State of Ohio
Environmental Protection Agency

Division of Surface Water

Total Maximum Daily Loads for the Tuscarawas River Watershed

Tuscarawas River upstream of Dover Dam, Tuscarawas County

Final Report
July 27, 2009

Ted Strickland, Governor
Chris Korleski, Director

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LIST OF ACRONYMS AND ABBREVIATIONS

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

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

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1.0 INTRODUCTION

Ohio EPA conducted a comprehensive physical, chemical and biological survey in portions of the Tuscarawas River watershed from 2003 to 2005. The water quality survey included monitoring of the Tuscarawas River and several streams within tributary sub-watersheds as described in Section 2.1. Several stream segments not meeting the Ohio water quality standards were identified during the survey. These findings and other information regarding water quality and habitat conditions are summarized in this report.

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

1.1 The Clean Water Act Requirement to Address Impaired Waters

The Clean Water Act (CWA) Section 303(d) requires States, Territories, and authorized Tribes to list and prioritize waters for which technology-based limits alone do not ensure attainment of water quality standards. Lists of these impaired waters (the Section 303(d) lists) are made available to the public for comment, and are then submitted to the U.S. Environmental Protection Agency (U.S. EPA) for approval in even-numbered years. Further, the CWA and U.S. EPA regulations require that TMDLs be developed for all waters on the Section 303(d) lists. The Ohio EPA identified the Tuscarawas River watershed as impaired on the 2008 303(d) list (available at http://www.epa.state.oh.us/dsw/tmdl/2008IntReport/2008OhioIntegratedReport.html). Table 1.1 summarizes the findings of the 2008 303(d) list.

In the simplest terms, a TMDL can be thought of as a cleanup plan for a watershed that is not meeting water quality goals. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that load among the various sources of that pollutant. TMDLs must also account for seasonal variations in water quality and include a margin of safety (MOS) to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards. Ultimately, the goal of Ohio's TMDL process is full attainment of Water Quality Standards (WQS) and subsequent removal of the water bodies from the 303(d) list.

Table 1.1 A summary of the 2008 303(d) listed impairments including priority points for the assessment units (11-digit Hydrologic Unit Codes) within the 2003 – 2008 Tuscarawas TMDL study area.

Assessment Unit (HUC – 11) 05040001 -	Drainage area (sq mi)	Aquatic Life Use Impairment	Recreational Use Impairment	Drinking Water Use Impairment	Human Health Impairment	Priority Points
010	151.0	Yes	No	Unknown	Yes	6
020	187.6	Yes	Yes	None	Yes	8
030	169.5	Yes	Yes	None	Yes	10
090	113.4	Yes	Yes	None	Unknown	6
130	100.1	Yes	Yes	None	Unknown	8
180	124.7	Yes	Yes	None	Unknown	8
190	116.4	Yes	Yes	None	Unknown	9

1.2 Public Involvement

Public involvement is important to the success of any TMDL project. From the beginning, Ohio EPA has invited participation in all aspects of the TMDL program. The Ohio EPA convened an external advisory group (EAG) in 1998 to assist the Agency with the development of the TMDL program in Ohio. The EAG issued a report in July, 2000 to the Director of Ohio EPA on their findings and recommendations. The Tuscarawas River watershed TMDL project has been completed using the process endorsed by the advisory group.

Public involvement activities specific to this TMDL project include ongoing communications between Ohio EPA and representatives from the Northeast Four County Regional Planning Commission (NEFCO), which is the major, locally-led watershed planning entity within the project area. Communications have included numerous electronic and phone correspondences and collaboration in meetings involving the public as well as local watershed group members. Other activities include preparation of newsletter articles for county agencies and holding an in-field demonstration to educate the public about the monitoring and TMDL processes and the specific water quality issues in this watershed.

Consistent with Ohio's current Continuous Planning Process (CPP), the draft TMDL report was available for public comment from November 13 through December 15, 2008. A copy of the draft report was available on Ohio EPA's web page (http://www.epa.state.oh.us/dsw/index.html). General information on TMDLs, water quality standards, 208 planning, permitting, and other Ohio EPA programs is also available on this site. A summary of the comments received and the associated responses is included in Appendix F.

Public involvement is vital to the success of any TMDL project. Ohio EPA will continue to support the implementation process and will facilitate, to the fullest extent possible, restoration actions that are acceptable to the communities and stakeholders in the study area and to Ohio EPA. Ohio EPA is reluctant to rely solely on regulatory actions and strongly upholds the need for voluntary actions facilitated by the local stakeholders, watershed organization, and agency partners to bring the Tuscarawas River watershed into water quality attainment.

2.0 Overview of the TMDL Study

2.1 Project Delineation

The Ohio EPA utilizes assessment units (AUs) based upon the 11-digit watershed Hydrologic Unit Code (HUC) boundaries established by the Natural Resources Conservation Service (NRCS, www.oh.nrcs.usda.gov). A Hydrologic Unit is the contributing drainage area to a stream or river as delineated by the U.S. Geologic Survey (USGS). Each numeric identifier is referred to as an 11-digit Hydrologic Unit Code (HUC11). The first eight characters (05040001) identify the AUs within the Tuscarawas watershed. The last three characters identify individual divisions of the land drained by the Tuscarawas River.

When discussing water quality assessment results it is appropriate to view the landscape at a finer scale. HUC11 watersheds are divided into smaller sub-watersheds identified by a 14-digit Hydrologic Unit Code (HUC14). The average area of a HUC14 sub-watershed is 20 to 25 square miles. Throughout this report HUC14 sub-watersheds are identified first by the HUC11 they are within, followed by their own three-digit number. Table 2.1 identifies all the HUC11 watersheds and HUC14 sub-watersheds that were sampled during the 2003-2005 Tuscarawas River survey.

Table 2.1 Assessment Units for the Tuscarawas River Survey (2003-2005).

HUC 11	*HUC 14*	*Narrative Description*	Drainage Area (Sq. Mi.)
05040001010	**Headwaters of Tuscarawas River to below Wolf Creek**		
	05040001010-010	*Tuscarawas River headwaters to Diversion Dam*	35.3
	05040001010-020	*Tuscarawas River below Diversion Dam to above Wolf Cr.*	38.0
	05040001010-030	*Wolf Creek Watershed*	29.1
	05040001010-040	*Pigeon Creek*	24.9
	05040001010-050	*Wolf Creek below Pigeon Cr. to Tuscarawas R.*	9.9
	05040001010-060	*Hudson Run*	13.8
05040001020	**Chippewa Creek**		
	05040001020-010	*Chippewa Creek to Chippewa Lk. Outlet*	22.3
	05040001020-020	*Chippewa Creek below Chippewa Lk. outlet to below Hubbard Cr.*	21.7
	05040001020-030	*Chippewa Creek below Hubbard Cr. to above River Styx [except L. Chippewa Cr.*	36.5
	05040001020-040	*Little Chippewa Creek*	32.2
	05040001020-050	*River Styx*	29.6
	05040001020-060	*Chippewa Creek below River Styx to above Red Run*	13.2
	05040001020-070	*Red Run*	15.1
	05040001020-080	*Chippewa Creek below Red Run to Tuscarawas R.*	17.0
05040001030	**Tuscarawas River (below Wolf Creek to below Sippo Creek) [except Chippewa Creek]**		
	05040001030-010	*Tuscarawas River below Wolf Cr. to above Chippewa Cr.*	22.7
	05040001030-020	*Tuscarawas River below Chippewa Cr. to above Fox Run [except Nimisila Cr.]*	14.5
	05040001030-030	*Nimisila Creek to Nimisila Reservoir*	17.4
	05040001030-040	*Nimisila Creek below Nimisila Res. to Tuscarawas R.*	14.1
	05040001030-050	*Fox Run* Fox Run	14.1
	05040001030-060	*Tuscarawas River below Fox Run to above Sippo Cr.*	8.8

Table 2.1 Assessment Units for the Tuscarawas River Survey (2003-2005).

HUC 11	HUC 14	Narrative Description	Drainage Area (Sq. Mi.)
		[except Mudbrook Cr., Newman Cr. & W. Sippo Cr.]	
	05040001030-070	*Mudbrook Creek*	9.2
	05040001030-080	*Newman Creek above Orrville Ditch*	12.4
	05040001030-090	*Orrville Ditch*	12.5
	05040001030-100	*Newman Creek below Orrville Ditch to Tuscarawas R.*	12.5
	05040001030-110	*West Sippo Creek*	11.6
	05040001030-120	*Sippo Creek*	17.9
05040001090	**Tuscarawas River (below Sippo Creek to above Sugar Creek)**		
	5040001090-010	Tuscarawas River below Sippo Cr. to above Pigeon Run	14.5
	05040001090-020	*Pigeon Run*	9.5
	05040001090-030	*Tuscarawas River below Pigeon Cr. to above Sandy Cr.*	52.2
	05040001090-040	*Tuscarawas River below Sandy Cr. to above Conotton Cr.*	25.1
	5040001090-050	Tuscarawas River below Conotton Cr. to above Sugar Cr.	12.0
05040001130	**Tuscarawas R. (below Sugar Creek to above Stillwater Creek)**		
	05040001130-010	*Stone Creek*	38.9
	5040001130-020	Tuscarawas River below Sugar Cr. to above Oldtown Cr. [except Stone Cr.]	7.9
	05040001130-030	*Oldtown Creek*	19.2
	05040001130-040	*Beaverdam Creek*	22.0
	05040001130-050	*Tuscarawas River below Oldtown Cr. to above Stillwater Cr. [except Beaverdam Cr.]*	12.2
05040001180	**Tuscarawas R. (below Stillwater Creek to above Evans Creek)**		
	05040001180-010	*Tuscarawas River below Stillwater Cr. to Co. Rd. 62*	11.3
	05040001180-020	*Tuscarawas River from Co. Rd. 62 to above Dunlap Cr.*	41.5
	05040001180-030	*Dunlap Creek*	26.6
	05040001180-040	*Tuscarawas River below Dunlap Cr. to above Evans Cr. [except Buckhorn Cr.]*	21.9
	05040001180-050	*Buckhorn Creek*	23.4
05040001190	**Tuscarawas R. (above Evans Creek to Muskingum River)**		
	05040001190-010	*Evans Creek*	24.2
	05040001190-020	*White Eyes Creek [except W. Fk. White Eyes Cr. & E. Fk. White Eyes Cr.]*	20.5
	05040001190-030	*West Fork White Eyes Creek*	20.9
	05040001190-040	*East Fork White Eyes Creek*	12.6
	05040001190-050	*Tuscarawas River below Evans Cr. to confluence with Walhonding R. [except White Eyes Cr.]*	38.2

Additional nomenclature used by Ohio EPA to identify locations within study areas used in this report is river miles (designated with the acronym RM). River miles refer to the point along a stream reach measured in miles from the mouth of the stream. In cases where a stream has no official name, the stream is identified as a tributary to the named stream it flows into followed by the river mile on the named stream where the tributary joins the named stream. River mile maps are maintained by Ohio EPA and are available via the Ohio EPA web page http://www.epa.state.oh.us/dsw/gis/RiverMileSystem.htm.

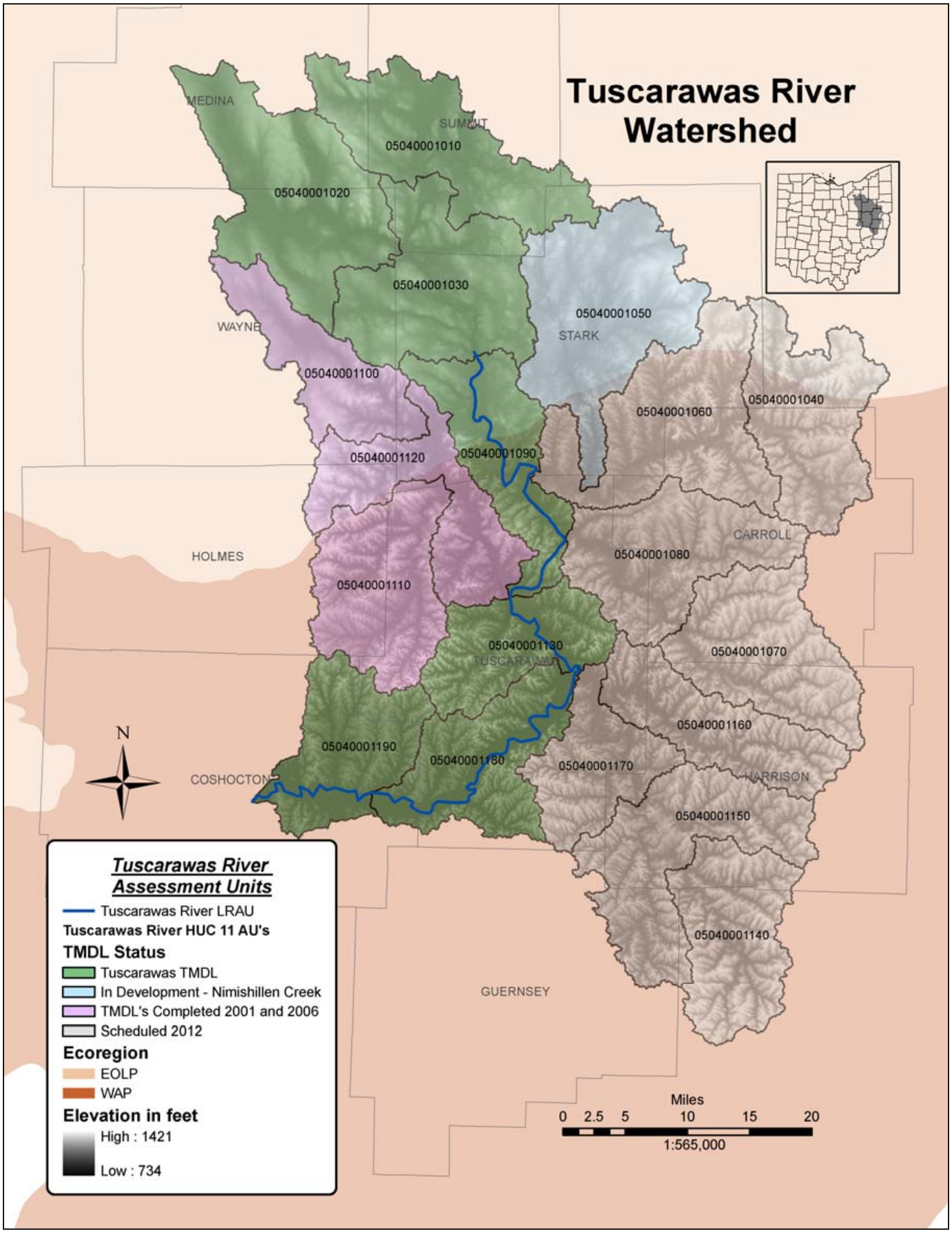

Figure 2.1 Tuscarawas River watershed and TMDL area.

Ohio EPA assesses larger rivers (drainage areas >500 mi^2) within the state as Large River Assessment Units (LRAUs). Data from these stream reaches are analyzed independently from the 11 digit HUC assessment units. The 90.82 mile long Tuscarawas River LRAU begins in

Massillon at the confluence with Sippo Creek and extends to Coshocton where the Tuscarawas River joins the Walhonding River to form the Muskingum River.

The portions of the 2003-2005 Tuscarawas River water quality survey included in this assessment addresses seven of the nineteen HUC11 AUs that comprise the Tuscarawas River watershed, as well as the entire Tuscarawas River LRAU (Figure 2.1). Also included in the 2003-2005 survey was the Nimishillen Creek watershed (tributary to Sandy Creek), which will be addressed in a separate TMDL report currently under development. Three HUC11 AUs that comprise the Sugar Creek watershed (tributary to the Tuscarawas River, confluence RM 58.07) were assessed by Ohio EPA in 1998 (Ohio EPA, 2000) and 2005 (Ohio EPA, 2006). Ohio EPA has completed TMDLs for nutrients, habitat, and sediment for the Sugar Creek AUs (Ohio EPA, 2001) and a TMDL for pathogens was approved in 2007. These reports are available via the Ohio EPA web page http://www.epa.state.oh.us/dsw/tmdl/SugarCreekTMDL.html . Water quality surveys to support the development of TMDLs have not yet been completed for HUC11 AUs that make up the Sandy Creek (exclusive of Nimishillen Creek), Conotton Creek, or Stillwater Creek watersheds within the Tuscarawas River basin.

2.2 Background of the Watershed and River System

The Tuscarawas River drains approximately 2,589 square miles in northeast and east –central Ohio (Figure 2.1). Major urban areas in the watershed include Akron, Barberton, Massillon, Canton, New Philadelphia, Dover, Newcomerstown and Coshocton. The Tuscarawas River begins upstream of the Portage Lakes region on the south side of Akron and flows through Summit, Stark, Tuscarawas, and Coshocton Counties. Excepting Stone Container Corporation which is located in the city of Coshocton, the heaviest concentrations of major municipal or industrial discharges are found in the middle and upper basin, primarily in Summit and Stark Counties. Table 2.2 lists the principal tributaries and the NPDES permitted dischargers to the mainstem of the Tuscarawas River.

Flows in the Tuscarawas River are regulated by a series of flow control structures located throughout the watershed. Major flow diversions, impoundments, and flood control dams within the watershed include the Long Lake – Ohio Canal diversion dam (Portage Lakes area - Summit County), Barberton Reservoir (Wolf Creek, Summit County), and a series of Muskingum Conservancy District flood control dams constructed in the 1930s including Bolivar Dam (Sandy Creek), Dover Dam (on the mainstem of the Tuscarawas River), Beach City Reservoir (Sugar Creek) and reservoirs along the eastern edge of the watershed which form Atwood, Leesville, Tappan, Clendening and Piedmont Lakes. These dams impound the Indian Fork of Conotton Creek, Little Stillwater Creek, the Brushy Fork of Stillwater Creek, and Stillwater Creek, respectively. These flood control systems have a profound effect upon the flow regime in the Tuscarawas River, especially in the lower portion below Sandy Creek. More information about these flood control systems can be found on websites provided by the U.S. Army Corps of Engineers http://www.lrh.usace.army.mil/projects/lakes/ and the Muskingum Conservancy District http://www.mwcd.org/ .

Table 2.2 Principal tributaries and NPDES dischargers to the Tuscarawas River.

Tributary / *Facility*	River Mile	River Code	Drainage Area (mi^2)	Permit Number	Design Flow (MGD)
Upper Tuscarawas WWTP	***119.80***			***3PK00013***	***4.0***
Long Lake/Ohio Canal	115.10				
Wolf Creek	110.69	17-540	77.0		
Barberton WWTP	***109.14***			***3PD00004***	***6.0***
Pancake Creek	105.61	17-539	8.0		
Chippewa Creek	103.22	17-550	188.0		
Nimisila Creek	100.86	17-538	31.8		
Canal Fulton WWTP	***97.70***			***3PB00008***	***1.5***
Fox Run	97.47	17-537	13.6		
Mudbrook Creek	95.05	17-536	11.5		
Newman Creek	91.93	17-534	41.6		
West Sippo Creek	91.18	17-575	10.0		
Sippo Creek	90.82	17-533	15.1		
Massillon WWTP	***88.87***			***3PE00007***	***15.8***
Pigeon Run	86.70	17-532	41.7		
Fohl Creek	83.74	17-580	7.9		
Navarre WWTP	***83.70***			***3PC00009***	***1.0***
Sherman Creek	79.58	17-568	5.0		
RM 77.96 Tributary	77.96	17-589	4.9		
Sandy Creek	73.10	17-450	503.1		
Wolf Run	69.71	17-529	3.6		
Middle Run	68.47	17-528	2.1		
Small Middle Run	67.62	17-527	3.2		
Connoton Creek	65.50	17-100	286.3		
Dover WWTP	***58.34***			***0PD00005***	***1.5***
Sugar Creek	58.07	17-400	357		
Stone Creek	56.67	17-525	38.9		
New Philadelphia WWTP	***53.63***			***0PD00012***	***3.0***
Oldtown Creek	51.94	17-524	18.7		
Beaverdam Creek	50.86	17-523	21.8		
Pike Run	47.76	17-521	6.4		
Stillwater Creek	47.05	17-350	485.1		
Mud Run	45.19	17-520	7.8		
Tuscarawas WWTP	***44.73***			***0PB00083***	***0.2***
Frys Creek	39.44	17-518	6.4		
Gnadenhutten WWTP	***38.50***			***0PB00017***	***0.3***
Dunlap Creek	25.33	17-515	26.6		
Newcomerstown WWTP	***19.80***			***0PD00024***	***1.3***
Buckhorn Creek	19.03	17-511	23.5		
Blue Ridge Run		17-509	3.0		
Evans Creek	14.80	17-505	24.0		
White Eyes Creek	10.81	17-502	53.4		
Morgan Run	5.62	17-501	4.1		
RM 3.78 Tributary	3.78	17-547	7.0		
Stone Container 002	***1.10***			***0IA00005***	***11.4***
Stone Container 003	***1.04***			***0IA00005***	***2.4***
Stone Container 004	***0.40***			***0IA00005***	***0.3***

2.2.1 Land Use and Population within the Watershed

Land use throughout the entire Tuscarawas watershed is approximated to be 34% forest, 31% pasture/hay, 19% cropland, 12% urban, and 4% open water based upon the National Land Cover Dataset (NLCD) and other ancillary data (see Figure 2.2). There is significantly more urbanized area in the upper Tuscarawas watershed than the lower Tuscarawas watershed, which is concentrated in parts of Summit and Stark counties. These urban areas include part of Akron, Massillon, and Canton. Relatively small but notable urban areas in the lower Tuscarawas watershed include Dover, New Philadelphia, and Coshocton. There is a higher percentage of pasture and row crop in the upper Tuscarawas watershed particularly in Wayne, Medina and Stark counties. The lower Tuscarawas watershed has significantly more forest cover than the upper watershed.

Table 2.3 Tuscarawas River land use by 11 digit HUC.

Upper Tuscarawas River						
11 digit HUC	**05040001-010**		**05040001-020**		**05040001-030**	
Land use	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**
Forest	24187	25%	22364	19%	24053	22%
Pasture	24339	25%	53898	45%	39032	36%
Row Crop	10116	10%	33140	28%	21528	20%
Urban	30839	32%	7792	6%	18462	17%
Water	7221	7%	2980	2%	5461	5%

Lower Tuscarawas River								
11 digit HUC	**05040001-090**		**05040001-130**		**05040001-180**		**05040001-190**	
Land use	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**
Forest	25212	35%	35485	55%	42213	53%	30881	41%
Pasture	23030	32%	15655	24%	19413	24%	29590	40%
Row Crop	16031	22%	7050	11%	13465	17%	11219	15%
Urban	6383	9%	4818	8%	2813	4%	1795	2%
Water	1960	3%	1121	2%	1943	2%	1057	1%

Population growth is relatively stable in the watershed but the fastest growing area is located in the headwaters in Medina County. Near-term impacts of population growth include stream channelization and pollution from construction-site runoff as housing and infrastructure are expanded to accommodate the growth. Long-term impacts include an increase in the watershed’s total impervious surface resulting in flow alterations and an increase in pollution runoff.

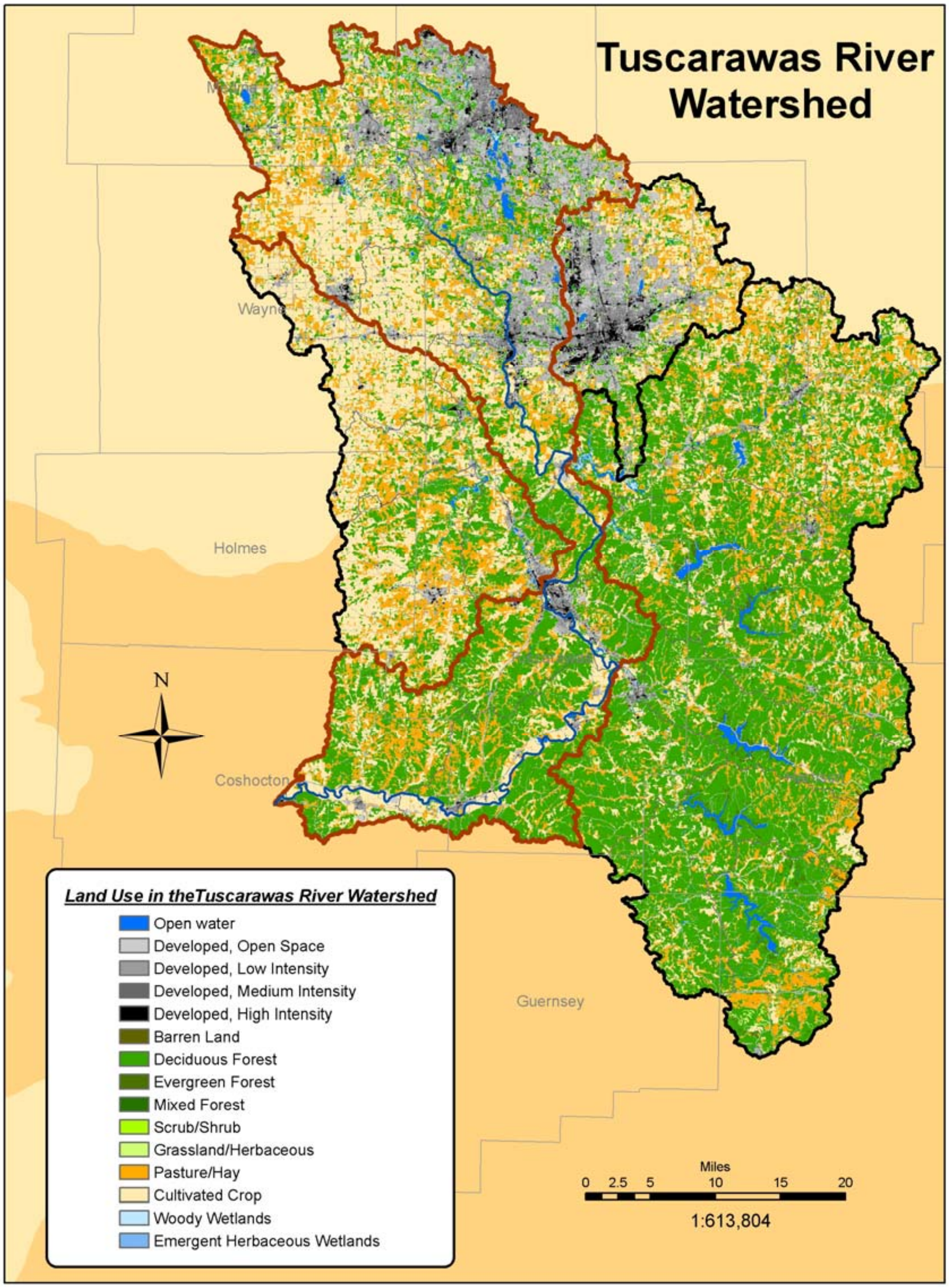

Figure 2.2 Land cover within the Tuscarawas River watershed and TMDL area.

2.2.2 Geology and Ecoregions of the Watershed

The upper reaches of the Tuscarawas River basin are contained within the Hydrologic Unit Codes (HUC) of 050400001-010, 020, and 030 and constitute three of the seven assessment units (AU) in this TMDL study area. These AUs lie within the glaciated Allegheny Plateau portion of the Erie/Ontario Lake Plain (EOLP) Ecoregion. This ecoregion is characterized by low lime drift and lacustrine deposits overlying rolling to level terrain. Lakes, wetlands, and swampy streams occur where the drainage pattern is deranged or where the land is flat and clayey. Groundwater fed headwater streams may be present where there are moraines or where bedrock has become exposed through erosion of the till. The upper (northern) Tuscarawas River watershed is divided between the Summit Interlobate and the Low Lime Drift Plains areas of the EOLP. The Summit Interlobate Area, where the Tuscarawas River arises is characterized by a highly deranged drainage pattern resulting from kame, esker and outwash deposits caused by the advance and meeting of two glacial lobes. Numerous wetlands, lakes and kettles were formed in this region, and the presence of these features overlying sandy outwash deposits may result in locally high groundwater discharge rates to surface waters. To the west, the characteristics of the Low Lime Drift Plains Area dominate the landscape. This area is typified by a rolling landscape composed of low hills and interspersed end moraines and kettles. Soils tend to be less fertile than those found in the Eastern Corn Belt Plains Ecoregion, and the terrain has much less relief than the unglaciated Western Allegheny Plateau Ecoregion to the south.

The lower portion of the Tuscarawas River watershed is located in the northern portion of the Western Allegheny Plateau Ecoregion (WAP). The WAP has a more rugged, unglaciated terrain with local relief up to 500 feet. The underlying strata are made of sandstone, siltstone, shale, and limestone. Soils are from these same materials with some isolated loess soils. Coal, oil and gas deposits are found in much of this region. Extraction of coal, oil, and gas has had and continues to have, a major effect on the ecology and culture of the region. Steep slopes in the region limit crop and cattle production to valley floors that reduces riparian corridors and concentrates animal wastes near the stream. Cattle are given free access to streams resulting in increased sedimentation and direct nutrient loading. Timber harvesting also contributes sediment loading to the streams.

2.3 Description of the Assessment Units

2.3.1 Tuscarawas River Headwaters to below Wolf Creek (05040001 010)

Assessment Unit 05040001010 lies completely within the glaciated Allegheny Plateau portion of the EOLP ecoregion and includes the uppermost headwaters of the Tuscarawas River (Figure 2.3). Along with the Tuscarawas River, streams located within this AU include Metzgers Ditch, Schocalog Run, Pigeon Creek, Van Hyning Run, Wolf Creek, and Hudson Run. Glacial kame and esker deposits interspersed with glacial outwash and ground moraine deposits dominate the surface geology of this AU, and give rise to a deranged drainage pattern associated with natural kettle lakes and wetlands that comprise the Portage Lakes area of Summit County.

Extensive historical flow alterations including diversion structures and feeder canals associated with the Tuscarawas River headwaters were used to provide water for the Portage Lakes and the Ohio and Erie Canal system that connected Lake Erie with the Ohio River in the 1800s. These modifications continue to impact the hydrology of Tuscarawas River upstream of Wolf Creek. In 1998, an agreement was reached with the Great Lakes Governors that allowed the diversion of Great Lakes derived drinking water into the Ohio River basin as part of a Joint Economic Development District between the City of Akron and communities in southern Summit County. To compensate for this diversion, the Ohio Department of Natural Resources (ODNR) - Division of Water, which manages the Portage Lakes system, diverts approximately 20 cubic feet per second (cfs) of Tuscarawas River water into the Cuyahoga River drainage via the Long Lake feeder to the Ohio Canal diversion dam. A description of the hydraulic controls for the Tuscarawas River, Portage Lakes, and the Ohio and Erie Canal can be viewed at the ODNR Division of Water web page: http://www.dnr.state.oh.us/water/pubs/fs_div/fctsht41.htm.

Streams located in the western half of the 010 AU originate predominately in Wisconsinan age end moraine deposits and often include higher gradient groundwater fed headwater streams in their drainage network. The upper portion of Wolf Creek flows predominantly through glacial outwash deposits and is a low gradient stream associated with wetland areas. Much of the Wolf Creek and Van Hyning Run drainages have been highly channel modified to facilitate drainage associated with the urbanization of the Akron area and suburbs. Wolf Creek has also been impounded to form Barberton Reservoir, a Public Water Supply reservoir, while Hudson Run is impounded to form Lake Dorothy and Columbia Lake, both of which were used as industrial water supplies.

Much of the 010 AU is served by central sewer systems, although significant unsewered areas exist in the western portion of the AU and in the Portage Lakes area. A significant portion of the urbanized portions of the watershed are served by wastewater treatment facilities that do not discharge within the 010 AU plant (e.g. areas served by the Akron WWTP and the Barberton WWTP). The only major wastewater treatment (a WWTP with greater than 1 MGD design flow) discharging in the 010 AU is the Summit County Upper Tuscarawas WWTP (1.5 MGD). This WWTP discharges to the Tuscarawas River at RM 119.0 and was required to meet a limit on the discharge of total phosphorus (TP) in 2004.

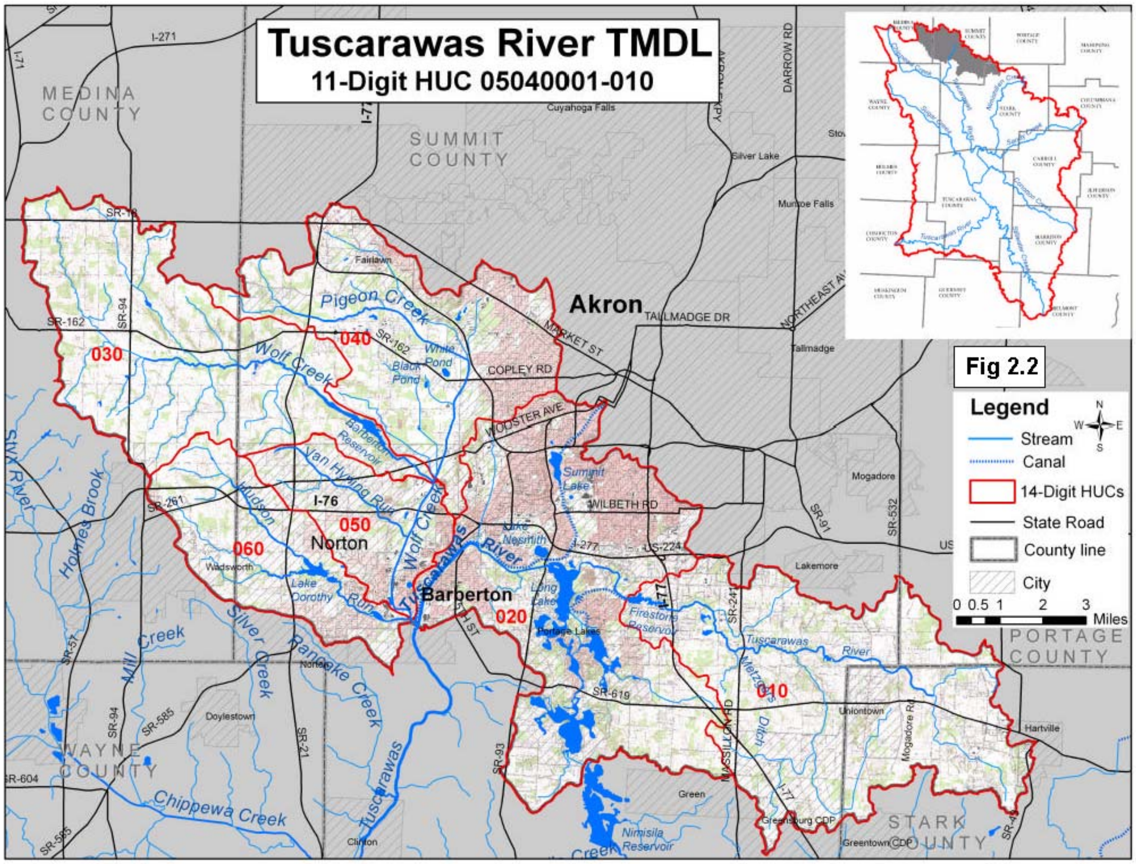

Figure 2.3 Map of the Tuscarawas River headwaters assessment unit (010).

2.3.2 Chippewa Creek (05040001 020)

The Chippewa Creek AU (Figure 2.4) lies within the Low Lime Drift Plains Area of the EOLP ecoregion, and consists of a broad valley filled with glacial lacustrine and outwash deposits bordered on its northern margin by Wisconsinan age end moraines. The moraine deposits may generate significant amounts of groundwater discharge to some of the small headwater tributaries, resulting in high gradient cool and coldwater streams. However, the mainstem of Chippewa Creek is a low gradient stream with associated wetland and lake complexes in its upper end in the area of Chippewa Lake. Tributary streams within the Chippewa Creek (020) AU include McCabe Creek, Hubbard Creek, Steele Ditch, Tommy Run, Little Chippewa Creek, Holmes Brook, River Styx, Mill Creek, Red Run, and Silver Creek.

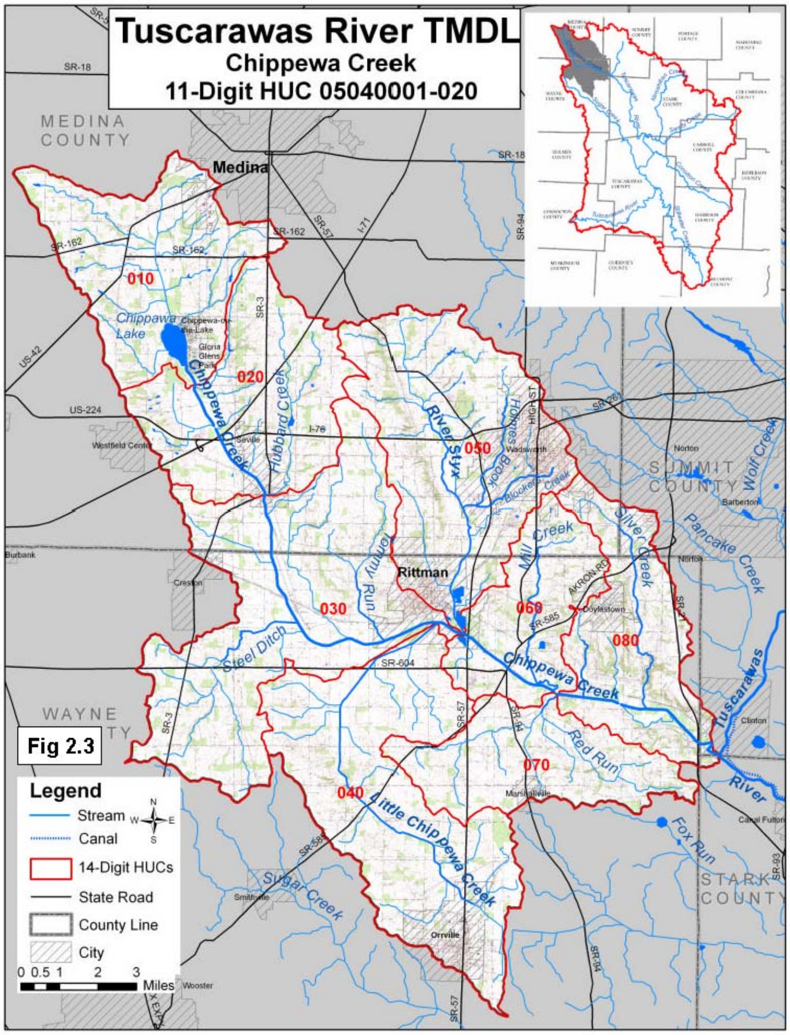

Figure 2.4 Map of the Chippewa Creek assessment unit (020).

Chippewa Creek, Little Chippewa Creek, Red Run, and River Styx were extensively modified through a flood control and drainage project conducted by the Muskingum Watershed Conservancy District between 1956 and 1980. A series of eight flood control dams along Chippewa Creek and its tributaries coupled with stream entrenchment were designed to reduce flooding hazards in the watershed (for information, see the following MWCD web page: http://www.mwcdlakes.com/chippewa/index.htm). These modifications as well as extensive agricultural ditching along many of the smaller tributary streams are long-standing perturbations that have reduced the habitat quality. Consequently, several stream reaches are designated with the Modified Warmwater Habitat (MWH) aquatic life use.

Wastewater treatment facilities discharging within the 020 AU include wastewater treatment plants serving Seville (Chippewa Creek), Wadsworth (River Styx), Rittman (River Styx), Orrville (Little Chippewa Creek), Marshallville (Red Run), and Doylestown (Silver Creek). Several smaller county operated facilities also exist within Wayne and Medina counties that discharge within this AU. Although agricultural land use within this AU has a profound effect upon water quality, rapid suburban development, especially within Medina County, also represents a significant challenge to long term water quality improvement in this part of the Tuscarawas River watershed.

2.3.3 Tuscarawas River: below Wolf Creek to below Sippo Creek, excluding Chippewa Creek (05040001 030)

The mainstem of the Tuscarawas River marks a dividing line between two distinct landscapes in AU 030 (Figure 2.5). To the east of the river the landscape lies within the Summit Interlobate Area of the EOLP (previously described for AU 010), giving rise to the deranged drainage pattern typified by interspersed wetland, bogs, and kettles making up the southern area of the Portage Lakes and the upper Nimisila Creek watershed. To the west, the landscape lies within the Low Lime Drift Plains Area of the EOLP (as described for AU 020). Land use patterns are also significantly different, with areas to the east being heavily impacted by suburban development, especially in the Village of Green (Summit County) and Jackson Township (Stark County), while areas to the west remain highly agricultural.

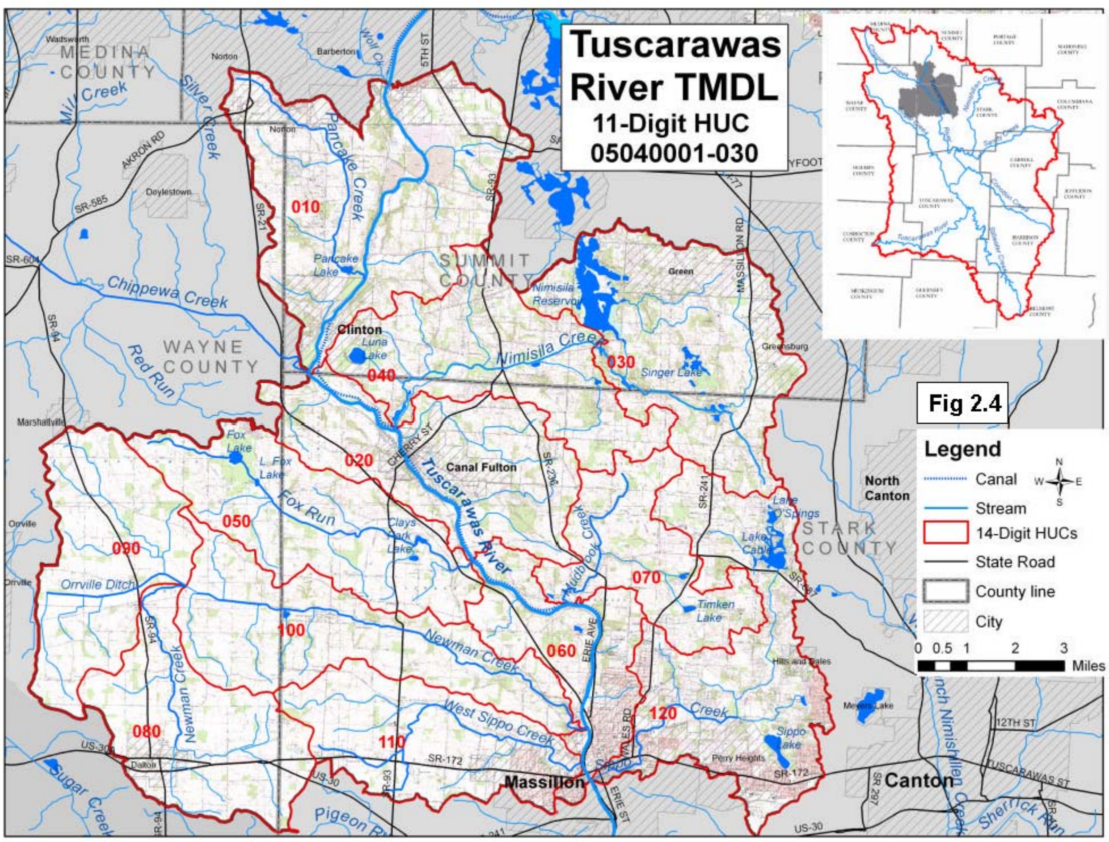

Figure 2.5 Map of the assessment unit for the Tuscarawas River below Wolf Creek to below Sippo Creek (030).

2.3.4 Tuscarawas River: below Sippo Creek to above Sugar Creek (05040001 090)

Within this AU there are three different types of landscape regions. The Summit Interlobate Area of the EOLP and the Low Lime Drift areas as described above are found in the northern portion and give way to the Western Allegheny Plateau (WAP) towards the south. The specific sub-region of the WAP found in this area is the Unglaciated Upper Muskingum Basin which is a dissected plateau with streams that are less degraded by coal mine effluent than those of other parts of the WAP.

This AU also marks a transition from a more urban setting to that of a forested and rural landscape. Likewise the number of point source dischargers begins to decrease relative to the upper three assessment areas. The Massillon WWTP has a major discharge (design flow is 15.8 MGD) at the upper portion of the AU and there are major WWTP discharges within the Sandy Creek watershed that are located relatively close to its confluence with the Tuscarawas River. The Dover WWTP is found near the end of this AU and is the only other major discharger therein.

There are two large tributary streams within this AU, Sandy Creek, which has a drainage area of 503 mi^2, and Connoton Creek which has a drainage area of 286 mi^2. Both of these tributaries have a substantial effect on the volume of stream flow within the Tuscarawas River. The Nimishillen Creek, a tributary that enters Sandy Creek near its mouth, is concurrently undergoing TMDL development. Connoton Creek drains a primarily forested watershed and contains Atwood and Leesville Lakes (see Section 2.2).

