stream channel	X	
		Install in-stream habitat structures		
		Install grade structures		
		Construct 2-stage channel	X	
		Restore natural flow		
Conservation Easements		Acquire agriculture conservation easements		
		Acquire non-agriculture conservation easements	X	
Home Sewage Planning and Improvement		Develop HSTS plan		X
		Inspect HSTS		X
		Repair or replace traditional HSTS		X
		Repair or replace alternative HSTS		X
Storm Water Best Mgt Practices	quantity controls	Post-construction BMPs: innovative BMPs		
		Post-construction BMPs: infiltration		X
		Post-construction BMPs: retention/detention		X
	quality controls	Post-construction BMPs: filtration		X
		Construction BMPs: erosion control		
		Construction BMPs: runoff control		

Restoration Categories		Specific Restoration Actions	05090202-08	
			02	03
		Construction BMPs: sediment control		
Agricultural Best Mgt Practices	farmland	Plant cover/manure crops	X	
		Implement conservation tillage practices	X	
		Implement grass/legume rotations	X	
		Convert to permanent hayland		
		Install grassed waterways		
		Install vegetated buffer strips	X	X
		Install / restore wetlands	X	
	nutrients / agro-chemicals	Conduct soil testing	X	
		Install nitrogen reduction practices	X	
		Develop nutrient management plans	X	
	drainage	Install sinkhole stabilization structures		X
		Install controlled drainage system	X	X
		Implement drainage water management	X	X
		Construct overwide ditch	X	
		Construct 2-stage channel	X	
	livestock	Implement prescribed & conservation grazing practices		
		Install livestock exclusion fencing		
		Install livestock crossings		
		Install alternative water supplies		
		Install livestock access lanes		
	manure	Implement manure management practices		X

Restoration Categories		Specific Restoration Actions	05090202-08	
			02	03
		Construct animal waste storage structures		
		Implement manure transfer practices		
		Install grass manure spreading strips		X
	misc. infra-structure and mgt	Install chemical mixing pads		
		Install heavy use feeding pads		
		Install erosion & sediment control structures		
		Install roof water management practices		
		Install milkhouse waste treatment practices		
		Develop whole farm management plans		

5.2.4 O'Bannon Creek-Little Miami River (05090202 – 09)

Five out of sixteen sites (nine of which are on the mainstem of the Little Miami River) are not fully meeting the biological criteria for aquatic life uses. Only one of these five sites (Muddy Creek – river mile 0.54) is impaired by human activities and the other were impacted by the dry summer and resulting low flow conditions. The cause of aquatic life use impairment at RM 0.54 on Muddy Creek is poor substrate quality largely due to coarse substrates being embedded by sand.

Loamy soils are present immediately adjacent to Muddy Creek and some of its unnamed tributaries. Stream side buffering in this area would benefit water quality since it is likely that sand is originating from these erodible loamy soils. The streams are also likely channelized and leading to bank erosion and transport of these loamy soils (i.e., especially the sand fraction) downstream. The cause of ALU impairment at RM 0.54 on Muddy Creek is poor substrate quality largely due to coarse substrates being embedded by sand. There is also indication of organic enrichment coming from the Mason WWTP. Buffers, bank stabilization and surface erosion controls are of highest priority in this area of the HUC 12 watershed.

Two sites were impaired for recreation uses in this watershed (Muddy Creek at river miles 2.5 and 0.54). Suspected sources are urban runoff from Mason, Lebanon and South Lebanon, and possible effects from the wastewater treatment plant.

