Ohio Environmental Protection Agency

Loading Analysis Plan and Supporting Data Acquisition Needed for the Ohio Tributaries to the Shenango River

(Including Pymatuning Creek, Yankee Creek, and Little Yankee Creek)
Total Maximum Daily Load Development

Ohio EPA Technical Report AMS/2008-SHENA-3

Division of Surface Water
Assessment and Modeling Section
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Introduction

This document provides an overview of the information considered in proposing the strategy to address water quality impairments in the Ohio Tributaries to the Shenango River watershed (including Pymatuning Creek, Yankee Creek, and Little Yankee Creek). These recommendations are based on data collected as part of a biological and water quality study in 2008. A description of the project area, sites, data types and methods can be found in the Ohio Tributaries to the Shenango River watershed 2008 study plan document at ***epa.ohio.gov/portals/35/tmdl/Pymatuning%20Study%20Plan%202008.pdf.***
A summary of the study results can be found in the biological and water quality report at ***epa.ohio.gov/portals/35/documents/ShenangoRiverTributariesTSD2008.pdf.***
Sites in the Ohio Tributaries to the Shenango River watershed (including Pymatuning Creek, Yankee Creek, and Little Yankee Creek) were assessed for aquatic life use, recreation use. The public water supply use was not assessed since no surface waters are used as a public water supply in this study area. The attainment of aquatic life and recreation use is based on specific restoration targets. This document examines those targets and lays out proposals for addressing each impairment. Where appropriate, methods are outlined to develop total maximum daily loads (TMDL) for specific pollutants.

Aquatic Life Use

Evaluation of Biocriteria

Attainment of Ohio EPA's biocriteria are based on fish and macroinvertebrate scores, as measured by the Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb) and Invertebrate Community Index (ICI). Further explanations of Ohio EPA's biocriteria can be found in Ohio Administrative Code (OAC) Chapter 3745-1-07 and additionally at ***epa.ohio.gov/dsw/bioassess/BioCriteriaProtAqLife.*** Goals for those indices in the Ohio Tributaries to the Shenango River watershed (including Pymatuning Creek, Yankee Creek, and Little Yankee Creek) are shown in Table 1. The attainment status for each site is shown in Figure 1 and the scores for impaired sites are shown in Table 2.

An aquatic life use (ALU) assessment was completed at 31 sites in the Ohio Tributaries to the Shenango River watershed (including Pymatuning Creek, Yankee Creek, and Little Yankee Creek) in 2008. The study encompassed eight HUC-12 watersheds in Ashtabula and Trumbull Counties. Out of the 31 sites, 16 were documented as having partial or non-attainment.

Table 1 – Biological criteria applicable in the Ohio Tributaries to the Shenango River watershed (including Pymatuning Creek, Yankee Creek, and Little Yankee Creek) for aquatic life use designations.

Ecoregion	Biological Index	Assessment Method[2, 3]	Biological Criteria for the Applicable Aquatic Life Use Designations[1]	
			EWH	WWH
Erie-Ontario Lake Plains (EOLP)	IBI	Headwater	50	40
		Wading	50	38
		Boat	48	40
	MIwb	Wading	9.4	7.9
		Boat	9.6	8.7
	ICI	All[4]	46	34

[1] Aquatic Life Use (ALU) designations: warmwater habitat (WWH); exceptional warmwater habitat (EWH).
[2] The assessment method used at a site is determined by its drainage area (DA) according to the following: Headwater: DA ≤ 20 mi^2; wading: DA >20 mi^2 and ≤ 500 mi^2; boat: DA > 500 mi^2.
[3] MIwb not applicable to drainage areas less than 20 mi^2 (headwater sites).
[4] Limited to sites with appropriate conditions for artificial substrate placement.