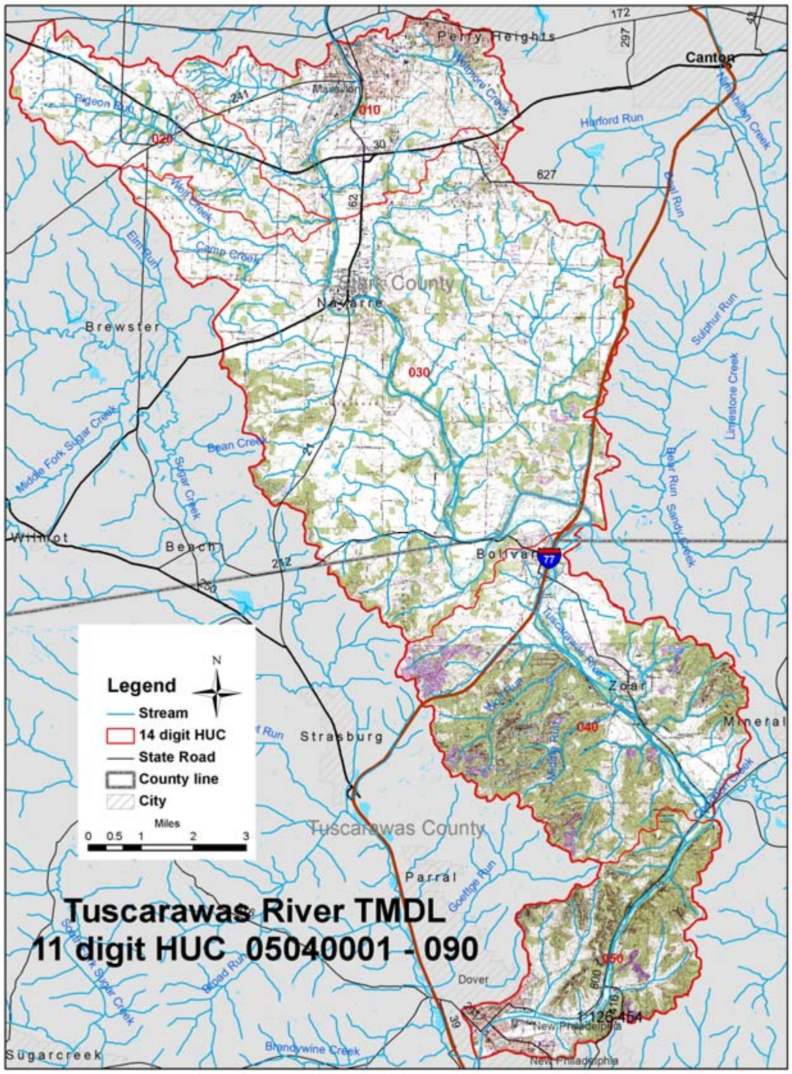

Figure 2.6 Map of the assessment unit for the Tuscarawas River below Sippo Creek to above Sugar Creek (090).

2.3.5 Tuscarawas River: below Sugar Creek to above Stillwater Creek (05040001 130)

This AU lies completely within the Unglaciated Upper Muskingum Basin of the WAP. Land use is primarily forested with pastureland interspersed. New Philadelphia is found along the upstream portion (northern) of this AU and the New Philadelphia WWTP (design flow is 3.0 MGD) discharges in this area. Sugar Creek which has a drainage area of 357 mi^2 joins the Tuscarawas River approximately 4.5 miles upstream of the New Philadelphia WWTP. The Sugar Creek watershed is primarily rural with row crop and dairy production dominating the land use. This watershed also has had TMDLs approved by U.S. EPA in 2002 and 2007 dealing with the water quality stressors of nutrients, sediment, habitat, and bacteria.

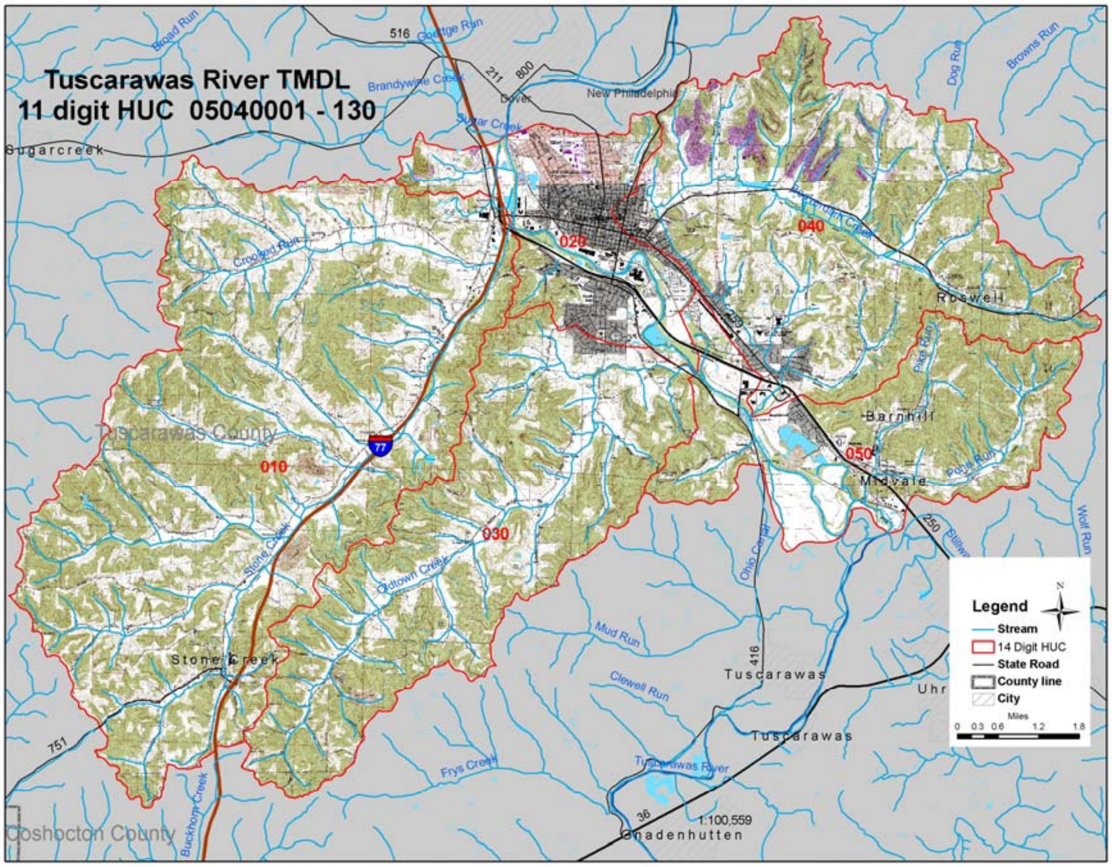

Figure 2.7 Map of the assessment unit for the Tuscarawas River below Sugar Creek to above Stillwater Creek (130).

2.3.6 Tuscarawas River: below Stillwater Creek to above Evans Creek (05040001 180)

This AU lies completely within the Unglaciated Upper Muskingum Basin of the WAP. Land use is primarily forested with pastureland interspersed. However, the small towns of Gnadenhutten, Port Washington, and Newcomerstown are located along the mainstem of the Tuscarawas River. The Newcomerstown WWTP (design flow is 1.3 MGD) is the only major discharger in this AU. Stillwater Creek, which has a drainage area of 485 mi^2, joins the Tuscarawas River at the upstream end of the AU near the town of Uhrichsville. The Stillwater Creek watershed contains Tappan, Clendening, and Piedmont Lakes.

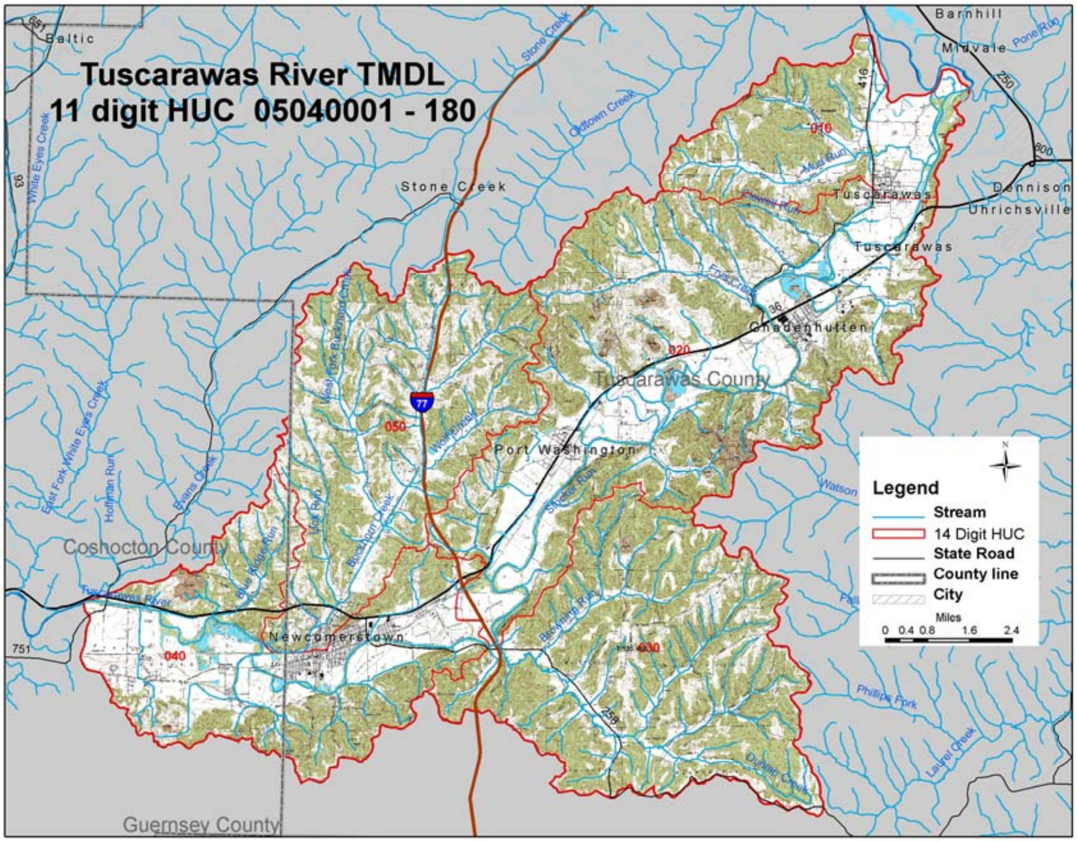

Figure 2.8 Map of the assessment unit for the Tuscarawas River below Stillwater Creek to above Evans Creek (180).

2.3.7 Tuscarawas River: above Evans Creek to Muskingum River (05040001 190)

This AU lies completely within the Unglaciated Upper Muskingum Basin of the WAP. Land use is primarily forested with pastureland interspersed. The town of West Lafayette and the northeast portion of Coshocton are found in this AU. Major point source dischargers in this AU are limited to the three outfalls of the Stone Container Corporation which have a total design flow of 14.1 MGD. There are no large tributary streams joining the mainstem of the Tuscarawas River in this AU.

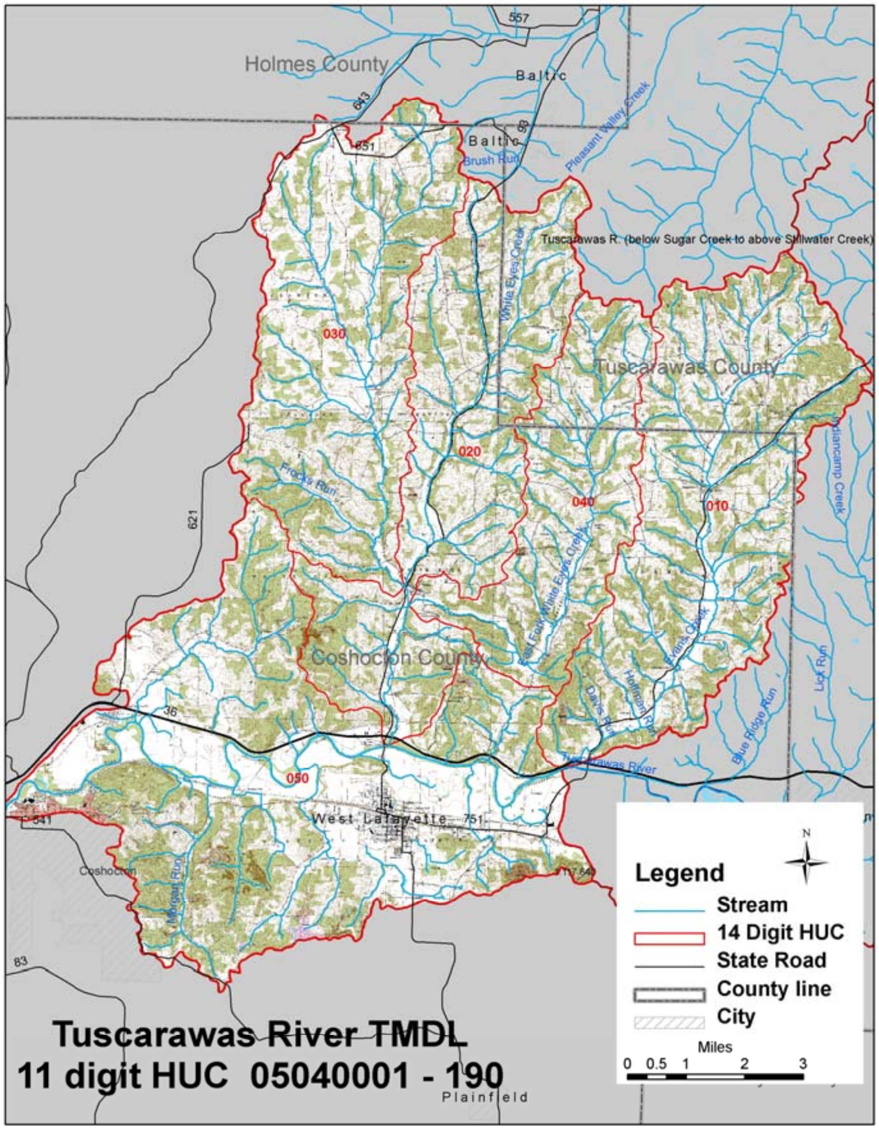

Figure 2.9 Map of the assessment unit for the Tuscarawas River above Evans Creek to Muskingum River (190).

2.4 Water Quality Standards and Designated Uses

Under the Clean Water Act, every state must adopt water quality standards to protect, maintain and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the goal of "swimmable/fishable" waters. Further information is available in Chapter 3745-1 of the Ohio Administrative Code (OAC) (http:/www.epa.state.oh.us/dsw/wqs/criteria.html).

In the Tuscarawas River study area, the aquatic life use designations that apply to various segments are Exceptional Warmwater Habitat (EWH), Warmwater Habitat (WWH), Modified Warmwater Habitat (MWH) and Limited Resource Water (LRW).

Waters designated as EWH are capable of supporting "exceptional or unusual" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly pollutant intolerant and/or are rare, threatened, or endangered. Waters designated as WWH are capable of supporting and maintaining a balanced integrated community of warmwater aquatic organisms. Waters designated as MWH and LRW have been modified significantly by human activity such as channelization or mining impacts and may also be small maintained drainage ditches.

Attainment of aquatic life uses is determined by directly measuring fish and aquatic macroinvertebrate populations to see if they are comparable to those seen at least impacted reference sites that are about the same size and located within the same ecoregion in Ohio. Attainment benchmarks from these least impacted areas are established in the WQS in the form of biocriteria, which are then compared to the measurements obtained from the study area. If measurements of a stream do not achieve the three biocriteria (fish: Index of Biotic Integrity (IBI) and Modified Index of Well-being (MIwb); aquatic macroinvertebrates: Invertebrate Community Index (ICI)) the stream is considered in "non-attainment." If the stream measurements achieve some of the biological criteria but not others, the stream is said to be in "partial-attainment." A stream that is in "partial attainment" is not achieving its designated aquatic life use, whereas a stream that meets all of the biocriteria benchmarks is in full attainment.

Other types of uses in the WQS are for recreational purposes. The recreational use for the majority of the Tuscarawas River study area is Primary Contact Recreation (PCR). The criterion for the PCR designation is being suitable for full-body contact recreation. Ohio EPA assigns the PCR use designation to a stream unless it is demonstrated through use attainability analysis that the combination of remoteness, accessibility, and depth makes full-body contact recreation by adults or children unlikely. In those cases, the Secondary Contact Recreation (SCR) designation is assigned. The attainment status of PCR and SCR is determined using pathogen indicators; the criteria for each are specified in the Ohio WQS.

Source water protections are also afforded in Ohio's WQS where surface water used to supply public, agricultural, or industrial consumption must meet minimum quality standards. The quality standards primarily deal with water chemistry and pathogen indicators. Public, agricultural, and industrial supply uses are designated to rivers and streams based on the proximity intake structures, publicly owned or public supply lakes and reservoirs, or where surface waters are otherwise known to be used for supply purposes.

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

2.5 Identification of the Causes and Sources of Water Quality Impairment

Ohio EPA surveyed the status of the water quality in the assessment units listed in Table 2.2 during 2003 through 2005. The study found impairments of both the Aquatic Life Use (ALU) and the Recreational Use (RU). The main causes of impairment along with associated sources from the 2008 Integrated Report are listed in Tables 2.4-2.5. The primary causes of impairment in the Tuscarawas River watershed addressed by this report are ***nutrient enrichment***, ***habitat alteration, sediment***, ***organic enrichment/dissolved oxygen***, and ***pathogens***.

Overlap in the linkage between the causes and sources of impairment provides additional justification for targeting a subset of high-magnitude causes. A single source may be contributing to multiple causes of impairment, so control strategies aimed at that source could help to remedy multiple problems. For example, actions taken to reduce pathogen (originating from livestock with free access to the creek and poor manure management) will also reduce sedimentation, nutrient enrichment and will improve habitat.

Mining impacts were identified in several smaller tributaries in the lower watershed; however, they were not addressed in this TMDL. To fully evaluate the mining impacts, Ohio EPA recommends that an Acid Mine Drainage Abatement and Treatment (AMDAT) report be completed by a local watershed group with the assistance of the county SWCD offices, ODNR, and Ohio EPA. These types of partnerships have been very successful in dealing with mining impacts for watersheds such as Huff Run, Raccoon Creek (in Vinton, Meigs, Jackson and Gallia Counties), Leading Creek, Sunday Creek, and Monday Creek.

2.5.1 Nutrient Enrichment

Nutrient enrichment is a cause of impairment in twelve subwatersheds (i.e., 14-digit HUCs) within the Tuscarawas River basin and in the upper reach of the Tuscarawas River LRAU. In-stream nutrient concentrations were found to have an impact on the health of the biological communities. For the purpose of this TMDL, total phosphorus is used as an indicator for the degree of nutrient enrichment. Habitat improvements can significantly ameliorate the harmful effects of nutrients on the biological community. Therefore, this study stresses the importance of habitat and other factors, in addition to instream nutrient concentrations, as having an impact on the health of biologic communities. This study also includes proposed total phosphorus target concentrations based on observed concentrations associated with acceptable ranges of expected biological communities.

2.5.2 Habitat Alteration and Sediment

Habitat alteration was also found to be a significant cause of impairment throughout the Tuscarawas River basin. Channelization (straightening or relocating streams), urbanization (increasing impervious surfaces leading to stream erosion), removing riparian vegetation, and agricultural activities (such as allowing livestock free access to the creek) are some of the sources of impairment in the Tuscarawas basin which have led to significant habitat impacts.

2.5.3 Organic Enrichment and Dissolved Oxygen

Organic enrichment and dissolved oxygen (DO) depletion are identified as major causes of impairment in several hydrologic units within the upper section of the Tuscarawas River watershed. The most dramatic violations of the D.O. water quality standards were measured in the Tuscarawas River in the vicinity of the City of Barberton. Several water quality surveys performed during the summers of 2004 and 2005 confirmed that there is a severe, consistent dissolved oxygen sag in the downtown Barberton area. A comprehensive D.O. survey conducted during September 14-16, 2005 showed average dissolved oxygen values below the MWH average WQS of 4 mg/l at river mile (RM) 114, RM 112.9 (State St), RM 111.6

(Tuscarawas Ave), and RM 110.8 (Snyder Ave). The minimum D.O. of 3 mg/l (MWH) is also exceeded at some of these sites. The Tuscarawas River does not attain the MWH designation in this reach.

2.5.4 Pathogens

Excessive loading of pathogenic organisms (fecal coliform) is the cause of recreational use impairment throughout the Tuscarawas River basin. The source of this impairment is from poorly treated wastewater from point sources (such as municipal wastewater treatment plants (WWTPs) and smaller package plants), failing or poorly maintained home septic treatment systems (HSTS), sludge or manure runoff from farm fields, and livestock with free access to streams.

Table 2.4 Aquatic life use (ALU) and recreation use (RU) attainment status for the Tuscarawas River (excluding all tributaries). Area shaded red indicates NON or partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
Assessment Unit 05040001 Tuscarawas River (headwaters to the Muskingum River)						
Tuscarawas River (17-500) WWH – Eastern Ontario Lake Plain (EOLP)						
126.7	NON	NON	70.5	Habitat alteration, siltation, organic enrichment, pathogen	Suburbanization, channelization	Yes
123.1	PART	FULL	70.5	Flow alteration, organic enrichment, nutrients	Suburbanization, channelization	Yes
122.7	PART	FULL	62.5	Flow alteration, organic enrichment, nutrients	Suburbanization, channelization	Yes
122.5	PART	FULL	71.0	Flow alteration, organic enrichment, nutrients	Suburbanization, channelization	Yes
120.1	FULL	FULL	75.0			Yes
119.3	FULL	FULL	58.0			Yes
Tuscarawas River (17-500) MWH – (EOLP) – Channel modification from RM 112.9-103.2						
110.8	PART	FULL	74.0	Flow alteration, organic enrichment, nutrients, dissolved solids	Suburbanization, channelization	Yes
Tuscarawas River (17-500) WWH – (EOLP)						

Table 2.4 Aquatic life use (ALU) and recreation use (RU) attainment status for the Tuscarawas River (excluding all tributaries). Area shaded red indicates NON or partial attainment status.

Stream & RM	Attainment Status ALU	Attainment Status RU	QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
100.0	PART	NON	71.5	Organic enrichment, suspended solids, nutrients, TDS, pathogen	Chippewa Creek, Barberton WWTP, PPG Lime Lakes	Yes
94.5/94.2	PART	NON	63.0	Organic enrichment, suspended solids, nutrients, TDS, pathogen	Chippewa Creek, Barberton WWTP, PPG Lime Lakes	Yes
Tuscarawas River Large River Assessment Unit, RM 90.82 to mouth Tuscarawas River (17-500) WWH – (EOLP)						
90.4/90.8	FULL	NON	58.5	Pathogen	Septic discharge	Yes
89.2/89.0	PART	NON	49.0	Habitat alteration, Unknown Toxicity, Organic Enrichment, pathogen	Levees, polluted runoff from closed industrial site (Republic Steel/ Mercury Stainless Steel),	Yes
88.5	PART	NON	71.5	Nutrients, Unknown Toxicity, Organic Enrichment, pathogen	Polluted runoff from closed industrial site (Republic Steel/ Mercury Stainless Steel), Massillon WWTP	Yes
85.2	FULL (NON)	FULL	76.5	Nutrients	Massillon WWTP	Yes
81.4	FULL (NON)	FULL	81.0	Nutrients	Massillon WWTP	Yes
78.2	FULL (NON)	PART	85.5	Nutrients, Pathogen	Massillon and Navarre WWTPs, septic discharges, livestock	Yes
Tuscarawas River (17-500) WWH – Western Allegheny Plateau (WAP)						
73.6	FULL (NON)	PART	73.5	Nutrients, Pathogen	Septic discharges, livestock	Yes
72.6	FULL	PART	78.5	Pathogen	Septic discharges, livestock	Yes
63.1	FULL	PART	78.0	Pathogen	Septic discharges, livestock	Yes
61.9	FULL	PART	74.5	Pathogen	Septic discharges, livestock	Yes
55.6	FULL	FULL	86.5			No
54.2	FULL	FULL	85.0			No
53.5	FULL	FULL	88.0			No
Tuscarawas River (17-500) EWH –(WAP)						
43.8	FULL	FULL	80.0			No

Table 2.4 Aquatic life use (ALU) and recreation use (RU) attainment status for the Tuscarawas River (excluding all tributaries). Area shaded red indicates NON or partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
38.7	FULL	FULL	84.0			No
37.5	FULL	FULL	83.0			No
30.9	FULL	FULL	87.5			No
20.5	FULL	FULL	85.5			No
17.6	FULL	FULL	85.0			No
13.0	FULL	FULL	82.5			No
12.6	FULL	FULL	82.5			No
7.2	FULL	PART	77.5	Pathogen	Septic discharges, livestock	Yes
3.5	FULL	PART	78.0	Pathogen	Septic discharges, livestock	Yes
0.3	FULL	PART	81.0	Pathogen	Septic discharges, livestock	Yes

Table 2.5 Aquatic life use (ALU) and recreation use (RU) attainment status for the Upper Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
Assessment Unit 05040001 010 Tuscarawas River Tributaries (Headwaters to below Wolf Creek)						
Wolf Creek (17-540) WWH (RM 4.6 to mouth MWH) - EOLP						
13.7/14.3	FULL	FULL	63.0			No
12.0	NON	FULL	53.0	Habitat alteration, siltation	Suburbanization, channelization	Yes
3.9	FULL	NON	47.5	Pathogen	Septic discharges	Yes
0.2	FULL	NON	79.0	Pathogen	Septic discharges	Yes
Tributary to Wolf Creek at RM 10.97 (17-594) WWH - EOLP						
0.6	FULL	NON	68.5	Pathogen	Septic discharges	Yes
Hudson Run (17-541) WWH (MWH RM 0.4 to mouth) - EOLP						
3.7	PART	FULL	71.5	Habitat Alteration, Siltation	Suburbanization, channelization	Yes
1.4/1.7	NON	FULL	55.5	Habitat Alteration, Siltation	Suburbanization, channelization	Yes
Unnamed Trib. to Hudson Run (L. Dorothy trib.) – WWH						
1.2	FULL	FULL	83.5			No
VanHyning Run (17-542) WWH – EOLP						
0.6	NON	NON	78.0	Organic enrichment, siltation, pathogen	Summit County Upper Tuscarawas WWTP, suburbanization, septic discharges	Yes
Pigeon Creek (17-543) – WWH (MWH from Jacoby Rd. (RM 5.2) to the mouth) - EOLP						
4.7	PART	FULL	39.0	Habitat alteration, siltation, organic enrichment, pathogen	Suburbanization, channelization, septic discharges	Yes
0.6	PART	NON	39.5	Habitat alteration, siltation, organic enrichment, pathogen	Suburbanization, channelization, septic discharges	Yes
Schocalog Run (17-544) WWH (– EOLP						
0.5	NON	FULL	35.0	Habitat alteration, siltation, organic enrichment, pathogen	Suburbanization, channelization, septic discharges	Yes
Metzgers Ditch (17-545) WWH – EOLP						
0.5/1.0	NON	FULL	60.5	Wetland stream	Natural	No
Assessment Unit 05040001 020 Chippewa Creek Basin						
Chippewa Creek (17-550) WWH (MWH Chippewa Lake Outlet (RM 20.4) to mouth) EOLP						

Table 2.5 Aquatic life use (ALU) and recreation use (RU) attainment status for the Upper Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
23.2	PART	FULL	38.5	Habitat alteration, flow alteration, siltation	Agricultural crop production and pasture land	Yes
17.2	FULL	PART	28.0	Pathogen	Septic discharges	Yes
6.5	FULL	PART	23.5	Pathogen	Septic discharges	Yes
0.4	PART	NON	42.0	Organic enrichment, siltation, flow alteration, habitat alteration, pathogen	Agricultural crop production, suburbanization, septic discharges	Yes
Silver Creek (17-562) WWH – EOLP						
3.7	NON	NON	63.0	Nutrients, pathogen	Doylestown WWTP, suburbanization	Yes
2.8	NON	NON	71.0	Nutrients, pathogen	Doylestown WWTP, suburbanization	Yes
0.4	FULL	NON	80.0	Pathogen	Septic discharges	Yes
Red Run (17-551) WWH - EOLP						
0.9	PART	NON	40.5	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Agricultural crop production, suburbanization, septic discharges	Yes
0.5	FULL	NON	33.0	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Agricultural crop production, suburbanization, septic discharges	Yes
Marshallville Trib. (Trib. to Red Run @ RM 0.66) (17-585) WWH –EOLP						
0.1	FULL	NON	36.7	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Agricultural crop production, suburbanization, septic discharges	Yes
Unnamed Trib to Marshallville Trib. (Trib. to Red Run @ RM 0.66/0.55) (17-586) – WWH-- EOLP						
0.7	PART	PART	63.0	Organic enrichment, pathogen	Suburbanization, septic discharges	Yes
Mill Creek (17-552) WWH -EOLP						
1.5/1.9	FULL	PART	40.0	Pathogen	Septic discharges	Yes
River Styx (17-553) WWH (MWH from Medina County Rd.(RM 3.9) to the mouth)						
3.9	FULL	FULL	29.0			No
3.5	FULL	FULL	32.5			No

Table 2.5 Aquatic life use (ALU) and recreation use (RU) attainment status for the Upper Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
3.3	FULL	FULL	--			No
2.7	PART	NON	40.0	Organic enrichment, siltation, flow alteration, habitat alteration, pathogen	Wadsworth WWTP and polluted runoff from sludge disposal, suburbanization	Yes
0.5/0.7	NON	NON	35.5	Organic enrichment, siltation, flow alteration, habitat alteration, pathogen	Suburbanization, septic discharges	Yes
Holmes Brook (17-554) WWH - EOLP						
0.2	PART	PART	49.0	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Suburbanization, septic discharges	Yes
Blockers Creek (17-555) WWH - EOLP						
0.8	NON	NON	--	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Suburbanization, septic discharges	Yes
Little Chippewa Creek (17-556) – WWH - EOLP						
8.8	NON	NON	67.5	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Agricultural crop production, suburbanization, septic discharges	Yes
8.0/6.8	NON	NON	46.5	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Agricultural crop production, suburbanization, septic discharges	Yes
0.3	NON	NON	33.0	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Agricultural crop production, suburbanization, septic discharges	Yes
Tributary to Little Chippewa Creek at RM 6.3 (17-561) WWH - EOLP						
0.1	FULL	PART	42.0	Pathogen	Septic discharge	Yes
Hubbard Creek (17-557) WWH - EOLP						
3.7	FULL	FULL	70.5			No
1.6	PART	FULL	84.0	Flow alteration	Upstream impoundment, suburbanization	Yes
McCabe Creek (17-559) WWH - EOLP						
0.8	PART	FULL	63.0	Unknown	Unknown	Yes

Table 2.5 Aquatic life use (ALU) and recreation use (RU) attainment status for the Upper Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
Steel Ditch (17-566) undesignated (recommend MWH from RM 1.57 to mouth and WWH ust RM 1.57) - EOLP						
1.0	FULL	NON	42.5	Pathogen	Septic discharges	Yes
Tommy Run (17-573) WWH - EOLP						
0.8	PART	PART	62.0	Habitat alteration, flow alteration, siltation, pathogen	Suburbanization, septic discharges	Yes
Assessment Unit 05040001 030 Tuscarawas River tributaries downstream Wolf Creek to Downstream Sippo Creek excluding Chippewa Creek.						
Sippo Creek (17-533) WWH - EOLP						
4.6	NON	NON	--	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Suburbanization, failing onsite wastewater systems	Yes
Newman Creek (17-534) WWH – EOLP						
11.9	NON	PART	54	Habitat alteration, flow alteration, siltation, organic enrichment, pathogen	Agricultural crop production, septic discharges	Yes
1.3	FULL	PART	88.0	pathogen	Septic discharges	Yes
Mudbrook Creek (17-536) WWH - EOLP						
2.5	FULL	PART	31.0	Pathogen	Septic discharges	Yes
0.5	FULL	PART	79.5	Pathogen	Septic discharges	Yes
Fox Run (17-537) WWH – EOLP						
4.9/4.7	NON	FULL	17.0	Habitat alteration, flow alteration, siltation, organic enrichment	Agricultural crop production, suburbanization	Yes
2.7	PART	FULL	61.0	Nutrient enrichment	Agricultural crop production	Yes
0.6	NON	N/A	47.0	Nutrient enrichment	Agricultural crop production	Yes
Nimisila Creek (17-538) WWH – EOLP						
7.0	PART	FULL	79.0	Organic enrichment	Suburbanization, failing onsite wastewater systems	Yes
4.9	FULL	FULL	67.0			No
Pancake Creek (17-539) WWH - EOLP						
2.5	FULL	FULL	40.5			No

Table 2.5 Aquatic life use (ALU) and recreation use (RU) attainment status for the Upper Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
West Sippo Creek (17-575) WWH - EOLP						
3.9	PART	NON	72.5	Pathogens, nutrient enrichment	Suburbanization, failing onsite wastewater systems	Yes
2.6	NON	NON	63.5	Pathogens, nutrient enrichment	Suburbanization, failing onsite wastewater systems	Yes
1.0	FULL	NON	75.0	Pathogen	Failing onsite wastewater systems	Yes
Tributary to Sippo Creek @ RM 4.54 (L. Cable Outlet)(17-587) – undesignated (recommend MWH) EOLP						
2.7	NON	NON	26.5	Pathogens, organic enrichment	Suburbanization, outflow from lake, septic discharges	Yes
Orrville Ditch (17-590) WWH – EOLP						
2.3	PART	PART	19.5	Pathogens, nutrient enrichment	Agricultural crop production, septic discharges	Yes
Tributary to Orrville Ditch @ RM 0.52 (17-591) WWH - EOLP						
1.2	NON	PART	69.5	Pathogens, nutrient enrichment	Agricultural crop production, septic discharges	Yes

Table 2.6 Aquatic life use (ALU) and recreation use (RU) attainment status for the Lower Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
Assessment Unit 05040001 090 Tuscarawas River Tributaries (Downstream from Sippo Creek to Upstream from Sugar Creek, excluding Sandy and Conotton Creeks)						
Small Middle Run (17-527) WWH - WAP						
0.1/0.7	NON	NON	72.5	Siltation, metals, pathogen	Habitat alteration, septic discharges	Yes
Middle Run (17-528) WWH - WAP						
0.3	NON	FULL	67.5	Siltation, metals	Habitat alteration	Yes
Wolf Run (17-529) WWH – WAP						
0.1	NON	FULL	52.0	Acid mine drainage, low pH	Mining	No – AMDAT recommended
Wolf Creek (Stark County) – WWH – EOLP						
0.32	PART	NON		Pathogen	Septic discharges	Yes
Camp Creek – WWH - EOLP						
0.20	NON	NON		Pathogen	Septic discharges	Yes
Pigeon Run (17-532) WWH - EOLP						
4.1	FULL	FULL	75.5			No
2.6/0.24	FULL	PART	74.5	Pathogen	Septic discharges	Yes
Sherman Creek (17-568) WWH - EOLP						
1.9	FULL	FULL	--	Pathogen		No
Tributary to Tuscarawas River at RM 83.74 WWH - WAP						
0.2	NON	NON	61.5	Flow alteration, nutrients	Habitat alteration, septic discharges	Yes
Tributary to Tuscarawas River at RM 82.02 – undesignated - WAP						
1.9	NON	NON		Pathogen	Septic discharges	Yes
Tributary to Tuscarawas River at RM 77.96 WWH - WAP						
0.3	FULL	NON	73.0	Pathogen	Septic discharges	No

Table 2.6 Aquatic life use (ALU) and recreation use (RU) attainment status for the Lower Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
Assessment Unit 05040001 130 Tuscarawas River (Downstream from Sugar Creek to upstream from Stillwater Creek)						
Pike Run (17-521) WWH - WAP						
0.2	NON	FULL	--	Acid mine drainage	Mining	No – AMDAT recommended
Pone Run (17-522) WWH - WAP						
0.2	NON	FULL	--	Acid mine drainage	Mining	No – AMDAT recommended
Beaverdam Creek (17-523) WWH - WAP						
7.0	NON	PART	--	Siltation, metals, pathogen	Habitat alteration, septic discharges	Yes
0.9	NON	NON	83.0	Siltation, metals, pathogen	Impervious surface, stormwater, septic discharges	Yes
Oldtown Creek (17-524) WWH - WAP						
7.9/7.3	FULL	FULL	48			No
4.8	PART	NON	44.5	Siltation, metals, habitat alteration, flow alteration, pathogen	Channelization/ unrestricted livestock access	Yes
0.9	NON	NON	--	Siltation, metals, habitat alteration, flow alteration, pathogen	Channelization/ unrestricted livestock access	Yes
Stone Creek (17-525) WWH - WAP						
7.2	NON	NON	47	Organic enrichment, habitat alteration, pathogen	Channelization/ unrestricted livestock access	Yes
6.4	FULL	NON	42	Pathogen	Unrestricted livestock access to the creek, septic discharges	Yes

Table 2.6 Aquatic life use (ALU) and recreation use (RU) attainment status for the Lower Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
3.1/4.2	FULL	NON	43	Pathogen	Unrestricted livestock access to the creek, septic discharges	Yes
Tributary to Stone Creek @ RM 6.0 WWH - WAP						
0.2	FULL	NON	58.5	Pathogen	Septic discharges	Yes
Crooked Creek (17-526) WWH - WAP						
2.4/1.8	NON	NON	53	Siltation, habitat alteration, flow alteration, pathogen	Channelization, septic discharges	Yes
HUC 05040001 180 Tuscarawas River *Tributaries* (Downstream from Stillwater Creek to Upstream from Evans Creek)						
Blue Ridge Run (17-509) WWH - WAP						
0.4	FULL	NON	--	Pathogen	Septic discharges	Yes
Rodney Run (17-510) WWH - WAP						
0.1	FULL	PART	--	Pathogen	Septic discharges	Yes
Buckhorn Creek (17-511) WWH - WAP						
5.1/4.9	PART	NON	64	Organic enrichment, habitat alteration, siltation, pathogen	Unrestricted livestock access to the creek	Yes
1.0/1.5	FULL	NON	59.5	Pathogen	Unrestricted livestock access to the creek	Yes
Lick Run (17-512) WWH - WAP						
1.4/0.4	PART	NON	40	Pathogen	Unrestricted livestock access to the creek	Yes
West Fork Buckhorn Creek (17-513) WWH - WAP						
2.0	FULL	FULL	31			No
0.1	PART	NON	30	Habitat, pathogen	Unrestricted livestock access to the creek	Yes
Indian Camp Creek (17-515) WWH - WAP						

Table 2.6 Aquatic life use (ALU) and recreation use (RU) attainment status for the Lower Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
0.1	PART	FULL	--	Low flow	Natural, headwater stream	No
Dunlap Creek (17-515) WWH - WAP						
4.2	PART	FULL	63	Habitat alteration, siltation	Unrestricted livestock access to the creek	Yes
2.4	FULL	NON	69	Pathogen	Unrestricted livestock access to the creek, septic discharges	Yes
0.2	N/A	PART		Pathogen	Unrestricted livestock	Yes
Browning Run (17-516) WWH -WAP						
0.8	FULL	FULL	60.5			No
Frys Creek (17-518) WWH - WAP						
2.1	FULL	FULL	61.2			No
1.2	NON	FULL	50	Habitat alteration, siltation, metals	Mining	No – AMDAT recommended
Johnson Run (17-519) WWH - WAP						
0.5/0.2	NON	NON	26	Siltation, metals, acid mine drainage, pathogen	Mining, septic discharge	No – AMDAT recommended
Mud Run (17-520) WWH - WAP						
1.6	NON	FULL	64	Siltation, metals, acid mine drainage	Mining	No – AMDAT recommended
HUC 05040001 190 Tuscarawas River (Upstream from Evans Creek to Muskingum River)						
Morgan Run (17-501) - WWH - WAP						
0.7	NON	FULL	70.5	pH, metals, acid mine drainage	Mining	No – AMDAT recommended
Tributary to Tuscarawas River @ RM 3.78 (17-547) WWH – WAP						
1.3	PART	FULL	61.5	Metals (iron)	Unknown	Yes
White Eyes Creek (17-502) WWH - WAP						
5.1/5.5	FULL	NON	49	Pathogen	Unrestricted livestock access to the	Yes

Table 2.6 Aquatic life use (ALU) and recreation use (RU) attainment status for the Lower Tuscarawas River tributaries. Area shaded red indicates NON or Partial attainment status.

Stream & RM	Attainment Status		QHEI	Impairment Cause	Impairment Source	Addressed in TMDL?
	ALU	RU				
					creek	
0.9	FULL	PART	58.5	Pathogen	Unrestricted livestock access to the creek	Yes
East Fork White Eyes (17-503) WWH - WAP						
3.0	PART	NON	67.5	Nutrients, ammonia, pathogen	Unrestricted livestock access	Yes
West Fork White Eyes Creek (17-504) WWH - WAP						
3.7	FULL	NON	34.0	Pathogen	Unrestricted livestock access to the creek	Yes
0.3	FULL	FULL	58.5			No
Evans Creek (17-505) WWH - WAP						
5.1	FULL	NON	50	Pathogen	Unrestricted livestock access to the creek	Yes
0.7/0.3	FULL	NON	67	Pathogen	Unrestricted livestock access	Yes
Davis Run – WWH - WAP						
0.3	FULL	FULL	--			No
Hoffman Run - WWH - WAP						
0.4	FULL	NON	--	Pathogen	Unrestricted livestock access to the creek	Yes
Sweigert Run – WWH - WAP						
0.3	NON	FULL	--	Low dissolved oxygen	Unknown	Yes

3.0 WATER QUALITY TARGETS AND TMDL DEVELOPMENT

This chapter discusses the pollutants and stressors addressed through this TMDL. Section 3.1 describes how each stressor impacts water quality and also provides water quality goals or targets. Section 3.2 discusses how water quality impairments are addressed through the development of the various TMDLs.

3.1 Factors Causing Impairment and Water Quality Targets Used for TMDL Development

Designated water uses related to recreation and aquatic life were evaluated to determine if minimum quality standards for supporting those uses are being achieved. For waterbodies that did not meet water quality standards, the causes of impairment and the associated pollution sources were determined. Causes of impairment for which TMDLs are developed include ***nutrient enrichment, habitat alteration, sedimentation, organic enrichment/dissolved oxygen and pathogens.***

The following sub-sections discuss the numeric targets used in developing TMDLs for the causes of impairment discussed above. Numeric targets are critical to the TMDL process because they serve as a measure of comparison between observed instream conditions and conditions that are expected to achieve minimum quality standards for the designated uses of the waterbody.

3.1.1 Nutrient Enrichment

Nutrient enrichment is a cause of impairment in twelve of the HUC 14 subwatersheds within the Tuscarawas River basin. For the purpose of this TMDL, total phosphorus is used as an indicator for the degree of nutrient enrichment because it is frequently the limiting nutrient to primary production in streams and rivers of Ohio. While the Ohio EPA does not currently have statewide numeric criteria for nutrients, potential targets have been identified in a technical report titled *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA, 1999). This document provides the results of a study analyzing the effects of nutrients on the aquatic biological communities of Ohio streams and rivers. The study shows the importance of habitat and instream nutrient concentrations on the health of biologic communities. Targets are proposed for total phosphorus concentrations based on observed concentrations associated with acceptable ranges of the biological community metrics. The total phosphorus targets used in this report are shown in Table 3.1.

Ohio's standards also include narrative criteria that limit the quantity of nutrients which may enter state waters. Specifically, OAC Rule 3745-1-04 (E) states that all waters of the state, "…shall be free from nutrients entering the waters as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae". In addition, OAC Rule 3745-1-04(D) states that all waters of the state, "…shall be free from substances entering the waters as a result of human activity in concentrations that are toxic or harmful to human, animal or aquatic life and/or are rapidly lethal in the mixing zone". Excess concentrations of nutrients that contribute to non-attainment of biological criteria may fall under either OAC Rule 3745-1-04 (D) or (E) prohibitions.

Table 3.1 Total phosphorus targets for warm water habitats (WWH) and modified warm water habitats (MWH)[1].

Use designation	Watershed size	Total phosphorus (mg/l)
WWH	Headwaters (drainage area < 20 mi^2)	0.08
	Wadeable (20 mi^2 < drainage area < 200 mi^2)	0.10
	Small River (200 mi^2 < drainage area < 1000 mi^2)	0.17
MWH	Headwaters (drainage area < 20 mi^2)	0.34
	Wadeable (20 mi^2 < drainage area < 200 mi^2)	0.28
	Small River (200 mi^2 < drainage area < 1000 mi^2)	0.25

[1] Based on state-wide targets found in the Association Between Nutrients, Habitat, and the Aquatic Biota of Ohio Rivers and Streams (Ohio EPA, 1999)

3.1.2 Habitat Alteration and Sedimentation

Habitat TMDL Targets and the Qualitative Habitat Evaluation Index (QHEI)
Habitat alteration is a significant cause of impairment throughout the Tuscarawas River basin. Poor habitat quality is an environmental condition, rather than a pollutant load, so development of a load-based TMDL for habitat is not possible. Nonetheless, habitat is an integral part of stream ecosystems and has a significant impact on aquatic community assemblage and consequently on the potential for a stream to meet the biocriteria within Ohio's water quality standards (see Section 2.3). In addition, U.S. EPA acknowledges that pollutants, conditions or other environmental stressors can be subject to the development of a TMDL to abate those stressors in order to meet water quality standards (U.S. EPA, 1991). Thus, sufficient justification for developing habitat TMDLs is established.

