Enclosure 1

Total Maximum Daily Load (TMDL) and Watershed Implementation Plan for Phosphorus and *E. coli* in Bad Axe Creek

Huron County, Michigan

June 2016

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Acronyms and Abbreviations

AUID	assessment unit identifier
BMP	Best Management Practice
CAFO	concentrated animal feeding operation
cfs	cubic feet per second
CCPI	Cooperative Conservation Partnership Initiative
CFR	Code of Federal Regulations
CMI	Clean Michigan Initiative
CREP	Conservation Reserve Enhancement Program
DMR	Discharge Monitoring Report
EQIP	Environmental Quality Incentives Program
GIS	Geographic Information System
GLPF	Great Lakes Protection Fund
GLRI	Great Lakes Restoration Initiative
GLWQA	Great Lakes Water Quality Agreement
HCD	Huron Conservation District
HCDC	Huron County Drain Commission
HCHD	Huron County Health Department
HCRC	Huron County Road Commission
HUC	Hydrologic Unit Code
I&E	Information and Education
I&I	inflow and infiltration
L-THIA	Long-Term Hydrologic Impact Analysis
LA	load allocation
LSPC	Loading Simulation Program C++
LTA	long-term average
MAEAP	Michigan Agriculture Environmental Assurance Program
MDARD	Michigan Department of Agriculture and Rural Development
MDC	maximum daily concentration
MDEQ	Michigan Department of Environmental Quality
MRLC	Multi-resolution Land Characteristics
MOS	margin of safety
MS4	Municipal Separate Storm Sewer System
NCWQR	National Center for Water Quality Research
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NWIS	National Water Information System
PBC	partial body contact
OIALW	Other Indigenous Aquatic Life and Wildlife
OSDS	On-Site Sewage Disposal System
R-B Index	Richards-Baker Flashiness Index
SBWCP	Saginaw Bay Watershed Conservation Partnership
STEPL	Spreadsheet Tool for Estimation of Pollutant Load
SWPPP	Storm Water Pollution Prevention Plan
SVSU	Saginaw Valley State University

TBC	total body contact
TNC	The Nature Conservancy
TP	total phosphorus
TSS	total suspended solids
TMDL	Total Maximum Daily Load
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	wasteload allocation
WMP	Watershed Management Plan
WPCRF	Water Pollution Control Revolving Fund
WQS	Water Quality Standards
WWSL	wastewater stabilization lagoon
WWTP	wastewater treatment plant

Executive Summary

A Total Maximum Daily Load (TMDL) Watershed Implementation Plan has been developed for Bad Axe Creek that addresses water quality impairments resulting from excess levels of nutrients and bacteria. The Bad Axe Creek watershed (04080103-0302) was placed on Michigan's Section 303(d) list due to documented dense aquatic plant communities that reach nuisance conditions and high nutrient concentrations (Cooper, 2009). Bad Axe Creek is also not meeting Michigan's total and partial body contact recreational designated uses due to exceedances of the state's *Escherichia coli* (*E. coli*) criteria.

This document is intended to meet the requirements of both the TMDL and the §319 watershed management plan for Bad Axe Creek. This TMDL establishes the allowable loading targets for total phosphorus (TP) through wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources (NPS). It also sets target concentrations for *E. coli*. Based on these targets, the TMDL Implementation Plan identifies appropriate actions to achieve target levels that will result in attainment of Michigan's water quality standards for Bad Axe Creek.

Key parts of the technical analysis used to support development of the Bad Axe Creek TMDL Watershed Implementation Plan include:

- Identifying 60 µg/L as a growing season average (June 1 to September 30) total phosphorus concentration target, which will protect aquatic life uses in Bad Axe Creek based on previous work by the Michigan Department of Environmental Quality (MDEQ) to address aquatic plant nutrient impairments **[Section 2.4 and Appendix A]**.
- Using a multi-scale analysis framework to evaluate land use data coupled with information on permitted National Pollutant Discharge Elimination System (NPDES) permitted facilities to assess sources of phosphorus and bacteria in the Bad Axe Creek watershed **[Section 3 and Appendix A]**.
- Linking the load analysis with source assessment information and field inventory data to identify critical areas in the Bad Axe Creek watershed where phosphorus and bacteria reductions can aid in addressing water quality problems **[Section 4.1 and Appendix J]**.
- Calculating the loading capacity (i.e., the greatest amount of phosphorus and bacteria that Bad Axe Creek can receive and still meet water quality standards) and establishing load and wasteload allocations for TP and *E. coli* **[Section 4.2 and Appendix J]**.

Finally, the U.S. Environmental Protection Agency recommends that a reasonable assurance assessment be a key part of the TMDL process. Reasonable assurance activities are programs that are in place, or actions that can be taken, to assist in meeting the Bad Axe Creek watershed TMDL allocations and applicable water quality standards. The Watershed Implementation Plan **[Section 6]** and Accountability Structure **[Section 7]** provide reasonable assurance documentation that the nonpoint source reduction required to achieve proposed wasteload allocations developed in point source / NPS (or mixed-source) TMDLs can and will occur over time.

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1. Introduction

Section 303(d) of the federal Clean Water Act and the United States Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations [CFR], Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are not meeting, nor expected to meet, water quality standards (WQS) with current pollution control technologies due to one or more pollutants. The TMDL process establishes the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. TMDLs provide a basis for determining the pollutant reductions necessary from both point and nonpoint sources to restore and maintain the quality of water resources.

The purpose of this TMDL Watershed Implementation Plan is to take the identified allowable levels of phosphorus and *E. coli* that will result in the attainment of the applicable WQS in Bad Axe Creek and present the appropriate nonpoint source pollution control actions needed to address documented water quality impairments, specifically through reduction of nutrients and bacteria loadings from sources in the Bad Axe Creek watershed (04080103-0302). An important aspect of this plan is the use of an outcome-based strategic planning framework to identify and encourage activities, which can be implemented and produce measureable results in a reasonable time-frame.

2. Problem Statement

2.1 Background

Bad Axe Creek, the Pinnebog River, and Saginaw Bay

This TMDL Watershed Implementation Plan is intended to address the primary water quality concerns in Bad Axe Creek, a tributary to the Pinnebog River, which in turn drains to Saginaw Bay *(Figure 1)*. Specific problems have been identified that are associated with §303(d) listings for nuisance aquatic plant conditions and elevated *E. coli* levels. The nuisance aquatic plant conditions indicate that the Other Indigenous Aquatic Life and Wildlife (OIALW) designated use is not supported. The elevated *E. coli* concentrations indicate that total and partial body contact (PBC) recreational designated uses are not supported.

The Saginaw Bay watershed is a priority area for inter-governmental efforts focusing on the reduction of sediment and phosphorus entering the Bay. The Saginaw Bay watershed also faces water quality challenges from bacteria loads that affect the total body contact (TBC) recreational designated use. Excess nutrients and bacteria in Saginaw Bay may come from a wide range of nonpoint and point sources including urban stormwater, livestock operations, runoff from agricultural crop land, industrial facilities, municipal wastewater treatment plants, atmospheric deposition, wildlife (waterfowl and terrestrial), soil erosion, illicit discharges, failing septic systems, pets, sewer overflows, and the land-application of livestock waste, biosolids, and septage. For that reason, nutrient and bacteria reductions in Bad Axe Creek will also benefit water quality in Saginaw Bay.

Pinnebog River Watershed Management Plan

The Pinnebog River Watershed Management Plan (WMP) was developed in 2008 as a tool to voluntarily correct identified concerns through local partnerships. This plan's mission was to work with stakeholders in a fact-based process to identify and prioritize the impairments, their causes, and the systems of Best Management Practices (BMPs) to address them. The Pinnebog WMP was developed through a local Steering Committee supported by an Inventory Subcommittee, an Information & Education Subcommittee, and a Technical Subcommittee. Information included within the Pinnebog River WMP was used to guide implementation activities and BMPs in the Bad Axe Creek TMDL and Watershed Implementation Plan (Section 6).

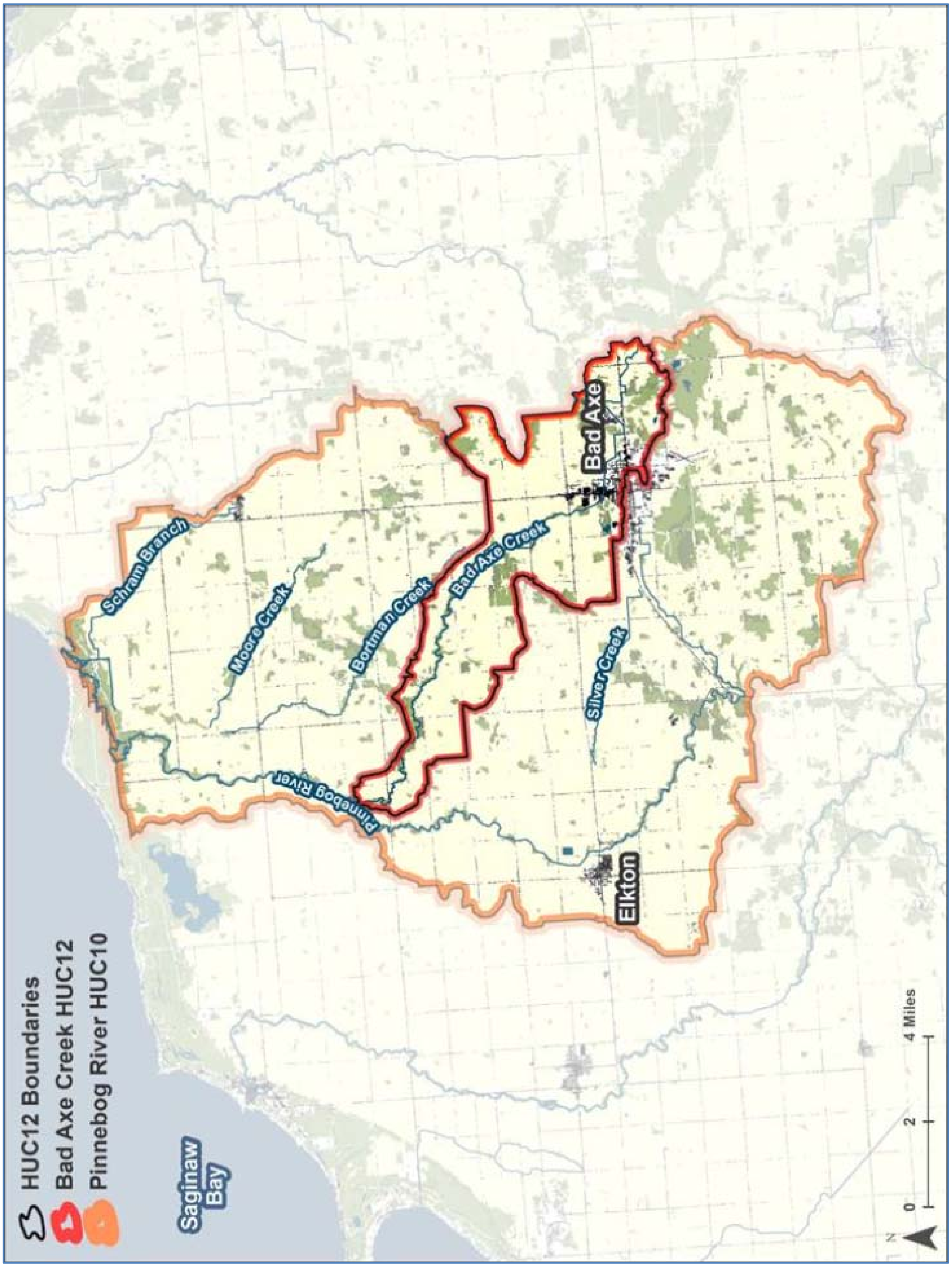


Figure 1. Location of Bad Axe Creek subwatershed relative to Saginaw Bay

2.2 Watershed Characterization

Bad Axe Creek is a warmwater stream located in Huron County, within Michigan's Lower Peninsula "thumb" area. The watershed itself encompasses an area of 29.5 square miles. The creek originates as Bad Axe Drain in the agricultural lands of Verona Township east of the City of Bad Axe *(Figure 2)*. Below the City of Bad Axe, the stream continues its flow through agricultural areas in Colfax Township. It becomes Bad Axe Creek below its confluence with Symons Drain in Meade Township. In Chandler Township, Bad Axe Creek joins the Pinnebog River, a tributary to Saginaw Bay.

The majority of the population in the watershed is located around the City of Bad Axe. Government units within the watershed include Verona, Colfax, Meade, Lincoln and Chandler townships and the City of Bad Axe. The area's economy is focused primarily on agriculture. Huron County ranks first in Michigan for production of dry beans, sugar beets, wheat, cattle / calves, milk cows, and milk production. The County also ranks second in the State for corn, grain, and hog production.

State-level water quality evaluations by MDEQ report overall conditions through assessment unit identifiers (AUIDs). There are two AUIDs in the Bad Axe Creek watershed; one for the upper portion, the second for the lower. Development of the Bad Axe TMDL Watershed Implementation Plan uses a multi-scale approach that partitions MDEQ's two AUIDs into six subwatershed groups (Table 1 and Figure 2). These groups provide the framework for a refined characterization and source analysis, which enables effective targeting of implementation efforts by identifying critical areas. These subwatershed group boundaries build on locations sampled by MDEQ shown in Figure 2.

Table 1. Bad Axe Creek subwatershed groups listed from upstream to downstream

AUID	Subwatershed Group		Area			
	ID	Outlet Point	Individual Group		Cumulative	
			(acres)	*(sq.mi.)*	*(acres)*	*(sq.mi.)*
04080103-0302-02 *(Listed in 2010 for E. coli and nutrients)*	**A**	Above Bad Axe WWTP	4,313	6.74	4,313	6.74
	B	Pigeon Road	761	1.19	5,075	7.93
	C	Berne Road	6,496	10.15	11,571	18.08
	D	Campbell Road	358	0.56	11,928	18.64
04080103-0302-01 *(Listed in 2010 for E. coli only)*	**E**	Pinnebog Road	3,853	6.02	15,781	24.66
	F	Bad Axe Creek mouth	3,099	4.84	18,880	29.50
		TOTAL	18,880	29.5		

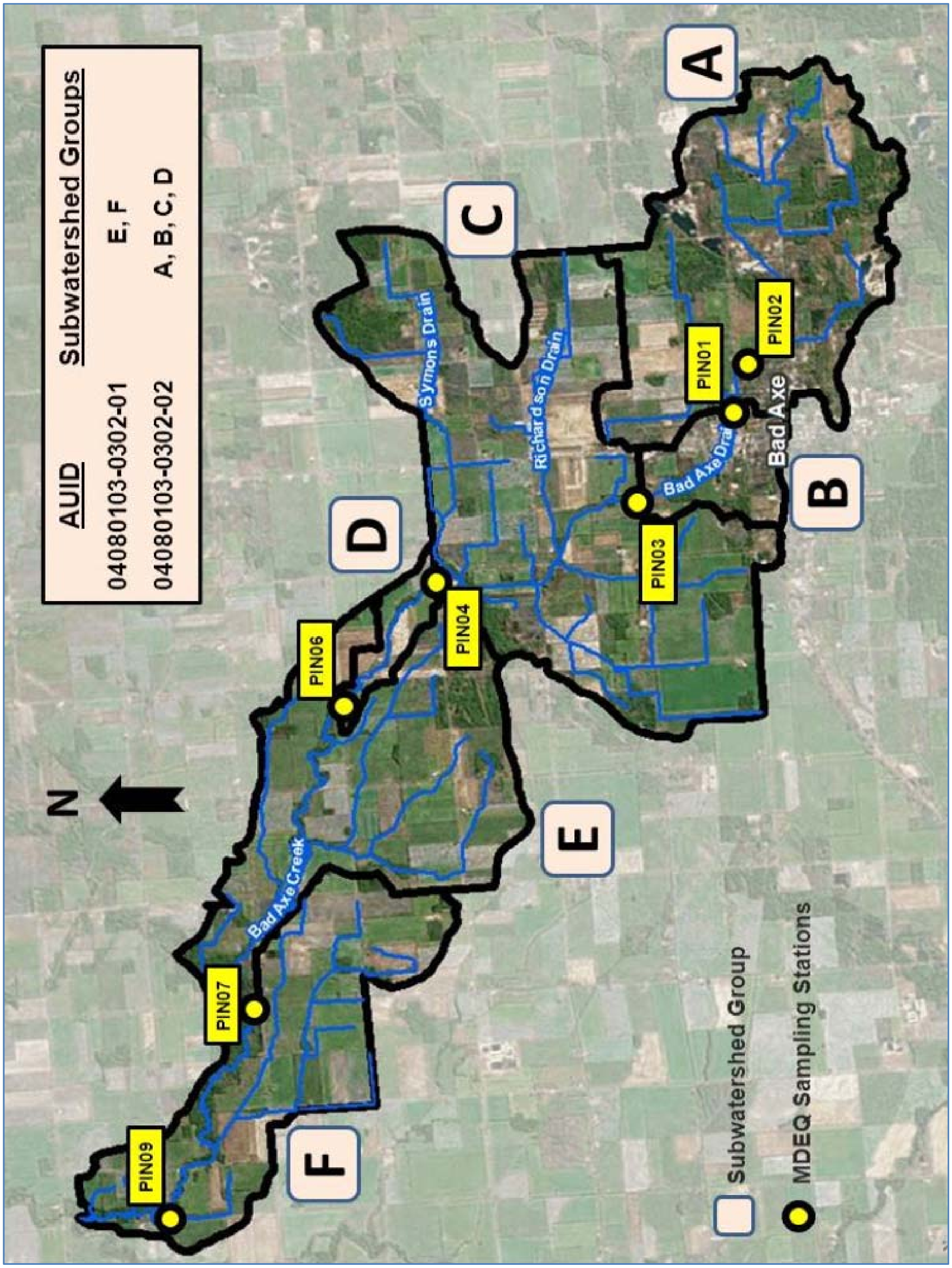


Figure 2. Bad Axe Creek subwatershed groups and 2008 monitoring locations

The type of land use affects nonpoint source pollutants that potentially reach Bad Axe Creek and its tributaries. Table 2 presents a summary of land use information for the Bad Axe Creek watershed by subwatershed group on a percentage basis.

Future growth is not expected to change significantly across the Bad Axe watershed. Land use is expected to remain stable; focused on agriculture and driven by commodity prices. However, population in the area has been declining. Census estimates indicate that population has decreased by approximately three percent from 2010 to 2014, both in the City of Bad Axe (from 3,129 to 3,029) and in Huron County (from 33,118 to 32,065).

Table 2. Bad Axe Creek watershed land use summary (percentage)

Land Use Category	Acreage	Subwatershed Group Land Use Percentage [a]					
		A	B	C	D	E	F
Open Water	66	*1%*	*0%* [b]	*0%*	-- [c]	--	--
Developed *(Open)*	971	*10%*	*12%*	*3%*	*4%*	*3%*	*3%*
Developed *(Low-Intensity)*	746	*7%*	*19%*	*3%*	*1%*	*1%*	*2%*
Developed *(Med-Intensity)*	200	*2%*	*14%*	*0%*	--	--	--
Developed *(High Intensity)*	132	*1%*	*12%*	*0%*	--	--	--
Barren Land	43	*1%*	--	*0%*	--	--	--
Forest	1,254	*7%*	*11%*	*4%*	*10%*	*8%*	*8%*
Shrub/Scrub	17	*0%*	--	*0%*	*0%*	*0%*	*0%*
Grassland/Herbaceous	147	*1%*	*1%*	*1%*	*1%*	*1%*	*0%*
Agriculture	13,538	*57%*	*28%*	*80%*	*82%*	*76%*	*81%*
Wetlands	1,766	*13%*	*4%*	*9%*	*2%*	*10%*	*7%*
TOTAL ACREAGE	18,880	4,313	761	6,496	358	3,853	3,099

Notes: [a] *Source*: 2006 National Land Cover Database (NLCD) (MRLC 2006).
[b] "0%" means land use present in subwatershed unit, but in amount less than 0.5%
[c] "--" means that land use not present in the subwatershed unit

2.3 Impairments to Bad Axe Creek

Section 303(d) List

In the 2014 §303(d) list of impaired waters, MDEQ determined that two AUIDs (040801030302-01 and 040801030302-02) of Bad Axe Creek, Bad Axe Drain, Richardson Drain, Symons Drain, and unnamed tributaries to these segments totaling 78.5 stream miles are not meeting total and partial body contact recreational designated uses due to levels of bacteria (*E. coli*) that exceed Michigan's WQS (Figure 3 and Table 3). In addition, 43.1 stream miles (AUID 040801030302-02) in the Bad Axe Creek watershed are impaired due to nutrients and are not meeting the OIALW designated use. The OIALW impairment for Bad Axe Creek is due to documented dense aquatic plant communities that reach nuisance conditions and high nutrient concentrations (Cooper, 2009).

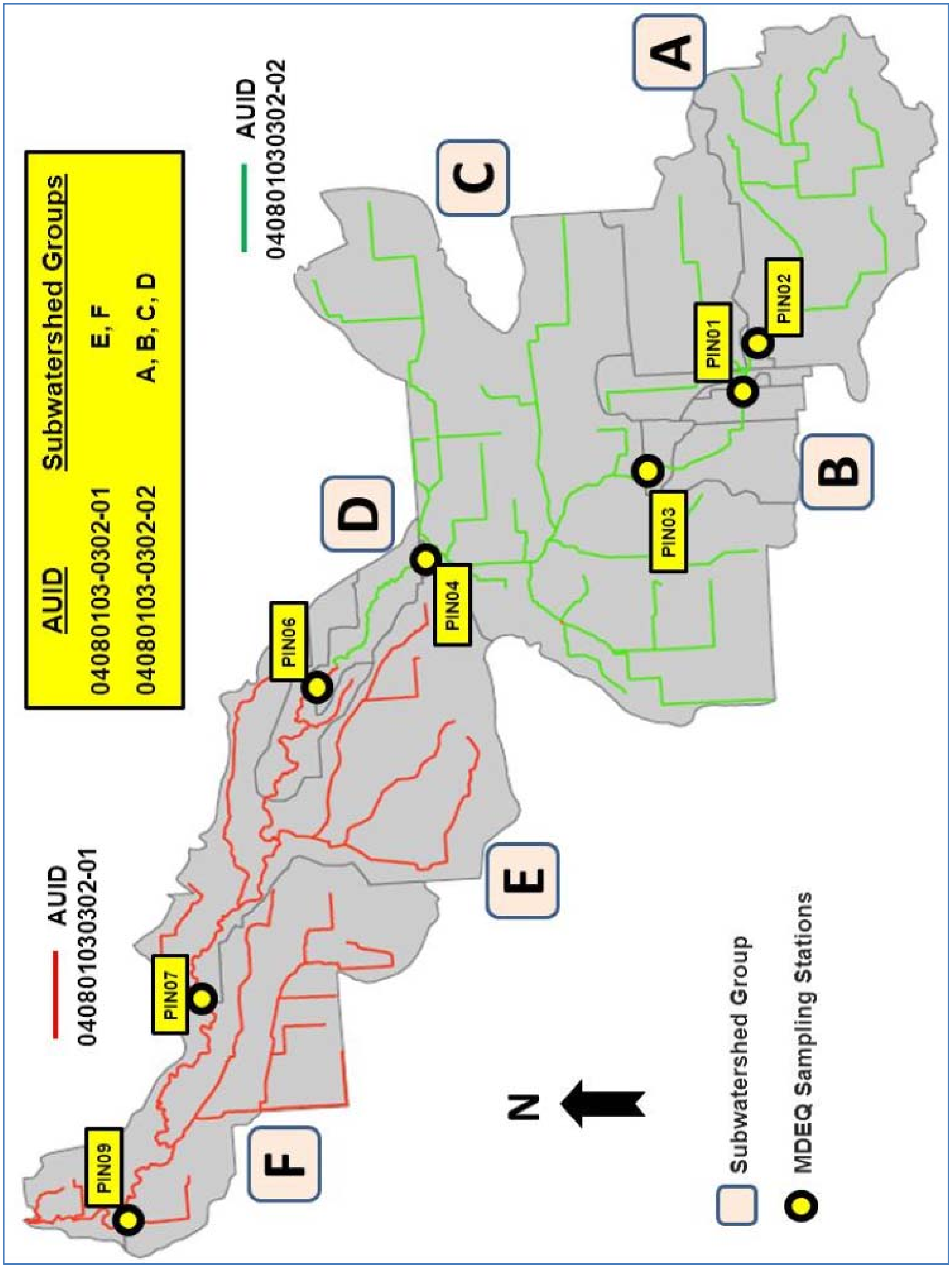


Figure 3. Bad Axe Creek assessment unit identifiers (AUIDs)

Table 3. Bad Axe Creek subwatershed impaired waters

Subwatershed: 040801030302	**Waterbody name:** **Bad Axe Creek**
Includes:	Bad Axe Creek, Bad Axe Drain, Richardson Drain, Symons Drain, Unnamed Tributaries to Bad Axe Creek, Unnamed Tributaries to Bad Axe Drain, Unnamed Tributaries to Richardson Drain, Unnamed Tributaries to Symons Drain
Impaired Designated Uses:	Total Body Contact Recreation (TBC) [AUID 040801030302-01, 040801030302-02] Partial Body Contact Recreation (PBC) [AUID 040801030302-01, 040801030302-02] Other Indigenous Aquatic Life and Wildlife (OIALW) [AUID 040801030302-02]
Cause:	*Escherichia coli* (TBC and PBC uses) Nutrient / Eutrophication Biological Indicator (OIALW use)
Size:	AUID 040801030302-01: 35.4 miles, AUID 040801030302-02: 43.1 miles
Year Placed on §303(d) List: 2010	**TMDL Year:** 2016

Priority Ranking

The State of Michigan recognizes the Saginaw Bay watershed as a priority area for inter-governmental efforts focusing on the reduction of sediment and phosphorus entering the Bay. Within the Saginaw Bay watershed, Bad Axe Creek has been targeted by MDEQ to receive §319 funding to implement measures that will reduce nonpoint source loads in the watershed. MDEQ also identified the Bad Axe Creek *E. coli* and phosphorus TMDL efforts as part of their priorities for protecting and restoring aquatic ecosystems under EPA's "Long Term Vision for Assessment, Restoration and Protection under the Clean Water Act Section 303(d) Program (TMDL Vision)". By completing TMDLs for these two pollutants in Bad Axe Creek MDEQ will be advancing its progress toward attaining its goals of the 2022 TMDL Vision.

2.4 Applicable Water Quality Standards

The authority to designate uses is granted through the Part 4 rules, WQS, promulgated under Part 31, Water Resources Protection, of Michigan's Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. Pursuant to this statute, MDEQ promulgated its WQS as Michigan Administrative Code R 323.1041 – 323.1117, Part 4 Rules. Designated uses to be protected in surface waters of the state are defined under R323.1100.

Designated Uses

At a minimum, all surface waters of the state are designated and protected for all of the following designated uses: agriculture, navigation, industrial water supply, warmwater fishery, other indigenous aquatic life and wildlife, partial body contact recreation, total body contact recreation (May 1 to October 31), and fish consumption. Some waters are protected for drinking water and coldwater fishery; however, those uses do not apply to the Bad Axe Creek watershed.

Numeric Criteria and Targets

Total Phosphorus.

MDEQ's Integrated Report (Section 4.6.2.2) describes the assessment methodology for determining nuisance aquatic plant growth conditions in streams (Goodwin et al, 2014). Evaluations include site-specific visual observations and / or water column nutrient concentration measurements. A determination of not supporting is made if excessive/nuisance growths of algae (particularly, *Cladophora*, *Rhizoclonium*, and cyanobacteria) or aquatic macrophytes are present.

Michigan does not have numeric criteria for total phosphorus, instead relying on the narrative WQS found under Rule R 323.1060(2) (Plant Nutrients). This rule was developed to provide the authority to limit the addition of nutrients to surface waters of the state, which are or may become injurious to the designated uses of the surface waters of the state.

Michigan's plant nutrient rule is as follows:

> R 323.1060 Plant Nutrients.
>
> Rule 60. (1) Consistent with Great Lakes protection, phosphorus which is or may readily become available as a plant nutrient shall be controlled from point source discharges to achieve 1 milligram per liter (mg/L) of total phosphorus as a maximum monthly average effluent concentration unless other limits, either higher or lower, are deemed necessary and appropriate by the department.
>
> (2) In addition to the protection provided under subrule (1) of this rule, nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended, and floating plants, fungi, or bacteria which are or may become injurious to the designated uses of the surface waters of the state.

Excess phosphorus can stimulate nuisance growths of algae and aquatic plants that indirectly reduce oxygen concentrations to levels that cannot support a balanced fish or aquatic macroinvertebrate community (e.g., extreme day/night time fluctuations in oxygen) and can shade out beneficial phytoplankton (algal) and aquatic macrophyte (vascular plant) communities that are important food sources and habitat areas for fish and wildlife. The period of time when it is most critical to reduce phosphorus loads is in the summer during the growing season. Between June 1 and September 30, environmental conditions such as higher temperatures, lower stream flows, and increased light intensity are most likely to result in nuisance plant growth if nutrient concentrations are elevated.

The numeric concentration targets for phosphorus in the Bad Axe Creek TMDL are developed based on a weight-of-evidence approach (Appendix J-1). Information obtained from scientific studies was coupled with data from similar streams in Michigan's southern Lower Peninsula that do not have nuisance levels of plant growth. To address plant nutrient impairments in Bad Axe Creek, the TMDL Watershed Implementation Plan target is 60 µg/L total phosphorus; applied as a growing season average (June 1 to September 30). This value is supported in the literature as a seasonal average target determined to be protective of the *other indigenous aquatic life and wildlife* and *warmwater fisheries* designated uses.

A daily maximum 200 µg/L total phosphorus target is identified, which recognizes fluctuations that occur with flow conditions or by season. The daily maximum limit also satisfies Clean Water Act §303(d) legal requirements. A multiplier is used that converts the growing season average value to a maximum daily concentration (MDC) target, following methods from EPA's *"Technical Support Document for Water Quality-Based Toxics Control"* (USEPA, 1991). For the Bad Axe Creek TMDL, the multiplier is based on characteristics that describe total phosphorus variability using data from a Michigan location with long-term monitoring information; in this case, daily data collected on the River Raisin by the National Center for Water Quality Research (NCWQR). The development of this target is described in Appendix J-1.

Bacteria *(E. coli)*.

The impaired designated recreational uses addressed by this TMDL are TBC and PBC. The designated use rule (Rule 100 [R 323.1100] of the Part 4 rules, WQS, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended) states that this water body be protected for TBC recreation from May 1 through October 31 and PBC recreation year-round. The target levels for these designated uses are the ambient *E. coli* standards established in Rule 62 of the WQS as follows:

> R 323.1062 Microorganisms.
>
> Rule 62. (1) All waters of the state protected for total body contact recreation shall not contain more than 130 *E. coli* per 100 milliliters (mL), as a 30-day geometric mean. Compliance shall be based on the geometric mean of all individual samples taken during five or more sampling events representatively spread over a 30-day period. Each sampling event shall consist of three or more samples taken at representative locations within a defined sampling area. At no time shall the waters of the state protected for total body contact recreation contain more than a maximum of 300 *E. coli* per 100 mL. Compliance shall be based on the geometric mean of three or more samples taken during the same sampling event at representative locations within a defined sampling area.
>
> (2) All surface waters of the state protected for partial body contact recreation shall not contain more than a maximum of 1,000 *E. coli* per 100 ml. Compliance shall be based on the geometric mean of 3 or more samples, taken during the same sampling event, at representative locations within a defined sampling area.

Sanitary wastewater discharges have an additional target:

> Rule 62. (3) Discharges containing treated or untreated human sewage shall not contain more than 200 fecal coliform bacteria per 100 ml, based on the geometric mean of all of five or more samples taken over a 30-day period, nor more than 400 fecal coliform bacteria per 100 ml, based on the geometric mean of all of three or more samples taken during any period of discharge not to exceed seven days. Other indicators of adequate disinfection may be utilized where approved by the Department.

For this TMDL, the WQS of 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum to protect the TBC use are the target levels from May 1 through October 31, and 1,000 *E. coli* per 100 mL as a daily maximum year-round to protect the PBC use.

2.5 Data Analysis

Phosphorus Loads

The load analysis sets the stage for moving from identified water quality concerns to meaningful solutions. A tiered approach is used to develop an effective TMDL watershed implementation plan for Bad Axe Creek. This framework builds on existing coarse watershed scale load estimates; specifically the Pinnebog WMP and a subsequent MDEQ assessment using the Long-Term Hydrologic Impact Analysis (L-THIA) tool (Appendix A). The watershed-scale L-THIA analysis, based on land use and soils data, estimated the total phosphorus load in Bad Axe Creek to be nearly 9,500 pounds per year.

Monitoring data collected by MDEQ along Bad Axe Creek (Figure 2) augments the watershed load estimates. This second tier refines the analysis, identifying critical areas that contribute the greatest load and highlighting the times when source reductions are most needed. A longitudinal glimpse at in-stream conditions for the stream is shown in Figure 4. The increase in phosphorus concentrations immediately below the Bad Axe wastewater treatment plant (WWTP) is very noticeable in upper Bad Axe Drain. However, in-stream processes appear to attenuate that effect. This attenuation is likely the result of nutrient uptake by the abundant vegetation in the channel and along the banks of Bad Axe Drain from the WWTP outfall to Pigeon Road, as illustrated in the adjacent photo, which shows Bad Axe Drain above M-53 (North VanDyke). Seasonal average phosphorus concentrations (summarized in Table 4) increase again as Bad Axe Creek flows through the lower portion of the watershed where drainage is affected by lands dominated by agricultural uses. Note that the needed reductions identified in Table 4 are based on the outlet of each AUID.

The load estimates driven by land use information with L-THIA can be coupled with coarse load estimates derived from the 2008 monitoring data using FLUX (a tool that estimates flow-weighted concentrations and loads). The FLUX estimate is scaled to the L-THIA value at the outlet for comparability between land use considerations and load increases based on data-driven concerns. Recognizing limitations with both estimates, the resultant profile (Figure 5) can be used to guide the source assessment and highlight potential critical areas that warrant closer examination (particularly those located in groups C, D, E, and F; noted by both large concentration and load increases).

An important aspect of the load analysis is to ensure that important pathways (source areas / delivery mechanisms) are considered relative to the timing associated with water quality concerns. The 2008 monitoring data indicate that phosphorus concentrations at locations sampled below subwatershed groups C through F increase following summer storms (Figure 6). These subwatershed groups are dominated by row crop agriculture supported by the use of field tile drainage. Vegetation is established during these months, likely limiting the effect of surface runoff. However, tiles are designed to move water quickly from fields to agricultural ditches and drains.

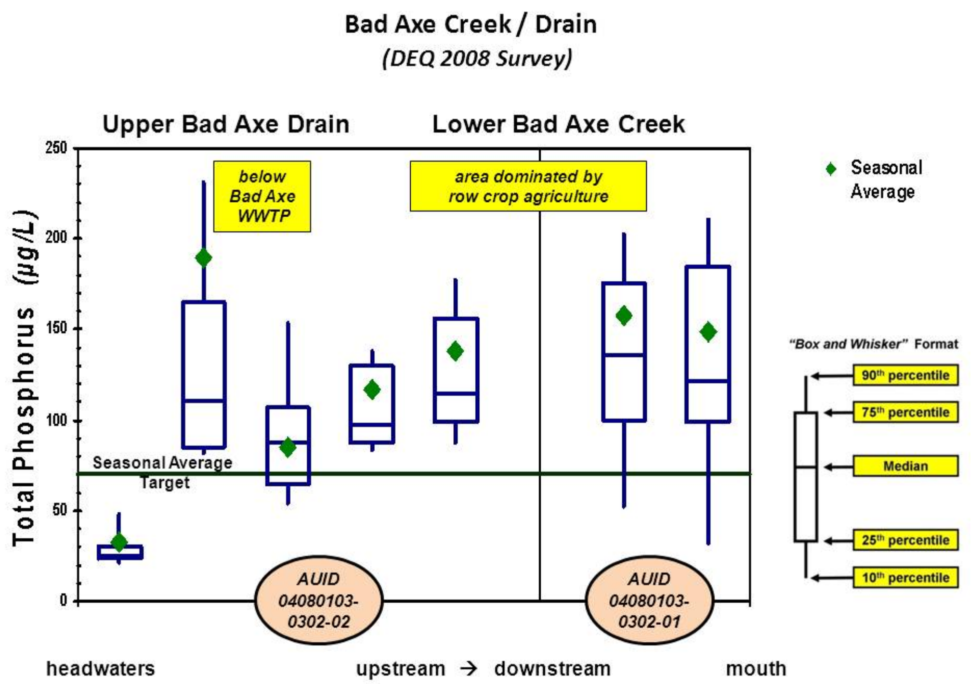


Figure 4. Bad Axe Creek total phosphorus concentration summary

Table 4. Bad Axe Creek total phosphorus sampling summary

AUID	Subwatershed Group	Cumulative Area (sq.mi.)	Monitoring Location ID	Monitoring Location	Total Phosphorus: Seasonal Average (µg/L)	Total Phosphorus: Needed Reduction [a]
04080103-0302-02	**A**	6.74	PIN02	above Bad Axe WWTP	33.0	
	B	7.93	PIN01	below Bad Axe WWTP	189.9	
			PIN03	Pigeon Road	85.0	
	C	18.08	PIN04	Berne Road	117.0	
	D	18.64	PIN06	Campbell Road	138.3	*57%*
04080103-0302-01 *[not currently on §303(d) list for nutrients]*	**E**	24.66	PIN07	Pinnebog Road	158.0	
	F	28.89	PIN09	Filion Road	149.1	*60%*

Note: [a] Needed reduction determined at AUID outlet, which represents MDEQ assessment methodology for evaluating OIALW nutrient impairments.

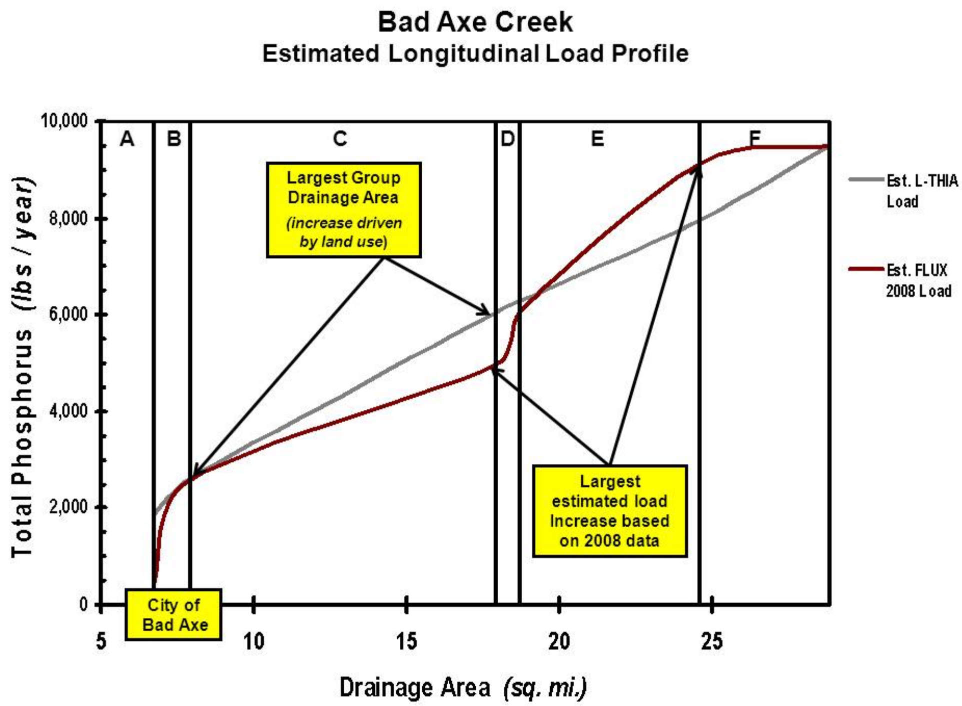


Figure 5. Bad Axe Creek estimated total phosphorus longitudinal load profile

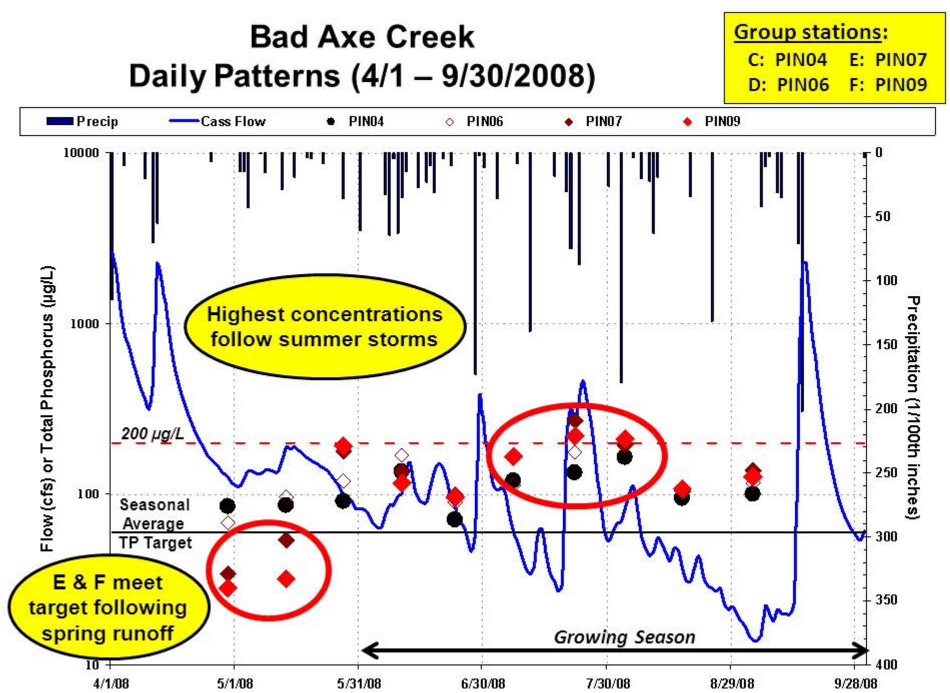


Figure 6. Bad Axe subwatershed total phosphorus sampling results *(groups C-F)*

Bacteria Conditions

In 2008, MDEQ sampled bacteria in the Bad Axe Creek watershed (Cooper and Alexander, 2009). The staff report noted that *E. coli* concentrations exceeded the geometric mean TBC criterion in 11 of 18 samples collected from Bad Axe Drain, and in 7 of 18 samples collected from Bad Axe Creek. Results of this survey, summarized in Figure 7, are used to determine needed reduction percentages based on water quality concentration exceedance percentages that reflects MDEQ's methodology for evaluating TBC impairments (Table 5).

A time series of the 2008 E. coli survey data is shown in Figure 8. Individual samples collected at Berne Road (PIN04) and Campbell Road (PIN06) exceeded 10,000 *E. coli* per 100 mL. Two other at both sites exceed 1,000 *E. coli* per 100 mL. Also noteworthy is that the excessively high Berne Road sample was more than an order of magnitude greater than all other samples taken across the watershed on the same day. This is indicative of a site-specific source, as opposed to a watershed-wide problem. Similarly, the high variability reflected by the wide "box and whisker" for the Campbell Road site also indicates the potential effect of a site-specific source influencing sample results at the location.

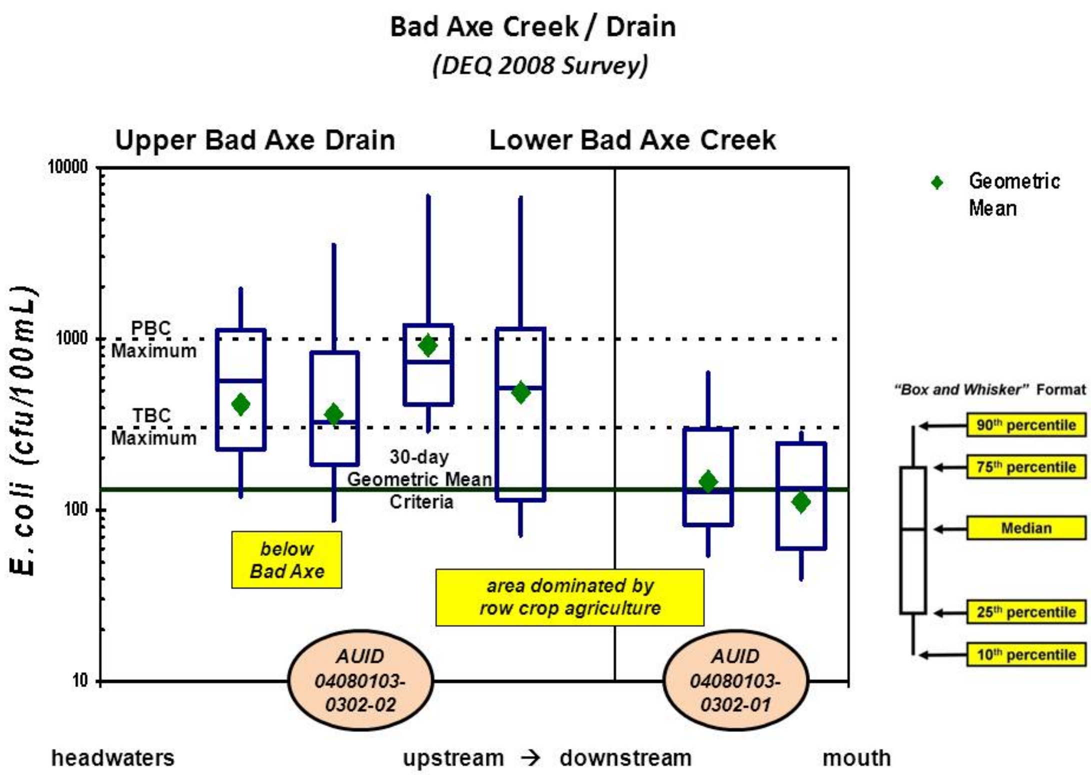


Figure 7. Bad Axe Creek *E. coli* concentration summary

Table 5. Bad Axe Creek *E. coli* sampling summary

AUID	Subwatershed Group		Monitoring Location		*E. coli*	
		Cumulative Area *(sq.mi.)*	ID	Location	*30-day Geometric Mean (#/100mL)*	*Needed Reduction* [a]
04080103-0302-02	A	6.74	PIN02	above Bad Axe WWTP		
	B	7.93	PIN01	below Bad Axe WWTP	697	*81%*
			PIN03	Pigeon Road	622	*79%*
	C	18.08	PIN04	Berne Road	721	*82%*
	D	18.64	PIN06	Campbell Road	737	*82%*
04080103-0302-01	E	24.66	PIN07	Pinnebog Road	205	*36%*
	F	28.89	PIN09	Filion Road	94	---

Note: [a] Needed reduction determined at each monitoring location, which represents MDEQ concentration-based assessment methodology for evaluating TBC impairments. This reduction is based on meeting the 30-day geometric mean May 1 – September 30 TBC criterion of 130 *E. coli* per 100 mL.

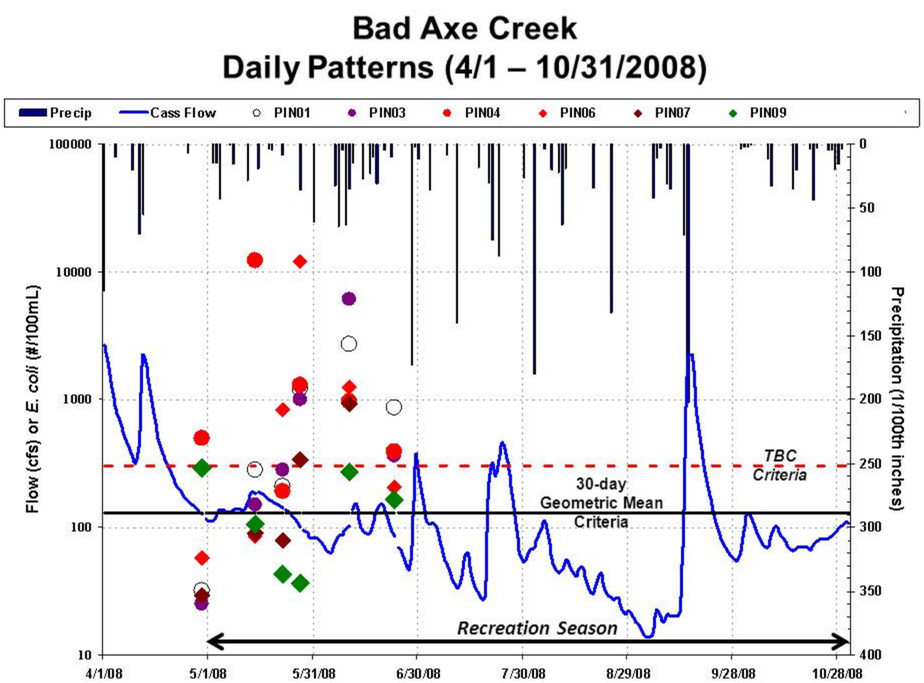


Figure 8. Bad Axe Creek *E. coli* sample results

3. Potential Sources

Sources of concern cover an array of nonpoint and point sources. Potential nonpoint sources include agricultural crop land (e.g., soil erosion, nutrient loss from fields, subsurface tile drainage, tile outlet problems), livestock (e.g., runoff from animal feeding areas, lack of manure storage, unregulated land-application of livestock waste), urban stormwater runoff, illicit discharges, failing septic systems, wildlife (waterfowl and terrestrial), pets, and atmospheric deposition.

Point sources are those originating from a single, identifiable source in the watershed (Table 6 and Figure 9). Point source discharges are regulated through NPDES permits. MDEQ may utilize an individual permit, general permit, or *"permit by rule"* for NPDES authorizations. MDEQ determines the appropriate permit type for each surface water discharge. An individual NPDES permit is facility-specific. The limitations and requirements are based on the permittee's wastewater discharge, the volume of discharge, facility operations, and receiving stream characteristics. A general permit is designed to cover permittees with similar operations and / or type of discharges. Within the Bad Axe watershed, these include Wastewater Stabilization Lagoons (WWSLs) and Concentrated Animal Feeding Operations (CAFOs). General permits may contain effluent limitations protective of most surface waters statewide. Locations where more stringent requirements are necessary require an individual permit. Facilities that are eligible for coverage under a general permit receive a Certificate of Coverage (COC).

Table 6. Bad Axe watershed facilities with NPDES permit coverage

Subwatershed Group	Permit ID	Expiration Date	Name	Permit Type
A	GW1510351	4/1/2020	J W Hunt OTC Inc	GW-Commercial
	MIS210993	4/1/2017	Rooney Contracting-Soper Rd	Industrial Storm Water Only
	MIS211067	4/1/2017	J W Hunt OTC Inc	
	MIS510074	4/1/2020	Huron & Eastern Railway Co	
B	MI0020958	10/1/2014 [a]	Bad Axe WWTP	Non-Industrial Sanitary Wastewater
	MIG580000	4/1/2019	Colfax Twp WWSL-Huron Co	
C	MIG440027	12/31/2007 [a,b]	Wil-Le Farms-CAFO	Concentrated Animal Feeding Operation (CAFO)
	MI0058179	AIP [b]	Wil-Le Farms-CAFO	
	MIG580000	4/1/2019	Huron Co Medical Care WWSL	Non-Industrial Sanitary Wastewater
D	MIG010042	4/1/2020	Hass Feedlot-2-CAFO	CAFO
A, B, C	MI0057364		MI Dept. of Transportation	MS4 [c] Stormwater

Notes: [a] Current expired permit extended until reissuance
[b] Application in process. Will replace MIG440027 when issued and includes groundwater coverage
[c] Municipal Separate Storm Sewer System (MS4)

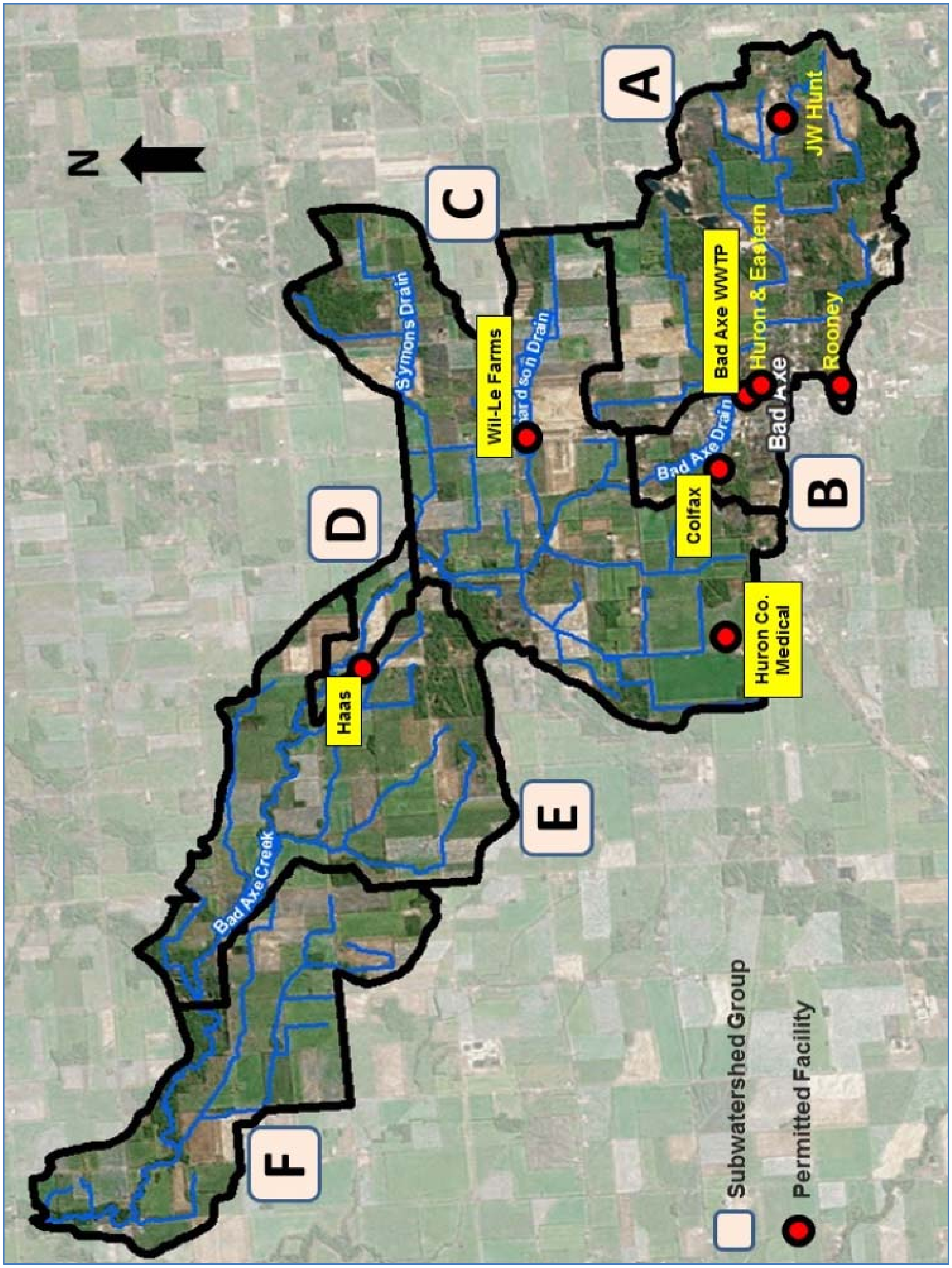


Figure 9. Bad Axe Creek point source locations

A $6.3 million upgrade was completed at the Bad Axe WWTP in 2007, which has enabled the facility to operate well below their NPDES permit limit for total phosphorus of 1 mg/L. In addition, the Wastewater Stabilization Lagoon (WWSL) general permit states that there will be *"no discharge from June 1 to September 30"*; consistent with the TP growing season target.