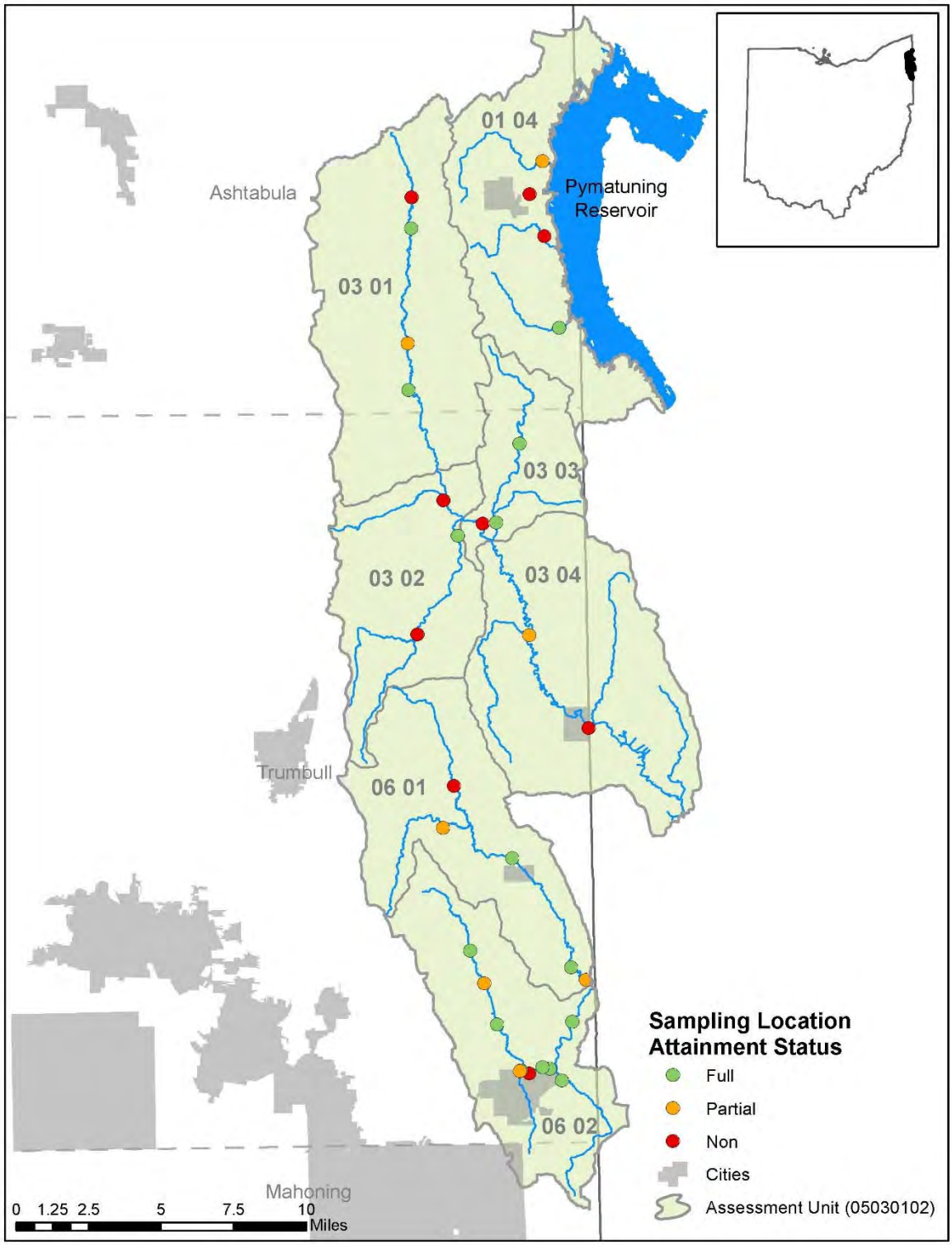

Figure 1 — Map summarizing ALU attainment status in the Ohio Tributaries to the Shenango River watershed (including Pymatuning Creek, Yankee Creek, and Little Yankee Creek) in 2008.

Table 2 – Aquatic life use attainment information for impaired sampling locations in the Ohio Tributaries to the Shenango River watershed (including Pymatuning Creek, Yankee Creek, and Little Yankee Creek), 2008.