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

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

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

Since its development the QHEI has been used to evaluate habitat at most biological sampling sites and currently there is an extensive database that includes QHEI scores and other water quality variables. Strong correlations exist between QHEI scores and some its component sub-metrics 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). For the aquatic life use designation of warm water habitat (WWH) an overall QHEI score of 60 is targeted to provide reasonable certainty that habitat is not deficient to the point of precluding attainment of the biocriteria.

One of the strongest correlations found through these statistical analyses described above is the negative relationship between the number of “modified attributes” and the IBI scores. Modified attributes are features or conditions that have low value in terms of 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.

In addition to the overall QHEI scores, targets for the maximum number of modified and high influence modified attributes have been developed. For streams designated as WWH, there should no more than four modified attributes of which no more than one should be a high influence modified attribute. Table 3.2 lists modified and high influence modified attributes and provides the QHEI targets used for this habitat TMDL. For simplicity, a pass/fail distinction is made telling whether each of the three targets are being met. Targets are set for: 1) the total QHEI score, 2) maximum number of all modified attributes, and 3) maximum number of high influence modified attributes only. 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.

The targets described above are designed to protect WWH aquatic life uses. However, habitat and sediment TMDLs are developed using these targets to address aquatic life use impairment within MWH designated streams. The absence of reliable targets for QHEI scores for MWH streams is a primary reason the above targets are used in such cases. However, Ohio EPA feels that the fact that MWH is an aquatic life use that falls short of the goals of the Clean Water Act provides justification for this decision.

Table 3.2 QHEI targets for the habitat TMDL.

	Overall QHEI Score	All Modified Attributes	
		High Influence Modified Attributes	All Other Modified Attributes
Range of Possibilities	12 to 100 points	- Channelized or No Recovery - Silt/Muck Substrate - Low Sinuosity - Sparse/No Cover - Max Pool Depth < 40 cm (wadeable streams only)	- Recovering Channel - Sand Substrate (boat sites) - Hardpan Substrate Origin - Fair/Poor Development - Only 1-2 Cover Types - No Fast Current - High/Moderate Embeddedness - Ext/Mod Riffle Embeddedness - No Riffle
Target	Overall score >= 60	Total number < 2	Total number < 5[1]
TMDL Points if Target Satisfied	+ 1	+ 1	+ 1

[1] Total number of modified attributes includes those counted towards the high influence modified attributes.

Sediment TMDL Targets and the Qualitative Habitat Evaluation Index (QHEI)
The QHEI is also used in developing the sediment TMDL for this project. Numeric targets for sediment are based upon 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 and riparian zone.

- The substrate sub-metric evaluates the dominant substrate materials (i.e., based on texture size and origin) and the functionality of coarser substrate materials in light of the amount of silt cover and degree of embeddedness. This is a qualitative evaluation of the amount of excess fine material in the system and the degree to which the channel has assimilated (i.e., sorts) the loading.
- The channel morphology sub-metric considers sinuosity, degree of channelization, and channel stability. Except for stability these aspects are directly related to channel form and consequently how sediment is transported, eroded, and deposited within the channel itself (i.e., this is related to both the system's assimilative capacity and loading rate). Stability reflects the degree of channel erosion which indicates the potential of the stream as being a significant source for the sediment loading.
- The bank erosion and riparian zone sub-metric also reflects the likely degree of instream sediment sources. The evaluation of floodplain quality is included in this sub-metric which is related to the capacity of the system to assimilate sediment loads.

Table 3.3 QHEI targets for the sediment TMDL.

Sediment TMDL =	Substrate	+	Channel Morphology	+	Riparian Zone/Bank Erosion	
For WWH >=	13	+	14	+	5	>= 32

The rationale for using the QHEI for development of the sediment TMDL is largely due to the fact that other measures and/or methods of evaluating sediment loading are problematic and have limited reliability. For example, total suspended solids (TSS) are commonly used as a modeling parameter, but gathering data that are reliable for calibration and validation is often uncertain (USGS, 2000). This uncertainty rests in the fact that TSS demonstrates a high degree of variability both over space and time and is also very sensitive to local disturbances. Additionally, models that adequately account for instream sediment dynamics (e.g., erosion and deposition processes) are lacking or require very high resource expenditures (e.g., much data collection) that often are not feasible.

Finally, the QHEI has a strong relationship with the biocriteria in Ohio's water quality standards, whereas TSS has a relatively weak correlation with biological performance, which is probably related to the variability and unreliability of TSS measures. The QHEI represents the end result of high sediment loading (either from the landscape or instream sources) as it impacts the biological community.

3.1.3 Organic Enrichment/Dissolved Oxygen

Organic enrichment /dissolved oxygen are identified as a major cause of impairment in several hydrologic units within the upper section of the Tuscarawas River watershed. Dissolved oxygen (D.O.) serves as an indicator of water quality, although it's not amenable to being quantified as a load. However, D.O. is easily measured and serves as surrogate for a variety of oxygen consuming substances commonly found in wastewater, runoff, combined sewer overflows, animal waste, etc.

The state of Ohio has specific water quality standards for D.O. for the protection of aquatic life. This makes D.O. a useful tool for TMDL development because it defines targets and forms a basis for measuring compliance. The D.O. criteria applicable to the impaired Tuscarawas River segments are shown in Table 3.2.

Table 3.4 Statewide dissolved oxygen criteria for warm water habitats (WWH) and modified warm water habitats (MWH).

Use designation		D.O. (mg/l)
WWH	Outside Mixing Zone Maximum	4.0
	Outside Mixing Zone Average	5.0
MWH	Outside Mixing Zone Maximum	3.0
	Outside Mixing Zone Average	4.0

3.1.4 Pathogens

Elevated bacteria loading is the cause of recreational use impairment in the Tuscarawas River basin. The proportion of pathogenic organisms present in assessed waters is generally small compared to non-pathogenic organisms. For this reason most pathogenic bacteria are difficult to isolate and identify. Additionally, pathogenic organisms are highly varied in their characteristics and type which also makes them difficult to measure. Nonpathogenic bacteria that are associated with pathogens transmitted by fecal contamination are more abundant and therefore are monitored as surrogates because of the greater ease in sampling and measuring. Fecal coliform are used as these indicator organisms and have promulgated water quality standards for the maximum geometric mean concentration and the ninetieth percentile concentration (OAC 3745-1-07). These values serve as the targets used in the development of the TMDLs that address recreation use impairments.

The criteria for fecal coliform specified in OAC 3745-1-07 are applicable outside the mixing zone and vary for waters determined primary contact recreation (PCR) and secondary contact recreation (SCR). One stream in the TMDL study area, Little Chippewa Creek, is currently designated secondary contact recreation. For PCR the standard states the geometric mean content, based on not less than five samples within a thirty-day period, shall not exceed 1000 counts per 100 ml and shall not exceed 2000 counts per 100 ml in more than 10 percent of the samples taken during any thirty-day period. As written the standards effectually establish both chronic and acute permissible instream fecal coliform concentrations. The SCR standard varies in that it requires fecal coliform not to exceed the geometric mean value of 5000 per 100 ml in more than ten percent of the samples taken during any thirty-day period. There is no geometric mean component of the standard for SCR designated waters.

TMDL development is conducted to reflect the chronic parts of the PCR standard. This calculation for the entire recreation season, as defined by OAC, is based upon a target of 1000 counts per 100 ml. This TMDL is intended to be protective of the chronic condition, and as such is based upon the thirty-day geometric mean criteria. The TMDL is altered using a target of 5000 counts per 100 ml for the single SCR stream in this report.

3.2 Impairments Addressed through this TMDL

The following subsections outline which causes of impairment will be addressed through the development of a TMDL in each of the 11-digit HUCs. TMDL parameters, method of development and the applicable location in the watershed are described in Tables 3.5-A and 3.5-B addressing aquatic life use and recreational use impairment respectively. More detail regarding the different TMDL approaches is found in Section 4.1. Refer to specific 11-digit HUCs sections in Chapter 5 for the rationale that went into selecting the various approaches. Chapter 5 also contains further explanation for the approaches listed in the “other” column found within the following tables.

The fecal coliform data that were collected provided the basis for determining where TMDLs are developed. Those data are summarized in Table 2.4. Note that impairment is not determined by following the geometric mean component of the recreational use standard described in subsection 3.1.4 above. This is because the proper sampling frequency (not less than five samples within a thirty-day period) was not practical for this watershed due to logistics involved with the watershed’s distance from field staff operations, distance to water quality labs and the short holding time of bacteria samples. However, only data collected in the 2003 recreational season (1 May through 15 October) are used for impairment determination. Table 3.5-A summarizes these finding and excludes the fourteen-digit HUCs in which no recreational use impairment was found.

3.2.1 Tuscarawas River (headwaters to below Wolf Ck) - 010

Table 3.5 Aquatic life use causes of impairment and TMDLs developed for -010.

14-digit HUC	Description	River mile	Causes	Method of TMDL (see Chapter 4)				
				QUAL2K nutrient/DO	GWLF nutrient	QHEI habitat	QHEI sediment	Other (explained)
010-010	Partial: Tusc River upstream of Mogadore Rd.	Upst-126.75	Unknown					Pathogen modeling (see Section 5.1.1)
010-020	Tusc. River – below Long Lake diversion dam to above Wolf Creek	118.01-110.7	Flow alteration, organic enrichment, nutrients	X				
010-030	Wolf Ck –head-waters to upst Pigeon Ck	Upst-3.95	Habitat alteration, siltation			X	X	
010-040	Pigeon Creek	All	Habitat alteration, siltation, organic enrichment		X	X	X	
010-050	Partial: Van Hyning Run	All	Organic enrichment, siltation				X	
010-060	Hudson Run	All	Habitat alteration, siltation			X	X	

Table 3.6 Recreational use impairment and TMDL approach for 010.

Site	RM	Observed Condition[1] (fecal coliform cfu/100 ml)		Impaired?	Area analyzed[2] (see Chapter 4)
05040001-010-010: Tuscarawas River headwaters to Diversion Dam (HUC 14)					
Tuscarawas R. @ Mogadore Ave	126.8	Geometric mean	1529	YES	Site (7.67 mi^2)
		90^{th} percentile	2900		
05040001-010-030: Wolf Creek headwaters to above Pigeon Cr. (HUC 14)					
UT to Wolf Ck RM 10.97 @ SR 162	0.52	Geometric mean	1226	YES	Site (4.83 mi^2)
		90^{th} percentile	3320		
05040001-010-040: Pigeon Creek (HUC 14)					
Pigeon Creek (Summit Co.) @ SR 261	0.64	Geometric mean	2277	YES	Site (<20 mi^2)
		90^{th} percentile	14720		
05040001-010-050: Wolf Creek below Pigeon Cr. to Tuscarawas R. (HUC 14)					
Wolf Creek (Summit Co.) @ Summit Rd.	3.91	Geometric mean	1948	YES	14-HUC
		90^{th} percentile	4400		
Van Hyning Run @ Clark Mill Rd.	0.61	Geometric mean	1612	YES	
		90^{th} percentile	2120		
Wolf Ck at Snyder Ave dst CSX RR	0.2	Geometric mean	1456	YES	
		90^{th} percentile	4990		

[1] Geometric mean criterion for fecal coliform bacteria is 1000 cfu/100 ml and 90th percentile criterion for fecal coliform is 2000 cfu/100 ml.

[2] "Site" indicates that the watershed analysis included the drainage area ending at that sample location; "LDC" indicates that a load duration curve was generated at that point; and "14-HUC" indicates that the entire 14 digit HUC was modeled.

3.2.2 Chippewa Creek – 020

Table 3.7 Aquatic life use causes of impairment and TMDLs developed for 020.

14-digit HUC	Description	River mile	Causes	Method of TMDL (see Chapter 4)			
				GWLF nutrient	QHEI habitat	QHEI sediment	Other (explained)
020-010	Chippewa Creek (The Inlet)	>21.6	Habitat alteration, flow alteration, siltation		X	X	
	McCabe Creek	All	Unknown		X	X	
020-020	Partial: Hubbard Creek	All	Flow alteration		X		
020-030	Partial: Tommy Run	All	Habitat alteration, flow alteration, siltation		X	X	
020-040	Little Chippewa Creek	All	Habitat alteration, flow alteration, siltation, organic enrichment	X	X	X	
020-050	River Styx	All	Organic enrichment, siltation, flow alteration, habitat alteration	X	X	X	
020-070	Red Run	All	Habitat alteration, flow alteration, siltation, organic enrichment	X	X	X	
020-080	Partial: Silver Creek	All	Nutrients	X			
020-080	Partial: Chippewa Creek mainstem	At mouth	Organic enrichment, silt, flow alteration, habitat alteration.		X	X	Upstream work*

* Load reductions for the Chippewa Creek tributaries should eliminate the organic enrichment problem in the mainstem. See Section 5.2.2 for explanation.

Table 3.8 Recreational use impairment and TMDL approach for 020.

Site	RM	Observed Condition[1] (fecal coliform cfu/100 ml)		Impaired	Area analyzed[2] (see Chapter 4)
05040001-020-020: Chippewa Creek below Chippewa Lk. outlet to below Hubbard Cr. (HUC 14)					
Chippewa Creek @ Greenwich Rd.	17.2	Geometric mean	598	YES	Discussed in Section 5.2.1
		90th percentile	2921		
05040001-020-030: Chippewa Creek below Hubbard Cr. to above River Styx [except L. Chippewa Cr.] (HUC 14)					
Steele Ditch @ Eby Rd.	0.96	Geometric mean	1026	YES	Site (11.73 mi^2)
		90th percentile	2580		
Tommy Run @ Blough Rd.	0.77	Geometric mean	1003	YES	Site (6.41 mi^2)
		90th percentile	1940		
05040001-020-040: Little Chippewa Creek (HUC 14)					
L. Chippewa Creek @ Five Points Rd.	8.63	Geometric mean	4478	YES	14-HUC
		90th percentile	12920		
L. Chippewa Creek @ Pleasant Home Rd.	4.42	Geometric mean	25099	YES	
		90th percentile	72000		
Trib. To L. Chippewa Cr @ Fox Lake Rd.	0.4	Geometric mean	842	YES	
		90th percentile	7080		
L. Chippewa Creek @ S. Main St. (SR 57)	0.16	Geometric mean	1876	YES	
		90th percentile	3040		
05040001-020-050: River Styx (HUC 14)					
River Styx @ Seville Rd.	3.93	Geometric mean	789	No	14-HUC
		90th percentile	1071		
R. Styx dst. Holmes Br., ust. Wadsworth WWTP	3.5	Geometric mean	869	No	
		90th percentile	1905		
River Styx @ Wall Rd.	2.8	Geometric mean	3485	YES	
		90th percentile	6800		
Blockers Creek @ Trease Rd.	0.75	Geometric mean	1803	YES	
		90th percentile	25694		
River Styx dst Salt St. (dst. Rittman WWTP)	0.7	Geometric mean	1640	YES	
		90th percentile	3740		
Holmes Brook NR Wadsworth - Weber Rd.	0.17	Geometric mean	908	YES	
		90th percentile	7195		
05040001-020-060: Chippewa Creek below River Styx to above Red Run (HUC 14)					
Chippewa Creek @ SR 585	6.58	Geometric mean	1296	YES	**LDC** for Site (based on '05 data)
		90th percentile	1680		
Mill Creek @ Galehouse Rd.	1.79	Geometric mean	822	YES	Site (6.89 mi^2)
		90th percentile	4879		
05040001-020-070: Red Run (HUC 14)					
Red Run @ Porr Rd. ust. Marshallville Trib.	0.95	Geometric mean	3560	YES	14-HUC
		90th percentile	35700		

Site	RM	Observed Condition[1] (fecal coliform cfu/100 ml)		Impaired	Area analyzed[2] (see Chapter 4)
UT to Marsvile. Trib (Trib to Red Run RM 0.66/0.55) @ Pleasant Home Rd.	0.65	Geometric mean	1106	YES	
		90th percentile	2060		
Red Run @ Porr Rd. dst. Marshallville Trib.	0.5	Geometric mean	4242	YES	
		90th percentile	63620		
Marshallville Trib.(RM 0.66) @ Warwick Rd.	0.04	Geometric mean	904	YES	
		90th percentile	2752		
05040001-020-080: Chippewa Creek below Red Run to Tuscarawas R. (HUC 14)					
Chippewa Creek @ Coal Bank Rd.	4.4	Geometric mean	2875	YES	LDC
		90th percentile	9340		
Silver Creek @ Edwards Rd.	2.79	Geometric mean	5491	YES	Silver Ck
		90th percentile	10520		
Chippewa Creek @ 2nd Ave.	0.35	Geometric mean	905	YES	LDC
		90th percentile	2680		

[1] Geometric mean criterion for fecal coliform bacteria is 1000 cfu/100 ml and 90th percentile criterion for fecal coliform is 2000 cfu/100 ml.

[2] "Site" indicates that the watershed analysis included the drainage area ending at that sample location; "LDC" indicates that a load duration curve was generated at that point; and "14-HUC" indicates that the entire 14 digit HUC was modeled.

3.2.3 Tuscarawas R. (below Wolf Ck to below Sippo Ck) [w/o Chip Ck] - 030

Table 3.9 Aquatic life use causes of impairment and TMDLs developed for 030.

14-digit HUC	Description	River mile	Causes	Method of TMDL (see Chapter 4)				
				QUAL2K nutrient/ DO	GWLF nutrient	QHEI habitat	QHEI sediment	Other (explained)
030-010	Tusc. R. mainstem below Wolf Ck to above Chippewa Ck	110.7-103.2	Flow alteration, organic enrichment, nutrients, total dissolved solids	X				
030-020	Tusc R. mainstem below Chippewa Ck to above Fox Run	103.2-97.5	Organic enrichment, suspended solids, nutrients, total dissolved solids	X				
030-030	Nimisila Ck headwaters to Nimisila Reservoir	Upst-5.5	Habitat alt., flow alteration, siltation, organic enrichment			X	X	†
030-050	Fox Run	All	Habitat alteration, flow alteration, siltation, organic enrichment		X	X	X	
030-060	Tusc R. mainstem below Fox Run to above Sippo Creek	97.5-90.83	Flow alteration, organic enrichment, nutrients	X				
030-080	Newman Creek above Orrville Ditch	Upst-9.76	Habitat alteration, flow alteration, siltation, organic enrichment		X	X	X	
030-090	Orrville Ditch	All	Habitat alteration, flow alteration, siltation, organic enrichment		X	X	X	
030-110	West Sippo Creek	All	Habitat alteration, flow alteration, siltation, organic enrichment		X	X	X	
030-120	Sippo Creek	All	Habitat alteration, flow alteration, siltation, organic enrichment			X	X	Pathogens to address enrichment

† The GWLF nutrient modeling method is not appropriate to address the 030-030 14-digit HUC. See Section 5.3.1.

Table 3.10 Recreational use impairment and TMDL approach for 030.

Site	RM	Observed Condition[1] (fecal coliform cfu/100 ml)		Impaired	Area analyzed[2] (see Chapter 4)
05040001-030-010: Tuscarawas River below Wolf Cr. to above Chippewa Cr. (HUC 14)					
Tuscarawas R. @ Van Buren Rd.	108.0	Geometric mean	990	YES	These mainstem sites are addressed with two LDC curves (Section 5.3.1)
		90th percentile	3060		
Tuscarawas R. @ Main St., Clinton	104.3	Geometric mean	741	YES	
		90th percentile	4040		
05040001-030-020: Tuscarawas River below Chippewa Cr. to above Fox Run [except Nimisila Cr.] (HUC 14)					
Tuscarawas R. @ Market St., Canal Fulton	100.3	Geometric mean	1271	YES	**LDC** for site
		90th percentile	3140		
5040001-030-060: Tuscarawas R below Fox Run to above Sippo Cr. [excluding named tributaries.] (HUC 14)					
Tuscarawas R. High Mill Rd.	94.87	Geometric mean	1185	YES	**LDC** for site
		90th percentile	10000		
05040001-030-070: Mudbrook Creek (HUC 14)					
Mudbrook Creek @ Crystal Lake Ave	0.47	Geometric mean	1018	YES	14-HUC
		90th percentile	1340		
05040001-030-080: Newman Creek above Orrville Ditch (HUC 14)					
Newman Creek @ Burkhart Rd.	11.9	Geometric mean	881	YES	Site ('05 data impair, 11.4 mi^2)
		90th percentile	3450		
05040001-030-090: Orrville Ditch (HUC 14)					
Orrville Ditch @ Tannerville Rd.	2.29	Geometric mean	684	YES	14-HUC
		90th percentile	5095		
1.03 UT to 0.52 UT to Orrville Ditch @ Coal Bank Rd.		Geometric mean	929	YES	
		90th percentile	3750		
05040001-030-100: Newman Creek below Orrville Ditch to Tuscarawas R. (HUC 14)					
Newman Creek @ Earl Rd.	0.75	Geometric mean	638	YES	14-HUC
		90th percentile	4950		
05040001-030-110: West Sippo Creek (HUC 14)					
W. Sippo Creek @ Skyland Ave.	3.8	Geometric mean	1099	YES	14-HUC
		90th percentile	2220		
W. Sippo Creek @ 17th Ave. NW	1.2	Geometric mean	1719	YES	
		90th percentile	4120		
05040001-030-120: Sippo Creek (HUC 14)					
Sippo Creek @ Belmont/ Meadowood St.	4.6	Geometric mean	1745	YES	14-HUC
		90th percentile	2710		
UT to Sippo Creek (L. Cable Outlet) @ Meadowview Dr.	2.77	Geometric mean	1859	YES	
		90th percentile	5060		

[1] Geometric mean criterion for fecal coliform bacteria is 1000 cfu/100 ml and 90th percentile criterion for fecal coliform is 2000 cfu/100 ml.
[2] "Site" indicates that the watershed analysis included the drainage area ending at that sample location; "LDC" indicates that a load duration curve was generated at that point; and "14-HUC" indicates that the entire 14 digit HUC was modeled.

3.2.4 Tuscarawas River (below Sippo Ck to above Sugar Ck) – 090

Table 3.11 Aquatic life use causes of impairment and TMDLs developed for 090.

14-digit HUC	Description	River mile	Causes	Method of TMDL (see Chapter 4)				
				QUAL2K nutrient/DO	GWLF nutrient	QHEI habitat	QHEI sediment	Other (explained)
090-010	Tusc R. mainstem below Sippo Creek to above Pigeon Run	90.83-86.7	Unknown toxicity, organic enrichment	X				
090-030	Partial: Unnamed tributary to Tusc River at river mile 83.74	All	Flow alteration, nutrients		X	X		
090-040	Partial: Wolf Run	All	pH, metals					AMD surrogate
090-040	Partial: Small Middle Run	All	Siltation, metals				X	
090-040	Partial: Middle Run	All	Siltation, metals				X	

Table 3.12 Recreational use impairment and TMDL approach for 090.

Site	RM	Observed Condition[1] (fecal coliform cfu/100 ml)		Impaired	Area analyzed[2] (see Chapter 4)
05040001-090-020: Pigeon Run (HUC 14)					
Pigeon Run @ Barrs Rd.	4.11	Geometric mean	405	No	14-HUC
		90th percentile	1590		
Pigeon Run @ Warmont Ave.	0.24	Geometric mean	990	YES	
		90th percentile	3159		
05040001-090-030: Tuscarawas River below Pigeon Cr. to above Sandy Cr. (HUC 14)					
UT to Tusc R. RM 83.74 (Fohl Creek) in Park	0.2	Geometric mean	2387	YES	Site (9.18 mi^2)
		90th percentile	20600		
UT to Tusc R. RM 77.96 @ Gravel road	0.3	Geometric mean	3817	YES	Site (5.22 mi^2)
		90th percentile	5460		
05040001-090-040: Tuscarawas River below Sandy Cr. to above Conotton Cr. (HUC 14)					
Small Middle Run @ CR 81 Canal Rd	0.06	Geometric mean 90th percentile	1594 5796	YES	Site (3.50 mi^2)

[1] Geometric mean criterion for fecal coliform bacteria is 1000 cfu/100 ml and 90th percentile criterion for fecal coliform is 2000 cfu/100 ml.
[2] "Site" indicates that the watershed analysis included the drainage area ending at that sample location; "LDC" indicates that a load duration curve was generated at that point; and "14-HUC" indicates that the entire 14 digit HUC was modeled.

3.2.5 Tuscarawas River (below Sugar Ck to above Stillwater Ck) -130

Table 3.13 Aquatic life use causes of impairment and TMDLs developed for 130.

14-digit HUC	Description	River mile	Causes	Method of TMDL (see Chapter 4)				
				QUAL2K nutrient/DO	GWLF nutrient	QHEI habitat	QHEI sediment	Other (explained)
130-010	Partial: Stone Creek upst of Crooked Creek	Upst-7.2	Organic enrichment					Pathogens to address enrichment
130-010	Partial: Crooked Creek	All	Siltation, habitat alteration, flow alteration			X	X	
130-030	Oldtown Creek	All	Siltation, metals, habitat alteration, flow alteration			X	X	
130-040	Beaverdam Creek	All	Siltation, metals				X	
130-050	Partial: Pike Run	All	pH, metals					AMD surrogate

Table 3.14 Recreational use impairment and TMDL approach for 130.

Site	RM	Observed Condition[1] (fecal coliform cfu/100 ml)		Impaired	Area analyzed[2] (see Chapter 4)
05040001-130-010: Stone Creek (HUC 14)					
Stone Creek - Dup A @ at North street	8.1	Geometric mean	17125	YES	14-HUC
		90th percentile	21200		
Stone Creek @ Rice Road	6.4	Geometric mean	2167	YES	
		90th percentile	3460		
UT to Stone Ck RM 6.0 @ Devonshire Park	0.2	Geometric mean	1298	YES	
		90th percentile	2108		
Stone Creek @ Mathias Raceway Rd.	4.3	Geometric mean	2483	YES	
		90th percentile	3380		
Crooked Run @ Private lane	1.8	Geometric mean	7461	YES	
		90th percentile	13980		
Stone Creek @ at mouth	0.1	Geometric mean	5874	YES	
		90th percentile	20850		
05040001-130-030: Oldtown Creek (HUC 14)					
Oldtown Creek @ TR 243	7.3	Geometric mean	673	No	14-HUC
		90th percentile	808		
Oldtown Creek @ TR 263 (Aubihl Rd)	5.39	Geometric mean	2883	YES	
		90th percentile	6760		
Oldtown Creek @ SR 416	0.3	Geometric mean	1118	YES	
		90th percentile	2000		
05040001-130-040: Beaverdam Creek (HUC 14)					
Beaverdam Creek @ TR 313	6.9	Geometric mean	224	YES	14 HUC
		90th percentile	4501		
Beaverdam Ck @ Baltzley Valley Rd	0.94	Geometric mean	1528	YES	
		90th percentile	12994		

[1] Geometric mean criterion for fecal coliform bacteria is 1000 cfu/100 ml and 90th percentile criterion for fecal coliform is 2000 cfu/100 ml.
[2] "Site" indicates that the watershed analysis included the drainage area ending at that sample location; "LDC" indicates that a load duration curve was generated at that point; and "14-HUC" indicates that the entire 14 digit HUC was modeled.

3.2.6 Tuscarawas River (below Stillwater Ck to above Evans Ck) – 180

Table 3.15 Aquatic life use causes of impairment and TMDLs developed for 180.

14-digit HUC	Description of HUC	River mile	Causes	Method of TMDL (see Chapter 4)				
				QUAL2K nutrient/DO	GWLF nutrient	QHEI habitat	QHEI sediment	Other (explained)
180-010	Partial: Mud Run	All	Siltation, metals				X	AMD surrogate
180-020	Partial: Frys Run	All	Habitat alteration, siltation, metals			X	X	AMD surrogate
180-030	Dunlap Creek	All	Habitat alteration, siltation			X	X	
180-050	Buckhorn Creek	All	Organic enrichment, habitat alteration, siltation		X	X	X	

Table 3.16 Recreational use impairment and TMDL approach for HUC 180.

Site	RM	Observed Condition[1] (fecal coliform cfu/100 ml)		Impaired	Area analyzed[2] (see Chapter 4)
05040001-180-030: Dunlap Creek (HUC 14)					
Dunlap Creek @ SR 258 (upper crossing)	4.0	Geometric mean	967	No	14-HUC
		90th percentile	1626		
Dunlap Creek @ TR 118 (Dog Rd)	2.1	Geometric mean	3162	YES	
		90th percentile	3680		
Dunlap Creek @ SR 258	0.2	Geometric mean	1421	YES	
		90th percentile	2060		
Browning Run @ SR 258 @ mouth	0.3	Geometric mean	603	No	
		90th percentile	674		
05040001-180-040: Tuscarawas River below Dunlap Cr. to above Evans Cr. [except Buckhorn Cr.] (HUC 14)					
Blue Ridge Run @ Twp Rd. 105	0.4	Geometric mean	2454	YES	Site (3.06 mi^2)
		90th percentile	3000		
Rodney Run @ Porcher Rd	0.1	Geometric mean	1245	YES	
		90th percentile	1774		
05040001-180-050: Buckhorn Creek (HUC 14)					
Buckhorn Creek @ Twp Rd 215	4.9	Geometric mean	4742	YES	14-HUC
		90th percentile	5800		
Buckhorn Creek @ Cross St.	1.4	Geometric mean	1391	YES	
		90th percentile	2360		
Lick Run @ 1st Lane near mouth	0.4	Geometric mean	1728	YES	
		90th percentile	2000		
W. Fk. Buckhorn Cr. @ Stone Cr. Rd	0.1	Geometric mean	8759	YES	
		90th percentile	57200		
Indiancamp Ck @ Mt. Zion Cem. Rd. (TR 225)		Geometric mean	319	No	
		90th percentile	894		

[1] Geometric mean criterion for fecal coliform bacteria is 1000 cfu/100 ml and 90th percentile criterion for fecal coliform is 2000 cfu/100 ml.

[2] "Site" indicates that the watershed analysis included the drainage area ending at that sample location; "LDC" indicates that a load duration curve was generated at that point; and "14-HUC" indicates that the entire 14 digit HUC was modeled.

3.2.7 Tuscarawas River (above Evans Ck to Muskingum R) – 190

Table 3.17 Aquatic life use causes of impairment and TMDLs developed for HUC 190.

14-digit HUC	Description	River mile	Causes	Method of TMDL (see Chapter 4)				
				QUAL2K nutrient/DO	GWLF nutrient	QHEI habitat	QHEI sediment	Other (explained)
190-040	East Fork White Eyes Creek	All	Ammonia, nutrients		X			
190-050	Partial: Morgan Run	All	Metals, pH					AMD surrogate
190-050	Partial: Tusc River unnamed tributary at river mile 3.78	All	Unknown					

Table 3.18 Recreational use impairment and TMDL approach for HUC 190.

Site	RM	Observed Condition[1] (fecal coliform cfu/100 ml)		Impaired	Area analyzed[2] (see Chapter 4)
05040001-190-010: Evans Creek (HUC 14)					
Evans Creek @ Twp Rd. 246	5.1	Geometric mean	3474	YES	14-HUC
		90th percentile	4780		
Evans Creek @ Evans Creek downstream cattle	3.1	Geometric mean	44572	YES	
		90th percentile	71600		
Evans Creek @ St. Rt. 751	0.7	Geometric mean	5915	YES	
		90th percentile	19000		
Davis Run @ Silverthorn Road TR 172	0.3	Geometric mean	509	No	
		90th percentile	724		
Hoffman Run @ SR 751	0.2	Geometric mean	1381	YES	
		90th percentile	2628		
Sweigert Run @ SR 751	0.3	Geometric mean	401	No	
		90th percentile	640		
05040001-190-020: White Eyes Creek [except W. Fk. White Eyes Cr. & E. Fk. White Eyes Cr.] (HUC 14)					
White Eyes Creek @ 2nd bridge ust Fresno	5.1	Geometric mean	3524	YES	14-HUC (RM 1 site impaired based on '05 data.)
		90th percentile	4700		
White Eyes Ck @ TR 170	1.0	Geometric mean	1042	YES	
		90th percentile	1916		
05040001-190-030: West Fork White Eyes Creek (HUC 14)					
West Fork White Eyes Creek W of Pearl - CR 10	3.68	Geometric mean	1429	YES	Site (11.85 mi^2)
		90th percentile	2980		
West Fork White Eyes Creek @ West of SR 93	0.3	Geometric mean	884	No	-
		90th percentile	1061		
05040001-190-040: East Fork White Eyes Creek (HUC 14)					
East Fork White Eyes Creek @ TR 171A	3.0	Geometric mean	8850	YES	14-HUC
		90th percentile	15080		
		90th percentile	880		

[1] Geometric mean criterion for fecal coliform bacteria is 1000 cfu/100 ml and 90th percentile criterion for fecal coliform is 2000 cfu/100 ml.
[2] "Site" indicates that the watershed analysis included the drainage area ending at that sample location; "LDC" indicates that a load duration curve was generated at that point; and "14-HUC" indicates that the entire 14 digit HUC was modeled.

4.0 TMDL DEVELOPMENT

A TMDL is a tool used in achieving water quality standards. TMDLs accomplish a first step towards restoring a waterbody by calculating how much water quality improvement must occur. This is done by estimating how much a given pollutant (or other type of stressor) is getting to the waterbody, and then determining the contributions made by each of the identified sources. These existing conditions are compared to target conditions, which is the loading capacity of the system. The difference between the two is the level of abatement that is needed. The loading capacity is the quantity of a pollutant that a waterbody can receive and still maintain water quality standards. The loading capacity is dependent upon the physical, chemical and biological processes occurring in the waterbody. Allocation of the TMDL involves the equitable distribution of the loading capacity to all known sources in consideration of technical and economical feasibility, as well as water-quality related implications.

In a more technical sense, a TMDL is defined as the sum of its load allocations, wasteload allocations and a margin of safety. Load allocations (LA) are the portion of the TMDL reserved for nonpoint sources of pollution. Wasteload allocations (WLA) are the portion reserved for point sources. The margin of safety (MOS) is a portion of the TMDL reserved for uncertainty in the method of calculation. MOS may be included explicitly or implicitly. TMDLs are required to consider both critical condition and seasonality for each parameter of concern.

TMDLs may be expressed in terms of either mass per time, toxicity or other appropriate measures. TMDLs are often calculated on a monthly, seasonal, or annual basis dependent upon the nature of the parameter of concern. The spatial scale at which a TMDL is calculated is dependent upon the distribution of impairment within the TMDL study area. TMDLs can be calculated for individual stream segments, subwatersheds or entire watersheds.

4.1 Methods of TMDL Development

This section outlines the TMDL methods that are used to address each cause of water quality impairment.

4.1.1 Watershed Hydrology (GWLF)

The hydrologic cycle for the subwatersheds receiving nutrient and/or pathogen TMDLs is simulated using the Generalized Watershed Loading Function or GWLF model (Haith, et al., 1992) through the desktop simulation called BasinSim 1.0 (Dai, et al., 2000). The model predicts stream flow based on precipitation, evapotranspiration, land uses and soil characteristics. Figure 4.1 shows the hydrologic model of GWLF.

GWLF simulates runoff, groundwater recharge and stream flow by a water-balance method using measurements of daily precipitation and average temperature. Runoff is calculated using the Natural Resources Conservation Service's Runoff Curve Number method (USDA, 1986). This method determines the amount of precipitation that runs off the surface and is adjusted for antecedent soil moisture before the precipitation event, growing or dormant season, detention potential and soil characteristics. Curve numbers vary by land cover, use and soil type; the higher the curve number the more runoff produced. The predicted surface runoff flow is the quick response flow including interflow and drainage from tiles.

Groundwater recharge is determined by tracking daily water balances in the unsaturated and shallow saturated zones. These zones act as reservoirs and have inputs and outputs. The input to the unsaturated zone is the infiltrated water calculated as the amount of the precipitation received less the surface runoff. Water leaves this zone to the atmosphere via plant root uptake through transpiration and down to the shallow saturated zone through percolation. Transpiration is grouped with evaporation to make an evapotranspiration function. GWLF determines a daily potential evapotranspiration based on day length, temperature and a cover coefficient of plant or crop in the area of interest. If there is enough available moisture in the unsaturated zone, the potential evapotranspiration will be lost to the atmosphere. If the available moisture in the unsaturated zone is less than that day's potential evapotranspiration, all water in that zone will go to the atmosphere. When the temperature is less than or equal to zero, there is no evapotranspiration. Percolation occurs daily when the unsaturated zone moisture volume exceeds the storage capacity after any evapotranspiration occurs. The shallow saturated zone receives the percolated water. This zone is treated as a linear reservoir; it can discharge water to the stream as baseflow or lose moisture to deep seepage. Each of these losses is determined by the product of the zone's moisture storage and a specific constant rate coefficient (one for baseflow and one for seepage).

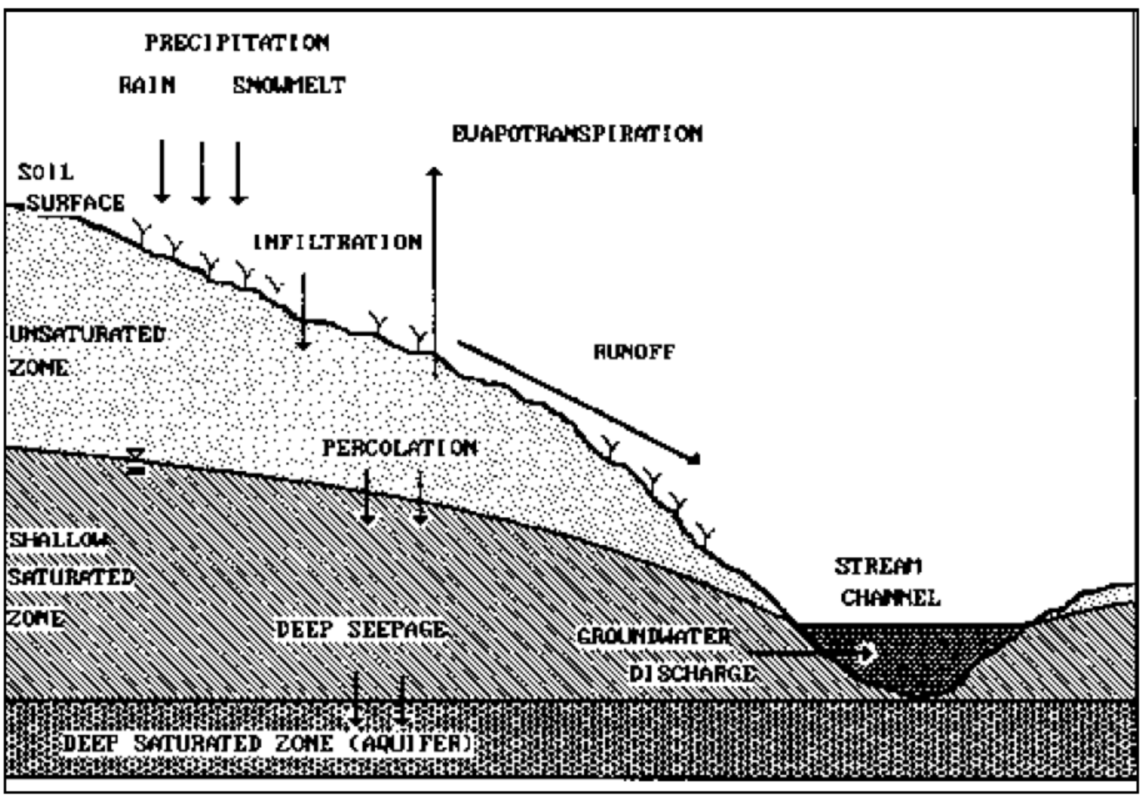

Figure 4.1 GWLF Model hydrology component interaction (Dai et al., 2000).

Stream flow is computed as the sum of the groundwater discharge from the shallow saturated zone (baseflow) and the surface runoff. The model computes the daily water balance and resulting stream flow.

GWLF hydrology transport files are prepared for four watersheds with USGS gage records in and near the Tuscarawas River watershed. Since no nutrient or pathogen impaired watersheds have a USGS gage at their outfalls, these four gages are used to determine transport functions applicable to the impaired watersheds. Table 4.1 shows which impaired watersheds each of the four gages characterize.

Model simulations are performed for each of the subwatersheds that are upstream of the listed gages using data from the appropriate weather stations. This includes more than 13 years of simulation computed for each watershed. Table 4.2 shows the time span for which the model simulation was performed and a ratio of the predicted stream flows over the observed data from the USGS gages. These data are aggregated by month to provide consideration for the medium level resolution of the GWLF model.

Hydrology calibration is carried out on all four gages to improve fit agreement with monthly aggregated observed gage flow. This is accomplished by comparing total flows, baseflow and runoff of the model output to the actual gage data. Gage baseflow and runoff are estimated using a hydrologic stream flow separation algorithm. After analysis, reasonable changes to GWLF transport functions and curve numbers are made whereupon the flow analysis would be repeated. Several calibration trials are carried out for each of the gages until the best model fit is established.

Two values used to determine how well the predicted calibrated model total flow results compare to the observed total flow are presented in Table 4.2. The coefficient of determination (the R^2 value) is a unitless measure ranging from 0 to 1 that indicates the degree of correlation between two data sets. Higher values indicate that the model results more closely correspond to the observed data, and the value of 1 reflects a perfect fit. The predicted to observed ratio indicates if the model is under or over predicting the stream flow, and also indicates how well the two data sets compare.

Table 4.1 USGS gage sites used as GWLF hydrology calibration watersheds.

USGS gage used for GWLF hydrology calibration	Impaired watershed		Impaired		
	14-dig HUC	Name	Nutrient	Target total phosphorus (mg/l)	Pathogen
Gage # 03115973 Schocalog Run at Copley Junction OH	010-010 part[1]	Tusc. River upst. Mogadore Rd.			X
	010-030 part	Wolf Ck UT RM 11			X
	010-030 full[1]	upper Wolf Creek	Modeled for upstream flow		
	010-040 full	Pigeon Creek	X	0.28	X
	010-050 full	middle Wolf Creek			X
Gage # 03116200 Chippewa Creek at Easton OH	020-030 part	Steel Ditch			X
	020-030 part	Tommy Run			X
	020-040 full	Little Chippewa Ck	X	0.28	X
	020-050 full	River Styx	X	0.28	X
	020-060 part	Mill Creek			X
	020-070 full	Red Run	X	0.34	X
	020-080 part	Silver Creek	X	0.17[2]	X
	030-120 full	Sippo Creek			X
Gage # 03123000 Sugar Creek above Beach City Dam at Beach City OH	030-050 full	Fox Run	X	0.08	
	030-070 full	Mudbrook Creek			X
	030-080 full	upper Newman Ck	X	0.08	X
	030-090 full	Orrville Ditch	X	0.34	X
	030-100 full	lower Newman Ck			X
	030-110 full	West Sippo Creek	X	0.08	X
	090-020 full	Pigeon Run			X
	090-030 part	Tusc R. UT RM 78.0			X
	090-030 part	Tusc R. UT RM 83.7	X	0.08	X
	090-040 part	Small Mid Run			X
Gage # 03140000 Mill Creek near Coshocton OH	130-010 full	Stone Creek			X
	130-030 full	Oldtown Creek			X
	130-040 full	Beaverdam Creek			X
	180-030 full	Dunlap Creek			X
	180-040 part	Blue Ridge Run			X
	180-050 full	Buckhorn Creek	X	0.10	X
	190-010 full	Evans Creek			X
	190-020 full	White Eyes Ck (excluding EF & WF)			X
	190-030 part	upper W. Fork White Eyes Creek			X
	190-030 full	Full W. Fork White Eyes Creek	Modeled for upstream flow		
	190-040 full	E.F. White Eyes Ck	X	0.08	X

[1]"Full" indicates that the entire HUC 14 subwatershed was modeled while "part" indicates only part of the HUC 14 subwatershed was modeled.
[2] See Silver Creek's modeling discussed in Section 5.2.1 for explanation of using this total phosphorus instream concentration target.

Table 4.2 Comparison of GWLF predicted stream flow with USGS stream flow values.

Gage #	Stream	Years of simulation	R^2 Value[1]	Predicted to observed ratio
Gage # 03115973	Schocalog Run at Copley Junction OH	14	0.742	1.027
Gage # 03116200	Chippewa Creek at Easton OH	22	0.764	1.205
Gage # 03123000	Sugar Creek above Beach City Dam at Beach City OH	26	0.755	1.103
Gage # 03140000	Mill Creek near Coshocton OH	49	0.816	1.093

[1] All p-values for the regressions are less than 0.05.

Sources of Data
Specifics of how the GWLF model was built and executed for this study are presented in Appendix E. Land use and weather data are critical components of hydrology functions of GWLF. The National Land Cover Dataset (NLCD) is used as the land cover resource for this study. NLCD is compiled from Landsat TM satellite imagery circa 1992 and includes 23 classes of land use (USGS, 2000). Several weather stations are used from around the Tuscarawas River watershed and its surrounding area. Daily precipitation and temperature data were acquired from the Midwestern Regional Climate Center.