Nonpoint sources of phosphorus in the Bad Axe Creek watershed are largely associated with agricultural activities. As indicated earlier in Table 2, agricultural land use dominates all subwatershed groups except B, where the City of Bad Axe is located. In addition, phosphorus concentrations in the watershed increase steadily as Bad Axe Creek flows through these agricultural areas, as shown in Figure 4. An extensive drainage network has been established to facilitate crop production resulting in highly modified channels in the tributaries to Bad Axe Creek (subwatershed groups C, D, E, and F).

Land used for crop production can be a source of phosphorus and *E. coli*. Crop land can accumulate phosphorus from the application of fertilizers (chemical and manure), decomposition of plant residue, wildlife excrement (waterfowl and terrestrial), and atmospheric deposition including wind erosion. The majority of nutrient loads from crop land is generally attributed to fertilizer application that exceeds plant growth requirements. Surface erosion from bare fields, nutrients carried through tile drain flow, and streambank erosion associated with the loss of vegetation or with increased flow rates in response to tile drainage are all potential sources of phosphorus delivered to Bad Axe Creek. Manure fertilizer improperly applied to crop land can also be a source of *E. coli* and TP during runoff conditions that carry pollutants through surface or tile flow. In addition, manure applied adjacent to or across streams or ditches can be a source of both phosphorus and *E. coli*.

Runoff from pastures and livestock operations can be potential agricultural sources of phosphorus and *E. coli*. Animals grazing in pasture land deposit manure directly upon the land surface. The manure is often concentrated near feeding and watering areas in the field or at stream access points. These areas can become compacted and barren of plant cover, increasing the possibility of erosion and contaminated runoff during storm events.

The small amount of urban / residential land use in the Bad Axe Creek watershed is also a potential source of phosphorus and *E. coli*, as On-Site Sewage Disposal Systems (OSDS) serve about 500 homes in the watershed[1]. When septic systems are not functioning properly, or are poorly designed, they can deliver phosphorus and *E. coli* to nearby streams. Across Michigan, the on-site septic system failure rate reportedly averages around 10% (*E. Coli* Work Group, 2009). The incidence of failure is variable depending on geology and age of the septic system. Another potential, but undocumented, source of phosphorus and *E. coli* could be illicit discharges from residential units.

[1] Molly Rippke, MDEQ, personal communication, February 1, 2016.

3.1 Timing of Pollutant Delivery

In addition to identified source categories, the timing of pollutant delivery to Bad Axe Creek is an equally important consideration in developing effective implementation strategies. For example, continuous point source discharges from the Bad Axe WWTP will have a greater effect on in-stream concentrations during low flows. Phosphorus and sediment loads delivered through watershed-scale runoff processes are more important during the spring and the onset of fall rains, particularly in areas more exposed by conventional tillage.

An examination of seasonal flow patterns in Huron County illustrates the role of timing in assessing sources of concern. Figure 10 summarizes monthly flows based on Pigeon River data collected by USGS. Periods of high watershed-scale erosion potential are highlighted. From an implementation perspective, these months represent periods when reduced tillage will be most effective in controlling source loads. As another example, general periods when tillage and fertilizer application could occur are also depicted in Figure 10. This is a potential reason for the significant phosphorus concentration increase noted in groups E and F towards the end of May (Figure 6).

As mentioned previously, pollutant delivery through uncontrolled tile drainage could occur throughout the year. However, the effect of this source category will be greatest on in-stream growing season concentrations during summer rain events due to the lower base flow conditions in the watershed during the summer months. Similarly, runoff from animal feeding areas adjacent to Bad Axe Creek could also be a significant source of concern during these periods.

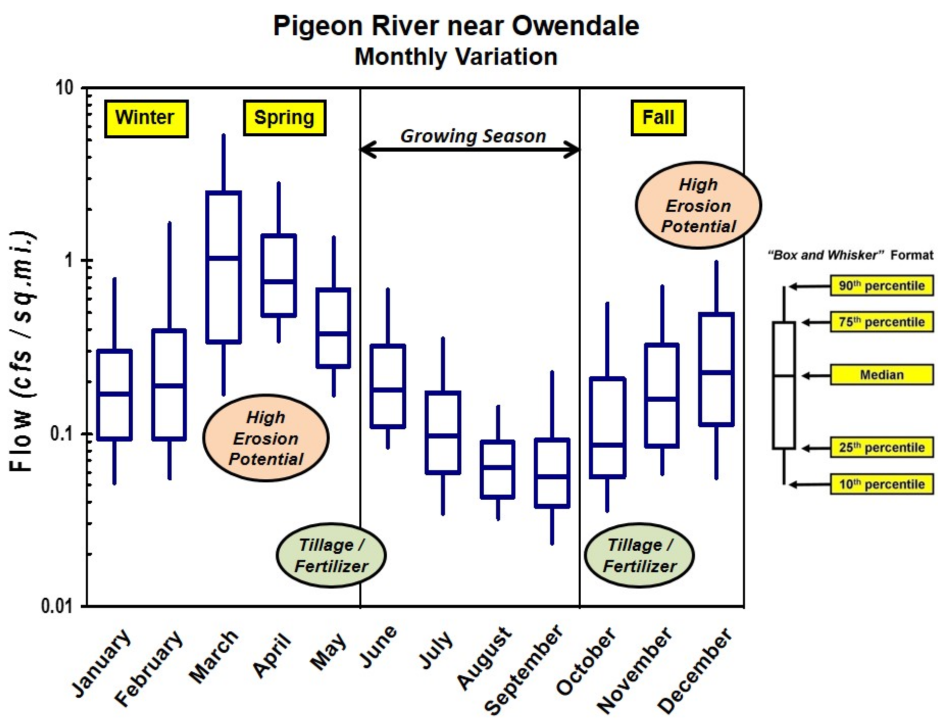


Figure 10. Huron County seasonal flow patterns -- Pigeon River gage

3.2 Surveys and Inventories

Field surveys were conducted by the Huron Conservation District (HCD) in 2010 and 2011 as part of the Pinnebog WMP (FTCH, 2012). Dominant source categories identified in the resultant inventory include rill / gully erosion, stream bank erosion, and erosion of tile outlets and side inlets to water courses. Runoff from animal operations was also identified at several locations.

Table 7 summarizes the field inventory information for high priority subwatershed groups identified in the load analysis (specifically C, D, E, F). A full summary table of the HCD field inventory with mapped locations by Bad Axe subwatershed group is presented in Appendix A.

Table 7. Summary of field inventory information in high priority subwatershed groups

Group (*Outlet Point*)	Critical Area ID		Rill / Gully Erosion	Streambank Erosion	Tile Outlet	Other [a]	Debris / Trash
C (*Berne Road*)	29	Bad Axe 149	2 [b]	2			
	30/31 [c]	**Wahl 6 N / Richardson 1077**	**5**	**5**	**3**	**1**	
	32/33	Evans 166 / Bad Axe 147		2			
	34	**Stenton 162**	**9**	**7**	**5**	**2**	
	35/39	**Bad Axe 146**	**3**	**1**	**2**	**1**	**5**
	36/37	**Symons Br 3 917 / 2 915**	**2**	**1**	**5**	**3**	
	38	**Symons 915**	**5**	**2**	**3**	**1**	
D (*Campbell Rd.*)	41	Bad Axe 915		1	2		3
E (*Pinnebog Rd.*)	51	Bad Axe 915	1	4			10
	52 / 54	**Ritter 913 / Sam 914**	**4**	**1**	**6**		**2**
	53	E Br of Pinnebog 918		1			3
	55/56	E Br of Pinnebog 918 / 912	1	2	1	1	3
	57	Hogan 919	2	1			1
	58	E Br of Pinnebog 912		1			1
F (*mouth*)	61/64	E Br of Pinnebog 912 / 806	1	7	1	1	13
	62/63	**Renn 910 / Renn 908**	**10**	**3**	**4**	**3**	**1**

Notes: [a] "Other" includes livestock access, barnyard runoff, stream crossing, or upland source.
[b] Numbers represent observed occurrences from field inventory.
[c] **Yellow highlighted cells** identify critical areas based on HCD field inventory information.

3.3 Critical Area Analysis

The Pinnebog WMP identified the entire Bad Axe Creek watershed as a critical area. The focus of this plan is to combine field inventory information with the data assessment, and develop a refined critical area analysis. The critical area analysis recognizes that achieving needed nutrient and bacteria reductions will require a mix of practices across multiple landscape positions. The critical area analysis must also consider timing and delivery mechanisms of key watershed processes that affect pollutant concentrations relative to water quality targets.


Bad Axe Drain
below Richardson Road

Total Phosphorus.

Soils across significant portions of the lower Bad Axe watershed have low infiltration rates (Figure A-13). This necessitates the use of field tile drainage to support viable row crop production. As indicated in the load analysis, the potential effect of tile drainage on phosphorus concentrations is noticeable in the 2008 MDEQ monitoring data. Locations sampled below Pigeon Road, particularly group E and F show an increase of phosphorus in the water column following summer storms (Figure 6). In addition, there appears to be a significant increase in phosphorus concentrations towards the end of May at these same locations, indicating the need to examine nutrient management practices in these two groups.

Critical areas in high priority subwatershed groups are summarized in Table 8. These areas are shown in Figure 11 through Figure 13 for groups C, E, and F. Practices that emphasize soil management and soil health (e.g., reduced or no tillage, cover crops, nutrient management) play an important role to improve nutrient- and water-use efficiencies in fields (Tomer et.al. 2013). Recommended BMP categories are also included in Table 8, which would address needed reductions based on the 2008 MDEQ ambient data and the 2011 HCD field inventory. Although this is currently the best available information, it does not account for practices that have been installed during the period following data collection.


Field tile installation

Management practice categories identified in Table 8 are listed in priority order from left to right. Nutrient management practices center on the 4R nutrient stewardship program (i.e., using the right source of nutrients at the right rate and right time in the right place), as well as the existing / revised NRCS nutrient standard. Water quantity management practices include controlled drainage structures, grassed waterways, saturated buffers, and blind inlets. Other practices identified in Table 8 are more widely accepted in the Bad Axe watershed including reduced tillage, cover crops, and filter strips.

Table 8. Critical area analysis summary for high priority subwatershed groups -- total phosphorus

Group *(Outlet Point)*	Critical Area ID		Nutrient Management [a,e]	Water Quantity Management [b]	Reduced Tillage [c]	Cover Crops	Other [d]
C *(Berne Road)*	30/31	Wahl 6 N / Richardson 1077	◗	◗	●●	●●	●●
	34	Stenton 162 / Stenton 165	◗	◗	●●	●●	●●
	35/39	Bad Axe 146	◗	◗	●●	●●	●●
	36/37/ 38	Symons Br 3 917 / Symons 2 915/ Symons 915	◗	◗	●●	●●	●●
D *(Campbell Rd.)*	41	Bad Axe 915	◗	◗	◗	◗	●●
E *(Pinnebog Rd.)*	52 / 54	Ritter 913 / Sam 914	●●	●●	◗	◗	●●
	53	E Br of Pinnebog 918	◗	◗	◗	◗	●●
F *(mouth)*	62/63	Renn 910 / Renn 908	●●	●●	◗	◗	●●

<u>Notes</u>: ●● High priority BMP ◗ Medium priority BMP ○ Provide general benefit for load reduction

[a] 4R nutrient stewardship program; existing / revised NRCS nutrient standard [e]
[b] controlled drainage structures; grassed waterways; saturated buffers; blind inlets
[c] no-till; zone building; strip tillage; shallow vertical tillage; corn stalk residue
[d] riparian buffers; filter strips
[e] NRCS 590: *(The link provided was broken and has been removed.)*

Additional field inventory information for each critical area is provided in Appendix C (Table C-3 through Table C-8). The field inventory coupled with the air photo and load analysis indicate a need to increase acreage under reduced tillage and cover crops for all group C, E, and F critical areas. Erosion concerns also point to a need to increase the number of miles of riparian buffers/filter strips in these same critical areas. This is due to the amount of streambank, gully, and rill erosion problems caused by field management of the riparian zone (i.e., streambank) and lack of vegetative cover.

Water quantity management practices could also address some concerns noted in all group C, E, and F critical areas. Surface ditching was identified in several instances; installation of grassed waterways, saturated buffers, or blind inlets might solve resultant erosion problems in these locations. The opportunity to use controlled drainage structures should be examined where tile outlet failures were identified. This practice is currently being implemented in the River Raisin and in northwest Ohio. In addition, there is a potential benefit for farm profitability, particularly during drought years.

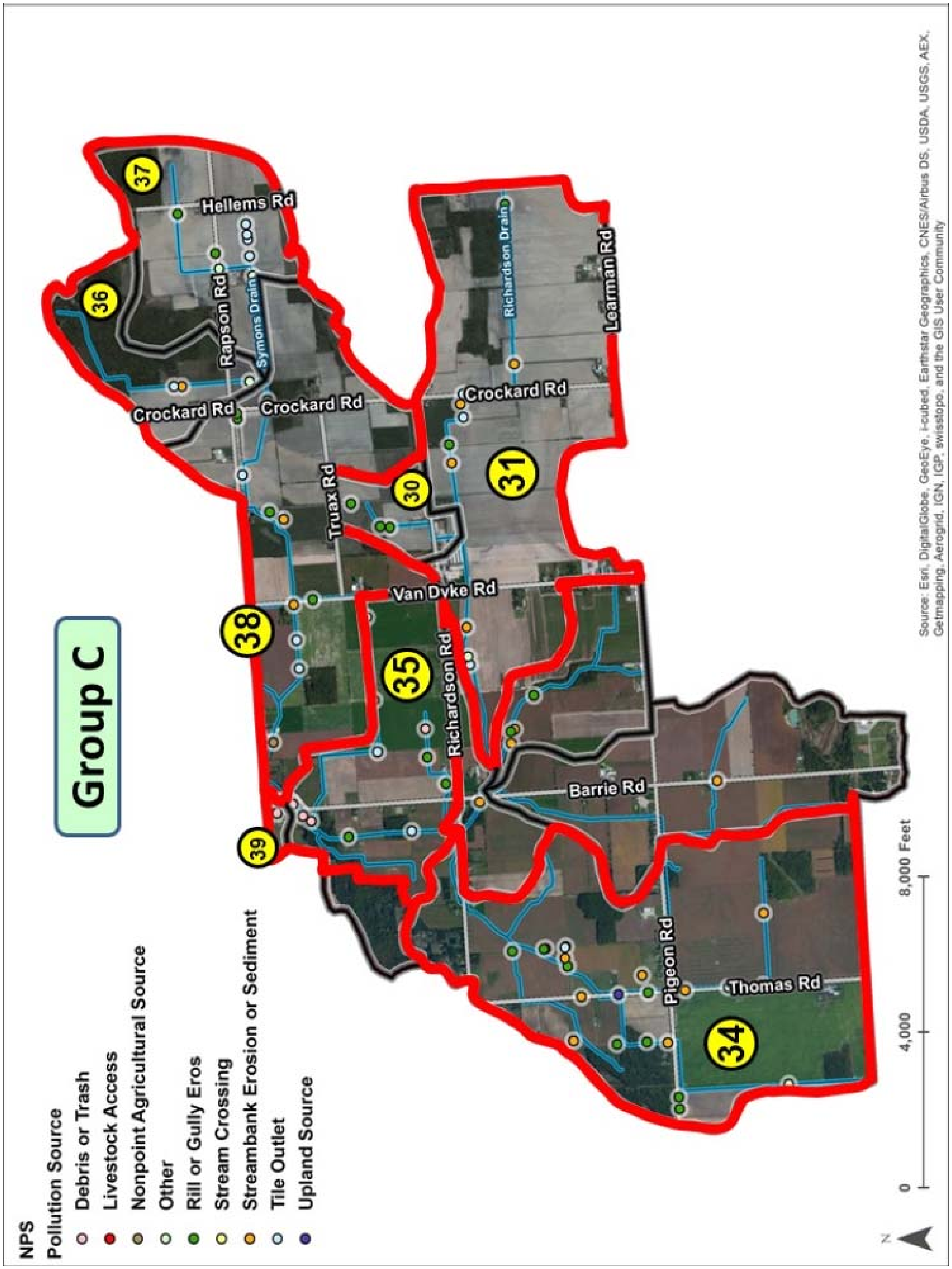


Figure 11. Critical areas -- subwatershed group C

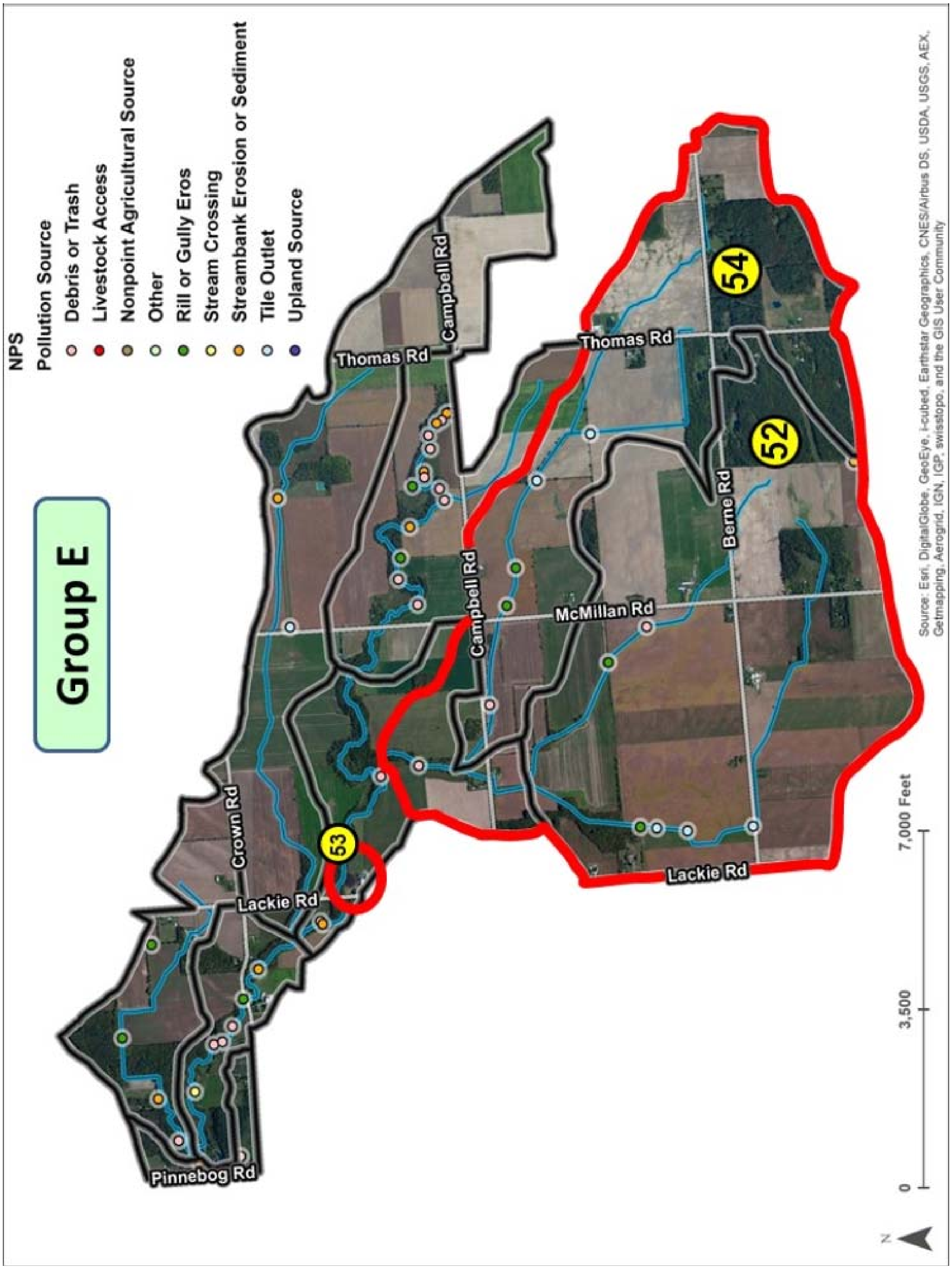


Figure 12. Critical areas -- subwatershed group E

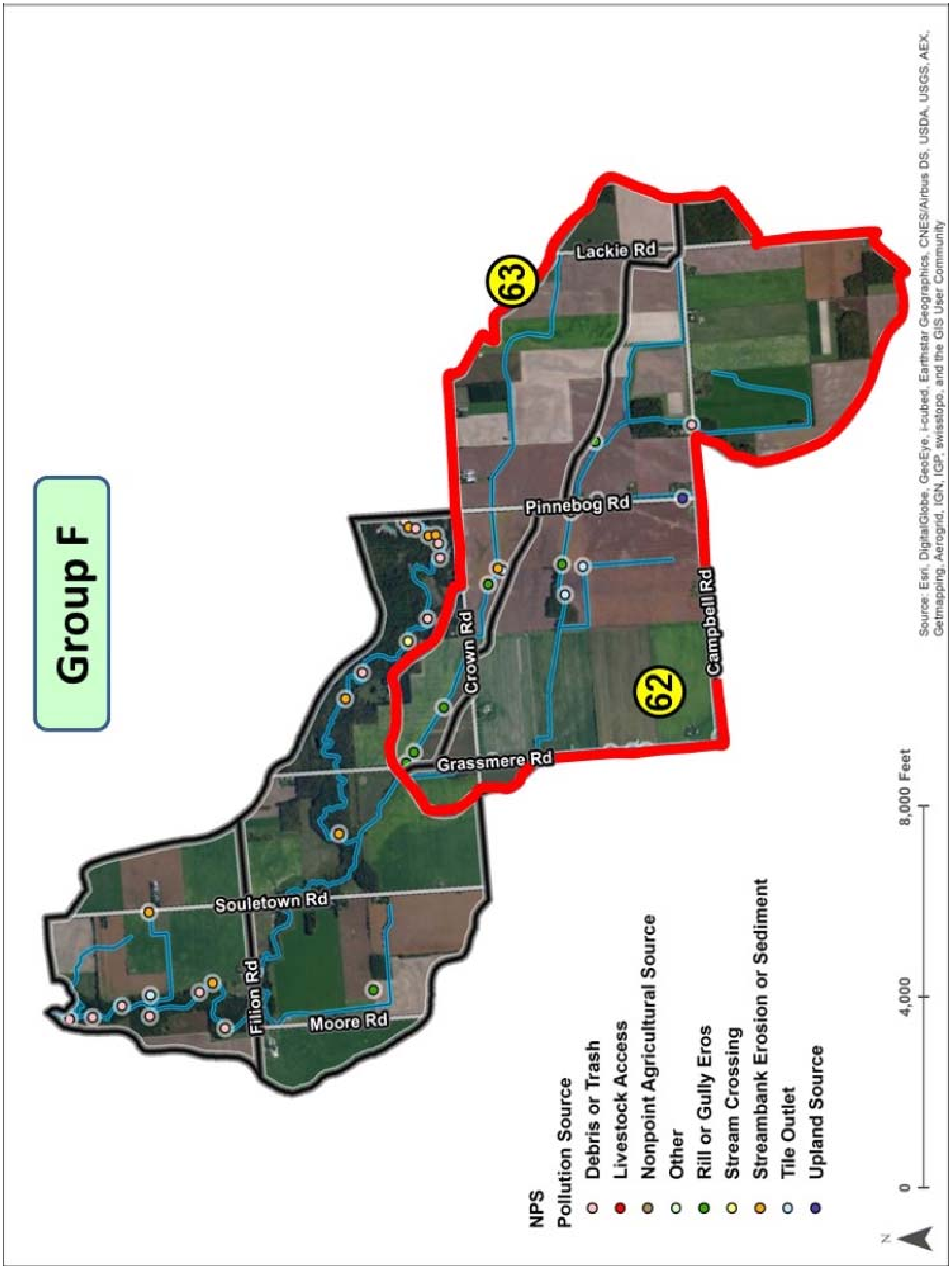


Figure 13. Critical areas -- subwatershed group F

Estimated load reductions associated with practices for each critical area are provided in Appendix C. Based on available information, these represent approximate ranges that reflect the anticipated effectiveness of individual practices. Actual reductions could vary depending on factors such as soil type / condition, whether practices are used alone or in combination, and the level of existing implementation in each critical area. These estimates may be refined as new information becomes available that accounts for existing BMPs, their location within the appropriate critical area, and their pollutant reduction effectiveness.

The importance of effective targeting in critical areas coupled with well-documented effectiveness monitoring is illustrated in Figure 14. In the case of the upper curve, the benefit derived from BMPs installed was high. The net result is a smaller area that requires additional treatment. As additional BMP installation moves forward in Bad Axe critical areas, the benefit derived from existing BMPs should be evaluated to ensure that needed load reductions occur and water quality targets are achieved.

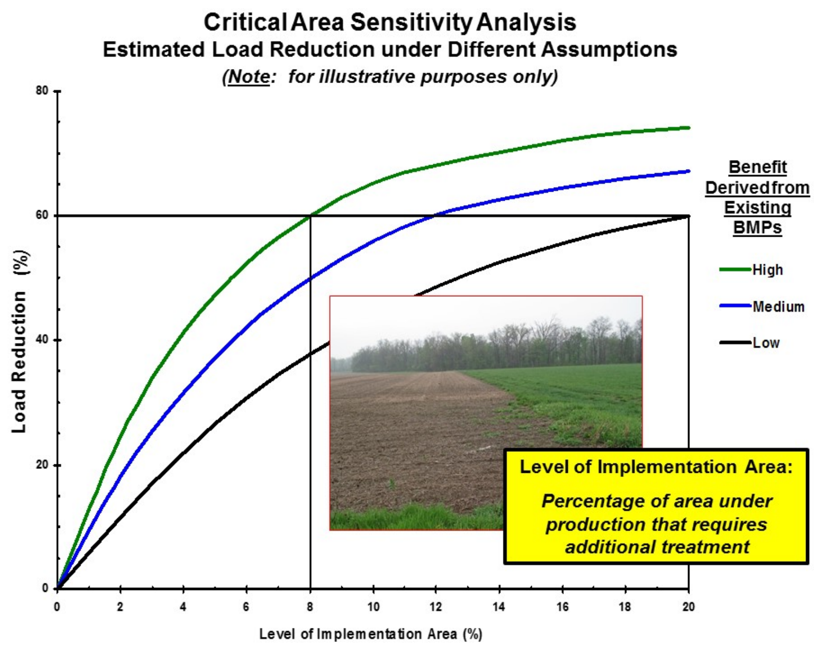


Figure 14. Critical area sensitivity analysis

Bacteria *(E. coli)*.

Critical area identification for bacteria source reduction is limited to the MDEQ 2008 monitoring information. This data indicates that priority subwatershed groups are A, B, C, and D. Field inventory work specifically targeted towards sources of *E. coli* was not conducted and remains a priority need for this TMDL implementation plan. A part of this priority implementation plan need includes *E. coli* source tracking (e.g., canine scent detection, biomarker methods).

Failing or poorly designed OSDS are likely a significant source of *E. coli* in unsewered areas, which was identified in the Pinnebog WMP. Management measures to address elevated bacteria concentrations from these sources include identifying / correcting on-site septic system failures. Reducing *E. coli* loads from agricultural sources include implementing livestock waste management practices, installing riparian buffers / filter strips where pasture runoff can reach local waters, restricting livestock access to streams / ditches, and drainage water management in critical areas where manure is applied to crop land as fertilizer. Management measures to address bacteria loads in urban critical areas include stormwater management, identify / eliminate illicit discharges, and reduce *E. coli* from pet waste.

In the absence of field inventory information, land use, soils, and air photo analysis is used to suggest starting points for follow-up. Based on this limited information, critical areas for *E. coli* are summarized in Table 9. These areas are shown in Figure 15 and Figure 16 for groups A and B. Critical areas for subwatershed group C are shown in Figure 11. Again, these determinations are based on current available information. Additional field inventory work for *E. coli* will be conducted as part of this TMDL Watershed Implementation Plan. The critical area analysis will be revised as new information becomes available through that effort.

Table 9. Critical area analysis summary for high priority subwatershed groups -- *E. coli*

Group *(Outlet Point)*	Critical Area ID		On-site Disposal Systems [a]	Livestock and Agriculture [b]	Urban Stormwater [c]
A *(above WWTP)*	11	Turner 1131	●●	○	○
	14	Crumback 632	●●	○	○
B *(Pigeon Road)*	21	Bad Axe 633	◗	○	●●
	23/24	Bad Axe 149	◗	○	●●
C *(Berne Road)*	31	Richardson 1077	◗	●●	n.a.
	34	Stenton 162 / Stenton 165	◗	◗	n.a.
	38	Symons 915	◗	◗	n.a.
D *(Campbell Rd.)*	41	Bad Axe 915	◗	●●	n.a.

Notes: ●● High priority BMP ◗ Medium priority BMP ○ Provide general benefit for load reduction

[a] correct on-site septic system failures
[b] livestock management; riparian buffers; filter strips; controlled drainage structures
[c] urban stormwater management; eliminate illicit discharges; reduce pet waste runoff

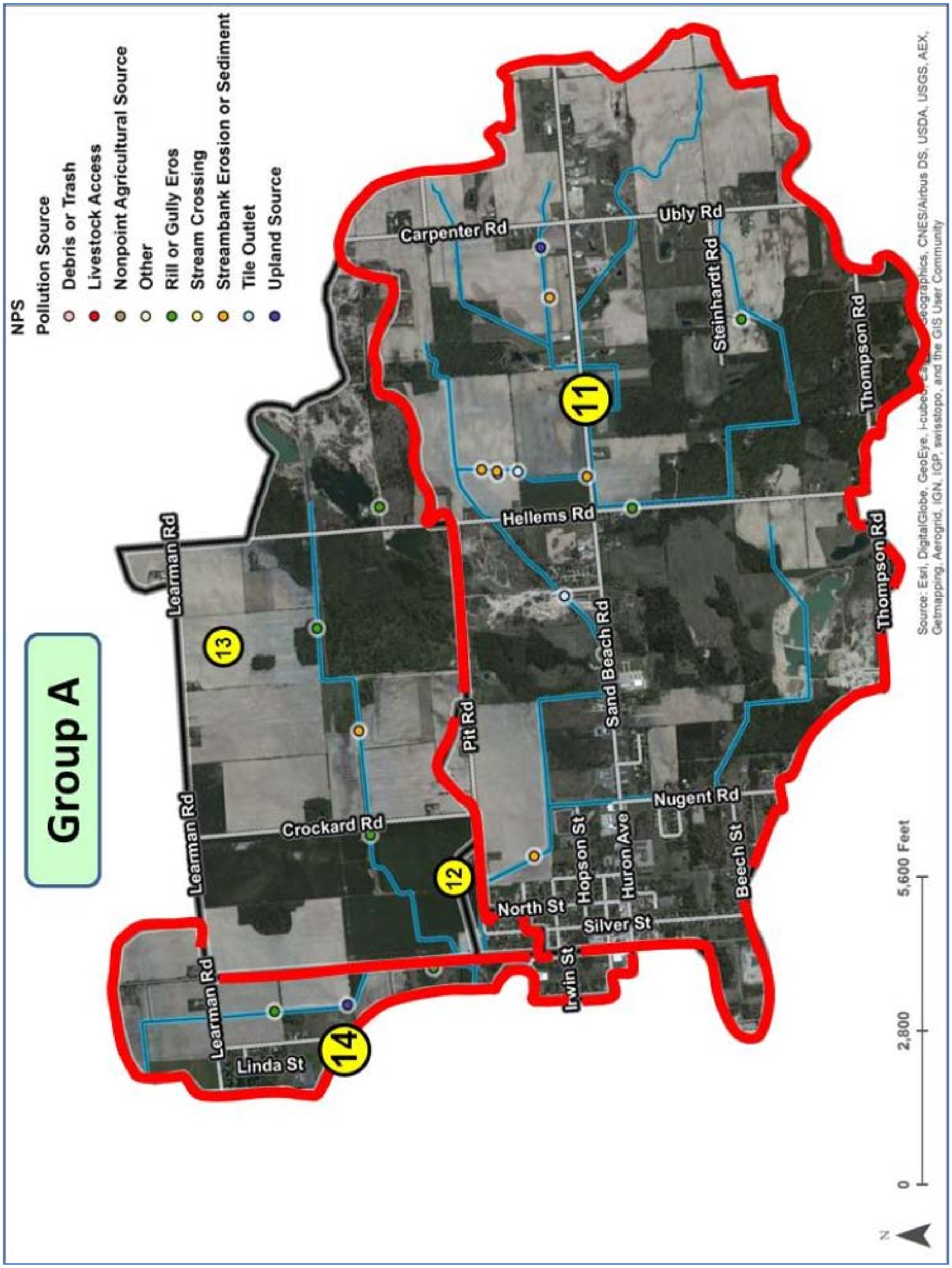


Figure 15. Critical areas -- subwatershed group A

Figure 16. Critical areas -- subwatershed group B

4. TMDL Development

The TMDL represents the maximum loading that can be assimilated by a waterbody while still achieving the applicable water quality standards. The currently impaired designated uses for the Bad Axe Creek TMDL are *"other indigenous aquatic life and wildlife"*, partial body contact recreation, and total body contact recreation (May 1 to October 31). The applicable WQS are described in Section 2.4, which includes a description of narrative and numeric criteria. Targets designed to achieve these criteria are identified for the Bad Axe Creek TMDL. TMDL development also involves a linkage analysis that connects TMDL targets with potential sources. Once these linkages are described, the loading capacity (or maximum allowable load) is defined and each source category is provided with an allocation; the sum of all allocations must fit within the maximum allowable load.

4.1 Linkage Analysis

TMDL development requires a combination of technical analysis, practical understanding of important watershed processes, and interpretation of watershed loadings and receiving water responses to those loadings. An essential component of TMDL development is establishing a relationship between numeric indicators used to determine attainment of designated uses and pollutant source loads. The linkage analysis examines connections between water quality targets, available data, and potential sources. The focus of the linkage analysis is to:

- interpret watershed loadings and receiving water responses to those loadings; and
- describe logic used to develop TMDL targets and allocations.

Hydrology plays an important role in the linkage analysis. A pollutant load is the product of flow times the concentration and a conversion factor. The hydrology of the Bad Axe Creek watershed is driven by local climate conditions. This includes surface runoff and subsurface flow, as ditching and channelizing has been used throughout this region to drain areas where soils are too wet for crop production.

Limited flow data makes it difficult to describe the full range of hydrologic conditions the Bad Axe Creek watershed may experience. However, information from two stations operated by the U.S. Geological Survey (USGS) provides some insight regarding hydrologic patterns in the area based on similar land use, geology, and topography: Pigeon River near Caseville (04159010) and Cass River near Cass City (04150500). Flow monitoring data from these locations was used to examine hydrologic patterns including seasonal and inter-annual variation. Using this evaluation, duration curves were developed, which provide a quantitative estimate that describes the full range of flow conditions in Bad Axe Creek (Appendix J-2).

Total Phosphorus

Phosphorus can exist in dissolved and particulate forms. When dissolved, some of the phosphorus is available for use by aquatic plants; increased growth in rooted plants and floating algae can result. Phosphorus in the particulate form, such as that adsorbed to eroding soil, can be released as dissolved phosphorus under certain conditions, contributing to increased plant growth. A reduction in phosphorus loadings to Bad Axe Creek (AUID 04080103-0302-02) is expected to directly address the causes of designated use nonattainment, including excess algal growth and nuisance levels of aquatic plants. Reduction needs based on the 2008 monitoring data are summarized in data analysis discussion (Section 2.5, Table 4).

The linkage analysis sets the stage for moving from identified water quality concerns to meaningful solutions. A longitudinal glimpse at in-stream conditions for Bad Axe Creek is shown in Figure 4. The increase in phosphorus concentrations immediately below the Bad Axe WWTP is very noticeable. However, in-stream processes appear to attenuate that effect. This attenuation is likely the result of nutrient uptake by the abundant vegetation in the channel and along the banks of Bad Axe Drain from the WWTP outfall to Pigeon Road. Even with this attenuation, total phosphorus concentrations still remain well above the 60 µg/L growing season target, which indicates the need for additional reductions. Seasonal average phosphorus concentrations increase again as Bad Axe Creek flows through the lower agricultural portion of the watershed.

The duration curve framework can be used in the linkage analysis to examine relationships between water quality and potential sources. Appendix J presents water quality duration curves for the MDEQ sites monitored for total phosphorus in Bad Axe Creek.

Phosphorus concentrations at locations sampled below subwatershed groups C through F increase following summer storms (Figure 6). As indicated in the water quality duration curves, most of the Bad Axe data was collected under moist conditions. There were only two samples under high flow conditions when the potential for the greatest concentrations (and loads) exists. However, the NCWQR operates a site in northwest Ohio of comparable size and land use to Bad Axe Creek that can be used to examine general patterns. This site (Rock Creek at Tiffin) is located in the Sandusky watershed; a tributary to western Lake Erie. The NCWQR data illustrates the potential magnitude of these high flow concentrations during the growing season, as shown in Figure 17 (the moist zone for Bad Axe Creek at Filion Road is included for comparison).

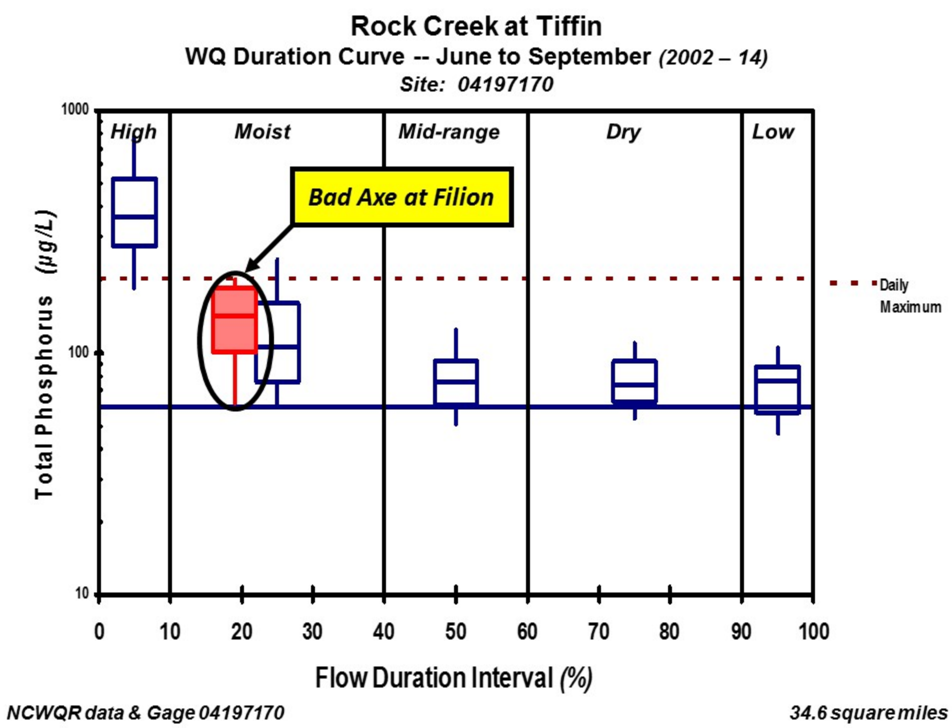


Figure 17. Water quality duration curve -- Bad Axe compared to Rock Creek TP

Bacteria *(E. coli)*

A longitudinal glimpse at *E. coli* conditions for Bad Axe Creek is shown in Figure 7. A time series of the 2008 E. coli survey data is shown in Figure 8. Again, the excessively high Berne Road sample was more than an order of magnitude greater than all other samples taken across the watershed on the same day. This is indicative of a site-specific source, as opposed to a watershed-wide problem. Similarly, the high variability reflected by the wide “box and whisker” for Campbell Road also indicates the potential effect of a site-specific source influencing sample results at the location. Again, the duration curve framework can be used in the linkage analysis to examine relationships between water quality and potential sources. Appendix J presents water quality duration curves for the MDEQ sites monitored for *E. coli* in Bad Axe Creek.

4.2 Loading Capacity and Allocations

Under the regulatory framework for development of TMDLs, calculation of the loading capacity for impaired segments identified on the §303(d) list is an important step. EPA’s regulation defines loading capacity as *“the greatest amount of loading that a water can receive without violating water quality standards”* [40 CFR Part 130.2(f)]. The loading capacity is the basis of the TMDL and provides a measure against which attainment with WQS will be evaluated. The loading capacity also guides pollutant reduction efforts needed to bring a water into compliance with standards.

The loading capacity comprises the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a Margin of Safety (MOS), either implicitly or explicitly, that accounts for uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

$$\text{Loading Capacity} = \Sigma\text{WLAs} + \Sigma\text{LAs} + \text{MOS}$$

All current and future NPDES permitted facilities discharging to listed AUIDs in the Bad Axe Creek watershed are subject to WLAs. Table 6 lists facilities that currently hold discharge permits to the TMDL area including three individual NPDES permits: Bad Axe Wastewater Treatment Plant (WWTP), Wil-Le Farms, and Michigan Department of Transportation (MDOT) Statewide Municipal Separate Storm Sewer System (MS4). Certificates of Coverage (COCs) under general NPDES permits include: one CAFO, one groundwater cleanup, two WWSLs, and three storm water discharges from industrial activities. Sources listed may be shifted from LA (nonpoint source) to WLA (point source), or from WLA to LA, in the future, depending on changes in regulations.

Development of the Bad Axe Creek loading capacity and allocations recognizes that the TMDL targets established to achieve the applicable WQS use concentration-based multiple averaging periods (e.g., growing season average, 30-day geometric mean, daily maximum). The loading capacity of most waterbodies is not constant over time (USEPA, 2007a). Reasons include changes in flow conditions, temperature, seasons, etc. This inherent variability is the reason that the Bad Axe TMDL will continue to express the loading capacity for the long-term average targets as concentrations; specifically, 60 µg/L total phosphorus as a growing season average (June 1 to September 30) and 130 *E. coli* per 100 mL as a 30-day geometric mean (May 1 through October 31).

A daily maximum value is also needed as part of the loading capacity to satisfy USEPA regulatory review requirements for approvable TMDLs. As discussed in Section 2.4 and Appendix J, these values are 200 µg/L for total phosphorus and 300 *E. coli* per 100 mL. The maximum *"daily load"* and long-term (or *"non- daily"*) average concentration-based target work together. The *"non-daily"* concentration-based target serves as a benchmark that connects to the applicable water quality standards. Multiple averaging periods in TMDLs provide a way to achieve both long-term program objectives and focus implementation efforts while avoiding short term problems.

Total Phosphorus

Loading Capacity.

Development of the loading capacity for total phosphorus in Bad Axe Creek uses multiple averaging periods. As described in Section 2.4, the primary target to address plant nutrient impairments in Bad Axe Creek is 60 µg/L total phosphorus; applied as a growing season average (June 1 to September 30). In addition, a maximum daily target of 200 µg/L is identified; one that recognizes the inherent variability associated with day-to-day fluctuations in phosphorus loads and that also accounts for critical conditions to avoid short-term water quality problems.

The 200 µg/L June 1 to September 30 seasonal daily maximum TP target is based on the statistical characteristics that describe total phosphorus variability. The statistical characteristics used to derive the 200 µg/L daily maximum target are based on long-term TP monitoring information collected in Michigan (Appendix J-1). The statistical relationship between these two values (i.e., the 200 µg/L and the 60 µg/L) ensures that attaining this maximum daily TMDL target will also lead to achieving the growing season average.

Typically, loads are expressed as mass per time, such as pounds per season or pounds per day. The loading capacity of a stream is determined using:

- the water quality criterion or target value; and
- a receiving water flow that reflects critical conditions.

Critical conditions used for TMDL development in Michigan are established with an acceptably low frequency of occurrence that, if protected for, should also be protective of other more frequent occurrences (Goodwin, 2007). Critical conditions are typically defined as an exceedance flow. An exceedance flow is a statistically determined flow that is exceeded a specific percentage of time using a flow duration curve. For example, the 95% exceedance flow is the flow expected to be exceeded 95% of the time; this reflects low flow conditions. Similarly, the 1-day exceedance flow represents the daily average flow expected to be exceeded one day each year (i.e., one day divided by 365 days, or 0.274% of the time), which reflects high flow conditions.

Critical conditions for the applicability of WQS are given in MDEQ's Rule 90 (R 323.1090). For water quality problems associated with low flow conditions, R323.1090(2)(a) defines this as the 95% exceedance flow. However, Rule 90 also provides that *"alternate design flows may be used for intermittent wet weather discharges as necessary to protect the designated uses of the receiving water"* [R 323.1090(4)]. The dense aquatic plant communities are the result of chronic conditions associated with seasonal average flows, as well as excessive phosphorus loads delivered during storm events (e.g., the 1-day exceedance flow). For this reason, the loading capacity and allocations for total phosphorus in Bad Axe Creek are expressed through the duration curve framework.

The duration curve approach uses the "flow to load" calculation across the range of all daily average flows. This method involves multiplying the flow times the daily maximum TP target concentration times a conversion factor. The conversion factor translates the product of flow (expressed as cubic feet per second) and concentration (expressed as micrograms per liter) into a load (expressed as pounds). On a daily basis, this value is 0.005393; derivation of this conversion factor is described in Appendix J (Table J-4). The TP loading capacity, expressed as pounds per day, is determined by using the following equation:

$$\text{Load Capacity} = \text{Flow} * \text{TP Target} * \text{Conversion Factor}$$

where:

Load Capacity = daily maximum load *(pounds / day)*
Flow = duration curve flow interval *(cubic feet per second)*
TP Target = 200 µg/L *(daily maximum)*
Conversion Factor = 0.005393 (see Table J-4)

Flow data in the Bad Axe watershed is limited to spot measurements associated with the 2008 water quality survey. In order to estimate flows for Bad Axe Creek, a drainage area weighting approach was used in conjunction with stream discharge data from the USGS Pigeon River gage. Thus, the design flow is determined using the Pigeon River gage (04159010) as a representative site, then applied to Bad Axe Creek based on a drainage area weighting factor (i.e., the Bad Axe Creek drainage area divided by the Pigeon River drainage area). These flows are summarized in Appendix J (Table J-5).

The total phosphorus loading capacity for both the listed AUID (04080103-0302-02) and the non-listed downstream AUID (04080103-0302-01) are shown in Table 10. The downstream AUID is included in this TMDL because higher phosphorus concentrations were observed throughout this reach of Bad Axe Creek. *Cladophora* was present, but in smaller concentrations in the downstream AUID because there were few attachment sites for algae and light was limited. However, there were substantial quantities of *Cladophora* in the channel where rock and cobble are exposed to sunlight. For that reason, phosphorus reductions will still benefit the downstream AUID and corresponding implementation opportunities should be considered.

Table 10. Bad Axe Creek watershed loading capacity -- Total Phosphorus

AUID	Group			Duration Curve Zone (pounds per day) [a]				
		Outlet Point	Area (sq.mi.)	*High*	*Moist*	*Mid*	*Dry*	*Low*
04080103-0302-02	**A**	Above Bad Axe WWTP	6.74	7.62	1.74	0.56	0.18	0.001
	B	Pigeon Road	7.93	10.21	3.30	1.91	1.46	1.251
	C	Berne Road	18.08	21.7	5.93	2.76	1.73	1.252
	D	**Campbell Road**	**18.64**	**22.3**	**6.08**	**2.81**	**1.74**	**1.252**
04080103-0302-01 *[not currently on §303(d) list for nutrients]*	**E**	Pinnebog Road	24.66	29.1	7.63	3.31	1.90	1.252
	F	**Bad Axe Creek mouth**	**29.50**	**34.6**	**8.89**	**3.72**	**2.03**	**1.253**

Note: [a] Flows used to derive each loading capacity listed in Appendix J, Table J-5.

The loading capacity values were determined using the duration curve framework because excessive phosphorus loads are delivered across all flow conditions. Under the duration curve framework, the loading capacity is essentially the curve itself, which sets the *"total maximum daily load"* on any given day, is determined by the flow on the particular day of interest. The use of duration curve zones can help provide a simplified summary through the identification of discrete loading capacity points by zone, as shown in Table 10. The shaded row in each AUID represents its loading capacity based on achieving a daily maximum of 200 µg/L total phosphorus. Sampled loads from the 2008 monitoring data relative to the loading capacity are provided in Appendix J-2.

Wasteload Allocations.

There are eight facilities and one agency (MDOT) with MDEQ permit coverage in the listed Bad Axe AUID 04080103-0302-02. The Bad Axe WWTP is the only one with a continuous discharge that requires a WLA across all flow conditions. The current NPDES permit limit for this facility is a maximum 5.1 pounds per day TP (determined as a monthly average based on a maximum daily concentration of 1 mg/L total phosphorus). A WLA for the Bad Axe WWTP, based on its current permit limit, exceeds the loading capacity at the AUID outlet (Campbell Road) across all zones except high and moist conditions. However, the current average growing season discharge TP from the Bad Axe WWTP is about half of its permit limit. In addition, the 2008 MDEQ monitoring data showed that phosphorus concentrations decrease by about 50 percent from the Bad Axe WWTP to Pigeon Road.

The focus of this TMDL is to achieve a growing season average concentration of 60 µg/L TP at the AUID outlet. For this reason, the WLA for the Bad Axe WWTP is less than the effluent load limit in the existing NPDES permit. The WLA is determined from the facility's current estimated load using Discharge Monitoring Report (DMR) data, and takes into account the apparent attenuation that occurs from the WWTP to Pigeon Road. Compliance with the WLA should be based on in-stream monitoring data at the Pigeon Road location. Additional ambient monitoring data collected in Bad Axe Drain at Pigeon Road can be used to support the translation of this WLA to any needed NPDES permit revisions during the next renewal cycle.

The WLAs for the stormwater permits are based on each facility's contributing area. Runoff from these facilities is only expected to occur under high flow and moist conditions. Similarly, the MS4 WLA for MDOT is based on the state road contributing area. The runoff generated for each area (determined as a unit area flow from the duration curve) is multiplied by the daily maximum concentration (200 µg/L) to determine high flow and moist condition WLAs.

The WWSL general permit does not allow a discharge from these facilities during the growing season. However, extreme weather conditions may force the need for an emergency discharge. For that reason, WLAs have been identified for these facilities under high flow conditions based on contributing area (similar to the stormwater WLAs described above).

The CAFO general permit prohibits any dry weather discharge. The Wil-Le Farms CAFO (MIG440027) and Hass Feedlot CAFO (MIG010042) must comply with all authorized discharge and overflow requirements described in the State of Michigan's NPDES CAFO General Permit (MIG010000). In accordance with the CAFO General Permit, overflow events from Wil Le Farms and Haas Feedlot CAFOs are allowable due to precipitation related overflows from CAFO storage structures which are properly designed, constructed, operated and maintained in accordance with CAFO permits (MIG440027 and MIG10042). Discharges from such overflows are allowable only if they do not cause or contribute to a violation of water quality standards.

The NPDES CAFO permit contains several measures designed to prevent *E.coli* and nutrients from entering surface waters from the production area and waste (manure) storage sites. At production facilities, and associated manure storage sites, the permit requires properly designed, constructed, and maintained manure storage structures. These structures must be designed to store at least six months of generated production area waste, with additional reserve capacity for normal and design-storm precipitation, and the required freeboard amount. All manure storage structures must be inspected once per week by the CAFO operator, providing assurance against overflow and potential structural damage.

Animal waste for land application from the CAFO is transferred to contract haulers. The CAFO general permit indicates that such waste is not under the operational control of the CAFO owner. However, the permit does require completion of a manifest to track the transfer and use of the CAFO waste.

Load Allocations.

Load allocations have been identified for the Bad Axe TMDL to account for runoff from nonpoint sources in the watershed. These allocations are based on meeting the loading capacity that will attain the WQS. Under low flow conditions, most water in Bad Axe Creek originates from the Bad Axe WWTP. Accordingly, the LA under low flow conditions is negligible. As flows increase, the LA is determined by summing up the WLAs and then subtracting that amount from the loading capacity for each respective duration curve zone. As flows increase, the percentage of the LA relative to the WLAs is progressively greater. This reflects the fact that under high flow conditions, most of the TP load originates from nonpoint sources.

Summary.

The 2008 monitoring defines overall reduction needs based on growing season average concentrations (Table 4). A summary of the components (WLAs and LAs) of the TMDL is presented in Table 11.