Station	Location	ALU	River Mile[a]	Drain. Area (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
05130102 01 04 – Frontal Pymatuning Reservoir											
N04K02	Gravel Run @ Pymatuning Lake Road	WWH	1.27[H]	5.3	38[ns]	NA	F[*]	65	Partial	Wetland habitat	Natural
N04K06	Wade Creek @ US 6; dst Andover WWTP	WWH	1.82[H]	3.1	28[*]	NA	LF[*]	69	Non	Wetland habitat	Natural
										Nutrient/organic enrichment	Municipal wastewater discharge
N04K01	Black Creek @ Pymatuning Lake Road	WWH	1.43[H]	5.2	28[*]	NA	F[*]	70.5	Non	Wetland habitat	Natural
05030102 03 01 – Headwaters Pymatuning Creek											
N04S27	Pymatuning Creek @ US 6	WWH	30.38[H]	11.8	34[*]	NA	F[*]	55.0	Non	Wetland habitat	Natural
N04S02	Pymatuning Creek @ US 322	WWH	24.50[W]	35.0	37[ns]	7.2[*]	52	46.0	Partial	Wetland habitat	Natural
05030102 03 02 – Sugar Creek-Pymatuning Creek											
N04S26	Pymatuning Creek @ State Route 87	WWH	17.78[B]	66.0	-	-	4[*]	-	(Non)	Low dissolved oxygen	Natural
										Wetland habitat	
N04K07	Sugar Creek @ State Route 88	WWH	5.72[H]	9.0	24[*]	NA	LF[*]	54.0	Non	Organic enrichment	Livestock
										Sedimentation/siltation	
										Low dissolved oxygen	
										Low dissolved oxygen	Channelization

Station	Location	ALU	River Mile[a]	Drain. Area (mi²)	IBI	MIwb[b]	ICI[c]	QHEI	Attain. Status	Causes	Sources
05030102 03 03 – Stratton Creek-Pymatuning Creek											
N04S23	Pymatuning Creek @ State Route 7; dst. Storm Sewer 2	WWH	15.80[B]	96.0	27*	6.4*	18*	61.0	Non	Low dissolved oxygen Wetland habitat	Natural
05030102 03 04 – Booth Run-Pymatuning Creek											
N04S01	Pymatuning Creek @ State Route 88	WWH	8.40[B]	135.0	34*	8.1*	34*	64.0	Partial	Low dissolved oxygen Wetland habitat	Natural
N04S20	Pymatuning Creek @ PA State Line at Orangeville	WWH	1.94[B]	148.0	31*	8.1*	24*	60.5	Non	Low dissolved oxygen Wetland habitat Flow alteration	Natural Dam/impoundment
05030102 06 01 – Yankee Run											
N04S34	Yankee Creek @ State Route 305	WWH	11.34[H]	14.8	34*	NA	LF*	44.5	Non	Low dissolved oxygen Wetland habitat	Natural
N04S33	Yankee Creek @ US 62 dst. Brookfield WWTP	WWH	0.30[B]	45.7	39[ns]	8.6[ns]	14*	64.0	Partial	Flow alterations	Dam/Impoundment (on Shenango R. dst. confluence)
N04K12	South Branch Yankee Creek @ Warner Road	WWH	1.54[H]	9.0	46	NA	F*	87.0	Partial	Unknown	Unknown
05030102 06 02 – Little Yankee Run											
N04S12	Little Yankee Creek @ Stewart-Sharon Rd	WWH	9.56[H]	11.0	31*	NA	48	66.0	Partial	Unknown	Unknown
N04Q01	Little Yankee Creek @ Valley Mould Dam Pool	WWH	5.00[W]	29.8	-	-	14*	-	(Non)	Low dissolved oxygen Sedimentation/siltation	Dam/impoundment
300534	Mud Run @ North Main Street	WWH	0.2[H]	5.2	40	NA	LF*	57.0	Partial	Sedimentation/siltation	Urban runoff

a River Mile (RM) represents the Point of Record (POR) for the station and may not be the actual sampling RM.

b MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi².

c A narrative evaluation of the qualitative sample based on attributes such as EPT taxa (Ephemeroptera / Piecoptera / Trichoptera) richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor; P=Poor; LF=Low Fair; F=Fair; MG=Marginally Good; G=Good; VG=Very Good; E=Exceptional

ns Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
* Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.
H Headwater site (draining ≤20 miles^2).
W Wading site (non-boat site draining >20 miles^2).
B Boat site (large or deep waters, necessitating the use of boat sampling methods)

Proposed Actions

Ohio EPA considers many factors when deciding how to address impairments. For some projects, no TMDL is required. The watershed may be in attainment or the impairment is being addressed by another program/entity so no further action by the Division of Surface Water is necessary. Additionally, the cause of impairment may be natural (i.e., flow or habitat), in which case no action is required. For those needing a TMDL, the complexity of each impairment—including the primary origin of the pollutant, its delivery mechanisms and the waterbody kinetics involved—will determine the complexity needed in a model. Ohio EPA must also take into consideration ongoing efforts in the watershed, previous TMDL analyses, the questions to be answered by a model and the amount of effort required to complete the model. Depending on the method selected, the Agency may be required to return to the watershed and collect additional data, and it is possible the modeling approach may change. A summary of Ohio EPA's preliminary modeling approaches is presented in Table 3.