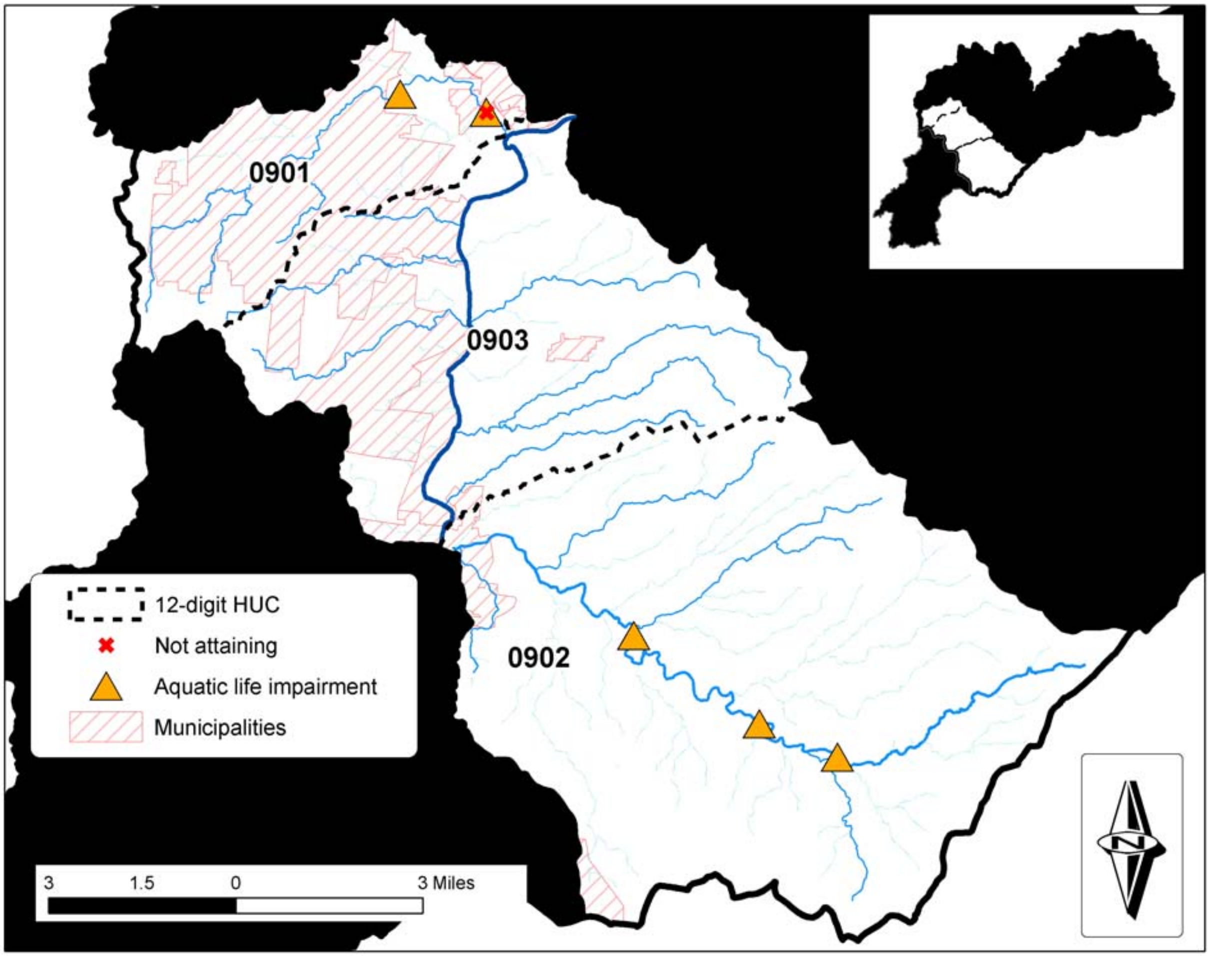


Figure 5.4 Map of the 09 ten-digit HUC with sites impaired for recreation and aquatic life uses and the respective 12-digit HUCs are shown.