Table 11. Bad Axe Creek TMDL allocations -- Total Phosphorus

AUID	Group		Duration Curve Zone *(pounds per day)*				
		Name [Type]	***High***	***Moist***	***Mid***	***Dry***	***Low***
04080103-0302-02	**A**	Rooney Contracting [d]	0.005	0.001	0.00	0.00	0.000
		J W Hunt [d,f]	0.005	0.001	0.00	0.00	0.000
		Huron & Eastern Railway [d]	0.005	0.001	0.00	0.00	0.000
	B	Bad Axe WWTP [a]	1.25	1.25	1.25	1.25	1.25
		Colfax Township WWSL [b]	0.01	0.00	0.00	0.00	0.000
	C	Wil-Le Farms [c]	1.2 [g]	0.00	0.00	0.00	0.000
		Huron Co Medical Care WWSL [b]	0.025	0.00	0.00	0.00	0.000
	D	Hass Feedlot-2 [c]	0.4 [g]	0.00	0.00	0.00	0.000
	A,B,C	MDOT [e]	0.20	0.057	0.00	0.00	0.000
	AUID LOAD ALLOCATIONS		19.2	4.77	1.56	0.49	0.002
	MARGIN OF SAFETY		Implicit				
	AUID TOTAL		**22.3**	**6.08**	**2.81**	**1.74**	**1.252**
04080103-0302-01 *[not currently on §303(d) list for nutrients]*	**AUID LOAD ALLOCATIONS**		12.3	2.81	0.91	0.29	0.001
	MARGIN OF SAFETY		Implicit				
	AUID TOTAL		**34.6**	**8.89**	**3.72**	**2.03**	**1.253**

Notes:
[a] Non-Industrial Sanitary Wastewater (WWTP). Low flow WLA based on the facility's DMR concentration and flow data. In-stream monitoring at Pigeon Rd. recommended to collect data that will help translate WLA into NPDES permit limit.
Non-Industrial Sanitary Wastewater (WWSL)
[b] Concentrated Animal Feeding Operation (CAFO)
[c] Industrial Storm Water Only
[d] MS4 Stormwater
[e] GW-Commercial
[f] WLAs must be consistent with the assumptions described in Section 4.2 [from Michigan's NPDES CAFO General
[g] Permit (MIG010000)]

Bacteria *(E. coli)*

Loading Capacity.

As indicated in Section 2.4, the targets for this bacteria TMDL are the TBC 30-day geometric mean WQS of 130 *E. coli* per 100 mL and daily maximum of 300 *E. coli* per 100 mL, and the PBC daily maximum WQS of 1,000 *E. coli* per 100 mL. Concurrent with the selection of a numeric concentration endpoint, development of the loading capacity requires identification of the critical condition. The “critical condition” is defined as the set of environmental conditions (e.g., flow) used in development of the TMDL that result in attaining WQS and has an acceptably low frequency of occurrence.

For most pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day). For *E. coli*, however, mass is not an appropriate measure, and the USEPA allows pathogen TMDLs to be expressed in terms of organism counts (or resulting concentration). Therefore, this pathogen TMDL is concentration-based, consistent with R 323.1062. The TMDL is equal to the TBC target concentrations of 130 *E. coli* per 100 mL as a 30-day geometric mean and daily maximum of 300 *E. coli* per 100 mL in all portions of the TMDL reach for each month of the recreational season (May through October), and PBC target concentration of 1,000 *E. coli* per 100 mL as a daily maximum year-round. The existence of multiple sources of *E. coli* to a water body result in a variety of critical conditions (e.g., high flow is the critical condition for storm water-related sources and low flow is the critical condition for dry weather sources such as illicit connections); therefore, no single critical condition is applicable for this TMDL. Expressing the TMDL as a concentration equal to the WQS ensures that the WQS will be met under all critical flow and loading conditions.

Because the *E. coli* portion of this TMDL is concentration-based, the total loading for this TMDL is equal to the TBC WQS of 130 *E. coli* per 100 mL as a 30-day geometric mean, 300 *E. coli* per 100 mL as a daily maximum during the recreation season, and PBC WQS of 1,000 *E. coli* per 100 mL as a daily maximum year-round.

Wasteload Allocations.

The bacteria WLA for the facilities discharging to the TMDL area is equal to 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum during the recreational season between May 1 and October 31, and 1,000 *E. coli* per 100 mL as a daily maximum the remainder of the year. The WLA for the discharge of unpermitted, untreated sanitary wastewater (including leaking sanitary sewer systems, Sanitary Sewer Overflows (SSOs), and illicit connections) is zero.

Load Allocation.

Load Allocation refers to the nonpoint source portion of the TMDL. The numeric LA depends upon whether the source is allowable or not allowable. Sources that are not allowable receive a LA of zero. Because this TMDL is concentration-based, the LA for allowable sources is set equal to 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum during the recreational season, and 1,000 *E. coli* per 100 mL as a daily maximum year-round. This LA is based on the assumption that runoff from all land, regardless of use, will be required to meet the WQS.

4.3 Margin of Safety

Section 303(d) of the Clean Water Act and EPA's regulations at 40 CFR 130.7 require that *"TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numeric water quality standards with seasonal variations and a margin of safety (MOS) which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality."* The margin of safety (MOS) can either be implicitly incorporated into conservative assumptions used to develop the TMDL or added as a separate explicit component of the TMDL (USEPA, 1991).

Total Phosphorus.

A MOS is implicit in the total phosphorus TMDL because the quality of the biological and plant community, its integrity, and overall composition represent an integration of the effects of spatial and temporal variability in nutrient loads to the aquatic environment. Ultimately it is the reflection by the biological community, signified by aquatic plant communities at less than nuisance conditions, which is the goal of the nutrient portion of this TMDL thereby providing a MOS for the secondary numeric TP target. Follow-up biological and habitat quality assessments will be conducted to determine the progress in attaining the TMDL goals.

Bacteria.

The bacteria component of this TMDL uses an implicit MOS because no rate of pollutant decay was used. Pathogen organisms ordinarily have a limited capability of surviving outside of their hosts, and therefore, a rate of pollutant decay could be developed. However, applying a rate of pollutant decay could result in an allocation that would be greater than the WQS, thus no rate of decay is applied to provide for a greater protection of water quality. The use of the TBC (130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum during the recreational season) and PBC (1,000 *E. coli* per 100 mL as a daily maximum the remainder of the year) WQS as a WLA and LA is a more conservative approach than developing an explicit MOS and accounts for the uncertainty in the relationship between pollutant loading and water quality, based on available data and the assumption to not use a rate of pollutant decay.

4.4 Seasonal Variation

TMDLs must consider critical conditions and seasonal variation for streamflow, loading, and water quality parameters. The critical condition is the set of environmental conditions for which controls designed to protect water quality will ensure attainment of water quality standards for all other conditions. The intent of this requirement is to ensure protection of water quality in waterbodies during periods when they are most vulnerable.

This data analysis evaluated Bad Axe Creek monitoring information under different flow conditions including use of the duration curve methodology. The approach demonstrated that TP concentrations and loads exert the greatest adverse effect on aquatic life under high flow conditions. The duration curve methodology considers both seasonal and flow variation. In addition, the 1-day maximum loading capacity for TP ensures seasonal variability is taken into consideration in the calculation of the TMDL. Finally, the concentration-based target for *E. coli* applies across the entire recreation season, ensuring that seasonal variation is accounted for in the bacteria TMDL.

4.5 Reasonable Assurance

The Bad Axe Creek watershed includes both point and nonpoint sources. Point sources discharges are regulated through NPDES permits. Based on current information, the NPDES permits in the Bad Axe Creek watershed appear consistent with the goals of the TMDL. U.S. EPA's 1991 TMDL guidance states that the TMDL should provide reasonable assurances that the implementation of nonpoint source control measures will achieve expected load reductions. Thus, the focus of reasonable assurance for this TMDL is to ensure that the nonpoint source reductions will occur in the Bad Axe Creek watershed. To that end, MDEQ coordinates with organizations and programs that have an important role or can provide assistance for meeting the goals and recommendations of this TMDL. Efforts specific to the Bad Axe Creek watershed are described below. When sufficient additional water quality information has been collected in the watershed, point and nonpoint source reduction efforts can be revisited via an adaptive management framework.

Stakeholders

An important aspect of the Bad Axe TMDL Watershed Implementation Plan is finding local partners who will be involved as work proceeds. The HCD plays a key role in the implementation of this Plan. Other major stakeholders include the Huron County Drain Commission (HCDC), the Huron County Road Commission (HCRC), the Huron County Health Department (HCHD), the City of Bad Axe, other NPDES permittees, key dairy, crop, and livestock producers, local recreational and resource interest groups, universities, local land improvement and drainage contractors who support agricultural producers, and local residents. Table 12 provides a list of stakeholders and partners.

Building on partnerships established during development of the Pinnebog WMP, the HCD will continue to lead short- and mid-term implementation activities. Key stakeholders in this effort include HCHD, the Michigan Department of Agriculture and Rural Development (MDARD), HCDC, the City of Bad Axe, and Saginaw Valley State University. In addition, regulatory authorities have been granted to several stakeholders. Included are: HCHD (on-site septic regulation and enforcement); HCRC (road stream crossing fixes); HCDC (manage drains and regulate drain inputs); MDEQ (permits, TMDLs, Part 31 regulations); and MDARD (right-to-farm issues).

Table 12. Implementation partners

Partner	Description	Role in Implementation
Huron Conservation District	Promote stewardship & create a desire to conserve, protect, or enhance natural resources. Assist landowners & operators with state and federal conservation programs that help to reduce soil erosion, improve water quality, & increase wildlife habitat.	Technical assistance, consultation
Local Governments • *City of Bad Axe* • *Huron Co. Board of Commissioners* • *Huron County Drain Commission* *** • *Huron County Road Commission* *** • *Huron County Health Department* *** • *Colfax Township* • *Verona Township* • *Meade Township* • *Chandler Township*	Local governments working cooperatively to improve water quality through operation of wastewater treatment facilities and through the MS4 program.	BMP implementation
Private Wastewater Systems • *Huron County Medical Care* • *Huron Memorial Hospital* Private sector & landowners	Private entities working cooperatively to improve water quality through operation of wastewater treatment facilities and through implementation of Best Management Practices.	BMP implementation
Advisors and Service Providers • *MSU Extension Service* • *Saginaw Valley State University* • *Crop Production Services* • *Cooperative Elevator Co.* • *Farmers Co-op Kinde* • *Farm Bureau (Huron Co. & state office)* • *Michigan Agribusiness Association* • *Michigan Sugar Company* • *Michigan Milk Producers Assoc.* • *Crop / land improvement advisors* • *Comprehensive Nutrient Management Plan providers* • *Drainage management contractors* • *Saginaw Bay Watershed Initiative Network* • *Greenstone Farm Credit Services*	Organizations and private entities working cooperatively to improve water quality through technical advice (e.g., certified crop advisors, nutrient management, drainage management, soil health, land improvement), financial assistance, and monitoring.	Technical & financial assistance Consultation
Interest Groups • *Saginaw Bay Land Conservancy* • *The Nature Conservancy* • *Pheasants Forever* • *Other recreational groups*	Organizations working cooperatively to improve water quality through technical assistance and consultation.	Technical assistance Consultation
Local NRCS Office USDA Farm Service Agency	Conservation leader for natural resources, ensuring private lands are conserved, restored, and more resilient to environmental challenges.	Technical & financial assistance Consultation
State & Federal Agencies • *MI Dept. of Environmental Quality* *** • *MI Dept. of Natural Resources* • *MI Dept. of Agriculture & Rural Dev.* *** • *MI Dept. of Transportation* • *US Environmental Protection Agency* • *US Geological Survey*	Provide technical expertise as well as grant funding for watershed protection programs and practices.	Technical & financial assistance
*** Denotes stakeholders with some regulatory authority.		

Point Sources

The Bad Axe WWTP is required to meet its NPDES permit limits. For TP, this is 1 mg/L and 5.1 pounds per day, both determined as a monthly average. For bacteria, Michigan regulates sanitary wastewater discharges using fecal coliform as the indicator. Sanitary wastewater discharges are required to meet 200 fecal coliform per 100 mL as a monthly average and 400 fecal coliform per 100 mL as a maximum. Michigan's WQS for *E. coli* are based upon USEPA's 1986 criteria document (USEPA, 1986). The USEPA criterion of 126 *E. coli* per 100 mL is the basis for Michigan's TBC WQS of 130 *E. coli* per 100 mL. It is intended to provide a level of protection producing no more than 8 illnesses per 1,000 swimmers and approximates the degree of protection provided by the fecal coliform indicator of 200 fecal coliform per 100 mL bacteria standard. The sanitary discharges are expected to be in compliance with the ambient PBC and TBC *E. coli* WQS if their NPDES permit limits for fecal coliform are met. The Bad Axe WWTP provides year-round disinfection, adding a level of confidence that the WQS for *E. coli* will be met.

All Wastewater Stabilization Lagoon discharges under general permit MIG580000 must receive MDEQ approval prior to beginning a discharge, and monitor their effluent for fecal coliform and TP. During discharge, monitoring occurs the first day and every other day after the first day of discharge. Discharge is prohibited between January 1 and February 28/29, and from June 1 through September 30. SSOs are illegal events, and the MDEQ will continue to take appropriate actions when they are reported.

The COCs for the general industrial storm water permit (MIS310000) listed in Table 6, specify that facilities need to obtain a certified operator who will supervise the control structures at the facility, eliminate any unauthorized non-storm water discharges, and develop and implement the Storm Water Pollution Prevention Plan (SWPPP) for the facility. The permittee shall determine whether its facility discharges storm water to a water body for which the MDEQ has established a TMDL. If so, the permittee shall assess whether the TMDL requirements for the facility's discharge are being met through the existing SWPPP controls or whether additional control measures are necessary. The permittee's assessment of whether the TMDL requirements are being met shall focus on the effectiveness, adequacy, and implementation of the permittee's SWPPP controls. The applicable TMDLs will be identified in the COC issued under this permit.

The TMDL watershed receives storm water discharges from MDOT (M-53, M-142, M-19), which operates under a statewide NPDES Individual Storm Water Permit (MI0057364) to cover storm water discharges from their MS4. This statewide permit requires MDOT to reduce the discharge of pollutants to the maximum extent practicable and employ BMPs to comply with TMDL requirements. The MS4 Permit also requires MDOT to identify and prioritize actions to be consistent with the requirements and assumptions of the TMDL. Through prioritizing TMDL actions, MDOT is able to focus its efforts, which will help to make progress towards meeting Michigan's WQS.

The NPDES CAFO permit (individual and general permits) contains several measures which help to reduce TP and *E. coli* entering surface waters from the production area, waste (manure) storage sites, and manure land application sites. At production facilities, and associated manure storage sites, the permit requires properly designed, constructed, and maintained manure storage structures. These structures must be designed to store at least six months of generated production area waste, normal precipitation, the 25-year 24-hour rainfall, and the required freeboard amount. All manure storage structures must be inspected once per week, providing assurance against overflow and potential structural damage. The CAFO permit states that direct contact of animals with the surface waters of the state is prohibited at the production area, and the disposal of dead animals shall not contaminate surface waters.

The CAFO permit requires the development of a CNMP, as well as annual reviews and reports. CNMPs do not specifically address *E. coli*, but by addressing nutrients contained in manure, these plans indirectly assist in controlling the amount of *E. coli* entering surface water. The CNMP is designed to prevent over-application of manure by requiring CAFO operators to plan and limit manure applications to meet agronomic needs. The CNMP requires the submission of maps to identify land application areas and reports on the quantities and types of manure applied. The permit requires an assessment of land application areas prior to land application, including the condition of all tile outlets, observations of soil cracking, moisture holding capacity of the soil, crop maturity, and the condition of designated conservation practices (i.e., grassed waterways, buffers, diversions). During land application of waste, a 100-foot set-back surrounding waterways and other sensitive areas is required to minimize potential contamination of waterways with manure. The 100-foot set-back may be replaced with a 35-foot vegetated riparian buffer where no land application can occur.

After any land application of manure, tile outlets must be inspected. If an inspection reveals a discharge with color, odor, or other characteristics indicative of an unauthorized discharge of CAFO waste, the permit instructs the permittee to immediately notify the MDEQ. CAFO waste may not be land applied if the field is flooded or saturated, it is raining, or if more than 0.5 inches of rain is forecasted within the next 24 hours with an occurrence greater than 70 percent chance. To help minimize contaminated runoff, CAFO waste on tillable fields must be injected or incorporated into the ground within 24 hours of application. The land application of CAFO waste where it may enter surface waters of the state is prohibited, if it cannot be incorporated due to no-till practice. The application of CAFO waste to frozen or snow-covered fields without incorporation is only allowed after a specific field-by-field demonstration is completed to assess and minimize the risk of surface water contamination. The CAFO permit requirements are designed to minimize the contamination of surface water by CAFO-generated waste by providing record keeping, inspection, and land application requirements and guidance.

NPDES individual permits, COCs, and general permits are reissued every five years on a rotating schedule, and the requirements within the permits (outlined above) may also change at reissuance. Pursuant to R 323.1207(1)(b)(ii) of the Part 8 rules, and 40 CFR, Part 130.7, NPDES permits issued or reissued after the approval of this TMDL are required to be consistent with the goals of this TMDL.

It is the responsibility of MDEQ staff to inspect and audit NPDES permitted facilities once every five years on a rotating basis. At the time of these audits, MDEQ staff review permits, permittee actions, submittals, and records to ensure that each permittee is fulfilling the requirements of its permit. Consistency of the permit with the TMDL, and any potential deficiencies will be reviewed and addressed as part of the audit and permit reissuance processes.

The MDEQ encourages the use of biosolids to enhance agricultural production in Michigan. Biosolids are residuals settled out of sanitary sewage during the treatment process (i.e., sewage sludge). Biosolids are categorized here as a point source, because they are regulated by an NPDES permit. Discharge of biosolids to surface waters of the state is prohibited; but if a spill should occur in violation of the permit, the permit holder (generator of the biosolids) is generally held accountable. Biosolids applications are regulated by Residuals Management Programs, required by the provisions of a facility's NPDES discharge permit for wastewater treatment or by a General Permit (MIG960000). Michigan’s administrative rules (R 323.2418 of Part 24, Land Application of Biosolids, of the NREPA) require pathogens in biosolids be significantly reduced through composting process prior to land application. Provisions contained in Part 24 that protect groundwater and surface water from contamination by land-applied biosolids include:

isolation distances from surface water (50 feet for surface application with incorporation, or 150 feet for surface application without incorporation within 48-hours), sampling to ensure that pathogen density requirements are met, and restrictions (but not prohibition) of land application to frozen, saturated, or highly sloped land. Information, applicable rules/laws, and MDEQ Biosolids staff contacts can be found on Michigan's Biosolids Program website (*www.michigan.gov/biosolids*).

Nonpoint Sources

Reasonable assurance for nonpoint sources center on key elements of the watershed implementation plan and the accompanying accountability structure. Details are provided in Sections 6 and 7 of this document including:

- Management Measures (6.1)
- Technical and Financial Assistance (6.2)
- Information and Education (6.3)
- Schedule (6.4)
- Interim Milestones (7.1)
- Progress Benchmarks (7.2)
- Monitoring (7.3)

In addition to the information in Sections 6 and 7, several implementation partners identified in Table 12 have regulatory authorities that are available to reduce or eliminate NPS pollution. The following paragraphs summarize these and several other programs that provide reasonable assurance for nonpoint sources.

Failing or poorly designed OSDS are likely a significant source to unsewered areas. Michigan has no unified statewide sanitary code and no centralized regulatory authority over OSDS (Sacks and Falardeau, 2004). Instead, Michigan regulatory code (Section 2435 of the Public Health Code, 1978 PA 368, as amended) gives local district health departments the authority to "adopt regulations to properly safeguard the public health and to prevent the spread of diseases and sources of contamination." The state of Michigan does issue design criteria for OSDS that are utilized by more than two homes and discharge 1,000-10,000 gallons per day (Michigan Department of Public Health, 1994). For systems that discharge less than 1,000 gallons per day, the system must be approved by the local health department in accordance with local sanitary code (R 323.2210 of the Part 22 rules). Local health departments must be accredited by the State in a process that involves evaluation of the local departments every three years. Additionally, adopted sanitary codes must meet minimum measures proscribed by the State.

Nonpoint source pollution from agricultural operations not subject to permits is generally addressed through voluntary actions funded under the Clean Michigan Initiative and federal Clean Water Act Section 319 grants; Farm Bill programs; and other federal, state, local, and private funding sources. AFOs may be required to apply for an NPDES permit in accordance with the circumstances set forth in R 323.2196 of the Part 21 rules. This authority allows the MDEQ to impose pollution controls and conduct inspections, thereby reducing pollutant contamination (i.e., *E. coli*, TP) from agricultural operations that have been determined to be significant contributors of pollutants.

Michigan has a general environmental complaint process, which provides citizens with an easy route to report agricultural problems and other environmental emergencies. A complaint submittal system is a component of MiWaters that allows for anonymous complaints as a way to report direct discharges of livestock waste (such as runoff containing manure, spills, dumping, etc) or illicit sewage connections to surface waters. For example, AFOs with direct animal access to TMDL water bodies, or with obvious runoff potential, are reported to the Michigan Department of Agriculture and Rural Development (MDARD), pursuant to Michigan's Right to Farm Act (Section 286.474, Michigan Compiled Laws, Public Act 93 of 1981). A Memorandum of Understanding between the MDEQ and MDARD specifies that MDARD staff will investigate these complaints.

Section 3109(1) of Part 31 states that a person shall not directly or indirectly discharge into the waters of the state a substance that is or may become injurious to public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other uses that may be made of such waters. Section 3109(2) further specifically prohibits the discharge of raw sewage of human origin, directly or indirectly, into any of the waters of the state. The municipality in which that discharge originates is responsible for the violation, unless the discharge is regulated by an NPDES permit issued to another party. The elimination of illicit discharges of raw human sewage to the TMDL water body will improve water quality by removing a public health threat and reducing pollutant concentrations.

The Michigan Agriculture Environmental Assurance Program (MAEAP) is a voluntary program established by Michigan law (Section *324.3109d* of Part 31) to minimize the environmental risk of farms, and to promote the adherence to Right-to-Farm Generally Accepted Agricultural Management Practices, also known as GAAMPs. For a farm to earn MAEAP verification, the operator must demonstrate that they are meeting the requirements geared toward reducing contamination of ground and surface water. Livestock*a*Syst is the portion of the MAEAP verification process that holds the most promise for protecting waters of the state from contamination, which includes: steps to promote the separation of contaminated storm water from clean storm water at the farm site; the completion of a CNMP similar to that required by NPDES permitted CAFOs; runoff control at feedlots and the identification of environmentally sensitive areas; the prevention of manure reaching tile lines; and controlling contamination of runoff through incorporation on land application fields. MAEAP verified farms are considered to meet the LA unless MDEQ finds a violation per the Part 31 rules.

The MDEQ endorses the use of its Landscape Level Wetland Functional Assessment (LLWFA) tool as a means to prioritize areas for wetland restoration and protection. Michigan's LLWFA methodology identifies historically lost wetlands, determines the functions they once provided, and helps to prioritize wetlands for restoration to obtain the most significant water quality improvements. Wetland restoration has the potential to decrease TP and *E. coli* concentrations in contaminated runoff by increasing the filtration provided by sediment and vegetation (Knox et al., 2008). Wetlands have been shown to have the capability to retain contaminated water long enough to cause increased bacterial mortality, and create conditions which increase mortality (such as high levels of sunlight) (Knox et al., 2008). Riparian wetlands (located between uplands and lakes/streams) with high amounts of emergent vegetation (such as wet meadows and emergent marsh) have the most potential to decrease *E. coli* in runoff, and also would not attract large amounts of waterfowl. It is important to note the TBC and PBC WQS apply in wetlands (both natural and created) that are designated as surface waters of the state.

The Bad Axe watershed, as part of the Saginaw Bay watershed, is one of only three Michigan watersheds included in the Conservation Reserve Enhancement Program (CREP). The CREP is an extension of the Conservation Reserve Program, administered through a partnership between the USDA and MDARD, which offers farmers annual rental payments for taking agricultural lands out of production and reimbursement for conservation activities in eligible areas. Beneficial activities associated with these programs include the installation of filter strips, conservation tillage, riparian buffer strips, controlled livestock access, and wetland restoration.

5. Watershed Management Objectives

5.1 Plan Requirements

In 2008, USEPA released the "Handbook for Developing Watershed Plans to Restore and Protect Our Waters" *(The link provided was broken and has been removed)*. This handbook describes nine key elements required for approval as a TMDL Watershed Plan that will address concerns on threatened or impaired waters *(Table 13)*. These nine key elements are designed to ensure that planned improvements within TMDL watersheds are sufficient to restore water quality.

5.2 Specific Goals and Objectives

The goal of this TMDL Watershed Implementation Plan is to restore and protect Bad Axe Creek for full or partial body contact recreation, warm water fisheries, and other indigenous aquatic life through a reduction in nutrients and pathogens discharged to the stream. Plan objectives will be achieved through agricultural BMPs placed in critical areas, eliminating at-risk or failing septic systems within the watershed followed by a documented outreach program, and implementing urban stormwater BMPs to reduce pollutant loads that contribute to water quality impairments in Bad Axe Creek.

In addition, recommendations from the "Saginaw Bay Coastal Initiative Phosphorus Committee Report" highlight source reduction steps relevant to the Bad Axe watershed. These recommendations form a secondary set of objectives for this plan, and include:

- Develop consistent nutrient recommendations, specific to the Saginaw Bay area, supported and promoted by all groups providing direction for agricultural producers.
- Provide incentives to promote on-farm conservation demonstrations in cooperation with producers and agri-businesses.
- Promote cover crops for control of wind erosion; allow more flexibility to adapt other wind erosion control practices to match specific site conditions.
- Purchase and maintain research farms in the Saginaw Bay area to demonstrate various management practices and evaluate their effectiveness under different cropping systems.
- Develop and promote a range of options to achieve a minimum vegetative setback from all drains, creeks, rivers, and lakes.
- Establish the Saginaw Bay area as Michigan's agricultural subsurface tile drainage research area for water quality.
- Promote GPS and/or zone soil sampling and testing along with fertilizer application to develop accurate baseline nutrient levels and apply fertilizers based on this information.
- Demonstrate erosion control BMPs to stabilize temporary v-ditches cut for field drainage.
- Promote innovative, environmentally sound drainage ditch design, construction, and maintenance in the Saginaw Bay area.

Table 13. USEPA's nine minimum elements of a watershed plan

Plan Element	Description
A	**Identify causes and sources of pollution.** *Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.*
B	**Estimate pollutant loading into the watershed and the expected load reductions.** *On the basis of existing source loads, determine reductions needed to meet WQS. After identifying various management measures that will help reduce pollutant loads, estimate load reductions expected as a result of implementing these measures, recognizing the difficulty in precisely predicting Best Management Practice (BMP) performance over time.*
C	**Describe management measures that will achieve load reductions and targeted critical areas.** *The plan should describe the management measures to be implemented to achieve needed load reductions.*
D	**Estimate amounts of technical and financial assistance and the relevant authorities needed to implement the plan.** *A description of the financial and technical assistance needed to implement the entire plan. This includes implementation and long-term operation and maintenance of management measures, information / education activities, monitoring, evaluation activities, and a description of relevant authorities that might play a role in implementing the plan.*
E	**Develop an information/education component.** *A component that identifies the education and outreach activities or actions that will be used to implement the plan. These activities may support the adoption and long-term operation and maintenance of management practices and support stakeholder involvement efforts.*
F	**Develop a project schedule.** *A schedule for implementing the management measures outlined in the plan. The schedule should reflect the milestones and activities that can begin right away (e.g., baseline monitoring and outreach).*
G	**Describe the interim, measurable milestones.** *The plan should include interim milestones to measure and track progress in implementing the management measures.*
H	**Identify benchmarks to measure progress.** *As projects are implemented in the watershed, indicators should be identified to track progress towards attaining WQS. These are the benchmarks or waypoints to measure against through monitoring. These interim targets can be direct measurements or indirect indicators of load reduction.*
I	**Develop a monitoring component.** *A monitoring component determines whether progress is being made toward attaining or maintaining the applicable WQS addressed in the plan. The monitoring program should be fully integrated with the established schedule and interim milestone criteria. The monitoring component should be designed to assess progress in achieving loading reductions and meeting WQS.*

6. Watershed Implementation Plan

The ultimate measure of success will be documented changes in water quality, showing improvement over time. The top priority for this plan is to identify and reduce sources of phosphorus and bacteria in critical areas that contribute to documented impairments of the OIALW, PBC, and TBC designated uses for Bad Axe Creek.

Management measures implemented to reduce phosphorus will also address several sources areas and delivery mechanisms that contribute to WQS exceedances of *E. coli* in the watershed. However, this implementation plan recognizes that phosphorus and bacteria are not equivalent with regard to the current understanding of sources in the watershed. For that reason, additional management measures needed to reduce sources of *E. coli* in the Bad Axe Creek watershed are part of this plan.

The Bad Axe TMDL Watershed Implementation Plan centers on: management measures that will achieve needed load reductions and target critical areas; technical and financial assistance needed to implement the plan; information and outreach activities to ensure management measures are implemented where most needed; and a schedule for implementing management measures outlined in the plan.

6.1 Management Measures

Phosphorus

Natural variability inherent in agricultural landscapes highlights the need for an integrated approach to achieve load reduction targets in Bad Axe Creek. Although priority actions may be identified as individual categories, overall implementation efforts focus on using a suite of management measures that function as a system. This integrated approach supports a "win-win" solution that will both minimize erosion / nutrient losses from agricultural lands and maximize farm profitability. The net outcome is greater acceptance of the plan that results in improved water quality.

These implementation actions, ranked in order of importance, are the foundation of this strategy that will bring Bad Axe Creek back into attainment with water quality standards, which include:

1) Improve ***nutrient management*** [Group C: #30/31, 34, 35/39, 36/37, 38; Group E: #52/54; Group F: #62/63]
2) Increase acreage using ***cover crops*** [Group C: #30/31, 34, 35/39, 36/37, 38; Group E: #52/54; Group F: #62/63]
3) Initiate / expand use of ***water quantity management*** [Group C: #30/31, 34, 35/39, 36/37, 38; Group E: #52/54; Group F: #62/63]. In addition to controlled drainage, this action includes practices such as grassed waterways, saturated buffers, and blind inlets.
4) Increase acreage under ***no-till and/or reduced tillage*** [Group C: #30/31, 34, 35/39, 36/37, 38; Group E: #52/54; Group F: #62/63]
5) Increase miles of ***riparian buffers / filter strips*** along critical reaches / drains

These priority actions will occur over a 15-year period with staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed nutrient reductions. Work plans to address phosphorus impairments should emphasize implementation of nutrient management, cover crops, and no-till / reduced tillage. In addition, water quantity management should be part of critical area implementation efforts to address the seasonal average target. This practice was included in the

"Saginaw Bay Coastal Initiative Phosphorus Committee Report" as a source reduction recommendation. Development of a *"farmer-to-farmer"* network, though not a field BMP, should also be a high priority for plan implementation in promoting an integrated approach that supports "win-win" solutions.

Seasonality affects the general importance of each management measure relative to water quality concerns. Timing considerations should be factored into reduction estimates, Information and Education (I&E), and follow-up effectiveness monitoring (Table 14). For example, cover crops and no-till are most effective in reducing loads delivered during spring runoff. Relatively wide-spread application of these BMPs in critical areas subwatershed groups E and F could explain the reason behind data indicating those reaches were below the seasonal average target following spring runoff (Figure 6). This provides a basis for targeting subwatershed groups C and D for these practices. In addition, these BMPs enhance soil health and improve the infiltration capacity of fields reducing delivery of nutrients from ditches to Bad Axe Creek through channel erosion and scour associated with high runoff events.

Nutrient management, while reducing annual loads, is a major consideration during establishment periods. This is evident in Bad Axe Creek by examining the 2008 MDEQ monitoring data (Figure 6). Specifically, nutrient concentrations below subwatersheds E and F increase dramatically between samples collected in early-May compared to those in late-May. This period likely coincides with the timeframe when planting and fertilizer application could have occurred. Levels remained above the seasonal average target throughout the remainder of the sampling timeframe. This highlights the importance of I&E, and the proposed follow-up monitoring to ensure critical areas and practices are identified that will reduce seasonal average levels.

Table 14. Timing considerations in evaluating management measures

Month	Management Practice				Notes
	No-till or reduced tillage	*Cover Crops*	*Nutrient Management*	*Water Quantity Management* [a]	
January	***	***	*	***	
February	***	***	*	***	
March	***	***	*	***	Generally highest runoff month
April	***	***	***	*	Depending on soil type & moisture conditions • Tillage generally begins in April • Beets generally planted in April • Corn & soybeans in May Fertilizer application crop / producer dependent
May	*	*	***	*	
June	*		***	***	
July	*		*	***	Controlling surface runoff / drainage water flow needed to meet growing season average target
August	*		*	***	
September	*		*	*	Depending on soil type & climate conditions • Crops harvested Sept – early November • Tillage / fertilizer application could occur (producer dependent)
October	*	*	***	*	
November	***	***	***	*	
December	***	***	*	***	

Notes *** Most important months for reducing pollutant loads.
* Moderately important months for reducing pollutant loads.
[a] Dependent on soil type

Bacteria (*E. coli*)

Several management measures designed to reduce nutrient loads are also expected to reduce bacteria concentrations in Bad Axe Creek (e.g., nutrient management, water quantity management, riparian buffers / filter strips). Other management measures that will address the *E. coli* WQS exceedances are listed in Table 15. However, as noted in Section 3.3, critical area identification for bacteria sources is limited to the MDEQ 2008 monitoring data. Field inventory work specifically targeted towards sources of *E. coli* remains a priority need. For that reason, implementation actions to reduce bacteria levels in Bad Axe Creek, ranked in order of importance, include:

1) ***Inventory E. coli sources, critical sites and BMPs*** focusing on areas with elevated bacteria concentrations from the 2008 monitoring data [Groups A, B, C, D]
2) ***Implement priority BMPs in critical areas***; monitor and update bacteria source inventory.
3) ***Implement BMPs in remaining source areas*** until applicable WQS achieved.

Table 15. Management measures to reduce bacteria loads

Management Measure or Action
On-site Disposal Systems
• Review existing OSDS isolation distances to ensure that open county drains are treated as conservatively as surface waters. Open county drains are waters of the state, and the same WQS apply. • Inspect OSDS and conduct Illicit Discharge Elimination Program in areas of aging or densely populated housing areas located near surface water. • Outreach to educate residents on signs of OSDS failures (particularly in riparian areas) and aspects of local sanitary code that are designed to protect surface water from contamination. • Consider the use of infra-red satellite imagery to detect OSDS failures (see https://www.hrwc.org/wp-content/uploads/2013/02/HRWC%20Septic%20System%20ID%20Report%20Final%20v1.pdf).
Livestock and Agriculture
• Use of water table management (controlled drainage) where manure is applied to tiled land. • Livestock exclusion from riparian areas and providing vegetated buffers between pasture and water. • Outreach to agricultural community to encourage becoming Michigan Agriculture Environmental Assurance Program verified and/or the use of Best Management Practices on manure management (storage, composting, and application).
Urban Stormwater, Pets, and Wildlife *(waterfowl and terrestrial)*
• Outreach to educate residents on backyard conservation (e.g., proper pet waste management, improving storm water infiltration and storage, and discouragement of congregating waterfowl). • Adoption of pet waste ("pooper scooper") ordinances to ensure that both public and private property do not accumulate pet feces. • Installation of vegetated riparian buffer strips to increase infiltration of storm water.

6.2 Technical and Financial Assistance

Technical and financial assistance identified includes Section 319, GLRI, Clean Michigan Initiative (CMI), Department of Agriculture (USDA) funding through the Environmental Quality Incentives Program (EQIP), and USDA's Cooperative Conservation Partnership Initiative (CCPI), which uses EQIP funds to target sediment and nutrient loading in the Pinnebog and Pigeon River watersheds.

Other technical assistance options include working with service providers, Certified Crop Advisors, MSU Extension Service, Saginaw Valley State University, and The Nature Conservancy. These groups and organizations have established networks within the Saginaw Bay watershed, which can take advantage of local partnership opportunities. The TMDL Reasonable Assurance discussion (Section 4.5) and Appendix D describe additional information regarding technical and financial assistance available for implementation of this plan including stakeholders who have regulatory authorities.

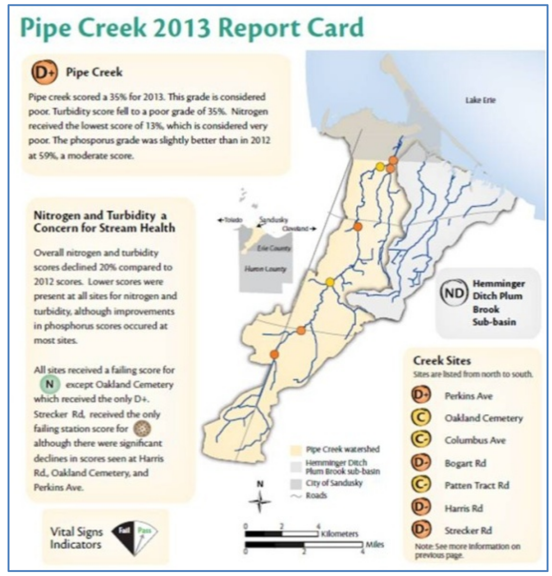
6.3 Information and Education

I&E is vital to the success of the Bad Axe TMDL Watershed Implementation Plan. The I&E strategy targets specific audiences to educate them regarding their potential impacts on water quality. The importance of this component is recognized by the local community as evidenced by activities that supported development of the Pinnebog Watershed Management Plan. The resultant strategy, which forms the basis for I&E in the Bad Axe Implementation Plan, outlines major educational opportunities and actions needed to successfully maintain and improve water quality in the watershed to meet the following objectives:

- Increase public knowledge and broaden awareness of the water quality challenges faced in the Bad Axe Creek watershed.
- Educate stakeholders about the environmental impacts of land use activities.
- Provide opportunities for comment and participation in implementing the plan.
- Develop partnerships among stakeholders by sharing ideas, resources, and facilitating cooperative activities that increase public awareness of watershed management and impact land use policies.
- Create a sense of individual responsibility for the proper use and care of surface water resources.

Specific activities to meet each I&E strategy objective are built around the key message, the target audience (e.g., all audiences, agricultural producers, all residents, businesses, elected officials, students / youth groups / clubs), the applicable component (e.g., awareness, education, action), a description of the delivery method, and potential partners. The Bad Axe TMDL Watershed Implementation Plan incorporates I&E activities conducted by HCD. Examples include their work with the Huron County Farm Bureau to promote conservation practices and programs. Other efforts include HCD's Project Rural Education Day; an outreach effort for Huron County students to explain and/or demonstrate the role of agriculture and natural resources in our lives. Information and education activities identified by HCD include documented outreach activities to agricultural stakeholders in and around the watershed. In addition, HCHD will develop a database to determine "at risk" septic systems and document their outreach program to address water quality problems in Bad Axe Creek caused by this source category.

An important aspect of the Bad Axe TMDL Watershed Implementation Plan involves targeting critical areas. Monitoring data plays a key role to ensure limited resources are directed towards those actions that will lead to measureable water quality improvements. For this reason, the Bad Axe I&E strategy includes initiating efforts to develop locally generated water quality data. This information can be used to strengthen education efforts as well as expand local awareness of concerns and needed solutions.



An option to initiate this program could start by examining NPDES-based cooperative efforts used in other states. For example, a program could build on WWTP effluent monitoring already conducted by the City of Bad Axe in partnership with other NPDES permittees in the watershed. With support from the Huron County Commission, a cooperative monitoring program could also include the Health Department, the Drain Commission, and local schools. Monitoring expertise available from Saginaw Valley State University (SVSU) could provide assistance to ensure the data meet quality objectives for subsequent use to guide cost-effective implementation efforts. Program results could be disseminated to the public through a watershed report card, similar to ones used by the Erie County (OH) Conservation District (http://erieconserves.org/ - Your Home, Watershed Report Cards).

One other additional I&E activity for the Bad Axe TMDL Watershed Implementation Plan follows a recommendation from the "Saginaw Bay Coastal Initiative Phosphorus Committee Report", specifically develop a network of on-farm demonstrations in cooperation with producers and agribusinesses. As stated in that report: "Conducting on-farm comparisons of management practices is one of the most effective ways to convince producers to adopt management changes. It is important that conservation messages come to producers from a partnership of key business community stakeholders, for example implement dealers, agronomy consultants, lenders, commodity groups, etc".

In summary, this TMDL Implementation Plan includes a priority recommendation to develop an updated I&E strategy for the Bad Axe watershed that includes the following:

- Focus on priority pollutants and sources
- Focus on critical areas
- Identify target audiences
- Identify key messages and delivery mechanisms
- Develop evaluation criteria

6.4 Schedule

Priority actions will occur over a 15-year period with staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed nutrient and bacteria reductions (Table 16). Short-term efforts (Year 1-3) include implementing practices in critical areas so that annual nutrient loads and high risk bacteria sources to Bad Axe Creek are significantly reduced. Mid-term efforts (Year 4-8) are intended to build on the results of short-term implementation activities. This includes evaluating the success of Phase 1 projects installed (success rate, BMP performance, pollutant reductions realized, actual costs, etc.). Long-term efforts (Year 9-15) are those implementation activities that result in Bad Axe Creek in full attainment with Michigan's WQS.

Two overarching actions include information / education (I&E) and monitoring. A general awareness of water quality issues exists within the community; the result of strong local involvement in development of the 2008 Pinnebog Watershed Management Plan (WMP). For that reason, general watershed education activities are not specifically included in the 15-year schedule. Instead, I&E is incorporated into each priority action and varies as plan implementation moves through each phase. Basic I&E activities associated with individual priority actions during each phase include:

- ✓ *Phase 1*: awareness, 1-on-1 meetings, leverage cost-share opportunities
- ✓ *Phase 2*: 1-on-1 meetings, cost-share, follow-up & monitor Phase 1 results
- ✓ *Phase 3*: 1-on-1 meetings, cost-share, follow-up, monitor results, evaluate plan effectiveness, adjust as needed

Short-term implementation activities also include monitoring in the Bad Axe watershed conducted by SVSU. Related to both monitoring and I&E, the short-term schedule includes exploring efforts to initiate a locally led monitoring program. In addition to elevating public awareness, information from this program would provide a technical basis to guide locally generated, cost-effective solutions.

7. Accountability Structure

The ultimate measure of program success will be documented changes in water quality, showing improvement over time. However, potential barriers to achieving this goal must be considered in implementation planning. Positive environmental feedback from even the most persistent efforts may be several years in the future due to the lead time needed to implement BMPs throughout the watershed. Stakeholders must set realistic expectations about the amount of time needed to implement projects or programs while waiting for positive results.

7.1 Interim Milestones

Interim milestones associated with each priority activity are included in the schedule (Table 16 for total phosphorus; Table 17 for E. coli). In addition, interim milestones in this plan emphasize: 1) documenting BMP implementation through each phase, as described under "BMP Effectiveness Monitoring"; 2) ensure that information collected will guide effective critical area planning in subsequent phases using adaptive management, as described under "Progress Benchmarks" and "Monitoring"; and 3) other implementation activities will be identified and conducted simultaneously to meet TMDL point source wasteload allocations.

Table 16. Implementation schedule and interim milestones for the load allocation -- TP

Activity	Source Reduced	Critical Area(s)	Timeframe [a]	Lead [b]	Interim Milestones
Nutrient Management	Row crop agriculture Livestock	E-52/54 G-62/63	Phase 1	HCD	500 acres w/o manure 500 acres with manure 2,800 acres pre-sidedress NO_3 test
				HCD CEC FCK SW	10 percent of critical acres under 4R program Summarize soil test data across critical acre groups Document successes / challenges for Phase 2
			Phase 2		20 percent of critical acres under 4R program Summarize soil test data across critical acre groups Document successes / challenges for Phase 3
			Phase 3		40 percent of critical acres under 4R program Summarize soil test data across critical acre groups Document successes / challenges for sustainable program
Cover crops	Row crop agriculture	C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	HCD	1,800 acres
			Phase 2		50 percent of critical acres under cover crops Document successes / challenges / costs for Phase 3
			Phase 3		75 percent of critical acres under cover crops Document successes / challenges / costs for sustainability
Water Quantity Management	Row crop agriculture	C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	HCD HCDC MABA AgDr	Evaluation report on potential use of DWM *(focus area: sites where tile outlet stabilization identified as a need)* Pre-design / implement WQM system at 1 location
			Phase 2		5 percent of critical acres under WQM system Document successes / challenges / costs for Phase 3
			Phase 3		10 percent of critical acres under WQM system Document successes / challenges / costs for sustainability
No-till / Reduced Tillage	Row crop agriculture	C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	HCD	900 acres no-till 200 acres zone building / strip tillage 200 acres zone building 300 acres strip tillage 400 acres shallow vertical tillage 800 acres corn stalk residue
			Phase 2		50 percent of critical acres under reduce tillage Document successes / challenges / costs for Phase 3
			Phase 3		75 percent of critical acres under reduce tillage Document successes / challenges / costs for sustainability
Riparian Buffers / Filter Strips	Row crop agriculture Livestock	E-53	Phase 1	HCD	25 percent of critical stream / drain miles with adequate riparian protection
			Phase 2		50 percent of critical stream / drain miles with adequate riparian protection
			Phase 3		75 percent of critical stream / drain miles with adequate riparian protection
Farmer-to-Farmer Network	Row crop agriculture Livestock	Any of the following: C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	HCD HCDC MABA AgDr	3-5 farms in network initiating system of BMPs
			Phase 2		Increase number of farms in network by 50 percent Document changes in farm profitability for Phase 1 farms
			Phase 3		Increase number of farms in network by 50 percent Document changes in farm profitability for Phase 1/2 farms
Other BMPs	Row crop agriculture	C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	HCD	10 sites tile outlet stabilization 3 sites grade stabilization
			Phase 2		10 percent of critical acres under integrated BMP system Document successes / challenges / costs for Phase 3
			Phase 3		25 percent of critical acres under integrated system Document successes / challenges / costs for sustainability

Notes: [a] Phase 1 (2015-17); Phase 2 (2018-22); Phase 3 (2023-29)
[b] HCD: Huron Conservation District; MABA: Michigan Agribusiness Association; CEC: Cooperative Elevator Corp.
CPS: Crop Production Services; FCK: Farmers Co-op Kinde; SW: Star of the West; AgDr: AgriDrain

As noted in Section 3.3, critical area identification for bacteria sources is limited to the MDEQ 2008 monitoring data. Field inventory work specifically targeted towards sources of *E. coli* remains a priority need. A part of this priority implementation plan need includes *E. coli* source tracking (e.g., canine scent detection, biomarker methods). An implementation schedule an interim milestones are described in Table 17.

Table 17. Implementation schedule and interim milestones for the load allocation -- *E. coli*

Activity	Source Reduced	Critical Area(s)	Timeframe [a]	Lead [b]	Interim Milestones
On-site Disposal Systems	Failing Septics	Any of the following: A-11,14 B-21,23,24 C-31,34,38	Phase 1	HCHD	Update field inventory to identify failing OSDS *E. coli* source tracking to locate problem areas Implement priority BMPs in critical areas
			Phase 2		Implement priority BMPs in critical areas Monitor & update bacteria source inventory
			Phase 3		Implement priority BMPs in remaining critical areas until WQS achieved
Livestock and Agricultural Management	Row crop agriculture Livestock	C-31,34,38 D-41	Phase 1	HCD	Update field inventory to identify critical areas for livestock & agricultural bacteria sources *E. coli* source tracking to locate problem areas Implement priority BMPs in critical areas
			Phase 2		Implement priority BMPs in critical areas Monitor & update bacteria source inventory
			Phase 3		Implement priority BMPs in remaining critical areas until WQS achieved
Urban Stormwater	Urban stormwater runoff, pet waste	B-21,23,24	Phase 1	HCD, City of Bad Axe	Update field inventory to identify critical areas for urban bacteria sources *E. coli* source tracking to locate problem areas Implement priority BMPs in critical areas
			Phase 2		Implement priority BMPs in critical areas Monitor & update bacteria source inventory
			Phase 3		Implement priority BMPs in remaining critical areas until WQS achieved

Notes: [a] Phase 1 (2015-17); Phase 2 (2018-22); Phase 3 (2023-29)
[b] HCD: Huron Conservation District; HCHD: Huron County Health Department

7.2 Progress Benchmarks

Implementation activities for the Bad Axe watershed are staged in three phases using outcome-based strategic planning and an adaptive management approach. Phase 2 (mid-term) and Phase 3 (long-term) are designed to build on results from the preceding phase. To guide plan implementation through each phase using adaptive management, water quality benchmarks are identified to track progress towards attaining water quality standards.

These interim targets (Table 18) are intended to reflect the time it takes to implement management practices, as well as the time needed for water quality indicators to respond. In addition to water column indicators (e.g., total phosphorus and *E. coli*), habitat, macroinvertebrate community, and aquatic plant evaluations conducted by MDEQ are included. These indicators will likely to respond more quickly to watershed changes that result from implementation of management practices.

Table 18. Progress benchmark summary

Indicator	Assessment Procedure	Implementation Phase	Progress Benchmark
Total Phosphorus *(µg/L)*	Average growing season concentration (June 1 – September 30)	Phase 1 (Year 1 – 3)	138 [a]
		Phase 2 (Year 4 – 8)	106 [a]
		Phase 3 (Year 9 – 15)	60 [d]
E. coli *(#/100 mL)*	30-day geometric mean (May 1 – October 31)	Phase 1 (Year 1 – 3)	616 [b]
		Phase 2 (Year 4 – 8)	413 [b]
		Phase 3 (Year 9 – 15)	130 [d]
Habitat Rating [c]	MDEQ Procedure 51	Phase 1 (Year 1 – 3)	Marginal [c]
		Phase 2 (Year 4 – 8)	Good [c]
		Phase 3 (Year 9 – 15)	Good [d]
Macroinvertebrate Community Rating [c]	MDEQ Procedure 51	Phase 1 (Year 1 – 3)	Acceptable (-4 to 4) [c]
		Phase 2 (Year 4 – 8)	Acceptable (trending up) [c]
		Phase 3 (Year 9 – 15)	Acceptable (trending up) [d]

Notes:
[a] Pinnebog Road (based on equal amount of needed reduction each year to meet target)
[b] Campbell Road (based on equal amount of needed reduction each year to meet target)
[c] Berne Road
[d] all stations

7.3 Monitoring

Monitoring is an important part of the Bad Axe TMDL Watershed Implementation Plan. Ambient monitoring provides the data used to assess progress towards achieving needed load reductions and meeting water quality standards. BMP effectiveness monitoring provides information that determines if planned activities are, in fact, being implemented and if management practices are performing as expected. Together, information from both monitoring components guide actual plan implementation through each phase using adaptive management.

Under adaptive management, the Bad Axe TMDL Watershed Implementation Plan is designed to use an iterative approach; one that continues while better data are collected, results analyzed, and the watershed plan enhanced. In this way, implementation activities can focus on a cumulative reduction in loadings under a plan that is flexible enough to allow for refinement, reflects the current state of knowledge about the system, and is able to incorporate new, innovative techniques.

Stakeholders have identified urban stormwater as an issue. As part of adaptive management, a priority recommendation for this TMDL Watershed Implementation Plan is to conduct ambient monitoring to assess the relative importance of urban stormwater as a source of total phosphorus or *E. coli*. If monitoring results indicate urban stormwater is a critical source, follow-up recommendations to address these problems will be incorporated into the plan. Another key part of adaptive management related to monitoring, and a priority need for this TMDL implementation plan is additional field inventory work specifically targeted towards sources of *E. coli*. This includes *E. coli* source tracking (e.g., canine scent detection, biomarker methods).

Ambient Water Quality Monitoring

Progress towards achieving water quality standards will be determined through ambient monitoring by MDEQ and grant recipients. Data collected in support of the biennial state-wide assessment include measurements of physical, chemical, and biological parameters (Goodwin et al. 2014). MDEQ has conducted studies of ambient conditions in the Bad Axe watershed at 5-year intervals (Morse 1994, Walterhouse 1999, MDEQ 2004, Cooper 2009). This ambient monitoring program will continue as the Bad Axe Watershed Plan is implemented.

Additional ambient monitoring in the Bad Axe watershed started in March 2016 and is expected to continue through the fall of 2017. This monitoring is being conducted by SVSU under an MDEQ grant. This effort aims to determine current levels and sources of phosphorus, *E. coli*, and other associated parameters in the Bad Axe Creek watershed including major tributary drains.

Finally, Phase 1 of the Bad Axe TMDL Watershed Implementation Plan will explore opportunities to develop a local ambient monitoring program. As part of this plan's I&E strategy, NPDES-based cooperative monitoring efforts used in other states will be examined. A local ambient monitoring program could build on WWTP effluent monitoring already conducted by the City of Bad Axe in partnership with other NPDES permittees in the watershed. Compliance with the Bad Axe WLA is based on in-stream monitoring data at the Pigeon Road location. Additional ambient monitoring data collected in Bad Axe Drain at Pigeon Road can be used to support the translation of this WLA to any needed NPDES permit revisions during the next renewal cycle. With support from the Huron County Commission, a cooperative monitoring program could also include the Health Department, the Drain Commission, and local schools. Monitoring expertise available from SVSU during their work in the Bad Axe watershed could provide assistance to ensure the data meet quality objectives for subsequent use that could guide cost-effective implementation efforts.

BMP Effectiveness Monitoring

Progress towards implementing planned activities and the performance of installed management measures will be evaluated through BMP effectiveness monitoring by grant recipients. Data collected as part this effort is typically qualitative information, which tracks both direct (e.g., acres managed under 4R nutrient stewardship program, miles of stream with adequate riparian buffers) and indirect (e.g., number of outreach events, mailed self-assessment survey of properties adjacent to Bad Axe Creek / tributary drains, partner organization field inventories) activities.