Table 3 – Summary of ALU impairments and potential modeling approaches

Station	Stream Name	River Mile	HUC 12 (05030102)	Cause(s) of Impairment	Source(s) of Impairment	Action	Method[1]
N04K02	Gravel Run	1.27	01 04	Wetland habitat	Natural	N/A	
N04K06	Wade Creek	1.82	01 04	Wetland habitat	Natural	N/A	
				Nutrient/organic enrichment	Municipal WWTP discharge	Other	Follow-up
N04K01	Black Creek	1.43	01 04	Wetland habitat	Natural	N/A	
N04S27	Pymatuning Creek	30.38	03 01	Wetland habitat	Natural	N/A	
N04S02	Pymatuning Creek	24.50	03 01	Wetland habitat	Natural	N/A	
N04S26	Pymatuning Creek	17.78	03 02	Low dissolved oxygen Wetland habitat	Natural	N/A	
N04K07	Sugar Creek	5.72	03 02	Organic enrichment Sedimentation/siltation Low dissolved oxygen	Livestock	TMDL	QHEI-sed
				Low dissolved oxygen	Channelization	TMDL	QHEI
N04S23	Pymatuning Creek	15.80	03 03	Low dissolved oxygen Wetland habitat	Natural	N/A	

Station	Stream Name	River Mile	HUC 12 (05030102)	Cause(s) of Impairment	Source(s) of Impairment	Action	Method[1]
N04S01	Pymatuning Creek	8.4	03 04	Low dissolved oxygen Wetland habitat	Natural	N/A	
N04S20	Pymatuning Creek	1.94	03 04	Low dissolved oxygen Wetland habitat	Natural	N/A	
				Flow alterations	Dam impoundment	N/A	
N04S34	Yankee Creek	11.34	06 01	Low dissolved oxygen Wetland habitat	Natural	N/A	
N04S33	Yankee creek	0.3	06 01	Flow alteration	Dam impoundment	N/A	
N04K12	South Branch Yankee Cr.	1.54	06 01	Unknown	Unknown	Other	Follow-up
N04S12	Little Yankee creek	9.56	06 02	Unknown	Unknown	Other	Follow-up
N04Q01	Little Yankee Creek	5.00	06 02	Low dissolved oxygen Sedimentation/siltation	Dam impoundment	TMDL	QHEI-sed
300534	Mud Run	0.2	06 02	Sedimentation/siltation	Urban Runoff	TMDL	QHEI-Sed

[1] Due to space limitations there are several abbreviations used to describe the analysis or remediation method. Those abbreviations are defined as follows:

Abbreviation	Definition/interpretation
Follow-up	Follow-up assessment is required to determine if attainment status has changed or to clarify/verify the listed cause of impairment.
Revise listing	Based on survey findings, the listing will be updated in a subsequent Integrated Report and a TMDL or other action will not be required (i.e., a category 5 could be revised to a category 4c-not a pollutant.
QHEI-sed	Sub-metrics of the QHEI used to evaluate aspects of habitat quality as a surrogate for addressing impairment due to excess sediment.
QHEI	"Qualitative habitat evaluation index" is used as means to address impairment due to inadequate habitat quality. More information regarding the QHEI method can be found at *epa.ohio.gov/portals/35/documents/QHEIManualJune2006.pdf*

The impairment from nutrient/organic enrichment on Wade Creek was directly linked to performance deficiency at the Village of Andover WWTP, which has been cited for being in significant non-compliance. From 1999 to February 2008, 643 limit violations and 318 code violations were recorded. The facility reported bypasses during times of heavy rain which likely exceeded the design capacity of the plant. All these violations resulted in Notices of Violations (NOVs). In order to bring the facility into compliance, Ohio EPA conducted thorough annual compliance inspection in 2011, 2012, and 2013. Also, during this time period a new operator was hired. These thorough inspections and having a new operator helped the facility to perform better. From February 2008 to September 2019, electronic discharge monitoring report (eDMR) data revealed that violations dropped to 140 limit violations and 66 code violations. The facility also reported 69 bypasses during this time with no reported bypasses since 2015. Ohio EPA will revisit these sites to assess whether Andover WWTP performance improvements have brought Wade Creek into full attainment or if a TMDL is necessary.