4.1.2 Nutrient Enrichment

The total existing nutrient (i.e., total phosphorus) load is equal to the sum of the individual source loads. For the purpose of this study, surface runoff, point sources, HSTS and groundwater are considered as potential sources. The methods used to calculate the existing load, loading capacity and allocations are summarized in Table 4.3.

The method of development has inherent assumptions that result in uncertainty in the calculated loads. Every effort is made to base each assumption upon a justifiable rationale or value. A description of the assumptions made in the calculation of the source loads and the loading capacity is provided below.

Table 4.3 Summary of nutrient TMDL development.

Development step	Source		Method
Existing load	Point source		Discharger self-monitoring data used to estimate total phosphorus loading.
	Surface runoff		GWLF nutrient simulations.
	Ground water		GWLF nutrient simulations.
	HSTS		Population served by failing HSTS is estimated via GIS and county Health Departments. Total phosphorus load based upon population estimate and a per capita loading rate.
Calculation of loading capacity	-		Product of the annual discharge volume from each sub-basin (GWLF hydrology) and the total phosphorus target concentration.
Allocation	WLA	Point Sources	Product of design flow rate and technology based effluent limitation of 1.0 mg TP/ml (or less depending on plant type).
		MS4	MS4s are allocated a portion of the total LA. MS4s allocations are the product of the percentage of the sub-basin area occupied by MS4s and the sub-basin surface runoff allocation.
	LA	Surface runoff	Surface runoff is equal to the sum of all WLAs, MOS and natural runoff subtracted from the assimilative capacity.
		Natural runoff	The expected background total phosphorus load is determined based on running GWLF considering all lands to be unmanaged.
		HSTS	Home sewage treatment systems are allocated a total phosphorus load of zero.
	Margin of safety		Five percent of the assimilative capacity is reserved for the margin of safety.

Surface Runoff

The Generalized Watershed Loading Function (GWLF) model's BasinSim application is used to determine the total phosphorus load from runoff and groundwater. Section 4.1.1 above addresses GWLF's hydrology calculations. GWLF inputs of total phosphorus sediment runoff concentrations for various land uses are determined using reference values from the user's guide augmented by any known values available. Since the model requires one groundwater phosphorus concentration per watershed, data from Ohio EPA's ambient groundwater sampling program are used. Specifics on the GWLF nutrient model use are included in Appendix E.

Effort is made to further break down managed agricultural land uses for GWLF phosphorus modeling. This includes determining the expected areas of manure application from livestock Concentrated Animal Feeding Operations (CAFOs) and regular livestock manure application. Areas receiving municipal wastewater sludge field application are also determined. A slightly increased concentration of phosphorus in runoff from these lands is included in the model simulations. Appendix E contains more information about this break down. Table 4.4 below shows the amount of pasture and row crop land receiving waste applications using model simulations for existing conditions.

Table 4.4 Amount of pasture and row crop receiving waste applications.

14-dig HUC	Name	% of Pasture				% of Row crop			
		CAFO	Regular manure	Sewage sludge	No manure application	CAFO	Regular manure	Sewage sludge	No manure application
010-040 full	Pigeon Creek	0	1.0	0.3	98.7	0	1.0	0.4	98.6
020-040 full	Little Chippewa Ck	5.2	37.2	1.7	55.8	3.6	9.4	1.9	85.0
020-050 full	River Styx	0	38.7	3.2	58.1	0	9.6	4.4	86.0
020-070 full	Red Run	19.1	28.7	9.1	43.1	10.4	8.2	7.7	73.7
020-080 part	Silver Creek	0	37.9	5.3	56.8	0	8.9	11.2	79.9
030-050 full	Fox Run	5.4	33.3	11.4	49.9	3.0	8.7	9.7	78.6
030-080 full	upper Newman Ck	0	36.7	8.2	55.1	0	9.0	9.5	81.4
030-090 full	Orrville Ditch	25.9	29.6	0	44.5	21.6	7.8	0	70.5
030-110 full	West Sippo Creek	0	22.7	9.4	68.0	0	7.3	9.1	83.7
090-030 part	Tusc R. UT RM 83.7	0	9.5	5.1	85.4	0	4.8	5.0	90.3
180-050 full	Buckhorn Creek	0	29.8	0.6	69.5	0	7.8	1.9	90.3
190-040 full	E.F. White Eyes Ck	0	30.0	0	70.0	0	8.0	0	92.0

Point Sources
The concentration of phosphorus effluent from conventional point source discharges is largely based on empirical data collected by the individual discharging entities. In the case of several smaller package plants, however, no phosphorus monitoring data are available to characterize the quality of their effluent. For these instances, effluent phosphorus concentrations are based upon the best professional judgment of Ohio EPA staff with knowledge of the operations at each facility. While the estimated effluent concentrations may result in under or over prediction of the contributed loads, the size of the loads are relatively small when compared to the major dischargers in the sub-basin. To calculate the existing load of total phosphorus discharged from these facilities each facility's current effluent flow rates are used. It should be noted that most dischargers' effluent flow is currently below design flow.

Home Sewage Treatment Systems
The number of HSTS in each 14-digit HUC is estimated based upon 1990 and 2000 census demographic information, except for watershed areas within Coshocton County. The Coshocton County Health Department provided their own GIS data of the distribution of HSTS. The percentage of failing HSTS is based on information from health departments, field observations and GIS analysis of the age of houses in a watershed. For detailed information regarding HSTS values see Appendix E.

HSTS pollutant loads are estimated as the product of the number of persons served by failing systems in each subwatershed, a per capita wastewater flow-rate and representative wastewater-quality pollutant concentrations (Metcalf & Eddy, 1991).

Existing Load Validation
Modeling results mirrored the actual total phosphorus water quality data in the watershed, although they are consistently slightly higher. This could partially be explained by the conservative manner in which the model parameters are determined. However, since the water quality dataset is relatively small and is neither seasonally distributed nor long-term, the validation results should be viewed with some caution.

Loading Capacity and TMDL
Annual loading capacity for each watershed is determined by taking the product of the annual stream flow and phosphorus concentration target. The annual stream flow is the average of the GWLF modeled hydrology (explained above in Section 4.1.1). The concentration target is dependent on the watershed's drainage area and aquatic life use designation (described in Section 3.1.1). The loading capacity calculation accounts only for dilution as a means of assimilation. The method makes no attempt to account for the chemical and biological cycling of phosphorus through the system that could potentially increase the loading capacity of the streams. No accurate prediction of instream processing is possible without the development of a receiving stream model or extensive empirical data. Since this method of TMDL is only being applied to 14-digit HUC watersheds or smaller, a receiving stream model is thought to be unnecessary. Section 4.1.4 describes more detailed instream modeling activities carried out for the Tuscarawas River mainstem.

Allocations
Existing phosphorus loads are allocated for each watershed to meet the annual TMDL. A five percent margin of safety is taken out of the loading capacity explicitly (see Section 4.3) and the natural, or background, load expected from each watershed is removed. This background load is estimated by a GWLF model simulation where all model inputs reflect unmanaged (forest) land uses. All HSTS are assumed to be discharging systems and must receive a zero load allocation. This assumption is made in part because there is a lack of information regarding the type of systems used in the watershed in addition to the fact that properly functioning HSTS otherwise make no pollutant contribution to surface waters. Point source facilities with a design flow at or greater than 0.1 million gallons per day and are believed to have average total phosphorus effluent concentrations above 1.0 mg/l receive the technology based effluent limitation of 1.0 mg/l of total phosphorus. Each facility's average design flow is used for all allocations, and because of this, facilities that do not require total phosphorus reductions often have higher load allocations than the calculated existing conditions. The remaining loading capacity is allocated to nonpoint sources (the load allocation) and MS4 areas such that prescribed percent reductions are equal to the proportion of the watershed that they constitute.

Application
Refer to Table 4.1 for a list of all the watersheds with this GWLF watershed nutrient TMDL method applied. This table also shows the target average nutrient concentration that is modeled for each watershed. These concentrations are based on the aquatic life use designation and stream size (see Section 3.1.1). Map 9 and Map 10 in Appendix D show the distribution of these watersheds.

4.1.3 Habitat Alteration and Sedimentation

The Qualitative Habitat Evaluation Index (QHEI) is used for the habitat and sediment TMDLs in this report. The QHEI provides a qualitatively derived score to indicate the quality of the habitat of a stream segment. Both the habitat and sediment TMDLs developed for this project area use these scores to determine the deviation from a prescribed target condition. Section 3.1.2 describes these targets as well as the QHEI in greater detail.

The QHEI evaluates a relatively short reach of stream and therefore can only be applied on a site by site basis. For this reason deviations and allocations for these TMDLs are also given on a site by site basis, which varies from the allocations that are given on a watershed or sub-watershed basis for parameters that have loading quantified (e.g., total phosphorus). Table 4.5

lists the watersheds that contain sites for which habitat and sediment TMDLs have been developed.

Table 4.5 Streams sites receiving QHEI habitat and/or sediment TMDL.

HUC 11	HUC 14	Description of area	Habitat TMDL	Sediment TMDL
010	030	Wolf Ck-headwaters to upstream Pigeon Ck	X	X
	040	Pigeon Creek	X	X
	050	Partial: Van Hyning Run		X
	060	Hudson Run	X	X
020	010	Partial: Sites that are Chippewa Lake inputs	X	X
	030	Partial: Tommy Run	X	X
	040	Little Chippewa Creek	X	X
	050	River Styx	X	X
	070	Red Run	X	X
	080	Partial: Chippewa Creek mainstem	X	X
030	030	Nimisila Creek-headwaters to Nimisila Reservoir	X	X
	050	Fox Run	X	X
	080	Newman Creek above Orrville Ditch	X	X
	090	Orrville Ditch	X	X
	110	West Sippo Creek	X	X
	120	Sippo Creek	X	X
090	030	Partial: Unnamed Trib. to Tusc. River (RM 83.74)	X	
	040	Partial: Small Middle Run		X
	040	Partial: Middle Run		X
130	010	Partial: Crooked Creek	X	X
	030	Oldtown Creek	X	X
	040	Beaverdam Creek		X
180	010	Partial: Mud Run		X
	020	Partial: Frys Run	X	X
	030	Dunlap Creek	X	X
	050	Buckhorn Creek	X	X

Protecting for Downstream Use

Aquatic life use designations are determined based on a stream or stream segment's ability to support a particular level of quality of its aquatic life. When a stream with a lower use designation flows into one with a higher use designation, the criteria of the downstream use need to be maintained. At times the criteria or targets applicable to a waterbody need to be more restrictive than those associated with its designated use to protect downstream uses. In the case of habitat, aquatic organisms not only respond to conditions at the local scale in which the QHEI evaluates, but also on a larger more regional scale, which is not accounted for with the QHEI. Therefore, protecting downstream uses may require upstream habitat conditions to be suitable for supporting that aquatic life use. In such instances the use of target intended for WWH is appropriate.

4.1.4 Organic Enrichment/Dissolved Oxygen

The Tuscarawas River in the vicinity of the City of Barberton showed consistently low dissolved oxygen during several low flow surveys conducted by Ohio EPA in 2004 and 2005. Dissolved oxygen is assessed using the QUAL2K Dissolved Oxygen model, version 2.04 (Chapra, 2005).

Besides simulating D.O., QUAL2K is used to simulate the decay of organic and inorganic phosphorus in the stream, because excessive phosphorus is conducive to nuisance algae problems. The study area is found to be enriched with excessive phosphorus concentrations (downstream of the Barberton WWTP), when compared to typical phosphorus concentrations in streams that meet their use designation. Calibration of the model is developed using data collected during a stream survey conducted by the Ohio EPA during 14-16 September 2005. The decay rates for CBOD, ammonia, phosphorus and other parameters are determined from survey data, and used in the model. Other relevant parameters (such as reaeration, sediment oxygen demand, benthic algae, etc.) are calculated or estimated based on field observations, literature values or predictive equations recommended by Ohio EPA. The model results are compared to the observed data and the estimated inputs adjusted accordingly.

QUAL2K Model Description

Qual2K is a one-dimensional, steady-state model which is used to simulate D.O., CBOD, organic & inorganic phosphorus, and the nitrogen series. All these parameters, as well as atmospheric reaeration, sediment oxygen demand, and many other physical and environmental factors are taken into consideration by the model to simulate dissolved oxygen.

QUAL2K uses a mass balance approach which divides each reach in the study area into computational elements that represent a series of linked completely mixed reactors. Each element is a separate system which has an initial external input and internal interactions that either add to or reduce the dissolved oxygen. The final output of an element is the sum of the input and these interactions and it represents the input into the next element.

Each reach represents a stretch of river that has constant hydraulic characteristics (e.g., slope, bottom width, etc.). The major branches of the system, the main stem and each of the tributaries, are referred to as segments (Chapra, 2005). Figure 4.2 shows a QUAL2K segment (with no tributaries) and its possible components. The reaches are numbered in ascending order starting from the headwater of the river's main stem. Appendix E provides more details about the QUAL2K simulations.

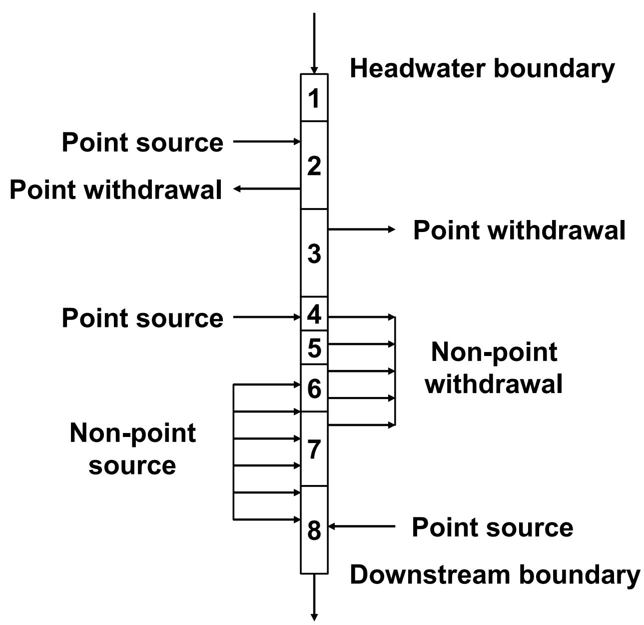

Figure 4.2 Segmentation scheme of the QUAL2K model (Chapra and Pelletier, 2003).

The QUAL2K model is applied to the segment shown in Figure 4.3 because it includes several reaches found to be impaired for the aquatic life use designation due to organic enrichment/D.O. and nutrients. Table 4.6 identifies the impaired segments, hydrologic unit codes, cause of impairment and target used for TMDL development.

Model Calibration
The QUAL2K model was calibrated from RM 115 to RM 106 (km 185 to 170) using a combination of data collected by Ohio EPA during several surveys conducted under low flow conditions in 2005. Figure 4.4 shows the results of the dissolved oxygen calibration performed for the Tuscarawas River near Barberton.

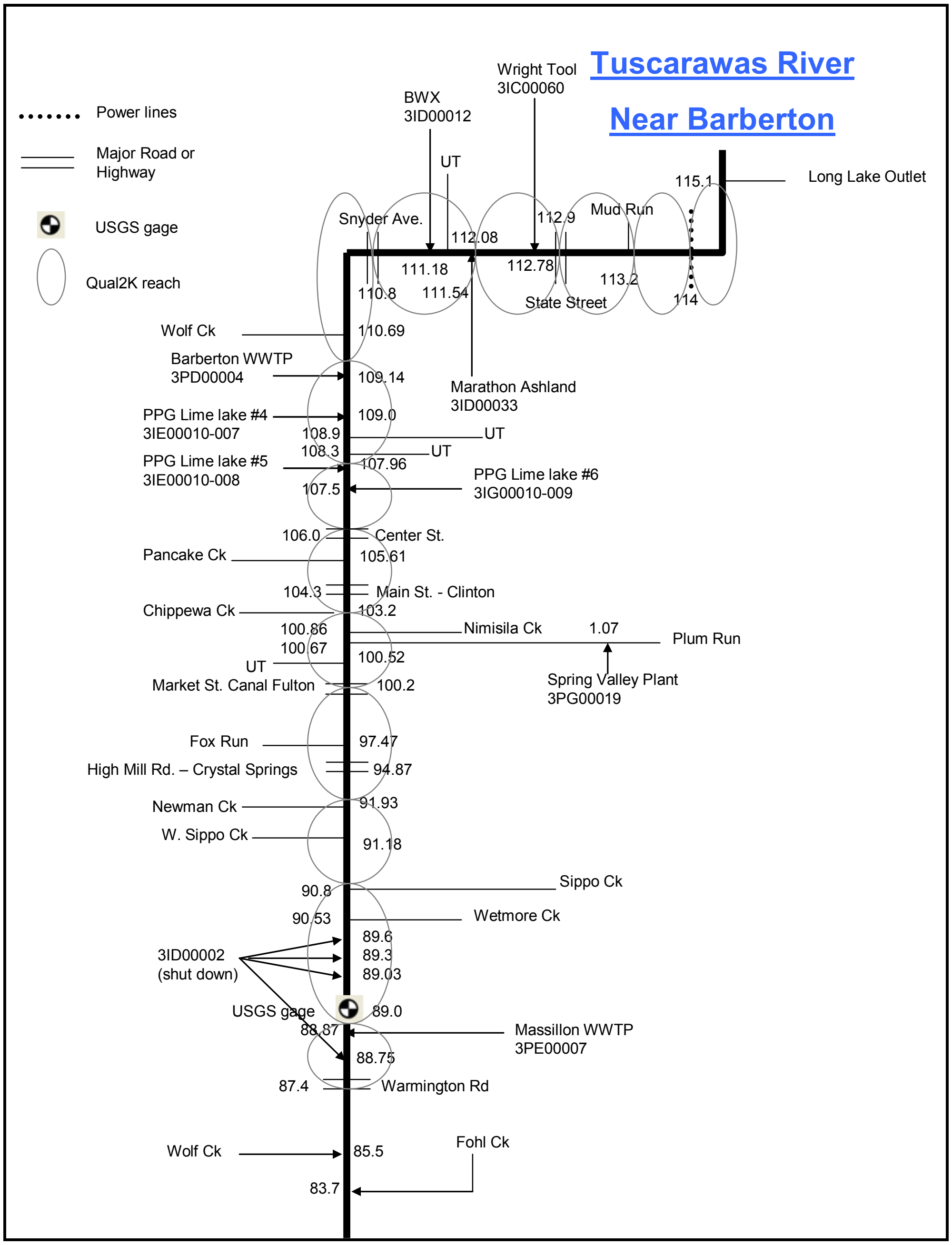

Figure 4.3 Reaches modeled with QUAL2K in the Tuscarawas River.

Table 4.6 Tuscarawas River segments and sites impaired by organic enrichment /DO and nutrients and modeled with QUAL2K.

14-dig HUC and Name	Impaired Sites		Parameter & Target		
	Use Designation	Name & River Mile	Total P	D.O.	Target (mg/l)
HUC 05040001-010-020 Tuscarawas River: below Diversion dam to upstream Wolf Ck	WWH	Tusc. River dst. Long Lake, RM 115.	-	-	D.O. = 5, P = 0.08
	WWH	Tusc. River at power lines, RM 114	-	X	D.O. = 5, P = 0.08
	WWH	Tusc. River at Highland RR bridge, RM 113.3	-	-	D.O. = 5, P = 0.08
	MWH	Tusc. River at State St, RM 112.9	-	X	D.O. = 4, P = 0.08
	MWH	Tusc. River at Snyder St. RM 110.8	-	X	D.O. = 4, P = 0.28
HUC 05040001-030-010 Tuscarawas River: Downstream Wolf Ck to above Chippewa Ck	MWH	Tusc. R. upst Barberton WWTP, RM 109.5	-	-	D.O. = 4, P = 0.28
	MWH	Tusc. R.dst Barberton WWTP, RM 108.0	X	-	D.O. = 4, P = 0.28
	MWH	Tusc. R. @ Main St, Clinton, RM 104.3	X	-	D.O. = 4, P = 0.28
HUC 05040001-030-020 Tuscarawas River: Downstream Chippewa Ck to above Fox Run	WWH	Tusc. R. @ Market St, Canal Fulton, RM100.3	X	-	D.O. = 5, P = 0.17
HUC 05040001-030-060 Tuscarawas River: Below Fox Run to Above Sippo Ck	WWH	Tusc. R. @ High Mill Rd, RM 94.87	X	-	D.O. = 5, P = 0.17
HUC 05040001-090-010 Tuscarawas River: Below Sippo Ck to Above Pigeon Run	WWH	Tusc. R. @ Walnut St, RM 90.4	X	-	D.O. = 5, P = 0.17
	WWH	Tusc. R @ Warmington Rd, RM 87.4	X	-	D.O. = 5, P = 0.17

- Indicates that this site is meeting its target

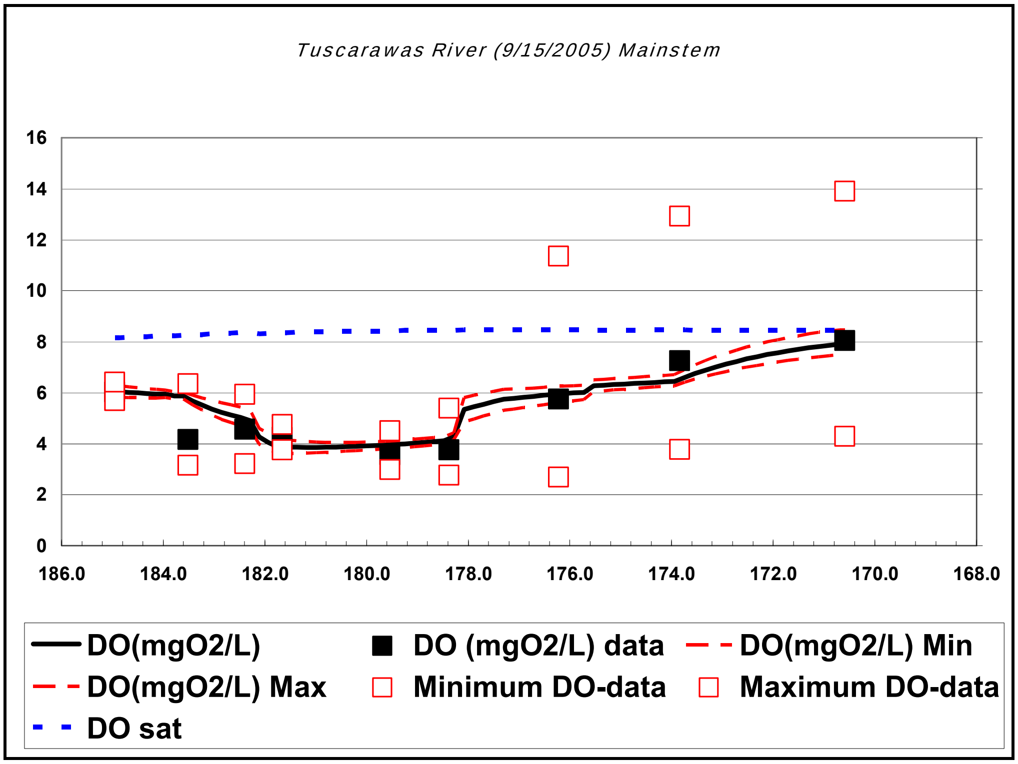

Figure 4.4 Comparison of calibration vs. observed D.O. in the Tuscarawas R. near Barberton on 15 September 2005.

Note: the *x*-axis displays distance upstream from the mouth of the Tuscarawas River as measured in kilometers (river mile interval corresponds to approximately 115 to 106).

The calibration survey (15 September 2005) was performed under 7Q10 conditions (i.e., the lowest seven day flow conditions over a ten year period). The reaeration coefficients were determined using the Negulescu-Rojanski equation recommended by Ohio EPA guidelines for the calculation of reaeration coefficients for Ohio streams, based on the stream's average slope (Skalsky et al., 2000). Downstream of Wolf Creek (RM 110.7) the Tuscarawas River is wider, due to channelization and a larger drainage area. The wider channel makes the stream shallower, and allows more sunlight to reach the stream bottom. Figure 4.5 shows the average stream widths in the Tuscarawas River between RM 115 and 106. Figure 4.6 shows the dissolved oxygen profile of the Tuscarawas River during the 14-16 September 2005 calibration survey. The dissolved oxygen remains depressed and within a narrow range of variability until RM 109.5. The large phosphorus load from the Barberton WWTP (RM 109.1) and nutrient-rich groundwater inflows (RM 108 to 106) induce an increase in algal productivity that generates large diurnal swings in dissolved oxygen. The extreme D.O. swings provide additional evidence of nutrient enrichment that is causing excessive algal productivity.

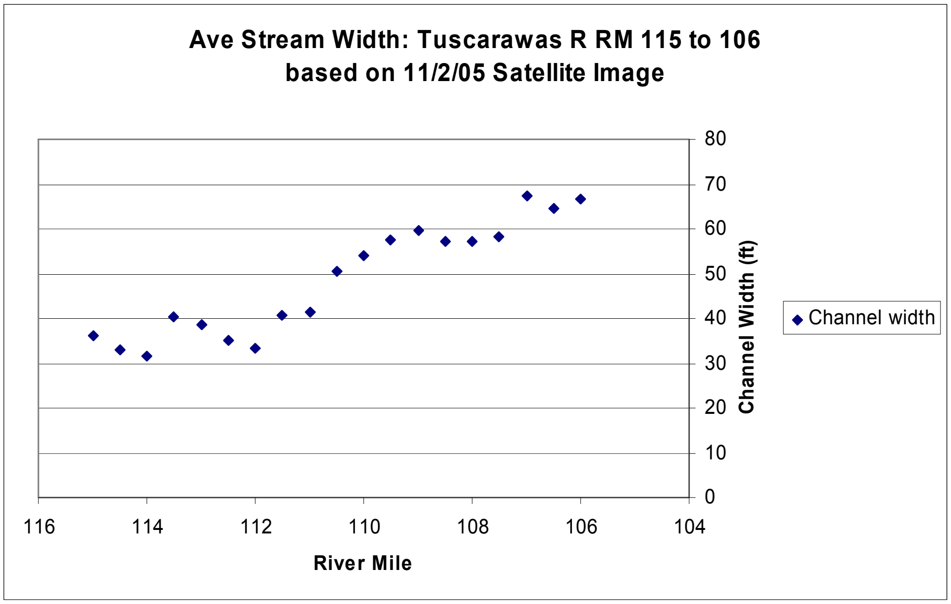

Figure 4.5 Estimated stream widths in the Tuscarawas R. near Barberton based on satellite imagery.

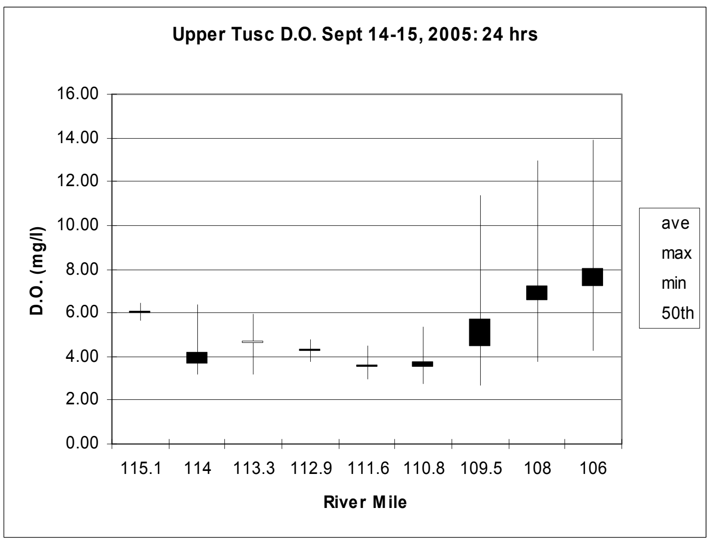

Figure 4.6 Range of observed dissolved oxygen data vs. river mile during the 14 September 2005 calibration survey in the Tuscarawas R. near Barberton.

The QUAL2K model was also calibrated for total phosphorus, as shown in Figure 4.7. During the calibration survey, the Barberton WWTP was discharging an effluent total phosphorus concentration of 10.9 mg/l, much higher than the typical effluent concentration for this plant (which has averaged 5.4 mg/l during the past few years).

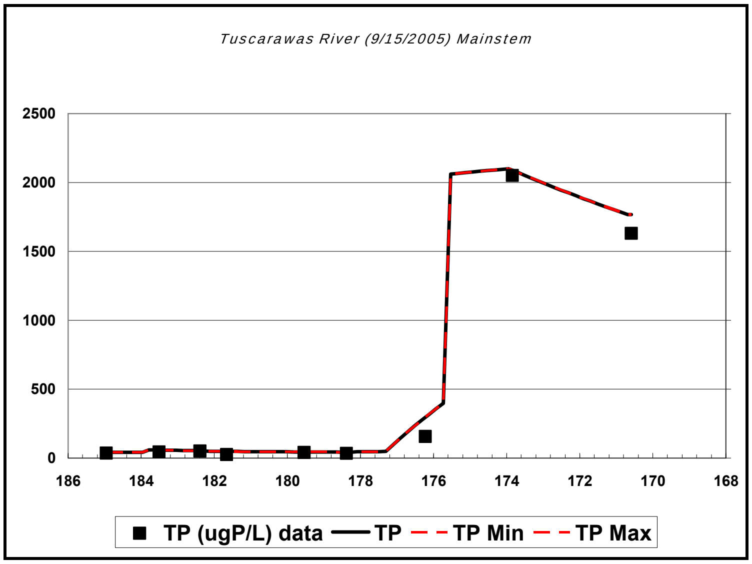

Figure 4.7 Comparison of calibration vs. observed total phosphorus in the Tuscarawas R. near Barberton on 15 September 2005.

Note: the *x*-axis displays distance upstream from the mouth of the Tuscarawas River as measured in kilometers (river mile interval corresponds to approximately 115 to 106).

4.1.5 Pathogens

The Bacteria Indicator Tool (BIT) is used for watersheds of a 14-digit HUC size (approximately 10-30 square miles). This method however, is not used for larger drainage areas due to limited availability of data of the appropriate spatial resolution for the BIT tool. Instead load duration curves are used to illustrate the current bacteria loading and the needed load reductions. Both TMDL methods use only fecal coliform for the load calculations and needed prescribed reductions.

The Bacteria Indicator Tool Method

Recreational use impairments are summarized in Section 3.2. If more than one site within a 14-digit HUC does not meet the recreational use attainment, or if there is an impaired site near the terminus of the subwatershed, the entire 14-digit HUC is modeled. If only an upstream site of a 14-digit HUC or a tributary within a 14-digit HUC is impaired and the mainstem is not, only the impaired part of the 14-digit HUC is assessed. The areas modeled with BIT are described in Section 3.2. All recreational use impaired watersheds are modeled by the Bacteria Indicator Tool method except the Chippewa Creek and Tuscarawas River mainstem sites. These are noted throughout Section 3.2 as 'LDC' meaning Load Duration Curve. That method is described below.

Table 4.7 Summary of pathogen TMDL development.

<table>
<tr><th>Development step</th><th colspan="2">Source</th><th>Method</th></tr>
<tr><td rowspan="4">Existing load</td><td colspan="2">Point source</td><td>Product of discharger design flow and the fecal coliform average standard currently in place.</td></tr>
<tr><td colspan="2">Surface runoff</td><td>BIT tool with spreadsheet washoff model.</td></tr>
<tr><td colspan="2">HSTS</td><td>Population served by failing HSTS estimated via GIS and county Health Departments. Fecal coliform load based upon population estimate and a per capita loading rate.</td></tr>
<tr><td colspan="2">Upstream load</td><td>Product of the recreation season discharge volume from any upstream drainage (GWLF hydrology) and the fecal coliform geometric mean concentration.</td></tr>
<tr><td>Calculation of loading capacity</td><td colspan="2">-</td><td>Product of the recreation season discharge volume from each sub-basin (GWLF hydrology) and the fecal coliform geometric mean concentration found in the water quality standards.</td></tr>
<tr><td rowspan="5">Allocation</td><td colspan="2">Upstream load</td><td>Product of the recreation season discharge volume from any upstream drainage (GWLF hydrology) and the fecal coliform geometric mean concentration.</td></tr>
<tr><td rowspan="2">WLA</td><td>Point sources</td><td>Product of discharger design flow and the fecal coliform average standard currently in place.</td></tr>
<tr><td>MS4</td><td>MS4s are allocated a portion of the total LA. MS4 allocations are the product of the percentage of the sub-basin area occupied by MS4s and the sub-basin surface runoff allocation.</td></tr>
<tr><td rowspan="2">LA</td><td>Surface runoff</td><td>LA is equal to the sum of all WLAs (except for MS4 runoff) and upstream load subtracted from the assimilative capacity.</td></tr>
<tr><td>HSTS</td><td>Home sewage treatment systems are allocated a bacteria load of zero.</td></tr>
</table>

Existing Loads

The U.S. EPA's Bacteria Indicator Tool (BIT) is employed to estimate the fecal coliform load accumulated within the watershed in each 14-digit HUC or tributary determined recreationally impaired. BIT estimates the monthly accumulation rate of fecal coliform bacteria on four land uses (cropland, forested, built-up, and pastureland), as well as the asymptotic limit for that accumulation when no washoff occurs. It also estimates direct input of fecal coliform bacteria to streams from grazing agricultural animals and failing septic systems (U.S. EPA, 2000).

The Bacteria Indicator Tool uses three types of values: user-defined, default and literature. User-defined values are to be specific to the study area. User-defined values required by the tool are land use distribution, numbers of agricultural animals and wildlife densities. Default values are supplied by the tool, but it is suggested that they are modified to reflect patterns in the study area. Default values include the fraction of each manure type applied each month, the fraction of manure type that is incorporated into the soil and the time spent grazing and confined by agricultural animals. Like default values, literature values are supplied by the tool, but they may be replaced with user values if better information is available for the study area. Literature values required by the tool are animal waste production rates and fecal coliform bacteria content, fecal coliform bacteria accumulation rates for built-up land uses and raw sewage fecal coliform bacteria content and waste production.

Literature values are unchanged for each HUC because limited watershed-specific information is available that would better characterize the area. Values for the amount of time cattle graze in streams is limited only to those streams with evidence of cattle access as observed by Ohio EPA field staff. All other default values are left unchanged. User-defined values are determined via the following methods:

- The land use distribution is derived from the National Land Cover Dataset (NLCD) via GIS analysis. The NLCD is compiled from Landsat TM satellite imagery circa 1992 (USGS, 2000). NLCD information is reclassified to agree with the land use categories of BIT.

- Populations of agricultural livestock and wildlife are derived from countywide figures. Information regarding the amount of livestock is obtained from Ohio Agricultural Statistics Service published data. Information regarding wildlife populations is obtained from Ohio Department of Natural Resource census data. In each case, the total number of animals within the county is divided by the total number of acres of relevant land use in the county. The resulting animal densities (animals per acre) are used to estimate the animal populations within each 14-digit HUC.

When all values are entered, a spreadsheet method is used to estimate the pollutant loads from bacteria washoff. This method uses a combination of empirical data and literature or default values in each calculation. Bacteria washoff is estimated using the daily land-surface accumulation rate generated by BIT, and a washoff equation common to SWMM, HSPF and GWLF. In addition to the daily accumulation rate, the washoff equation requires daily runoff and a washoff coefficient as inputs. Daily runoff is estimated using the SCS curve-number method. Appendix E explains this in more detail.

The method used to calculate pollutant loads from NPDES dischargers takes into consideration that all facilities with fecal coliform as an expected effluent are already required to meet the water quality standard for primary contact recreational use. Because of this, the product of each facility's design flow and the fecal coliform geometric mean standard of 1000 cfu per 100 ml are used for existing load calculations.

The number of HSTS and the percentage of those which are failing are determined in the same manner as was done modeling nutrient concentrations from HSTS. See Section 4.1.2 for details.

Bacteria loading is often difficult to quantify because there are rarely adequate data to accurately characterize individual sources. In such situations, BIT provides a means to make estimations of bacteria loads based upon justifiable values. While the use of literature values results in uncertainty, it is the best option available considering time and resource limitations. It is assumed that the literature and default values used in the load calculations are accurate representations of the actual watershed conditions. In the case of animal population information, the method assumes that the populations are evenly distributed across the county on the relevant land uses. Resources are not available to verify the accuracy of these assumptions.

Upstream Flow

The pathogen load contributed by upstream sub-watersheds to downstream waters is accounted for by adding a calculated load to the existing load generated within the receiving sub-watershed. This load is calculated by the product of the 1000 cfu per 100 ml geometric mean water quality standard concentration and the average annual flow volume of the upstream sub-watershed. The water quality standard concentration is used because it is a conservative assumption (i.e., an implicit margin of safety) that the upstream sub-watershed is just at the maximum value for the recreational use quality criterion. Additionally, the fact that bacteria is treated conservatively (i.e., no die-off) also adds an implicit margin of safety (see Section 4.3). If part or all of the upstream watersheds do not meet primary contact recreational use then that watershed is being addressed in this report and those exceedances should not have to be addressed again in the downstream sub-watersheds.

Loading Capacity and TMDL

Seasonal loading capacity for each watershed is determined by calculating the product of the seasonal stream flow and fecal coliform geometric mean concentration target. The seasonal stream flow is the average of the GWLF modeled hydrology for May through October 15 (explained above in Section 4.1.1). The geometric mean target is 1000 cfu per 100 ml for all primary recreational use streams and is described in Section 3.1.1. The loading capacity calculation accounts only for dilution as a means of assimilation.

Allocations

Existing fecal coliform loads are allocated for each watershed to meet the seasonal TMDL. Loading from unmanaged lands requires no reduction. NPDES dischargers currently have limits equal to the geometric mean fecal coliform standard, and their wasteload allocations are equal to this times their design flow. HSTSs should not contribute loading, therefore, have a zero allocation. Fecal coliform from cows grazing in streams also receive a zero allocation. The remaining loading capacity is allocated equally to NPS and MS4 sources of runoff. This results in an equal proportion of required reduction from all NPS and MS4 runoff source areas.

Application

Refer to Table 4.1 above for list of all streams segments with the GWLF watershed nutrient TMDL method applied in HUC order. Maps 13 and 14 in Appendix D show the watersheds with pathogen modeling in the upper and lower Tuscarawas River watersheds.

Load Duration Curves

Load duration curves (LDCs) have been developed for Tuscarawas River and Chippewa Creek mainstem at three sites to characterize seven mainstem sites that are impaired for recreational uses. A load duration curve is generated by the product of a target pollutant concentration and the values of a flow duration curve (FDC). A flow duration curve is the cumulative frequency of the daily mean flows that are ordered based on flow magnitude without consideration of the date or the time of year at which the flow occurred. The cumulative frequency is arranged from the highest magnitude flows to the lowest. From this, the percent of time (i.e., measured in the number of days) that a given flow is exceeded is expressed along the x-axis of the curve. The highest flows are exceeded at the lowest frequency and the lowest flows are exceeded at the highest frequencies which are at or near one hundred percent of the time.

The record of flow used to generate the FDC comes from USGS gages that have been gathering flow data at locations on the Tuscarawas River for some period of time. The available period or record is used to order the flows from the highest to lowest. To establish FDCs for locations that do not have USGS gages, a unit area hydrograph approach is taken. This is accomplished by multiplying the ratio of the drainage area of the point of interest and the drainage area at the gage. In essence the flow duration curve for locations upstream of the gage are identical to the FDC at the gage but corrected with some percent reduction in the magnitude of the flow (i.e., the shape of the curve is the same).

One of the values of the LDC is that it illustrates what the load should be for any flow event that occurs. A comparison can be made between the target load (i.e., reflected in the LDC) and the actual load which is derived by multiplying actual concentration data by actual or modeled flow data for a given day. Plotting all of the actual load data on the LDC shows which types of flow events are most often responsible for loads that are in excess of the target. This is particularly useful in identifying whether point sources or nonpoint sources are having a greater impact on the overall pollutant loading of the system. Load exceedences that are mostly associated with low flows suggest that point sources and/or illicit discharges are causing water quality problems. However, exceedances associated with high flow suggest that pollutants are reaching the stream system through runoff and controls should be directed to such sources.

The LDC method does not model pollutant loading to the system or provide specific information that is used to allocate load reductions to the respective sources. However, in this report the LDC method is used to illustrate the overall needed reduction within the larger streams of the basin. The following three reasons outline why using the BIT method is inappropriate for large streams and why using the simplified approach of the LDC is a reasonable alternative.

1) The BIT method employed for 14-digit HUC drainages (see above) only considers bacterial decay in land accumulated bacteria before it is washed off during precipitation. Following the simulated loading to the stream, decay is no longer accounted for in the model and downstream waters receive highly inflated estimated loads from upstream sources.

2) There are flow impoundments and withdraws that would significantly reduce the precision of the BIT method.

3) Subwatersheds with recreational use impairment that drain to impaired sites on large streams are dealt with using the BIT method. As those watersheds are brought into recreational use attainment, it can be expected that the ensuing load reductions to these larger stream sites would result in them achieving full attainment of water quality standards.

<u>Application</u>
These curves are included in Chapter 5 sections 5.2.1 and 5.3.1.

4.1.6 Other Water Quality Considerations

Some additional water quality considerations are addressing less frequent causes of impairment and areas where the modeling methods used in this report are not applicable. These special cases are noted in the tables in Section 3.2, and explained throughout Chapter 5. These cases include water quality impairment caused by acid mine drainage, total dissolved solids, nutrient enrichment in a very small watershed, among others.

4.2 Critical Condition and Seasonality

4.2.1 Nutrients

The critical condition for nutrient enrichment is the summer warm season, when the potential for primary production is highest. The summer concentration of phosphorus in the water column, however, is dependent upon more than the summer phosphorus load contributed to the stream. Phosphorus attached to sediment is transported to waterways during runoff events occurring at relatively wet times of the year. This phosphorus can become pooled in bottom sediment and later, detachment of this phosphorus can lead to elevated instream concentrations. This means that instream phosphorus concentrations can be high regardless of the magnitude of short-term loads. As a result, it is the long-term, or chronic, phosphorus load that is directly related to the degradation of water quality. For this reason phosphorus TMDLs are developed for all times of the year and reflective of all conditions, rather than a single critical condition.

4.2.2 Habitat and Sediment

A critical period regarding habitat quality and sediment loading is the summer dry period when environmental stress upon aquatic organisms is the greatest. It is during this period that the presence of high-quality habitat features, such as deep pools and unembedded substrate, is essential to provide refuge for aquatic life. QHEI scores, the basis of the habitat and sediment TMDLs, are assessed during the summer field season. The habitat and sediment TMDLs are therefore reflective of the critical condition.

Suitable habitat features are also critical during high flow events when aquatic organisms need refugia from high shear stresses and flow velocities as well as transported debris. These refugia come in the form of instream structures such as rootwads and boulders as well as floodplain habitats. High flow events are most frequent in the spring but occur fairly regularly throughout year.

4.2.3 Organic Enrichment/Dissolved Oxygen

The summer low flow period represents the most critical design condition for dissolved oxygen. The high temperatures induce faster decay of oxygen consuming wastes, causing a higher oxygen demand at a time when the water’s ability to absorb oxygen is reduced (because oxygen solubility in water is lower at higher temperatures). For this reason, the recommended effluent limits for CBOD and D.O., designed to meet the oxygen criteria during the summer, will provide year round protection of the dissolved oxygen standard. Ammonia effluent limits, which have been determined separately to prevent aquatic life toxicity, are also taken into account by QUAL2K simulations.

4.2.4 Pathogens

The critical condition for pathogens is the summer dry period when flows are lowest, and thus the potential for dilution is the lowest. Additionally, bacteria growth rates are highest during the warmer months of the year making load reductions more critical. Summer is the period when the probability of recreational contact is the highest. Recreational use designations are only applicable in the period May 1 to October 15 and pathogen TMDLs are developed for the same time period in consideration of the critical condition, and for agreement with Ohio WQS.

4.3 Margin of Safety

A margin of safety (MOS) is required to account for the uncertainty associated with estimating pollutant loads and the loading capacity of the system. Specifically, it is to safeguard against underestimating the needed level of abatement. The MOS can be incorporated implicitly by the conservative assumptions in the development of TMDLs. They can also be incorporated explicitly by allocating a portion of the loading capacity specifically for the MOS.

4.3.1 Nutrients

A margin of safety is incorporated both implicitly and explicitly into the nutrient (total phosphorus) TMDL. An implicit margin of safety is incorporated into the 303(d) listing process and the target development process (see below). Another implicit MOS is that the total phosphorus effluent limits apply year-round, although they are designed to meet the phosphorus target during the summer low flow critical conditions. There is also an explicit margin of safety to further account for uncertainty.

303(d) Listing

In Ohio, the attainment of designated aquatic life uses is determined through the direct measure of the biological community and the subsequent calculation of the appropriate biological indices. Ohio's water quality standards establish criteria for the aquatic life uses which are minimum scores for these indices. This direct measure of the biological community is the ultimate determination of attainment of designated aquatic life uses which supersedes water chemistry data.

Such an approach to evaluating aquatic life use attainment status results in assurance that these uses are being met before a given segment can be removed from the 303(d) list. This provides a safety net for any inadequacies of the established TMDLs used to address aquatic life use impairment. Specifically, if achieving the TMDL for a given pollutant does not lead to meeting the biocriteria, then the assessment unit must remain on the 303(d) list and the TMDL must be revisited.