The Bad Axe watershed field inventory represents a logical starting point from which to build a BMP effectiveness monitoring program. This information was compiled by HCD into an Excel© spreadsheet and is organized by tributary drain. Using this organizational framework, direct implementation practice attributes that can be monitored and recorded include:

- type (e.g., structural, management, both)
- implementation units (e.g., acres, linear feet)
- treated area (e.g., whole crop field, thin area along the edge of a crop field)
- mode (e.g., capturing pollutant, avoiding pollution)
- sequence or simplicity (e.g., single BMP, system of practices)
- performance pattern (e.g., full performance, declining performance over time)
- timing and seasonality (e.g., winter cover crops, constructed wetlands treat continuously)
- lifespan

BMP effectiveness monitoring results that document practice implementation (e.g., cover crops, water quantity management installations) can be recorded in the spreadsheet. Monitoring elements will be based on the schedule, key milestones, and adaptive management procedures used as part of Phase 2 and Phase 3 implementation. Potential BMP effectiveness monitoring elements include:

- Implementation activity (i.e., specific direct activities, not general implementation practices)
- Expected installation (e.g., date, cost, location, funding organization, installation organization)
- Expected performance (e.g., pollutant reduction loads, efficiency, lifespan)
- Installation (e.g., date, cost, location, funding organization, installation organization)
- Maintenance (e.g., date, cost, location, funding organization, maintenance organization)
- Performance (e.g., pollutant load reduction estimates, efficiency)

It is recommended that BMP effectiveness monitoring address annual implementation (i.e., installed this year), cumulative implementation, and cumulative implementation with an adjustment for practices that have exceeded their expected lifespan. These totals should be compared with implementation targets and full implementation potential to indicate progress over time.

8. Public Participation

A public meeting to present, discuss, and gather comments on the TMDL was held on March 23, 2016, in Bad Axe. Individual meeting invitation letters were sent to stakeholders (Table 12) and NPDES permitted facilities in the TMDL watershed. Approximately 50 stakeholders attended the public meeting. The availability of the draft TMDL and public meeting details were announced on the MDEQ Calendar. The TMDL was public noticed from March 7 to April 5, 2016. Copies of the draft TMDL were available upon request and posted on the MDEQ's web site.

9. References

Baker D.B., Richards R.P., Loftus T.T., and Kramer J.W. 2004. *A new flashiness index: Characteristics and applications to Midwestern rivers and streams*. Journal of the American Water Resource Association. April: 503-522.

Cooper, J. and C. Alexander. March 2009. *E. coli, Total Phosphorus, and Soluble Reactive Phosphorus Monitoring in the Pinnebog River, Pigeon River, and Shebeon Drain, Huron County, Michigan (April 29 – September 4, 2008)*. Michigan Department of Environmental Quality. Water Bureau Staff Report: MI/DEQ/WB-09/023 (Revised January 2010). Lansing, MI.

Cooper, J. November 2009. *A Biological Survey of Southwestern Lake Huron and Eastern Saginaw Bay Coastal Streams, Huron and Sanilac Counties, Michigan*. Michigan Department of Environmental Quality. Water Bureau Staff Report: MI/DEQ/WB-09/011. Lansing, MI.

Duris, J.W. and S.K. Haack. 2005. *Water Quality Data, Huron County, Michigan 2004*. U.S. Geological Survey Open File Report 2005-1380. 30p.

Fishbeck, Thompson, Carr & Huber, Inc (FTCH). September 2008. *Pinnebog River Watershed Management Plan*. MDEQ#2005-0142. Prepared for Huron Conservation District. Grand Rapids, MI.

Fishbeck, Thompson, Carr & Huber, Inc (FTCH). March 2010. *Data Evaluation Report of Pinnebog River Watershed Water Quality Sampling for E. coli*. Prepared for Huron Conservation District. Grand Rapids, MI.

Fishbeck, Thompson, Carr & Huber, Inc (FTCH). 2012. *Addendum to the Pinnebog River Watershed Management Plan*. MDEQ#2008-0027. Prepared for Huron Conservation District. Grand Rapids, MI.

Fongers, D., R. Day, and J. Rathbun. May 2012. *Application of the Richards-Baker Flashiness Index to Gaged Michigan Rivers and Streams*. MDEQ Report No. MI/DEQ/WRD-12/028. Michigan Department of Environmental Quality, Water Resources Division. Lansing, MI.

Goodwin, K., S. Noffke, and J. Smith. March 2014. *Water Quality and Pollution Control in Michigan, 2014 Sections 303(d), 305(b), and 314 Integrated Report*. MDEQ Report No. MI/DEQ/WB-14/001. Michigan Department of Environmental Quality, Water Resources Division. Lansing, MI.

Goodwin, K. August 2007. *Total Maximum Daily Load for Biota for the River Rouge Watershed, Including Bishop and Tonquish Creeks -- Washtenaw, Wayne, and Oakland Counties*. Surface Water Assessment Section. Water Bureau. Michigan Department of Environmental Quality. Lansing, MI.

Michigan Department of Environmental Quality. January 2004. *A Biological Survey of Southwestern Lake Huron and Eastern Saginaw Bay Coastal Streams, Huron and Sanilac Counties, Michigan (June - August, 2003)*. Michigan Department of Environmental Quality. Water Bureau Staff Report: MI/DEQ/WD-03/094. Lansing, MI.

Michigan Department of Environmental Quality. December 2012. *Michigan's Nonpoint Source Program Plan*. Michigan Department of Environmental Quality. Water Resources Division. Nonpoint Source Program. Lansing, MI.

Morse, D. November 1994. *Biological Survey of the Pinnebog River and Bad Axe Drain, Huron County (June 14-15, 1993)*. Michigan Department of Natural Resources. Surface Water Quality Division Staff Report: MI/DNR/SWQ-94/028. Lansing, MI.

Multi-resolution Land Characteristics (MRLC). 2006. Available at: *https://www.mrlc.gov*

PG Environmental, LLC. September 2012. *Saginaw Bay Nutrient Load Analysis*. Prepared for U.S. Environmental Protection Agency Region 5. Herndon, VA.

Rathbun, J. January 2010. *Update on Phosphorus Load Data for Saginaw Bay*. Michigan Department of Environmental Quality. Water Resources Division Staff Report: MI/DEQ/WB-10/006. Lansing, MI.

Tomer, M.D. S.A. Porter, D.E. James, K.M.B. Boomer, J.A. Kostel, and E. McLellan. 2013. *Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning*. Journal of Soil and Water Conservation. Vol. 68, No. 5.

U.S. Environmental Protection Agency. 2008. *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*. EPA-841-B-08-002. U.S. Environmental Protection Agency, Office of Water, Nonpoint Source Control Branch, Washington, DC.

U.S. Environmental Protection Agency. 2007a. *Options for Expressing Daily Loads in TMDLs*. Office of Wetlands, Oceans, & Watersheds. Washington, DC.

U.S. Environmental Protection Agency. 2007b. *An Approach for Using Load Duration Curves in the Development of TMDLs*. EPA 841-B-07-006. Watershed Branch, Office of Wetlands, Oceans and Watersheds, Washington, DC.

U.S. Environmental Protection Agency. 2003. *National Management Measures to Control Nonpoint Source Pollution from Agriculture*. EPA 841-B-03-004. U.S. Environmental Protection Agency, Office of Water, Nonpoint Source Control Branch, Washington, DC.

U.S. Environmental Protection Agency. April 1991. *Guidance for Water Quality-based Decisions: The TMDL Process*. Office of Water. EPA 440/4-91-001. Washington, D.C.

Vincent, P. January 2011. *Presurvey Analysis of the Pinnebog River, Pigeon River, and Shebeon Creek Watershed*. Michigan Department of Environmental Quality. Water Resources Division Staff Report: MI/DEQ/WB-09/035 (Revised: January 2011). Lansing, MI.

Walterhouse, M. May 1999. *Biological Surveys of Selected East Saginaw Bay Coastal Streams, Huron County, Michigan (June 30 - July 2, 1998 and August 3, 1998)*. Michigan Department of Environmental Quality. Surface Water Quality Division Staff Report: MI/DEQ/SWQ-99/062. Lansing, MI.

Appendix A. Causes and Sources

Objective

Describe the watershed including impaired waterbodies, and locate major causes and sources of impairment in the planning area.

Intent

The plan should set goals to meet (or exceed) the appropriate water quality standards for pollutant(s) that threaten or impair the physical, chemical, or biological integrity of the watershed. This element includes an accounting of the significant point and nonpoint sources in addition to the natural background levels that make up the pollutant loads causing problems in the watershed.

Key Questions

- Are water body use designations (from relevant Water Quality Standards) listed for waters in the planning area?
- Are water quality criteria (from relevant Water Quality Standards) for the use designations cited?
- Are impaired, partially impaired, and/or threatened uses (from state 303[d] or integrated report) listed by water segment or area?
- Are specific causes and sources (303[d]) of impairments and/or threats (if applicable) listed by waterbody segment or area?
- Are causes of impairment (or threats) listed as loads, WQC exceedance amounts/ percentages, or via other quantifiable method?
- Are sources of impairments/threats (if applicable) mapped or identified by area, category/subcategory, facility type, etc?
- Are contributions from each source location or category quantified by load, percentage, priority, or other method?
- Are estimates, assumptions, or data used in the analysis presented or cited? Do they appear reasonable?

Discussion

Water body use designations (from relevant Water Quality Standards) are listed for waters in the planning area.

At a minimum, all surface waters of the state are designated and protected for all of the following designated uses: agriculture, navigation, industrial water supply, warmwater fishery, other indigenous aquatic life and wildlife, partial body contact recreation, total body contact recreation (May 1 to October 31), and fish consumption (R 323.1100, Designated Uses, of the Part 4 rules, Water Quality Standards, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended [Act 451]).

The impaired designated uses for the Bad Axe Creek subwatershed addressed by this watershed implementation plan are the *warmwater fishery*, *other indigenous aquatic life and wildlife*, and *partial and total body contact recreation* uses [R 323.1100(1)(d, e, and f), and R 323.1100(2)], due to excessive algal growths, the presence of nuisance aquatic plants, and elevated bacteria levels. Excess phosphorus can stimulate nuisance growths of algae and aquatic plants that indirectly reduce oxygen concentrations to levels that cannot support a balanced fish or aquatic macroinvertebrate community (e.g., extreme day/night time fluctuations in oxygen) and can shade out beneficial phytoplankton (algal) and aquatic macrophyte (vascular plant) communities that are important food sources and habitat areas for fish and wildlife.

Water quality criteria (from relevant Water Quality Standards) for the use designations are cited.

Michigan does not have a numeric water quality standard (WQS) for total phosphorus, but relies on the narrative WQS found under Rule R 323.1060(2) (Plant Nutrients) which was developed to provide the authority to limit the addition of nutrients to surface waters of the state which are or may become injurious to the designated uses of the surface waters of the state.

The period of time when it is most critical to reduce phosphorus loads is in the summer during the growing season. Between June 1 and September 30, environmental conditions such as higher temperatures, lower stream flows, and increased light intensity are most likely to result in nuisance plant growth if nutrient concentrations are elevated.

To address plant nutrient impairments in the Bad Axe Creek watershed, the implementation plan target is 60 µg/L total phosphorus, which is a growing season average (June 1 to September 30). This value is supported in the literature as a seasonal average target determined to be protective of the *other indigenous aquatic life and wildlife* and *warmwater fisheries* designated uses.

The impaired designated recreational uses addressed by this TMDL are TBC and PBC. The designated use rule (Rule 100 [R 323.1100] of the Part 4 rules, WQS, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended) states that this water body be protected for TBC recreation from May 1 through October 31 and PBC recreation year-round.

Impaired, partially impaired, and/or threatened uses (from state 303[d] or integrated report) are listed by water segment or area.

In the 2014 §303(d) list of impaired waters, MDEQ determined that 43.1 stream miles of Bad Axe Creek, Bad Axe Drain, Richardson Drain, Symons Drain, and unnamed tributaries to these segments were impaired due to nutrients and are not meeting the OIALW designated use *(Table 3).* Bad Axe Creek was placed on the §303(d) list due to documented dense aquatic plant communities that reach nuisance conditions and high nutrient concentrations (Cooper, 2009). The assessment unit identifier (AUID) associated with this 43.1 mile segment is AUID 040801030302-02. Two Bad Axe subwatershed AUIDs are also not meeting total and partial body contact recreational designated use due to bacteria (040801030302-01 and 040801030302-02).

Specific causes and sources (303[d]) of impairments and/or threats (if applicable) are listed by waterbody segment or area.

The Bad Axe Creek drainage has been partitioned into subwatershed groups and catchments for critical area planning. Groups used for the source assessment are identified in Table 1 and Figure 2. The type of land use in each subwatershed unit affects nonpoint source pollutants that potentially reach Bad Axe Creek and its tributaries. This includes pollutants from both agricultural land and urban areas. Table A-1 presents a summary of land use information for the Bad Axe Creek watershed by subwatershed unit in terms of acreage. Field inventory information was collected by the Huron Conservation District (HCD) as part of the Pinnebog WMP development. This data is summarized by subwatershed group and critical area in Table A-2.

Table A-1. Bad Axe Creek watershed land use summary (acreage)

Land Use / Land Cover	Subwatershed Group ID					
	A	B	C	D	E	F
Open Water	56	1	9	---	---	---
Developed, Open	436	90	219	14	115	96
Developed, Low-Intensity	308	143	173	2	57	63
Developed, Medium-Intensity	71	103	26	---	---	---
Developed, High Intensity	34	91	7	---	---	---
Barren Land	41	---	2	---	---	---
Forest	315	82	262	36	327	233
Shrub/Scrub	8	---	4	1	2	1
Grassland/Herbaceous	49	8	38	3	48	1
Agriculture	2,444	211	5,159	294	2,913	2,499
Wetlands	551	32	578	8	391	206
TOTAL	4,313	761	6,477	358	3,853	3,099

Table A-2. Summary of Bad Axe watershed field inventory information

Group (Outlet Point)	Critical Area ID		Rill / Gully Erosion	Streambank Erosion	Tile Outlet	Other [a]	Debris / Trash
A (WWTP)	11	Turner 1131	2 [b]	5	3	2	
	13	Coleman 1129	3	1			
	14	Crumback 632	2			1	
B (Pigeon Rd.)	22	Bad Axe 633		3	1		
	23	Bad Axe 149	2			1	
	24	Bad Axe 149			1	2	
C (Berne Road)	29	Bad Axe 149	2	2			
	30 [c]	Wahl 6 N	3				
	31	**Richardson 1077**	**2**	**5**	**3**	**1**	
	32	Evans 166		1			
	33	Bad Axe 147		1			
	34	**Stenton 162**	**9**	**7**	**5**	**2**	
	35	Bad Axe 146	3	1	2	1	4
	36	Symons Br 3 917		1	1	1	
	37	Symons Br 2 915	2		4	2	
	38	**Symons 915**	**5**	**2**	**3**	**1**	
	39	Bad Axe 146					1
D (Campbell Rd.)	41	Bad Axe 915		1	2		3
E (Pinnebog Rd.)	51	Bad Axe 915	1	4			10
	52	**Ritter 913**	**2**	**1**	**4**		**1**
	53	E Br of Pinnebog 918		1			3
	54	Sam 914	2		2		1
	55	E Br of Pinnebog 918		1	1		
	56	E Br of Pinnebog 912	1	1		1	3
	57	Hogan 919	2	1			1
	58	E Br of Pinnebog 912		1			1
F (mouth)	61	E Br of Pinnebog 912	1	5		1	7
	62	**Renn 910**	**6**	**2**	**3**	**3**	**1**
	63	Renn 908	4	1	1		
	64	E Br of Pinnebog 806		2	1		6
		TOTAL	**54**	**50**	**37**	**19**	**42**

Note:
[a] "Other" includes livestock access, barnyard runoff, stream crossing, or upland source.
[b] Numbers represent observed occurrences from field inventory.
[c] **Yellow highlighted cells** identify TP critical areas based on HCD field inventory information.

Causes of impairment (or threats) are listed as loads, WQC exceedance amounts/ percentages, or via other quantifiable method.

Bad Axe Creek was placed on the §303(d) list due to documented dense aquatic plant communities that reach nuisance conditions and high nutrient concentrations (Cooper, 2009). The 60 µg/L growing season average total phosphorus target is used to identify reduction targets to guide development of the Bad Axe Creek implementation plan. Bad Axe Creek is also not meeting Michigan's total and partial body contact recreational designated use due to exceedances of the *E. coli* criteria.

In 2008, MDEQ sampled nutrients and bacteria in the Bad Axe Creek watershed (Figure 2). Results of this survey, shown in Figure 4 and Figure 7, are used to determine needed reduction percentages based on water quality concentration exceedance percentages (Table A-3).

Table A-3. Bad Axe Creek water quality concentration exceedance percentages

Subwatershed Group		Monitoring Location		Total Phosphorus		*E. coli*	
ID	Cumulative Area *(sq.mi.)*	ID	Location	*Seasonal Average (µg/L)*	*Needed Reduction*	*Geometric Mean (#/100mL)*	*Needed Reduction*
A	6.74	PIN02	above Bad Axe WWTP	33.0	---		
B	7.93	PIN01	below Bad Axe WWTP	189.9	*68%*	697	*81%*
		PIN03	Pigeon Road	85.0	*29%*	622	*79%*
C	18.08	PIN04	Berne Road	117.0	*49%*	721	*82%*
D	18.64	PIN06	Campbell Road	138.3	*57%*	737	*82%*
E	24.66	PIN07	Pinnebog Road	158.0	*62%*	205	*36%*
F	28.89	PIN09	Filion Road	149.1	*60%*	94	---
	29.50		Bad Axe Creek mouth				

Sources of impairments/threats.

Point sources in the Bad Axe Creek watershed are listed in Table 6 and shown in Figure 9. Maps depicting land use and air photos are provided for each subwatershed group in Figure A-1 through Figure A-12. Locations associated with individual field inventory data points are included on each map.