Table 5.6 Restoration and abatement actions recommended for the 09 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	05090202-09
			01
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering	X
		Restore streambank by recontouring or regrading	X
	planted	Plant grasses in riparian areas	X
		Plant prairie grasses in riparian areas	X
		Remove/treat invasive species	
		Plant trees or shrubs in riparian areas	X

Restoration Categories		Specific Restoration Actions	05090202-09 01
Stream Restoration		Restore flood plain	X
		Restore stream channel	X
		Install in-stream habitat structures	
		Install grade structures	
		Construct 2-stage channel	X
		Restore natural flow	
Wetland Restoration		Reconnect wetland to stream	X
		Reconstruct & restore wetlands	X
		Plant wetland species	
Conservation Easements		Acquire agriculture conservation easements	
Home Sewage Planning and Improvement		Develop HSTS plan	
		Inspect HSTS	
		Repair or replace traditional HSTS	
		Repair or replace alternative HSTS	
Education and Outreach		Distribute educational materials	
		Host meetings, workshops and/or other events	
Storm Water Best Mgt Practices	quantity controls	Post-construction BMPs: innovative BMPs	X
		Post-construction BMPs: infiltration	X
		Post-construction BMPs: retention/detention	X
	quality controls	Post-construction BMPs: filtration	X
		Construction BMPs: erosion control	X

Restoration Categories		Specific Restoration Actions	05090202-09 01
		Construction BMPs: runoff control	
		Construction BMPs: sediment control	
Point Source Controls (Regulatory Programs)	collection and new treatment	Install sewer systems in communities	
		Develop and/or implement long-term control plan (CSOs)	
		Eliminate SSOs/CSOs/by-passes	
	storm water	Implement an MS4 permit	
		Implement an industrial permit	
		Implement a construction permit	
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)	
		Improve quality of effluent	X
	monitoring	Establish ambient monitoring program	
		Increase effluent monitoring	
	alternatives	Establish water quality trading	
Agricultural Best Mgt Practices	farmland	Plant cover/manure crops	X
		Implement conservation tillage practices	X
		Implement grass/legume rotations	
		Convert to permanent hayland	
		Install grassed waterways	X
		Install vegetated buffer strips	X
		Install / restore wetlands	X
	nutrients / agro-	Conduct soil testing	

Restoration Categories		Specific Restoration Actions	05090202-09 01
	chemicals	Install nitrogen reduction practices	
		Develop nutrient management plans	
	drainage	Install sinkhole stabilization structures	
		Install controlled drainage system	
		Implement drainage water management	
		Construct overwide ditch	X
		Construct 2-stage channel	X
	livestock	Implement prescribed & conservation grazing practices	
		Install livestock exclusion fencing	
		Install livestock crossings	
		Install alternative water supplies	
		Install livestock access lanes	
	manure	Implement manure management practices	
		Construct animal waste storage structures	
		Implement manure transfer practices	
		Install grass manure spreading strips	
	misc. infra-structure and mgt	Install chemical mixing pads	
		Install heavy use feeding pads	
		Install erosion & sediment control structures	
		Install roof water management practices	
		Install milkhouse waste treatment practices	

Restoration Categories		Specific Restoration Actions	05090202-09
			01
		Develop whole farm management plans	

5.2.5 Sycamore Creek-Little Miami River (05090202 – 14)

Five out of thirteen sites (eight of which are on the mainstem of the Little Miami River) are not fully meeting the biological criteria for aquatic life uses. Sycamore Creek is impaired by organic enrichment from urban runoff. Duck Creek has severe habitat impacts due to the several mile stretch of this stream being routed through a concrete channel. Combined sewers are also having a substantial impact on the biology due to organic enrichment. Clough Creek is impacted by combined sewers creating siltation in the channel. The Metropolitan Sewer District is currently implementing their long term control plan to abate combined sewer overflows.

Only one site on the mainstem of the Little Miami River (river mile 13.07) is not meeting recreation use criteria. The suspected sources are combined sewer discharges, urban runoff, and agriculture runoff.