Target Development

A conservative assumption implicit in target development lies in the selection of the median statistic used to represent the phosphorus target that corresponds to an unimpaired biological community. Since Ohio EPA's evaluation of phosphorus data for generating target values is based on measured performance of aquatic life and since full attainment can be observed at concentrations above this target (reinforcing the concept that habitat and other factors play an important role in supporting fully functioning biological communities), water quality attainment can occur at levels higher than the target. The difference between the pollutant concentrations where attainment has been observed and the selected target is an implicit margin of safety.

Explicit Margin of Safety

Five percent of the loading capacity is reserved as an explicit margin of safety for the nutrient TMDLs. The explicit margin of safety is included to account for any remaining uncertainty following the application of the implicit measures described above.

4.3.2 Habitat and Sediment

A MOS is implicitly incorporated into the sediment and habitat TMDLs through the use of conservative target values. The target values are developed though a comparison of paired IBI and QHEI evaluations (Ohio EPA, 1999). Using an IBI score of 40 as being representative of the attainment of WWH, individual components of the QHEI are analyzed to determine their magnitude at which WWH attainment is probable. Attainment does, however, occur at levels lower than the established targets (Ohio EPA, 1999). The difference between the habitat and sediment targets and the levels at which attainment has been observed is an implicit margin of safety.

4.3.3 Organic Enrichment/Dissolved Oxygen

The MOS is incorporated implicitly into this modeling process by selecting the critical low flow and running the model at summer water temperatures, with design flows and permit limits for the major wastewater treatment plants in the study area. Effluent concentrations at most of the wastewater treatment plants (WWTP) are lower than their permit limits, and most WWTPs are not discharging at their design flows. This results in a margin of safety because the calculated loading was determined by the product of the permit limit concentration and the design flow of the facility. Also, the relatively good fit for the hydrology calibration suggests that a key component of the model simulation is predicting the system accurately (see Appendix E for more details).

4.3.4 Pathogens

A margin of safety is implicitly incorporated into the pathogen TMDL. Loading of fecal coliform to each 14-digit HUC is quantified, as is the fecal coliform loading capacity at the outlet to each 14-digit HUC. Loading capacity is calculated as the product of the seasonal flow volume and the fecal coliform target concentration. Only die-off of land accumulated bacteria prior to runoff is considered in the BIT method. In reality, considerable die-off occurs between the source of loading and the TMDL endpoint, and this loss represents an implicit margin of safety.

4.4 Future Growth

Table 4.8 presents population data and growth rates for counties in the Tuscarawas River watershed. These data indicate that population growth is in general expected be low throughout most of the watershed. Coshocton County is expected to stagnate with nearly no population growth and Stark County is currently losing population. Only Medina County has experienced population growth greater than 2% in the last five years, but this growth is generally greater in the northern part of the county. For this reason only an implicit allowance for future growth is included in the TMDLs. Most wastewater treatment plants in the study area are currently operating well below their design capacity. The allocation of facilities at design flow is an implicit allowance for future growth.

Table 4.8 Population growth figures for Tuscarawas River watershed counties.

County	Population			2000-2005 % change	2005-2010 (projected) % change	County's rank (in state) of current growth
	2000[†]	2005[‡]	2010[▫]			
Coshocton County	**36,655**	**36,945**	**37,074**	**0.79**	**0.35**	**48**
Medina County	**151,095**	**167,010**	**173,758**	**10.53**	**4.04**	**5**
Guilford Township.	3,177	3,214	-	1.16	-	-
Sharon Township	4,244	4,389	-	3.42	-	-
Wadsworth Township	2,645	2,823	-	6.73	-	-
Westfield Township	3,118	3,559	-	14.14	-	-
Stark	**378,098**	**380,608**	**376,471**	**0.66**	**-1.09**	**53**
Bethlehem Township	5,650	5,857	-	3.66	-	-
Jackson Township	37,744	40,276	-	6.71	-	-
Lawrence Township	13,382	13,502	-	0.90	-	-
Perry Township	29,167	28,560	-	-2.08	-	-
Tuscarawas Township	6,093	6,163	-	1.15	-	-
Massillon, city	31,325	32,150	-	2.63	-	-
Summit County	**542,899**	**546,604**	**557,659**	**0.68**	**2.02**	**51**
Tuscarawas County	**90,914**	**91,944**	**93,164**	**1.13**	**1.33**	**44**
Wayne County	**111,564**	**113,697**	**119,846**	**1.91**	**5.41**	**35**

[†] US Census Bureau, 2000
[‡] US Census Bureau, 2005
[▫] Ohio Department of Development, 2003

5.0 WATERSHED ANALYSIS, LOADING CAPACITY, AND ALLOCATIONS

The following sections present results and discussion of the watershed analyses carried out for the Tuscarawas River TMDL watershed. The sections are organized by HUC 11 watersheds and each includes a brief overview of the TMDL analysis. The subsections are organized according to cause of impairment and are presented as nutrients and pathogens followed by habitat and sediment and conclude with the instream modeling (i.e., QUAL2K) which addresses organic enrichment and nutrients. When applicable, additional water quality issues are discussed, such as acid mine drainage.

Nutrient and pathogen TMDLs are presented together because they use a similar modeling approach and can be summarized using the same tables. Following a brief discussion of the modeling results and any special considerations, tables are used to show existing loads, TMDLs, and allocated loads for total phosphorus and fecal coliform. The first table shows the load values by recreation season for fecal coliform and annually for total phosphorus, while the second table contains their daily loads. Daily loads are calculated by distributing the overall load equally across the year and/or season (i.e., dividing by the modeled time interval). In both tables the overall percent reduction needed to meet the TMDL is shown.

In following tables the existing nonpoint source load is presented exclusively with the relative contribution from the various source areas. Other tables include allocations for NPDES dischargers, Municipal Separate Storm Sewer Systems (MS4) areas and home sewage treatment systems (HSTS).

In subsequent tables the existing nonpoint source loads are and their allocations presented, subdivided by source area. Existing and allocated loads for point sources are subdivided into NPDES facilities, Municipal Separate Storm Sewer Systems (MS4s) and home sewage treatment systems (HSTS). The next table subdivides the NPDES facility discharges among the individual permit holders within each subwatershed. If any NPDES facility discharger is required to reduce effluent pollutant loads this is outlined on another table. Finally a table listing the MS4 entities within each watershed is presented.

The habitat and sediment TMDLs, which are developed using the QHEI by site, are grouped together for each 11-digit HUC. First there is a discussion of the modeling results. The TMDL tables found within include the applicable targets per component in the header. The information presented in the body of the table is grouped by each of the 14-digit HUCs from upstream to downstream. The existing scores for each category and the total existing sediment and habitat score is given. The percent deviation from target is presented for each of the QHEI sub-metrics used in the sediment TMDLs. The sub-metric which is most responsible for the non-attainment of the overall sediment target is also indicated. The actual total habitat score per site can be compared to the allowable habitat score to make the same deviation determination. This table shows what components of the habitat need improvement and to what degree, and it can be used to guide management decisions and implementation activities.

Receiving stream QUAL2K modeling results and discussion are presented in the third subsection for each 11-digit HUC with this type of modeling.

5.1 Tuscarawas River (Headwaters to below Wolf Ck) – 010

This 11-digit HUC is split between the Tuscarawas River headwaters to Wolf Creek and Wolf Creek itself. The Tuscarawas River is further subdivided by a series of lakes in the mid-southern section of Summit County. Upstream of those lakes (14-digit HUC 010-010) exist some recreational and aquatic life use impairment. Below the most downstream of these lakes (the Long Lake Diversion Dam) in the 14-digit HUC 010-020, the Tuscarawas River mainstem has severe dissolved oxygen limitations and no recreational use impairment. Wolf Creek is heavily urbanized with several impaired tributaries: Pigeon Creek, Van Hyning Run and Hudson Run. As Wolf Creek joins the Tuscarawas River it is in full attainment of modified warm water habitat use, but does not meet the primary contact recreational use. The Tuscarawas River mainstem's impairment continues into the next 11-digit HUC, 030.

5.1.1 Watershed Nutrients and Pathogens

Pathogen Modeling

Four out of six subwatersheds do not meet primary contact recreational use in this 11-digit HUC (010-010, 010-030, 010-040, and 010-050). With the home sewage treatment systems (HSTS) bacteria allocation put to zero for two of these subwatersheds (010-040 Pigeon Creek and 010-050 lower Wolf Creek), no additional fecal coliform reduction is needed. Because of this no nonpoint source load bacteria reduction is required in those subwatersheds. The partial 14-digit HUC considered for 010-030, which is the unnamed tributary to Wolf Creek at river mile 10.96, only requires a 7% reduction of nonpoint source fecal coliform load. The partial 14-digit HUC considered for 010-010, which is the Tuscarawas River mainstem upstream of Mogadore Ave., requires a large nonpoint source reduction of 67.1%. Since most of these subwatersheds contain higher urbanized drainage, less fecal coliform from agriculture exists than in Tuscarawas River tributaries in other 11-digit HUCs.

Table 5.1 Total existing load, TMDL and allocations for 11-digit HUC 010 (annual/seasonal).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				%Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
010-010 partial	Tuscarawas R. upstream Mogadore Ave.	Headwaters - 126.7	FC[1]	493.4	9.1	-	502.5	99.4	3.00	0.008	3.0	-	implicit
010-030 partial	Unnamed tributary to Wolf Ck at RM 10.97	Head-3.95	FC[1]	42.0	1.8	-	43.9	96.1	1.71	0.00	1.7	-	implicit
010-040	Pigeon Creek	Entirety	FC[1]	747.8	3.8	-	751.6	98.6	10.72	0.4	3.8	-	implicit
			TP[2]	10907.36	4529.6	-	15437.0	0.0[3]	18619.3	10907.36	4529.6	-	931.0
010-050	Wolf Creek below Pigeon Cr. To Tuscarawas R	Entirety	FC[1]	451.1	1.7	18.0	470.7	95.3	22.19	0.07	1.65	18.0	-

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$
[3] The nutrient assessment and analysis for Pigeon creek indicates that existing loads are below the target for that waterbody and therefore reductions are not necessary.

Table 5.2 Total existing load, TMDL and allocations for 11-digit HUC 010 (daily).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				%Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
010-010 partial	Tuscarawas R. upstream Mogadore Ave.	Head-126.7	FC[1]	3.58	0.07	-	3.64	99.4	0.02	0.00006	0.02	-	-
010-030 partial	Unnamed tributary to Wolf Ck at RM 10.97	Head-3.95	FC[1]	0.30	0.01	-	0.32	96.1	0.01	0.00	0.01	-	-
010-040	Pigeon Creek	Entirety	FC[1]	5.42	0.03	-	5.45	98.6	0.08	0.002	0.03	-	-
			TP[2]	29.88	12.41	-	42.29	0.0[3]	51.01	29.88	12.41	-	2.55
010-050	Wolf Creek below Pigeon Cr. To Tuscarawas R	Entirety	FC[1]	3.27	0.01	0.13	3.41	93	0.16	0.0005	0.01	0.13	-

[1] cfu * 10^{13} * day^{-1}
[2] lbs * day^{-1}
[3] The nutrient assessment and analysis for Pigeon creek indicates that existing loads are below the target for that waterbody and therefore reductions are not necessary.

Table 5.3 Existing nonpoint source loads for 11-digit HUC 010.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Non-Point Source Loads						
				Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
010-010 Partial	Tuscarawas R. upstream Mogadore Ave.	Head - 126.7	FC[1]	0.98	8.10	0.004	-	-	0.004	9.09
010-030 partial	Unnamed tributary to Wolf Ck at RM 10.97	Head-3.95	FC[1]	0.13	1.67	0.01	-	-	0.03	1.84
010-040	Pigeon Creek	Entirety	FC[1]	0.19	3.62	0.03	-	-	0.0006	3.84
			TP[2]	1563.7	879.9	475.3	1596.4	-	14.3	4529.6
010-050	Wolf Creek below Pigeon Cr. To Tuscarawas R	Entirety	FC[1]	0.07	1.57	0.01	-	-	0.0004	1.65

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.4 Nonpoint source allocations for 11-digit HUC 010.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		Individual Non-Point Sources						
					Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
010-010 partial	Tuscarawas R. upstream Mogadore Ave.	Headwaters - 126.7	FC[1]	Allocation	0.32	2.67	0.004	-	-	0.001	3.00
				% Reduction	67.1	67.1	0.0	-	-	67.1	-
010-030 partial	Unnamed tributary to Wolf Ck at RM 10.97	Head-3.95	FC[1]	Allocation	0.12	1.55	0.01	-	-	0.02	1.71
				% Reduction	7.1	7.1	0.0	-	-	7.1	-
010-040	Pigeon Creek	Entirety	FC[1]	Allocation	0.19	3.62	0.03	-	-	0.0006	3.84
				% Reduction	0.0	0.0	0.0	-	-	0.0	-
			TP[2]	Allocation	1563.7	879.9	475.3	1596.4	-	14.3	4529.6
				% Reduction	0.0	0.0	0.0	0.0	-	0.0	-
010-050	Wolf Creek below Pigeon Cr. To Tuscarawas R	Entirety	FC[1]	Allocation	0.07	1.57	0.01	-	-	0.004	1.65
				% Reduction	0.0	0.0	0.0	-	-	0.0	-

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.5 Point source existing and allocated loads for 11-digit HUC 010.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		NPDES Discharger	MS4	HSTS
010-010 partial	Tuscarawas R. upstream Mogadore Ave.	126.7	FC[1]	Existing	0	0.02	493.38
				% reduction	-	67.1	100
				Allocation	0	0.008	0
010-030 partial	Unnamed tributary to Wolf Ck at RM 10.97	Head-3.95	FC[1]	Existing	0	0	42.04
				% reduction	-	-	100
				Allocation	0	0	0
010-040	Pigeon Creek	Entirety	FC[1]	Existing	0.23	0.15	747.40
				% reduction	0	0	100
				Allocation	0.23	0.15	0
			TP[2]	Existing	3335.8	3991.9	3579.6
				% reduction	0	0	0
				Allocation	3335.8	3991.9	3579.6
010-050	Wolf Creek below Pigeon Cr. To Tuscarawas R	Entirety	FC[1]	Existing	0.003	0.07	451.01
				% reduction	0	0	100
				Allocation	0.003	0.07	0

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.6 Existing and allocated loads for point source dischargers (not including MS4s and HSTSs) for HUC 010.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent	Facility	Parameter	Existing load	Percent Reduction	Allocated load
010-040	Pigeon Creek	Entirety	3PH00004 Copley Square Water Co.	FC[1]	0.1	0	0.1
			3PR00184 Cavanaugh Bldg Corp		0.001	0	0.001
			3PR00309 Covenant of Grace Church		0.001	0	0.001
			3PR00331 Metropolitan Vet Hospital		0.0007	0	0.0007
			3PR00381 Copley Towne Center		0.006	0	0.006
			3PT00038 Copley Fairlawn Middle School		0.02	0	0.02
			3GS00012 Copley Square Building		0.02		0.02
			3PG00118 Frasure Park Estates WWTP No 46		0.04	0	0.04
			3PT00047 Copley Fairlawn High Sch		0.02	0	0.02
			3PT00126 Arrowhead Elementary School		0.006	0	0.006
			3PT00127 Spring Garden Waldorf School		0.003	0	0.003
			3PW00008 Martin House Apts STP		0.02	0	0.02
			3IE00007 PVS Chemicals Inc Ohio	TP[2]	4.721	0	4.721
			3IR00102 Karman Rubber Co		1.426	0	1.426
			3IS00055 Adjusta-Post Mfg Co Norton		50.412	0	50.412
			3PH00004 Copley Square Water Co		1553.495	0	1553.495
			3PR00184 Cavanaugh Bldg Corp		13.707	0	13.707
			3PR00309 Covenant of Grace Church		13.707	0	13.707
			3PR00331 Metropolitan Vet Hospital		12.337	0	12.337
			3PR00381 Copley Towne Center		91.382	0	91.382
			3PT00038 Copley Fairlawn Middle School		219.317	0	219.317
			3GS00012 Copley Square Building		228.455	0	228.455
			3PG00118 Frasure Park Estates WWTP No 46		548.293	0	548.293
			3PR00184 Cavanaugh Bldg Corp		13.707	0	13.707
			3PT00047 Copley Fairlawn High Sch		219.317	0	219.317
			3PT00126 Arrowhead Elementary School		91.382	0	91.382
			3PT00127 Spring Garden Waldorf School		45.69104		45.69104
			3PW00008 Martin House Apts STP		228.455	0	228.455
010-050	Wolf Ck mouth	Entirety	3PR00205 VFW Loyal Oak Post No 4466	FC[1]	0.003	0	0.003

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.7 MS4 entities for 11-digit HUC 010.

14-Digit HUC	**Sub-Watershed**	**Sub-Watershed Extent** (Upper RM-Lower RM)	**MS4 entities**
010-010 Partial	Tuscarawas R. upstream Mogadore Ave.	126.7	Suffield Township (Portage County), Lake Township (Stark County), Hartville Village, Springfield Township (Summit County)
010-040	Pigeon Creek	Entirety	City of Akron
010-050	Wolf Creek below Pigeon Cr. To Tuscarawas R	Entirety	Barberton City, Norton City, Copley Township (Summit County)

5.1.2 Habitat and Sediment

010-030
The upper Wolf Creek 14-digit HUC 010-030 is impaired by both habitat and sediment. The two sites assessed on Wolf Creek and the unnamed tributary to Wolf Creek at river mile 10.97 fail to meet the habitat TMDL. While the Wolf Creek sites in this HUC both scored total QHEI scores of 60 or higher, there are many modified attributes which indicates channel and riparian disturbances. The portion of Wolf Creek that is just upstream of the Barberton Reservoir undergoes ditch maintenance by Summit County. That stream segment and the reservoir itself are sections that have not been assessed with the QHEI, but very much appear to have poor habitat quality.

The sediment TMDL for Wolf Creek in this 14-digit HUC meets expectations for a WWH stream and is therefore not impaired by sediment. The Wolf Creek unnamed tributary at river mile 10.97 is however impaired by sediment and is lacking about a third of the points needed to meet the target. Poor substrate is the primary reason for the deviation. The unnamed tributary to Wolf Creek at river mile 9.96 is in full attainment and is only included in the sediment and habitat TMDL table (which indicates it passes both TMDLs) to show all sites assessed in this 14-digit HUC.

010-040
All of Pigeon Creek and most of its tributaries, including Schocalog Run, are maintained as drainage ditches by Summit County. All three stream reaches assessed in this 14-digit HUC failed to meet the habitat TMDL targets and had scores of zero out of three. Additionally all of the QHEI assessment scores were less than 40. These sites also failed to meet the sediment TMDL by large margins. Recent channelization with no channel recovery, and various poor substrate attributes are observed throughout the watershed as described above (5.1.1). Pigeon Creek is not impaired by nutrients. Because of this, and given the large degree by which the Pigeon Creek sites fail to meet the habitat and sediment TMDLs, it is clear that habitat and sediment are the primary causes of impairment despite the lower water quality targets that are associated with MWH designated streams. This situation also occurs in the Chippewa Creek watershed (11-digit HUC 020).

010-050
Van Hyning Run is designated WWH and is listed as having sediment as a cause of impairment. However this stream meets the sediment TMDL with a total score of 39.5 out of the 31 points needed. The other cause of impairment listed (organic enrichment) appears to be the primary cause for this stream's non-attainment.

010-060
Hudson Run is considered impaired by habitat and sediment. The upper part of this watershed is slightly urbanized, but the lower section contains more dense development. At the river mile 3.7 sampling site both the habitat and sediment TMDLs meet expectations. This site however is in partial attainment. Just downstream of the river mile 3.7 site the stream is impounded becoming Lake Dorothy. Downstream of this lake is the river mile 1.4 sampling site. This site is in non-attainment of aquatic life use and fails both the sediment and habitat TMDLs. No recovery from channelization, very fine substrate, and low stream sinuosity are attributes of modification noted at this site. Just downstream of this site the stream is impounded again becoming Columbia Lake. This lake has PPG Industries facilities surrounding the entire north and southeastern end. Downstream of Columbia Lake the stream becomes MWH with an

artificial channel. No QHEI or aquatic life use assessments were made downstream of this point to the stream’s mouth.

Table 5.8 Sediment and habitat TMDLs for 11-digit HUC 010.

TMDL Targets For WWH		Sediment TMDL						Habitat TMDL						
		Allocations			TMDL			Allocations			Subscore			TMDL
		≥ 13	≥ 14	≥ 5	32			≥ 60 = *1 pt*	< 2 = *1 pt*	< 5 = *1 pt*				*3 pts*
Existing Scores Stream/River (Use) ***Impaired indicates use is not met***	**River Mile**	**QHEI Categories: Substrate**	**Channel**	**Riparian**	**Total Sediment Score**	**% Deviation from target**	**Main impaired category if any**	**QHEI Score**	**# of High Influence Attributes**	**Total # of Modified Attributes**	**QHEI**	**High influence**	**# Modified Attributes**	**Total Habitat Score**
Wolf Creek headwaters to above Pigeon Creek (05040001-010-030)														
Wolf Creek	13.7	12	13	8	33	**Meets**	Substrate	61	1	5	1	1	0	2
	11.9	15.5	15	2	32.5	**Meets**	Riparian	60	1	5	1	1	0	2
Trib to Wolf Creek (RM 10.97)	0.8	1	15	6	22	31.25	Substrate	48	1	6	0	1	0	1
Trib to Wolf Creek (RM 9.96)	0.6	16	17	8	41	**Meets**	**None**	68.5	0	3	1	1	1	**3**
Pigeon Creek (05040001 010 040)														
Pigeon Creek	4.7	9	5	6	20	37.50	Channel	37	3	8	0	0	0	0
	0.6	2.5	4	5	11.5	64.06	Substrate	39.5	2	8	0	0	0	0
Shocalog Run	0.5	2	5	5.5	12.5	60.94	Substrate	35.5	4	9	0	0	0	0
Wolf Creek below Pigeon Cr. to Tuscarawas R. [Excluding Hudson Run] (05060001-010-050)														
Van Hyning Run	0.6	15	18	6.5	39.5	**Meets**	**None**	**Not applicable**						
Hudson Run (05040001 010 060)														
Hudson Run	3.7	18	14.5	3	35.5	**Meets**	Riparian	69.5	0	0	1	1	1	**3**
	1.4	6.5	5.5	4.5	16.5	48.44	Channel	53.5	3	8	0	0	0	0
Trib to Hudson Run (RM 3.02)	1.1	18	20	9.5	47.5	**Meets**	**None**	81.5	0	0	1	1	1	**3**

5.1.3 Organic Enrichment/Dissolved Oxygen

010-020

The segment of the Tuscarawas River within this assessment unit begins at river mile 118 and leaves at river mile 110.7. The Tuscarawas River is classified Modified Warmwater Habitat (MWH) from river mile 112.9 (State Street) to RM 103.2 (mouth of Chippewa Creek). The river enters this assessment unit with very low concentrations of phosphorus and nitrogen, because most upstream nutrients have been assimilated as the stream travels through several lakes. The phosphorus target is met at all the monitoring sites therefore no phosphorus load reductions are required. However, numerous water quality surveys conducted by Ohio EPA (2004-2005) revealed a severe dissolved oxygen deficit between river miles 114 and 110.8. The extent of this segment is shown in Figure 5.1.

The main reason for the oxygen deficit is low reaeration. Reaeration is a process by which a stream entrains oxygen into the water column through turbulence associated with riffles and waterfalls and through diffusion at the water surface. Between the Long Lake outlet and the mouth of Wolf Creek the Tuscarawas River is channelized and has a low gradient (slope). The slow water velocity in conjunction with few riffles and other turbulence-causing features results in little opportunity for the stream to reaerate. Other suspected reasons for the D.O. deficit (although not measured in the field) are high sediment oxygen demand (from deposition of suspended solids and organic debris) and periodic contribution of nutrient-enriched water from the Ohio-Erie canal, through several cross-connections.

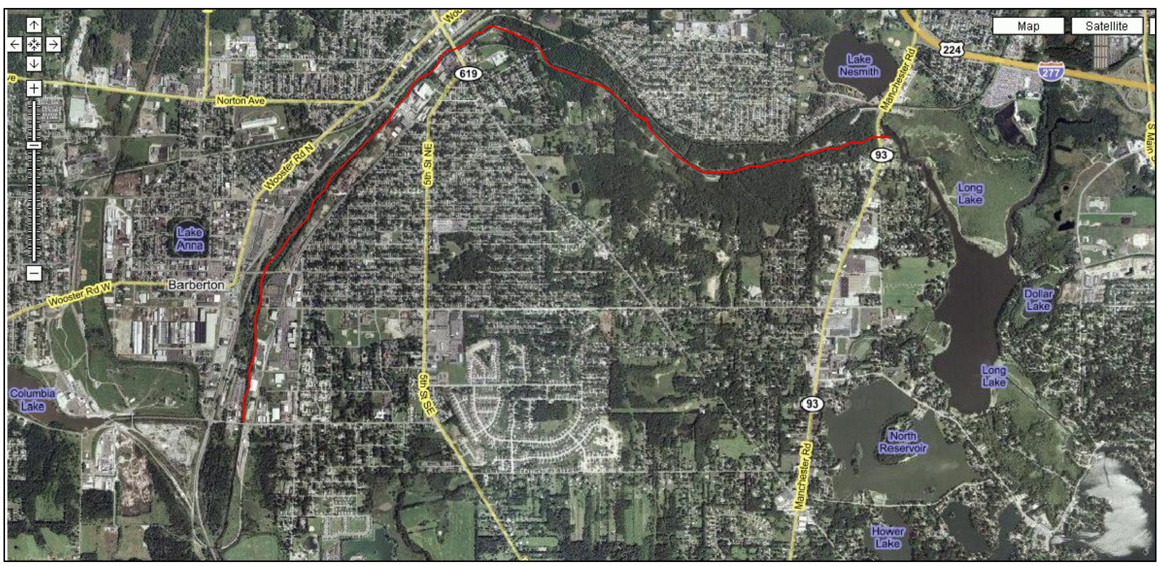

Figure 5.1 Tuscarawas River segment with low dissolved oxygen levels (highlighted in red).

The dissolved oxygen deficit in this segment is believed to be mostly due to physical limitations of the stream channel caused by hydrologic modifications, rather than a pollutant load issue. This report therefore does not attempt to quantify any load reductions needed to achieve D.O. water quality standards. The following general recommendations provide some guidance for city or county officials that wish to pursue improvements in this river segment:

- Field work performed by Ohio EPA determined that the pollutant loads from the Ohio-Erie Canal, unnamed tributary at R.M. 111.5 and Mud Run (the major tributaries to the Tuscarawas River in this reach) are insignificant under low flow conditions. However, the loads of oxygen-demanding substances during storm events may be significant, and could contribute to sediment oxygen demand. Storm event monitoring is recommended to estimate storm flow pollutant loads.

- A larger flow release from Long Lake (particularly during summer period) can increase the stream velocity and enhance natural re-aeration. The higher stream velocity can also reduce the deposition of solids that contribute to sediment oxygen demand. However, water volume management within this area is the subject of agreements between local units of government and the state of Ohio which are necessary for meeting IJC (International Joint Commission) commitments to prevent diversions of water from the Great Lakes basin in order to allow JEDD (Joint Economic Development Districts) activities in southern Summit County. Ohio EPA recommends that a larger discussion take place among affected stakeholders that will allow future balance of water quality considerations in the Tuscarawas River within the context of the protection against Great Lakes water diversions. Once the stakeholders have reached agreement, the QUAL2K D.O. model can be used to estimate additional aeration provided by higher streamflows (although some additional field work will be required).

Figure 5.2 shows a total P concentration duration curve that was developed for the Tuscarawas River at Snyder Road (RM 110.8), where Ohio EPA had a temporary monitoring station from 2004 to 2005 (see Section 4.1.4 for a brief description of load duration curves which are analogous to concentration duration curves). The plot shows that the concentrations of total P are below the target level (for Modified Warmwater Habitat streams) of 0.28 mg/l under a wide variety of streamflow conditions, based on data collected during 2003-04. Additional samples (not shown in the graph) were collected in 2005 under lower flow conditions, and also showed phosphorus concentration well below the target of 0.28 and the WWH target of 0.1 mg/l. For this reason, no phosphorus reductions are recommended at this time.

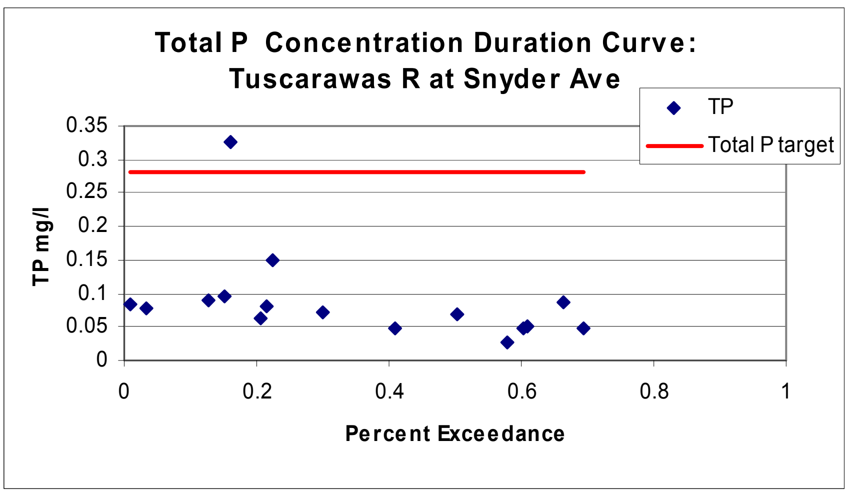

Figure 5.2 Concentration duration curve for total P for the Tuscarawas River at Snyder Road (2003-04 data).

010-050

Van Hyning Run is a small tributary designated as WWH, with a total drainage area of approximately 5 mi^2. It flows into Wolf Creek, which in turn meets the Tuscarawas River in Barberton. Although Van Hyning Creek at the mouth shows evidence of enrichment (with a concentration of total P of 0.31 mg/l near the mouth), the excess phosphorus is assimilated in

Wolf Creek, and meets the desired target by the time that Wolf Creek reaches the Tuscarawas River. Organic enrichment appears to be the primary cause for this stream's nonattainment. The suspected sources are two small wastewater treatment plants (Norton Acres and Brentwood Estates) and a greenhouse/ornamental plants retail business.

5.2 Chippewa Creek – 020

Chippewa Creek and several of its tributaries are under drainage maintenance by the Muskingum Watershed Conservancy District's Chippewa Subdistrict. The areas under this assessment program carry widespread habitat and sediment problems. Habitat and sediment are causes of impairment to tributaries upstream of Chippewa Lake in the upper portion of this watershed. In addition to channel modifications, grazing cattle with stream access is a source for the aquatic life and recreational use impairments in Little Chippewa Creek, Red Run and Steele Ditch. Point sources are also a significant cause of impairment of aquatic life use in Little Chippewa Creek, River Styx, Red Run and Silver Creek.

All of the Chippewa Creek mainstem sites located downstream of Chippewa Lake were found to be attaining the MWH aquatic life use except for the site closest to the mouth (RM 0.35) which is in non-attainment. This is not the case with respect to the recreational use criteria in Chippewa Creek downstream of Chippewa Lake. Fecal coliform bacteria counts at the sites located in this reach exceeded the Primary Contact Recreation Use geometric mean criterion of 1,000 cfu/100 ml (the observed geometric mean was 1012 cfu/100 ml based on 22 samples). Fifty percent of the samples collected in 2003 and 2004 exceeded 1000 cfu/100mL. This value is the maximum allowable concentration of the geometric mean for 5 or more samples collected within a 30 day period during the recreation season (ORC 3745-1). The 90th percentile of the data (3,870 cfu/100 ml) also exceeds the applicable water quality criterion of 2,000 cfu/100 ml. Modeling estimations indicate that most of the fecal coliform bacteria present in Chippewa Creek are derived from loadings from tributary streams, not from direct releases to the creek.

5.2.1 Watershed Nutrients and Pathogens

Nutrient Modeling

Little Chippewa Creek, River Styx, Red Run and Silver Creek are all impaired due to nutrient enrichment. Average total P concentrations in Little Chippewa Creek were 1.45 mg/l. Average concentrations for the other streams mentioned are River Styx – 0.855 mg/l, Red Run – 0.134 mg/l and Silver Creek – 0.537 mg/l.

<u>Little Chippewa Creek</u>

Modeling results for Little Chippewa Creek show 31% of annual total P load is from point sources. Most of this point source load is from the Orrville Municipal Power Plant and Orrville Wastewater Treatment Plant. Based on the criteria for reducing point source total P loads from NPDES permitted facilities in nutrient impaired streams, as explained in Section 4.1.2, these facilities shall be required to lower their total P effluent to a concentration of 1.0 mg/l (see Table 5.14). The Little Chippewa Creek nonpoint source total P load is extremely elevated. Primarily derived from pasture land, this load needs a 68.7% reduction in order to meet the expectations of this MWH designated stream.

River Styx
River Styx receives greater than 50% of its total P load from point sources. Wadsworth and Rittman wastewater treatment plants are the primary sources of this load and have been required to reduce total P effluent concentrations to 1.0 mg/l. Even with this restriction on permitted dischargers and due to the facilities' average design effluent flow a large load of total P will enter the watershed. Because of this, the nonpoint source load and total P load from Municipal Separate Storm Sewer Systems (MS4s) runoff requires an 85.1% reduction to meet the lower total P target for wadeable MWH streams.

Red Run
Red Run modeling results show the watershed's total P load requires a 52% reduction to meet the headwater MWH target total P average concentration of 3.4 mg/l. The only NPDES permitted discharger in this watershed, Marshallville STP, requires a total P load reduction to an average effluent concentration of 1.0 mg/l. The nonpoint sources of total P load, which is mostly from pastures and croplands, require a 54.4% load reduction.

Silver Creek
The total phosphorus target of 0.17 mg/l is used instead of 0.08 mg/l. This is the WWH target outlined for small river watersheds (those with watershed drainage area greater than >200 mi^2 and < 1000 mi^2) outlined in the document *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA, 1999).

For this particular case, it is appropriate to exercise the flexibility inherent to establishing TMDL targets for total phosphorus (i.e., since there currently are no WQS for this parameter). The targets recommended in the *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA, 1999) are conservative and attainment of the biocriteria frequently occurs at TP concentrations that are higher than these recommended values. Likewise, at River Mile 0.4, near the terminus of the subwatershed, there was full attainment of the WWH use criteria despite receiving a relatively high total phosphorus load that includes the effluent from Doylestown WWTP. Meeting the biological criteria at this point in the watershed suggests that other watershed specific factors are ameliorating the effect of a relatively high nutrient load.

The instream total P target of 0.17 mg/l provides a TMDL at 3919.6 lbs/year for Silver Creek. A total P effluent concentration reduction is required for the Doylestown Water Pollution Control Facility at 1.0 mg/l. This facility effluent outfall is at river mile 3.16 in the upper, impaired, section of Silver Creek. This TMDL requires a reduction of 75.3% of the existing total P load being received by the stream.

Pathogen Modeling
Impairments of designated recreation uses were observed in all of the 14-digit HUCs within the Chippewa Creek assessment unit except for HUC 020-010, upstream Chippewa Lake. As explained in Section 4.1.5, cattle in streams are only considered in the pathogen loading model when they have actually been observed in streams within a watershed. In this case, loadings from cattle with direct access to streams were modeled for Steel Ditch, Little Chippewa Creek and Red Run. The result of the modeling estimations found that direct access to streams by cattle was the highest single source of fecal coliform bacteria in all three of these drainages. For TMDL allocations, these livestock sources are allocated zero load (a target of compete exclusion of cattle from streams).

The fecal coliform loads from NPDES dischargers in all subwatersheds within the Chippewa Creek assessment unit are allocated at the applicable permit limits using the permit design flows. In all cases the permit limits established for the dischargers are at the PCR geometric mean water quality criterion (1,000 cfu/100 ml) during the recreational season. Modeling estimations indicate that these loads represent only a small percentage of the total fecal coliform loadings within the assessment unit and that no load reductions are necessary to meet the TMDL.

In all subwatersheds with the loading model applied, except for Little Chippewa Creek, the nonpoint source load allocation still requires a large reduction of at least 74.5%. Little Chippewa Creek's load allocation only requires 52% nonpoint source reduction since that stream is designated as a secondary contact recreational use stream, which has less stringent fecal coliform concentration limits.

The Chippewa Creek at Greenwich Road site (river mile 17.2) in the 020-020 14-digit HUC is impaired of primary contact recreational use. This site cannot have the pathogen watershed loading TMDL method applied to it because it receives the Chippewa Lake drainage. This lake is too large for this modeling approach because it renders most of the model assumptions inappropriate. Since this site only has four bacteria samples, no further modeling is done.

Confined Animal Feeding Operations

Little Chippewa Creek and Red Run both drain pastures and crop land that are a part of the two large Confined Animal Feeding Operations (CAFO) located in western Wayne County. As explained in Section 4.1.2, the fields believed to receive manure from these farms are considered in the total P modeling as having a slightly higher concentration of total P in their runoff. This consideration may put greater importance on the manure management for these fields in implementation practices aspiring to reducing both nutrients and pathogens from running off of fields and through tile waters.

Load Duration Curve

The Chippewa Creek mainstem sampling site at river mile 6.58 and the site nearest the mouth at river mile 0.35 both have impairment to their primary contact recreational use. As explained in the pathogen modeling methods section 4.1.5, these segments in Chippewa Creek have a watershed too large for the basic watershed loading assessment. Additionally, most of the pathogen sources are dealt with by addressing the tributaries' pathogen loads.

A load duration curve (LDC) for the river mile 6.58 site has been developed in order to illustrate the occurrence of elevated fecal coliform concentrations. This location contained a USGS stream flow gage from 1960 through 1981. A stream flow measurement or water surface elevation measurement which could later be related to stream flow was made each time fecal coliform was sampled at this site in the 2003-2005 recreational seasons. By knowing the stream flow for each fecal coliform sample, the fecal coliform load for each sample can be calculated. Using the daily average stream flows from the gage record of this site, stream discharge was calculated to understand the frequency of flow exceedance; one through 100.

Figure 5.3 shows the LDC for this site's fecal coliform. The x-axis contains the percentile of flow exceedances and the y-axis is fecal coliform loads with a logarithmic scale. Plotted on this figure with squares is the observed fecal coliform load at the frequency of flow exceedance that matches the stream's discharge at the time of the fecal coliform sample. The curve of diamond shaped symbols shows the allowable fecal coliform load throughout the frequency of flow exceedance.

Note that only eight sample points are presented on the LDC. While this is a limited sample population, the associated range of flows covers 74% of the flow regime. This includes a high and low flow sample at 18 and 92 percentile exceedance respectively. More important, this LDC shows the observed loads greater than allowable in 75% of the samples and both ends of the flow regime. This indicates that pathogens are entering the Chippewa Creek at high and low flow. The watershed loading modeling results for the Chippewa Creek tributaries confirm this based on the low flow (cows in streams) and high flow (runoff of manure from land application) fecal coliform existing sources calculated.

These results from the Chippewa Creek at river mile 6.58 site can reasonably be applied to the site near the mouth at river mile 0.3. This is because the same types of land use continue to drain to the Chippewa Creek between these two sites.

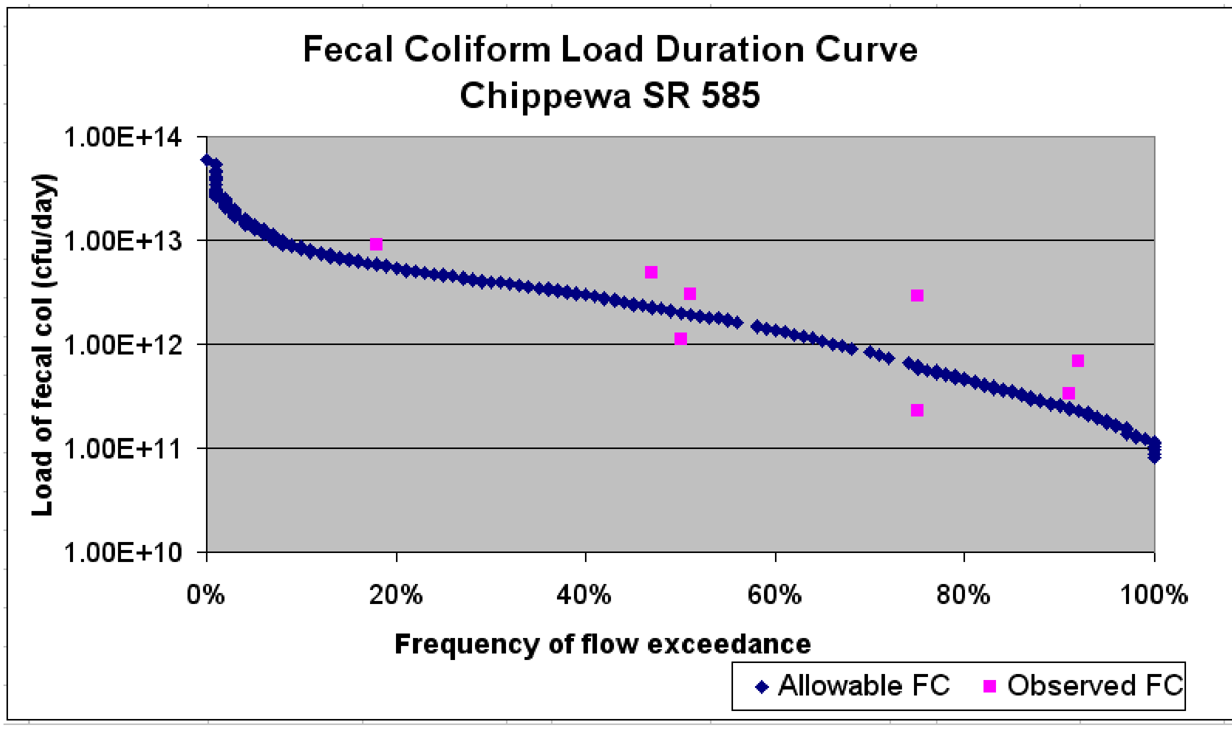

Figure 5.3 Load duration curve for fecal coliform bacteria on Chippewa Creek at State Route 585.

Table 5.9 Total existing load, TMDL and allocations for 11-digit HUC 020 (annual/seasonal).

14-Digit HUC	**Subwatershed**	**Sub-Watershed Extent** (Upper RM-Lower RM)	**Parameter**	**Existing Loads**				**% Reduction**	**TMDL**	**Allocations**			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
020-030 partial	Tommy Run	Entirety	FC[1]	93.3	32.9	-	126.2	97.3	3.39	0.0	3.4	-	-
	Steele Ditch	head waters-0.96	FC[1]	80.4	1338.8	-	1419.2	99.6	5.07	0.0	5.1	-	-
020-040	Little Chippewa Creek	Entirety	FC[1]	160.5	3414.0	-	3574.4	97.8	78.59	2.04	76.6	-	-
			TP[2]	22846.9	46475.2	-	69322.0	60.4	27423.9	11083.7	14968.9	-	1371.2
020-050	River Styx	Entirety	FC[1]	349.8	49.8	-	399.6	95.8	16.94	4.2	12.7	-	-
			TP[2]	35555.9	31535.1	-	67091.0	60.0	26863.1	20325.9	5194.1	-	1343.2
020-060 partial	Chippewa Creek at SR 585	6.58	FC	**LDC**									
	Mill Creek	Entirety	FC[1]	202.3	29.5	-	231.8	98.7	3.03	0.0003	3.0	-	-
020-070	Red Run	Entirety	FC[1]	84.4	1623.4	-	1707.8	99.6	6.43	0.08	6.35	-	-
			TP[2]	1182.8	26433.9	-	27616.7	52.0	13255.7	365.5	12227.5	-	662.8
020-080 partial	Silver Creek	Entirety	FC[1]	591.9	31.6	-	623.5	99.4	3.67	0.4	3.3	-	-
			TP[2]	6048.6	9810.1	-	15858.8	75.3	3919.6	2119.3	1604.3	-	196.0
	Chippewa Creek below Red Run to Tusc R.	Entirety	FC	**LDC**									

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.10 Total existing load, TMDL and allocations for 11-digit HUC 020 (daily).