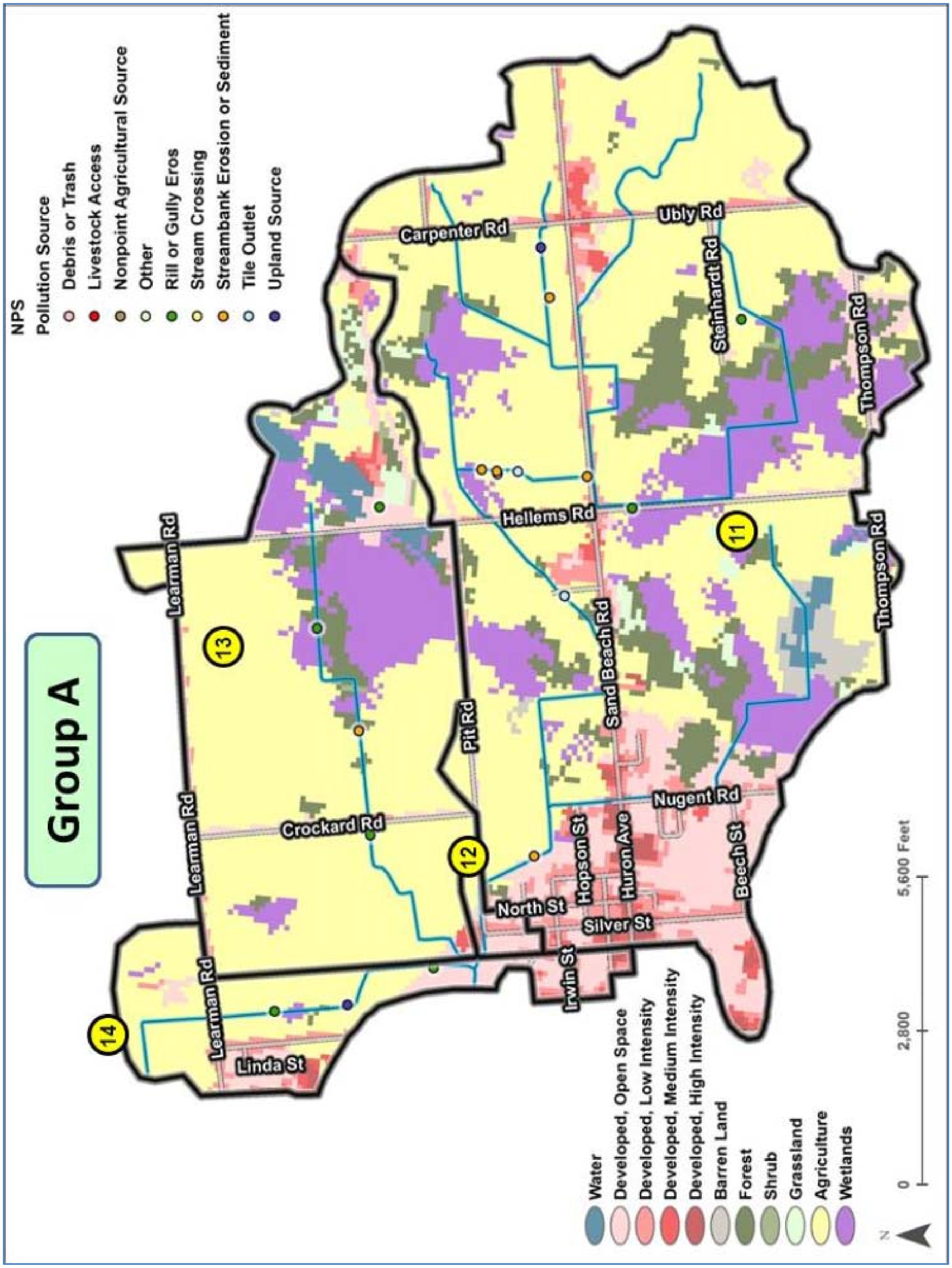


Figure A-1. Bad Axe Creek subwatershed group A -- land use

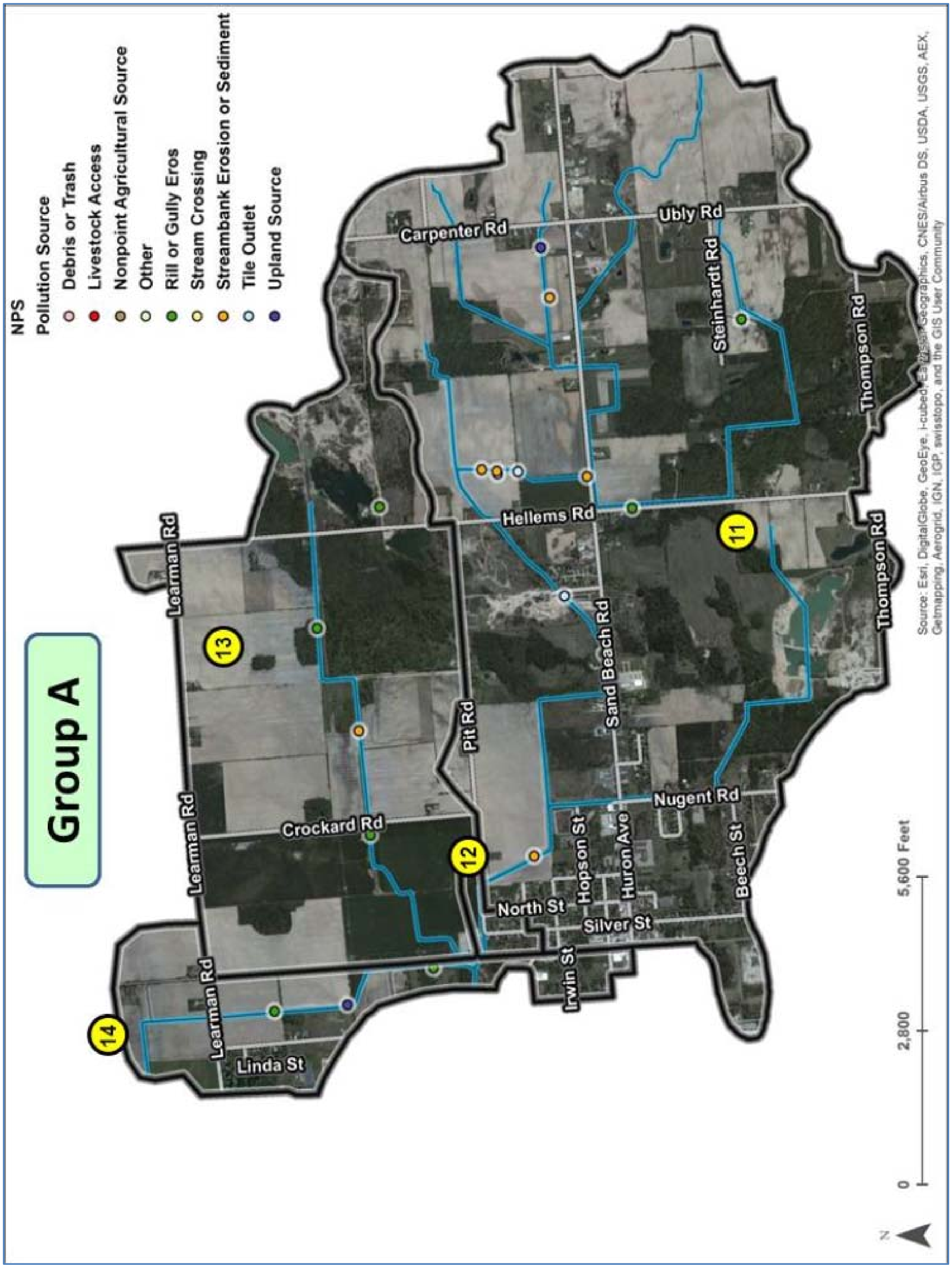


Figure A-2. Bad Axe Creek subwatershed group A -- air photo

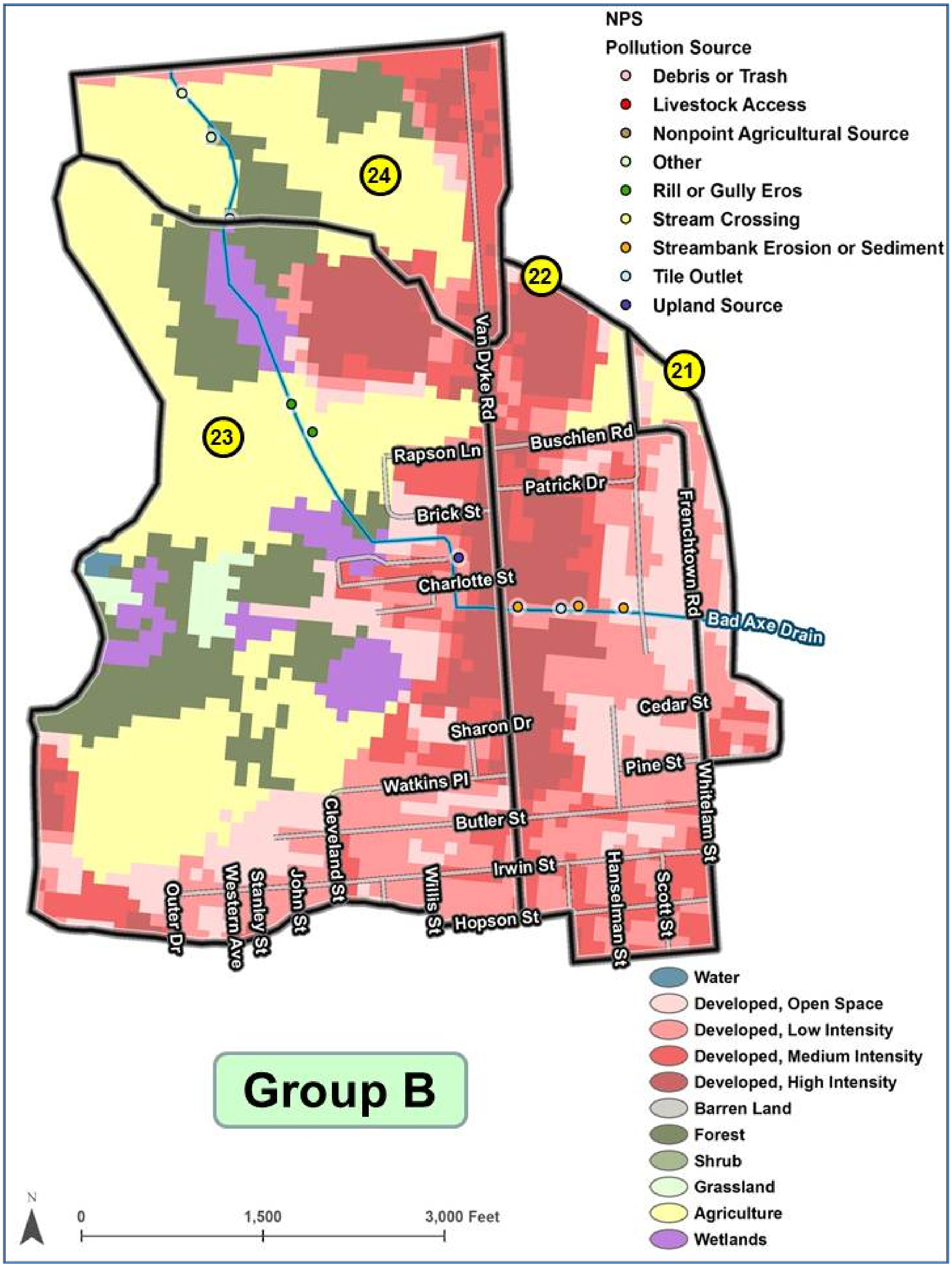


Figure A-3. Bad Axe Creek subwatershed group B -- land use

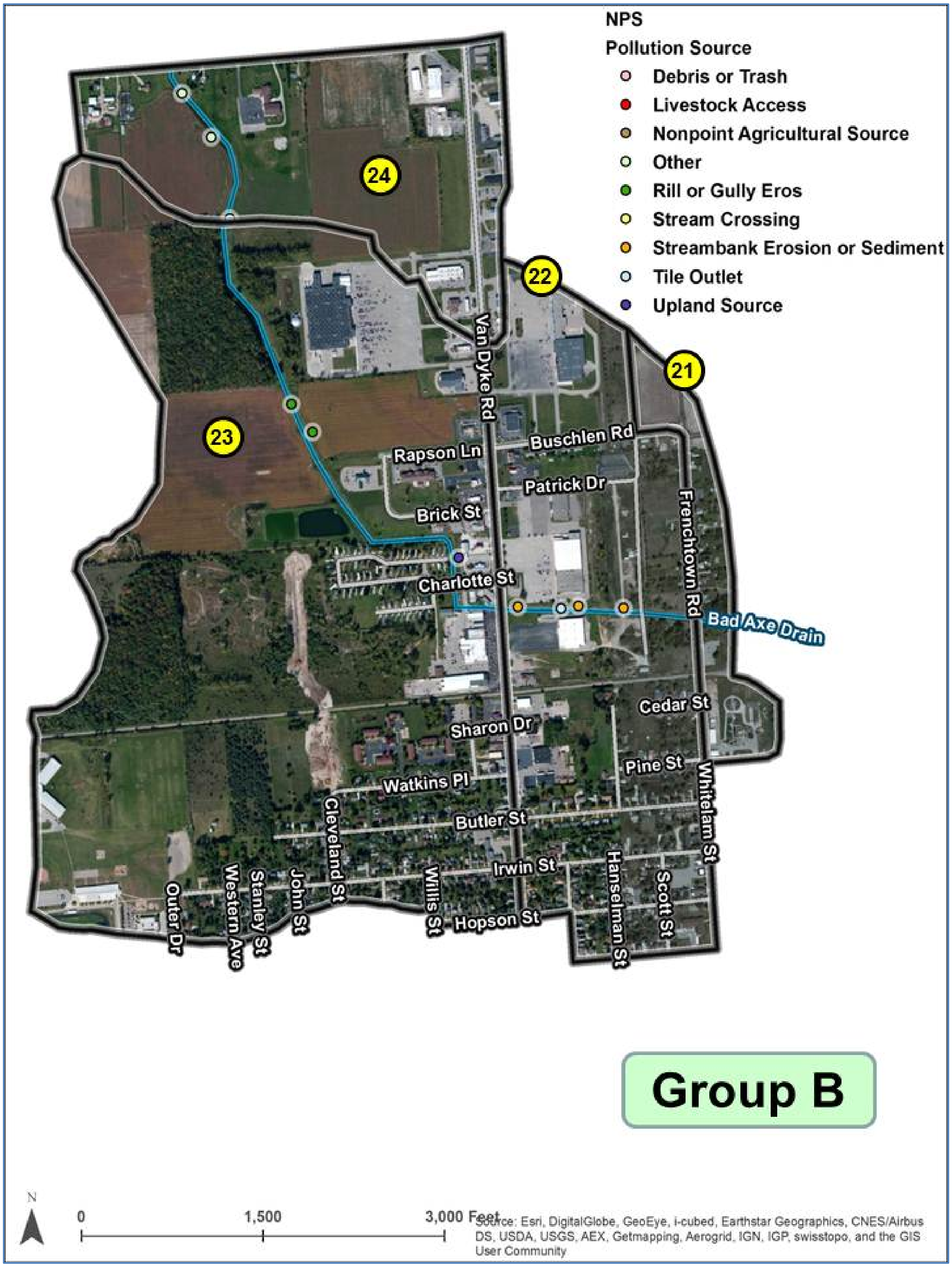


Figure A-4. Bad Axe Creek subwatershed group B -- air photo

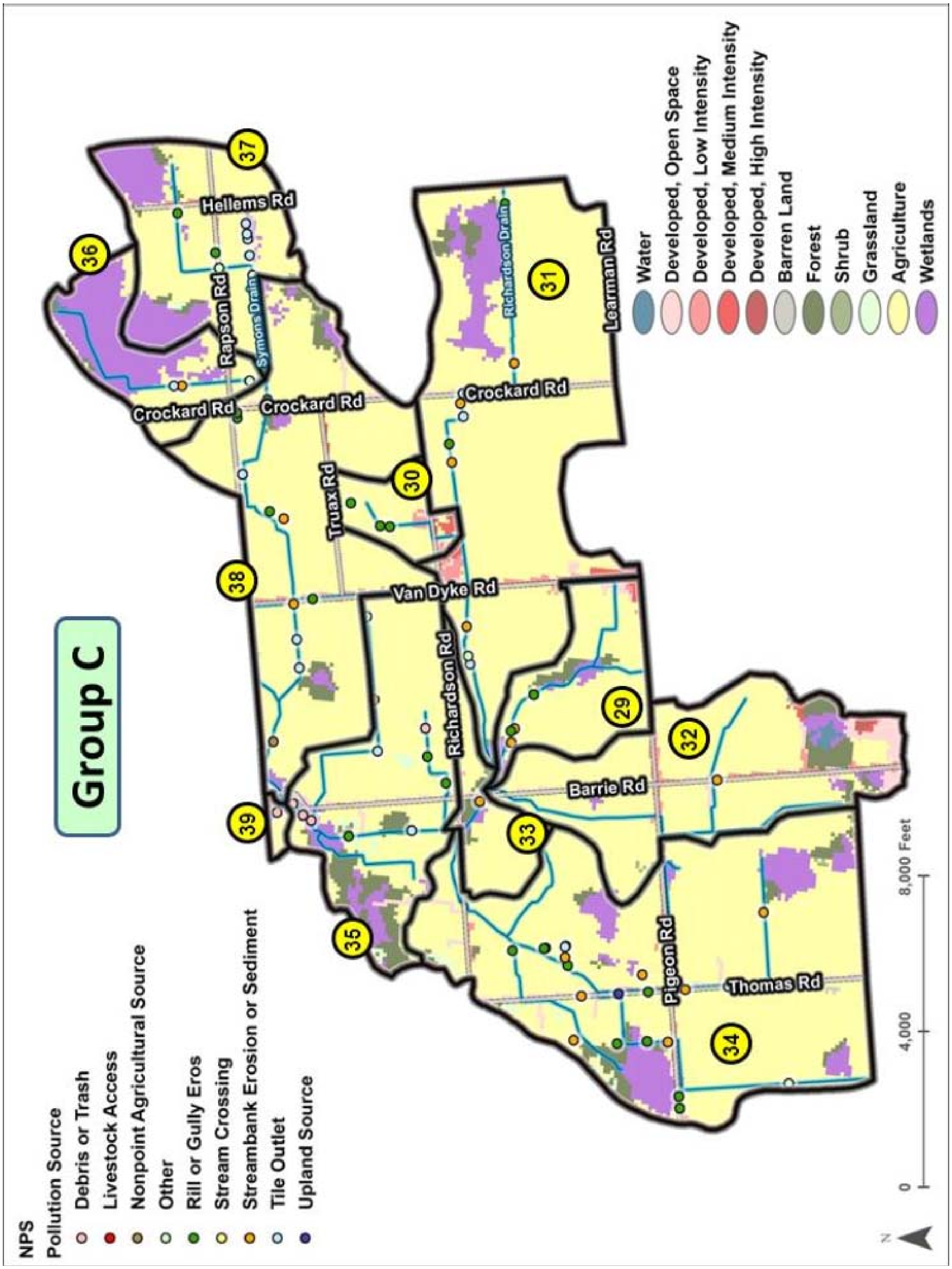


Figure A-5. Bad Axe Creek subwatershed group C -- land use

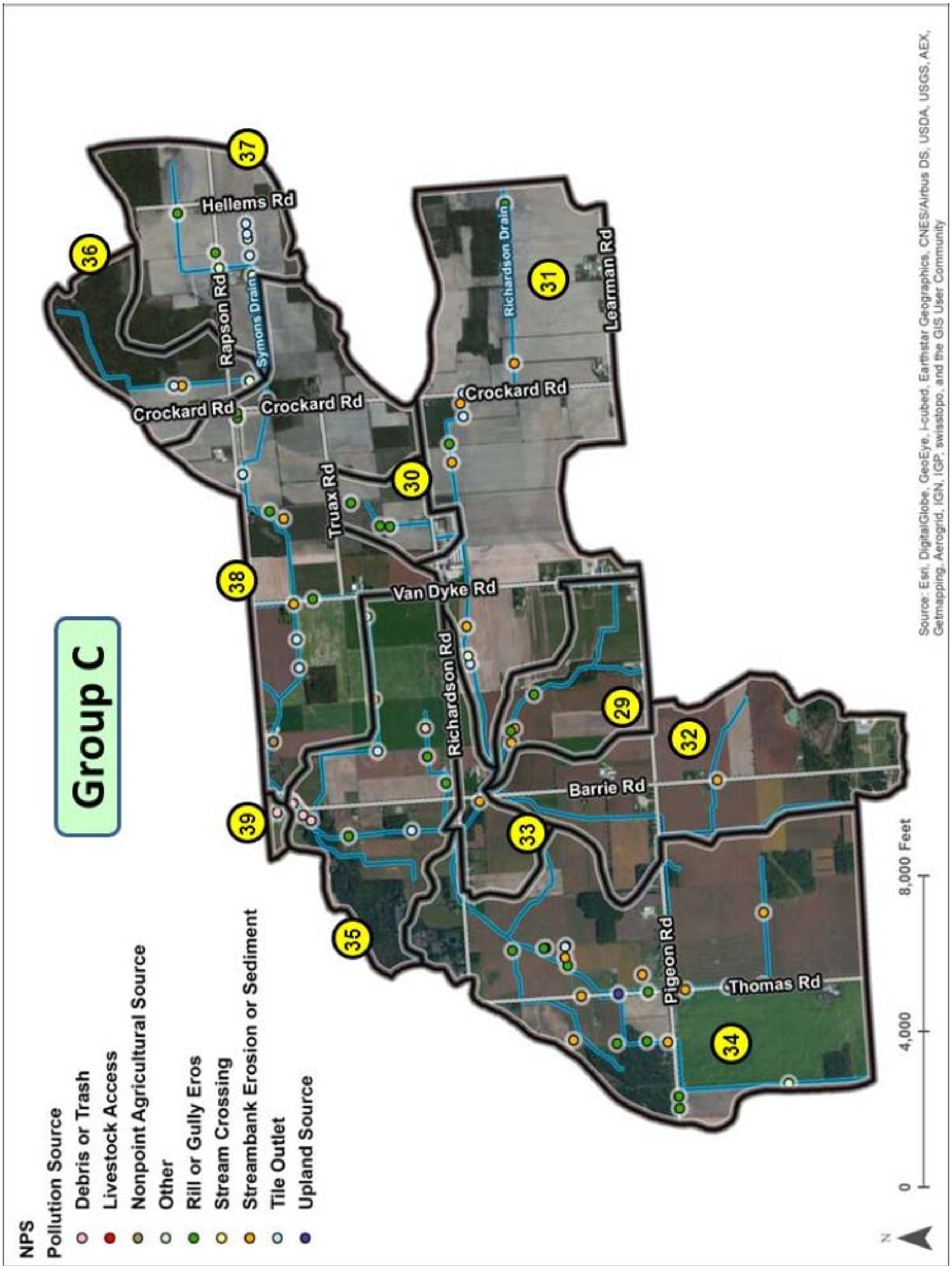


Figure A-6. Bad Axe Creek subwatershed group C -- air photo

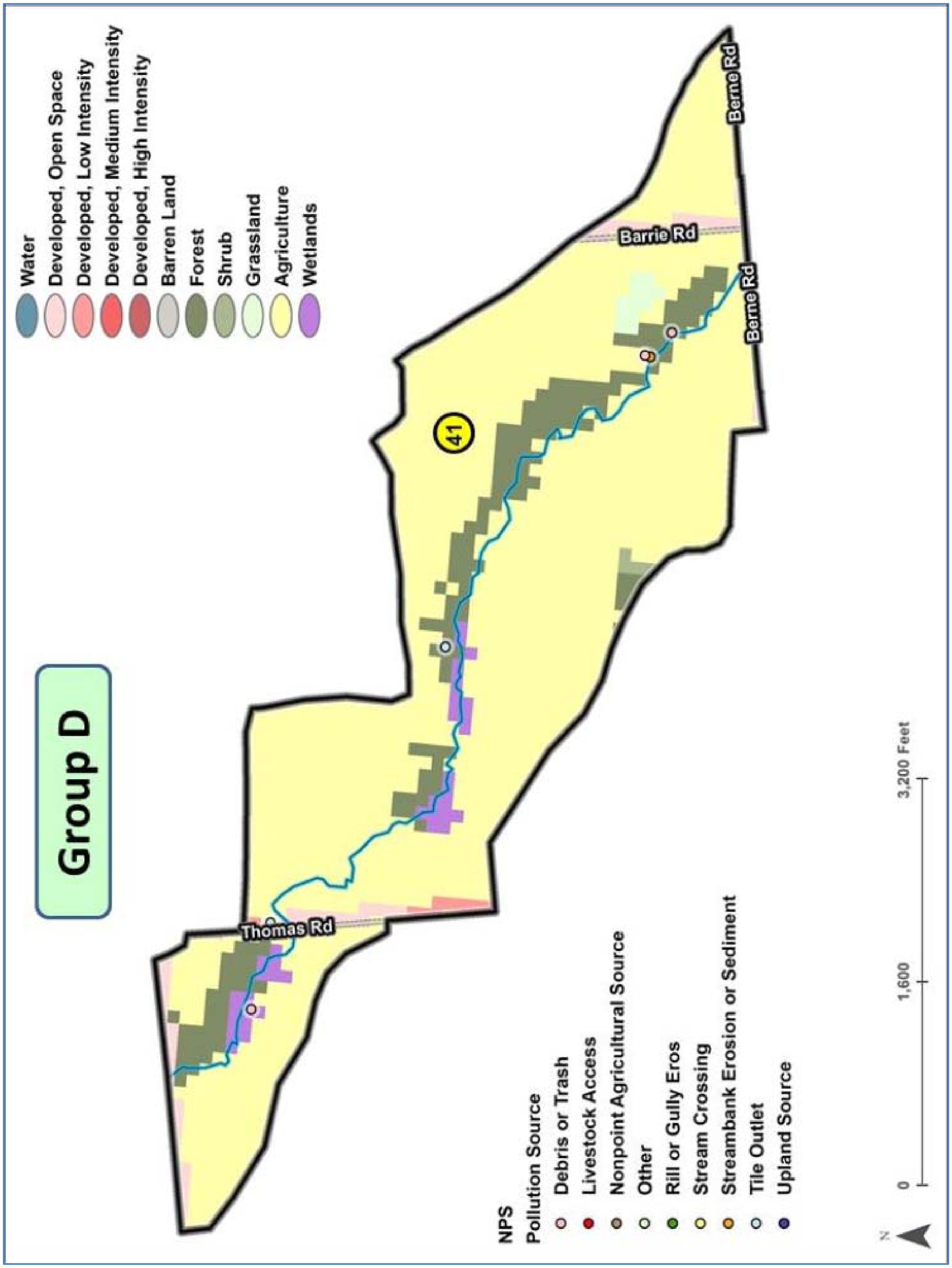


Figure A-7. Bad Axe Creek subwatershed group D -- land use

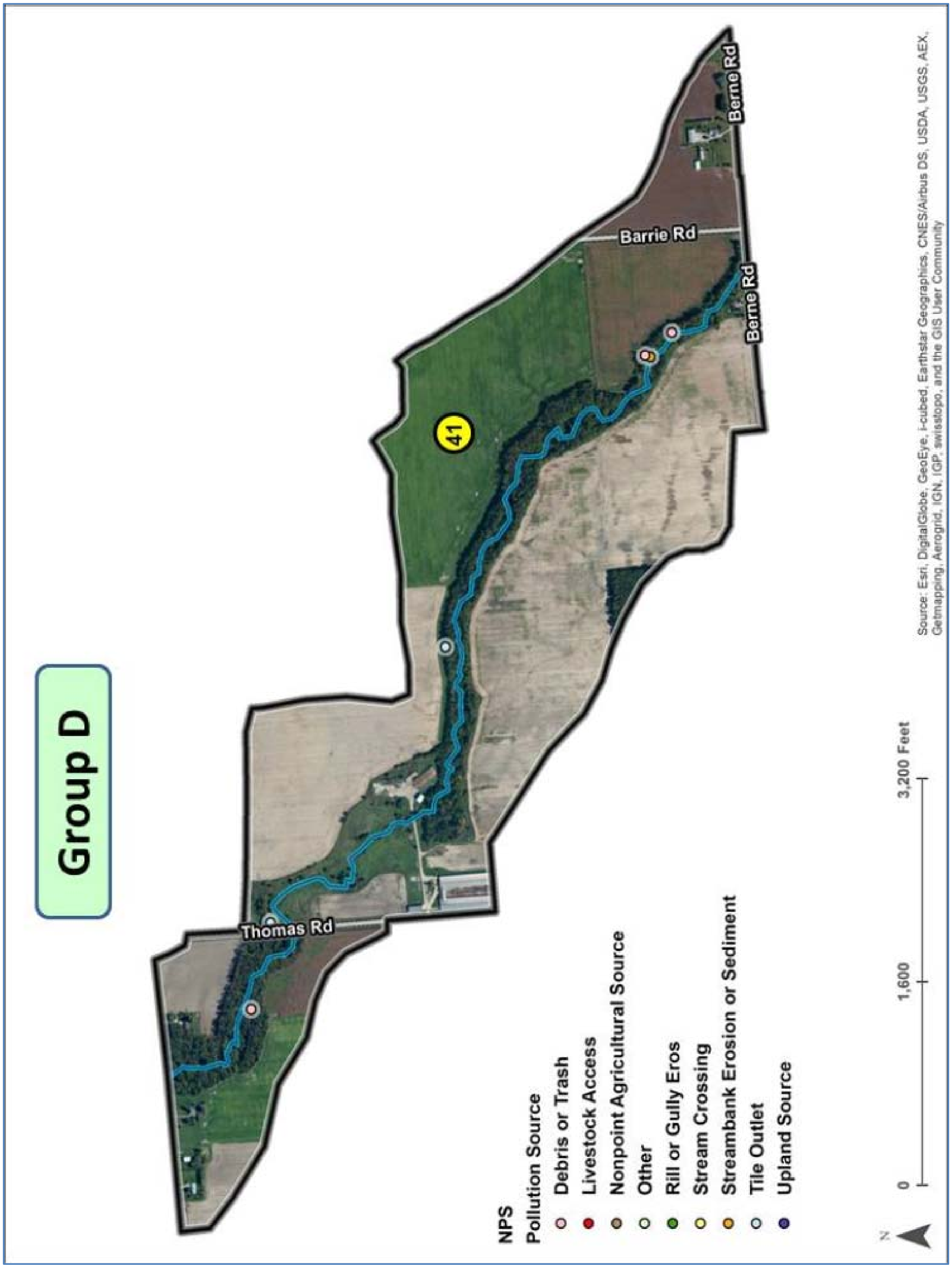


Figure A-8. Bad Axe Creek subwatershed group D -- air photo

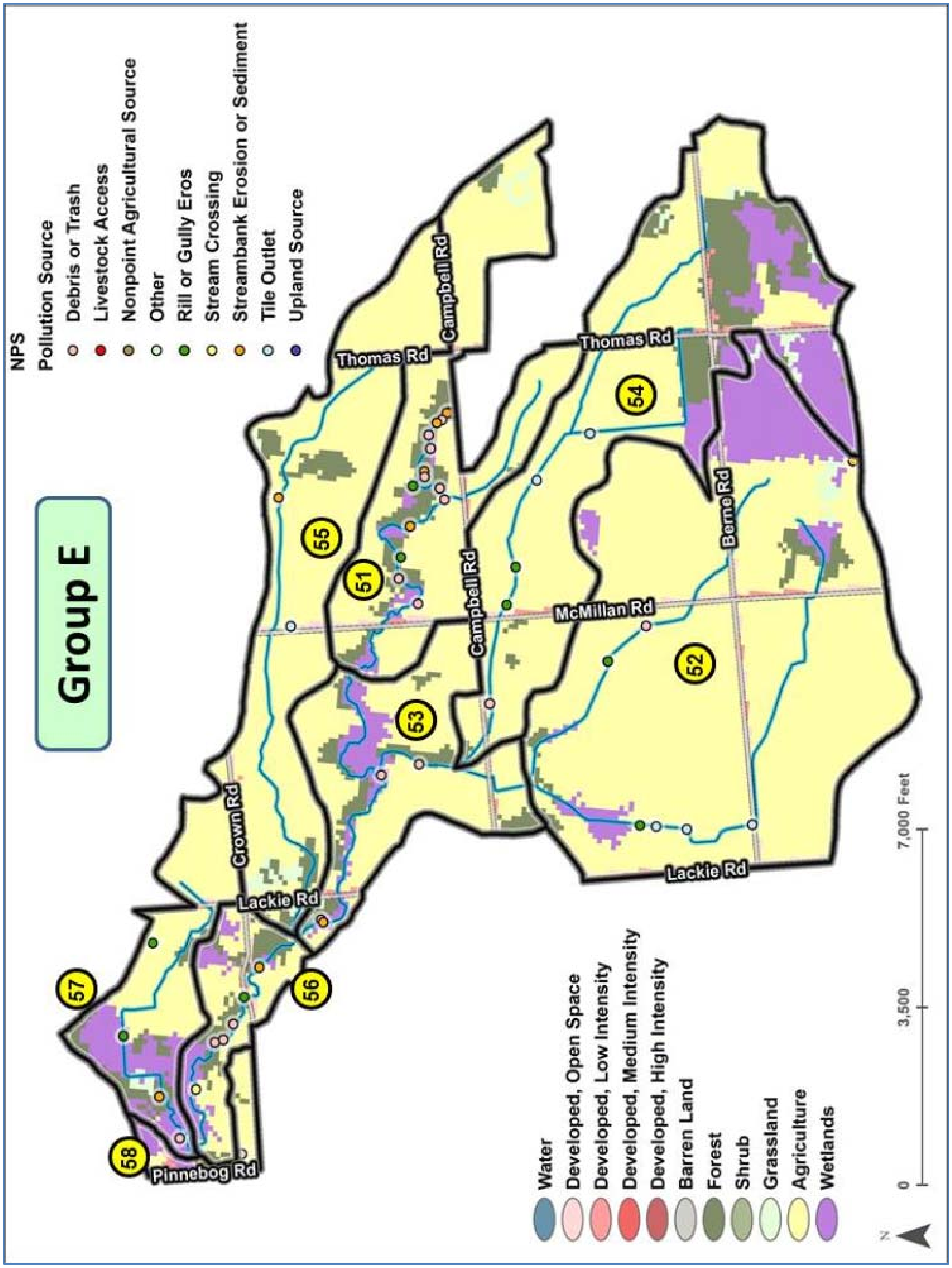


Figure A-9. Bad Axe Creek subwatershed group E -- land use

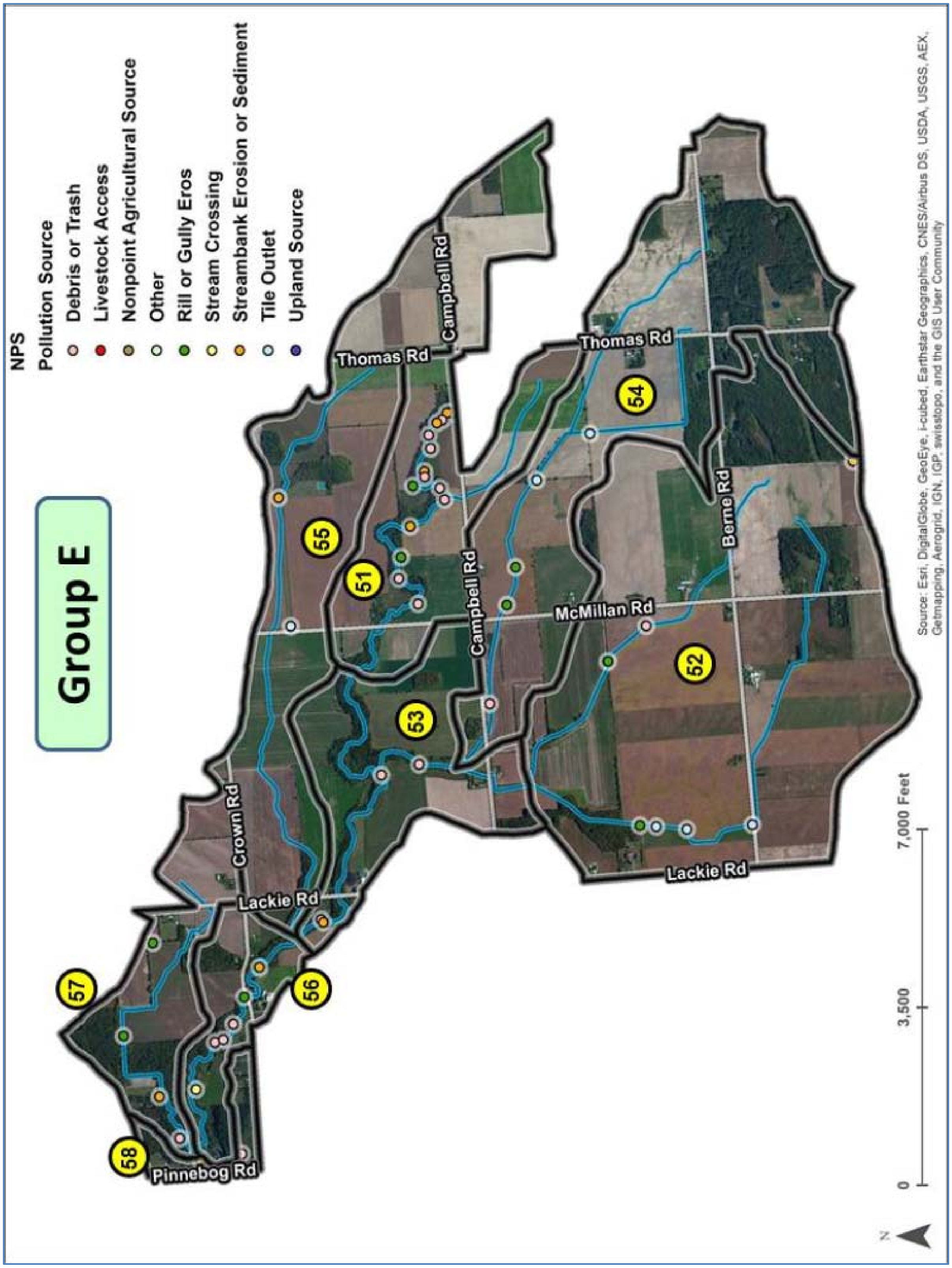


Figure A-10. Bad Axe Creek subwatershed group E -- air photo

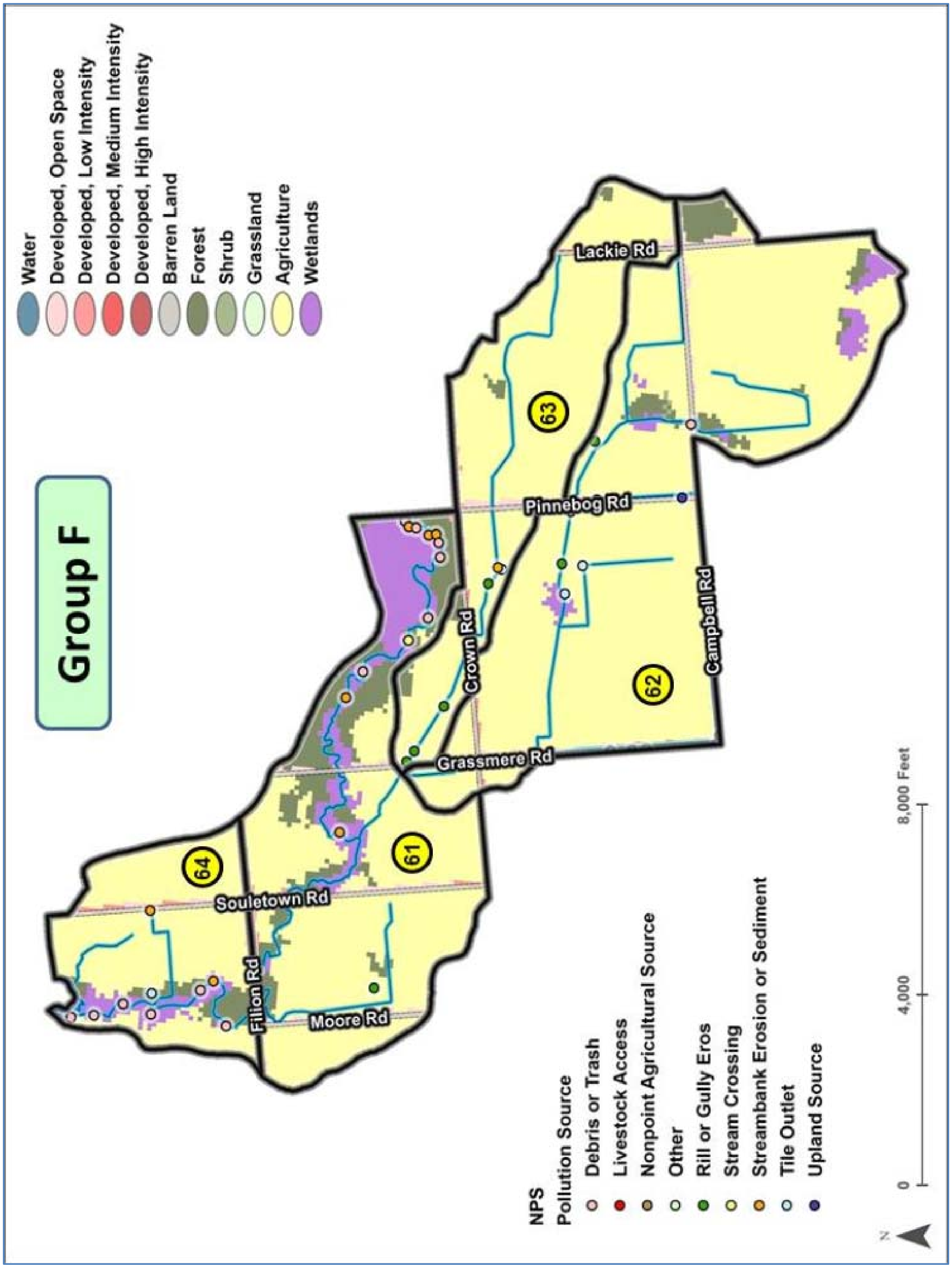


Figure A-11. Bad Axe Creek subwatershed group F -- land use

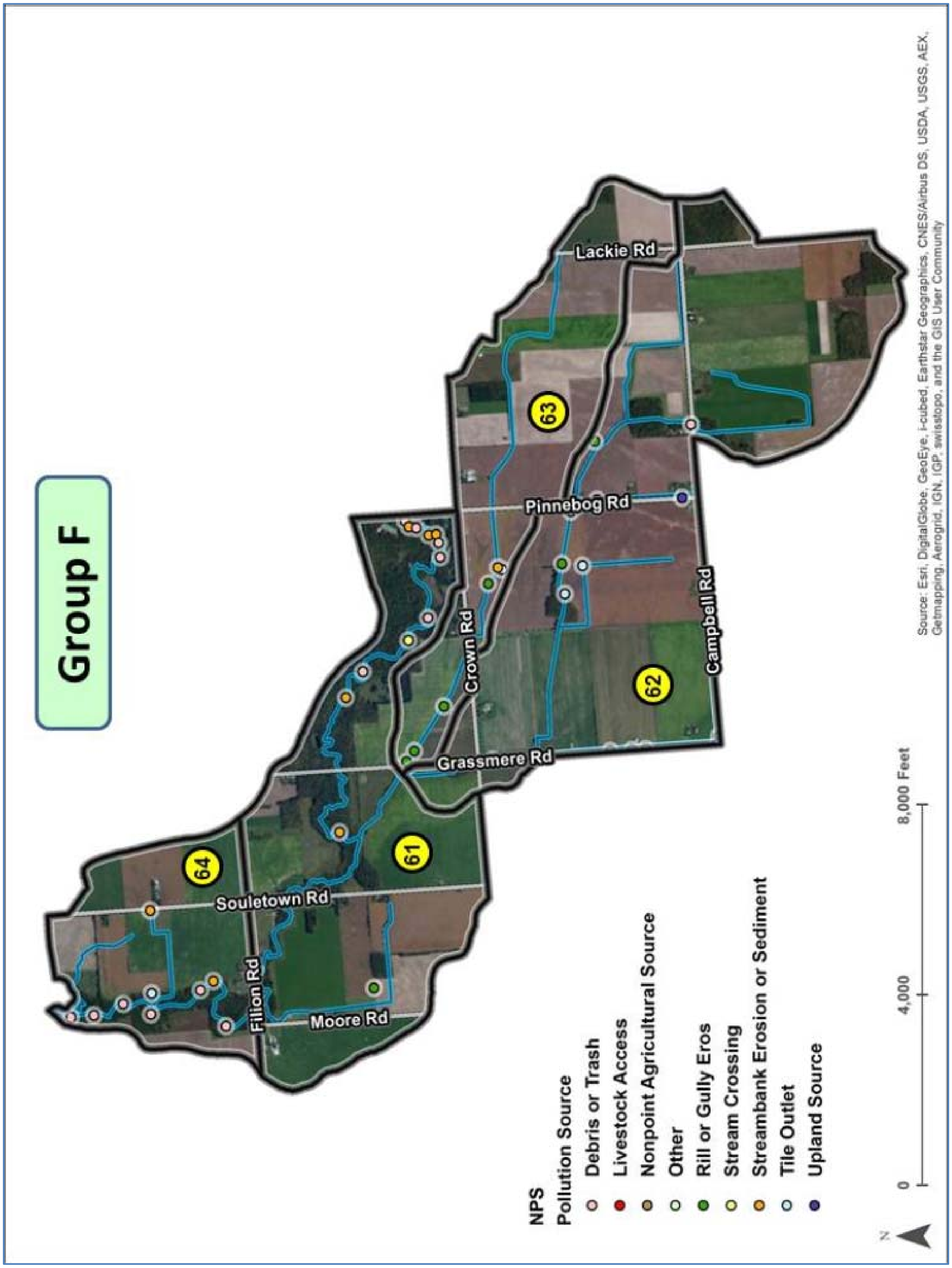


Figure A-12. Bad Axe Creek subwatershed group F -- air photo

Soils across significant portions of the lower Bad Axe watershed have low infiltration rates (Figure A-13). This necessitates the use of field tile drainage to support viable row crop production. The potential effect of tile drainage on phosphorus concentrations is noticeable in the 2008 MDEQ monitoring data. In particular, locations sampled below subwatershed groups C through F increase following summer storms (Figure 6).

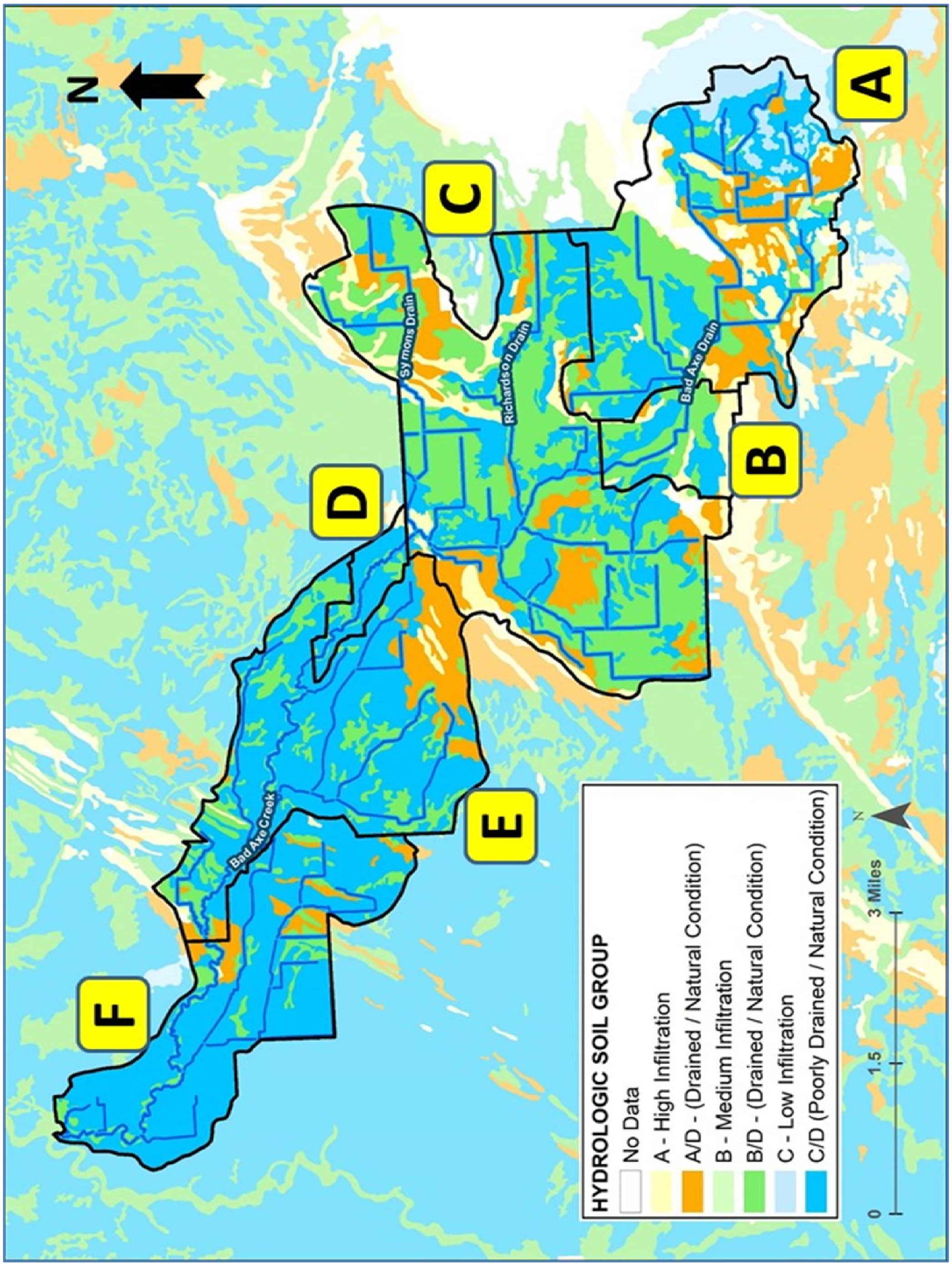


Figure A-13. Bad Axe subwatershed hydrologic soil groups

Contributions from each source location or category is quantified by load, percentage, priority, or other method.

The *"Addendum to the Pinnebog River Watershed Management Plan"* (FTCH, 2008) provided initial estimates of loads in the Bad Axe Creek watershed for several source categories. The estimates were derived from actual measurements at NPS sites inventoried in agricultural areas following development of the plan. Calculations were based on methods described in *"Pollutant Controlled Calculations and Documentation for Section 319 Watersheds Training Manual"* (MDEQ, 1999). Results are summarized in Table A-4, which indicate the largest source contributions are associated with rill and gully erosion.

Table A-4. Bad Axe watershed pollutant loads estimates from Pinnebog WMP Addendum

Subwatershed	Sediment Loading *(tons/year)*				Total Phosphorus *(lbs/year)*
	Stream Bank Erosion	*Rill & Gully Erosion*	*Tile Outlet*	**Total** *(tons/year)*	
Upper Bad Axe Drain	485.3	755.1	209.5	1,449.9	1,450
Lower Bad Axe Creek	197.9	500.5	151.1	849.5	850

The *"Spreadsheet Tool for Estimation of Pollutant Load"* (STEPL) provides another simple method to estimate loads by land use (just over 7,400 pounds per year for total phosphorus).

A low-level model assessment was conducted in 2011 by MDEQ using the Long-Term Hydrologic Impact Analysis (L-THIA) tool. This analysis estimated the total phosphorus load in Bad Axe Creek to be nearly 9,500 pounds per year (Table A-5); a value noticeably different from the *"Addendum to the Pinnebog River Watershed Management Plan"* estimates. Because L-THIA is GIS-based, load and runoff estimates can developed at the outlet point of each subwatershed group.

Table A-5. Bad Axe watershed pollutant loads estimates from L-THIA

Land Use	Hydrologic Soil Group	Subwatershed Group *(cumulative pounds / year)*					
		A	B	C	D	E	F
Water/Wetlands	B	0	0	0	0	0	0
Water/Wetlands	C	0	0	0	0	0	0
Commercial	B	10	94	94	94	94	94
Commercial	C	12	113	113	113	113	113
Agricultural	B	475	600	1,375	1,450	1,875	2,249
Agricultural	C	1,350	1,669	4,309	4,503	5,744	6,894
High Density Residential	B	7	68	68	68	68	68
High Density Residential	C	1	14	14	14	14	14
Low Density Residential	B	5	30	32	34	34	36
Low Density Residential	C	3	16	18	18	20	21
Grass/Pasture	B	0	0	1	1	1	1
Grass/Pasture	C	0	0	1	2	4	5
Forest	B	1	1	1	1	2	2
Forest	C	1	1	2	2	3	4
		1,864	2,607	6,028	6,299	7,971	9,500

These source contribution estimates are fairly coarse, either derived from aggregated field inventory data or land use percentages. Though based on best available information, neither adequately incorporates patterns observed from the 2008 ambient monitoring survey shown in Figure 4 (though the L-THIA estimates do reflect the significant effect of agricultural lands corresponding with the increased phosphorus concentrations). This is because the 2008 patterns reflect actual in-stream data whereas the other estimates are derived from annual average calculations driven by land use assumptions.

Development of the Bad Axe Watershed Plan is intended to identify and encourage activities, which can be quickly implemented and demonstrate improved water quality, i.e., outcome-based. For that reason, a staged approach is used that focuses on priority subwatersheds and critical areas to identify implementation opportunities that will produce measurable results.

This outcome-based approach recognizes that key elements of the watershed plan are developed concurrently in order to address data gaps, yet also initiate projects that will reduce pollutant loads in critical locations.

Appendix B. Load Estimates and Expected Reductions

Objective

Determine reductions needed to meet water quality standards on the basis of the existing source loads estimated for Element A.

Intent

After identifying the various management measures that will help to reduce the pollutant loads (Element C), the load reductions expected as a result of implementing these management measures will be estimates (recognizing the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as that required in the scale and scope described in Element A.

Key Questions

- Are reductions needed to address impairments listed, and quantified by weight, concentration, percentage reduction needed, etc?
- Are listed reduction estimates linked to each cause and source location or category?
- Will reductions achieve water quality criteria, address threats (if applicable), or achieve other goals?
- Are estimates, assumptions, or data used in the analysis presented or cited? Do they appear reasonable?

Discussion

Load reductions needed to address each impairment and threat (if applicable) are listed, and are quantified by weight, concentration, percentage reduction needed, etc.

The reductions needed to address the impairments are based on water quality concentration exceedance percentages using MDEQ 2008 ambient monitoring data (Table 4 and Table 5 in the main report).

Listed reduction estimates are linked to each cause and source location or category.

The 2008 MDEQ monitoring locations used to determine reduction estimates isolate major source categories in the Bad Axe subwatershed. Sites identified in Figure 2 are located above and below the Bad Axe WWTP (PIN02 / PIN01), below the City of Bad Axe (PIN03), below two major agricultural drains and CAFOs (PIN04 / PIN06), and below the lower two agricultural subwatershed groups (PIN07 / PIN09).

Load reductions will achieve water quality criteria, address threats (if applicable), or achieve other goals.

The reductions are based on growing season average concentration exceedances for total phosphorus and 30-day geometric mean PBC WQS criteria for *E. coli*, and will therefore achieve the water quality criteria and targets.

Estimates, assumptions, or data used in the analysis are presented or cited and appear reasonable.

The management plan charts a path that leads to implementing the most effective management measures that will result in load reductions required to achieve water quality targets. To that end, the intent of element B is to examine expected reductions based on management measures to be implemented. Combined with element C, plan development must consider important pathways (source areas / delivery mechanisms) including the timing associated with water quality concerns.

Based on an analysis of the 2008 Bad Axe Creek data that considers key source areas, delivery mechanisms, and timing, it appears that practices beyond those currently implemented in Huron County will be needed to meet the growing season average target of 60 µg/L total phosphorus. In particular, locations sampled below subwatershed groups C through F increase following summer storms (Figure B-1). These subwatershed groups are dominated by row crop agriculture supported by the use of field tile drainage. Vegetation is established during these months, likely limiting the effect of surface runoff. However, tiles are designed to move water quickly from fields to agricultural drains.

While practices generally implemented in Huron County (e.g., cover crops, no-till, reduced tillage, nutrient management, grade stabilization, tile outlet stabilization) will have an effect in reducing annual nutrient loads, these practices alone will not be enough to meet the growing season average target. In looking at the data (Figure B-1) that reflects water quality in reaches most affected by the critical agricultural areas, water quantity management should be an integral part of the implementation plan.

Critical area identification for bacteria source reduction is limited to the MDEQ 2008 monitoring information. This data indicates that priority subwatershed groups are A, B, C, and D. Field inventory work specifically targeted towards sources of *E. coli* was not conducted and remains a priority need for this TMDL implementation plan.

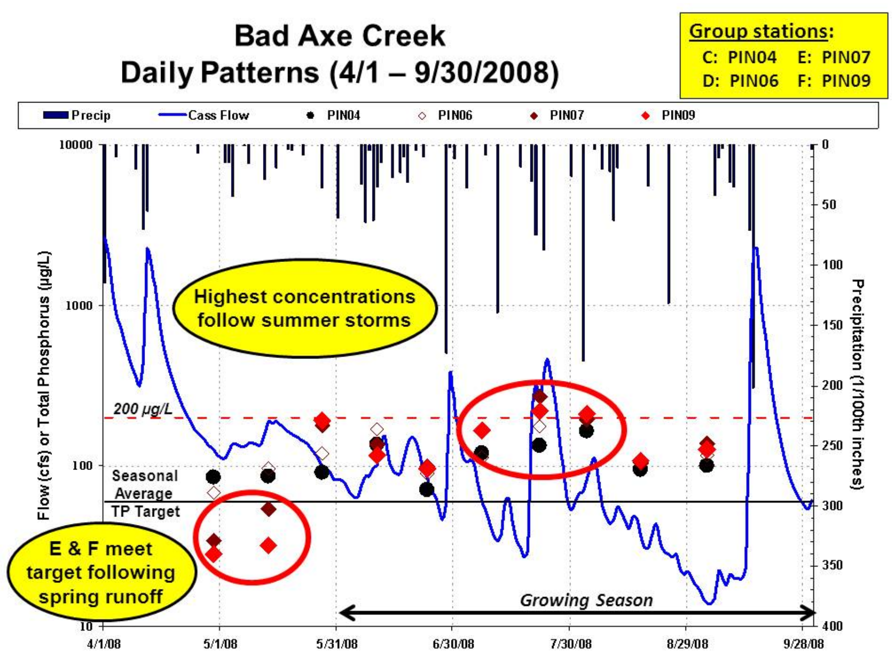


Figure B-1. Bad Axe subwatershed total phosphorus sampling results *(groups C-F)*

Appendix C. Management Measures

Objective

Describe the system of measures that need to be implemented to achieve the load reductions estimated under Element B, as well as other watershed management objectives (e.g., habitat restoration and protection).

Intent

Pollutant loads vary even within land use types, so the plan should identify the critical areas in which those systems will be needed to implement the plan. These systems are designed to meet landowner/operator requirements and site specific needs. The description should be detailed enough to guide implementation activities throughout the watershed and can be greatly enhanced by developing an accompanying map with priority areas and systems. Thought should also be given to the possible use of measures that protect important habitats (e.g. wetlands, vegetated buffers, and forest corridors) and other non-polluting areas of the watershed. In this way, waterbodies would not continue to degrade in some areas of the watershed while other parts are being restored.

Key Questions

- Are management systems needed to address each cause and source of pollution or impairment (or threat) listed, described, and prioritized?
- Are proposed management measures feasible?
- Are critical locations or high-priority sites for each management measure mapped or described?
- Are load reductions linked to each management system listed and quantified via reasonable estimates?

Discussion

***Management Measures Prioritization*.**

Natural variability inherent in agricultural landscapes highlights the need for an integrated approach to prioritize management systems that will achieve load reduction targets in Bad Axe Creek. For areas which are mostly agricultural, a conservation cropping system consisting of nutrient management, residue management, cover crops, and drainage water management should be considered. Although management systems and priority actions may be identified as individual categories, overall implementation efforts focus on using a suite of management measures that function as a system. This integrated approach supports a “win-win” solution that will both minimize erosion / nutrient losses from agricultural lands and maximize farm profitability. The net outcome is greater acceptance of the plan that results in improved water quality and usually increased farm profitability.

These implementation actions, ranked in order of implementation importance, are the foundation of this strategy that will bring Bad Axe Creek back into attainment with water quality standards, which include:

1) Improve ***nutrient management***.
2) Increase acreage using ***cover crops***.
3) Initiate / expand use of ***water quantity management***. In addition to controlled drainage, this action includes practices such as grassed waterways, saturated buffers, and blind inlets.
4) Increase acreage under ***no-till and/or reduced tillage***.
5) Increase miles of ***riparian buffers / filter strips*** along critical reaches / drains.

The priority management measures listed above consider important aspects needed to achieve the in-stream growing season target for Bad Axe Creek and lead to uniform implementation of conservation cropping systems. This includes both spatial position of BMPs relative to delivery paths and timing of load reductions relative to water quality concerns. To date, efforts in Huron County have emphasized implementation of cover crops, no-till, reduced tillage, and nutrient management. Water quantity management should now be the priority of critical area implementation efforts to build off existing efforts and to address the seasonal average targets. This practice was included in the "Saginaw Bay Coastal Initiative Phosphorus Committee Report" as a source reduction recommendation. Development of a *"farmer-to-farmer"* network is an implementation mechanism that is a high priority for plan implementation in promoting an integrated approach that supports "win-win" solutions.

For bacteria, failing or poorly designed OSDS are likely a significant source of *E. coli* in unsewered areas, which was identified in the Pinnebog WMP. Management measures to address elevated bacteria concentrations from these sources include identifying / correcting on-site septic system failures. Reducing *E. coli* loads from agricultural sources include implementing livestock waste management practices, installing riparian buffers / filter strips where pasture runoff can reach local waters, restricting livestock access to streams / ditches, and drainage water management in critical areas where manure is applied to crop land as fertilizer. Management measures to address bacteria loads in urban areas include stormwater management, identify/eliminate illicit discharges, and reduce *E. coli* from pet waste.

Critical Areas.

The Pinnebog WMP identified the entire Bad Axe Creek watershed as a critical area. The focus of this plan is combine the field inventory information with the load analysis, and develop a refined critical area analysis. The critical area analysis recognizes that achieving needed nutrient reductions will require a mix of practices across multiple landscape positions. Practices that emphasize soil management and soil health (e.g., reduced or no tillage, cover crops, nutrient management) play an important role to improve nutrient- and water- use efficiencies in fields (Tomer et.al. 2013).

Soils across significant portions of the lower Bad Axe watershed have low infiltration rates (Appendix A, Figure A-13). This necessitates the use of field tile drainage to support viable row crop production. As indicated in the load analysis, the potential effect of tile drainage on phosphorus concentrations is noticeable in the 2008 MDEQ monitoring data. Locations sampled below Pigeon Road, particularly group E and F increase following summer storms (Figure B-1). In addition, there appears to be a significant increase in phosphorus concentrations towards the end of May at these same locations, indicating the need to examine nutrient and drainage water management practices in these two groups.

Critical areas in high priority subwatershed groups (C, E, and F) are summarized in Table C-1. Included are recommended BMP categories, which would address needed reductions based on the 2008 MDEQ ambient data and the 2011 field inventory. Management practice categories identified in Table C-1 are listed in priority order from left to right. Nutrient management practices center on the 4R nutrient stewardship program (i.e., using the right source of nutrients at the right rate and time in the right place), as well as the existing / revised NRCS nutrient standard. Water quantity management practices include controlled drainage structures, grassed waterways, saturated buffers, and blind inlets. Other practices identified in Table C-1 are more widely accepted in the Bad Axe watershed including reduced tillage, cover crops, and filter strips.

Critical areas listed in each row of Table C-1 are identified by major drain or stream reach using information contained in the field inventory. For instance, the first critical area in subwatershed group C (row 1) corresponds to Richardson Drain and includes two critical areas (30/31). These critical areas are shown in Figure C-1 through Figure C-3. Field inventory information for each critical area is provided in Table C-3 through Table C-8 including:

- critical area(s)
- drainage area (both total and amount in agricultural production based on GIS land use data)
- waterbody (e.g., drain name)
- survey identification code
- field source
- comments / notes in the field inventory

The field inventory information coupled with examination of air photos and the load analysis indicate a need to increase acreage under reduced tillage and cover crops for all group C critical areas [30/31, 34, 35, 36/37/38]. In addition, erosion concerns point to a need to increase the number of miles of riparian buffers / filter strips in group C critical areas. This is evidenced by the amount of streambank, gully, and rill erosion problems caused by plowing to the streambank and lack of vegetative cover.

Water quantity management practices could also address some concerns noted in group C critical areas. Surface ditching was identified in several instances; installation of grassed waterways, saturated buffers, or blind inlets might solve resultant erosion problems in these locations. The opportunity to use controlled drainage structures could be examined where tile outlet failures were identified. This practice is currently being implemented in the River Raisin and in northwest Ohio. In addition to contributing to water quality improvement, there is a potential benefit for farm profitability, particularly during drought years.

Table C-1. Critical area analysis summary for high priority subwatershed groups -- TP

Group *(Outlet Point)*	**Critical Area ID**		**Nutrient Management** [a, e]	**Water Quantity Management** [b]	**Reduced Tillage** [c]	**Cover Crops**	**Other** [d]
C *(Berne Road)*	30/31	Wahl 6 N / Richardson 1077	◗	◗	●●	●●	●●
	34	Stenton 162 / Stenton 165	◗	◗	●●	●●	●●
	35/39	Bad Axe 146	◗	◗	●●	●●	●●
	36/37/38	Symons Br 3 917 / Symons 2 915/ Symons 915	◗	◗	●●	●●	●●
D *(Campbell Rd.)*	41	Bad Axe 915	◗	◗	◗	◗	○
E *(Pinnebog Rd.)*	52 / 54	Ritter 913 / Sam 914	●●	●●	◗	◗	●●
	53	E Br of Pinnebog 918	◗	◗	◗	◗	●●
F *(mouth)*	62/63	Renn 910 / Renn 908	●●	●●	◗	◗	●●

Notes: ●● High priority BMP ◗ Medium priority BMP ○ Provide general benefit for load reduction

[a] 4R nutrient stewardship program; existing / revised NRCS nutrient standard
[b] controlled drainage structures; grassed waterways; saturated buffers; blind inlets
[c] no-till; zone building; strip tillage; shallow vertical tillage; corn stalk residue
[d] riparian buffers; filter strips
[e] NRCS 590: *(The link provided was broken and has been removed.)*

Estimated load reductions associated with practices for each critical area are provided in Table C-2. Based on available information, these represent approximate ranges that reflect the anticipated effectiveness of individual practices. Actual reductions could vary depending on factors such as soil type / condition, whether practices are used alone or in combination, and the level of existing implementation in each critical area. These estimates may be refined as new information becomes available that accounts for existing BMPs, their location within the appropriate critical area, and their pollutant reduction effectiveness.

Table C-2. Estimated phosphorus load reductions for critical areas to meet water quality targets

Group *(Outlet Point)*	Critical Area ID		Nutrient Management	Water Quantity Management	Reduced Tillage	Cover Crops	Other
C *(Berne Road)*	30/31	Wahl 6 N / Richardson 1077	20-40%	20-40%	20-30%	20-30%	5-10%
	34	Stenton 162 / Stenton 165	20-40%	20-40%	20-30%	20-30%	5-10%
	35/39	Bad Axe 146	20-40%	20-40%	20-30%	20-30%	5-10%
	36/37/ 38	Symons Br 3 917 / Symons 2 915/ Symons 915	20-40%	20-40%	20-30%	20-30%	5-10%
D *(Campbell Rd.)*	41	Bad Axe 915	20-40%	20-40%	15-25%	15-25%	5-10%
E *(Pinnebog Rd.)*	52 / 54	Ritter 913 / Sam 914	30-50%	30-50%	15-25%	15-25%	5-10%
	53	E Br of Pinnebog 918	20-40%	20-40%	15-25%	15-25%	5-10%
F *(mouth)*	62/63	Renn 910 / Renn 908	30-50%	30-50%	15-25%	15-25%	5-10%

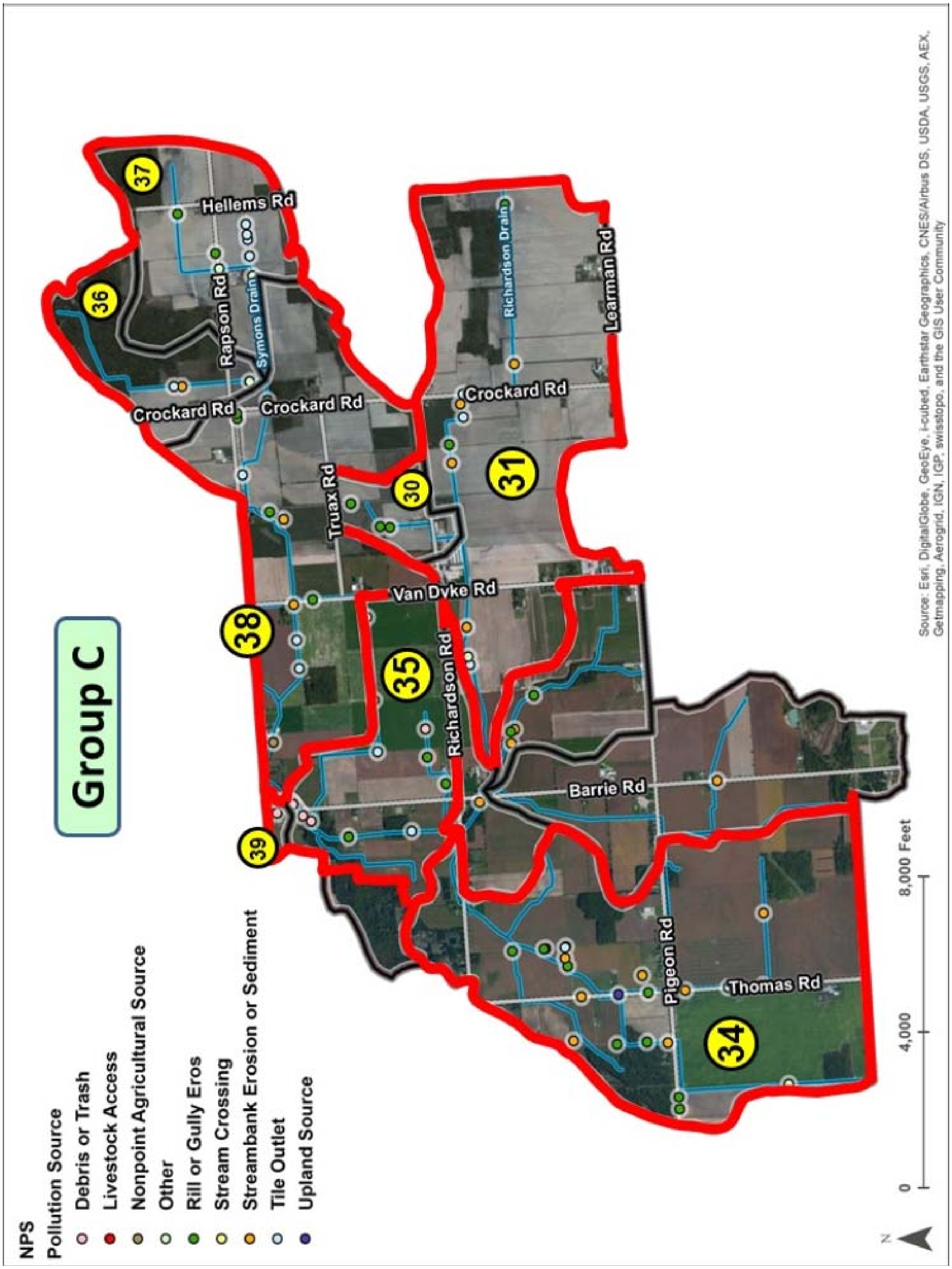


Figure C-1. Critical areas -- subwatershed group C

Table C-3. Field inventory information -- Group C (30/31)

Critical Area	Area *(acres)* Total	Area *(acres)* Agr.	Waterbody	Survey ID	Field Source	Comments / Notes
30	130	109	Wahl 6N	VE060601	gully erosion	Plowing to streambank
				VE060602	gully erosion	Surface water collection
				VE060603	gully erosion	Plowing to streambank
31	1,252	1,086	Richardson 1128	VE113102107	gully erosion	Surface ditching
				VE11280804	streambank erosion	Systemic
				VE11280803	streambank erosion	No vegetative cover
				VE11280802	tile outlet	Outlet failure
			Richardson 1077	VE10770701	streambank erosion	No vegetative cover
				VE10770702	tile outlet	Outlet failure
				VE10770703	gully erosion	Plowing to streambank
				VE10770704	streambank erosion	No vegetative cover
				CX107701203	streambank erosion	No vegetative cover
				CX107701202	other	Barnyard runoff
				CX107701201	tile outlet	Outlet failure
TOTAL	1,382	1,195				

Table C-4. Field inventory information -- Group C (35)

Critical Area	Area *(acres)* Total	Area *(acres)* Agr.	Waterbody	Survey ID	Field Source	Comments / Notes
35	600	449	Bad Axe 1A	CX1A0103	obstruction	Log jam
				CX1A0102	rill erosion	Tillage to streambank
				CX1A0101	gully erosion	Surface ditching
			Bad Axe 146	CX1460201	tile outlet	Outlet failure
				CX1460202	gully erosion	Surface ditching
			Bad Axe 916	CX9160102	field crossing	Water eroded through streambank
				CX9160101	streambank erosion	No vegetative cover
				CX9160103	tile outlet	Outlet failure
TOTAL	600	449				

Table C-5. Field inventory information -- Group C (34)

Critical Area	Area *(acres)* Total	Area *(acres)* Agr.	Waterbody	Survey ID	Field Source	Comments / Notes
34	1,539	1,237	Stenton 165	CX16501405	streambank erosion	No vegetative cover
				CX16501404	tile outlet	Outlet failure
				CX16501403	tile outlet	Outlet failure
				CX16501402	streambank erosion	No vegetative cover
				CX16501401	tile outlet	Outlet failure
			Stenton 165A/B	CX165A01103	gully erosion	Low spot
				CX165B01101	streambank erosion	No vegetative cover
				CX165A01102	urban	Suspected sewage septage
				CX165A01101	streambank erosion	No vegetative cover
			Stenton 162	CX16201503	other	Renter to close to ditch edge
				CX16201502	gully erosion	Surface ditching
				CX16201501	gully erosion	Surface ditching
				CX16201001	streambank erosion	No vegetative cover
				CX16201002	gully erosion	Plowing to streambank
				CX16201003	gully erosion	Plowing to streambank
				CX16201004	streambank erosion	No vegetative cover
				CX16201101	gully erosion	Washout
				CX16201102	streambank erosion	No vegetative cover
				CX16201103	tile outlet	Severe erosion around broken outlet
				CX16201104	tile outlet	Outlet failure
				CX16201105	gully erosion	Plowing to streambank
				CX16201106	gully erosion	Plowing to streambank
				CX16201107	gully erosion	Plowing to streambank
TOTAL	1,539	1,237				

Table C-6. Field inventory information -- Group C (36/37/38)

Critical Area	Area *(acres)* Total	Area *(acres)* Agr.	Waterbody	Survey ID	Field Source	Comments / Notes
36	282	112	Symons Br 3 917	LN91703201	streambank erosion	No vegetative cover (500+ feet)
				LN91703202	tile outlet	Gully erosion
			Symons 915	VE9150508	surface inlet	Surface inlet, farmer dug through ditch bank, bare furrow 3 x 5 ft.
37	489	339	Symons Br 2 915	LN91503201	rill erosion	Tillage to streambank
				LN91503202	gully erosion	Surface ditching
			Symons 915	VE9150507	other: surface inlet	Surface inlet, barnyard, bare ground
				VE9150506	tile outlet	Plunge pool
				VE9150505	tile outlet	Gully erosion
				VE9150504	tile outlet	Gully erosion
				VE9150503	tile outlet	Plunge pool
				VE9150502	surface inlet	Barnyard, bare surface inlet, streambank erosion
38	974	842	Symons 915	VE9150501	gully erosion	Plowing to streambank
				VE9150602	gully erosion	Plowing to streambank
				VE9150601	gully erosion	Plowing to streambank
				VE9150603	tile outlet	Plunge pool
				VE9150604	gully erosion	Plowing to streambank
				VE9150605	streambank erosion	No vegetative cover
				VE9150607	gully erosion	Plowing to streambank
				CX9150103	streambank erosion	Stormwater outfall (M-53)
				CX9150102	tile outlet	Outlet failure
				CX9150101	tile outlet	Outlet failure
				CX9150105	other	Beef operation / narrow buffer
TOTAL	1,293	1,744				

The field inventory information coupled with examination of air photos and the load analysis indicate a need to increase acreage under reduced tillage and cover crops for all group E and F critical areas [52/54, 62/63]. In addition, erosion concerns point a need to increase the number of miles of riparian buffers / filter strips in group E and F critical areas. This is evidenced by the amount of streambank, gully, and rill erosion problems caused by plowing to the streambank and lack of vegetative cover.

Water quantity management practices could also address some concerns noted in group E and F critical areas. Surface ditching was identified in several instances; installation of grassed waterways, saturated buffers, or blind inlets might solve resultant erosion problems in these locations. The opportunity to use controlled drainage structures could be examined where tile outlet failures were identified.

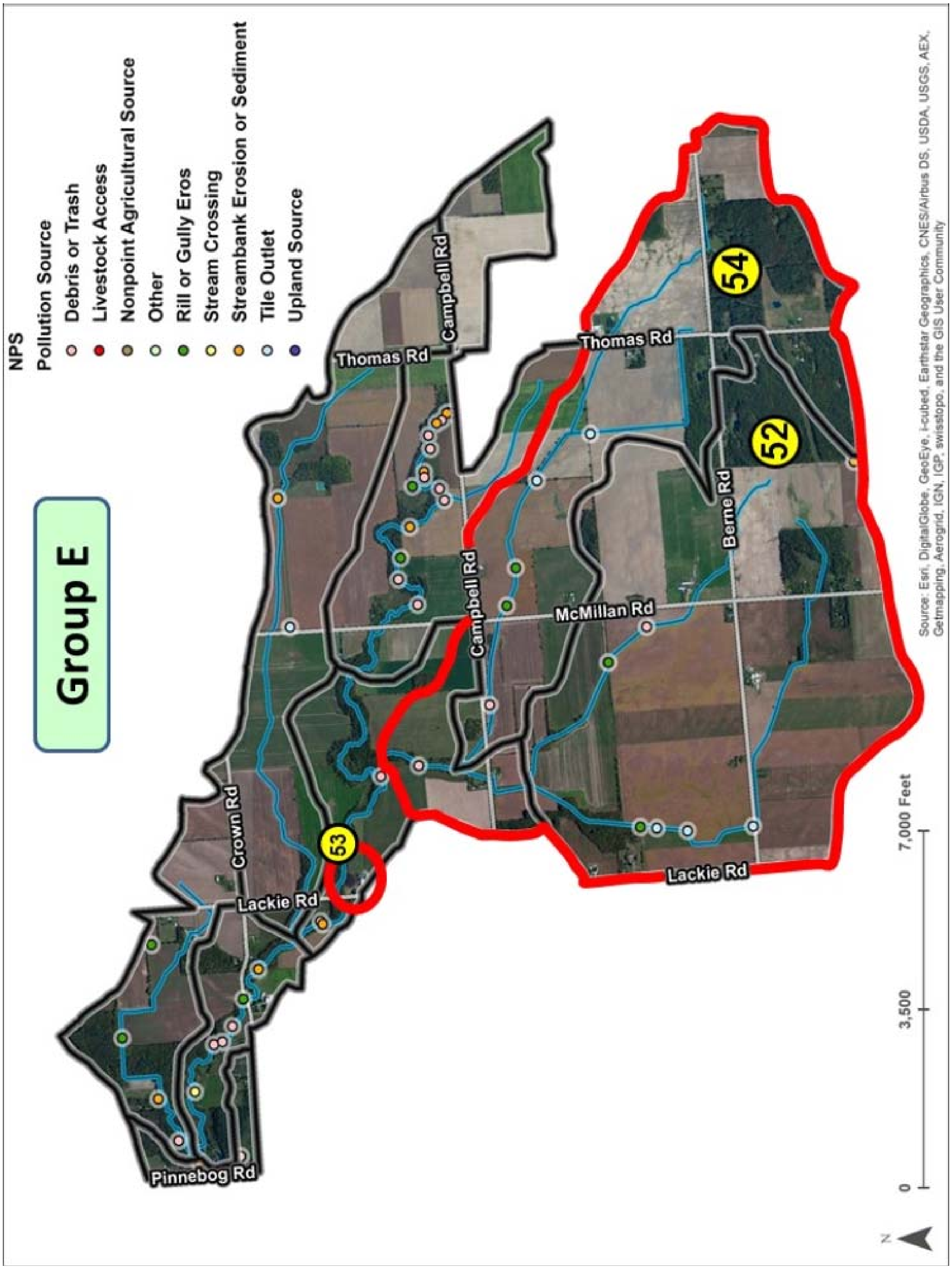


Figure C-2. Critical areas -- subwatershed group E

Table C-7. Field inventory information -- Group E (52/54)

Critical Area	Area *(acres)* Total	Area *(acres)* Agr.	Waterbody	Survey ID	Field Source	Comments / Notes
52	1,274	1,064	Ritter 912	ME91203301	obstruction	Log jam
				ME91203302	tile outlet	Erosion around outlet
				ME91203303	gully erosion	Surface ditching
			Ritter 913	ME91303301	tile outlet	Outlet failure
				ME91303302	tile outlet	Outlet failure
				ME91303304	tile outlet	Outlet failure
				ME91303303	gully erosion	Surface ditching
54	793	519	Sam 914A	ME914A03401	tile outlet	Outlet failure
			Sam 914	ME91403402	tile outlet	Gully erosion
				ME91403403	gully erosion	Plowing to streambank
				ME91403401	gully erosion	Surface ditching
				ME91403301	obstruction	Log jam
TOTAL	2,067	1,583				

Table C-8. Field inventory information -- Group F (62/63)

Critical Area	Area *(acres)* Total	Area *(acres)* Agr.	Waterbody	Survey ID	Field Source	Comments / Notes
62	1,297	1,152	Renn 911	ME91102901	obstruction	Log jam
			Renn 910	ME91002901	gully erosion	Surface ditching
				ME91002903	gully erosion	Plowing to streambank
				ME91003001	streambank erosion	No vegetative cover
				ME91003002	streambank erosion	No vegetative cover
				ME91003003	gully erosion	Lack of cover
				ME91003004	tile outlet	Washed out around outlets
			Renn 910B S	ME910B03001	tile outlet	Outlet failure
			Renn 909	ME90903001	gully erosion	Surface ditching
63	569	516	Renn 908	ME90803003	streambank erosion	No vegetative cover
				ME90803002	tile outlet	Outlet failure
				ME90803001	gully erosion	Plowing to streambank
				ME90801901	gully erosion	Plowing to streambank
				ME90801902	gully erosion	Plowing to streambank
				ME90801903	gully erosion	Plowing to streambank
TOTAL	1,866	1,668				

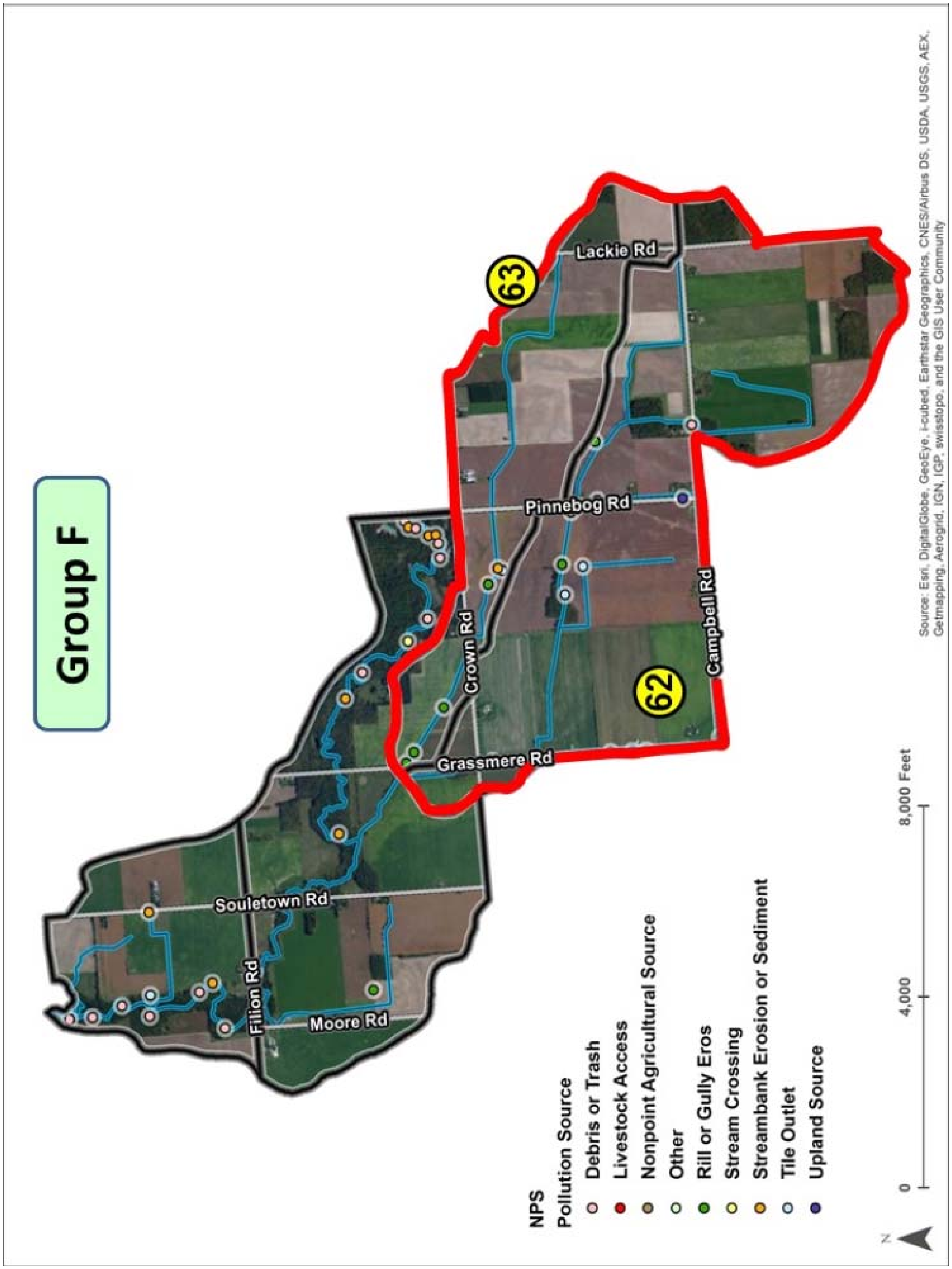


Figure C-3. Critical areas -- subwatershed group F

Critical area identification for bacteria source reduction is limited to the MDEQ 2008 monitoring information. This data indicates that priority subwatershed groups are A, B, C, and D. Field inventory work specifically targeted towards sources of *E. coli* was not conducted. In the absence of field inventory information, land use, soils, and air photo analysis is used to suggest starting points for follow-up. Based on this limited information, critical areas for *E. coli* are summarized in Table C-9. These areas are shown in Figure C-4 and Figure C-5 for groups A and B. Critical areas for subwatershed group C are shown in Figure C-1. Again, these determinations are based on current available information. Reduction estimates for *E. coli* in Table C-10 are very rough until better field inventory and source tracking information becomes available following implementation of Phase 1.

Table C-9. Critical area analysis summary for high priority subwatershed groups -- *E. coli*

Group *(Outlet Point)*	**Critical Area ID**		**On-site Disposal Systems** [a]	**Livestock and Agriculture** [b]	**Urban Stormwater** [c]
A *(above WWTP)*	11	Turner 1131	●●	○	○
	14	Crumback 632	●●	○	○
B *(Pigeon Road)*	21	Bad Axe 633	◗	○	●●
	23/24	Bad Axe 149	◗	○	●●
C *(Berne Road)*	31	Richardson 1077	◗	●●	n.a.
	34	Stenton 162 / Stenton 165	◗	◗	n.a.
	38	Symons 915	◗	◗	n.a.
D *(Campbell Rd.)*	41	Bad Axe 915	◗	●●	n.a.

Notes: ●● High priority BMP ◗ Medium priority BMP ○ Provide general benefit for load reduction

[a] correct on-site septic system failures
[b] livestock management; riparian buffers; filter strips; controlled drainage structures
[c] urban stormwater management; eliminate illicit discharges; reduce pet waste runoff

Table C-10. Estimated *E. coli* reductions for critical areas to meet water quality targets

Group *(Outlet Point)*	**Critical Area ID**		**On-site Disposal Systems**	**Livestock and Agriculture**	**Urban Stormwater**
A *(above WWTP)*	11	Turner 1131	Unknown *(E. coli for this group not monitored in 2008)*		
	14	Crumback 632			
B *(Pigeon Road)*	21	Bad Axe 633	10-70%	n.a.	10-70%
	23/24	Bad Axe 149	10-70%	n.a.	10-70%
C *(Berne Road)*	31	Richardson 1077	10-70%	10-70%	n.a.
	34	Stenton 162 / Stenton 165	10-70%	10-70%	n.a.
	38	Symons 915	10-70%	10-70%	n.a.
D *(Campbell Rd.)*	41	Bad Axe 915	10-70%	10-70%	n.a.