Sugar Creek is impaired due to low dissolved oxygen (D.O.), organic enrichment and sedimentation/siltation. This is noted as being caused by unrestricted cattle access to the stream. The general disturbance of stream banks and riparian zones by cattle will lead to increased erosion. The added sediment, plus the deposition of manure directly into the stream, which is a cause of organic enrichment, causes a high level of sediment oxygen demand. Mechanisms to decrease cattle in the stream (fencing, riparian improvements, etc.) will also address sedimentation, dissolved oxygen and organic enrichment impairment, therefore a sediment TMDL using qualitative habitat evaluation index (QHEI) sub-metrics will be sufficient in handling all other causes as well. Channelization, which can also cause low dissolved oxygen, can be addressed via a QHEI TMDL.

Pymatuning Creek at river mile 1.94 is listed as impaired due to low dissolved oxygen, wetland habitat and flow alteration. Low dissolved oxygen and wetland habitat are considered natural causes of impairment and do not require TMDLs. Flow alterations due to a dam impoundment can't be considered a pollutant (category 4C in the Integrated Report) therefore, no TMDL is required at this site.

Yankee Creek at river mile 0.3 is impaired due to flow alteration. Because flow alteration is not a pollutant (category 4C in the Integrated report), no TMDL is required at this site.

South Branch Yankee Creek and Little Yankee Creek at river mile 9.56 are impaired due to unknown causes and sources; therefore, Ohio EPA will revisit these sites to determine the causes and sources of impairment.

Little Yankee Creek is listed as impaired due to low dissolved oxygen and sedimentation/siltation. There was no datasonde deployment to verify low D.O. as a cause. In addition, there were six D.O. measurements with an average D.O. of 5.9 mg/L and minimum D.O. of 5.1 mg/L which is above the D.O. standard. The source of impairment in Little Yankee Creek is an old industrial dam at river mile 4.96 which does not serve local industry anymore. This industrial dam results in water impoundment which reduces the energy of the stream during high flows and thus, limits the stream's ability to process sediment. A sediment TMDL using QHEI sub-metrics can justify the removal of the old dam to bring the creek into full attainment.

Mud Run is impaired due to sedimentation/siltation caused by urban runoff. A sediment TMDL using QHEI sub-metrics will be the proper action to handle this impairment.

Proposed Targets

Habitat

Since its development, the QHEI has been used to evaluate habitat at most biological sampling sites and there is an extensive database that includes QHEI scores and other water quality variables. Strong correlations exist between QHEI scores and the biological indices used in Ohio's water quality standards such as the Index of Biotic Integrity

(IBI). Through statistical analyses of data for the QHEI and the biological indices, target values have been established for QHEI scores with respect to the various aquatic life use designations (Ohio EPA 1999). These targets are shown in Table 4.

One of the strongest correlations found through the statistical analyses described above is the negative relationship between the number of modified attributes and the IBI scores. Modified attributes are features or conditions of the stream that have poor habitat quality and therefore are assigned relatively fewer points or negative points in the QHEI scoring. A sub-group of the modified attributes shows a stronger impact on biological performance; these are termed high influence modified attributes (Table 5).

In addition to the overall QHEI scores, targets for the maximum number of modified and high influence modified attributes have been developed. For example, to meet the targets, streams designated as WWH cannot have more than four modified attributes, of which no more than one can be a high influence modified attribute. For simplicity, a pass/fail distinction is made indicating whether or not each of the three targets is being met. Targets are set for: 1) the total QHEI score; 2) the maximum number of all modified attributes; and 3) the maximum number of high influence modified attributes. If the minimum target is satisfied, then that category is assigned a "1," if not, it is assigned a "0." To satisfy the habitat TMDL, the stream segment in question should achieve a score of three.