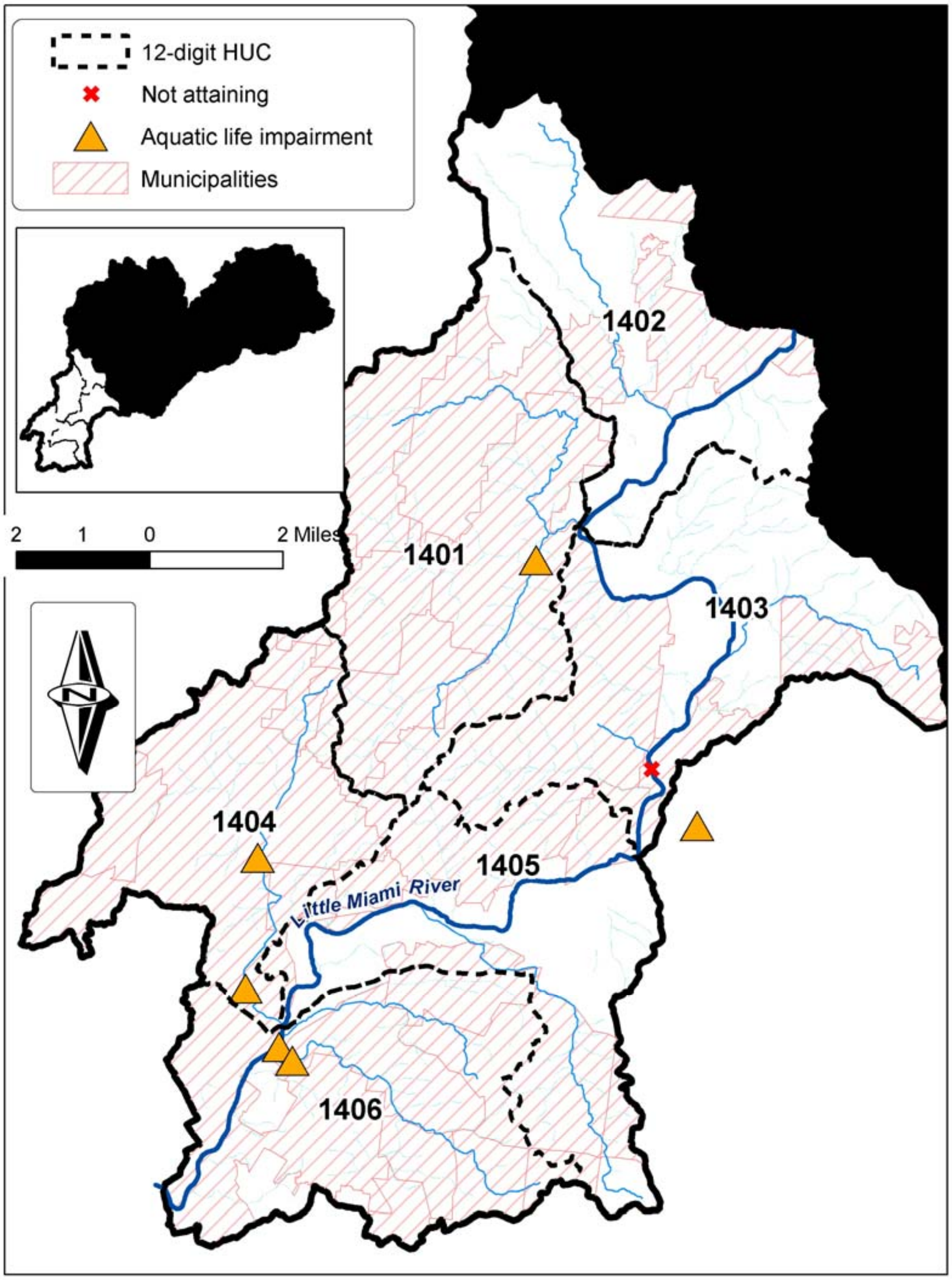


Figure 5.5 Map of the 14 ten-digit HUC with sites impaired for recreation and aquatic life uses and the respective 12-digit HUCs are shown.