14-Digit HUC	Subwatershed	Sub-watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
020-030 partial	Tommy Run	Entirety	FC[1]	0.68	0.24	-	0.92	97.3	0.02	0.0	0.02	-	-
	Steele Ditch	Upst-0.96	FC[1]	0.58	9.70	-	10.28	99.6	0.04	0.0	0.04	-	-
020-040	Little Chippewa Creek	Entirety	FC[1]	1.16	24.74	-	25.90	97.8	0.57	0.01	0.56	-	-
			TP[2]	62.59	127.33	-	502.33	60.4	198.72	80.32	108.47	-	9.94
020-050	River Styx	Entirety	FC[1]	2.53	0.36	-	2.89	95.8	0.12	0.03	0.09	-	-
			TP[2]	97.41	86.40	-	183.81	60.0	73.60	55.69	14.23	-	3.68
020-060 partial	Chippewa Creek at SR 585	6.58	FC	**LDC**									
	Mill Creek	Entirety	FC[1]	1.47	0.21	-	1.68	98.7	0.02	0.000002	0.02	-	-
020-070	Red Run	Entirety	FC[1]	0.61	11.76	-	12.38	99.6	0.05	0.0006	0.05	-	-
			TP[2]	3.24	72.42	-	75.66	52.0	36.32	1.00	33.5	-	1.82
020-080 partial	Silver Creek	Entirety	FC[1]	4.29	0.23	-	4.52	99.4	0.03	0.003	0.02	-	-
			TP[2]	16.57	26.88	-	43.45	75.3	10.74	5.81	4.40	-	0.54
	Chippewa Creek below Red Run to Tusc R.	Entirety	FC	**LDC**									

[1] cfu * 10^{13} * day^{-1}
[2] lbs * day^{-1}

Table 5.11 Existing nonpoint source loads for 11-digit HUC 020.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Nonpoint Source Loads						
				Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
020-030 partial	Tommy Run	Entirety	FC[1]	6.72	26.17	0.006	-	-	0.002	32.90
	Steele Ditch	Upst-0.96	FC[1]	18.66	47.51	0.01	-	1272.59	0.001	1338.77
020-040	Little Chippewa Creek	Entirety	FC[1]	40.78	118.75	0.02	-	3254.40	0.04	3413.98
			TP[2]	11699.1	31133.5	617.7	1743.6	-	1281.3	46475.2
020-050	River Styx	Entirety	FC[1]	5.73	43.99	0.04	-	-	0.03	49.79
			TP[2]	6830.6	21942.4	579.8	1571.0	-	611.3	31535.1
020-060 partial	Chippewa Ck @ SR 585	6.58	FC	**LDC**						
	Mill Creek	Entirety	FC[1]	3.78	25.74	0.01	-	-	0.003	29.54
020-070	Red Run	Entirety	FC[1]	15.68	51.07	0.01	-	1556.63	0.003	1623.39
			TP[2]	8551.9	16669.8	299.2	848.8	-	64.2	26433.9
020-080 partial	Silver Creek	Entirety	FC[1]	3.35	28.20	0.01	-	-	0.002	31.57
			TP[2]	1978.2	7061.8	184.7	565.0	-	20.3	9810.1
	Chippewa Ck dwst Red Run to Tusc R.	Entirety	FC	**LDC**						

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.12 Nonpoint source allocations for 11-digit HUC 020.

14-Digit HUC	Sub-Watershed	Sub-shed Extent (Upper RM-Lower RM)	Parameter		Individual Non-Point Sources: Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
020-030 partial	Tommy Run	Entirety	FC[1]	Allocation	0.69	2.69	0.006	-	-	0.0003	3.39
				% Reduction	89.7	89.7	0.0	-	-	89.7	-
	Steele Ditch	Upst-0.96	FC[1]	Allocation	1.43	3.63	0.01	-	0.00	0.00009	5.07
				% Reduction	92.4	92.4	0.0	-	100	92.4	-
020-040	Little Chippewa Creek	Entirety	FC[1]	Allocation	19.6	56.96	0.02	-	0.00	0.02	76.55
				% Reduction	52.0	52.0	0.0	-	100	52.0	-
			TP[2]	Allocation	3661.2	9743.3	617.7	545.6	-	401.0	14968.9
				% Reduction	68.7	68.7	0.0	68.7	-	68.7	-
020-050	River Styx	Entirety	FC[1]	Allocation	1.46	11.22	0.04	-	-	0.006	12.73
				% Reduction	74.5	74.5	0.0	-	-	74.5	-
			TP[2]	Allocation	1018.1	3270.8	579.8	234.1	-	91.1	5194.1
				% Reduction	85.1	85.1	0.0	85.1	-	85.1	-
020-060 partial	Chippewa Creek at SR 585	6.58	FC	**LDC**							
	Mill Creek	Entirety	FC[1]	Allocation	0.39	2.63	0.01	-	-	0.0003	3.03
				% Reduction	89.8	89.8	0.0	-	-	89.8	-
020-070	Red Run	Entirety	FC[1]	Allocation	1.49	4.85	0.01	-	0.00	0.0003	6.35
				% Reduction	90.5	90.5	0.0	-	100	90.5	-
			TP[2]	Allocation	3903.3	7608.4	299.2	387.4	-	29.3	12227.5
				% Reduction	54.4	54.4	0.0	54.4	-	54.4	-
020-080 partial	Silver Creek	Entirety	FC[1]	Allocation	0.35	2.95	0.01	-	-	0.0002	3.31
				% Reduction	89.6	89.6	0.0	-	-	89.6	-
			TP[2]	Allocation	291.7	1041.5	184.7	83.3	-	3.1	1604.3
				% Reduction	85.3	85.3	85.3	85.3	-	85.3	-
	Chippewa Ck dwst Red Run to Tusc R.	Entirety	FC	**LDC**							

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.13 Point source existing and allocated loads for 11-digit HUC 020.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent	Para-meter		NPDES Discharger	MS4	HSTS	Para-meter		NPDES Discharger	MS4	HSTS
020-030 partial	Tommy Run	Entirety	FC[1]	Existing	0	0	93.29					
				% reduction	-	-	100					
				Allocation	0	0	0					
	Steele Ditch	Upst-0.96	FC[1]	Existing	0	0	80.39					
				% reduction	-	-	100					
				Allocation	0	0	0					
020-040	Little Chippewa Creek	Entirety	FC[1]	Existing	2.04	0	158.41	TP[2]	Existing	22088.1	0	758.6
				% reduction	0	-	100		% reduction	49.8	-	100
				Allocation	2.04	0	0		Allocation	11083.7	0	0
020-050	River Styx	Entirety	FC[1]	Existing	4.20	0.05	345.52	TP[2]	Existing	32603.9	1297.2	1654.8
				% reduction	0	74.5	100		% reduction	38.3	85.1	100
				Allocation	4.20	0.01	0		Allocation	20132.6	87.7	0
020-060 partial	Mill Creek	Entirety	FC[1]	Existing	0	0.003	202.29					
				% reduction	-	89.8	100					
				Allocation	0	0.0003	0					
020-070	Red Run	Entirety	FC[1]	Existing	0.08	0	84.30	TP[2]	Existing	779.1	0	403.7
				% reduction	0	-	100		% reduction	53.1	-	100
				Allocation	0.08	0	0		Allocation	365.5	0	0
020-080 partial	Silver Creek	Entirety	FC[1]	Existing	0.36	0.02	591.51	TP[2]	Existing	3045.0	170.6	2832.9
				% reduction	0	89.6	100		% reduction	31.2	85.3	100
				Allocation	0.36	0.002	0		Allocation	2094.2	25.1	0

[1] cfu * 10^{13} * season^{-1}
[2] lbs * year^{-1}

Table 5.14 Existing and allocated loads of point source dischargers (not including MS4s and HSTSs) for HUC 020.

14-Digit HUC	Sub-Water-shed	Sub-Water-shed Extent	Facility	Parameter	Existing load	% reduction	Allocated load	Parameter	Existing load	% reduction	Allocated load
020-040	Little Chippewa Creek	Entirety	3IB00017 ORRVILLE MUNICIPAL POWER	FC[1]	-	-	-	TP[2]	3996.7	77.6	912.9
			3ID00075 TECHNOCAST INC		-	-	-		100.6	none	213.8
			3IN00310 QUALITY CASTINGS CO		-	-	-		14.0	none	14.0
			3IW00090 ORRVILLE WTP		-	-	-		3.1	none	85.9
			3PD00017 ORRVILLE WWTP		2.04	0	2.04		17869.4	45.5	9747.4
			3PR00144 APOSTOLIC CHRISTIAN HOME		0.008	0	0.008		104.4	none	109.7
020-050	River Styx	Entirety	3IN00037 HUBBELL POWER SYSTEMS/OHIO WADSWORTH M.O.V. PLANT	FC[1]	-	-	-	TP[2]	14.5	none	18.4
			3IR00053 GOLDSMITH AND EGGLETON INC		-	-	-		8.8	none	8.8
			3IW00015 WADSWORTH WTP		-	-	-		1.2	none	1.2
			3PD00022 WADSWORTH WWTP		3.18	0	3.18		27259.0	44.1	15230.4
			3PD00047 RITTMAN WWTP		1.02	0	1.02		5320.2	8.4	4873.7
020-070	Red Run	Entirety	3PB00032 MARSHALLVILLE STP	FC[1]	0.08	0	0.08	TP[2]	779.1	53.1	365.5
020-080 partial	Silver Creek	Entirety	3PB00014 DOYLESTOWN WPCF	FC[1]	0.32	0	0.32	TP[2]	2740.6	85.8	1523.0
			3PV00031 WESTVIEW MHP		0.03	0	0.03		304.4	none	388.4
			3PV00121 SUNDIAL MHP STU 1 WWTP†		0.01	0	0.01		0	none	182.8

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$
† This facility is not yet built and operating; since the permit has been issued its future permitted load is included in the allocation.

Table 5.15 Facilities with required total P reductions in 11-digit HUC 020.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent	Facility	Outfall #	Average total P effluent concentration (mg/l)		Average effluent flow (MGD)	
					Existing	Required	Existing	Design
020-040	Little Chippewa Creek	Entirety	3IB00017 ORRVILLE MUNICIPAL POWER	006	4.88	1.0	0.268	0.27072
			3PD00017 ORRVILLE WWTP *	001	3.98	1.0	1.58	3.2
020-050	River Styx	Entirety	3PD00022 WADSWORTH WWTP	001	3.00‡	1.0	2.98	5.0
			3PD00047 RITTMAN WWTP *	001	2.27	1.0	0.933	1.6
020-070	Red Run	Entirety	3PB00032 MARSHALLVILLE STP	001	3.00‡	1.0	0.0853	0.12
020-080 partial	Silver Creek	Entirety	3PB00014 DOYLESTOWN WPCF *	001	2.51	1.0	0.30	0.5

‡ This concentration of total P (3.0 mg/l) is assumed for effluent from public waste facilities with no representative data.
* Facilities where several actual reported effluent total P concentration and flow values are used to calculate existing conditions. Other are calculated either using less robust, but still discharger submitted, total P concentrations (from 2C reports) or assumed concentrations as noted.

Table 5.16 MS4 entities for 11-digit HUC 020.

14-Digit HUC	**Sub-Watershed**	**Sub-Watershed Extent** (Upper RM-Lower RM)	**MS4 entities**[1]
020-050	River Styx	Entirety	City of Wadsworth
020-060 partial	Mill Creek	Entirety	Village of Doylestown, Wadsworth Township (Medina County), City of Wadsworth
020-080 partial	Silver Creek	Entirety	Chippewa Township (Wayne County), Village of Doylestown, City of Norton, Wadsworth Township (Medina County), City of Wadsworth

[1] Table 4.3 of this report describes how the WLAs are distributed among the relevant MS4 communities.

5.2.2 Habitat and Sediment

Due to the channel and riparian maintenance and historical channel alteration for drainage purposes by the Chippewa Subdistrict of the Muskingum Watershed Conservancy District, impairment from habitat and sediment is widespread and severe in this 11-digit HUC.

020-010
Only two streams that flow into Chippewa Lake have been assessed. The lower reaches of both streams and many tributaries that flow into Chippewa Lake are probably modified channels that drain former wetlands; therefore, recovery to the point of meeting habitat and sediment TMDL targets may be significantly reduced. Such low gradient streams are very slow to recover to a natural channel shape and better aquatic habitat because flow energy is relatively low and the needed instream sediment dynamics do not readily occur.

The one stream site on Chippewa Creek, known as “The Inlet” upstream Chippewa Lake, is only in partial attainment of WWH. The habitat of this site is severely impacted. The TMDL fails with a score of 0 out of 3, with channel modifications being the major source. The sediment TMDL at this site also fails to meet expectations mostly due to channel modifications.

McCabe Creek was monitored before it flows into Chippewa Lake. It is in partial attainment of WWH with the cause of impairment listed as unknown. The sediment and habitat TMDLs are applied to the sampling site’s QHEI results. Sediment targets are met indicating that it is not a cause of impairment. However, habitat does not meet the target and has a score of 2 out of the needed 3 points. Poor instream cover (vegetation and physical materials that provide aquatic habitat) specifically a lack of pools greater than 40 cm in depth, is the primary cause of this site not meeting the habitat TMDL.

020-020
Hubbard Creek is the only part of this 14-digit HUC not meeting its aquatic life use. Specifically the sampling site downstream of the approximately 20 acre lake impounding Hubbard Creek is in partial attainment of the MWH designated use. Flow alteration is the listed cause of impairment and the source is flow impoundment and suburbanization. However, sites on Hubbard Creek located upstream of the lake are meeting the habitat TMDL targets. This is likely an example of the limitation of the QHEI and its use in the habitat TMDL procedure. Impacts from some types of flow alterations cannot be ascertained using this tool. Because of the favorable habitat assessment of Hubbard Creek this impairment is a lower priority than other stream segments in the Chippewa Creek watershed. It should be noted that the impoundment on Hubbard Creek is a flood control structure maintained by the Chippewa Subdistrict of Muskingum Watershed Conservancy District.

020-030
Tommy Run is the only stream in this 14-digit HUC not meeting its aquatic life use attainment. The one sampling site assessed on this stream has poor habitat and increased stream embeddedness. The sediment and habitat scores at this site fall just short of their targets due to the presence of fine substrate material. Tommy Run does not show signs of recent channelization and is not part of the current Chippewa Subdistrict drainage project. Because of this it is likely that sediment entering the stream is mostly from upland erosion. Additionally, Tommy Run experiences less sedimentation than recently ditched streams probably due to its more stable stream banks resulting in less channel erosion.

020-040
Little Chippewa Creek is part of the Chippewa Subdistrict drainage project from its mouth upstream to near its crossing of Steiner Road (river mile 3.4). Of the three Ohio EPA assessment sites on Little Chippewa Creek, the lower two sites failed to meet the sediment and habitat TMDLs. These two sites, plus a Little Chippewa Creek unnamed tributary, scored zero out of the three points needed to meet the habitat TMDL. Channel modifications leading to poor in stream cover and low stream sinuosity are the major factors for this non-attainment. Grazing cattle with stream access are also observed in the lower section of Little Chippewa Creek; downstream river mile 8.0. These cattle are not only contributing to the pathogen and nutrient loads, but also create poor channel/bank habitat while exacerbating channel erosion and increasing stream sediment loads. The most upstream site sampled on Little Chippewa Creek is found to meet both the sediment and habitat TMDLs. Riparian habitat and instream cover (vegetation and physical components of aquatic habitat) are better established at this point (river mile 8.9). There is a dry dam flood control structure on Little Chippewa Creek upstream of Chippewa Rd. (around river mile 7.4). This is within the reach that has been determined to be impaired by habitat and sediment as well as excessive nutrient concentrations. Figure 5.4 shows Little Chippewa Creek near its mouth to Chippewa Creek.

020-050
All four stream assessment sites on River Styx, and a site near the mouth to Homes Brook, do not meet the habitat TMDL achieving 0 out of 3 of the targets. The sediment TMDL also fails at each site by at least 39% deviation from the target scores. Like the sediment and habitat impaired areas in Little Chippewa Creek, these sites are designated MWH and these TMDLs are developed for WWH. Even though the TMDLs used are not well suited for the lower expectations of this watershed the great degree of channel modification, lack of forested riparian corridor, poor instream cover and embeddedness of fine substrates are significant causes of impairment throughout this watershed. All of the sites on River Styx and well upstream are part of the active bank maintenance through the Chippewa Subdistrict. There is also a flow restriction structure on River Styx downstream of its confluence with Holmes Brook and upstream of the Wadsworth WWTP outfall. This structure forces all the stream flow to move around a constricted channel on the left side of the stream when facing downstream (Figure 5.5 and Figure 5.6). The high flow velocities through this structure make upstream movement of aquatic animals difficult at any flow level.

Additionally, there is reason to believe that Wadsworth WWTP may be over applying sewage sludge on the fields surrounding River Styx in the proximity of their plant. On several repeat visits to River Styx by Ohio EPA staff noted application on the same fields. Episodic water quality spikes in ammonia, BOD-5 day, and other parameters indicate runoff from fields with an over application of this sewage sludge. Table 5.16 shows water quality data results upstream and downstream of the Wadsworth WWTP and several of the fields receiving the plant's sewage sludge. Figure 5.7 is a photograph of the downstream sampling location, Wall Rd.

Table 5.17 River Styx water quality data bracketing the Wadsworth WWTP.

Parameter	River Styx upstream Wadsworth WWTP (RM 3.5)		River Styx down-stream Wadsworth WWTP (RM 2.8)	
	Average	Max	Average	Max
Total phosphorus (mg/l)	0.053	0.079	1.55	4.54
Ammonia (mg/l)	0.08	0.126	1.87	8.69
BOD 5-day	<2.	2.	15.05	79.

Figure 5.4 Little Chippewa Creek at South Main St. /Benner Rd. just south of the City of Rittman.

Figure 5.5 River Styx just upstream from Wadsworth WWTP looking upstream at the flow control structure.

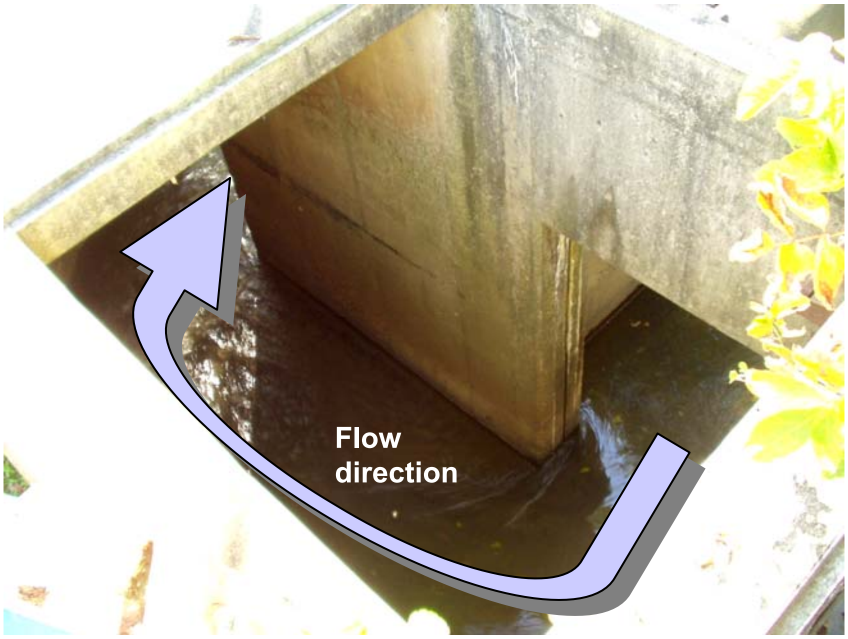

Figure 5.6 Looking down into flow diversion on structure in River Styx.

Figure 5.7 River Styx at Wall Rd. looking upstream (downstream of Wadsworth WWTP).

020-070

Red Run is impacted by habitat and flow alterations, excessive siltation and organic enrichment. Results from the habitat and sediment TMDL analysis show that these stressors are having a substantial impact on the system. Figure 5.8 shows Red Run near its mouth downstream of its crossing at Porr Rd. At all sites surveyed except for the upstream site of the Red Run's unnamed tributary at river mile 0.66 the sediment and habitat TMDLs are not met. The habitat TMDL for those three failing sites are all scored zero out of 3. These sites are all MWH streams and have been extensively channelized; therefore it is likely that habitat quality will remain low.

Figure 5.8 Red Run downstream of Porr Road.

020-080

The most downstream 14-digit HUC in the Chippewa Creek watershed contains the Chippewa Creek at river mile 0.5 sampling site. Like all of the other monitoring sites directly on Chippewa Creek downstream of Chippewa Lake, this site is designated MWH. However unlike those other sites, this one is not in full attainment of that designation. The sediment and habitat scores for this site are consistent with sites that have had substantial channel modifications. At this site the sediment TMDL does not meet the target for the channel metric and has the largest deviation out of the sites in this subwatershed. This site also has very poor riparian habitat. The overall habitat TMDL score is zero out of three. While the other Chippewa Creek mainstem sites downstream Chippewa Lake are not shown in Table 5.17 because they are in full attainment, those sites yield similar sediment and habitat scores. This site receives the drainage from all the impaired tributaries discussed in this section. Excessive loading of sediment and nutrients from tributary streams under high flow conditions is the likely reason this site does not meet the use attainment expectations.

Organic enrichment is also a cause of impairment for the downstream site on Chippewa Creek (RM 0.4). This cause is not explicitly modeled by the watershed loading of total P method used in the report because the watershed drainage area (188.0 square miles) is too large given the constraints of the GWLF model. TMDLs require a large portion of the nutrients that drain to this site from Little Chippewa Creek, River Styx, Red Run and Silver Creek to be reduced. It is reasonable to believe, without complex calculations, that these reductions are sufficient to address the enrichment at this site.

Table 5.18 Sediment and habitat TMDLs for 11-digit HUC 020.

TMDL Targets For WWH		Sediment TMDL						Habitat TMDL						
		Allocations			TMDL			Allocations			Subscore			TMDL
		≥ 13	≥ 14	≥ 5	32			≥ 60= *1 pt*	< 2 = *1 pt*	< 5 = *1 pt*				*3 pts*
Existing Scores Stream/River (Use)	**River mile**	**QHEI Categories: Sub-strate**	**Chan -nel**	**Rip-arian**	**Total Sediment Score**	**% Dev-iation**	**Main impair. cat.**	**QHEI Score**	**# of High Influence Attributes**	**Total # of Modified Attributes**	**QHEI**	**Hi inf-luence**	**Tot # Mod At**	**Total Habitat Score**
Chippewa Creek to Chippewa Lake outlet (05040001-020-010)														
Chippewa Creek	23.2	12.5	6	2	20.5	35.94	Riparian	36.5	4	9	0	0	0	0
McCabe Creek	0.8	17	17	10	44	**Meets**	**None**	61	2	3	1	0	1	2
Chippewa Creek below Chippewa Lake outlet to below Hubbard Creek (05040001-020-020)														
Hubbard Creek	3.6	**Not applicable**						68.5	1	3	1	1	1	**3**
	1.6							82	0	1	1	1	1	**3**
Chippewa Creek below Hubbard Creek to above River Styx [except Lower Chippewa Creek] (05040001 020 030)														
Tommy Run	0.8	11.5	15	4.5	31	3.13	Substrate	60	1	5	1	1	0	2
Little Chippewa Creek (05040001-020-040)														
Little Chippewa Creek	8.9	14	15	5	34	**Meets**	**None**	65.5	0	3	1	1	1	**3**
	8	9	10	4.5	23.5	26.56	Substrate	46.5	2	8	0	0	0	0
	0.2	10	4	3	17	46.88	Channel	33	2	8	0	0	0	0
Trib to L. Chip. (RM 6.3)	0.1	13	10.5	2.5	26	18.75	Riparian	40	3	10	0	0	0	0
River Styx (05040001-020-050)														
River Styx (WWH) *Impaired*	3.9	10	4	1	15	53.13	Riparian	29	3	8	0	0	0	0
	3.5	10	4	5.5	19.5	39.06	Channel	32.5	2	9	0	0	0	0
	2.8	10.5	4	3.5	18	43.75	Channel	40	2	8	0	0	0	0
	0.5	10.5	5	4	19.5	39.06	Channel	35.5	2	8	0	0	0	0
Holmes Brook	0.2	11	5.5	1.5	18	43.75	Riparian	47	2	5	0	0	0	0
Red Run (05040001-020-070)														
Red Run	1	10	9	3.5	22.5	29.69	Channel	39.5	3	9	0	0	0	0
	0.5	10	4	1	15	53.13	Riparian	33	3	8	0	0	0	0
Trib to Red Run (RM 0.66)	1.2	16.5	14	3.5	34	-	Riparian	61	0	2	1	1	1	**3**
	0.1	10	7	2	19	40.63	Riparian	36.5	3	9	0	0	0	0
Chippewa Creek below Red Run to Tuscarawas River (05040001-020-080)														
Chippewa Creek	0.5	10	4	9	23	28.13	Channel	42	2	8	0	0	0	0

5.3 Tuscarawas River (below Wolf Creek to below Sippo Creek) [Excluding Chippewa Creek] – 030

This 11-digit HUC contains 19.9 river miles of the Tuscarawas River mainstem and small and medium sized tributaries. The severe dissolved oxygen (D.O.) problems that were observed upstream of Wolf Creek show substantial improvement in this hydrologic unit. The dissolved oxygen levels improve because the stream has a more pronounced slope and faster velocities that increase stream re-aeration. However, the stream receives large nutrient loads from the Barberton WWTP, Chippewa Creek and other tributaries, which stimulate excessive algal growth and contribute to pronounced D.O. swings and nutrient enrichment. The Tuscarawas River tributaries included in this watershed have a variety of impairments. The tributaries to the west of the Tuscarawas River have impairments similar to, but not as severe as, the Chippewa Creek tributaries. In general, the tributaries to the east of the Tuscarawas River are much more urbanized.

5.3.1 Watershed Nutrients and Pathogens

Nutrient Modeling
The upper Nimisila Creek 14-digit HUC is listed as having organic enrichment as a cause of impairment, but the GWLF total P loading model is not appropriate due to the lakes in this subwatershed. Since no other method is available this cause of impairment will not be addressed in this report.

Fox Run, Newman Creek upstream of Orrville Ditch (upper Newman Creek), Orrville Ditch itself (which is the Newman Creek tributary at river mile 9.76) and West Sippo Creek are all streams in this 11-digit HUC considered impaired due to nutrient enrichment. Fox Run and West Sippo Creek are direct Tuscarawas River tributaries. The one sampling site within the lower Newman Creek subwatershed shows the stream is in full attainment. Except for Orrville Ditch the other subwatersheds impaired by nutrient enrichment are headwater (less than 20 square miles) WWH designated sites.

Land use in the Orrville Ditch and upper Newman Creek sub-watersheds is more than 80% row crops and pastureland. The majority of the total P draining to these streams is from nonpoint source runoff from agricultural land use. After the point source wasteloads are allocated (i.e., based on their design flow and effluent limits) meeting the remaining available load for the TMDL requires that nonpoint source runoff be reduced by 90%.

Figure 5.9 Silage leachate contaminated storm water runoff from Stoll Farms, Inc.

<u>Confined Animal Feeding Operations (CAFOs)</u>
The permitted confined animal feeding operations (CAFOs) in the Tuscarawas River watershed included in this report lie in the Orrville Ditch sub-watershed. As described in the nutrient modeling methods (Section 4.1.2), the runoff derived from fields with CAFOs have been considered to have a slightly higher than average total P concentration.

In May 2003, Ohio EPA documented several issues at Stoll Farms, Inc. including a manure storage pond overflow, lack of adequate freeboard in the manure storage pond and discharge of silage leachate from the feed storage bunkers. Stoll Farms, Inc. applied for coverage under the CAFO NPDES permit program in September 2003. From August 2001 to May 2005, Ohio EPA received 11 separate complaints regarding improper manure application with five complaints relating to discharge of manure into surface waters. Stoll Farms, Inc. has installed a manure sand separator which improves the farm's manure management efforts. As of October 2006 a CAFO NPDES permit has been finalized and the discharge of silage leachate discharge has been eliminated. Figure 5.9 shows silage runoff from Stoll Farms, Inc facility's documented by Wayne County Health Department on 23 May 2006.

While nutrients delivered to streams from accidents on and around both CAFOs are not explicitly calculated, they are taken into consideration in the increased total P soil runoff concentration.

Upper Newman Creek
It is recommended that one point source in the upper Newman Creek sub-watershed, Dalton WWTP, receive an effluent concentration limit of 1 mg/l for total P.

West Sippo Creek
West Sippo Creek drains an area that is much more developed with residential land uses than the other nutrient impaired streams in this 11-digit HUC. Failing HSTS have been observed draining to West Sippo Creek from some of this development, and is a much greater aspect of the total existing load; 15.3% compared to only 2.1% in Orrville Ditch. Even after the total P load from HSTS is given a zero load allocation, staying within the remainder of the available TMDL requires that runoff sources be reduced by 82.1%.

Sippo Creek
Despite having organic enrichment as a cause of impairment, the total P loading method is not applied to the Sippo Creek subwatershed. This is because the several lakes and heavy urbanization in the subwatershed make the method not practical. Resources are not available to develop an alternative method of nutrient loading for this subwatershed. Reducing the fecal coliform load from the pathogen TMDL efforts; however, will likely reduce some of the nutrient loads in this watershed.

Fox Run
The majority of Fox Run's total P load reduction is needed from nonpoint source runoff. The three small point source dischargers are all operating well below their design flow. These facilities are small enough not to be required to reduce effluent phosphorus concentrations. Because of this, the total wasteload allocation is greater than what the existing load is from these facilities (Table 5.18).

Pathogens: Watershed-Based Modeling
All of the six subwatersheds modeled for fecal coliform loading in this 11-digit HUC require large bacteria reductions (greater than 95%). In two of these sub-watersheds livestock (mostly cattle) with access to streams are included in the existing load calculation. Since the BIT model always predicts this as a large bacterial source it makes up greater than 73% of the existing load in each of these watersheds. Failing HSTSs are the major sources of fecal coliform in the other four sub-watersheds and are a particular problem in the West Sippo Creek sub-watershed.

The Sippo Creek sub-watershed presents challenges for conducting a TMDL assessment using the methodologies employed elsewhere throughout this report. The sub-watershed contains two large lakes, Lake Cable and Sippo Lake, as well as a great deal of urbanized area (greater than 50% of its land cover). After the fecal coliform from HSTS is removed from Sippo Creek no additional reductions are required. Therefore the nonpoint source load allocation requires no reduction from the calculated existing load.

Pathogens: Load Duration Curves
The Tuscarawas River mainstem sampling sites at river mile 108.0, 104.3, 100.3 and 94.87 are all impaired of primary contact recreational use. As explained in the pathogen modeling methods section 4.1.5, the Tuscarawas River drains an area too large for the basic watershed loading assessment at these sites. Additionally, most of these sites' pathogen sources are dealt with by addressing the tributaries pathogen loads.

Two load duration curves (LDC) are developed in order to add some understanding of the occurrence of elevated fecal coliform concentrations. A record of stream flow for each site, river mile 100.3 and 94.87, is determined using a yield calculation based a USGS gage downstream on the Tuscarawas River in Massillon. A stream flow measurement or water surface elevation measurement which was later related to stream flow was made each time fecal coliform was sampled at these sites in 2003 and 2004. In knowing the stream flow for each fecal coliform concentration a load for each sample is calculated. Using the daily average stream flow from the gage record of this site, stream discharge is calculated to understand the frequency of flow exceedance; 1 through 100.

Figures 5.10 and 5.11 show the LDC curves for the four Tuscarawas River sites at river mile 100.25 and 94.87 respectively. The x-axis contains the percentile of flow exceedances and the y-axis is fecal coliform loads with a logarithmic scale. Plotted on this figure with squares is the observed fecal coliform load at the frequency of flow exceedance that matches the stream's discharge at the time of the fecal coliform sample. The curve of diamond shaped symbols shows the allowable fecal coliform load throughout the frequency of flow exceedance.

Note that of the samples collected, none are at flow levels less than the median flow (or greater than the 50th percentile exceedance). This limits the amount we can learn from these plots, however both show a trend indicating bacteria loads are more likely to exceed the geometric mean standard at higher flows. Since these data do not cover as great an amount of the flow regime as the Chippewa Creek LDC it is possible that low flow concerns could still be present. The high flow exceedance trend does confirm a great deal of bacteria from runoff, likely much from grazing animals and field applied manure. Given that the Tuscarawas River's drainage area is so large (greater than 430 square miles at the river mile 94.87 site) the flow is great enough in the middle of the flow regime to dilute the steady sources of fecal coliform such as failing HSTS and livestock in streams. In addition to the LDCs, the summary of the fecal coliform data in Table 3.9 shows a geometric mean at or only slightly above 1000 cfu per 100 ml for all four of the impaired mainstem sites. However the 90th percentile value is well above the 2000 cfu per 100 ml standard for that sampling frequency.

Table 5.19 Total existing load, TMDL and allocations for 11-digit HUC 030 (annual/seasonal).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
030-020	Tusc R below Chippewa Creek to above Fox Run	103.2-97.5	FC	**LDC**									
030-050	Fox Run	Entirety	TP[2]	846.4	15025.8	-	15872.1	84.9	2398.2	904.7	1373.6	-	119.9
030-060	Tusc R below Fox Run to above Sippo Ck-mainstem	97.5-90.83	FC	**LDC**									
030-070	Mudbrook Creek	Entirety	FC[1]	173.9	18.3	-	192.2	98.5	2.88	0.02	2.86	-	-
030-080	Newman Creek above Orrville Ditch (RM 9.76)	Head-9.76	FC[1]	174.7	793.6	-	968.3	99.6	3.87	0.2	3.7	-	-
			TP[2]	2906.1	14319.5	-	17225.5	88.3	2135.6	1261.1	767.8	-	106.8
030-090	Orrville Ditch	Entirety	FC[1]	71.9	800.3	-	872.3	99.6	3.56	0.00	3.6	-	-
			TP[2]	344.5	15766.1	-	16110.6	46.0	8707.2	0.0	8271.7	-	435.3
030-100	Lower Newman Creek (dwst of Orrville D)	9.76-mouth	FC[1]	206.3	60.1	7.6	273.9	95.7	11.68	0.001	4.1	7.6	-
030-110	West Sippo Creek	Entirety	FC[1]	359.5	18.8	-	378.3	99.1	3.56	0.006	3.6	-	-
			TP[2]	2244.2	8978.6	-	11222.8	82.6	1954.2	93.4	1763.1	-	97.7
030-120	Sippo Creek	Entirety	FC[1]	391.7	8.14	-	399.9	97.9	8.58	0.2	8.1	-	-

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.20 Total existing load, TMDL and allocations for 11-digit HUC 030 (daily).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
030-020	Tusc R below Chippewa Creek to above Fox Run	103.2-97.5	FC	**LDC**									
030-050	Fox Run	Entirety	TP[2]	2.32	41.17	-	43.49	84.9	6.57	2.48	3.76	-	0.33
030-060	Tusc R below Fox Run to above Sippo Ck-mainstem	97.5-90.83	FC	**LDC**									
030-070	Mudbrook Creek	Entirety	FC[1]	1.26	0.13	-	1.39	98.5	0.02	0.0001	0.02	-	-
030-080	Newman Creek above Orrville Ditch (RM 9.76)	Head-9.76	FC[1]	1.27	5.75	-	7.02	99.6	0.03	0.001	0.03	-	-
			TP[2]	7.96	39.23	-	47.19	88.3	5.85	3.46	2.10	-	0.29
030-090	Orrville Ditch	Entirety	FC[1]	0.52	5.80	-	6.32	99.6	0.03	0.00	0.03	-	-
			TP[2]	0.94	43.19	-	44.14	46.0	23.86	0.0	22.66	-	1.19
030-100	Lower Newman Creek (dwst of Orrville D)	9.76-mouth	FC[1]	1.49	0.44	0.06	1.98	95.7	0.08	0.000007	0.03	0.06	-
030-110	West Sippo Creek	Entirety	FC[1]	2.61	0.14	-	2.74	99.1	0.03	0.00004	0.03	-	-
			TP[2]	6.15	24.60	-	30.75	82.6	5.35	0.26	4.83	-	0.27
030-120	Sippo Creek	Entirety	FC[1]	2.84	0.06	-	2.90	97.9	0.06	0.001	0.06	-	-

[1] cfu * 10^{13} * day^{-1}
[2] lbs * day^{-1}

Table 5.21 Existing nonpoint source loads for 11-digit HUC 030.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Non-Point Source Loads						
				Cropland	Pasture	Forest	Ground Water	Cattle in stream	Urban	Total
030-050	Fox Run	Entirety	TP[2]	9931.2	3982.9	227.5	818.1	-	66.1	15025.8
030-070	Mudbrook Creek	Entirety	FC[1]	1.47	16.86	0.007	-	-	0.003	18.34
030-080	Newman Creek above Orrville Ditch (RM 9.76)	Head-9.76	FC[1]	21.17	59.01	0.009	-	713.35	0.01	793.55
			TP[2]	4730.9	8426.1	209.9	742.3	-	210.3	14319.5
030-090	Orrville Ditch	Entirety	FC[1]	18.27	55.83	0.009	-	726.22	0.0007	800.3
			TP[2]	4349.9	10442.2	196.0	756.6	-	21.4	15766.1
030-100	Newman Creek below Orrville Ditch to Tuscarawas	9.76-mouth	FC[1]	13.11	46.99	0.02	-	-	0.006	60.13
030-110	West Sippo Creek	Entirety	FC[1]	2.81	15.99	0.007	-	-	0.007	18.82
			TP[2]	3700.9	4330.8	191.4	646.8	-	108.7	8978.6
030-120	Sippo Creek	Entirety	FC[1]	0.63	7.49	0.01	-	-	0.004	8.14

[1] cfu * 10^{13} * $season^{-1}$ [2] lbs * $year^{-1}$

Table 5.22 Nonpoint source load allocations for 11-digit HUC 030.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameters		Individual Non-Point Sources						
					Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
030-050	Fox Run	Entirety	TP[2]	Allocation	769.2	308.4	227.5	63.3	-	5.1	1373.6
				% Reduction	92.3	92.3	0.0	92.3	-	92.3	-
030-070	Mudbrook Creek	Entirety	FC[1]	Allocation	0.23	2.62	0.007	-	-	0.0005	2.86
				% Reduction	84.4	84.4	0.0	-	-	84.4	-
030-080	Newman Creek above Orrville Ditch (RM 9.76)	Head-9.76	FC[1]	Allocation	0.96	2.68	0.009	-	0.00	0.0005	3.65
				% Reduction	95.5	95.5	0.0	-	100	95.5	-
			TP[2]	Allocation	187.2	333.1	209.9	29.3	-	8.4	767.8
				% Reduction	96.0	96.0	0.0	96.0	-	96.0	-
030-090	Orrville Ditch	Entirety	FC[1]	Allocation	0.87	2.67	0.009	-	0.00	0.00003	3.56
				% Reduction	95.2	95.2	0.0	-	100	95.2	-
			TP[2]	Allocation	2256.2	5416.1	196.0	392.4	-	11.0	8271.7
				% Reduction	48.1	48.1	0.0	48.1	-	48.1	-
030-100	Lower Newman Creek (dwst of Orrville D)	9.76-mouth	FC[1]	Allocation	0.90	3.22	0.02	-	-	0.0004	4.14
				% Reduction	93.2	93.2	0.0	-	-	93.2	-
030-110	West Sippo Creek	Entirety	FC[1]	Allocation	0.53	3.02	0.007	-	-	0.001	3.56
				% Reduction	81.1	81.1	0.0	-	-	81.1	-
			TP[2]	Allocation	662.0	774.7	191.4	115.7	-	19.4	1763.1
				% Reduction	82.1	82.1	0.0	82.1	-	82.1	-
030-120	Sippo Creek	Entirety	FC[1]	Allocation	0.63	7.49	0.01	-	-	0.004	8.14
				% Reduction	0.0	0.0	0.0	-	-	0.0	-

[1] cfu * 10^{13} * $season^{-1}$ for cfu * 10^{13} * day^{-1} divide each value by 138
[2] lbs * $year^{-1}$ for lbs * day^{-1} divide each value by 365

Table 5.23 Point source existing and allocated loads for 11-digit HUC 030.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent	Parameter		NPDES Discharger	MS4	HSTS
030-050	Fox Run	Entirety	TP[2]	Existing	114.0	0	732.4
				% reduction	none	-	100
				Allocation	904.8	0	0
030-070	Mudbrook Creek	Entirety	FC[1]	Existing	0.02	0.02	173.82
				% reduction	0	84.4	100
				Allocation	0.02	0.003	0
030-080	Newman Creek above Orrville Ditch (RM 9.76)	Head-9.76	FC[1]	Existing	0.22	0	174.52
				% reduction	0	-	100
				Allocation	0.22	0	0
			TP[2]	Existing	2070.1	0	835.8
				% reduction	39.1	-	100
				Allocation	1261.0	0	0
030-090	Orrville Ditch	Entirety	FC[1]	Existing	0	0	71.94
				% reduction	-	-	100
				Allocation	0	0	0
			TP[2]	Existing	0	0	344.6
				% reduction	-	-	100
				Allocation	0	0	0
030-100	Lower Newman Creek (dwst of Orrville D)	9.76-mouth	FC[1]	Existing	0.001	0.001	206.26
				% reduction	0	93.2	100
				Allocation	0.001	0.0001	0
030-110	West Sippo Creek	Entirety	FC[1]	Existing	0	0.03	359.49
				% reduction	-	81.1	100
				Allocation	0	0.006	0
			TP[2]	Existing	0	522.5	1721.8
				% reduction	-	82.1	100
				Allocation	0	93.5	0
030-120	Sippo Creek	Entirety	FC[1]	Existing	0	0.16	391.56
				% reduction	-	0	100
				Allocation	0	0.16	0

[1] cfu * 10^{13} * $season^{-1}$ for cfu * 10^{13} * day^{-1} divide each value by 138
[2] lbs * $year^{-1}$ for lbs * day^{-1} divide each value by 365

Table 5.24 Existing and allocated loads for point source dischargers (not including MS4s and HSTSs) for HUC 030.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent	Facility	Parameter	Existing load	% Reduction	Allocated load
030-010	Tusc R, below Wolf Ck to above Chippewa Ck	RM 110.7 to RM 103.2	3PD00004 Barberton WWTP	TP[2]	98505	80%	19701
030-050	Fox Run	Entirety	3PR00280 CLAY'S PARK RESORTS FOX RUN	TP[2]	18.9	none	639.7
			3PR00288 OHIO FAMILY FOUNDATION INC.		67.7	none	182.8
			3PV00099 TOP-O-HILL MHP		27.4	none	82.2
030-070	Mudbrook Creek	Entirety	3PV00097 FORTY CORNERS MOBILE VLG	FC[1]	0.02	0	0.02
030-080	Newman Creek above Orrville Ditch (RM 9.76)	Head-9.76	3PB00013 DALTON WWTP	FC[1]	0.19	0	0.19
			3PV00017 LINCOLN TERRACE ESTATES MHP		0.02	0	0.02
			3PB00013 DALTON WWTP	TP[2]	1895.3	51.8	913.8
			3PV00017 LINCOLN TERRACE ESTATES MHP		174.9	none	347.3
030-100	Lower Newman Creek (dwst of Orrville D)	9.76-mouth	3PR00180 NORTH LAWRENCE VOLUNTEER FIRE DEPT	FC[1]	0.001	0	0.001

[1] cfu * 10^{13} * $season^{-1}$ for cfu * 10^{13} * day^{-1} divide each value by 138
[2] lbs * $year^{-1}$ for lbs * day^{-1} divide each value by 365

Table 5.25 Facilities with required total P reductions in 11-digit HUC 030.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent	Facility	Outfall #	Average total P effluent concentration (mg/l)		Average effluent flow (MGD)	
					Existing	Required	Existing	Design
030-010	Tusc R, below Wolf Ck to above Chippewa Ck	RM 110.7 to RM 103.2	3PD00004 Barberton WWTP	001	5.39	1.0	5.5	6.0
030-080	Newman Ck upst Orrville D.	Head-9.76	3PB00013 DALTON WWTP	001	3.0[+]	1.0	0.207	0.3

[†] This concentration of total P (3.0 mg/l) is assumed for effluent from public waste facilities with no representative data

Table 5.26 MS4 entities for 11-digit HUC 030.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	MS4 entities	Exempt MS4 entities (wavier granted)
030-070	Mudbrook Creek	Entirety	Jackson Township (Stark County), Lawrence Township (Stark County)	-
030-100	Lower Newman Creek (dwst of Orrville D)	9.76-mouth	City of Massillon, Lawrence Township (Stark County), Tuscarawas Township (Stark County), Perry Township (Stark County)	-
030-110	West Sippo Creek	Entirety	Tuscarawas Township (Stark County), City of Massillon	-
030-120	Sippo Creek	Entirety	City of Massillon, Perry Township (Stark County), Jackson Township (Stark County)	Village of Hills and Dale

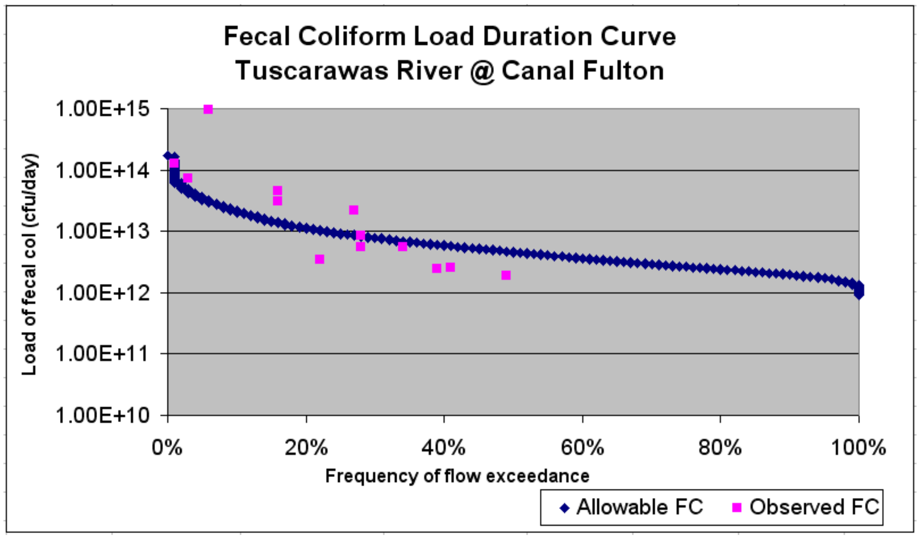

Figure 5.10 Load duration curve for the Tuscarawas River at river mile 100.3.