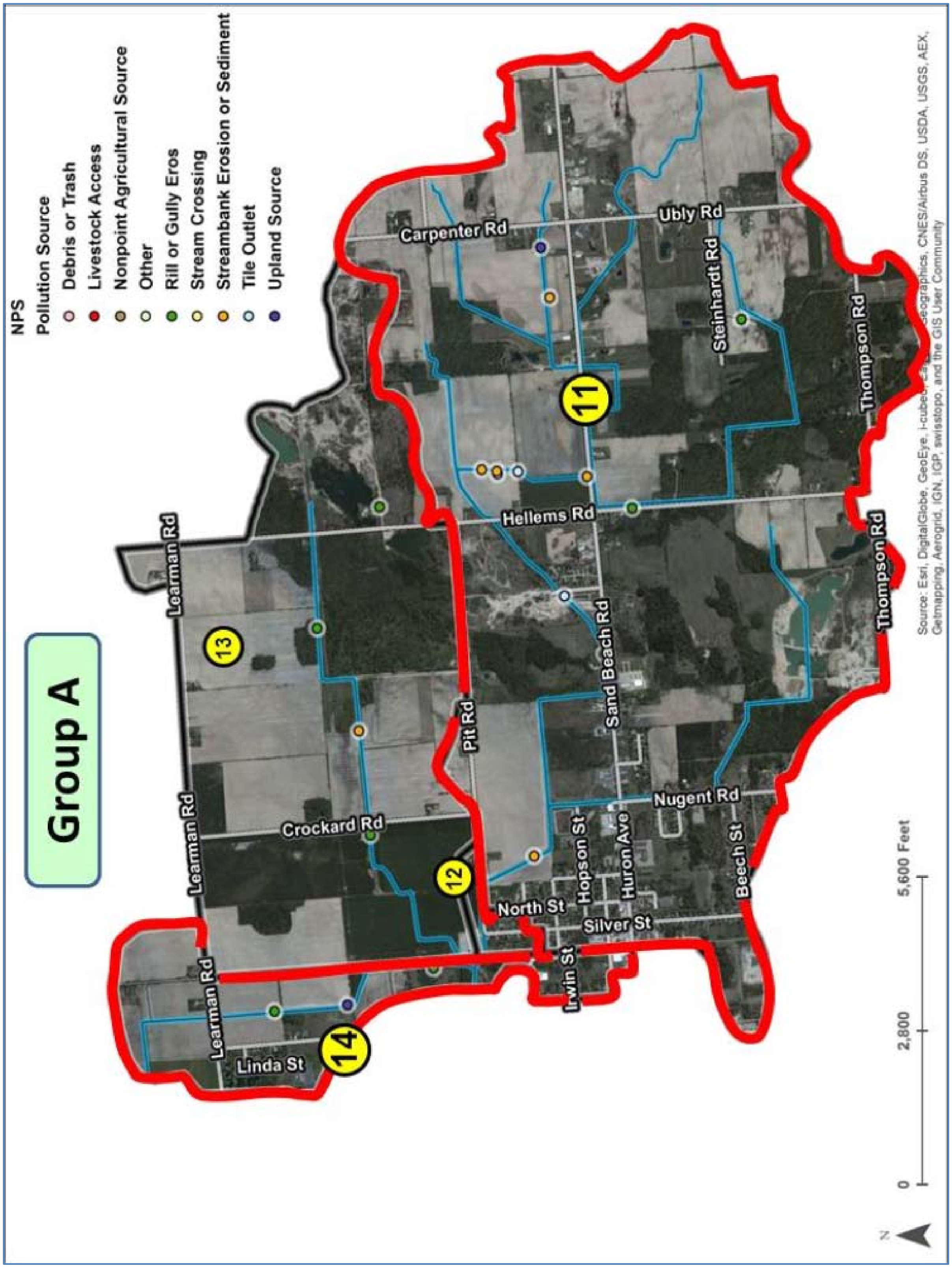


Figure C-4. Critical areas -- subwatershed group A

Figure C-5. Critical areas -- subwatershed group B

Seasonality affects the general importance of each management measure relative to water quality concerns. Timing considerations should be factored into the identification of critical areas (Table C-11). For example, cover crops and no-till are most effective in reducing loads delivered during spring runoff. Relatively wide-spread application of these BMPs in critical areas subwatershed groups E and F could explain the reason behind data indicating those reaches were below the seasonal average target following spring runoff (Figure B-1). This provides a basis for targeting subwatershed groups C and D for these practices. In addition, these BMPs enhance soil health and improve the infiltration capacity of fields reducing delivery of nutrients from ditches to Bad Axe Creek through channel erosion and scour associated with high runoff events and flashiness (as illustrated in Figure C-6).

Nutrient management, while reducing annual loads, is a major consideration during establishment periods. This is evident in Bad Axe Creek by examining the 2008 MDEQ monitoring data (Figure B-1). Specifically, nutrient concentrations below subwatersheds E and F increase dramatically between samples collected in early-May compared to those in late-May. This period likely coincides with the timeframe when planting and fertilizer application could have occurred. Levels remained above the seasonal average target throughout the remainder of the sampling timeframe.

Table C-11. Timing considerations in critical area analysis

<table>
<tr><th rowspan="2">Month</th><th colspan="4">Management Practice</th><th rowspan="2">Notes</th></tr>
<tr><th>No-till or reduced tillage</th><th>Cover Crops</th><th>Nutrient Management</th><th>Drainage Water Management</th></tr>
<tr><td>January</td><td>***</td><td>***</td><td>*</td><td>***</td><td></td></tr>
<tr><td>February</td><td>***</td><td>***</td><td>*</td><td>***</td><td></td></tr>
<tr><td>March</td><td>***</td><td>***</td><td>*</td><td>***</td><td>Generally highest runoff month</td></tr>
<tr><td>April</td><td>***</td><td>***</td><td>***</td><td>*</td><td rowspan="3">Depending on moisture conditions
• Tillage generally begins in April
• Beets generally planted in April
• Corn & soybeans in May
Fertilizer application crop / producer dependent</td></tr>
<tr><td>May</td><td>*</td><td>*</td><td>***</td><td>*</td></tr>
<tr><td>June</td><td>*</td><td></td><td>***</td><td>***</td></tr>
<tr><td>July</td><td>*</td><td></td><td>*</td><td>***</td><td rowspan="2">Controlling surface runoff / drainage water flow needed to meet growing season average target</td></tr>
<tr><td>August</td><td>*</td><td></td><td>*</td><td>***</td></tr>
<tr><td>September</td><td>*</td><td></td><td>*</td><td>*</td><td rowspan="3">Depending on climate conditions
• Crops harvested Sept – early November
• Tillage / fertilizer application could occur (producer dependent)</td></tr>
<tr><td>October</td><td>*</td><td>*</td><td>***</td><td>*</td></tr>
<tr><td>November</td><td>***</td><td>***</td><td>***</td><td>*</td></tr>
<tr><td>December</td><td>***</td><td>***</td><td>*</td><td>***</td><td></td></tr>
<tr><td colspan="6"><u>Notes</u> *** Most important months for reducing pollutant loads.
* Moderately important months for reducing pollutant loads.</td></tr>
</table>

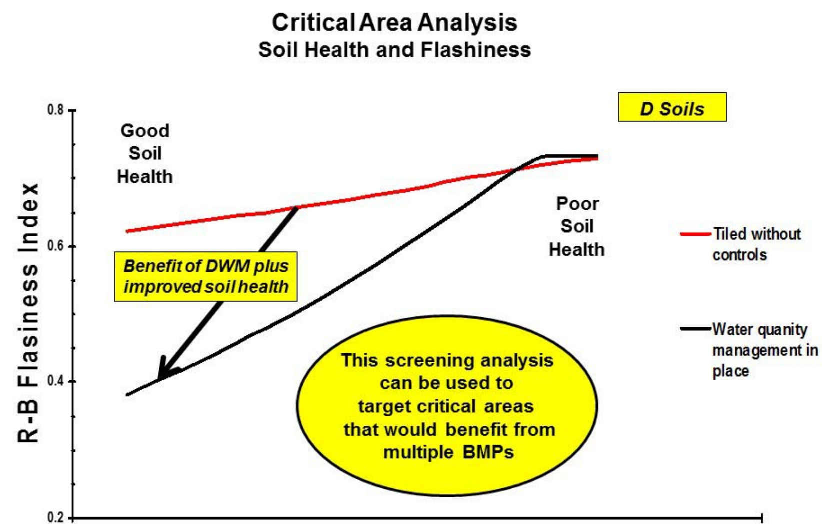


Figure C-6. Critical area screening analysis *(benefit of soil health and water quantity management)*

***Feasibility*.**

Nutrient loads from agricultural sources are delivered to Bad Axe Creek through surface and subsurface runoff. Measures to reduce these loads are recommended in the Pinnebog WMP and the “Saginaw Bay Coastal Initiative Phosphorus Committee Report”. These fall into four broad categories including upland management, livestock management, water quantity management, and riparian management.

Upland management measures are applicable to causes of impairments in the Bad Axe watershed through a focus on source reduction. These measures are designed to:

1) reduce erosion and sediment loss (which carries nutrients), and
2) limit manure and fertilizer application to only those levels that meet the agronomic need of crops in the rotation.

Upland management strategies recognize the importance of soil health. Soil health determines how rainwater and nutrients either infiltrate or runoff into ditches and streams. Table C-12 summarizes the relationship of each management measure to source areas highlighting benefits to water quality.

While Table C-12 appears to emphasize management measures related to nutrients, implementation of these practices will also benefit bacteria pollutant reduction needs and address *E. coli* criteria exceedances.

Table C-12. Management measures and water quality benefits

Management Measure	Benefits *(water quality, air quality, and/or soil health)*
Nutrient Management ✓ e.g., 4R *(**R**ight source, **R**ight rate, **R**ight time, **R**ight place)*	• Maximize crop uptake of nutrients • Minimize loss of nutrients from crop land
Cover Crop	• Reduces soil erosion • Increases soil organic matter • Increases soil porosity and promotes matrix flow in the soil profile • Reduces compaction • Improves infiltration • Improves water efficiency for crops • Improves nutrient use efficiency
Water Quantity Management	• Reduces delivery of pollutants to streams and ditches
Conservation Tillage ✓ No till ✓ Zone / Strip till ✓ Mulch till	• Minimize / eliminate tillage and minimize soil disturbance • Reduces soil erosion • Increases soil organic matter • Promotes matrix flow in the soil profile • Reduces compaction (if done properly) • Improves infiltration • Improves water efficiency for crops
Filter Strips	• Reduces delivery of pollutants to streams and ditches
Manure Management	• Maximize crop uptake of nutrients • Minimize loss of nutrients from crop land • Reduces delivery of pollutants to streams and ditches

Appendix D. Technical and Financial Assistance

Objective

Describe the financial and technical assistance available to implement the plan (installation of management measures, long-term operation and maintenance, information/education activities, monitoring, program evaluation, etc.).

Intent

Document the organizations that might play a role in implementing the plan including the use of federal, state, local, and private resources that might be available to assist. Identify shortfalls between needs and available resources.

Key Questions

- What are the general types and amounts of technical assistance needed to implement the management measures?
- What are the actual or potential sources of needed technical assistance?

Discussion

General type & amount of technical assistance needed to implement the management measures.

A wide array of partners is available who can provide technical and financial assistance to address water quality concerns in the Bad Axe watershed. Although participation levels may vary by location and project type, each agency or group identified in Table 12 has an existing or potential role to play. Organizations within the community include the Huron Conservation District, the Huron County Drain Commission, and the Huron County Health Department. These groups provide local technical expertise, promote I&E, and pursue funding opportunities. Other local resources include the City of Bad Axe, other NPDES permittees, key dairy, crop, and livestock producers, local recreational and resource interest groups, local university groups, local land improvement and drainage contractors who support agricultural producers, and local residents.

Actual or potential/possible sources of the needed technical assistance.

At the State level, MDEQ's Nonpoint Source Program is the focal point for facilitating implementation of projects designed to help solve NPS problems and / or restore impaired waters. Program staff provides local assistance through technical expertise, grant funding, and coordination with state / federal agencies (e.g., other MDEQ offices, Department of Natural Resources, Department of Agriculture & Rural Development, U.S. EPA, U.S. Department of Agriculture).

<u>Possible/potential sources of financial assistance needed to implement the management measures</u>.

Financial assistance available through MDEQ to support certain Bad Axe TMDL Watershed Implementation Plan efforts include: Section 319(h) grants, Clean Michigan Initiative (CMI) grants, GLRI grants, and several other stand-alone programs that contribute to successfully restoring streams impacted by high magnitude nonpoint source causes of impairment (MDEQ 2012). In addition to NPS program funding, MDEQ's Office of Financial Assistance administers the Water Pollution Control Revolving Fund (WPCRF). The WPCRF is a revolving loan fund that provides low interest loans and other financial / technical assistance to address water quality concerns.

The U.S. Department of Agriculture (USDA) through the Natural Resources Conservation Service (NRCS) offers voluntary programs to eligible landowners and agricultural producers, which provides financial and technical assistance that address natural resource concerns. Included is the Environmental Quality Incentives Program (EQIP) and the Cooperative Conservation Partnership Initiative (CCPI). The most comprehensive of these programs is EQIP, which offers cost-sharing and incentives to producers who utilize approved conservation practices.

Other sources of assistance, both technical and financial, are available through several Great Lakes programs including GLRI, the Great Lakes Commission, and the Great Lakes Protection Fund (GLPF). GLFP is a private endowment created to stimulate development of innovative methods and practical actions to improve the health of the Great Lakes ecosystem. For example, GLPF supported efforts to explore development and application of real-time drain tile management. Through funding to TNC, opportunities to use this technology in the Saginaw Bay watershed are being examined.

The Saginaw Bay Watershed Conservation Partnership (SBWCP) provides another assistance opportunity to support the Bad Axe TMDL Watershed Implementation Plan. SBWCP is funded under the Regional Conservation Partnership Program, which was created under the 2014 Farm Bill. This work, co-led by the Michigan Agri-Business Association and TNC, represents a collaboration between conservation organizations, agronomy retailers, higher education institutions, commodity groups, agribusinesses, and government agencies. The focus of this effort is to help producers implement practices designed to reduce nutrient loads to Saginaw Bay.

<u>Regulatory or other authorities responsible for (or needed) to implement the management measures and/or entities exercising the regulatory or other authorities are identified</u>.

Regulatory authorities have been granted to several stakeholders. Included are: HCHD (on-site septic regulation and enforcement); HCRC (road stream crossing fixes); HCDC (manage drains and regulate drain inputs); MDEQ (permits, TMDLs, Part 31 regulations); and MDARD (right-to-farm issues).

Appendix E. Information and Education

Objective

Describe the education and outreach activities or actions that will be used to implement the plan.

Intent

These activities may support the adoption and long-term operation and maintenance of management practices and support stakeholder involvement efforts.

Key Questions

- Are Information, education, and public participation goals and objectives for the management program listed?
- Is an overall strategy or plan for the public information, education, and participation component provided?

Discussion

Information, education, and public participation goals and objectives for the management program.

Information and education (I&E) is vital to the success of the Bad Axe TMDL Watershed Implementation Plan. The I&E strategy targets specific audiences to educate them regarding their potential impacts on water quality. The importance of this component is recognized by the local community as evidenced by activities that supported development of the Pinnebog Watershed Management Plan. Efforts to prepare the Pinnebog plan included an I&E subcommittee.

The resultant strategy, which forms the basis for I&E in the Bad Axe Implementation Plan, outlines major educational opportunities and actions needed to successfully maintain and improve water quality in the watershed to meet the following objectives:

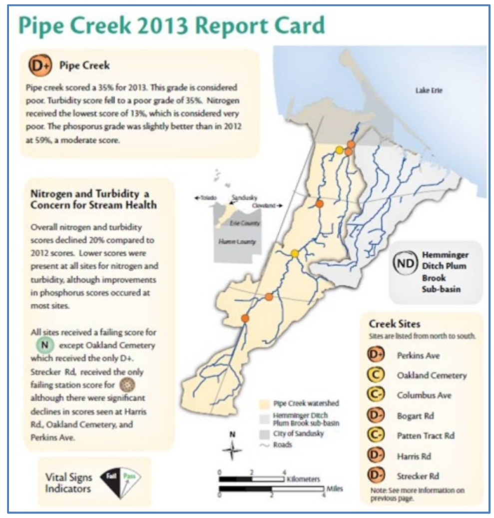
- Increase public knowledge and broaden awareness of the water quality challenges faced in the Bad Axe Creek watershed.
- Educate stakeholders about the environmental impacts of land use activities.
- Provide opportunities for comment and participation in implementing the plan.
- Develop partnerships among stakeholders by sharing ideas, resources, and facilitating cooperative activities that increase public awareness of watershed management and impact land use policies.
- Create a sense of individual responsibility for the proper use and care of surface water resources.

Details identified in the Pinnebog WMP are equally applicable to the Bad Axe watershed and incorporated into this plan. The approach consists of three basic components including:

- ✓ Awareness
- ✓ Education
- ✓ Action

Specific activities to meet each I&E strategy objective are built around the key message, the target audience (e.g., all audiences, agricultural producers, all residents, businesses, elected officials, students / youth groups / clubs), the applicable component (e.g., awareness, education, action), a description of the delivery method, and potential partners.

In addition, an important aspect of the Bad Axe TMDL Watershed Implementation Plan involves targeting critical areas. Monitoring data plays a key role in ensuring that limited resources are directed to those actions that will lead to measureable water quality improvements. For this reason, the Bad Axe I&E strategy includes initiating efforts to develop locally generated water quality data. This information can be used to strengthen education efforts as well as expand local awareness of concerns and needed solutions.



An option to initiate this program could start by exploring examining NPDES-based cooperative efforts used in other states. For example, a program could build on WWTP effluent monitoring already conducted by the City of Bad Axe in partnership with other NPDES permittees in the watershed. With support from the Huron County Commission, a cooperative monitoring program could also include the Health Department, the Drain Commission, and local schools. Monitoring expertise available from Saginaw Valley State University could provide assistance to ensure the data met quality objectives for subsequent use to guide cost-effective implementation efforts. Program results could be disseminated to the public through a watershed report card, similar to ones used by the Erie County (OH) Conservation District (*http://erieconserves.org/ - Your Home, Watershed Report Cards).*

An overall strategy or plan for the public information, education, and participation component.

This TMDL Implementation Plan includes a priority recommendation to develop an updated I&E strategy for the Bad Axe watershed that includes the following:

- Focus on priority pollutants and sources
- Focus on critical areas
- Identify target audiences
- Identify key messages and delivery mechanisms
- Develop evaluation criteria

Appendix F. Outcome-based Schedule

Objective

Describe the schedule for implementing the management measures outlined in the watershed plan.

Intent

The schedule should reflect the milestones developed for Element G. Implementation should begin as soon as possible. Conducting baseline monitoring and outreach for implementing water quality projects are examples of activities that can start right away. It is important that schedules not be "shelved" for lack of funds or program authorities; instead they should identify steps towards obtaining needed funds as feasible.

Key Questions

- Is an overarching timeline or schedule showing projected dates for developing and implementing each management measure presented?
- Does the timeline or schedule indicates the actions, steps, or accomplishments associated with implementing the management measures in the plan?
- Does the timeline or schedule follows a logical sequence for implementing the management measures?
- Does the timeline or schedule list short-term (up to 3 years) and long-term (up to 10 or more years) implementation steps?

Discussion

An overarching timeline or schedule showing projected dates for developing and implementing each management measure.

The Bad Axe TMDL Watershed Implementation Plan is envisioned to occur over a 15-year period; staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed nutrient and bacteria reductions. Short-term efforts (Year 1-3) include implementing practices in critical areas so that annual nutrient loads and high risk bacteria sources to Bad Axe Creek are significantly reduced. This approach is consistent with the direction currently pursued by HCD in conjunction with local partners.

Short-term implementation activities also include monitoring in the Bad Axe watershed conducted by SVSU. Related to both monitoring and I&E, the short-term schedule includes exploring efforts to initiate a locally led monitoring program. In addition to elevating public awareness, information from this program would provide a technical basis to guide locally generated, cost-effective solutions.

Timeline or schedule indicates the actions, steps, or accomplishments associated with implementing the management measures.

The timeline and schedule are described in the main document (Section 6.4 and Table 16).

The timeline or schedule follows a logical sequence for implementing the management measures.

An important aspect of watershed plan development is to identify and encourage activities, which can be quickly implemented and produce measureable results. As with many watersheds of comparable size, the Bad Axe watershed faces a variety of implementation challenges. These challenges include how to assess the benefits of a variety of water quantity and quality control strategies, how to select the optimal combination of BMPs that minimize costs, how to be consistent with community goals and characteristics, and how to meet reductions needed to achieve WQS.

To meet these challenges and ensure the watershed implementation plan is outcome-based with local support, it is important to evaluate water quality, pollutant source, and drainage system information at a level detailed enough to recommend specific actions and responsibilities (Figure F-1). This is accomplished in stages building on the NPS field inventory and critical areas for BMP implementation. The plan is re-evaluated through each phase of implementation and program adjustments made as new information becomes available.

A generalized outcome-based strategic planning framework is presented in Figure F-1. The primary focus is to take advantage of local input to address reduction needs by continuing to identify implementation opportunities in each phase that will produce measurable results. In general, the outcome-based strategic planning framework begins with Stage 1, which represents the watershed-scale scoping at the start of each phase. Available Bad Axe Creek watershed information is reviewed during each phase of plan implementation as it relates to each of USEPA's Nine Minimum Elements. Data gaps are identified and priorities established at the watershed scale.

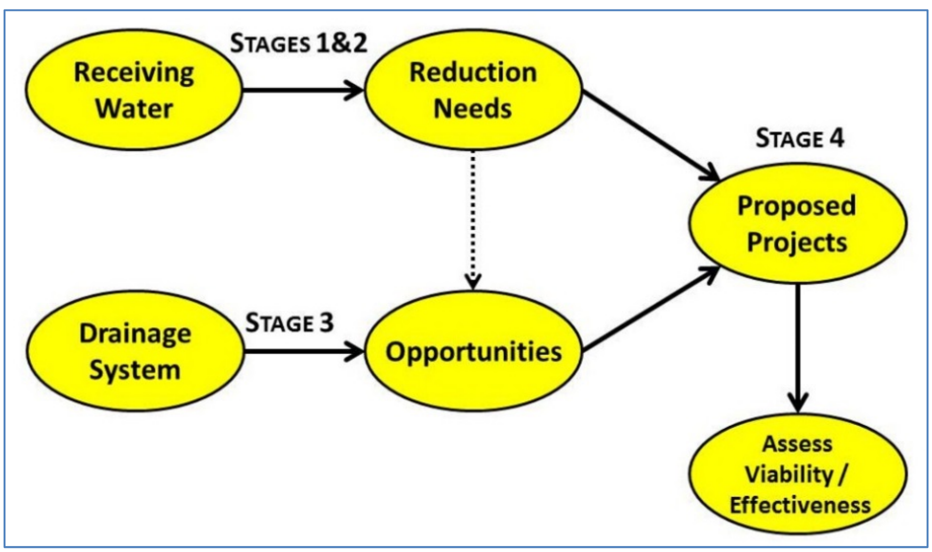


Figure F-1. Outcome-based strategic watershed planning framework

Based on reduction needs information (Table F-1, Plan Element B), Stage 2 targets critical areas for development of source-specific strategies to address NPS pollution described in "Michigan's Nonpoint Source Program Plan" (MDEQ, 2012). The emphasis in Stage 3 is on examining and prioritizing locations within critical areas where water quality improvements are needed and opportunities to implement BMPs are available. Stage 4 examines potential projects in "areas of opportunity". Key factors are considered including feasibility, constraints, potential effectiveness, and associated benefits.

Again the framework shown in Figure F-1 is intended to be iterative through each phase of the implementation plan using adaptive management; one that continues while better data are collected, results analyzed, and the watershed plan enhanced. In this way, implementation activities can focus on a cumulative reduction in loadings under a plan that is flexible enough to allow for refinement, reflects the current state of knowledge about the system, and is able to incorporate new, innovative techniques.

The relationship between the nine minimum elements and outcome-based scheduling is summarized in Table F-1. This table briefly describes key activities based on priority concerns and implementation opportunities as the adaptive management process iteratively cycles from watershed scale to progressively smaller geographic areas in each stage. This framework provides a platform to identify, prioritize, and target implementation projects in ways that improve the cost-effectiveness of limited resources to address water quality problems in the Bad Axe watershed. The approach recognizes the dynamic nature of program implementation. As efforts continue, detailed work may reveal additional gaps or discover methods to improve the process.

The timeline or schedule lists short-term (up to 3 years) and long-term (up to 10 or more years) implementation step.

Priority actions will occur over a 15-year period with staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed nutrient and bacteria reductions (Table 16). Short-term efforts (Year 1-3) include implementing practices in critical areas so that annual nutrient loads and high risk bacteria sources to Bad Axe Creek are significantly reduced. Mid-term efforts (Year 4-8) are intended to build on the results of short-term implementation activities. This includes evaluating the success of Phase 1 projects installed (success rate, BMP performance, pollutant reductions realized, actual costs, etc.). Long-term efforts (Year 9-15) are those implementation activities that result in Bad Axe Creek in full attainment with Michigan's WQS.

Table F-1. Relationship between nine minimum elements and strategic planning stages

Plan Element		Stage			
		1 *(Subwatershed)*	**2** *(Critical Areas)*	**3** *(Opportunities)*	**4** *(Projects)*
A	Causes and sources	Summarize available characterization information and identify targeted subwatersheds	Update & re-assess NPS field inventory to evaluate critical area status. Revise list of critical areas, if needed.	Evaluate field inventory of critical source areas in the context of potential BMPs that could be implemented	On-the-ground feasibility assessment of suitable BMPs in critical source areas and develop pre-design information for incorporation into detailed implementation plan
B	Estimated loading and reductions	Summarize TMDL information and prioritize subwatersheds based on estimated reduction needs	Confirm and/or revise source loads and reduction needs based on refined survey information	Develop opportunity-specific load reduction estimates for potential BMPs located in critical areas guided by field inventory information	
C	Management measures	Summarize existing applicable BMP information	Summarize GIS targeting tool data in targeted subwatersheds		
D	Technical and financial assistance	Review range of assistance programs	Identify needs to address specific concerns in critical areas	Engage CCAs, retailers, drainage contractors, and TSP resources	Leverage cost-share or partnership opportunities
E	Information and education	Review ongoing watershed I&E activities	1-on-1 meetings with critical area stakeholders	Work with critical area stakeholders to identify funding & partnership options	Incorporate lessons learned into farmer-to-farmer network
F	Schedule	Review overall framework	Revise, as needed, based on updated critical area information	Incorporate planned opportunities info	Update project implementation info
G	Measurable milestones	Review interim milestones from watershed perspective	1-on-1 meetings with critical area stakeholders relative to milestones	Engage CCAs, retailers, drainage contractors, and TSP resources relative to milestones	Ensure projects are consistent with milestones or vice versa.
H	Progress benchmarks	Evaluate monitoring data relative to benchmarks	1-on-1 meetings with critical area stakeholders relative to benchmarks	Engage CCAs, retailers, drainage contractors, and TSP resources relative to benchmarks	Ensure projects are consistent with benchmarks or vice versa.
I	Monitoring	Update assessment. Identify data gaps & prioritize monitoring needs	Evaluate monitoring data & determine if critical area revisions needed	Engage CCAs, retailers, drainage contractors, and TSP resources in monitoring efforts	Incorporate project info into BMP effectiveness monitoring

Appendix G. Interim Milestones

Objective

The WMP should include interim, measurable implementation milestones to measure progress in implementing the management measures.

Intent

These milestones are used to track implementation of the management measures (i.e., whether they are being implemented according to the schedule outlined in Element F). In contrast Element H identifies criteria to measure the effectiveness of the management measures (e.g., documenting improvements in water quality). For example, the watershed plan may include milestones for a pollutant found at high levels in a stream. An initial milestone may be a 30% reduction in measured stream concentrations of that pollutant after 5 years and management measures have been implemented in 50 percent of the critical areas. The next milestone could be a 40% reduction after 7 years, when management measures have been implemented in 80 percent of the critical areas. The final goal, which achieves the water quality standard for that stream, may require a 50% reduction in 10 years. Having these waypoints lets the watershed managers know if they are on track to meet their goals, or if they need to re-evaluate treatment levels or timelines.

Key Questions

- Is a list of reasonable and attainable interim milestones, benchmarks, phases, or steps for implementing each group of management measures or control actions provided?
- Is a logical sequence of dates for achieving the milestones, benchmarks, phases, or steps listed?

Discussion

A list of reasonable and attainable interim milestones, benchmarks, phases, or steps for implementing each group of management measures or control actions.

Interim milestones associated with each priority activity are shown in Table G-1. In addition, interim milestones in this plan emphasize: 1) documenting BMP implementation through each phase, as described under "BMP Effectiveness Monitoring"; 2) ensure that information collected will guide effective critical area planning in subsequent phases using adaptive management, as described under "Progress Benchmarks" and "Monitoring"; and 3) other implementation activities will be identified and conducted simultaneously to meet TMDL reasonable assurance requirements for WLAs.

A logical sequence of dates for achieving the milestones, benchmarks, phases, or steps.

Priority actions will occur over a 15-year period with staging activities in three phases (short-, mid-, and long-term) that will ultimately achieve needed reductions (Table 16). Short-term efforts (Year 1-3) include implementing practices in critical areas high risk sources to Bad Axe Creek are significantly reduced. Mid-term efforts (Year 4-8) are intended to build on the results of short-term implementation activities. This includes evaluating the success of Phase 1 projects installed (success rate, BMP performance, pollutant reductions realized, actual costs, etc.). Long-term efforts (Year 9-15) are those implementation activities that result in Bad Axe Creek in full attainment with Michigan's WQS.

Table G-1. Interim milestones

Activity	Source Reduced	Critical Area(s)	Timeframe [a]	Interim Milestones
Farmer-to-Farmer Network	Row crop agriculture Livestock	Any of the following: C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	3-5 farms in network initiating system of BMPs
			Phase 2	Increase number of farms in network by 50 percent Document changes in farm profitability for Phase 1 farms
			Phase 3	Increase number of farms in network by 50 percent Document changes in farm profitability for Phase 1/2 farms
Nutrient Management	Row crop agriculture Livestock	E-52/54 G-62/63	Phase 1	500 acres w/o manure 500 acres with manure 2,800 acres pre-sidedress NO_3 test
				10 percent of critical acres under 4R program Summarize soil test data across critical acre groups Document successes / challenges for Phase 2
			Phase 2	20 percent of critical acres under 4R program Summarize soil test data across critical acre groups Document successes / challenges for Phase 3
			Phase 3	40 percent of critical acres under 4R program Summarize soil test data across critical acre groups Document successes / challenges for sustainable program
Water Quantity Management	Row crop agriculture	C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	Evaluation report on potential use of DWM *(focus area: sites where tile outlet stabilization identified as a need)* Pre-design / implement WQM system at 1 location
			Phase 2	5 percent of critical acres under WQM system Document successes / challenges / costs for Phase 3
			Phase 3	10 percent of critical acres under WQM system Document successes / challenges / costs for sustainability
Riparian Buffers / Filter Strips	Row crop agriculture Livestock	E-53	Phase 1	25 percent of critical stream / drain miles with adequate riparian protection
			Phase 2	50 percent of critical stream / drain miles with adequate riparian protection
			Phase 3	75 percent of critical stream / drain miles with adequate riparian protection
No-till / Reduced Tillage	Row crop agriculture	C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	900 acres no-till 200 acres zone building / strip tillage 200 acres zone building 300 acres strip tillage 400 acres shallow vertical tillage 800 acres corn stalk residue
			Phase 2	50 percent of critical acres under reduce tillage Document successes / challenges / costs for Phase 3
			Phase 3	75 percent of critical acres under reduce tillage Document successes / challenges / costs for sustainability
Cover crops	Row crop agriculture	C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	1,800 acres
			Phase 2	50 percent of critical acres under cover crops Document successes / challenges / costs for Phase 3
			Phase 3	75 percent of critical acres under cover crops Document successes / challenges / costs for sustainability
Other BMPs	Row crop agriculture	C-31,35,38 C-34 E-52/54 G-62/63	Phase 1	10 sites tile outlet stabilization 3 sites grade stabilization
			Phase 2	10 percent of critical acres under integrated BMP system Document successes / challenges / costs for Phase 3
			Phase 3	25 percent of critical acres under integrated system Document successes / challenges / costs for sustainability
Notes: [a] Phase 1 (2015-17); Phase 2 (2018-22); Phase 3 (2023-29)				

Appendix H. Progress Indicators

Objective

As projects are implemented in the watershed, describe water quality benchmarks to track progress towards attaining water quality standards.

Intent

The *criteria* in Element H are the benchmarks or waypoints to measure against through monitoring. These interim targets can be direct measurements (e.g., fecal coliform concentrations, nutrient loads) or indirect indicators of load reduction (e.g., number of beach closings). These criteria should reflect the time it takes to implement pollution control measures, as well as the time needed for water quality indicators to respond, including lag times (e.g., water quality response as it is influenced by ground water sources that move slowly or the extra time it takes for sediment bound pollutants to break down, degrade or otherwise be isolated from the water column). Indicate how it will be determined whether the WMP needs to be revised if interim targets are not met. These revisions could involve changing management practices, updating the loading analyses, and reassessing the time it takes for pollution concentrations to respond to treatment.

Key Questions

- Are criteria identified that are linked to the causes and/or sources of impairments/threats (if applicable)?
- Do the listed criteria include numeric and/or narrative water quality criteria, instream physical habitat assessment criteria, or other criteria linked to the causes/sources?
- Do listed criteria include those incorporated into any TMDLs developed or to be developed for waterbodies addressed by the plan?
- Are provisions for reviewing progress and revising the plan or any TMDLs involved addressed?

Discussion

Criteria linked to the causes and/or sources of impairments/threats.

Implementation activities for the Bad Axe watershed are staged in three phases using outcome-based strategic planning and an adaptive management approach. Phase 2 (mid-term) and Phase 3 (long-term) are designed to build on results from the preceding phase. In order to guide actual plan implementation through each phase using adaptive management, water quality benchmarks are identified to track progress towards attaining water quality standards.

Listed criteria include numeric and/or narrative water quality criteria, instream physical habitat assessment criteria, or other criteria linked to the causes/sources.

These interim targets (Table 18) are intended to reflect the time it takes to implement management practices, as well as the time needed for water quality indicators to respond. In addition to water column indicators (e.g., total phosphorus and *E. coli*), habitat and macroinvertebrate community evaluations conducted by MDEQ are included. These indicators will likely to respond more quickly to watershed changes that result from implementation of management practices.

Criteria include those incorporated into any TMDLs developed or to be developed for waterbodies addressed by the plan.

Criteria described under TMDL Reasonable Assurance (Section 4.5).

Provisions for reviewing progress and revising the plan or any TMDLs involved are addressed.

Provisions are described under TMDL Reasonable Assurance (Section 4.5).

Appendix I. Monitoring

Objective

Describe the monitoring component to determine whether progress is being made toward attaining or maintaining the applicable water quality standards for the waterbody(ies) addressed in the plan.

Intent

The monitoring program should be fully integrated with the established schedule and interim milestone criteria. The monitoring component should be designed to assess progress in achieving loading reductions and meeting water quality standards. Watershed-scale monitoring can be used to measure the effects of multiple programs, projects, and trends over time. Instream monitoring does not have to be conducted for individual BMPs unless that type of monitoring is particularly relevant to the project.

Key Questions

- Is an approach for establishing monitoring sites or procedures and relevant parameters provided, or procedures for acquiring and reviewing other monitoring data described?
- Are non-environmental monitoring parameters are clearly identified and provide a reasonable yardstick for measuring progress toward implementing the management measures?
- Do monitoring parameters include the criteria identified in Element H and the milestones, benchmarks, phases, or steps cited in Element G?
- Is frequency of monitoring or schedules for assessing implementation progress included in the plan?
- Are parties responsible for implementing the monitoring program listed?
- Are Quality Assurance Project Plans for water quality parameters referenced or cited, if appropriate?

Discussion

An approach for establishing monitoring sites or procedures and relevant parameters is provided, or procedures for acquiring and reviewing other monitoring data is described.

Monitoring is an important part of the Bad Axe TMDL Watershed Implementation Plan. Ambient monitoring provides the data used to assess progress towards achieving needed load reductions and meeting water quality standards. BMP effectiveness monitoring provides information that determines if planned activities are, in fact, being implemented and if management practices are performing as expected. Together, information from both components guides actual plan implementation through each phase using adaptive management.

Under adaptive management, the Bad Axe TMDL Watershed Implementation Plan is designed to use an iterative approach; one that continues while better data are collected, results analyzed, and the watershed plan enhanced. In this way, implementation activities can focus on a cumulative reduction in loadings under a plan that is flexible enough to allow for refinement, reflects the current state of knowledge about the system, and is able to incorporate new, innovative techniques.

Stakeholders have identified urban stormwater as an issue. As part of adaptive management, a priority recommendation for this TMDL Watershed Implementation Plan is to conduct ambient monitoring to assess the relative importance of urban stormwater as a source of total phosphorus or *E. coli*. If monitoring results indicate urban stormwater is a critical source, follow-up recommendations to address these problems will be incorporated into the plan. Another key part of adaptive management related to monitoring, and a priority need for this TMDL implementation plan is additional field inventory work specifically targeted towards sources of *E. coli*. This includes *E. coli* source tracking (e.g., canine scent detection, biomarker methods).

Ambient Water Quality Monitoring.

Progress towards achieving water quality standards will be determined through ambient monitoring by MDEQ and grant recipients. Data collected in support of the biennial state-wide assessment include measurements of physical, chemical, and biological parameters (Goodwin et al. 2014). MDEQ has conducted studies of ambient conditions in the Bad Axe watershed at 5-year intervals (Morse 1994, Walterhouse 1999, MDEQ 2004, Cooper 2009). This ambient monitoring program will continue as the Bad Axe Watershed Plan is implemented.

Additional ambient monitoring in the Bad Axe watershed started in March 2016 and is expected to continue through the fall of 2017. This monitoring is being conducted by SVSU under an MDEQ grant. This effort aims to determine current levels and sources of phosphorus, *E. coli*, and other associated parameters in the Bad Axe Creek watershed including major tributary drains.

Finally, Phase 1 of the Bad Axe TMDL Watershed Implementation Plan will explore opportunities to develop a local ambient monitoring program. As part of this plan's I&E strategy, NPDES-based cooperative monitoring efforts used in other states will be examined. A local ambient monitoring program could build on WWTP effluent monitoring already conducted by the City of Bad Axe in partnership with other NPDES permittees in the watershed. Compliance with the Bad Axe WLA is based on in-stream monitoring data at the Pigeon Road location. Additional ambient monitoring data collected in Bad Axe Drain at Pigeon Road can be used to support the translation of this WLA to any needed NPDES permit revisions during the next renewal cycle. With support from the Huron County Commission, a cooperative monitoring program could also include the Health Department, the Drain Commission, and local schools. Monitoring expertise available from SVSU during their work in the Bad Axe watershed could provide assistance to ensure the data meet quality objectives for subsequent use that could guide cost-effective implementation efforts.

Non-environmental monitoring parameters are clearly identified and provide a reasonable yardstick for measuring progress toward implementing the management measures.

BMP Effectiveness Monitoring.

Progress towards implementing planned activities and the performance of installed management measures will be evaluated through BMP effectiveness monitoring by grant recipients. Data collected as part this effort is typically qualitative information, which tracks both direct (e.g., acres managed under 4R nutrient stewardship program, miles of stream with adequate riparian buffers) and indirect (e.g., number of outreach events, mailed self-assessment survey of properties adjacent to Bad Axe Creek / tributary drains, partner organization field inventories) activities.

The Bad Axe watershed field inventory represents a logical starting point from which to build a BMP effectiveness monitoring program. This information was compiled by HCD into an Excel© spreadsheet and is organized by tributary drain. Using this organizational framework, direct implementation practice attributes that can be monitored and recorded include:

- type (e.g., structural, management, both)
- implementation units (e.g., acres, linear feet)
- treated area (e.g., whole crop field, thin area along the edge of a crop field)
- mode (e.g., capturing pollutant, avoiding pollution)
- sequence or simplicity (e.g., single BMP, system of practices)
- performance pattern (e.g., full performance, declining performance over time)
- timing and seasonality (e.g., winter cover crops, constructed wetlands treat continuously)
- lifespan

BMP effectiveness monitoring results that document practice implementation (e.g., cover crops, water quantity management installations) can be recorded in the spreadsheet. Monitoring elements will be based on the schedule, key milestones, and adaptive management procedures used as part of Phase 2 and Phase 3 implementation. Potential BMP effectiveness monitoring elements include:

- Implementation activity (i.e., specific direct activities, not general implementation practices)
- Expected installation (e.g., date, cost, location, funding organization, installation organization)
- Expected performance (e.g., pollutant reduction loads, efficiency, lifespan)
- Installation (e.g., date, cost, location, funding organization, installation organization)
- Maintenance (e.g., date, cost, location, funding organization, maintenance organization)
- Performance (e.g., pollutant load reduction estimates, efficiency)

It is recommended that BMP effectiveness monitoring address annual implementation (i.e., installed this year), cumulative implementation, and cumulative implementation with an adjustment for practices that have exceed their expected lifespan. These totals should be compared with implementation targets and full implementation potential to indicate progress over time.

Monitoring parameters include the criteria identified in (H) and the milestones, benchmarks, phases, or steps cited in (G) above.

Monitoring parameters are identified as part of the interim targets discussion (Table 18).

Frequency of monitoring or schedules for assessing implementation progress.

Additional ambient monitoring in the Bad Axe watershed will be conducted by SVSU under an MDEQ grant. This effort aims to determine current levels and sources of phosphorus, *E. coli*, and other associated parameters in the Bad Axe Creek watershed including major tributary drains. Information from this monitoring effort is intended to support TMDL development and guide the Bad Axe TMDL Watershed Implementation Plan. Data collection by SVSU will begin in 2016 continuing into 2017.

Parties responsible for implementing the monitoring program are listed.

Additional ambient monitoring in the Bad Axe watershed will be conducted by SVSU under an MDEQ grant. Furthermore, Phase 1 of the Bad Axe TMDL Watershed Implementation Plan will explore opportunities to develop a local ambient monitoring program. A local ambient monitoring program could build on WWTP effluent monitoring already conducted by the City of Bad Axe in partnership with other NPDES permittees in the watershed. With support from the Huron County Commission, a cooperative monitoring program could also include the Health Department, the Drain Commission, and local schools.

Quality Assurance Project Plans for water quality parameters are referenced or cited.

Any monitoring funded by MDEQ will have an approved QAPP prior to initiating data collection.

Appendix J. Supplemental TMDL Development Information

The TMDL represents the maximum loading that can be assimilated by a waterbody while still achieving the applicable water quality standards. The currently impaired designated uses for the Bad Axe Creek TMDL are *"other indigenous aquatic life and wildlife"*, partial body contact recreation, and total body contact recreation (May 1 to October 31). The applicable WQS are described in Section 2.4, which includes a description of narrative and numeric criteria. Targets designed to achieve these criteria are identified for the Bad Axe Creek TMDL. TMDL development also involves a linkage analysis that connects TMDL targets with potential sources. Once these linkages are described, the loading capacity (or maximum allowable load) is defined and each source category is provided with an allocation; the sum of all allocations must fit within the maximum allowable load.

J-1 Targets

Total Phosphorus.

Bad Axe Creek was placed on the §303(d) list due to documented dense aquatic plant communities that reach nuisance conditions and high nutrient concentrations (Cooper, 2009).

> Bad Axe Creek, a significant tributary to the Pinnebog River was surveyed at two locations to investigate a previous report of potential impairment due to nutrient enrichment. Headwater portions of the stream between the city of Bad Axe and southeastern Meade Township, Huron County, contained dense colonies of *Cladophora*, strongly suggesting a chronic exposure to elevated, ambient nutrient concentrations. A biological survey at Berne Road (Station 25) found a macroinvertebrate community that was considered minimally acceptable and dominated by taxonomic groups considered to be tolerant of poorer water quality. The community was supported by habitat that was rated as marginal as the channel lacked stable hard substrate materials to support diverse macroinvertebrate colonization. *Cladophora* was present but in small concentrations as there were few attachment sites for algae and light was limited to the channel. Station 26 was located downstream near the confluence. Flow velocity was significantly greater with a significant increase in hard substrate materials. There were substantial quantities of *Cladophora* in the channel where rock and cobble are exposed to sunlight. The macroinvertebrate community was substantially better than that found at Station 25 and supported by a habitat that was rated as good.

Michigan's Integrated Report describes DEQ's assessment methodology for determining nuisance aquatic plant growth conditions in streams (Goodwin et al, 2014). Designated use evaluations include site-specific visual observations and / or water column nutrient concentration measurements (Section 4.6.2.2 of the Integrated Report). A determination of not supporting is made if excessive/nuisance growths of algae (particularly, *Cladophora*, *Rhizoclonium*, and cyanobacteria) or aquatic macrophytes are present. Although the determination of excessive, nuisance conditions is generally made using BPJ (best professional judgment) in accordance with narrative WQS, DEQ's Procedure 51 offers the following guidance to make these determinations for streams:

- *Cladophora* and/or *Rhizoclonium* greater than 10-inches long covering greater than 25% of a riffle,
- Rooted macrophytes present at densities that impair the designated uses of the water body, or
- Presence of bacterial slimes.

Michigan does not have numeric criteria for total phosphorus, instead relying on the narrative WQS found under Rule R 323.1060(2) (Plant Nutrients). This rule was developed to provide the authority to limit the addition of nutrients to surface waters of the state, which are or may become injurious to the designated uses of the surface waters of the state.

Excess phosphorus can stimulate nuisance growths of algae and aquatic plants that indirectly reduce oxygen concentrations to levels that cannot support a balanced fish or aquatic macroinvertebrate community (e.g., extreme day/night time fluctuations in oxygen) and can shade out beneficial phytoplankton (algal) and aquatic macrophyte (vascular plant) communities that are important food sources and habitat areas for fish and wildlife. The period of time when it is most critical to reduce phosphorus loads is in the summer during the growing season. Between June 1 and September 30, environmental conditions such as higher temperatures, lower stream flows, and increased light intensity are most likely to result in nuisance plant growth if nutrient concentrations are elevated.

The numeric concentration targets for phosphorus in the Bad Axe Creek watershed are developed based on a weight-of-evidence approach that uses biological threshold information obtained from the scientific studies and data from similar streams that:

1) drain agricultural land in Michigan's southern Lower Peninsula, and
2) do not have nuisance levels of plant growth.

A numeric goal of 60 µg/L of phosphorus in the Bad Axe Creek watershed, as an average during the growing season of June 1-September 30, is expected to prevent nuisance plant growths, and will also protect the *warmwater fishery* and *other indigenous aquatic life and wildlife* designated uses.
An average in-stream phosphorus concentration of 60 µg/L is supported in the literature as a seasonal average target determined to be protective of the *other indigenous aquatic life and wildlife* and *warmwater fisheries* designated uses.

In order to clarify how this target is to be interpreted, seasonal average is defined as the mean value calculated from measurements collected over several years covering a representative range of flow conditions (e.g., high, moist, mid, dry, low) determined using techniques, such as a duration curve analysis. In addition, a daily maximum 200 µg/L total phosphorus target is identified, which recognizes daily fluctuations associated with seasonal variability or flow conditions. The use of multiple averaging periods (i.e., growing season average and daily maximum) provides a greater level of clarity that which describes how the targets are to be interpreted.

States and USEPA have also long recognized the need to use multiple averaging periods for parameters that exhibit variability, such as bacteria and total suspended solids (TSS). Both USEPA's *"An Approach for Using Load Duration Curves in the Development of TMDLs"* and *"Options for Expressing Daily Loads in TMDLs"* describe methods to develop targets that reflect multiple averaging periods (e.g., annual average, daily maximum, etc), particularly when a daily maximum value is needed to meet regulatory requirements. These techniques are particularly applicable for pollutants such as bacteria, sediment, or nutrients that can vary with weather, season, and flow conditions.

Dynamic pollutant targets with multiple averaging periods have been used in other Michigan TMDL efforts. For example, the Ox Creek TMDL established a 25 mg/L long-term annual average total suspended solids (TSS) and 300 mg/L maximum daily average TSS to address siltation problems that had an adverse effect on the macroinvertebrate community. A *"multiple lines of evidence"* approach was used that started with a long-term average target widely supported in the literature at a level where fisheries would not be harmed. The daily maximum target also satisfies Clean Water Act §303(d) legal requirements. This is consistent with other statistics used in water resource management, which are intended to take into account natural fluctuations in conditions (e.g., day-to-day, week-to-week, month-to-month, year-to-year, wet versus dry, etc).

A multiplier that converts a long-term average (LTA) value to a maximum daily concentration (MDC) target is used, which follows an approach described in EPA's *"Technical Support Document for Water Quality-Based Toxics Control"*, also known as the TSD (USEPA, 1991). The TSD approach considers patterns and variability in a consistent manner. The method is based on the assumption that water quality data follow a log-normal distribution. Identification of a MDC is based on the recurrence interval associated with the LTA period and a coefficient of variation that reflects the data.

For the Bad Axe Creek TMDL, the multiplier is based on statistical characteristics that describe total phosphorus variability using data from a Michigan location with long-term monitoring information; in this case, daily data collected on the River Raisin from 2002 to 2013 by the NCWQR. Figure J-1 graphically illustrates a *"log probability plot"* of the TSD equation using the River Raisin data. The x-axis is expressed as the z-score of a normal probability distribution and concentrations are displayed on a logarithmic scale. A probability plot is one method that can be used to check the assumption of log-normality. If data follow the pattern of a log-normal distribution, they will fall approximately along a straight line, as shown in Figure J-1.

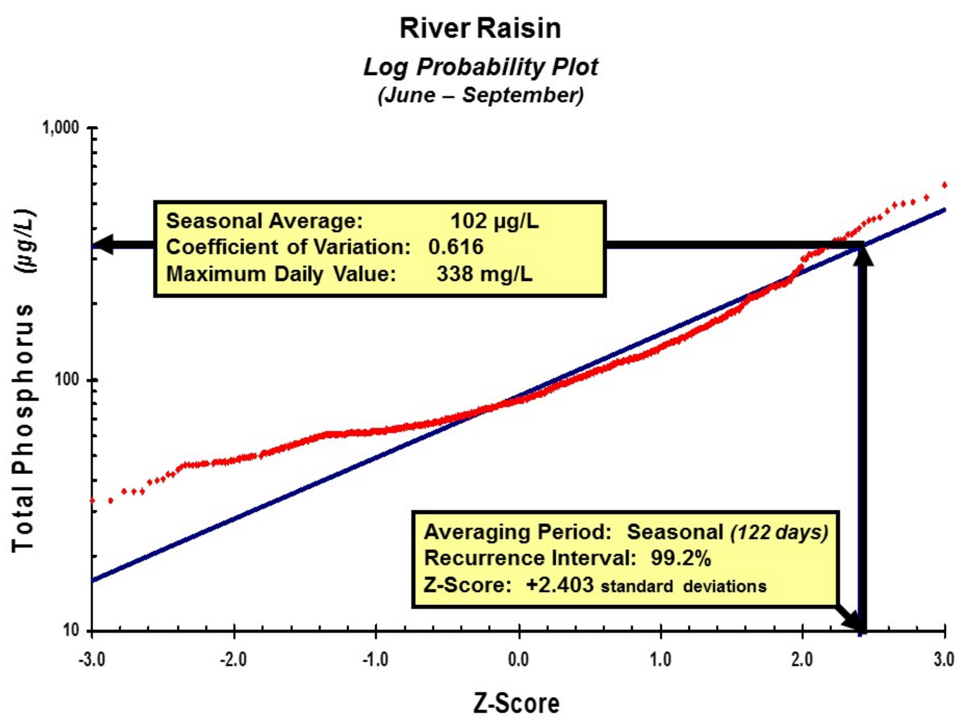


Figure J-1. Log probability display of River Raisin total phosphorus data

Using the TSD approach, a table of LTA to MDC multipliers is constructed for several recurrence interval / coefficient of variation combinations. Table J-1 provides a summary of these multiplier values to determine a maximum daily concentration based on a June 1 to September 30 seasonal, or 122-day, averaging period. This averaging period is also expressed as a recurrence interval in order to identify the appropriate multiplier using the TSD equation.

A daily maximum concentration is represented by a June 1 to September 30 seasonal (or 122-day) averaging period, which equates to a recurrence interval of 99.2% [e.g., (122/123)% or (k/k+1)% where k is the number of averaging period days] and corresponding z-score of 2.403. In the case of the River Raisin, where the coefficient of variation for total phosphorus is 0.616 (Figure J-1), the multiplier to convert the long-term average to a maximum daily concentration is 3.33 (*Note:* key boxes for this combination are shaded in Table J-1).

Table J-1. Multipliers -- Seasonal average to maximum daily concentration

Averaging Period *(days)*	Recurrence Interval	Z-Score	Coefficient of Variation					
			0.2	**0.4**	**0.6**	**0.616**	**0.8**	**1.0**
122	**99.2%**	**2.403**	1.58	2.34	3.25	3.33	4.23	5.23

Using the approach described in the TSD, the seasonal maximum daily total phosphorus concentration for the River Raisin is determined through a four-step process, as follows:

1) Display the observed total phosphorus data using a probability plot to ensure that the assumption of a log-normal distribution is valid *(Figure J-1)*.
2) Use Excel© to calculate a mean, standard deviation, and coefficient of variation for the total phosphorus data.
3) Establish the averaging period to determine the corresponding z-score based on a recurrence interval of (k/k+1), or 99.2% for a 122-day averaging period.
4) Determine the appropriate multiplier using the z-score to convert the LTA concentration to a maximum daily concentration

Thus, the maximum daily concentration for the River Raisin is 338 µg/L *(Figure J-1)*. Determination of this value is based on a June 1 to September 30 seasonal average of 102 µg/L with a coefficient of variation of 0.616 using procedures described in the TSD and the USEPA document *"Options for Expressing Daily Loads in TMDLs"*.

For the Bad Axe Creek TMDL, the multiplier is based on statistical characteristics that describe total phosphorus variability using data from a Michigan location with long-term monitoring information (in this case, daily data collected on the River Raisin from 2002 to 2013 by the National Center for Water Quality Research). The resultant multiplier is 3.33, which translates to a June 1 to September 30 seasonal daily maximum value of 200 µg/L (i.e., 3.33 times 60 µg/L). The statistical relationship between these two values ensures that attaining the maximum daily target in the TMDL will lead to achieving the growing season average of 60 µg/L.