Table 5.7 Restoration and abatement actions recommended for the 14 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	05090202-14					
			01	02	03	04	05	06
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering						
		Restore streambank by recontouring or regrading						
	planted	Plant grasses in riparian areas						
		Plant prairie grasses in riparian areas						
		Remove/treat invasive species						
		Plant trees or shrubs in riparian areas						
Stream Restoration		Restore flood plain		X	X		X	
		Restore stream channel		X	X		X	
		Install in-stream habitat structures		X				
		Install grade structures						
		Construct 2-stage channel						
		Restore natural flow						
Wetland Restoration		Reconnect wetland to stream		X				
		Reconstruct & restore wetlands		X				
		Plant wetland species						
Conservation Easements		Acquire agriculture conservation easements						
		Acquire non-agriculture conservation easements						
Home Sewage Planning and Improvement		Develop HSTS plan						
		Inspect HSTS						
		Repair or replace traditional HSTS						
		Repair or replace alternative HSTS						

Restoration Categories		Specific Restoration Actions	05090202-14					
			01	02	03	04	05	06
Education and Outreach		Distribute educational materials						
		Host meetings, workshops and/or other events						
Storm Water Best Mgt Practices	quantity controls	Post-construction BMPs: innovative BMPs						
		Post-construction BMPs: infiltration	X	X		X	X	X
		Post-construction BMPs: retention/detention	X	X		X	X	X
	quality controls	Post-construction BMPs: filtration	X	X		X	X	X
		Construction BMPs: erosion control						
		Construction BMPs: runoff control						
		Construction BMPs: sediment control						
Point Source Controls (Regulatory Programs)	collection and new treatment	Install sewer systems in communities						
		Develop and/or implement long-term control plan (CSOs)				X		X
		Eliminate SSOs/CSOs/by-passes				X		X
	storm water	Implement an MS4 permit	X	X	X	X		X
		Implement an industrial permit						
		Implement a construction permit						
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)						
		Improve quality of effluent						
	monitoring	Establish ambient monitoring program						
		Increase effluent monitoring						
	alternatives	Establish water quality trading						

5.3 Phosphorus Task Force

Ohio's Phosphorus Task Force is working to gather the information needed to effectively manage phosphorus in the Lake Erie watershed, particularly areas draining to the western basin. In doing so the task force laid out several objectives. Those that are especially good for increasing the understanding of phosphorus dynamics and have implications for management decisions in other watersheds in Ohio include:

- Evaluate potential sources of phosphorus
- Identify agricultural practices that may increase the loading of dissolved reactive phosphorus
- Recommend management actions

The task force published a report which tells of the group's findings and recommendations for management and monitoring activities that are aimed at reducing phosphorus loading to Lake Erie. This report is available at:
http://www.epa.state.oh.us/portals/35/lakeerie/ptaskforce/Task_Force_Final_Report_April_2010.pdf

Information presented significant to the lower Little Miami River watershed relate to the proportion of the loading and the loading dynamics of dissolved reactive phosphorus (DRP), which is entirely or almost entirely biologically available for plant production and ultimately this plant productivity is the cause of impaired aquatic life communities. In contrast to DRP, particulate forms of phosphorus have been estimated to be only about 30 percent biologically available. The dominant sources in the western Lake Erie basin (WLEB) are agriculture and point sources. Major point source dischargers are required to treat to an effluent quality no more than 1.0 mg/l of total phosphorus, a limit applied to relatively large waste water treatment plants in the lower Little Miami River watershed.

Factors impacting phosphorus delivery to surface waters via nonpoint sources include the clay content of the soils, where higher clay content translates to more phosphorus delivery (related to clay's affinity for particulate phosphorus). Once in the stream system, phosphorus bound to the clay particles may dissolve into solution and become biologically available for algae production. The disassociation of phosphorus from clay more readily occurs under hypoxic or anoxic conditions where iron species on the clay particle are reduced and becomes more soluble. In contrast to soils found in the WLEB, soils in the lower Little Miami River watershed have a much lower clay content where, proportionally speaking, they occur as low as one sixth of what they do in the Portage River watershed (a significant WLEB tributary river).