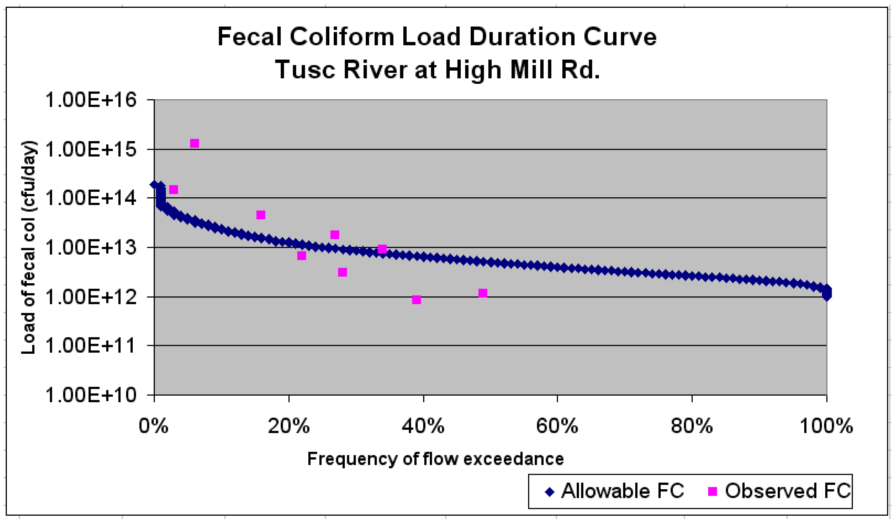

Figure 5.11 Load duration curve for the Tuscarawas River at river mile 94.87.

5.3.2 Habitat and Sediment

030-030

The upper Nimisila Creek sub-watershed has causes of impairments including siltation, habitat and flow alteration and organic enrichment. The one stream site in this sub-watershed met the sediment and habitat TMDL targets. There is only a slight deviation for one of the three measures included in the substrate metric of the sediment TMDL. Similar to Hubbard Creek in the 14-digit HUC 020-020, the habitat TMDL method using the QHEI does not indicate that areas with lake flow alterations fail to meet the habitat targets. The biology at this stream sampling site indicates the site only marginally misses the use attainment criteria for full attainment.

030-050
Fox Run sediment and habitat measurements fail to meet TMDL expectations throughout the subwatershed. Excessive siltation and channelization (although the channel is recovering) are cited as causes of impairment to the more downstream site (river mile 2.7). The upstream sampling site, river mile 4.9, has recently been channelized creating very poor habitat conditions which make this segment largely uninhabitable by aquatic life. Excessive fine stream sediment deposits, poor instream habitat cover and poor stream morphology lacking sinuosity are all noted as impairments of this site. The total QHEI score is only 18, the lowest of all the QHEIs calculated for this TMDL assessment unit.

030-080
One stream assessment site on upper Newman Creek has very little habitat cover, is dominated by fine sediments and is highly embedded. The sediment TMDL meets expectations with only the riparian metric not meeting its target. Despite the high degree of embeddedness, the large proportion of cobbles in the bed material was sufficient to raise the substrate score above the target value. The habitat measurements fails with two out of the three points needed to satisfy the TMDL. The only high influence attribute of modified conditions is sparse instream cover.

030-090
One site on Orrville Ditch and one site on an unnamed tributary to Orrville Ditch at river mile 0.52 are assessed in this 14-digit HUC. Orrville Ditch is designated as a MWH aquatic life use stream, and fails to meet the sediment and habitat targets by a large margin. Since these TMDLs are developed for WWH designated streams this TMDL is not fully appropriate. However the degree to which this site fails these TMDLs indicates the level of impact channel modifications have brought about. The unnamed tributary to Orrville Ditch drains the area containing the two CAFO operations discussed above in Section 5.3.1. The sediment and habitat TMDLs both meet expectations for WWH at this sampling site indicating these are not the main causes of impairment to this tributary. Organic enrichment is also a cause of impairment for this subwatershed, and reductions of nutrients and silage drainage from the Stoll Farms, Inc. should improve water quality and biology in Orrville Ditch's unnamed tributary as well as Orrville Ditch.

030-110
Three sampling sites on West Sippo Creek exist. The most upstream and downstream sites both meet the sediment and habitat TMDLs. The site in the middle, at river mile 2.6, fails to meet the sediment TMDL with a deviation of 27% and the habitat TMDL target is missed with a score of 2 points out of the 3 that are needed. These results indicate that the subwatershed impairment is primarily from its organic enrichment source which is dealt with above in Section 5.3.1.

030-120
Sippo Creek drains an area with a large population, and many historical channel alterations. Both the sediment and habitat miss TMDL expectations by a large degree. A muck substrate which creates complete embeddedness causes the substrate metric of the Sippo Creek sampling to be zero. Additionally the channelized nature of the stream is another reason for it scoring zero out of the three needed points for the habitat TMDL.

The unnamed tributary to Sippo Creek at river mile 4.54 contains the drainage from Lake Cable. This stream meanders in an altered channel through low density residential areas until it converges with Sippo Creek. While this stream is designated MWH it fails to meet the sediment and habitat TMDLs by a large margin. The low lying areas in this tributary's watershed were likely heavily influenced by wetlands. This fact should be considered when examining QHEI results.

Table 5.27 Sediment and habitat TMDLs for 11-digit HUC 030.

TMDL Targets For WWH		Sediment TMDL						Habitat TMDL						
		Allocations			TMDL			Allocations			Subscore			TMDL
		≥ 13	≥ 14	≥ 5	32			≥ 60 = *1 pt*	< 2 = *1 pt*	< 5 = *1 pt*				*3 pts*
Existing Scores Stream/River (Use) ***Impaired indicates use is not met***	**River Mile**	**QHEI Categories: Substrate**	**Channel**	**Riparian**	**Total Sediment Score**	**% Deviation from target**	**Main impaired category if any**	**QHEI Score**	**# of High Influence Attributes**	**Total # of Modified Attributes**	**QHEI**	**High influence**	**# Modified Attributes**	**Total Habitat Score**
Nimisila Creek to Nimisila Reservoir (05040001-030-030)														
Nimisila Creek	7	11.5	16	10	37.5	**Meets**	Substrate	77.5	0	3	1	1	1	**3**
Fox Run (05040001-030-050														
Fox Run	4.9	1	4	2	7	78.13	Substrate	18	4	10	0	0	0	0
	2.7	13.5	12.5	4.5	30.5	4.69	Channel	59.5	1	6	0	1	0	1
Newman Creek above Orrville Ditch (05040001-030-080)														
Newman Creek	11.9	17	15	2	34	**Meets**	Riparian	66.5	1	5	1	1	0	2
Orrville Ditch (05040001-030-090)														
Orrville Ditch	2.3	1	4	2	7	78.13	Substrate	20	4	9	0	0	0	0
Trib to Orville Ditch (RM 0.52)	1.2	17.5	15.5	3.5	36.5	**Meets**	Riparian	68.5	0	3	1	1	1	**3**
West Sippo Creek (05040001-030-110)														
West Sippo Creek (WWH)	3.8	16	15	4	35	**Meets**	Riparian	71.5	0	3	1	1	1	**3**
	2.6	6	14.5	3	23.5	26.56	Substrate	61.5	1	6	1	1	0	2
	1.1	17.5	16.5	5	39	**Meets**	**None**	73	0	1	1	1	1	**3**
Sippo Creek (05040001-030 120)														
Sippo Creek	4.6	0	10	4.5	14.5	54.7	Substrate	35.5	3	9	0	0	0	0
Trib to Sippo Creek (RM 4.54)	2.8	1	6	4.5	11.5	64.06	Substrate	27.5	4	10	0	0	0	0

5.3.3 Organic Enrichment/Dissolved Oxygen

030-010

This 14-digit HUC receives a large nutrient load from the Barberton WWTP. The effluent concentration of total phosphorus (based on the discharger's self monitoring data from 2002-2005) ranges from 1.2 to 11.8 mg/l, with an average of 5.4 mg/l. On average, the Barberton WWTP releases 122 kg/day of total phosphorus to the stream. Figure 5.12 shows a load duration curve for total P, developed from water quality and streamflow data collected by Ohio EPA in the Tuscarawas River at RM 104.3, about 4.8 miles downstream from the Barberton WWTP. The red line indicates the target load of phosphorus, which is being exceeded under most flow regimes, except the extremely high flows. The blue data points indicate total phosphorus loads measured in the stream. Notice that most load data points do not increase with streamflow, other than under extremely high flows (those exceeded from 0 to 14% of the time). This confirms that the Barberton WWTP (a fairly constant load) is the main phosphorus contributor, rather than nonpoint sources associated with runoff events.

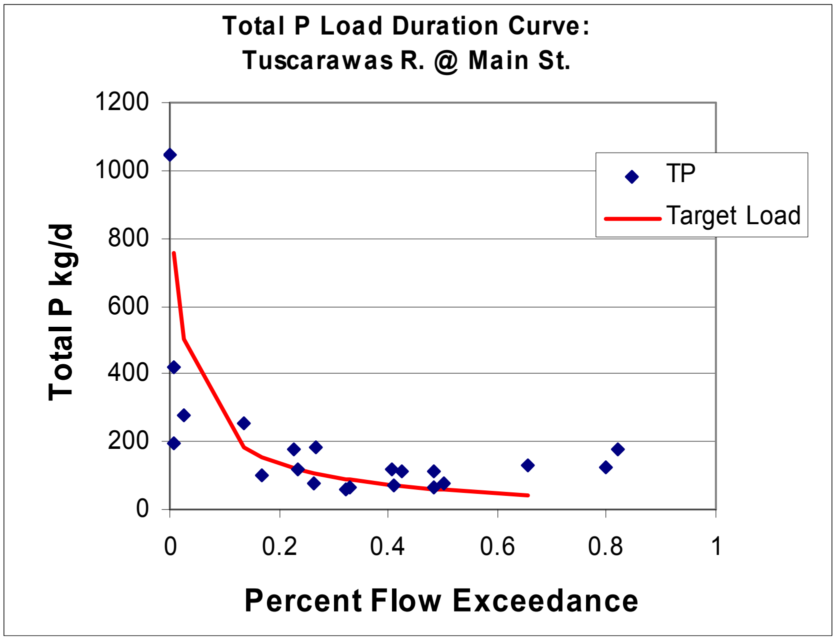

Figure 5.12 Total P load duration curve for the Tuscarawas River at Main St., Clinton (RM 104.3).

Figure 5.13 shows the dramatic increase in the Tuscarawas River total P concentration in the vicinity of the Barberton WWTP outfall, well above the target instream concentrations of 0.28 mg/l (MWH target) and 0.17 mg/l (WWH target). The plots are based on data collected by Ohio EPA between 2003 and 2005.

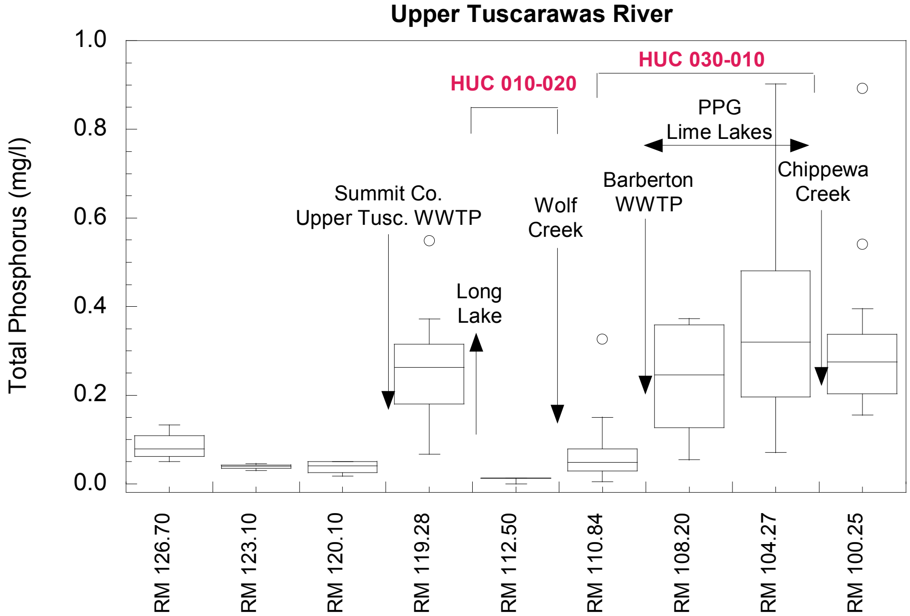

Figure 5.13 Range of Total P measured from Ohio EPA water quality surveys (2003-2005) in the Upper Tuscarawas River.

The other large contributor of total P in the reach (assumed to be mostly in dissolved form) seems to be groundwater inflow near the PPG lime lakes, based on mass balance analysis of the streamflows, water quality, and effluent data collected during the 13-15 September 2005 Ohio EPA survey. The PPG lime lakes contain waste from soda ash production, which consist of fine-grained lime spoil that is alkaline, lacks nutrients, and is unable to support vegetation. Reclamation efforts included mixing the waste with sewage sludge, regrading, and planting of mixed herbaceous and woody vegetation (Foos, et al., 2000).

Additional field data collection is recommended to confirm the source of the unaccounted flow and nutrients downstream of the Barberton WWTP.

The calibrated QUAL2K model for the upper Tuscarawas River is used to simulate water quality under summer $7Q_{10}$ design conditions. Input data for the QUAL2K D.O. model is shown in Appendix E. Figure 5.14 shows some scenarios simulated under summer low flow conditions. The three scenarios shown are:

- existing conditions (total P concentration of 5.4 mg/l at 5.5 MGD)
- recommended total P concentration of 1 mg/l at design flow (6 MGD)
- effluent total P concentration of 1.0 mg/l at design flow, in addition to 80% reduction in suspected groundwater /lime lakes phosphorus contribution.

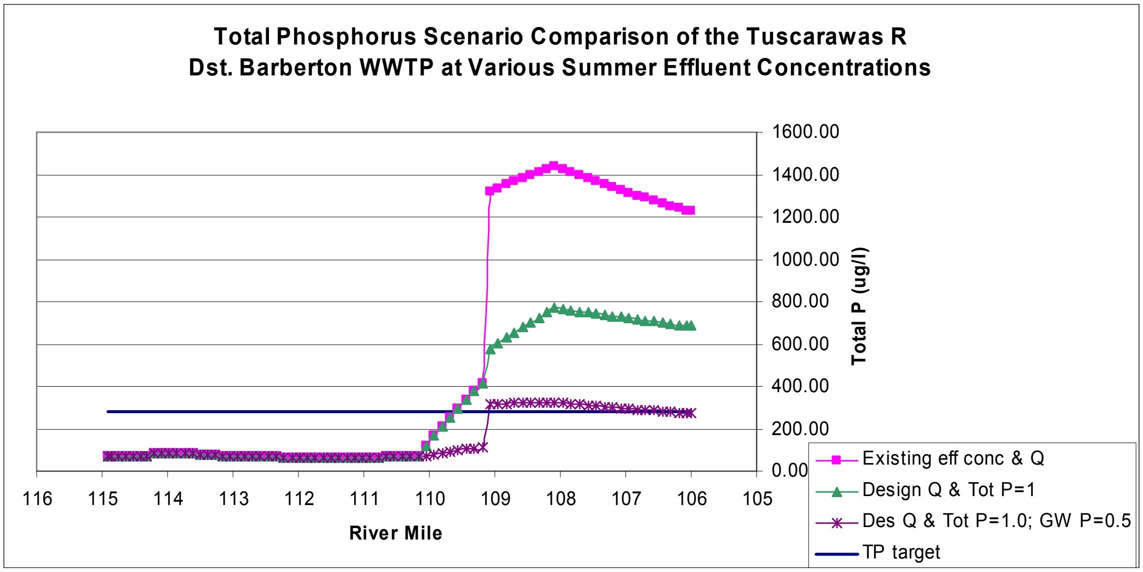

Figure 5.14 Possible scenarios for total P reduction in Tuscarawas River near Barberton, from QUAL2K model summer simulations.

The simulations indicate that even with an effluent total P of 1 mg/l, the instream concentration of total P downstream of the Barberton WWTP will not meet the total P target of 0.28 mg/l unless the phosphorus contribution from unknown sources (possibly from groundwater/PPG lime lakes) drops from an estimated 2.2 mg/l to less than 0.5 mg/l.

The effluent concentration shown in Table 5.24 represents an 80% reduction in total P load for the Barberton WWTP.

5.4 Tuscarawas River (below Sippo Creek to above Sugar Creek) [Excluding Sandy Creek and Conotton Creek]– 090

This 11-digit HUC, like 030, contains a large amount of the Tuscarawas River mainstem (32.7 river miles) and several smaller tributaries. Downstream of the City of Massillon at river mile 85.2 the mainstem of the Tuscarawas River achieves full attainment of the WWH use designation and remains that way downstream to the end of this 11-digit HUC. Also in this watershed, the landscape changes from rolling glacial deposits to hills and valleys of the Appalachian foothills (from the glaciated to unglaciated Allegheny Plateaus). This landscape change, which occurs approximately at the Stark/Tuscarawas County line, restricts most agricultural activity to the valley bottoms while hillsides contain increased wooded areas (Pavey, et al., 1999). While this generally improves stream quality, several of these hillsides contain old coal mines with drainage that is acidic and/or contains high concentrations of metals.

5.4.1 Watershed Nutrients and Pathogens

Nutrient Modeling
Only the unnamed tributary to the Tuscarawas River at river mile 83.73 is impaired due to nutrients in this 11-digit HUC. The permitted point source on that watershed, P.J. Lohr Elementary School, is allocated a greater total phosphorus load than it is currently discharging since it is small, less than 0.1 MGD design flow. The school is not operating at its design flow. Allocating a concentration of 0.08 mg/l at the facility design flow, plus reducing the HSTS load to zero, will still require 79.0% of all total P from nonpoint sources and MS4 runoff be reduced to meet the TMDL.

Pathogen Modeling
Four subwatersheds are impaired for recreational use in this 11-digit HUC, and failing HSTS are the primary source of pathogens in all four. However, even after HSTS are given a zero load allocation, the remaining nonpoint source runoff load of fecal coliform still must be reduced by more than 75% in each subwatershed in order to meet applicable TMDLs.

Table 5.28 Total existing load, TMDL and allocations for 11-digit HUC 090 (annual/seasonal).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameters	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
090-020	Pigeon Run	Entirety	FC[1]	156.5	16.2	-	172.7	98.4	2.71	0.0003	2.7	-	-
090-030 partial	UT to Tusc. 83.73	Head-0.2	FC[1]	111.2	20.6	-	131.8	97.9	2.75	0.009	2.7	-	-
			TP[2]	858.5	5652.2	-	6510.6	76.3	1540.6	152.6	1310.9	-	76.9
	UT to Tusc 77.96	Head-0.3	FC[1]	26.9	8.4	-	35.3	94.1	2.10	0.00	2.1	-	-
090-040 partial	Small Middle Run	Entirety	FC[1]	5.22	5.06	-	10.3	90.2	1.01	0.00	1.0	-	-

Table 5.29 Total existing load, TMDL and allocations for 11-digit HUC 090 (daily).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
090-020	Pigeon Run	Entirety	FC[1]	1.13	0.12	-	1.25	98.4	0.02	0.000002	0.02	-	-
090-030 partial	UT to Tusc. 83.73	Head-0.2	FC[1]	0.81	0.15	-	0.96	97.9	0.02	0.00007	0.02	-	-
			TP[2]	2.35	15.49	-	17.84	76.3	4.22	0.42	3.59	-	0.21
	UT to Tusc 77.96	Head-0.3	FC[1]	0.20	0.06	-	0.26	94.1	0.02	0.00	0.02	-	-
090-040 partial	Small Middle Run	Entirety	FC[1]	0.04	0.04	-	0.08	90.2	0.007	0.00	0.007	-	-

[1] cfu * 10^{13} * day^{-1}
[2] lbs * day^{-1}

Table 5.30 Existing nonpoint source loads for 11-digit HUC 090.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Non-Point Source Loads						
				Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
090-020	Pigeon Run	Entirety	FC[2]	1.87	14.31	0.01	-	-	0.006	16.20
090-030 partial	UT to Tusc. 83.73	Head-0.2	FC[2]	5.37	15.26	0.008	-	-	0.004	20.65
			TP[2]	2848.2	2067.7	156.3	522.3	-	57.8	5652.2
	UT to Tusc 77.96	Head-0.3	FC[2]	2.21	6.17	0.01	-	-	0.0001	8.39
090-040 partial	Small Middle Run	Entirety	FC[2]	0.53	4.52	0.01	-	-	0.002	5.06

[1] cfu * 10^{13} * $season^{-1}$ for cfu * 10^{13} * day^{-1} divide each value by 138
[2] lbs * $year^{-1}$ for lbs * day^{-1} divide each value by 365

Table 5.31 Nonpoint source allocations for 11-digit HUC 090.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		Individual Non-Point Sources						
					Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
090-020	Pigeon Run	Entirety	FC[1]	Allocation	0.31	2.39	0.01	-	-	0.001	2.71
				% Reduction	83.3	83.3	0.0	-	-	83.3	-
090-030 partial	UT to Tusc. 83.73	Head-0.2	FC[1]	Allocation	0.71	2.02	0.008	-	-	0.0005	2.74
				% Reduction	86.8	86.8	0.0	-	-	86.8	-
			TP[2]	Allocation	598.3	434.3	156.3	109.8	-	12.1	1310.9
				% Reduction	79.0	79.0	0.0	79.0	-	79.0	-
	UT to Tusc 77.96	Head-0.3	FC[1]	Allocation	0.55	1.54	0.01	-	-	0.00003	2.10
				% Reduction	75.1	75.1	0.0	-	-	75.1	-
090-040 partial	Small Middle Run	Entirety	FC[1]	Allocation	0.10	0.90	0.01	-	-	0.0004	1.01
				% Reduction	80.2	80.2	0.0	-	-	80.2	-

[1] cfu * 10^{13} * $season^{-1}$ for cfu * 10^{13} * day^{-1} divide each value by 138
[2] lbs * $year^{-1}$ for lbs * day^{-1} divide each value by 365

Table 5.32 Point source existing and allocated loads for 11-digit HUC 090.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		NPDES Discharger	MS4	HSTS
090-020	Pigeon Run	Entirety	FC[1]	Existing	0	0.002	156.53
				% reduction	-	83.3	100
				Allocation	0	0.0003	0
090-030 partial	UT to Tusc. 83.73	Head-0.2	FC[1]	Existing	0.006	0.02	111.16
				% reduction	0	86.8	100
				Allocation	0.006	0.003	0
			TP[2]	Existing	34.6	291.5	532.4
				% reduction	none	79.0	100
				Allocation	91.5	61.3	0
	UT to Tusc 77.96	Head-0.3	FC[1]	Existing	0	0	26.89
				% reduction	-	-	100
				Allocation	0	0	0
090-040 partial	Small Middle Run	Entirety	FC[1]	Existing	0	0	5.22
				% reduction	-	-	100
				Allocation	0	0	0

[1] cfu * 10^{13} * $season^{-1}$ for cfu * 10^{13} * day^{-1} divide each value by 138
[2] lbs * $year^{-1}$ for lbs * day^{-1} divide each value by 365

Table 5.33 Existing and allocated loads of point source dischargers (not including MS4s and HSTSs) for HUC 090.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent	Facility	Para-meter	Existing load	% Reduction	Allocated load
090-010	Tuscarawas R	Dst. Sippo Ck to Upst. Pigeon Run	3PE00007 Massillon WWTP	TP[2]	79194	60%	31680
090-030 partial	UT to Tusc. 83.73	Head-0.2	3PT00100 PJ LOHR ELEM SCH	FC[1]	0.006	0	0.006
			3PT00100 PJ LOHR ELEM SCH	TP[2]	34.6	none	91.5

[1] $cfu * 10^{13} * season^{-1}$ for $cfu * 10^{13} * day^{-1}$ divide each value by 138
[2] $lbs * year^{-1}$ for $lbs * day^{-1}$ divide each value by 365

Table 5.34 Facilities with required total P reductions in 11-digit HUC 090.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent	Facility	Outfall #	Average total P effluent concentration (mg/l)		Average effluent flow (MGD)	
					Existing	Required	Existing	Design
090-010	Tuscarawas River	RM 90.8 to RM 86.8	3PE00007 Massillon WWTP	001	2.60	1.0	9.75	10.0

Table 5.35 MS4 entities for 11-digit HUC 090.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	MS4 entities	Exempt MS4 entities (wavier granted)
090-020	Pigeon Run	Entirety	Tuscarawas Township (Stark County)	-
090-030 partial	UT to Tusc. 83.73	Head-0.2	Village of Navarre	Bethlehem Township (Stark County)

5.4.2 Habitat and Sediment

090-030
The only stream in this 11-digit HUC that is considered impaired because of habitat alterations is the unnamed tributary to the Tuscarawas River at river mile 83.74. Poor instream habitat and stream channel development, especially the lack of deeper pools, are the main reasons that this site does not meet the habitat targets. Unknown flow alterations resulting in low flow is also noted as a cause of impairment.

090-040
Two small Tuscarawas River tributaries in this 14-digit HUC are impaired due to sediment. These tributaries, in addition to Wolf Run, drain areas that are heavily wooded in the stream valleys, but contain abandoned strip mines on the hilltops. Legacy mining spoil and current erosion of those mined areas contribute sediment to these streams. Middle Run narrowly misses the sediment TMDL target, but Small Middle Run does meet it. The TMDL results indicate that higher channel and riparian scores inflate these sediment TMDLs (Table 5.35). This is because the riparian and near-upland areas in these streams' watersheds are heavily wooded.

Table 5.36 Sediment and habitat TMDLs for 11-digit HUC 090.

TMDL Targets For WWH		**Sediment TMDL**						**Habitat TMDL**						
		Allocations			**TMDL**			**Allocations**			**Subscore**			**TMDL**
		≥ 13	**≥ 14**	**≥ 5**	**32**			**≥ 60 = *1 pt***	**< 2 = *1 pt***	**< 5 = *1 pt***				***3 pts***
Existing Scores Stream/River (Use) ***Impaired indicates use is not met***	**River Mile**	**QHEI Categories: Substrate**	**Channel**	**Riparian**	**Total Sediment Score**	**% Deviation from target**	**Main impaired category if any**	**QHEI Score**	**# of High Influence Attributes**	**Total # of Modified Attributes**	**QHEI**	**High influence**	**# Modified Attributes**	**Total Habitat Score**
Tuscarawas River below Pigeon Creek to above Sandy Creek (05040001-090-030)														
Trib to Tuscarawas River (RM 83.74)	0.2	**Not applicable**						61.5	2	5	1	0	0	1
Tuscarawas River below Sandy Creek to above Conotton Creek (05040001-090-040)														
Middle Run	0.5	5.5	16	9	30.5	4.69	Substrate	**Not applicable**						
Small Middle Run	0.5	12	16.5	10	38.5	**Meets**	Substrate							

5.4.3 Organic Enrichment/Dissolved Oxygen

The segment of the Tuscarawas River mainstem located within this 11-digit HUC is partially impaired due to organic enrichment and unknown toxicity.

090-010

The largest point source nutrient load within this 14-digit HUC comes from the Massillon WWTP. The treatment plant's effluent concentration of total P (based on 2002-2005 self monitoring data) ranges from 0.6 to 8.2 mg/l, with an average of 2.6 mg/l. On average, the Massillon WWTP releases 91 kg/day of phosphorus to the stream. Figure 5.15 shows a load duration curve for total P, based on water quality and streamflow data collected by Ohio EPA in the Tuscarawas River at Warmington Road (RM 87.4), about 1.3 miles downstream from the Massillon WWTP. The red line indicates the target load of phosphorus, which is being exceeded under all flow regimes, except for a few occasions. The blue data points indicate total P loads measured in the stream. Notice that the total P load increases gradually with streamflow. This indicates that, while the Massillon WWTP contributes a fairly constant phosphorus load, there are upstream nonpoint sources that are also contributing phosphorus during periods of high precipitation. These sources are being addressed through the TMDLs performed on impaired tributaries, using GWLF or load duration curves.

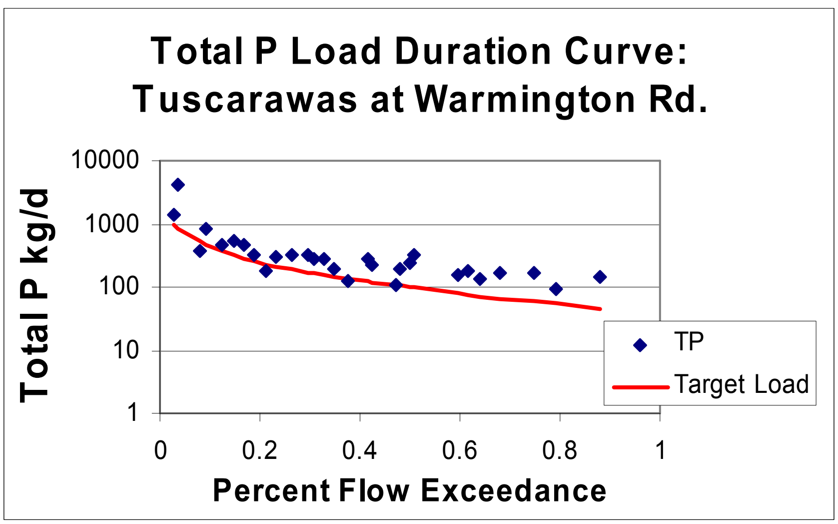

Figure 5.15 Total P load duration curve for the Tuscarawas River at Warmington Road, Massillon (RM 87.4).

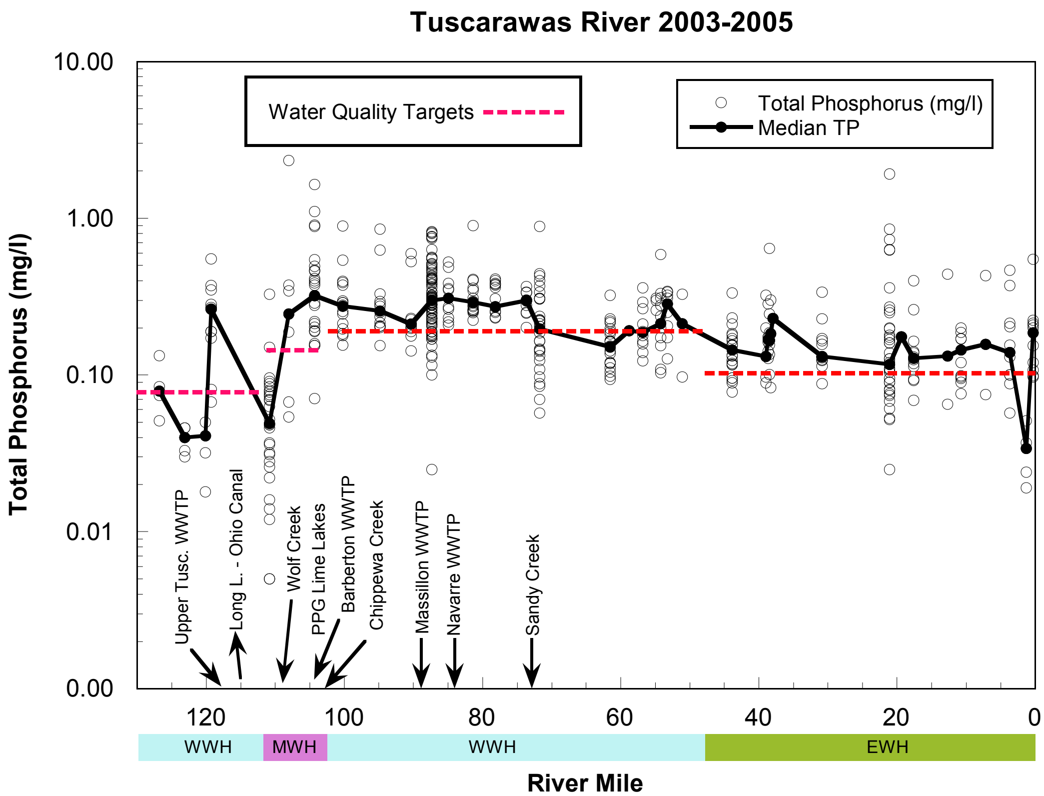

Figure 5.16 Total P concentration trends for the Tuscarawas River Mainstem, from headwaters to mouth.

Total P data from the Tuscarawas River in the vicinity of Massillon is summarized in Figure 5.16. The contributions of total P from the Barberton and Massillon WWTPs are evident because the stream concentrations rise due to their discharge. Another relatively large source of total P seems to be Chippewa Creek. Seasonal phosphorus limits may be sufficient for the Massillon WWTP, since this segment of the river appears to assimilate nutrients well.

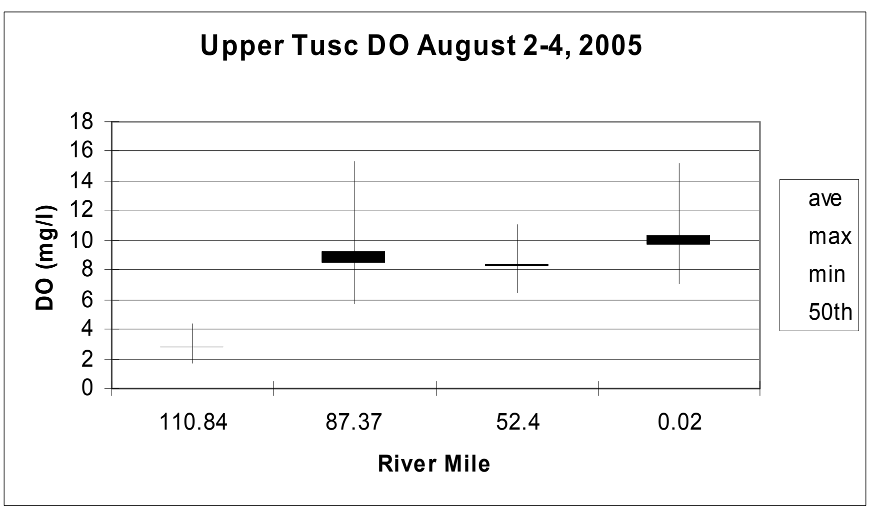

Figure 5.17 Dissolved Oxygen concentration trends for the Tuscarawas River Mainstem, from Barberton (RM 110.8) to the mouth (Aug 2005).

The dissolved oxygen data show the influence of nutrient enrichment downstream of the Massillon WWTP (RM 87.37). While there are no dissolved oxygen violations at that site, the fluctuation between a minimum of 5.8 mg/l and a maximum of 15.3 mg/l indicates that there is an abundance of algae producing oxygen during the day, as well as those consuming it at night. The Tuscarawas River achieves full attainment downstream of river mile 87.

The effluent concentration shown in Table 5.33 represents a 60% reduction in total P load for the Massillon WWTP.

5.5 Tuscarawas River (below Sugar Ck to above Stillwater Ck) – 130

This entire 11-digit HUC is within the unglaciated portion of the watershed. It contains 11.02 river miles of the Tuscarawas River and several small and medium sized tributaries. The Tuscarawas River is in full attainment of WWH aquatic life use designation throughout this 11-digit HUC, therefore only tributaries are discussed in this section.

5.5.1 Watershed Pathogens

The cause of impairment in the section of Stone Creek not meeting its aquatic life use attainment is organic enrichment. A large amount of failing HSTS discharging directly upstream of this sampling site are present. Addressing these sources of organic enrichment through the pathogen TMDL is sufficient to address this cause of impairment.

Figure 5.18 Pipes discharging gray water to Stone Creek in the Village of Stone Creek.

Only three subwatersheds require pathogen modeling. This is partly because streams with acid mine drainage, of which they are several in this 11-digit HUC, are typically inhospitable to bacteria.

Pathogen Modeling
Modeling results show that in all three subwatersheds with bacteria TMDLs failing HSTS are responsible for greater than 70% of the fecal coliform load. Particularly on Stone Creek, in the Village of Stone Creek, numerous discharges of gray and soapy water can be observed (Figure 5.18). Similar to other subwatersheds with this modeling method applied, after the HSTS loads are reduced to zero, large reductions of nonpoint source loads are still required. The majority of this nonpoint source load is from grazing animals on pasture land.

Table 5.37 Total existing load, TMDL and allocations for 11-digit HUC 130 (Annual/Seasonal).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
130-010	Stone Creek	Entirety	FC[1]	213.7	90.7	-	304.4	96.0	12.18	0.0	12.2	-	-
130-030	Oldtown Creek	Entirety	FC[1]	122.7	34.9	-	157.6	96.3	5.88	0.00006	5.88	-	-
130-040	Beaverdam Creek	Entirety	FC[1]	241.6	33.6	-	275.2	97.4	7.03	0.008	7.02	-	-

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.38 Total existing load, TMDL and allocations for 11-digit HUC 130 (daily).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
130-010	Stone Creek	Entirety	FC[1]	1.55	0.66	-	2.21	96.0	0.09	0.0	0.09	-	-
130-030	Oldtown Creek	Entirety	FC[1]	0.89	0.25	-	1.14	96.3	0.04	0.0000004	0.04	-	-
130-040	Beaverdam Creek	Entirety	FC[1]	1.75	0.24	-	1.99	97.4	0.05	0.00006	0.05	-	-

[1] cfu * 10^{13} * day^{-1}

Table 5.39 Existing nonpoint source loads for 11-digit HUC 130.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Non-Point Source Loads						
				Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
130-010	Stone Creek	Entirety	FC[1]	13.58	77.00	0.11	-	-	0.02	90.70
130-030	Oldtown Creek	Entirety	FC[1]	5.21	29.68	0.06	-	-	0.005	34.94
130-040	Beaverdam Creek	Entirety	FC[1]	4.82	28.72	0.06	-	-	0.01	33.61

[1] cfu * 10^{13} * $season^{-1}$

Table 5.40 Nonpoint source allocations for 11-digit HUC 130.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		Individual Non-Point Sources						
					Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
130-010	Stone Creek	Entirety	FC[1]	Allocation	1.81	10.26	0.11	-	-	0.002	12.18
				% Reduction	86.7	86.7	0.0	-	-	86.7	-
130-030	Oldtown Creek	Entirety	FC[1]	Allocation	0.87	4.95	0.06	-	-	0.0008	5.88
				% Reduction	83.3	83.3	0.0	-	-	83.3	-
130-040	Beaverdam Creek	Entirety	FC[1]	Allocation	1.00	5.96	0.06	-	-	0.002	7.02
				% Reduction	79.3	79.3	0.0	-	-	79.3	-

[1] cfu * 10^{13} * $season^{-1}$

Table 5.41 Point source existing and allocated loads for 11-digit HUC 130.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		NPDES Discharger	MS4	HSTS
130-010	Stone Creek	Entirety	FC[1]	Existing	0	0	213.72
				% reduction	-	-	100
				Allocation	0	0	0
130-030	Oldtown Creek	Entirety	FC[1]	Existing	0	0.0003	122.70
				% reduction	-	83.31	100
				Allocation	0	0.00005	0
130-040	Beaverdam Creek	Entirety	FC[1]	Existing	0.005	0.01	241.61
				% reduction	0	79.26	100
				Allocation	0.005	0.003	0

[1] cfu * 10^{13} * $season^{-1}$

Table 5.42 Existing and allocation loads of point source dischargers (not including MS4s and HSTSs) for HUC 130

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent	Facility	Parameter	Existing load	% Reduction	Allocated load
130-040	Beaverdam Creek	Entirety	0PG00031 KERR ALLOTMENT WWTP	FC[1]	0.0000005	0	0.0000005

[1] cfu * 10^{13} * $season^{-1}$

Table 5.43 MS4 entities for 11-digit HUC 130.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	MS4 entities
130-030	Oldtown Creek	Entirety	City of New Philadelphia
130-040	Beaverdam Creek	Entirety	City of New Philadelphia

5.5.2 Habitat and Sediment

130-010
The Stone Creek subwatershed has impaired habitat and excessive deposited sediment throughout its drainage network. The one QHEI site on Stone Creek and the one site on its tributary, Crooked Creek, score zero out of three on the habitat TMDL. Fine sediments creating high channel embeddedness, poor instream habitat cover and modified channels are noted at these sites. The sediment TMDL target is also not met at both sites with the riparian metric deviating from the target the greatest. Stone Creek parallels Interstate-77 throughout most of its length and has been channelized at various locations. Throughout the upland part of the watershed extensive land disturbance from strip mining has occurred. This and various agriculture uses nearer the waterways are likely causes of stream sediment.

130-030
The health of Oldtown Creek increasingly declines as the stream flows downstream. The sediment and habitat TMDLs for the uppermost sampling site at river mile 7.9 are presented in Table 5.43 only to show all of the sites in this 14-digit HUC. While the stream is in full attainment of WWH at this sampling site, both the sediment and habitat scores fall substantially below the TMDL targets. The downstream sampling site, which does not meet WWH aquatic life use expectations, also fails the sediment and habitat TMDLs. Excessive fine stream substrates is the major cause for both of these sites' impairments. Like Stone Creek, old strip mines that cover much of the hillside areas throughout the Oldtown Creek subwatershed are likely contributors of much of the stream's deposited sediment. Suburban development from New Philadelphia also seems to be contributing to the stream's sediment accumulation. Figure 5.19 shows storm waters laden with sediment running off of a housing project after a short storm. Note in the photograph that downstream of the pipe a large shelf of fine sediments is already deposited from earlier runoff.

Figure 5.19 Oldtown Creek sediment laden storm water discharge (the stream is flowing from the right to the left of the photograph).

130-040

The causes of impairment listed for Beaverdam Creek are siltation and metals. However, two measures of aquatic life use attainment involving fish sampling were not conducted. Also, the target for the sediment TMDL at the one Beaverdam Creek assessment site is currently being met.

Table 5.44 Sediment and habitat TMDLs for 11-digit HUC 130.

TMDL Targets For WWH		**Sediment TMDL**						**Habitat TMDL**						
		Allocations			**TMDL**			**Allocations**			**Subscore**			**TMDL**
		≥ 13	**≥ 14**	**≥ 5**	**32**			**≥ 60 = *1 pt***	**< 2 = *1 pt***	**< 5 = *1 pt***				***3 pts***
Existing Scores Stream/River (Use) ***Impaired indicates use is not met***	**River Mile**	**QHEI Categories**			**Total Sediment Score**	**% Deviation from target**	**Main impaired category if any**	**QHEI Score**	**# of High Influence Attributes**	**Total # of Modified Attributes**	**QHEI**	**High influence**	**# Modified Attributes**	**Total Habitat Score**
		Substrate	**Channel**	**Riparian**										
Stone Creek (05040001-130-010)														
Crooked Creek	2.4	13	11	2.5	26.5	17.19	Riparian	53	2	7	0	0	0	0
Stone Creek	7.2	12.5	10	3.5	26	18.75	Riparian	47	2	8	0	0	0	0
Oldtown Creek (05040001-130-030)														
Oldtown Creek	7.9	5	14.5	4.5	24	25.00	Substrate	47	2	8	0	0	0	0
	4.8	6	9	3.5	18.5	42.19	Substrate	42.5	2	10	0	0	0	0
Beaverdam Creek (05040001-130-040)														
Beaverdam Creek	0.95	18	18	5	41	**Meets**	**None**	**Not applicable**						

5.6 Tuscarawas River (below Stillwater Ck to above Evans Ck) – 180

The Tuscarawas River mainstem is in full attainment of EWH aquatic life use throughout the 32.25 miles it runs in this 11-digit HUC. Most of the tributaries with sampling sites not meeting expected aquatic life use criteria also contain a sampling site where the criteria are met. Recreational use impairment stems from cattle grazing in or near streams and some HSTS failure, particularly in Buckhorn Creek.

5.6.1 Watershed Nutrients and Pathogens

Nutrient Modeling
Buckhorn Creek is the only subwatershed modeled for nutrients in this 11-digit HUC. Grazing cattle are responsible for much of the total P load, in the form of pasture-land runoff. Other nonpoint source runoff and failing HSTS, particularly in the unincorporated area of Wolf community, contribute the rest of the nutrient load. After the HSTS is allocated to zero the remaining nonpoint sources (which includes pasture-land runoff) require an 84.4% reduction to meet the TMDL.

Pathogen Modeling
Of the three 14-digit HUCs with pathogen loading modeling, Dunlap Creek and Buckhorn Creek both have cattle grazing in streams providing a direct source of fecal coliform. The unincorporated area of Wolf contains several houses close together that discharge poorly treated sewage water directly to Buckhorn Creek. Because of this, the failure rate for HSTS in this subwatershed is calculated higher than other subwatersheds in this area. The majority of Dunlap Creek land area is forested. After allocations are set reducing the cattle grazing in streams and HSTS loads, the remaining nonpoint sources only require a 57.6% reduction. Buckhorn Creek requires a higher 84.4 % nonpoint source reduction.