Bacteria *(E. coli)*.

The impaired designated recreational uses addressed by the Bad Axe watershed TMDL are TBC and PBC. The designated use rule (Rule 100 [R 323.1100] of the Part 4 rules, WQS, promulgated under Part 31, Water Resources Protection of the NREPA states that this water body be protected for TBC recreation from May 1 through October 31 and PBC recreation year-round. The target levels for these designated uses are the ambient *E. coli* standards established in Rule 62 of the WQS described in Section 2.4. For this TMDL, the WQS of 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum to protect the TBC use are the target levels for the TMDL reach from May 1 through October 31, and 1,000 *E. coli* per 100 mL as a daily maximum year-round to protect the PBC use.

J-2 Linkage Analysis

TMDL development requires a combination of technical analysis, practical understanding of important watershed processes, and interpretation of watershed loadings and receiving water responses to those loadings. An essential component of TMDL development is establishing a relationship between numeric indicators used to determine attainment of designated uses and pollutant source loads. The linkage analysis examines connections between water quality targets, available data, and potential sources. The focus of the linkage analysis is to:

- interpret watershed loadings and receiving water responses to those loadings; and
- describe logic used to develop TMDL targets and allocations.

Hydrology plays an important role in the linkage analysis. A pollutant load is the product of flow times the concentration and a conversion factor. The hydrology of the Bad Axe Creek watershed is driven by local climate conditions. This includes surface runoff and subsurface flow, as ditching and channelizing has been used throughout this region to drain areas where soils are too wet for crop production.

Limited flow data makes it difficult to describe the full range of hydrologic conditions the Bad Axe Creek watershed may experience. Prior to a more detailed analysis of water quality and pollutant loads for the Bad Axe Creek drainage, an assessment of long-term hydrologic information is needed. One station currently operated by USGS on the Pigeon River near Caseville (04159010) provides a starting point to evaluate long-term patterns in this area (e.g., annual runoff, frequency of occurrence of flows, seasonal variation). In addition, the USGS operated a stream gage on Cass River near Cass City (04150500) during the MDEQ 2008 survey. Both sites are shown in Figure J-2.

Information from these stations provides some insight regarding hydrologic patterns in the area. As indicated in Table J-2, annual runoff varies between 7.5 and 9.7 inches per year. Hydrograph separation on the flow data enables an approximate analysis comparing the amount of base flow to surface runoff, also described in Table J-2. The amount of surface runoff estimated through hydrograph separation includes tile drainage, which explains the higher percentage for Columbia Drain; a subwatershed dominated by row crop agriculture using tiles to increase productivity.

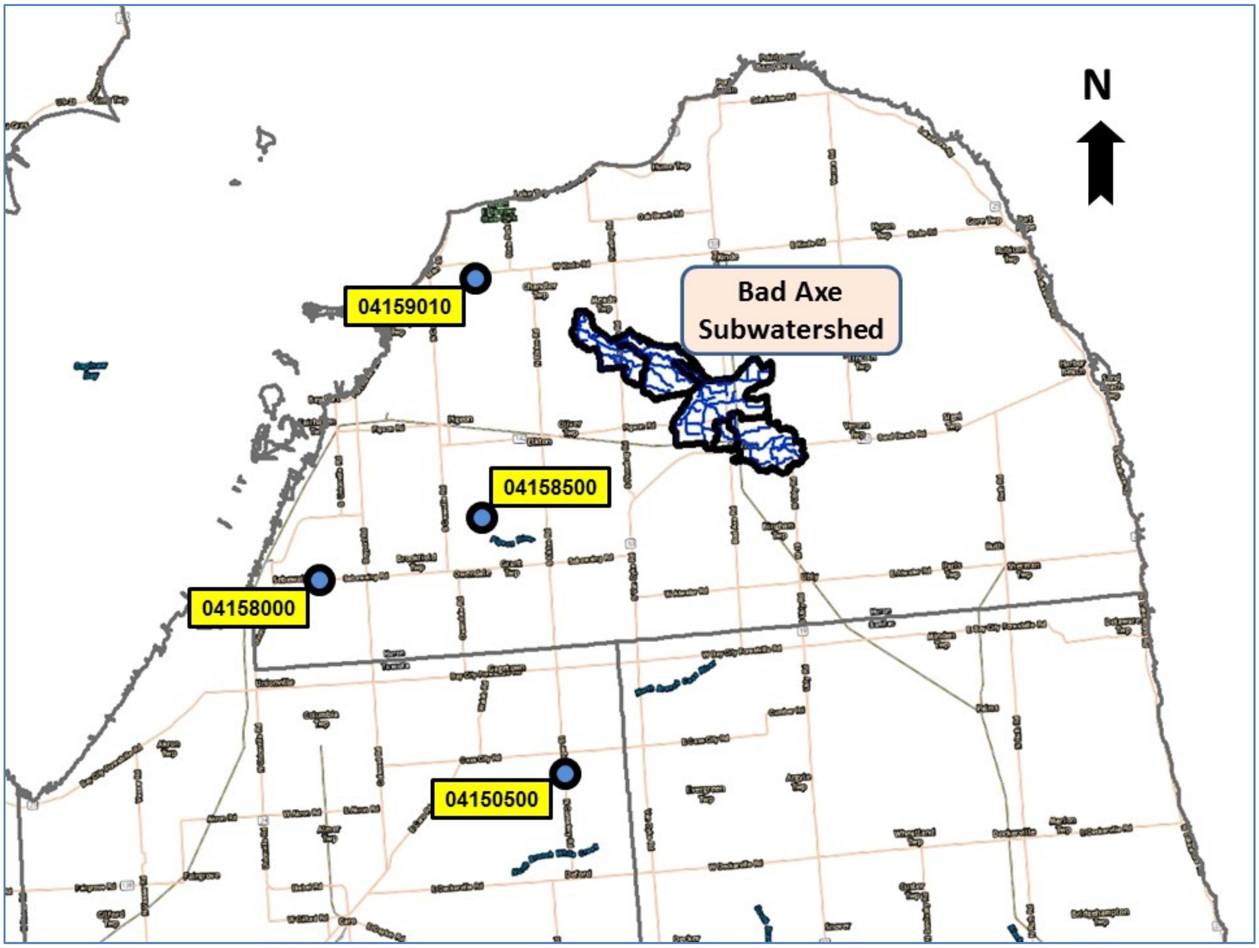


Figure J-2. Location of USGS gages considered for Bad Axe hydrologic analysis

Table J-2. Summary statistics for USGS gages considered

Gage ID	Location	Period of Record	Area *(mi.²)*	Average Annual Flow *(cfs/mi.²)*	Annual Runoff *(in.)*		
					Total	*Base*	*Surface*
04159010	Pigeon River near Caseville	10/1986 - 9/1993 10/2014 – Present	125	0.713	9.7	*5.0*	*4.7*
04150500	Cass River near Cass City	10/1948 – 9/1997 8/2001 – 9/2011	359	0.640	8.7	*4.2*	*4.5*
04151500	Cass River at Frankenmuth	6/1939 - Present	841	0.653	8.9	*4.9*	*4.0*
04158000	Columbia Drain near Sebewaing	1/1988 – 9/1990	33.9	0.556	7.5	*2.9*	*4.6*
04158500	Pigeon River near Owendale	10/1952 – 9/1982	53.2	0.606	8.2	*4.6*	*3.6*

Seasonal Variation

One important part of the linkage analysis for the Bad Axe Creek area is to examine seasonal patterns. Figure J-3 depicts seasonal variation in unit area flows for the Pigeon River. Another useful aspect of seasonal variation is to evaluate runoff patterns relative to precipitation. Table J-3 provides a monthly summary of Bad Axe monthly average precipitation from 1980 to 2014. In order to compare seasonal precipitation patterns to flow information, Table J-3 includes monthly average runoff from the Pigeon and Cass Rivers. Table J-3 also summarizes the runoff for Pigeon River gage as a percentage of the monthly precipitation.

As shown, the lowest precipitation occurs in January, February, and March. Interestingly, March also corresponds to the greatest runoff. It is likely that runoff in March is significantly higher due to the spring snow melt coupled with the absence of mature vegetation and saturated soils. This observation is supported by the fact that July, August, and September have greater amounts of precipitation, yet less of runoff. Vegetation is more mature during these summer months and soils are less saturated (as opposed to March). This likely slows, absorbs, and soaks up precipitation, minimizing runoff.

The seasonal variation in phosphorus concentrations is another significant part of the Bad Axe linkage analysis. The TMDL target is a growing season average. Seasonal patterns in phosphorus concentrations can help identify potential sources or activities that may need to be addressed in order to restore beneficial uses that are impaired. As indicated earlier, long-term TP monitoring in Michigan streams is very limited. However, NCWQR operates a site in northwest Ohio of comparable size and land use to Bad Axe Creek that can be used to examine general patterns (Figure J-4). This site (Rock Creek at Tiffin) is located in the Sandusky watershed; a tributary to western Lake Erie. Daily data collected by NCWQR dates from 1983 to present.

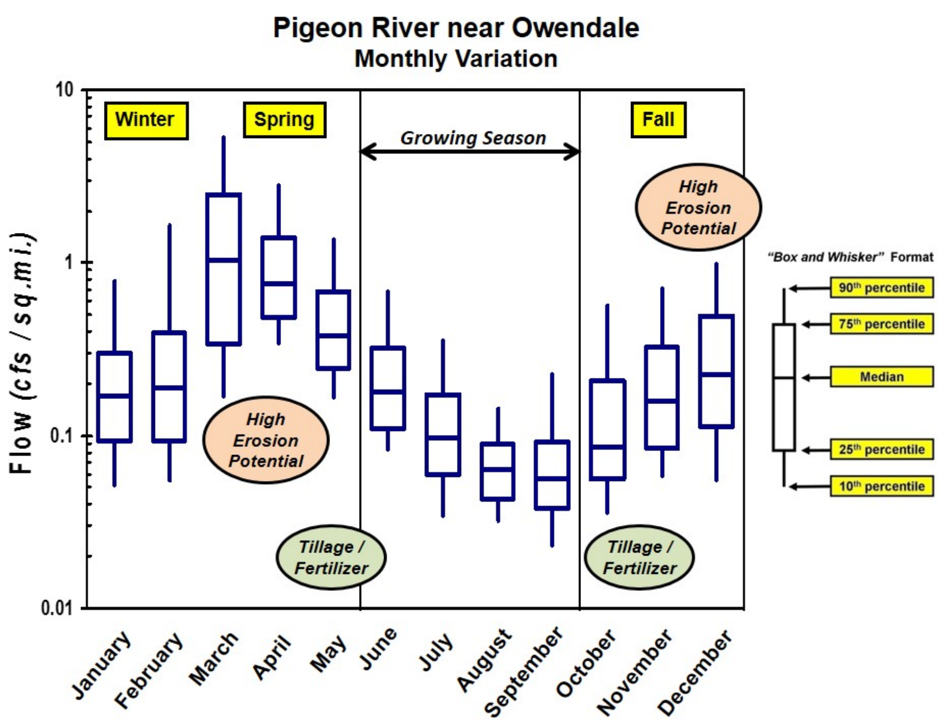


Figure J-3. Seasonal variation of Pigeon River flows

Table J-3. Seasonal precipitation and runoff patterns

	Average Monthly Precipitation and Runoff *(in.)*											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation	1.83	1.79	1.95	3.07	3.16	3.08	3.38	3.50	3.81	2.92	2.77	2.09
Pigeon River	0.46	0.78	2.44	1.53	0.89	0.39	0.24	0.11	0.16	0.28	0.35	0.60
Cass River	0.65	0.85	2.31	1.59	0.85	0.45	0.23	0.11	0.29	0.27	0.43	0.66
Ratio *(Pigeon)*	25%	44%	125%	50%	28%	13%	7%	3%	4%	10%	13%	29%

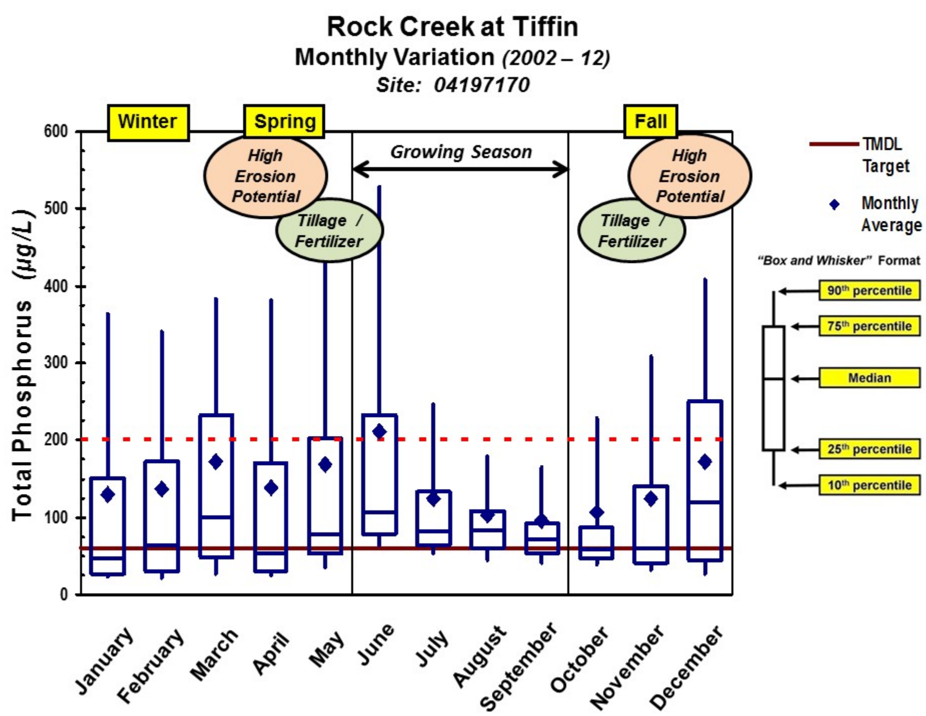


Figure J-4. Seasonal variation of phosphorus concentrations -- Rock Creek

Interannual Variation

Interannual variation is another significant factor to consider in the linkage analysis. Average values for the same month or season can vary by as much as an order of magnitude due to varying weather conditions (e.g., an unusually dry spring or an abnormally wet summer). Interannual variation in Cass River flow for the timeframe 2002 to 2014 is shown in Figure J-5. This graph depicts the variation in flow that occurs between March 1 and July 31, a period of interest to the Great Lakes Water Quality Agreement (GLWQA) Nutrients Annex Subcommittee (also known as Annex 4). The Annex 4 group identified March to July as the spring phosphorus loading period as a determining factor in the production of cyanobacteria in western Lake Erie; similar nutrient load concerns exist in Saginaw Bay.

Flow patterns for 2008 in the Cass River are noted in Figure J-5, corresponds to the year Bad Axe Creek was monitored. The interannual variation in phosphorus load for the River Raisin during this same timeframe (2002-14) is shown in Figure J-6. Loads are expressed as a unit area (e.g., pounds / square mile per day) for comparison with data from other watersheds. Again, 2008 is highlighted, which is coincidently considered a baseline year by the Annex 4 group.

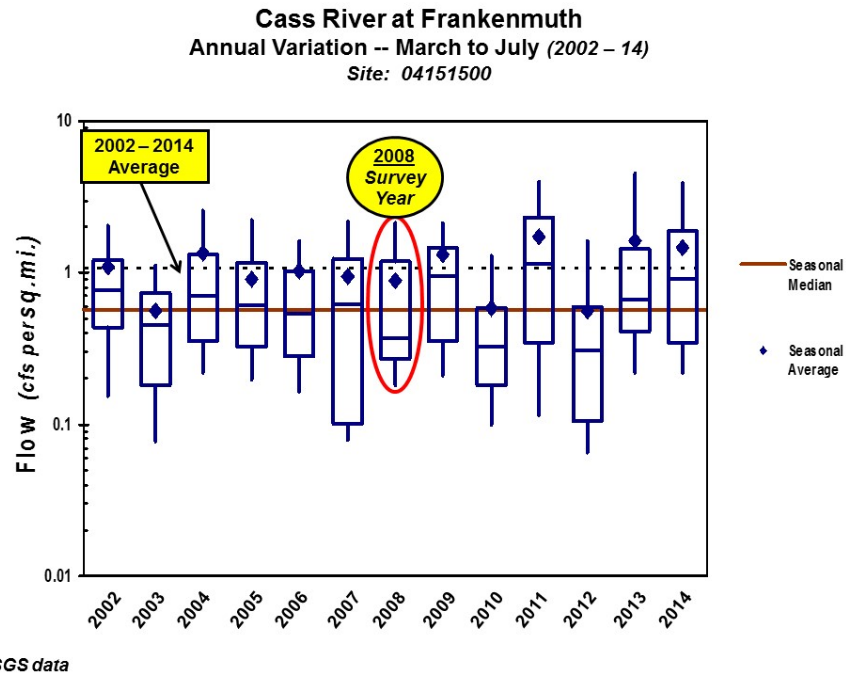


Figure J-5. Interannual flow variation -- Cass River

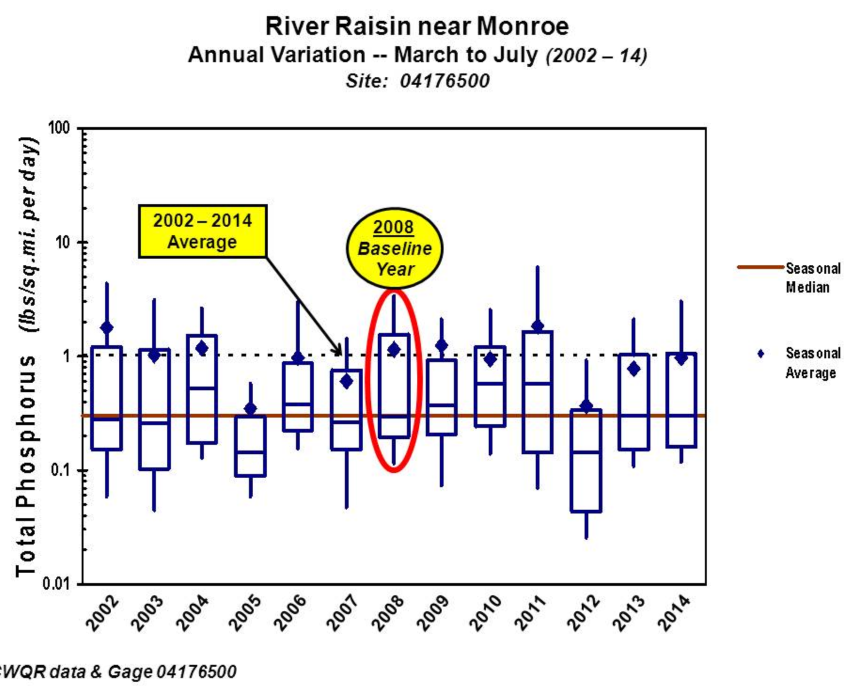


Figure J-6. Interannual phosphorus load variation -- River Raisin

Duration Curves

Duration curves are an important component of the overall linkage analysis. Duration curves provide a quantitative summary that describes the full range of flow conditions, both magnitude and frequency of occurrence. Duration curves provide a method to account for both seasonal and interannual variation. Figure J-7 depicts flow duration curves for two USGS gages considered in the linkage analysis (Pigeon River near Caseville and Cass River at Cass City). These curves are expressed as unit area flows (i.e., cfs / square mile) in order to provide a meaningful comparison between sites. The Water Year (WY) 1987-93 time frame is used, as this represents the period where daily data was collected concurrently at both sites. This approach ensures that the comparison between these sites is not influenced by year-to-year variation in meteorological conditions (e.g., differences in annual precipitation and temperature).

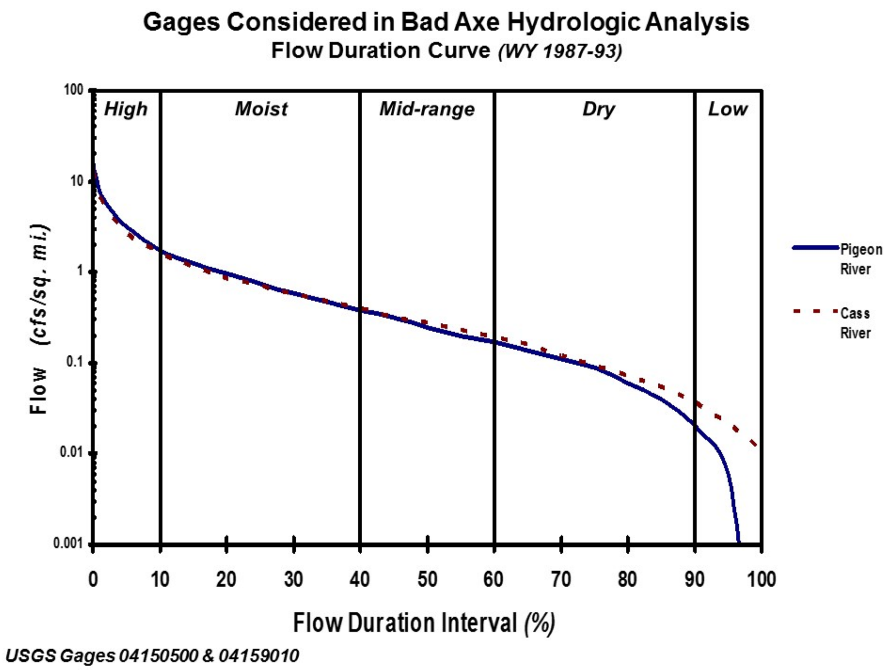


Figure J-7. Flow duration curves for Bad Axe area USGS gages

Total Phosphorus.

The linkage analysis sets the stage for moving from identified water quality concerns to meaningful solutions. A longitudinal glimpse at in-stream conditions for Bad Axe Creek is shown in Figure J-8. The increase in phosphorus concentrations immediately below the Bad Axe WWTP is very noticeable. However, in-stream processes appear to attenuate that effect. This attenuation is likely the result of nutrient uptake by the abundant vegetation in the channel and along the banks of Bad Axe Drain from the WWTP outfall to Pigeon Road. Seasonal average phosphorus concentrations increase again as Bad Axe Creek flows through the lower agricultural portion of the watershed.

The duration curve framework can be used in the linkage analysis to examine relationships between water quality and potential sources. Figure J-9 through Figure J-15 present water quality duration curves for the MDEQ sites monitored for total phosphorus in Bad Axe Creek.

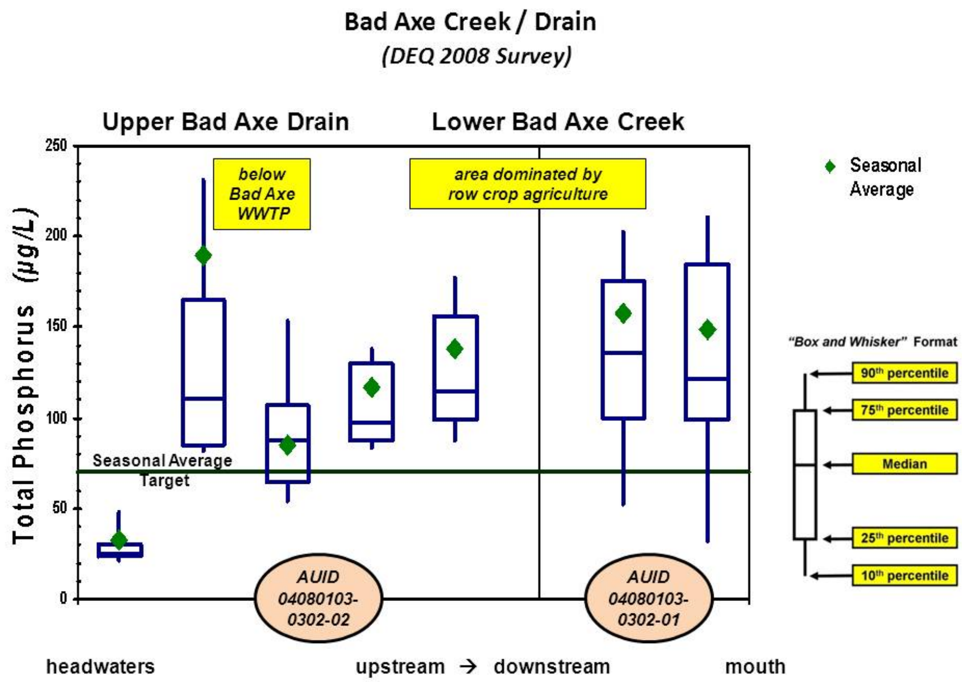


Figure J-8. Bad Axe Creek total phosphorus concentration summary

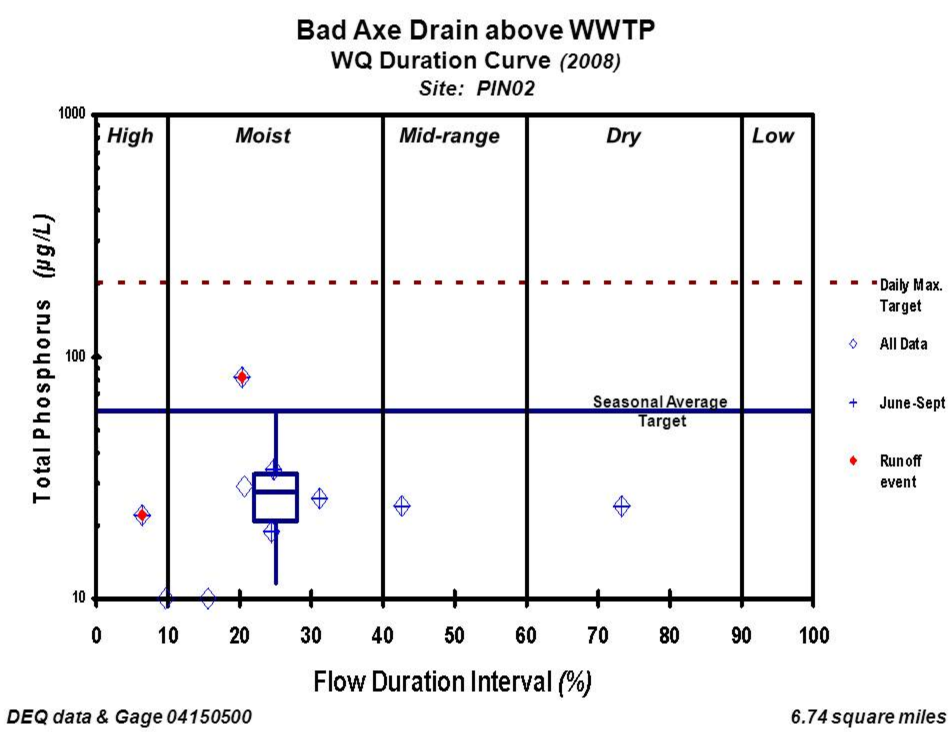


Figure J-9. Water quality duration curve -- Bad Axe Drain above WWTP

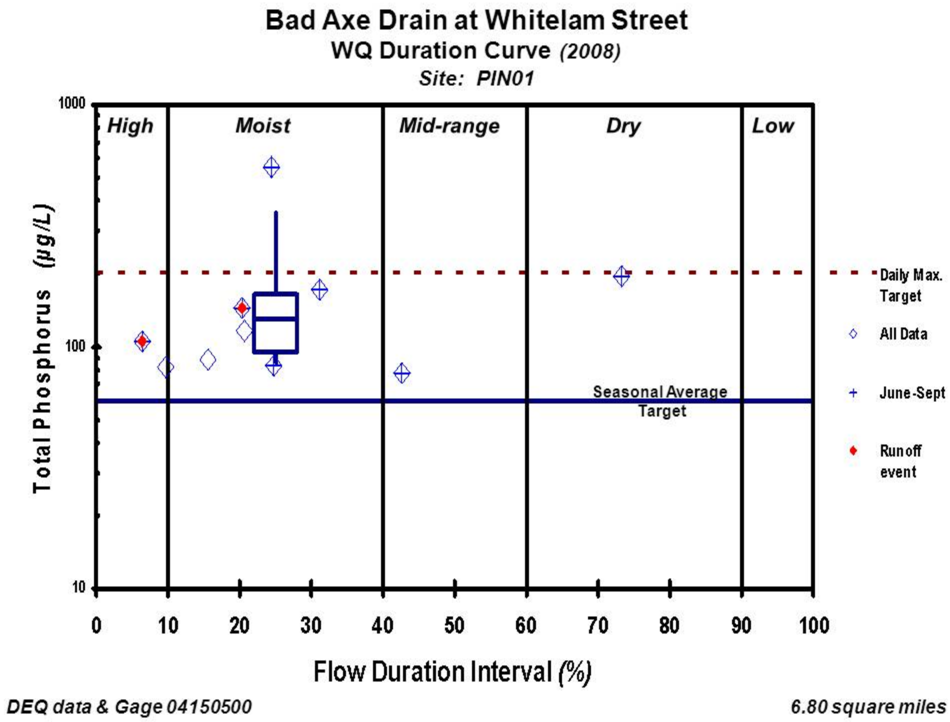


Figure J-10. Water quality duration curve -- Bad Axe Drain below WWTP

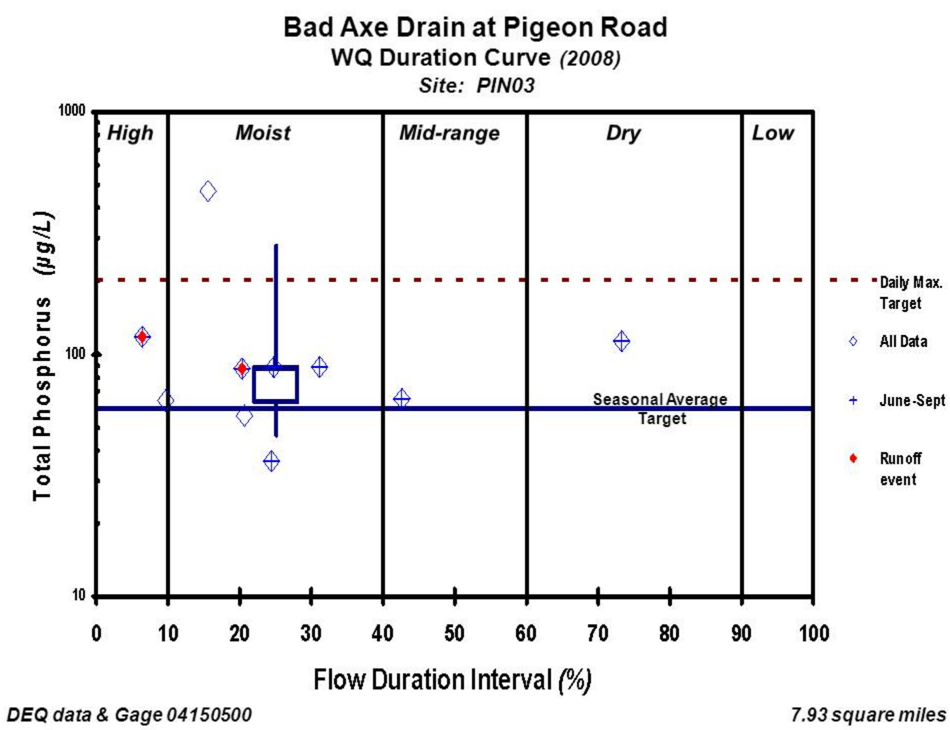


Figure J-11. Water quality duration curve -- Bad Axe Drain at Pigeon Road

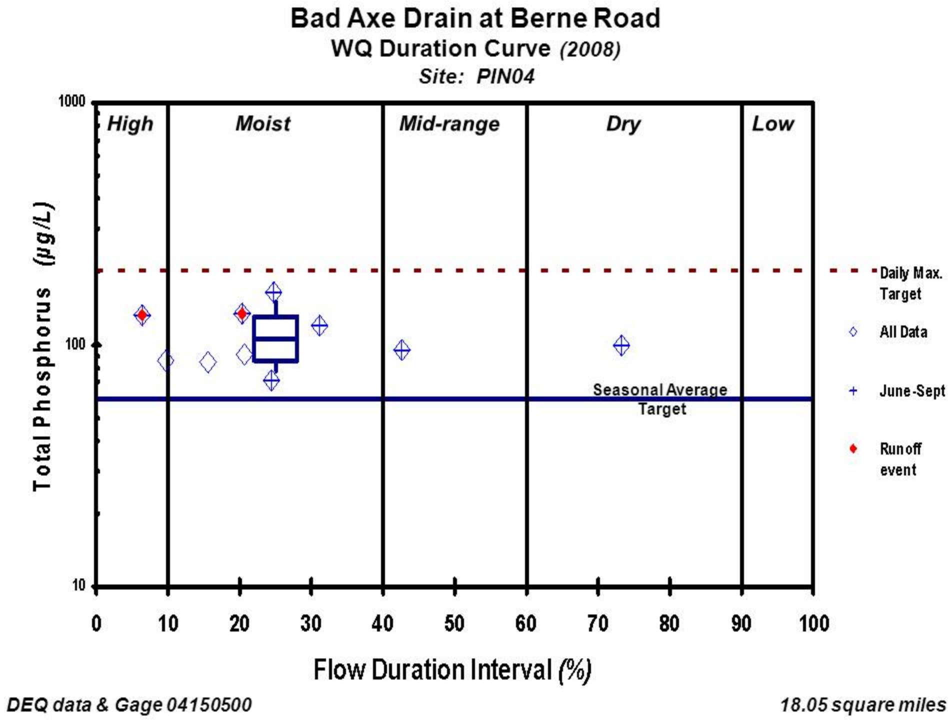


Figure J-12. Water quality duration curve -- Bad Axe Creek at Berne Road

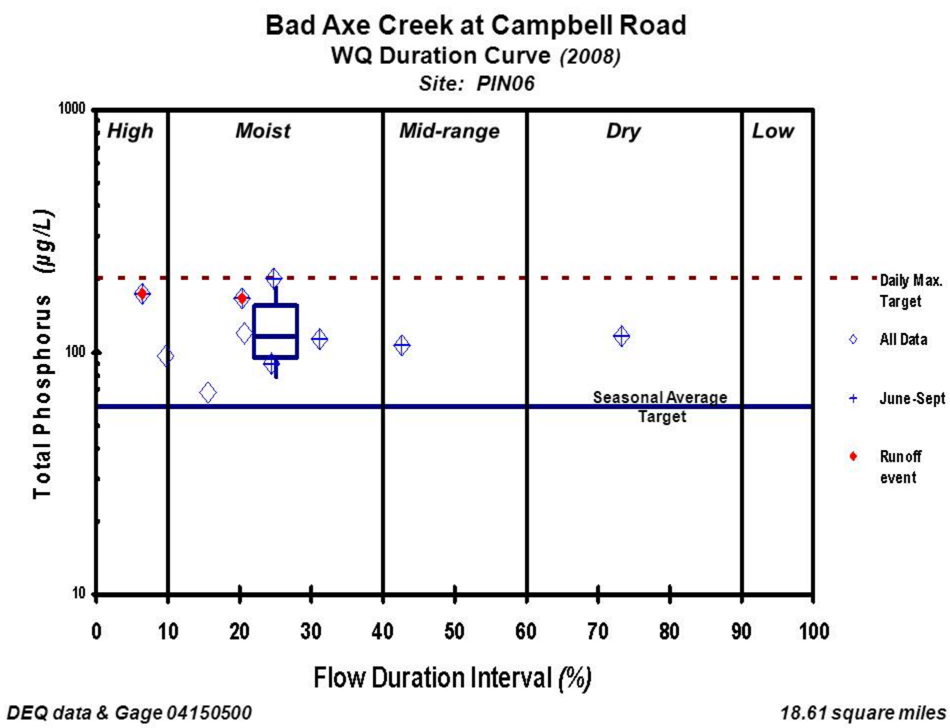


Figure J-13. Water quality duration curve -- Bad Axe Creek at Campbell Road

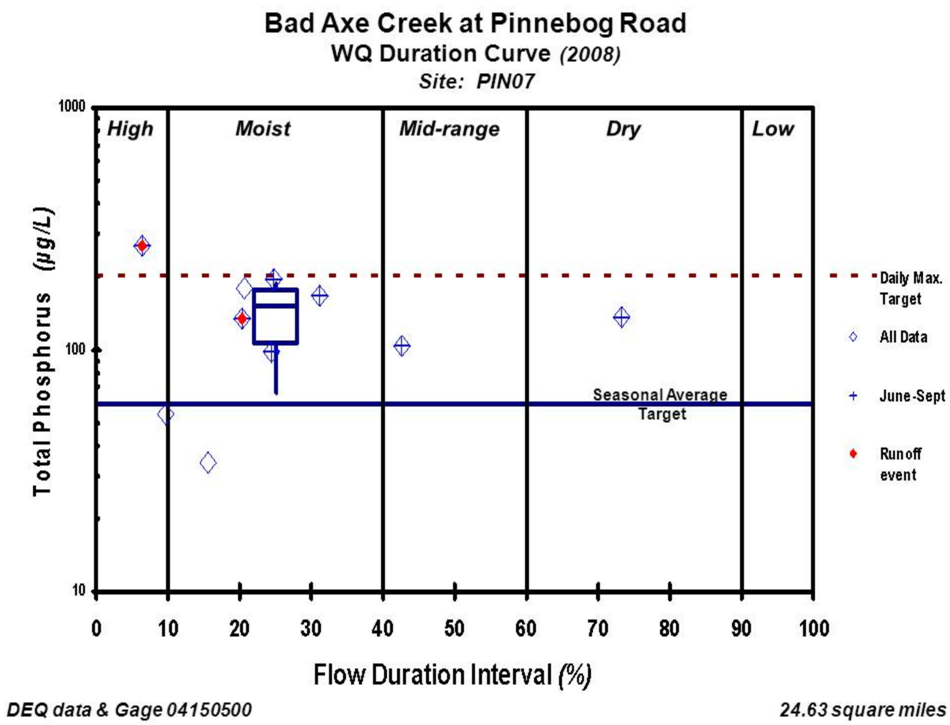


Figure J-14. Water quality duration curve -- Bad Axe Creek at Pinnebog Road

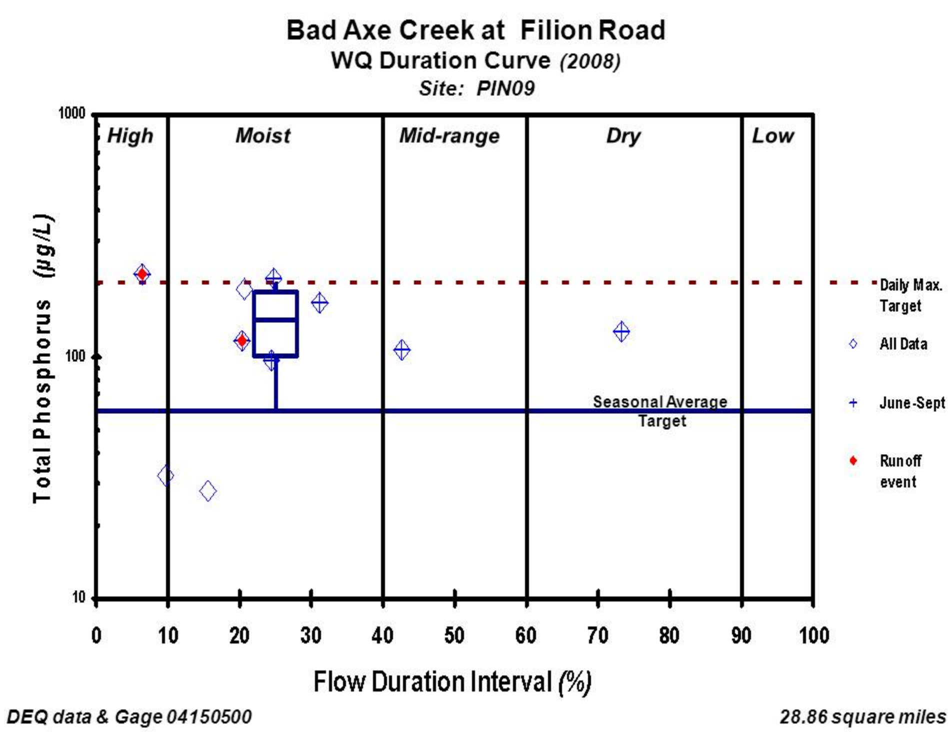


Figure J-15. Water quality duration curve -- Bad Axe Creek at Filion Road

Phosphorus concentrations at locations sampled below subwatershed groups C through F increase following summer storms (Figure J-16). As indicated in the water quality duration curves, most of the Bad Axe data was collected under moist conditions. There were only two samples under high flow conditions when the potential for the greatest concentrations (and loads) exists. The NCWQR data illustrates the potential magnitude of these high flow concentrations during the growing season, as shown in Figure J-17 (the moist zone for Bad Axe Creek at Filion Road is included for comparison).

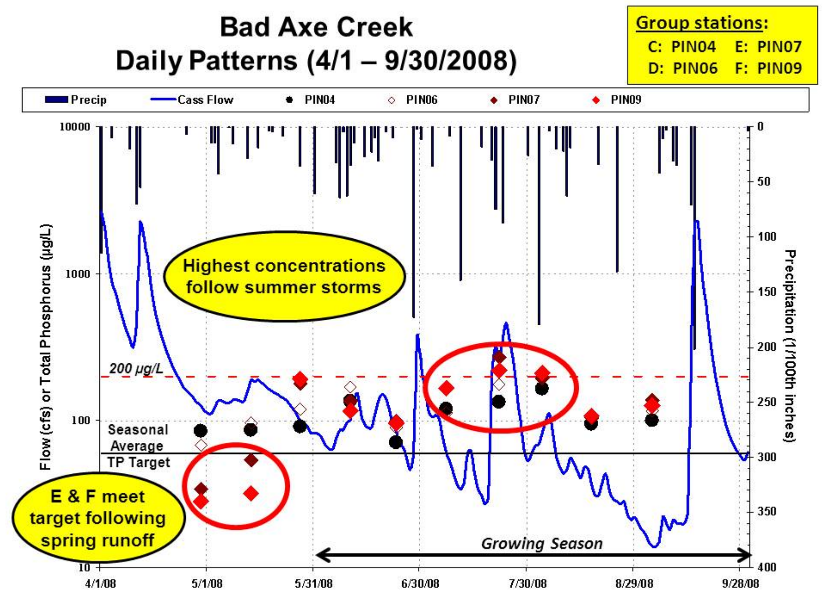


Figure J-16. Bad Axe subwatershed total phosphorus sampling results *(groups C-F)*

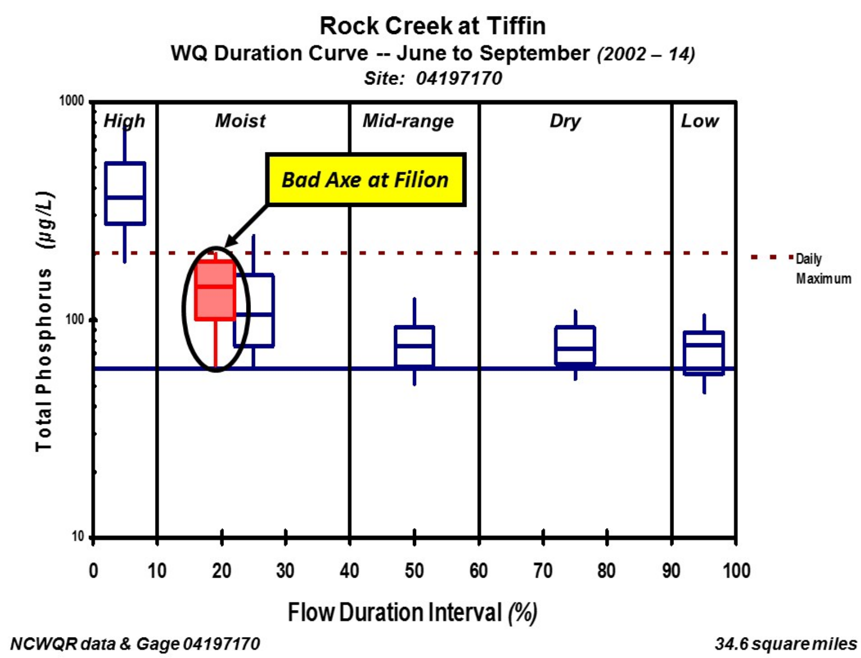


Figure J-17. Water quality duration curve -- Rock Creek total phosphorus

Bacteria *(E. coli)*.

A longitudinal glimpse at *E. coli* conditions for Bad Axe Creek is shown in Figure J-18. A time series of the 2008 E. coli survey data is shown in Figure J-19. Noteworthy is that the excessively high Berne Road sample was more than an order of magnitude greater than all other samples taken across the watershed on the same day. This is indicative of a site-specific source, as opposed to a watershed-wide problem. Similarly, the high variability reflected by the wide “box and whisker” for Campbell Road also indicates the potential effect of a site-specific source influencing sample results at the location. Again, the duration curve framework can be used in the linkage analysis to examine relationships between water quality and potential sources. Figure J-20 through Figure J-25 present water quality duration curves for the MDEQ sites monitored for *E. coli* in Bad Axe Creek.

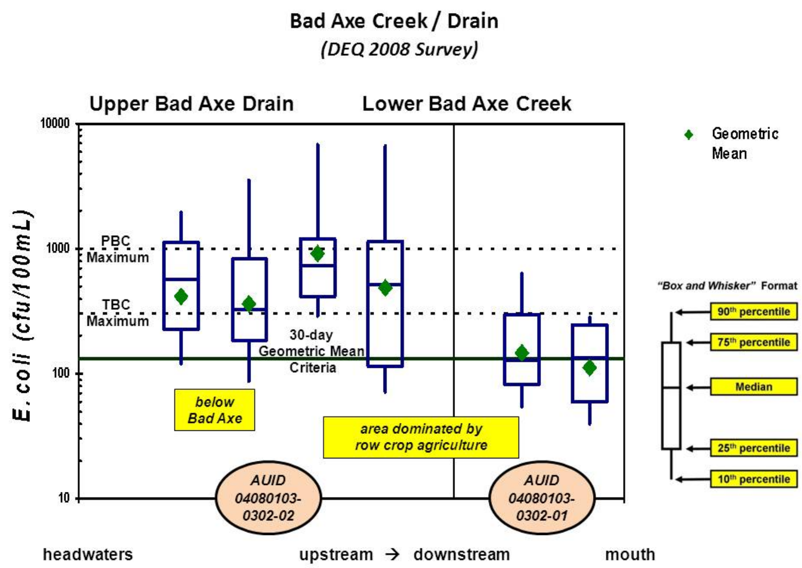


Figure J-18. Bad Axe Creek *E. coli* concentration summary

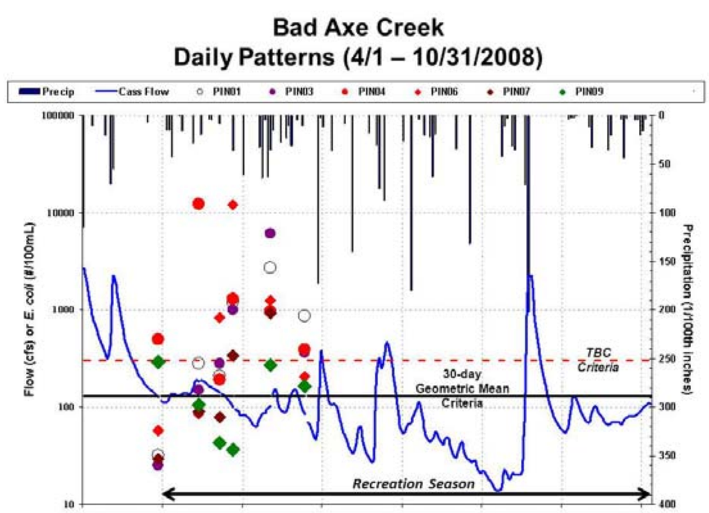


Figure J-19. Bad Axe Creek *E. coli* sample results

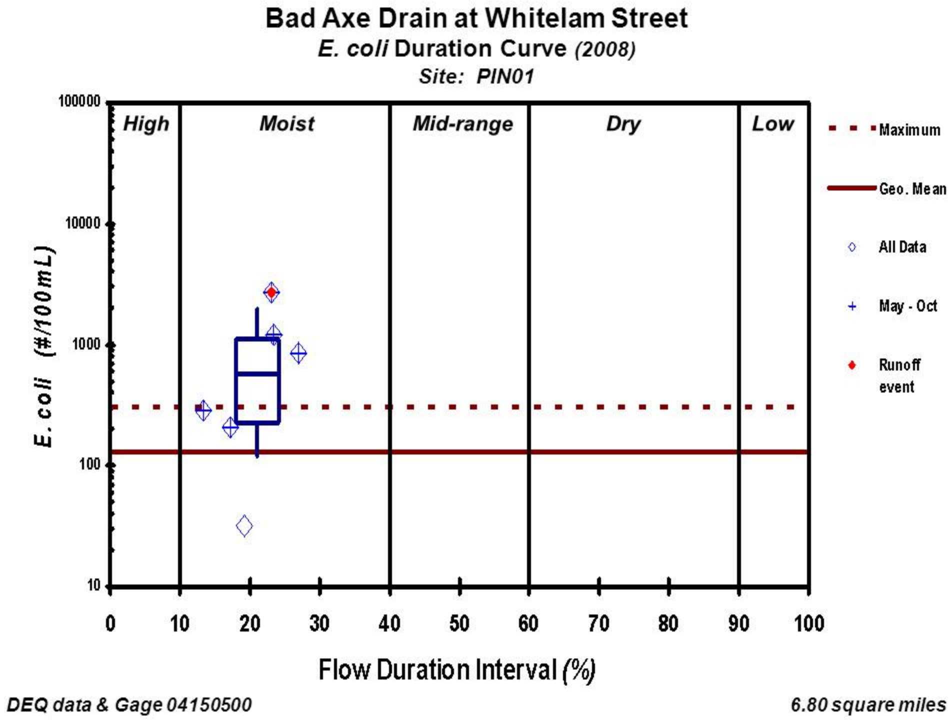


Figure J-20. *E. coli* duration curve -- Bad Axe Drain below WWTP

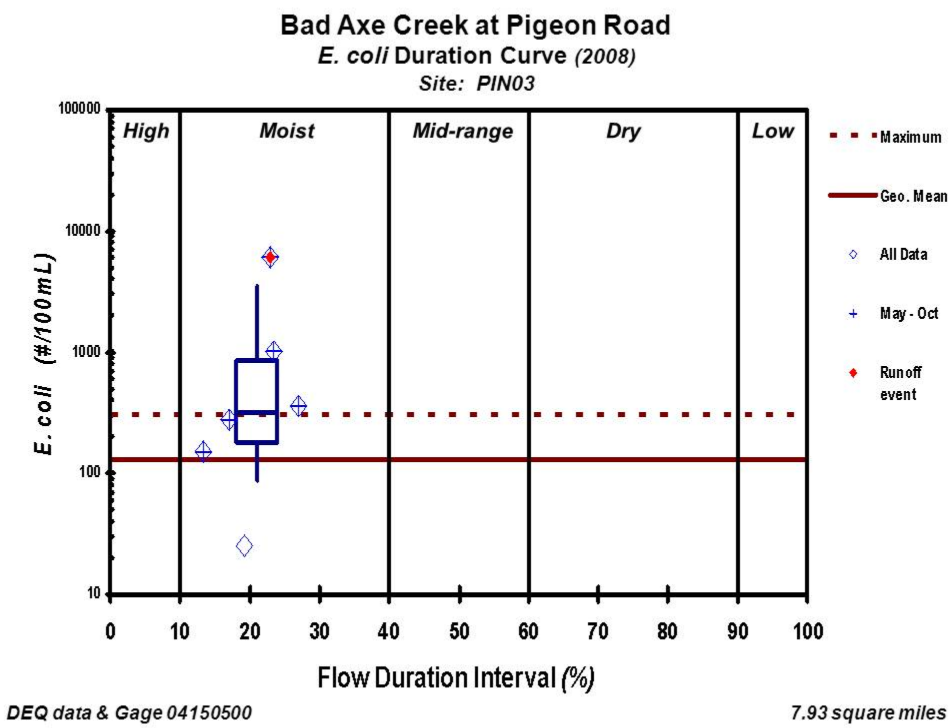


Figure J-21. *E. coli* duration curve -- Bad Axe Drain at Pigeon Road

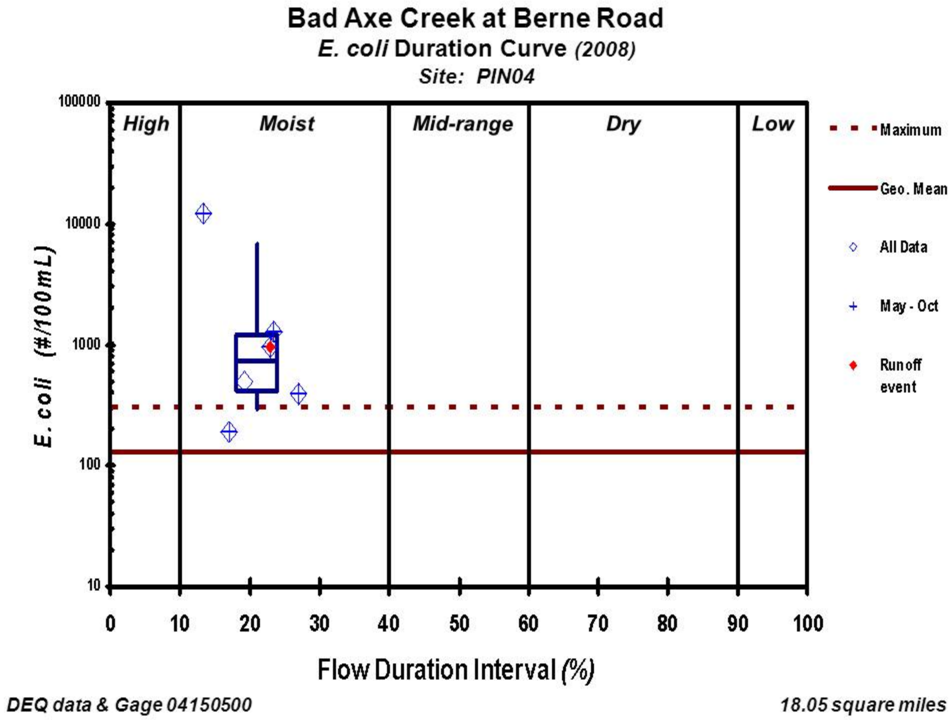


Figure J-22. *E. coli* duration curve -- Bad Axe Creek at Berne Road

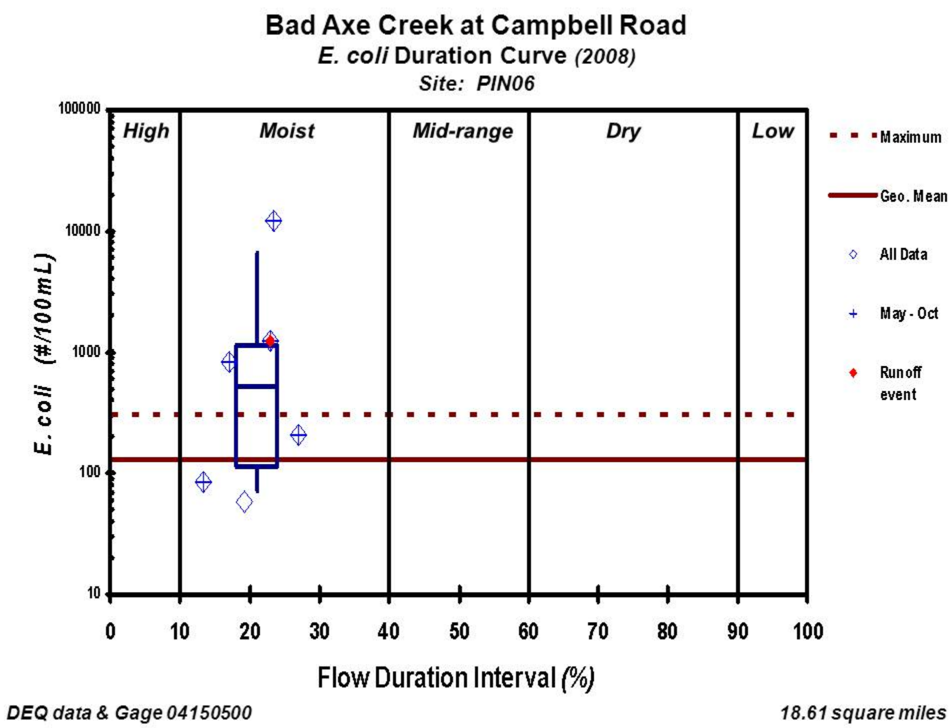


Figure J-23. *E. coli* duration curve -- Bad Axe Creek at Campbell Road

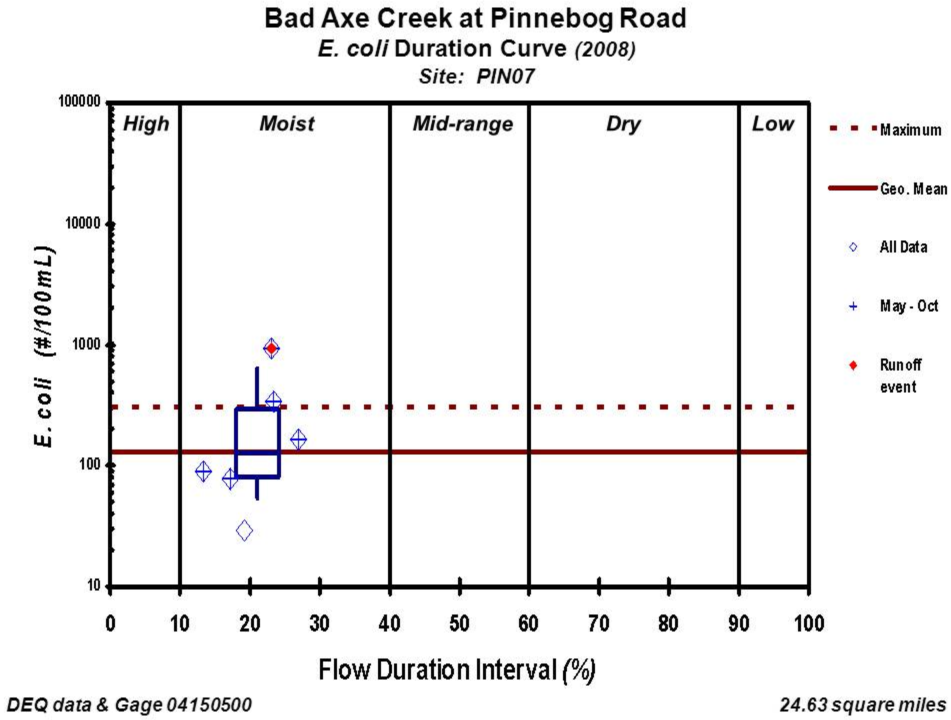


Figure J-24. *E. coli* duration curve -- Bad Axe Creek at Pinnebog Road

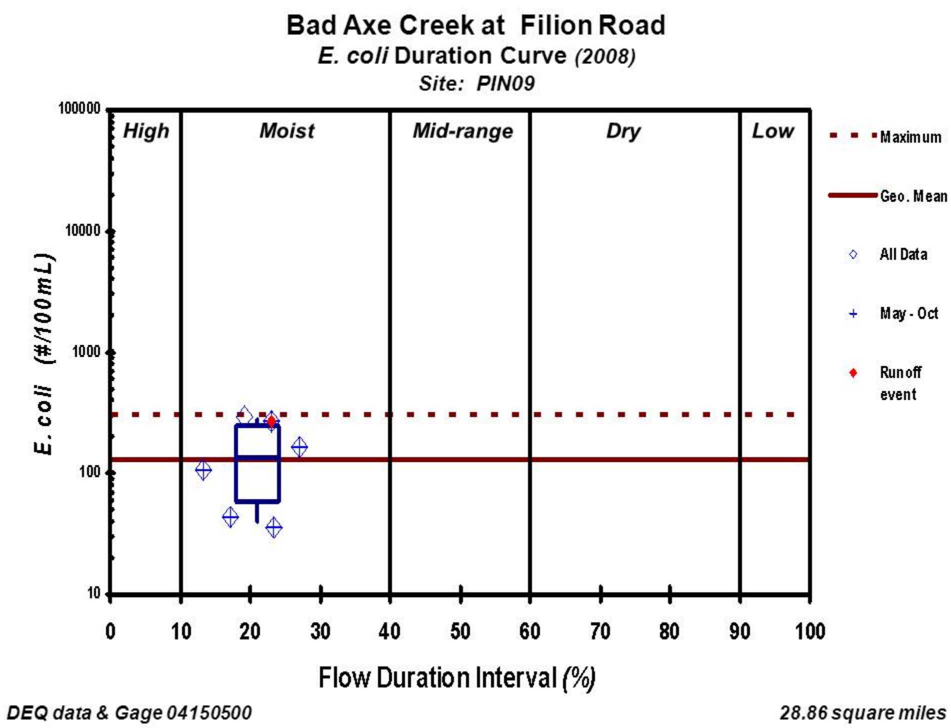


Figure J-25. *E. coli* duration curve -- Bad Axe Creek at Filion Road

J-3 Loading Capacity and Allocations

Development of the Bad Axe Creek loading capacity and allocations recognizes that the TMDL targets established to achieve the applicable WQS use concentration-based multiple averaging periods (e.g., growing season average, 30-day geometric mean, daily maximum). The loading capacity of most waterbodies is not constant over time (USEPA, 2007a). Reasons include changes in flow conditions, temperature, seasons, etc. This inherent variability is the reason that the Bad Axe TMDL will continue to express the loading capacity for the long-term average targets as concentrations; specifically, 60 µg/L total phosphorus as a growing season average (June 1 to September 30) and 130 *E. coli* per 100 mL as a 30-day geometric mean (May 1 through October 31).