Other notable facts regarding source loading on a per unit area basis is that runoff from highly managed turf areas, primarily residential lawns, is decreasing over time due to lower phosphorus content in commercial fertilizers and improved practices regarding application, which includes better timing and the equipment and methods used in application. Although this is progress, abating runoff from residential and commercial areas remains important, particularly in watersheds like the lower Little Miami River watershed where these types of land uses are extensive.

In terms of transport pathways for phosphorus, it is recognized that hydraulic retention is likely to be a significant way to reduce loading to streams. The dissolved fraction of the phosphorus is believed to be readily transported in subsurface drainage tiles, along with nitrates. Therefore, reducing the overall volume of discharge from this pathway would likely abate nutrient issues substantially. Water table management or controlled drainage could, with minimal management and at relatively little sacrifice in terms of operational efficiencies to producers, reduce annual tile flow discharges by about 40 percent (with a corresponding reduction in the annual nutrient loading). This is achieved if tiles are essentially put out of use for the period beginning just after harvest (e.g., early November) until the period just before planting preparations are being made in the spring (e.g., March to April). More intense and sophisticated management may lead to even greater load reductions and may also produce benefits in terms of increased crop yield.

Run-off based hydraulic retention and targeted treatments are largely aimed at minimizing and/or treating concentrated flow paths. Filter areas (or wetlands) strategically located within fields or on the margins in low depression areas where flow accumulates (and possibly switches from sheet flow to a more concentrated flow), can be areas where infiltration occurs or, at a minimum, flows are detained, sediment is settled and nutrient are more readily assimilated. There are also management options that can reduce the concentrated flow that are not as widely promoted nor researched as practices such as grassed waterways, contour farming, and strip cropping. Specifically, designing buffers in consideration of ratios of effective buffer areas to contributing runoff area (i.e., ensuring that there is sufficient effective buffer area per runoff area in order to achieve the desired reduction efficiencies). Likewise, orienting furrows perpendicular to the buffer margin so that runoff is better dispersed across the buffer area would improve phosphorus treatment; however, consideration needs to be made of the any deleterious consequences like increased rill or gulley erosion on more steeply sloped soils. Hydraulic retention is discussed at length in Section 5 of the report generated by the Phosphorus Task Force.

Recommendations from the Phosphorus Task Force include:

- Develop consistent state-wide minimum standards for home septic treatment systems
- Minimize the use of systems that have off-lot discharges
- Provide training and continuing education opportunities for designers, installers, inspectors, regulators, and maintainers and operators of these systems
- Develop memorandum of understanding between the State and lawn care manufacturers to achieve reductions in phosphorus applied in lawn care products
- Develop outreach and education programs for homeowners to better water resource stewardship
- Promote use of Tri-State agronomic recommendations for cropland through such means as providing opportunities for training and education
- Develop and implement a phosphorus risk index for cropland including incentivizing its use through such means as tax reductions or rebates on fertilizer purchases
- Expand and promote consistent standards in soil testing and develop a clearinghouse of soil phosphorus concentration data
- Discourage application of phosphorus when critical threshold values are exceeded with the phosphorus risk index

6 Future Evaluations of the Project Area and Corrective Actions

6.1 Current and Ongoing Monitoring

The effectiveness of actions implemented based on the TMDL recommendations should be validated through ongoing monitoring and evaluation. Information derived from water quality analyses can guide changes to the implementation strategy to more effectively reach the TMDL goals. Additionally, monitoring is required to determine if and when formerly impaired segments meet applicable water quality standards (WQS).

This section of the report provides a general strategy for continued monitoring and evaluation and lists parties who can potentially carry out such work. It highlights past efforts and those planned to be carried out in the future by the Ohio EPA and others. It also outlines a process by which changes to the implementation strategy can be made if needed.