Table 4 – QHEI targets for habitat TMDLs

Habitat TMDL Targets		
QHEI Category	*Target*	*Score*
	WWH	
QHEI Score	≥ 60	+ 1
High Influence #	≤ 1	+ 1
Total # Modified	≤ 4	+ 1
	Habitat TMDL ►	+ 3

Table 5 – Itemization of modified attributes for computing habitat TMDLs

High Influence Modified Attributes	**Moderate Influence Modified Attributes**	
• Recent channelization or no recovery • Silt/muck substrate • Low or no sinuosity (drainage area ≤ 20 mi^2) • Sparse/no cover • Maximum pool depth < 40 cm (wadeable or headwater sites)	• Recovering channelization • Heavy/moderate silt cover • Sand substrate (boat sites) • Hardpan substrate origin • Fair/poor development • Low or no sinuosity (drainage area > 20 mi^2) • Only 1-2 cover types	• Intermittent pools and max pool depth < 40 cm • No fast current • High/moderate substrate embeddedness • High/moderate riffle embeddedness • No riffle

Sediment

Numeric targets for sediment are based on three sub-metrics of the QHEI. Although the QHEI evaluates the overall quality of stream habitat, some of its component sub-metrics consider particular aspects of stream habitat that are closely related to and/or impacted by the sediment delivery and transport processes occurring in the system. The QHEI sub-metrics used in the sediment TMDL are the substrate, channel morphology, and bank erosion/riparian zone. Table 6 lists targets for each of these metrics.

Table 6 – QHEI targets for sediment TMDLs

Sediment TMDL Targets	
QHEI Category	WWH
Substrate	≥ 13
Channel	≥ 14
Riparian	≥ 5
Sediment TMDL ►	≥ 32

The substrate sub-metric evaluates predominant substrate types, the amount and origin of these types and the degree of embeddedness and silt cover. This is a qualitative evaluation of the amount of excess fine material in the system and the ability of the channel to assimilate or sort the sediment load.

The channel morphology sub-metric considers sinuosity, riffle and pool development, channelization and channel stability. Except for stability, each of these aspects is directly related to channel form, sediment transport, erosion, and deposition within the channel. Stability reflects the degree of channel erosion, which indicates the potential of the stream to be a significant sediment source.

The bank erosion and riparian zone sub-metric also reflects the likely degree of in-stream sediment sources. The evaluation of floodplain quality is included in this sub-metric, which relates to the capacity of the system to assimilate sediment loads.

Recreation Use

Evaluation of Criteria

Attainment of recreation use goals is based on numeric criteria for *Escherichia coli* (*E. coli*) as an indicator bacterium. These criteria, shown in Table 7, are also the targets used for TMDLs. Table 8 lists attainment of recreation use based on criteria at the time of assessment, which were different than the current standards. However, any TMDLs created for those assessment units will use the updated values in Table 7.

Table 7 – Water quality criteria for recreation use

Recreation Use	*Escherichia coli* (colony forming units per 100 mL)	
	90-day geometric mean	Statistical threshold value[1]
Bathing water	126	410[a]
Primary contact recreation	126	410
Secondary contact recreation	1030	1030

[1] These criteria shall not be exceeded in more than 10 percent of the samples taken during any ninety-day period.

[a] A beach action value of 235 E. coli colony counts per 100 mL shall be used for the purpose of issuing beach and bathing water advisories.

Table 8 – Recreation use attainment information for impaired sampling locations in the Ohio Tributaries to the Shenango River watershed, 2008.

Station	Stream Name	River Mile	# Samples	Geometric Mean	Maximum Value	Attainment Status	Possible Source(s)
05130102 01 04 - Pymatuning Reservoir Tributaries							
N04K01	Black Creek @Pymatuning Lake Rd.	1.43	5	467	2400	NON	HSTS[1], Agriculture
N04K02	Gravel Run Creek @ Pymatuning Lake Rd.	1.27	5	311	2000	NON	HSTS, Agriculture, WWTP discharge
N04K03	McMichael Creek @ Pymatuning Lake Rd.	1.26	5	361	1500	NON	HSTS, WWTP discharge
N04K04	Wade Creek @ US 6 (ust Andover WWTP)	2.74	5	501	1000	NON	HSTS, Agriculture
N04K06	Wade Creek @ US 6 (dst Andover WWTP)	1.82	5	671	1100	NON	WWTP discharge, HSTS
05030102 03 01 - Headwaters Pymatuning Creek							
N04S27	Pymatuning Creek @ US 6	30.38	5	203	290	NON	Agriculture, HSTS
N04S02	Pymatuning Creek @ US 322	24.5	5	389	1600	NON	Agriculture
N04Q06	Pymatuning Creek @ Underwood Rd.	22.7	5	672	12000	NON	Agriculture
05030102 03 02 - Sugar Creek - Pymatuning Creek							
N04S26	Pymatuning Creek @ SR 87	17.78	5	195	200	NON	Agriculture
N04K07	Sugar Creek @ SR 88	5.72	5	328	840	NON	Agriculture, HSTS
N04S28	Sugar Creek @ Burnett Rd.	0.92	5	300	790	NON	Agriculture, HSTS, WWTP discharge
05030102 03 03 – Stratton Creek - Pymatuning Creek							
N04S23	Pymatuning Creek @ SR 7, dst. storm sewer 2	15.8	6	235	410	NON	HSTS
N04S22	Pymatuning Creek S. of Kingsman adj, SR 7	15.2	5	202	1200	NON	HSTS
N04K08	Stratton Creek @ Weber Rd.	4.21	5	270	550	NON	HSTS
05030102 03 04 – Booth Run - Pymatuning Creek							
N04S01	Pymatuning Creek @ SR 88	8.4	5	818	3500	NON	Agriculture, HSTS
05030102 06 01 – Yankee Run							
N04S34	Yankee Creek @ SR 305, W of Hartford	11.34	5	466	770	NON	Agriculture
N04Q03	Yankee Creek @ CR 361A	6.5	5	350	820	NON	HSTS
N04S35	Yankee Creek upst Brookfield WWTP.	1.23	6	665	620	NON	Urban runoff, HSTS
N04S33	Yankee Creek dst Brookfield WWTP	0.3	5	300	40	NON	WWTP discharge, HSTS