A daily maximum value is also needed as part of the loading capacity to satisfy USEPA regulatory review requirements for approvable TMDLs. As discussed in the targets Section J-1, these values are 200 µg/L for total phosphorus and 300 *E. coli* per 100 mL. The maximum *"daily load"* and long-term (or *"non-daily"*) average concentration-based target work together. The *"non-daily"* concentration-based target serves as a benchmark that connects to the applicable water quality standards. Multiple averaging periods in TMDLs provide a way to achieve both long-term program objectives and focus implementation efforts while avoiding short term problems.

Total Phosphorus

Loading Capacity.

The loading capacity and allocations for total phosphorus in Bad Axe Creek are expressed through the duration curve framework using the "flow to load" calculation across the range of all daily average flows. This method involves multiplying the flow times the daily maximum TP target concentration times a conversion factor. The conversion factor translates the product of flow (expressed as cubic feet per second) and concentration (expressed as micrograms per liter) into a load (expressed as pounds). On a daily basis, this value is 0.005393, as shown in Table J-4.

Table J-4. Calculation of phosphorus loads

Load *(tons per day)* = Flow *(cfs)* * Concentration *(µg/L)* * Factor			
multiply by **86,400** *to convert*	seconds per day	→	ft^3 / day
multiply by **7.48** *to convert*	ft^3	→	gallons / day
divide by **1,000** *to convert*	µg	→	mg
divide by **453,592** *to convert*	mg	→	pounds
multiply by **3.7854** *to convert*	liters	→	gallons
multiply by **0.005393** *to convert*	**(ft^3 / sec) * (µg/L)**	→	**pounds / day**

The TP loading capacity, expressed as pounds per day, is determined by using the following equation:

$$\text{Load Capacity} = \text{Flow} * \text{TP Target} * \text{Conversion Factor}$$

where:

Load Capacity = daily maximum load *(pounds / day)*
Flow = duration curve flow interval *(cubic feet per second)*
TP Target = 200 µg/L *(daily maximum)*
Conversion Factor = 0.005393

Flow data in the Bad Axe watershed is limited to spot measurements associated with the 2008 water quality survey. In order to estimate flows for Bad Axe Creek, a drainage area weighting approach was used in conjunction with stream discharge data from the USGS Pigeon River gage. Thus, the design flow is determined using the Pigeon River gage (04159010) as a representative site, then applied to Bad Axe Creek based on a drainage area weighting factor (i.e., the Bad Axe Creek drainage area divided by the Pigeon River drainage area). For locations below the Bad Axe WWTP (specifically, all subwatershed groups except A), the average discharge flow from that facility was added to estimates derived from the Pigeon River gage. This is reflected in the flows used to determine loading capacities across all zones presented in Table J-5.

The total phosphorus loading capacity for both the listed AUID and the non-listed downstream AUID are shown in Table J-5. The downstream AUID is included in this TMDL because higher phosphorus concentrations were observed throughout this reach of Bad Axe Creek. *Cladophora* was present, but in smaller concentrations in the downstream AUID because there were few attachment sites for algae and light was limited. However, there were substantial quantities of *Cladophora* in the channel where rock and cobble are exposed to sunlight. This highlights the need to include this AUID in the TMDL to prevent excessive algal growth given the high phosphorus concentrations in this reach of Bad Axe Creek.

The loading capacity values were determined using the duration curve framework. Under the duration curve framework, the loading capacity is essentially the curve itself, which sets the *"total maximum daily load"* on any given day, is determined by the flow on the particular day of interest. The use of duration curve zones can help provide a simplified summary through the identification of discrete loading capacity points by zone, as shown in Table J-5. The shaded row in each AUID represents its loading capacity based on achieving a daily maximum of 200 µg/L total phosphorus. Sampled loads from the 2008 monitoring data are shown relative to the loading capacity in Figure J-26 through Figure J-32. Note that the shape of the loading capacity curve shown in Figure J-26 (Group A) is different than the other curves. This reflects the effect of the Bad Axe WWTP on the flow duration curves mentioned above.

Table J-5. Bad Axe Creek watershed loading capacity -- Total Phosphorus

AUID	Group			Duration Curve Zone				
		Outlet Point	Area *(sq.mi.)*	*High*	*Moist*	*Mid*	*Dry*	*Low*
FLOW [a]				*(cfs)*				
04080103-0302-02	**A**	Above Bad Axe WWTP	6.74	7.06	1.62	0.52	0.17	0.001
	B	Pigeon Road	7.93	9.47	3.06	1.77	1.35	1.160
	C	Berne Road	18.08	20.1	5.50	2.56	1.60	1.160
	D	**Campbell Road**	**18.64**	**20.7**	**5.63**	**2.61**	**1.62**	**1.160**
04080103-0302-01	**E**	Pinnebog Road	24.66	27.0	7.08	3.07	1.77	1.161
	F	**Bad Axe Creek mouth**	**29.50**	**32.1**	**8.24**	**3.45**	**1.88**	**1.161**
TOTAL PHOSPHORUS				*(pounds per day)*				
04080103-0302-02	**A**	Above Bad Axe WWTP	6.74	7.62	1.74	0.56	0.18	0.001
	B	Pigeon Road	7.93	10.21	3.30	1.91	1.46	1.251
	C	Berne Road	18.08	21.7	5.93	2.76	1.73	1.252
	D	**Campbell Road**	**18.64**	**22.3**	**6.08**	**2.81**	**1.74**	**1.252**
04080103-0302-01 *[not currently on §303(d) list for nutrients]*	**E**	Pinnebog Road	24.66	29.1	7.63	3.31	1.90	1.252
	F	**Bad Axe Creek mouth**	**29.50**	**34.6**	**8.89**	**3.72**	**2.03**	**1.253**

Note: [a] Flows based on growing season (June 1 – September 30) duration curve.

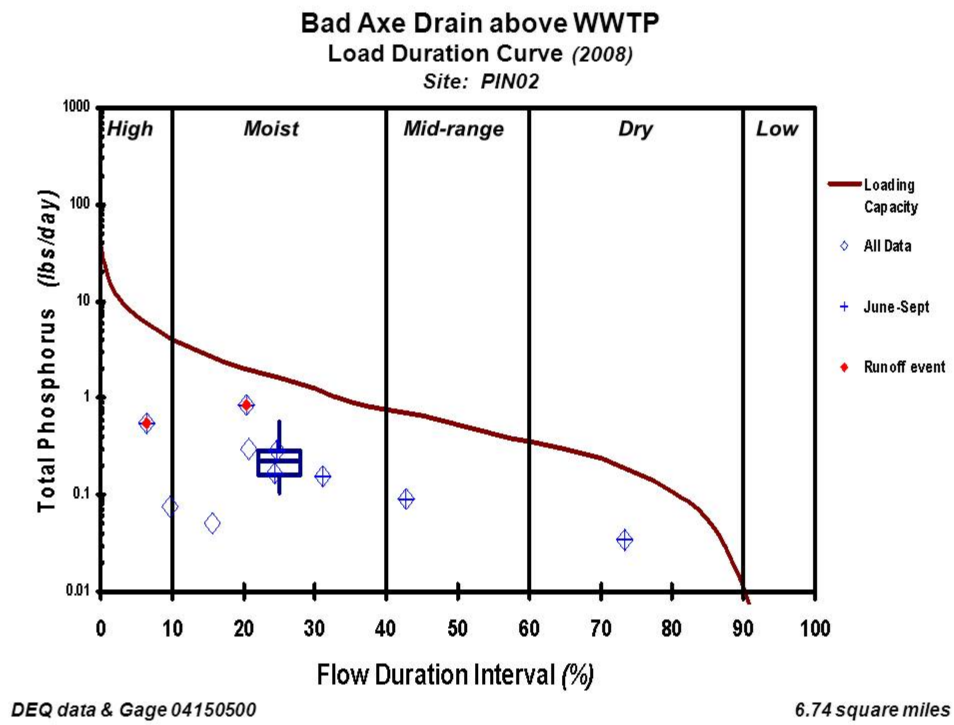


Figure J-26. TP load duration curve -- Bad Axe Drain above WWTP

Figure J-27. TP load duration curve -- Bad Axe Drain below WWTP

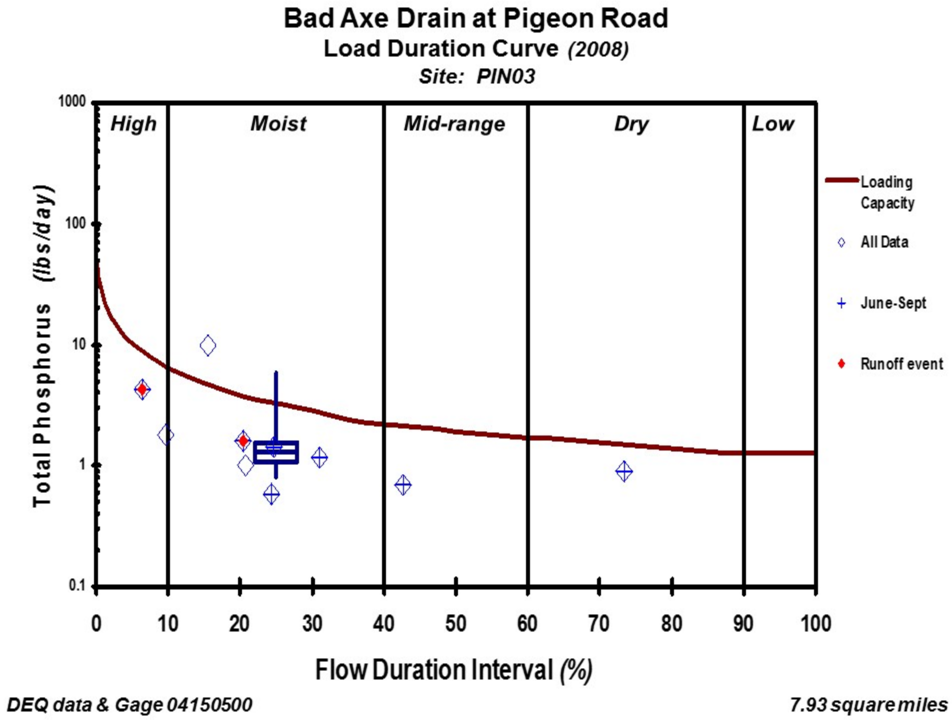


Figure J-28. TP load duration curve -- Bad Axe Drain at Pigeon Road

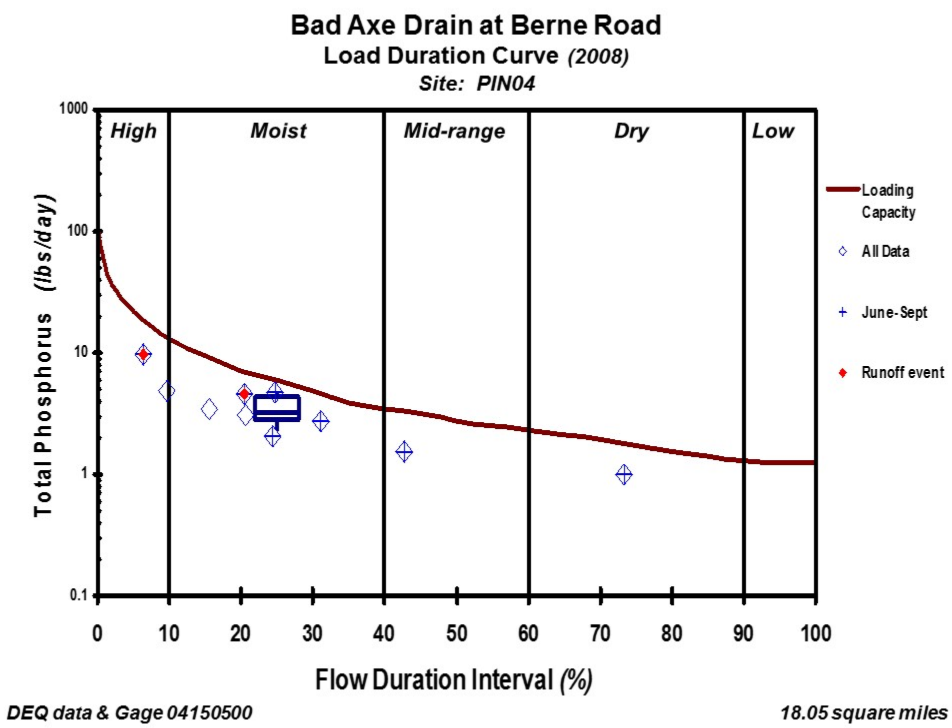


Figure J-29. TP load duration curve -- Bad Axe Creek at Berne Road

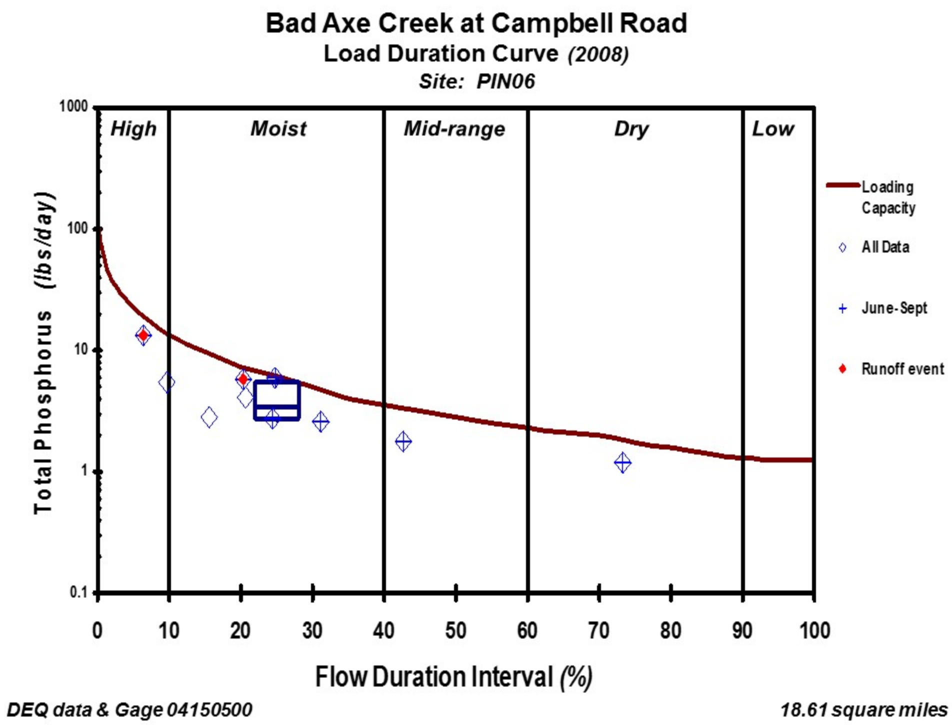


Figure J-30. TP load duration curve -- Bad Axe Creek at Campbell Road

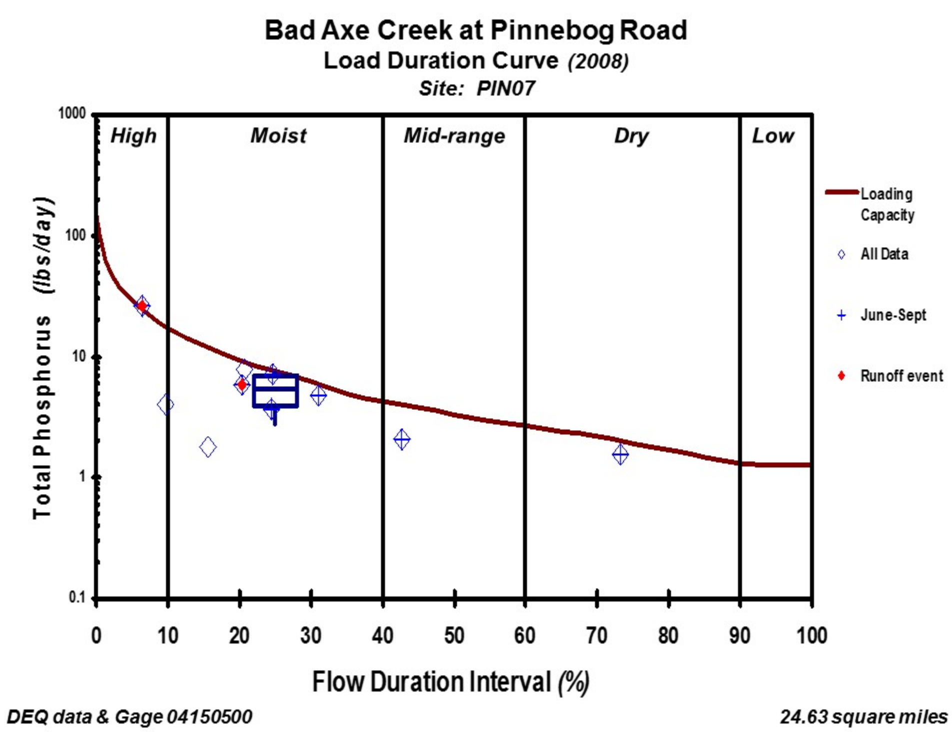


Figure J-31. TP load duration curve -- Bad Axe Creek at Pinnebog Road

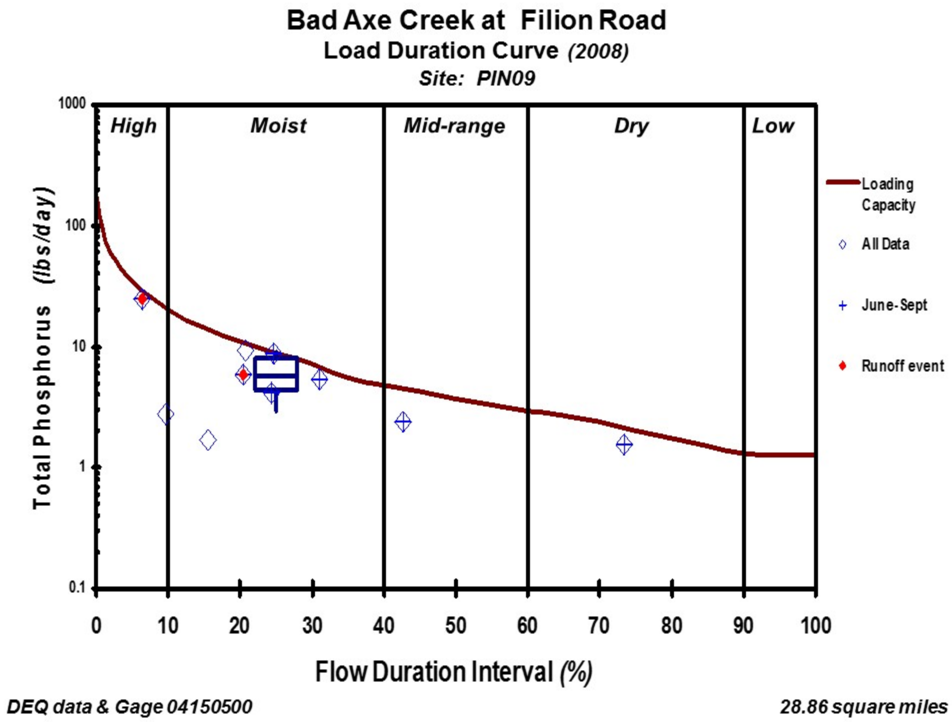


Figure J-32. TP load duration curve -- Bad Axe Creek at Filion Road

Allocations.

There are eight facilities and one agency (MDOT) with MDEQ permit coverage in the listed Bad Axe AUID that require WLAs. The Bad Axe WWTP is the only one with a continuous discharge that requires a WLA across all flow conditions. The current NPDES permit limit for this facility is a maximum 5.1 pounds per day TP (determined as a monthly average based on a maximum daily concentration of 1 mg/L total phosphorus). A WLA for the Bad Axe WWTP, based on its current permit limit, exceeds the loading capacity at the AUID outlet (Campbell Road) across all zones except high and moist conditions. However, the current average growing season discharge TP from the Bad Axe WWTP is about half of its permit limit. In addition, the 2008 MDEQ monitoring data showed that phosphorus concentrations decrease by about 50 percent from the Bad Axe WWTP to Pigeon Road.

This TMDL is designed to achieve a growing season average concentration of 60 µg/L TP at the AUID outlet. For this reason, the WLA for the Bad Axe WWTP is less than the effluent load limit in the existing NPDES permit. The WLA is determined from the facility’s current estimated load using DMR data, and takes into account the apparent attenuation that occurs from the WWTP to Pigeon Road. Compliance with the WLA should be based on in-stream monitoring data at the Pigeon Road location. Additional ambient monitoring data collected in Bad Axe Drain at Pigeon Road can be used to support the translation of this WLA to any needed NPDES permit revisions during the next renewal cycle.

The WLAs for the stormwater permits are based on each facility’s contributing area. Runoff from these facilities is only expected to occur under high flow and moist conditions. Similarly, the MS4 WLA for MDOT is based on the state road contributing area. The runoff generated for each area (determined as a unit area flow from the duration curve) is multiplied by the daily maximum concentration (200 µg/L) to determine high flow and moist condition WLAs.

The WWSL general permit does not allow a discharge from these facilities during the growing season. However, extreme weather conditions may force the need for an emergency discharge. For that reason, WLAs have been identified for these facilities under high flow conditions based on contributing area (similar to the stormwater WLAs described above).

The CAFO general permit prohibits any dry weather discharge. The Wil-Le Farms CAFO (MIG440027) and Hass Feedlot CAFO (MIG010042) must comply with all authorized discharge and overflow requirements described in the State of Michigan's NPDES CAFO General Permit (MIG010000). In accordance with the CAFO General Permit, overflow events from Wil Le Farms and Haas Feedlot CAFOs are allowable due to precipitation related overflows from CAFO storage structures which are properly designed, constructed, operated and maintained in accordance with CAFO permits (MIG440027 and MIG10042). Discharges from such overflows are allowable only if they do not cause or contribute to a violation of water quality standards.

The NPDES CAFO permit contains several measures designed to prevent nutrients from entering surface waters from the production area and waste (manure) storage sites. At production facilities, and associated manure storage sites, the permit requires properly designed, constructed, and maintained manure storage structures. These structures must be designed to store at least six months of generated production area waste, with additional reserve capacity for normal and design-storm precipitation, and the required freeboard amount. All manure storage structures must be inspected once per week by the CAFO operator, providing assurance against overflow and potential structural damage.

Animal waste for land application from the CAFO is transferred to contract haulers. The CAFO general permit indicates that such waste is not under the operational control of the CAFO owner. However, the permit does require completion of a manifest to track the transfer and use of the CAFO waste.

The CAFO WLAs are set to zero across all duration curve zones except high flows. Extreme high flows are the only conditions when authorized overflows from CAFOs would be expected to occur. Load estimates for these conditions are based on the runoff volume generated by the 25-year, 24-hour storm identified in the COC or permit for these facilities (3.56 inches for Huron County). The contributing area for each facility was estimated from air photos (2.5 acres for HAAS; 7.5 acres for Wil-Le). The flow generated for each area from this rainfall event was multiplied by the daily maximum concentration (200 µg/L) to determine the high flow WLA. This value is conservative (and represents a portion of the margin of safety) as this magnitude event is only expected to occur once every 25 years.

Load allocations have been identified for the Bad Axe TMDL to account for runoff from NPS in the watershed. These allocations are based on meeting the loading capacity that will attain the WQS. Under low flow conditions, most water in Bad Axe Creek originates from the Bad Axe WWTP. Accordingly, the LA under low flow conditions is negligible. As flows increase, the LA is determined by summing up the WLAs and then subtracting that amount from the loading capacity for each respective duration curve zone. As flows increase, the percentage of the LA relative to the WLAs is progressively greater. This reflects the fact that under high flow conditions, most of the TP load originates from NPS.

A summary of the components (WLAs and LAs) of the TMDL is presented in Table J-6.

Table J-6. Bad Axe Creek TMDL allocations -- Total Phosphorus

AUID	Group	Name [Type]	Duration Curve Zone (pounds per day) High	Moist	Mid	Dry	Low
04080103-0302-02	**A**	Rooney Contracting [d]	0.005	0.001	0.00	0.00	0.000
	A	J W Hunt [d,f]	0.005	0.001	0.00	0.00	0.000
	A	Huron & Eastern Railway [d]	0.005	0.001	0.00	0.00	0.000
	B	Bad Axe WWTP [a]	1.25	1.25	1.25	1.25	1.25
	B	Colfax Township WWSL [b]	0.010	0.00	0.00	0.00	0.000
	C	Wil-Le Farms [c]	1.2 [g]	0.00	0.00	0.00	0.000
	C	Huron Co Medical Care WWSL [b]	0.025	0.00	0.00	0.00	0.000
	D	Hass Feedlot-2 [c]	0.4 [g]	0.00	0.00	0.00	0.000
	A,B,C	MDOT [e]	0.20	0.057	0.00	0.00	0.000
	AUID Load Allocations		19.2	4.77	1.56	0.49	0.002
	Margin of Safety		Implicit				
	AUID Total		**22.3**	**6.08**	**2.81**	**1.74**	**1.252**
04080103-0302-01 *[not currently on §303(d) list for nutrients]*	**AUID Load Allocations**		12.3	2.81	0.91	0.29	0.001
	Margin of Safety		Implicit				
	AUID Total		**34.6**	**8.89**	**3.72**	**2.03**	**1.253**

Notes:
- [a] Non-Industrial Sanitary Wastewater (WWTP). Low flow WLA based on the facility's DMR concentration and flow data. In-stream monitoring at Pigeon Rd. recommended to collect data that will help translate WLA into NPDES permit limit.
- Non-Industrial Sanitary Wastewater (WWSL)
- [b] Concentrated Animal Feeding Operation (CAFO)
- [c] Industrial Storm Water Only
- [d] MS4 Stormwater
- [e] GW-Commercial
- [f] WLAs must be consistent with the assumptions described in Section 4.2 [from Michigan's NPDES CAFO General
- [g] Permit (MIG010000)]

Bacteria *(E. coli)*

Loading Capacity.

As indicated in Section 2.4, the targets for this bacteria TMDL are the TBC 30-day geometric mean WQS of 130 *E. coli* per 100 mL and daily maximum of 300 *E. coli* per 100 mL (May 1 through October 31), and 1,000 *E. coli* per 100 mL as a daily maximum the remainder of the year. Typically loading capacities are expressed as a mass per time (e.g. pounds per day). However, for bacteria loading capacity calculations, mass is not always an appropriate measure because indicators such as *E. coli* are expressed in terms of organism counts; hence Michigan's focus on a concentration-based approach for bacteria TMDLs.

This appendix provides additional information needed to satisfy USEPA TMDL review requirements, consistent with the EPA's regulations which define *"load"* as *"an amount of matter that is introduced into a receiving water"* (40 CFR §130.2). The duration curve framework is used as the basis to identify appropriate flows needed to calculate bacteria loads. Daily average flow estimates from May 1 through October 31 are used to derive the duration curves. Because flow data in the Bad Axe watershed is limited, a drainage area weighting approach is used in conjunction with stream discharge data from the USGS Pigeon River gage.

Loading capacities are determined at each MDEQ 2008 monitoring location. The loading capacities are calculated by multiplying the duration curve flows times the daily maximum *E. coli* criteria times the appropriate conversion factor (0.02446), as described in Table J-7.

Table J-7. Calculation of bacteria loads

Load ***(organisms/day)*** **= Concentration** ***(org/100mL)*** *** Flow** ***(cfs)*** *** Factor**			
multiply by **3785.2** *to convert*	mL per gallon	→	organisms / 100 gallon
divide by **100** *to convert*		→	organisms / gallon
multiply by **7.48** *to convert*	gallon per ft^3	→	organisms / ft^3
multiply by **86,400** *to convert*	seconds per day	→	ft^3 / day
divide by **1,000,000,000**	billion	→	G (or billion)-organisms
multiply by **0.02446** *to convert*	**(organisms/100mL) * ft^3 / sec**	→	**G-organisms / day**

The loading capacities for the midpoints of the duration curve flow zones, expressed as billion organisms per day, are shown in Table J-8. Sampled loads from the 2008 monitoring data are shown relative to the loading capacity in Figure J-33 through Figure J-38.

Table J-8. Bad Axe Creek watershed loading capacity -- *E. coli*

AUID	Group			Duration Curve Zone				
		Outlet Point	Area (sq.mi.)	*High*	*Moist*	*Mid*	*Dry*	*Low*
FLOW [a]				(cfs)				
04080103-0302-02	**A**	Above Bad Axe WWTP	6.74	9.32	2.29	0.81	0.29	0.001
	B	Pigeon Road	7.93	12.1	3.86	2.11	1.50	1.160
	C	Berne Road	18.08	26.2	7.31	3.33	1.93	1.160
	D	**Campbell Road**	**18.64**	**26.9**	**7.50**	**3.40**	**1.95**	**1.160**
04080103-0302-01	**E**	Pinnebog Road	24.66	35.2	9.54	4.12	2.20	1.161
	F	**Bad Axe Creek mouth**	**29.50**	**41.9**	**11.19**	**4.70**	**2.41**	**1.161**
E. COLI				(billion - organisms per day)				
04080103-0302-02	**A**	Above Bad Axe WWTP	6.74	68.4	16.8	5.94	2.10	0.004
	B	Pigeon Road	7.93	89.0	28.3	15.5	11.0	8.51
	C	Berne Road	18.08	192	53.6	24.4	14.1	8.52
	D	**Campbell Road**	**18.64**	**198**	**55.0**	**24.9**	**14.3**	**8.52**
04080103-0302-01	**E**	Pinnebog Road	24.66	259	70.0	30.2	16.2	8.53
	F	**Bad Axe Creek mouth**	**29.50**	**308**	**82.1**	**34.5**	**17.7**	**8.53**

Note: [a] Flows based on PBC recreation season (May 1 – October 31) duration curve.

Figure J-33. *E. coli* load duration curve -- Bad Axe Drain below WWTP

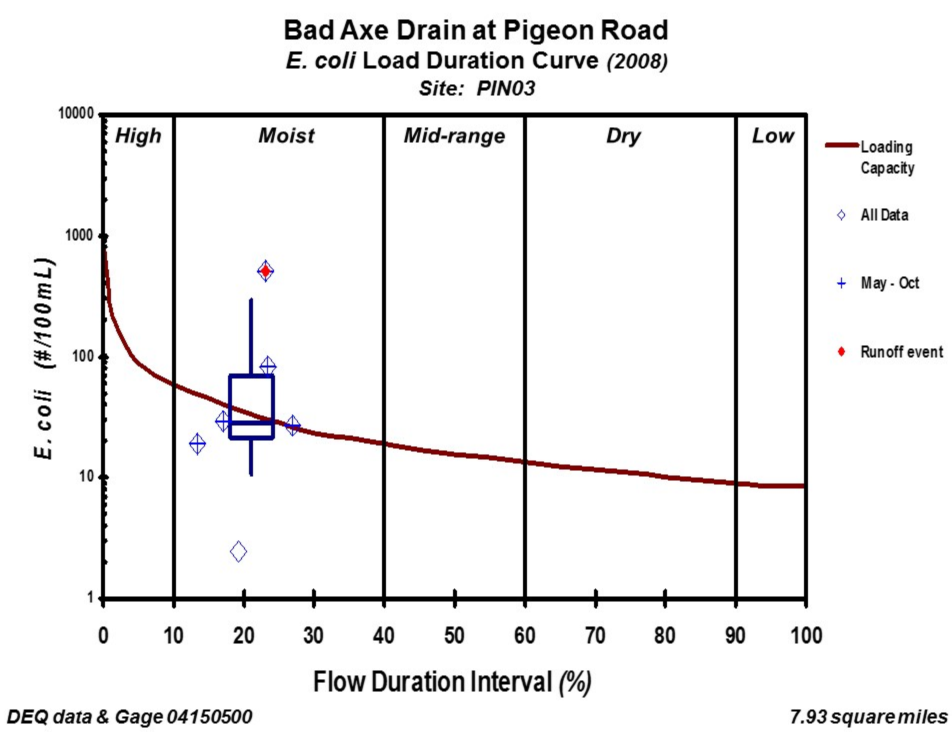


Figure J-34. *E. coli* load duration curve -- Bad Axe Drain at Pigeon Road

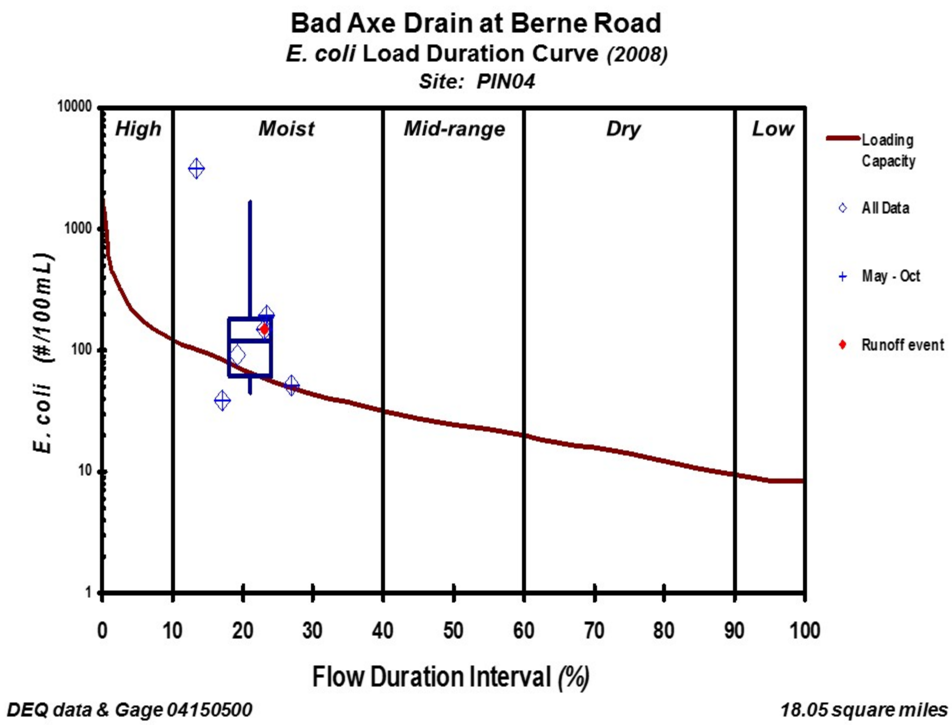


Figure J-35. *E. coli* load duration curve -- Bad Axe Creek at Berne Road

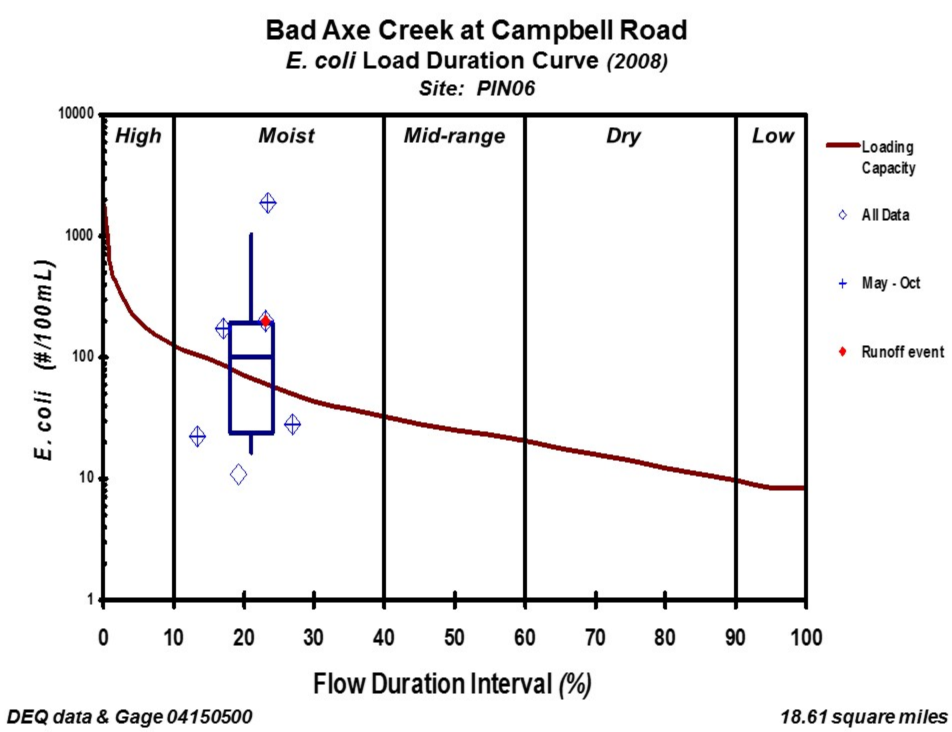


Figure J-36. *E. coli* load duration curve -- Bad Axe Creek at Campbell Road

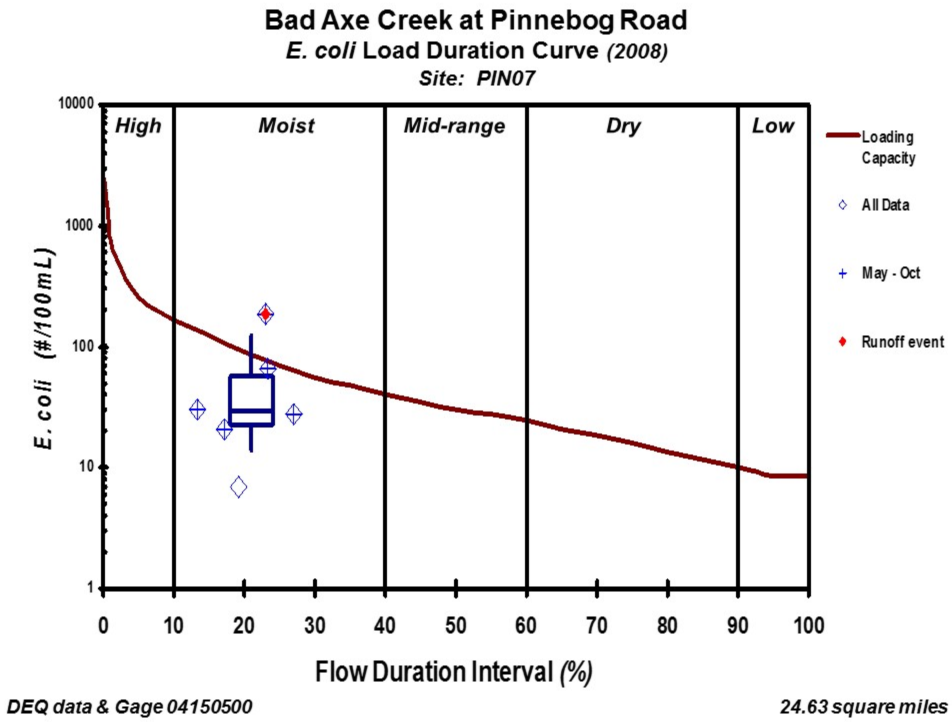


Figure J-37. *E. coli* load duration curve -- Bad Axe Creek at Pinnebog Road

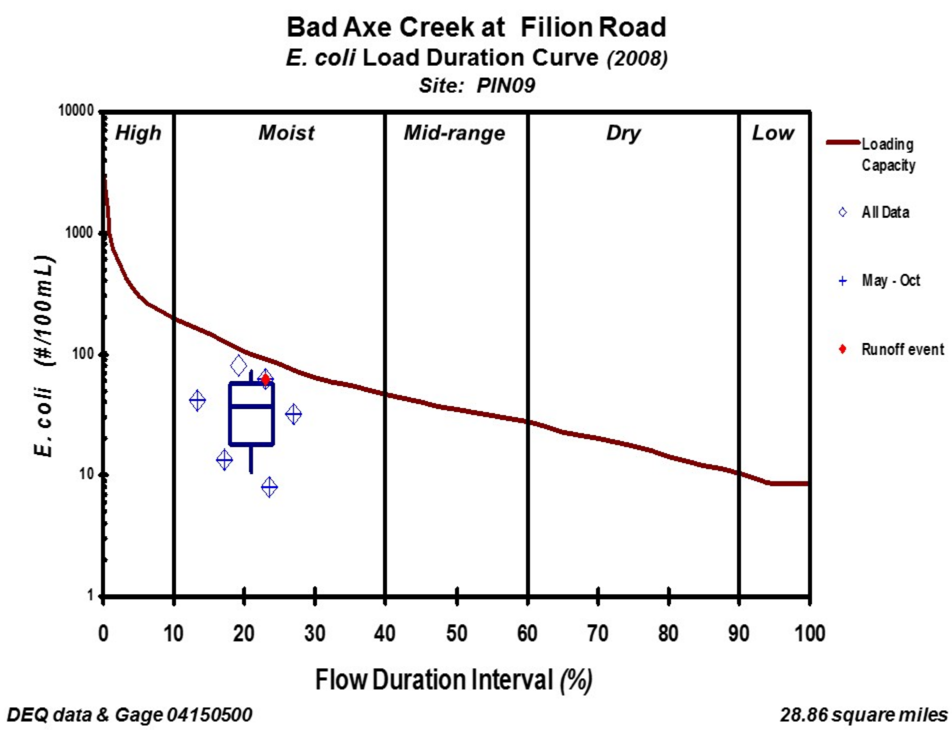


Figure J-38. *E. coli* load duration curve -- Bad Axe Creek at Filion Road

Allocations.

There are eight facilities and one agency (MDOT) with MDEQ permit coverage in the listed Bad Axe AUID that require WLAs. The Bad Axe WWTP is the only one with a continuous discharge that requires a WLA across all flow conditions. A WLA for the Bad Axe WWTP, based on the facility design flow, exceeds the loading capacity across all zones except high conditions. However, the average discharge from the Bad Axe WWTP is less than 20 percent of its design flow.

The focus of this TMDL is to achieve a 30-day geometric mean concentration of 130 E. coli per 100 ml. For this reason, the WLA for the Bad Axe WWTP is less than the load limit that would be determined based on the design flow in the NPDES permit. The WLA is calculated from the facility's current estimated flow based on Discharge Monitoring Report (DMR) data.

The WLAs for the stormwater permits are based on the percentage of the facility's contributing area relative to the area of the entire AUID. Runoff from these facilities is only expected to occur under high flow and moist conditions. Similarly, the MS4 WLA for MDOT is based on the percentage of the state road contributing area relative to the area of the entire AUID.

The WWSL general permit does not allow a discharge from these facilities during the growing season. However, extreme weather conditions may force the need for an emergency discharge. For that reason, WLAs have been identified for these facilities under high flow conditions.

The CAFO general permit prohibits any dry weather discharge. The Wil-Le Farms CAFO (MIG440027) and Hass Feedlot CAFO (MIG010042) must comply with all authorized discharge and overflow requirements described in the State of Michigan's NPDES CAFO General Permit (MIG010000). In accordance with the CAFO General Permit, overflow events from Wil Le Farms and Haas Feedlot CAFOs are allowable due to precipitation related overflows from CAFO storage structures which are properly designed, constructed, operated and maintained in accordance with CAFO permits (MIG440027 and MIG10042). Discharges from such overflows are allowable only if they do not cause or contribute to a violation of water quality standards.

The NPDES CAFO permit contains several measures designed to prevent *E.coli* from entering surface waters from the production area and waste (manure) storage sites. At production facilities, and associated manure storage sites, the permit requires properly designed, constructed, and maintained manure storage structures. These structures must be designed to store at least six months of generated production area waste, with additional reserve capacity for normal and design-storm precipitation, and the required freeboard amount. All manure storage structures must be inspected once per week by the CAFO operator, providing assurance against overflow and potential structural damage.

Animal waste for land application from the CAFO is transferred to contract haulers. The CAFO general permit indicates that such waste is not under the operational control of the CAFO owner. However, the permit does require completion of a manifest to track the transfer and use of the CAFO waste.

Load allocations have been identified for the Bad Axe TMDL to account for runoff from nonpoint sources in the watershed. These allocations are based on meeting the loading capacity that will attain the WQS. Under low flow conditions, most water in Bad Axe Creek originates from the Bad Axe WWTP. Accordingly, the LA under low flow conditions is negligible. As flows increase, the LA is determined by summing up the WLAs and then subtracting that amount from the loading capacity for each respective duration curve zone. As flows increase, the percentage of the LA relative to the WLAs is progressively greater. This reflects the fact that under high flow conditions, most of the *E. coli* load originates from nonpoint sources.

A summary of the components (WLAs and LAs) of the *E. coli* TMDL is presented in Table J-9.

Table J-9. Bad Axe Creek allocations -- *E. coli*

AUID	Group		Duration Curve Zone (billion - organisms per day)				
		Name [Type]	High	Moist	Mid	Dry	Low
04080103-0302-02	A	Rooney Contracting [d]	0.05	0.01	0.00	0.00	0.00
		J W Hunt [d,f]	0.05	0.01	0.00	0.00	0.00
		Huron & Eastern Railway [d]	0.05	0.01	0.00	0.00	0.00
	B	Bad Axe WWTP [a]	8.5	8.5	8.5	8.5	8.5
		Colfax Township WWSL [b]	0.10	0.02	0.00	0.00	0.00
	C	Wil-Le Farms [c]	8.1 [g]	0.0	0.00	0.00	0.00
		Huron Co Medical Care WWSL [b]	0.3	0.06	0.00	0.00	0.00
	D	Hass Feedlot-2 [c]	2.7 [g]	0.0	0.00	0.00	0.00
	A,B,C	MDOT [e]	2.15	0.39	0.00	0.00	0.00
	AUID LOAD ALLOCATIONS		176	46.0	16.4	5.8	0.02
	MARGIN OF SAFETY		Implicit				
	AUID TOTAL		**198**	**55.0**	**24.9**	**14.3**	**8.52**
04080103-0302-01	AUID LOAD ALLOCATIONS		110	27.1	9.6	3.4	0.01
	MARGIN OF SAFETY		Implicit				
	AUID TOTAL		**308**	**82.1**	**34.5**	**17.7**	**8.53**

Notes:
[a] Non-Industrial Sanitary Wastewater (WWTP)
[b] Non-Industrial Sanitary Wastewater (WWSL)
[c] Concentrated Animal Feeding Operation (CAFO)
[d] Industrial Storm Water Only
[e] MS4 Stormwater
[f] GW-Commercial
[g] WLAs must be consistent with the assumptions described in Section 4.2 [from Michigan's NPDES CAFO General Permit (MIG010000)]