Evaluation and Analyses
Aquatic life habitat and recreational uses are impaired in the watershed, so monitoring that evaluates the stream system with respect to these uses is a priority to the Ohio EPA. The degree of impairment of aquatic life habitat is exclusively determined through the analysis of biological monitoring data. Recreational use impairment is determined through bacteria counts from water quality samples. Ambient conditions causing impairment include ***point sources (home septic treatment systems, sanitary sewer overflows, storm sewers, wastewater treatment plants), and non point sources (agricultural activity, maintenance of drainage infrastructure, urban/suburban land uses)***. This report sets targets values for these parameters (Chapters 3 and 4), which should also be measured through ongoing monitoring.

A serious effort should be made to determine if and to what degree the recommended implementation actions have been carried out. This should occur within an appropriate timeframe following the completion of this TMDL report and occur prior to measuring the biological community, water quality or habitat.

Past and Ongoing Water Resource Evaluation
The Ohio EPA has surveyed various sections of the Little Miami River basin several times in the past. The following is a brief overview of this activity:

Table 6.1 Ohio EPA reports on water quality in the lower Little Miami River watershed.

Survey year	Area covered	Publication year
2007	Lower Little Miami watershed (HUC 10s - 06, 07, 08, 09, and 14)	2009 TSD
2007	Area around Peters Cartridge – mainstem LMR from RMs 31.5 to 29.0	2007 TSD
1998	Entire LMR watershed – mainstem and major tributaries	2000 TSD
1999	Area around Peters Cartridge – mainstem LMR from RMs 32.5 to 29.0	1999 TSD
1993	LMR mainstem and 18 tributaries	1994 TSD

USGS scientists collected samples from streams and ground water, sediment, and ecological samples in the Great and Little Miami River Basins in southwestern Ohio and southeastern Indiana from 1999 to 2001, as part of a nationwide study. The study was one of 15 for which summary reports were just released and one of 51 regional studies conducted since 1991 by the USGS National Water-Quality Assessment (NAWQA) Program. The report from that study is titled; Water Quality in the Great and Little Miami River Basins, Ohio and Indiana, 1999–2001 (circular 1229).

Greenacres Water Quality Project (WQP) Limited Liability Company (LLC) is an educational community outreach project that works with school groups, citizens, environmental organizations, local communities, government agencies, and youth organizations to educate them about water resource issues and to work with them to preserve and protect water resources. The goal is to improve, preserve, and protect local water resources through education and involvement of school children, families, and adults in water quality issues.

The groups monitors the lower Little Miami Watershed (all tributaries and main stem of the Little Miami River from Todd's Fork to the mouth of the river excluding East Fork every second Saturday of the month annually from March – November to get a "Snapshot" of water quality conditions in neighborhood streams. The types of data collected include bacteria, nutrient, and turbidity once a month from March – November. These data are preserved in the Little Miami Watershed Volunteer Monitoring Database and is shared with responsible parties who can address the issues.

Recommended Approach for Gathering and Using Available Data
Early communications should take place between the Ohio EPA and any potential collaborators to discuss research interests and objectives. Through this, areas of overlap should be identified and ways to make all parties research efforts more efficient should be discussed. Ultimately important questions can be addressed by working collectively and through pooling resources, knowledge, and data.

6.2 Schedule for Ohio EPA Monitoring

In accordance with the Ohio 2010 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2010), the next scheduled Ohio EPA evaluation of this watershed is in 2022.

6.3 TMDL Revisions

An adaptive management approach will be taken in the lower Little Miami River watershed. Adaptive management is recognized as a viable strategy for managing natural resources (Baydack et al., 1999) and this approach is applied on federally-owned lands. An adaptive management approach allows for changes in the management strategy if environmental indicators suggest that the current strategy is inadequate or ineffective.

The recommendations put forth for the lower Little Miami River watershed largely center on point source controls, reducing pathogen, nutrient and sediment loading into streams and preventing further habitat loss.

If chemical water quality does not show improvement and/or water bodies are still not attaining water quality standards after the implementation plan has been carried out, then a TMDL revision would be initiated. The Ohio EPA would initiate the revision if no other parties wish to do so.

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