N04K12	South Branch Yankee Creek @ Warner Rd.	1.54	5	406	2000	NON	WWTP discharge, HSTS
05030102 06 02 – Little Yankee Run							
N04K13	Little Yankee Creek @ Albright-McKay Road	10.99	5	450	3400	NON	Agriculture (livestock access)
N04S12	Little Yankee Creek @ Stewart-Sharon Rd.	9.56	5	280	2600	NON	HSTS
N04Q01	Little Yankee Creek Valley Mould dam pool	5.2	5	515	7100	NON	Urban runoff, HSTS
N04S10	Little Yankee Creek @ Mill Street	4.7	6	1002	6500	NON	Urban runoff, HSTS
N04S08	Little Yankee Creek @ 1st RR bridge dst Hubbard WWTP	4.4	5	259	7900	NON	WWTP discharge, HSTS
N04W06	Little Yankee Creek @ Chestnut Ridge Road	1.58	5	209	6500	NON	WWTP discharge, HSTS, agriculture
N04S13	Little Deer Creek @SR 304	0.4	5	701	3400	NON	Agriculture, HSTS
300534	Mud Run @ North Main Street	0.07	5	624	7800	NON	Urban runoff, HSTS

[1] HSTS stands for Household Sewage Treatment System

Proposed Actions

Concentrations of *E. coli* exceeding the water quality standard are due to both pervasive and direct sources. Two predominant pathways exist for pathogen delivery to water bodies. The first pathway is pathogen-rich discharge, including material such as poorly treated or untreated effluent from wastewater treatment plants, combined sewer overflows, sanitary sewer overflows, household sewage treatment systems and livestock access to streams. This is delivered to the stream by direct discharge. The second pathway is pathogen-rich runoff/drainage from nonpoint sources. The associated delivery mechanism is precipitation-driven wash-off. This type of transport involves the delivery of pathogen-rich material by overland flow during precipitation and runoff events (e.g., summer storms, snowmelt, etc.).

Because of the rural nature of most of the study area, there are a good number of homes with household sewer treatment systems (HSTS). Therefore, failing HSTS as well as agricultural operations and livestock pastures are suspected as the main sources of *E. coli* in the Pymatuning Reservoir tributaries and the Pymatuning Creek headwaters. In addition, poorly treated sewage from regulated WWTP may contribute E. coli bacteria to the streams in which they discharge.

Due to these mechanisms of delivery, the sources of pathogens in surface waters can be determined to a certain extent via the level of stream flow observed. Therefore, Ohio EPA proposes using the load duration curve (LDC) framework for recreation use TMDLs. LDCs are an empirical method of determining TMDL pollutant loading and needed reductions. The main advantage of the use of LDCs is in this method's ability to differentiate loads from various types of sources based on stream flow regime. While this is a fairly basic modeling method, relationships between bacteria source contributions and flow regimes are straight forward. In-stream processes and interactions between pathogen sources are assumed conservative (i.e., not occurring) in this method. Figure 2 shows an example LDC with corresponding TMDL calculations represented in Table 9.

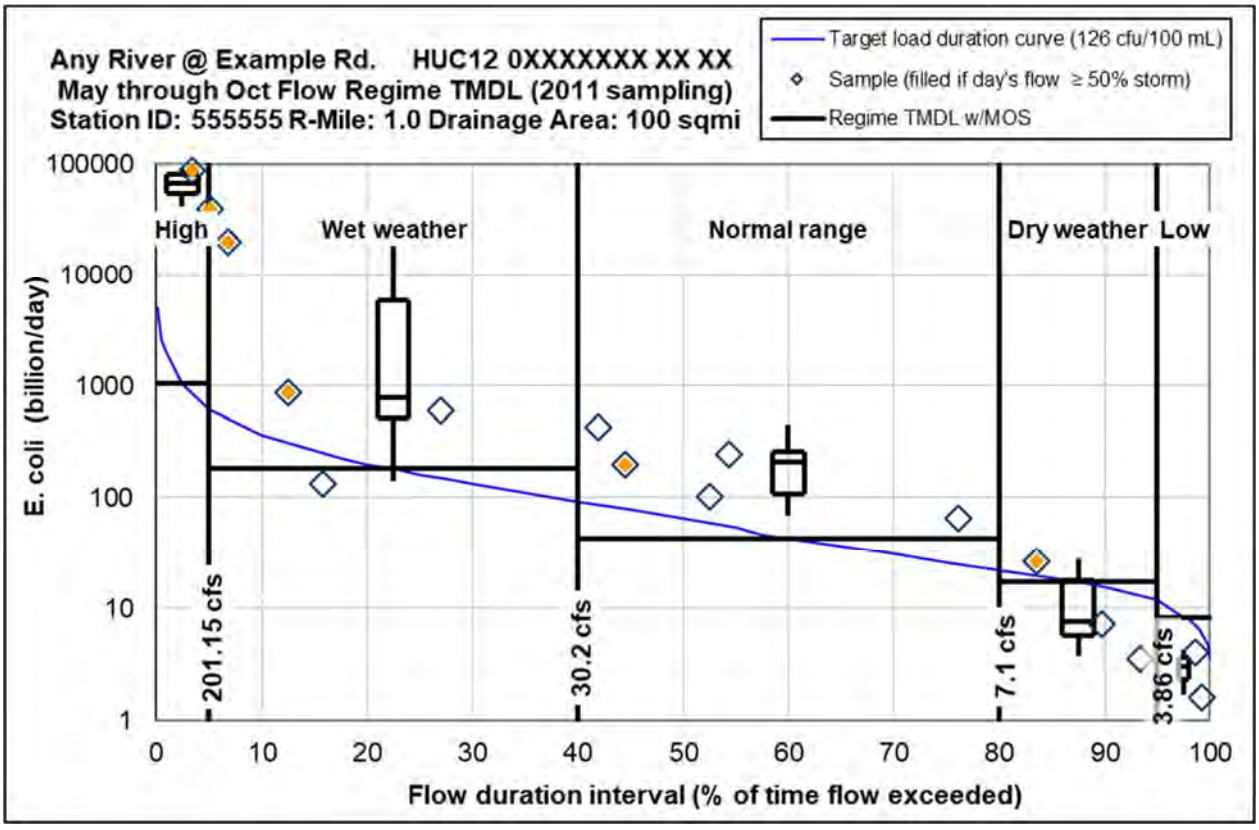

Figure 2 – Example load duration curve.

Table 9 – Example TMDL table calculations (from above load duration curve).

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	2	4	5	3	2
Median Sample load	66807	781	209.25	7.72	2.99
Total Load Reduction Required	98.9%	82.8%	84.7%	NA	NA
Total Maximum Daily Load	1036.68	182.09	43.25	17.26	8.35
Margin of Safety: 20%	207.34	36.42	8.65	3.45	1.67
Allowance for Future Growth	62.20	10.93	2.60	1.04	0.50
Load Allocation	740.71	127.29	27.63	8.98	2.58
Wasteload Allocation Total	26.43	7.46	4.37	3.80	3.60
MS4	23.01	4.04	0.96	0.38	0.19
Example Town WWTP XPX00XXX	3.41	3.41	3.41	3.41	3.41

References

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 1999. *Association between nutrients, habitat, and the aquatic biota of Ohio's rivers and streams.* Published at: https://*epa.ohio.gov/portals/35/guidance/assoc_load.pdf*