Table 5.45 Total existing load, TMDL and allocations for 11-digit HUC 180 (annual/seasonal).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
180-030	Dunlap Creek	Entirety	FC[1]	70.1	505.0	-	575.2	98.7	7.67	0.00	7.67	-	-
180-040 partial	Blue Ridge Run	Head-0.4	FC[1]	10.6	4.8	-	15.4	93.7	0.97	0.00	0.97	-	-
180-050	Buckhorn Creek	Entirety	FC[1]	354.2	760.9	-	1115.0	99.3	7.36	0.00	7.36	-	-
			TP[2]	1696.2	28146.9	-	29843.1	82.0	5367.2	0.00	5098.9	-	268.4

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.46 Total existing load, TMDL and allocations for 11-digit HUC 180 (daily).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
180-030	Dunlap Creek	Entirety	FC[1]	0.51	3.66	-	4.17	98.7	0.06	0.00	0.06	-	-
180-040 partial	Blue Ridge Run	Head-0.4	FC[1]	0.08	0.03	-	0.11	93.7	0.007	0.00	0.007	-	-
180-050	Buckhorn Creek	Entirety	FC[1]	2.57	5.51	-	8.33	99.3	0.05	0.00	0.05	-	-
			TP[2]	4.65	77.11	-	81.76	82.0	14.70	0.00	13.97	-	0.74

[1] cfu * 10^{13} * day^{-1}
[2] lbs * day^{-1}

Table 5.47 Existing nonpoint source loads for 11-digit HUC 180.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Non-Point Source Loads						
				Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
180-030	Dunlap Creek	Entirety	FC[1]	1.80	16.09	0.07	-	487.04	0.002	505.01
180-040 partial	Blue Ridge Run	Head-0.4	FC[1]	0.55	4.27	0.004	-	-	0.0009	4.83
180-050	Buckhorn Creek	Entirety	FC[1]	4.05	24.41	0.04	-	732.36	0.007	760.87
			TP[2]	7804.8	17765.3	845.7	1510.8	-	220.2	28146.9

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.48 Nonpoint source allocations for 11-digit HUC 180.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		Individual Non-Point Sources						
					Cropland	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
180-030	Dunlap Creek	Entirety	FC[1]	Allocation	0.76	6.82	0.07	-	0.00	0.0007	7.67
				% Reduction	57.6	57.6	0.0	-	100	57.6	-
180-040 partial	Blue Ridge Run	Head-0.4	FC[1]	Allocation	0.11	0.86	0.004	-	-	0.0002	0.97
				% Reduction	79.9	79.9	0.0	-	-	79.9	-
180-050	Buckhorn Creek	Entirety	FC[1]	Allocation	1.04	6.27	0.04	-	0.00	0.002	7.36
				% Reduction	74.3	74.3	0.0	-	100	74.3	-
			TP[2]	Allocation	1215.8	2767.7	845.7	235.5	-	34.4	5098.9
				% Reduction	84.4	84.4	0.0	84.4	-	84.4	-

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.49 Point source existing and allocation loads for 11-digit HUC 180.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		NPDES Discharger	MS4	HSTS
180-030	Dunlap Creek	Entirety	FC[1]	Existing	0	0	70.15
				% reduction	-	-	100
				Allocation	0	0	0
180-040 partial	Blue Ridge Run	Head-0.4	FC[1]	Existing	0	0	10.61
				% reduction	-	-	100
				Allocation	0	0	0
180-050	Buckhorn Creek	Entirety	FC[1]	Existing	0	0	354.15
				% reduction	-	-	100
				Allocation	0	0	0
			TP[2]	Existing	0	0	1696.2
				% reduction	-	-	100
				Allocation	0	0	0

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

5.6.2 Habitat and Sediment

180-010
Mud Run is a small Tuscarawas River tributary that fails to meet the WWH aquatic life use designation. Siltation and metals are listed as causes of impairment to Mud Creek. The sediment TMDL does not indicate sediment impairment; however the QHEI assessment does show several factors of excessive deposited material. Mud Run drains areas that have been strip mined and it is likely that this activity is the source for much of the siltation and metals.

180-020
Of the two sampling sites on Frys Creek the downstream site is in non-attainment. The causes for this impairment are habitat alteration, siltation and metals. The sediment and habitat TMDLs have been applied to both of the Frys Creek sampling sites even though only the downstream site is not in attainment. Both sites fail to meet each TMDL target; however, the downstream site has a greater deviation. Habitat improvements to the upstream site are likely to be beneficial to downstream sites.

Channel modifications and lack of instream habitat cover are the main reasons for habitat impairment at the downstream Frys Creek site, though excessive fine sediments are noted. The riparian metric has the greatest deviation from the target for both Frys Creek sediment TMDLs. Strip mining has occurred in the hillside in the Frys Creek watershed and most of the stream valley is being used as cropland.

180-030
Of the two sampling sites on Dunlap Creek the upstream site (RM 4.1) is not meeting its aquatic life use designation. Both the downstream Dunlap Creek sampling site (RM 2.1) and the sampling site on the Dunlap Creek tributary Browning Run are in full attainment. The causes of impairment for Dunlap Creek are habitat alteration and siltation. The RM 4.1 site meets the habitat TMDL, but fails to meet the sediment TMDL. Poor riparian habitat exists at this site and the RM 2.1 sampling site. Cattle have access to Dunlap Creek at and around the RM 4.1 site and contribute to channel instability and erosion in addition to the poor riparian conditions.

180-050
Buckhorn Creek is not meeting its WWH aquatic life use designation at the upstream sampling site. West Fork Buckhorn Creek is MWH and does not meet the lower expectations for that designation at its downstream site. In addition to organic enrichment, habitat alteration and siltation are described as causes of impairment in this subwatershed. All four sampling sites, two on Buckhorn Creek and two on West Fork Buckhorn Creek, fail to meet both the sediment and habitat TMDLs. Channel modification and a buildup of sediments are the main causes for these habitat impairments. Grazing cattle throughout the stream valleys and in some fields in the stream channel are also a contributor to the habitat and sediment impairments.

Table 5.50 Sediment and habitat TMDLs for 11-digit HUC 180.

		Sediment TMDL						**Habitat TMDL**						
TMDL Targets For WWH		**Allocations**			**TMDL**			**Allocations**			**Subscore**			**TMDL**
		≥ 13	**≥ 14**	**≥ 5**	**32**			**≥ 60 = *1 pt***	**< 2 = *1 pt***	**< 5 = *1 pt***				***3 pts***
Existing Scores Stream/River (Use) ***Impaired indicates use is not met***	**River Mile**	**QHEI Categories** **Substrate**	**Channel**	**Riparian**	**Total Sediment Score**	**% Deviation from target**	**Main impaired category if any**	**QHEI Score**	**# of High Influence Attributes**	**Total # of Modified Attributes**	**QHEI**	**High influence**	**# Modified Attributes**	**Total Habitat Score**
Tuscarawas River below Stillwater Creek to Co. Rd. 62 (05040001-180-010)														
Mud Run	1.5	14	15	8	37	**Meets**	**None**	**Not applicable**						
Tuscarawas River from Co. Rd. 62 to above Dunlap Creek (05040001-180-020)														
Frys Creek	2.1	12	13	2.5	27.5	14.06	Riparian	61.5	0	5	1	1	0	2
	1.2	10.5	13.5	3	27	15.63	Riparian	50	3	8	0	0	0	0
Dunlap Creek (05040001-180-030)														
Dunlap Creek	4.1	10	13.5	3.5	27	15.63	Riparian	61	0	4	1	1	1	3
	2.1	13.5	14	2.5	30	6.25	Riparian	68	0	4	1	1	1	3
Browning Run	0.8	10.5	13.5	5.5	29.5	7.81	Substrate	58.5	0	5	0	1	0	1
Buckhorn Creek (05040001-180-050)														
Buckhorn Creek	5.1	9.5	12	4	25.5	20.31	Substrate	64	0	5	1	1	0	2
	1	12	11	5	28	12.5	Channel	58.5	1	7	0	1	0	1
West Fork Buckhorn Creek	2	1	5	4	10	68.75	Substrate	31	4	10	0	0	0	0
	0.1	7	5.5	2	14.5	54.69	Channel	29	4	10	0	0	0	0

5.7 Tuscarawas River (above Evans Ck to Muskingum R) – 190

The Tuscarawas River is in full attainment of its aquatic life use criteria in this 11-digit HUC which contains the river's most downstream 14.8 mile reach. The only streams with aquatic life use impairment are East Fork White Eyes Creek, Morgan Run and the unnamed tributary to the Tuscarawas River at river mile 3.78. The cause of impairment for the unnamed tributary at river mile 3.78 is unknown. This is a small stream that drains less than 10 square miles.

5.7.1 Watershed Nutrients and Pathogens

Nutrient Modeling
East Fork White Eyes Creek is the only 14-digit HUC considered impaired by nutrients in this 11-digit HUC. Nonpoint sources of nutrients contain the vast majority of the stream load. Pasture land contributes the greatest portion of nonpoint source about 73%. Grazing cattle is the source of much of this pastureland nutrient runoff. Well over 85% of the total P from nonpoint sources needs to be reduced to meet the TMDL.

Pathogen Modeling
Cattle grazing in and near streams are major sources of the fecal coliform in the four subwatersheds not meeting recreational use criteria in this 11-digit HUC. While these subwatersheds are not in densely populated areas, failing HSTS are present. White Eyes Creek drains the unincorporated village of Fresno; an area with about 74 residences and non-commercial structures. This community is served by numerous failing HSTS with documented discharges of raw or poorly treated sewage flowing to White Eyes Creek. In January 2005, the Coshocton County Health District complained to Ohio EPA that unsanitary conditions exist in Fresno due to these untreated sewage discharges. In March 2005, Ohio EPA confirmed the unsanitary conditions in the Fresno area. On December 6, 2005 the Ohio EPA issued Director's Final Findings and Orders to the Coshocton County Commissioners, these Orders require the County to submit a plan for and construct an adequate sewerage system for this area prior to June 2010.

Table 5.51 Total existing load, TMDL and allocations for 11-digit HUC 190 (annual/seasonal).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
190-010	Evans Creek	Entirety	FC[1]	62.0	890.3	-	952.3	99.2	7.82	0.0	7.8	-	-
190-020	White Eyes Creek (without WF or EF)	Entirety	FC[1]	153.5	768.6	10.8	932.8	98.1	17.56	0.002	6.7	10.8	-
190-030 partial	Upper West Fork White Eyes Creek	Head-1.0	FC[1]	46.7	422.8	-	469.5	99.2	3.81	0.0	3.8	-	-
190-040	East Fork White Eyes Creek	Entirety	FC[1]	33.2	504.3	-	537.5	99.2	4.14	0.0	4.1	-	-
			TP[2]	158.8	17910.1	-	18068.9	87.1	2332.7	0.0	2216.1	-	116.6

Table 5.52 Total existing load, TMDL and allocations for 11-digit HUC 190 (daily).

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Loads				% Reduction	TMDL	Allocations			
				PS	NPS	Upstream	Total			WLA	LA	Upstream	MOS
190-010	Evans Creek	Entirety	FC[1]	0.45	6.45	-	6.90	99.2	0.06	0.0	0.06	-	-
190-020	White Eyes Creek (without WF or EF)	Entirety	FC[1]	1.11	5.57	0.08	6.76	98.1	0.13	0.00001	0.05	0.08	-
190-030 partial	Upper West Fork White Eyes Creek	Head-1.0	FC[1]	0.34	3.06	-	3.40	99.2	0.03	0.0	0.03	-	-
190-040	East Fork White Eyes Creek	Entirety	FC[1]	0.24	3.65	-	3.89	99.2	0.03	0.0	0.03	-	-
			TP[2]	0.44	49.07	-	49.50	87.1	6.39	0.0	6.07	-	0.32

[1] cfu * 10^{13} * day^{-1}
[2] lbs * day^{-1}

Table 5.53 Existing nonpoint source loads for 11-digit HUC 190.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter	Existing Non-Point Source Loads: Crop-land	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
190-010	Evans Creek	Entirety	FC[1]	7.36	15.56	0.05	-	867.30	0.02	890.29
190-020	White Eyes Creek (without West Fork or East Fork)	Entirety	FC[1]	8.71	35.62	0.08	-	724.13	0.02	768.55
190-030 partial	Upper West Fork White Eyes Creek	Head-1.0	FC[1]	8.35	17.30	0.04	-	397.09	0.005	422.78
190-040	East Fork White Eyes Creek	Entirety	FC[1]	4.21	19.60	0.02	-	480.50	0.001	504.33
			TP[2]	3658.6	13049.8	434.1	759.3	-	8.4	17910.1

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.54 Nonpoint source allocations for 11-digit HUC 190.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		Individual Non-Point Sources: Crop-land	Pasture	Forest	Ground water	Cattle in stream	Urban	Total
190-010	Evans Creek	Entirety	FC[1]	Allocation	2.49	5.28	0.05	-	0.00	0.008	7.82
				% Reduction	66.1	66.1	0.0	-	100	66.1	-
190-020	White Eyes Creek (without WF or EF)	Entirety	FC[1]	Allocation	1.30	5.33	0.08	-	0.00	0.003	6.72
				% Reduction	85.0	85.0	0.0	-	100	85.0	-
190-030 partial	Upper West Fork White Eyes Creek	Head-1.0	FC[1]	Allocation	1.23	2.54	0.04	-	0.00	0.0008	3.81
				% Reduction	85.3	85.3	0.0	-	100	85.3	-
190-040	East Fork White Eyes Creek	Entirety	FC[1]	Allocation	0.73	3.39	0.02	-	0.00	0.0002	4.14
				% Reduction	82.7	82.7	0.0	-	100	82.7	-
			TP[2]	Allocation	373.0	1330.7	434.1	77.4	-	0.9	2216.1
				% Reduction	89.8	89.8	0.0	89.8	-	89.8	-

[1] cfu * 10^{13} * $season^{-1}$
[2] lbs * $year^{-1}$

Table 5.55 Point source existing and allocated loads for 11-digit HUC 190.

14-Digit HUC	Sub-Watershed	Sub-Watershed Extent (Upper RM-Lower RM)	Parameter		NPDES Discharger	MS4	HSTS
190-010	Evans Creek	Entirety	FC[1]	Existing	0	0	62.04
				% reduction	-	-	100
				Allocation	0	0	0
190-020	White Eyes Creek (without WF or EF)	Entirety	FC[1]	Existing	0.002	0	153.46
				% reduction	0	-	100
				Allocation	0.002	0	0
190-030 partial	Upper West Fork White Eyes Creek	Head-1.0	FC[1]	Existing	0	0	46.70
				% reduction	-	-	100
				Allocation	0	0	0
190-040	East Fork White Eyes Creek	Entirety	FC[1]	Existing	0	0	33.16
				% reduction	-	-	100
				Allocation	0	0	0
			TP[2]	Existing	0	0	158.8
				% reduction	-	-	100
				Allocation	0	0	0

[1] cfu * 10^{13} * season^{-1}
[2] lbs * year^{-1}

Table 5.56 Existing and allocated loads of point source dischargers (not including MS4s and HSTSs) for HUC 190.

14-Digit HUC[1]	Sub-Watershed	Sub-Watershed Extent	Facility	Para-meter	Existing load	% Reduction	Allocated load
190-020	White Eyes Creek (without WF or EF)	Entirety	0PT00052 FRESNO ELEMENTARY SCHOOL	FC[1]	0.002	0	0.002

[1] cfu * 10^{13} * season^{-1}

6.0 WATER QUALITY IMPROVEMENT STRATEGY

This section provides a strategy for improving water resources in the Tuscarawas River watershed to the full attainment of applicable water quality standards (WQS). The actions recommended are aimed at reaching the water quality goals and load reductions discussed in this report and address the documented sources of impairment. Additionally, protections are recommended for sustaining water quality in areas currently meeting the applicable WQS. Some recommendations rely on regulatory authority, while others are based on voluntarily action.

Several factors related to the recommended actions are addressed, including:
- Water quality problems addressed
- Effectiveness
- Relative costs
- Potential barriers to success
- Resources available for assistance
- Locations where activities should take place
- Participation needed for successful implementation
- Timeframe under which actions should occur.

A process for validating that the recommended actions are effectively achieving the water quality goals is also provided. Details include a recommended monitoring strategy, conditions sufficient to warrant revising the existing recommendations, and a methodology for selecting alternative actions.

This chapter is organized as follows:
- Implementation approach and rationale
- Recommendations for each of the sub-watersheds (assessment units)
- Reasonable assurance that recommended actions are carried out
- Process for evaluation and revision of the water quality improvement strategy

6.1 Implementation Approach and Rationale

TMDLs are developed for ***pathogens*** to address impairment of recreational uses and also for ***habitat***, ***sediment***, and ***total phosphorus (TP)*** to address impairment of aquatic life uses. Recreational use impairment is pervasive throughout much of the basin while aquatic life use impairment occurs more discretely on a segment by segment basis. The recommendations that follow provide a basic approach for addressing each of these causes of impairment and their respective sources. Also included are recommendations regarding ***stream geomorphology, floodplain connectivity***, and ***storm water management*** that are intended to provide further enhancement and protection of aquatic life uses.

It is possible that some stream segments not surveyed are impaired by sources that have been identified in surveyed segments. A broad application across the watershed of some of the recommendations is likely to abate those sources as well.

The discussion in this section is organized according to the cause of impairment, providing a broad overview of what is necessary for meeting and maintaining water quality standards and often includes technical or scientific rationale. A more detailed discussion regarding causes and sources of impairment can be found in Chapter 2 of this report.

Table 6.1 Summary of the cause/source associations for impaired recreational and/or aquatic life uses.

Region of watershed	Major causes of impairment addressed by reasonable assurances	
Tuscarawas River (headwaters to below Wolf Creek) HUC 05040001-010	• Channelization • WWTP discharges • Nutrients • Suburbanization • Nutrients	• Habitat • Siltation • Septic tanks • Stream modification
Chippewa Creek HUC 05040001-020	• Habitat • Agriculture • Siltation • Septic tanks • WWTP discharges	• Suburbanization • Organic enrichment • Flow alteration • Sludge management • Impoundment
Tuscarawas River (below Wolf Creek to below Sippo Creek) HUC 05040001-030	• Habitat • Siltation • WWTP discharges • Septic tanks	• Organic enrichment • Agriculture • Suburbanization • Channelization
Tuscarawas River (below Sippo Creek to above Sugar Creek, excluding Sandy Creek and Conotton Creek) HUC 05040001-090	• Habitat • Siltation • Septic tanks	• Flow alteration • Nutrients • Acid mine drainage
Tuscarawas River (below Sugar Creek to above Stillwater Creek) HUC 05040001-130	• Habitat • Siltation • Septic tanks • Flow alteration	• Acid mine drainage • Channelization • Agriculture
Tuscarawas River (below Stillwater Creek to above Evans Creek) HUC 05040001-180	• Septic tanks • Organic enrichment	• Agriculture • Acid mine drainage
Tuscarawas River (above Evans Creek to Muskingum River) HUC 05040001-190	• Septic tanks • Acid mine drainage	• Agriculture

6.1.1 Pathogens

Recreation use impairments in the Tuscarawas River watershed are primarily failing HSTS and agriculture, both crops and livestock. Livestock farming is not intense in the watershed, however a number of operations are sources of impairment. Wildlife is believed to make a relatively small contribution to the pathogen load. In urban areas, pathogen contamination is partially attributable to storm water runoff and failing HSTS.

Home Sewage Treatments Systems

Addressing HSTS as a source of bacterial pollution is best served by eliminating reliance on these systems for treating human wastes. Connecting unsewered residences to centralized treatment systems is an effective and permanent way to eliminate this source of impairment. However it is not practical to extend sanitary sewers to some of the problematic areas in the watershed due to prohibitive costs and the potential for environmental degradation during the installation of sewer lines. An effective alternative to centralization requires improving failed systems through upgrades or the installation of new systems. Installation of new systems must be in compliance with applicable regulations (OAC 3701-29). Ensuring that HSTS be properly maintained is important for preventing pollution problems in the future.

Any direct routing of septic lines to surface waters, such as by-passing leach fields and/or septic tanks, is an illegal practice (OAC 3701-29) and creates unhealthy and unsafe conditions. These types of connections should be identified and enforcement and/or other actions be taken to correct the situation. Local health departments are responsible for responding to complaints issued regarding illicit connections and are expected to be proactive in locating them (OAC 3701-29).

Livestock Production

Pathogen contamination from livestock manure can be reduced by fencing or other exclusion practices that limit or deny livestock access to streams. Proper manure handling and storage reduces runoff contamination and is achieved through the construction of adequate storage facilities and storm water controls. Manure that is land applied should be done so according to guidance from the Natural Resource Conservation Service (NRCS) and applicable standards (Standard 633) or a Comprehensive Nutrient Management Plan (CNMP) that is specific to a given operation. Manure discharges occurring through sub-surface drainage tiles following field application can often be avoided if drainage water management control structures are in place. NRCS conservation practices that are appropriate for abating this source of pollution include ***Livestock Use Exclusion (472), Waste utilization (633), Nutrient Management (590), Watering Facility (614), Waste Storage Facility (313) and Drainage Water Management (554).***

Composting manures may also be a viable way to utilize livestock waste and reduce the threat to water quality. The stabilization of the manure materials during the composting process and the proper handling and storage of this material reduces the risk of pollutant loading via storm water runoff. More information regarding composting can be found on the Ohio Composting and Manure Management Program’s web site (http://www.oardc.ohio-state.edu/ocamm/).

Table 6.2 Summary of the strategies for addressing each listed cause of impairment in the Tuscarawas River watershed.

PATHOGENS	

• Reduce point sources
• Reduce manure sources
  o Eliminate/reduce livestock access to streams
  o Improve storage and handling operations
  o Improve land application methods and rates
  o Utilize drainage water management
	• Reduce loading from HSTS
	  o Identify/detect failing systems
	  o Upgrade/replace as appropriate
	  o Protect against future failures through training and education on system maintenance
	  o Provide sewers (where feasible)

HABITAT	
Channelization	*Stream Stability*

• Increase heterogeneity of channel morphology and flow conditions
  o Natural Channel design and stream restoration
  o Two-stage approach to drainage ditches
• Create and protect instream habitat
  o Stream restoration and bio-engineering techniques
• Increase floodplain connection
	• Approximate natural hydrology of watershed
	  o Reduce urban runoff
	    ▪ Minimize imperviousness of landscape
	    ▪ Increase storm water infiltration
	  o Water table management
	  o Increase natural vegetative cover
	  o Wetland creation and restoration
	• Increase floodplain connection

TOTAL PHOSPHORUS	

• Reduce point sources
  o Permit restrictions
• Reduce overland sources
  o Reduce overland sediment loading (see below)
  o Reduce land application
  o Improve timing of fertilizer application
  o Provide stream side buffering
	• Increase assimilative capacity of stream system
	  o Increase floodplain connection
	  o Improve bed substrate (e.g., reduce fines)
	  o Increase stream detention time
	    ▪ Increase sinuosity
	    ▪ Increase riffle-pool development

SEDIMENT	

• Reduce overland source loading
  o Reduce potential for surface erosion
    ▪ Protective cover
    ▪ Conservation tillage
  o Provide stream side buffering
	• Reduce instream erosion
	  o Improve stream stability (see habitat above)
	• Increase assimilative capacity of stream system (see total phosphorus above)

ACID MINE DRAINAGE	
• Develop Acid Mine Drainage Abatement Plans	

6.1.2 Habitat

In the Tuscarawas River watershed, degraded stream habitat is primarily the result of channelization and ongoing maintenance activities carried out to improve water conveyance. These activities are related to agricultural drainage and flood control improvements, but there is also channelization in urban areas where buildings and other infrastructure lie in close proximity to the streams. Most channelization is found on small to medium sized tributaries but also along some parts of the mainstem of the Tuscarawas River.

Habitat is also impaired or threatened by channel instability resulting from altered hydrology. In agricultural areas, practices specifically designed to increase drainage efficiency (e.g., sub-surface drainage, channelization) as well as unintended impacts of farming (e.g., soil compaction, poor vegetative cover) increase storm flows. Efficient drainage also results in more extreme and more frequent low flow conditions. This diminishes the capacity of the system to assimilate pollutants and support diverse aquatic communities. In urban and developing areas, impervious surfaces create substantial increases in runoff which increases channel erosion and decreases stability.

Other habitat impairments include impounded flows from lowhead dams and sedimentation, and livestock access to streams. Sedimentation impairs substrate habitat and the aquatic communities; however, discussion regarding its abatement will be reserved for Section 6.2.3. The following three sub-sections discuss habitat improvements that address channelization, stream instability, and impoundments, respectively.

Channelization

Channelization creates deeply incised and straight ditches or streams. This disconnects waterways from floodplains, which has damaging impacts on the quality of the system, including exacerbating flooding and increasing in stream erosion. Channelized streams change little along their length, lack features such as riffles and pools and have minimal variation in flow characteristics. This homogenous configuration reduces biological diversity (Hahn, 1982; Mathias and Moyle, 1992). Additionally, the instream cover important for diverse aquatic communities is often absent.

Channelization enhances the drainage of agricultural land, which increases field accessibility and improves and/or protects crop growth (OSU, 1998 Bulletin 871-98 http://ohioline.osu.edu/b871/index.html). These practices are sanctioned through Ohio's drainage laws (ORC 6131 and OAC 1511) despite the deleterious effects on water resources. A challenge is to carry out actions that improve water quality while maintaining adequate drainage for profitable agriculture.

In terms of drainage related to agriculture, a primary function of a stream or ditch is to provide an outlet for sub-surface drainage infrastructure (i.e., drain tiles). This requires that the elevation of the channel bottom be far below (usually several feet) the elevation of the surrounding crop fields, which results in floodplain disconnections. Adequate outlets can be provided and habitat improvements achieved through stream restoration and a two-stage ditch approach.

The following three minor sub-sections discuss stream restoration, two-stage ditch management, and bio-engineering techniques as a means to improve habitat and water quality in channelized streams and ditches.

Stream Restoration

The recommended stream restoration will create or lead to the development of well connected floodplain areas, channel sinuosity, and also riffle and pool habitats where appropriate. The detention and temporary storage of high flows in created floodplains will likely mitigate downstream impacts associated with flooding. Stream restoration provides greater capacity to accommodate sub-surface drainage and enhances that use of the system. Although land drainage is not a goal of the Clean Water Act, this may provide some compensatory benefits that make landowners more willing to take this approach.

Restoration of agricultural ditches is not commonly done, and there is only one such project that is known to the Ohio EPA to have taken place in Ohio (www.oxbowriver.com/Web_Pages/Project_pages/P-Bokes-03.html).
To provide the maximum benefit of stream restoration (i.e., suitable physical habitat), the location of potential projects should be considered from the perspective of the sub-basin scale or larger. Higher priority should be given to locations that facilitate upstream migration of high quality fish communities to areas with good habitat and adequate water quality. In essence restored stream segments should bridge gaps between segments of high quality habitat. Generally speaking, downstream areas of degraded habitat should be addressed first in order to maximize continuous (or nearly continuous) high quality habitat, providing the greatest opportunity for upstream re-colonization by downstream source populations.

Additional information regarding natural channel design can be accessed at http://www.epa.gov/region4/water/watersheds/coordination/streamrestoration.html.

Two-stage Approach
Stream restoration that employs natural channel design is superior to a two-stage ditch approach when strictly considering environmental benefits, but since stream restoration entails more earth work and is considerably more expensive, a two-stage approach may be practical for addressing channelization on a large scale.

A two-stage ditch is similar to a typical drainage ditch (i.e., one-stage) but differs in some key ways. Two-stage ditches are wider at the top of their banks which increases the overall capacity of the ditch and out-of-bank flooding occurs less often. The bottom of a two-stage ditch has low elevation benches that are inundated during moderately high and higher flow events. The low flow channel is narrower than a typical ditch bottom and often develops a low-amplitude, sinusoidal pattern within the larger ditch. More information regarding two-stage ditches can be found at http://streams.osu.edu/naturalchannel.php. See Figure 6.1 for depictions of a two-stage ditch.

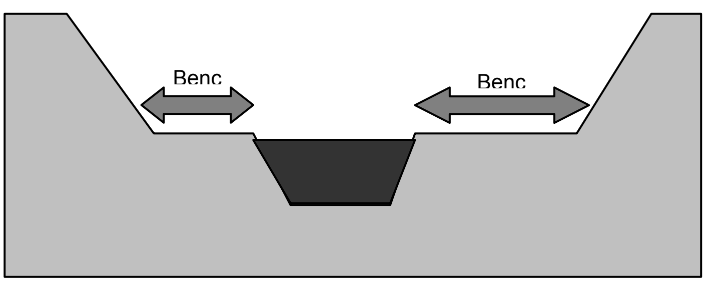

Figure 6.1 Graphical depiction of a two-stage ditch (left) and photo (right) taken in Wood County, Ohio.

Two-stage channels yield modest improvements to stream habitat as compared to one-stage ditches. These benefits are realized because benches function to some degree like floodplains and the channels undergo more stable erosion and deposition processes. Bank erosion is less likely to occur because the toe (i.e., where the bank meets the channel bottom) is protected by vegetated bench deposits and flow depths are lower, which results in lower shear stress. Less bank erosion in these fairly unstable systems is beneficial to immediate and downstream reaches because instream sources of sediment are reduced.

Stream flow in the narrower low flow channel is better able to move and redistribute fine sediment than wider channel bottoms typical of highly maintained ditches. Fine sediment is deposited and stored on the benches, which increases assimilative capacity of the system. Channel substrate has less fine material (i.e., is of higher quality) and habitat associated with channel sinuosity and riffle-pool development is likely to increase (Sablak, 2004), which adds habitat heterogeneity to these extremely homogenous systems. Two-stage channels may also have greater assimilative capacity for nutrients (Powell, 2004), which will be discussed in following sections.

Construction of a two-stage channel requires widening the ditch and/or creating the low-elevation benches. However, if conditions permit, two-stage ditches form on their own; in this case simply refraining from removing bench sediment (i.e., dipping) is nearly all that is necessary from a maintenance or management perspective. Simon and Hupp (1986) describe a model for channel evolution of incised streams in which the end result is analogous to a two-stage channel. Optimal conditions for two-stage channels to develop on their own are when the channel is overly wide for the amount of contributing drainage area, banks are steep, and riparian trees are absent.

The Ohio Department of Natural Resources (ODNR) is promoting over-wide ditch construction as a lower cost means for achieving two-stage form in ditches. The over-wide channel approach may avoid problems associated with errors in design and/or construction that result in inappropriate channel dimensions (i.e., does not facilitate desirable sediment transport processes). Over-wide channels also rely on fluvial deposits to form the benches, which are likely to have large contributions from upland soils that are richer in organic matter and have a greater potential for de-nitrification and other biological processing of pollutants.

Applying a two-stage channel approach to highly maintained ditches (e.g., streams designated as MWH) is likely to be a reasonably cost-effective way to improve these resources over a substantial percentage of the drainage network. Although cost analysis for three two-stage ditch construction projects show expenses to range from $5 to $25 per linear foot (Jeong, 2005, unpublished), when the two-stage approach is applied by leaving existing benches intact, costs may be lower than typical ditch maintenance that includes periodic re-construction. It is probable that a two-stage approach can be widely adopted at relatively low costs for landowners, county governments, and/or local organizations.

Important for the adoption of a two-stage approach is to effectively communicate the overall benefits to decision makers and designers who rely on familiar methods or ones they are comfortable using. Individuals who are particularly important to communicate with regarding a two-stage ditch approach include County Engineers and their staff, SWCD/NRCS personnel, and drainage contractors who conduct much of the design and construction work associated with drainage improvement. The benches that form in two-stage channels are often regarded as flow impedances that result in a reduction in the flow capacity of ditches. Ohio EPA is unaware of hydrologic analyses that support this idea but rather concurs that the capacity of the ditch to contain high flows increases if the ditch widens in forming the benches (http://streams.osu.edu/streams_pdf/2stage(ward).pdf).

Two-stage construction may be inappropriate for improving the stream biota and/or water quality when it is necessary to remove riparian trees in the process. Such consideration is particularly important when the channel demonstrates that it is recovering from past channelization.

Two-stage ditches are clearly inappropriate when it results in a reduction in the amount of floodplain connectivity. This includes natural to moderately modified streams that have an intact connection to a floodplain and riparian areas. Such action would degrade the resource and the ameliorative effects of the benches will be far inferior to those of an established floodplain.

Bio-engineering Techniques

Bank stabilization and channel erosion controls that use hard engineering techniques (e.g., placement of concrete and/or rock) have little value in terms of aquatic habitat. Bio-engineering techniques promoted by the Ohio Department of Natural Resources (http://www.dnr.state.oh.us/water/pubs/fs_st/streamfs.htm) use more natural materials and construction techniques that provide bank habitat structure. When bank erosion control is necessary, bio-engineering approaches should be promoted by local conservation authorities (e.g., NRCS and SWCD) and used by private and public entities as a means for abatement. However, it should be noted that channel erosion and lateral migration occurs naturally even in stable streams. If property loss is not an issue, abating bank erosion should be considered in light of whether it is occurring under stable stream conditions, and avoided if unnecessary.

Stream Stability

Stream stability is related to habitat quality and sedimentation, and can have a significant impact on stream biota. The geomorphology of a stream is a primary indicator of stability. Areas of the basin that currently exhibit poor stream geomorphology (i.e., unstable) are associated with channelization. Other areas include incised channels in the urban or urbanizing areas of the watershed. Additionally there is a significant threat to the stability of stream channels in the rapidly developing areas of the basin because of the changes in land cover, sediment supply, and hydrology.

Floodplains are important for maintaining stream stability and provide additional water quality benefits. For this reason, it is recommended that throughout the entire Tuscarawas River watershed an effort should be made to protect, maintain, create, or facilitate the development of floodplains.

Agricultural Areas

Ameliorating the impact of channelization can be achieved by methods discussed earlier. Natural channel design and/or a two-stage ditch approach can reduce the severity of erosion processes and provide some storage of fine sediment. Additionally, the strong relationship between hydrology and stream stability and aquatic communities, indicates that steps taken to stabilize watershed hydrology will be ecologically beneficial.

Activities related to agriculture may be substantially impacting watershed hydrology (Baker et al., 2004) and the stability of stream channels. Baker et al. (2004) suggest that subsurface drainage in combination with reduced surface water retention (i.e., due to smoothing of the landscape and altering vegetation and soil properties) is increasing peak storm discharges. At the other extreme, more efficient drainage results in less infiltration and storage in the watershed which leads to a reduction in base flow (i.e., flows based on groundwater contributions) during drier periods (Baker et al., 2004; Robinson and Rycroft, 1999). The two phenomena result in an increase in the flashiness of the watershed, which is a measure of the rate and magnitude of changes in stream flow.

Although the causes of the observed increase in flashiness are not yet completely understood, activities that are likely to increase infiltration and reduce runoff should be pursued. In areas where drainage improvement practices are applied intensely, the use of infrastructure and management measures such as water table management and wetland detention are recommended.

Water table management (NRCS Practice Standard 554) is a means to reduce the discharge of sub-surface drainage water (http://ohioline.osu.edu/aex-fact/0321.html). Water table management requires the use of controlled drainage structures (e.g., Agri-Drain or Hancore types) that are installed within new or retrofitted to existing sub-surface tile systems. Drainage water passing through these structures must have adequate hydraulic head to rise to an elevation that is pre-set according to the height of the flashboard risers that are part of the structure. This system allows for management of the effective elevation of the drainage tile outlets. When this elevation is set high enough the effect is analogous to there being no sub-surface drainage infrastructure.

Benefits of water table management are reductions in annual drainage water discharges. These reductions have been estimated over several years of research to be approximately 40% (Fausey, 2004). Although Ohio EPA is unaware of comprehensive water budgets completed for water table management, it is reasonable to assume that a significant proportion returns to the stream as base flow and interflow over a protracted timeframe or is otherwise taken up through evapo-transpiration. The extended period of discharge can also benefit the aquatic community by providing flow during critical drier periods.

The use of water table management may be limited in some areas. Topography dictates the area that can be controlled by a given structure because water table elevations greater than the top of the control structure are no longer influenced by it. This means that control of the water table depth is reduced when moving upslope from the control structure. Additional structures would often be needed within fields (i.e., as opposed to along the field margins) to be able to manage an entire sub-surface drainage system. Other factors that may limit use of water table management include the layout of the sub-surface drainage system and whether or not the pipes can be readily located.

A viable way to offset the problem of limited control associated with a given water table control structure is aligning the drain tiles of new sub-surface drainage systems along elevation contours. This decreases the slope of the drain tiles which allows drainage management infrastructure to have control over a larger area. Additionally, it is possible that significant benefits are realized even if it is only the lower portion of the sub-surface drainage system (i.e., near the outlet) that is controlled.

Wetlands provide detention capacity for runoff and increase infiltration. Numerous studies have shown that wetlands improve water quality and watershed hydrology as well as provide excellent wildlife habitat (Mitsch and Gosselink, 2000; Vellidis, et al., 2003). Establishing wetlands often entails disabling a portion of the drainage infrastructure servicing that area and a relatively minor amount of earth work. The NRCS standards for wetland creation (NRCS Practice Standard 658) and wetland enhancement (NRCS Practice Standard 659) provide details regarding size and site condition considerations.

Depressions on the landscape with appropriate soils (i.e., hydric) are ideal locations for creating or enhancing wetlands, since it is likely that they were wetlands prior to land use conversions.

In such cases, reversion to wetland is likely to require less effort and will have a greater probability of meeting the goals of the water resource improvements. The placement of wetlands adjacent to or near streams or ditches allows for treatment just prior to entering those waters, which may facilitate the treatment of a greater volume of runoff due to the wetland's position in the drainage system.

Land use conversions from crop fields to grassland or forest also increases the retention and/or detention of rainwater. These land covers result in greater infiltration and a higher degree of storage through initial abstraction compared to row crops and/or barren ground and may help restore a more suitable hydrology. Such improvement may take several years to reach their full benefits, especially when land returns to forest cover. The Conservation Reserve Program compensates producers for land set-asides.

Developing Areas

One serious threat to channel stability, and possibly overall water quality and biological integrity, is the rapid conversion of forest and/or agriculture land uses to residential, commercial, and industrial uses. Numerous scientific studies show that increasing impervious cover in a watershed (i.e., through development) is commensurate with the degradation of water quality and biological communities (Booth et al., 2005; Brabec et al., 2002; Roy et al., 2003; Roy et al., 2006; Morgan and Cushman, 2005). A general model for this relationship can be seen in Figure 6.2.

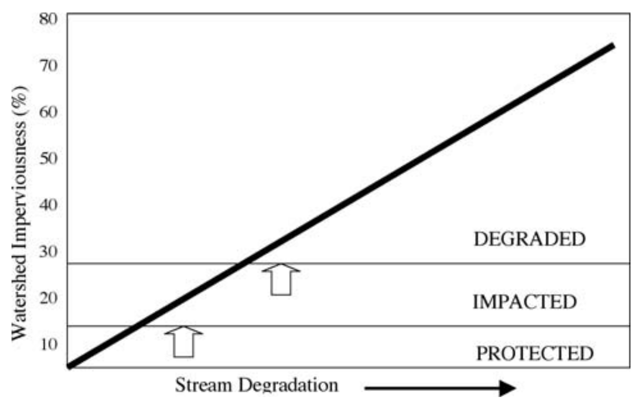

Figure 6.2 General model of relationship between stream health and imperviousness (adapted from Schueler).

Land conversion to greater impervious uses substantially increases the volume of runoff, which is eventually routed to the stream system. Ultimately the sediment transport capacity of the system increases, resulting in more channel erosion and instability (Booth, 2005). The resulting morphology provides poor habitat and may have a reduced capacity for nutrient assimilation (Walsh et al., 2005). Higher runoff volume increases pollutant loading (e.g., nutrients, metals, salts, pesticides, sediment). Additionally, stream temperatures can be raised when runoff is heated by impervious surfaces such as asphalt and concrete or while residing in detention basins. Temperature increases reduce dissolved oxygen concentration and create stressful conditions for aquatic biota (Ward, 1992; Cossins and Bowler, 1987).

Controlling runoff associated with development typically consists of end-of-pipe measures such as storm water detention and retention. These controls abate flooding and reduce erosion, thus providing some water quality protection. However, studies show that water quality degradation occurs in developing watersheds despite these controls due to the altered hydrologic regime (Brabec et al., 2002; Booth, 2005).

A hydrologic regime that approximates that of pre-development conditions is important for protecting water quality and aquatic biological communities (Roy et al., 2006). Initial abstraction of rainfall by vegetation, surface storage, long sub-surface flow paths, evapo-transpiration, and deep percolation, which are associated with relatively undisturbed watersheds, often prevent flashy hydrology. Peak flows are often smaller as a significant proportion of precipitation is delayed or altogether diverted from reaching the stream system. Base flows are usually higher because of the greater subsurface discharges during dry periods as a result of increased storm water infiltration and storage.

Approximating the pre-development hydrology is not likely to be achieved with centralized controls (i.e., end of pipe retention/detention basins). However, onsite retention and infiltration is a realistic and potentially effective way to accomplish this (Andoh and Declerck, 1997). With an onsite approach, storm water is managed near the area generating the runoff and infiltration is maximized. Onsite storm water management contrasts centralized systems that collect runoff over a broad area and provide relatively little opportunity for infiltration and consequently must manage very large volumes. Individual onsite controls operate on a small scale but systems are distributed to act collectively in managing runoff across a large area. Incentives, utilities and/or market based programs should be explored as a means to achieve more effective and ecologically meaningful storm water management. Parikh et al. (2005) provide an analysis of options for addressing storm water management in an environmentally and economically sustainable manner.

Onsite, or decentralized, storm water management increases infiltration and reduces runoff generation by decreasing imperviousness. This is accomplished through appropriate planning, such as that used for Low Impact Development (LID). Low Impact Development is based on maximizing contiguous open space, protecting sensitive areas, namely floodplains and wetlands, and preserving existing vegetation (especially trees). Web based resources for LID include: www.lowimpactdevelopment.org/ . In a Low Impact Development, houses are located closer to one another, roadways are narrower, and bio-retention and infiltration techniques are used. LID reduces runoff and can provide cost savings in storm water infrastructure. Additional non-environmental benefits include a greater than average increase in property values.

One potential barrier to LID is zoning ordinances that set minimum lot sizes. However, employing LID at the level needed to provide significant protections for the Tuscarawas River watershed requires action on the part of land planners, zoning officials, and developers. Serious communication between these groups and LID experts who can address the conditions of this basin is needed and highly encouraged by this TMDL.

Watersheds that retain relatively large areas of forest are able to better mitigate the impacts of increasing imperviousness than those with little forest cover (Brabec et al., 2006, Booth, 2005). The procurement of conservation easements, and the establishment of parkland and nature preserves can help retain some of the existing forest cover as well as facilitate the conversion from open land to forest. Although land preservation alone is not likely to occur at a level necessary to mitigate development impacts, it will augment other measures that are taken (e.g., LID and/or discrete onsite storm water management).

Storm water abatement techniques that are employed in commercial developments and on individual residences (i.e., that are not a part of a LID) will provide protections to water quality. In particular, parking lots often account for a very high proportion of the impervious surfaces in urban watersheds. According to the University of Connecticut Extension, impervious cover associated with automobile traffic accounts for a significant proportion of the total impervious cover in a given watershed (http://nemo.uconn.edu/).

At the scale of individual residences or businesses storm water abatement techniques can be used that include diverting drainage from rooftops, driveways, and other impervious surfaces away from a centralized collection system (e.g., outlets to either curb-and-gutter drains or storm water sewer lines) and to permeable areas that can provide infiltration and/or temporary storage. Minimizing the extent of impervious surfaces by limiting their size or substituting them with permeable surfaces will also increase infiltration and detention for a given property. Outreach and education activities are likely to result in some increase in this type of voluntary action taken by watershed residents, however to what extent would be very difficult to predict. Outreach efforts that include landscape design and construction companies may also be beneficial as they can present options for enhanced storm water management to their prospective clients.

The current draft of the Rainwater and Development Guide that is posted on the ODNR website at ftp://ftp.dnr.state.oh.us/Soil_&_Water_Conservation/rainwater/ provides a great deal of information regarding storm water management. This resource highlights the goals, effectiveness, and limiting conditions for both planning and structural controls. The following topics are discussed:

- Reduction in impervious area
- Low Impact Development
- Conservation Development (similar to LID)
- Setbacks
- Water quality ponds
- Infiltration trenches
- Sand and organic filters
- Grass filters
- Bioretention area

Floodplains abate the impacts of development on stream systems. The reduction of the erosive power of storm flows, temporary flood storage, and sediment assimilation all act to mitigate the damage caused by increased runoff volume during flood events. Wetlands also provide storm water retention, increase infiltration and reduce the energy of surface flows (i.e., reduces erosion potential). These important environmental areas must be protected and preserved to the greatest reasonable extent.

Timely and adequate public notification of fill requests (permitting process) and opportunity for public hearings are recommended to ensure that permitting decisions are based on an adequate array of information, scientific as well as socio-economic.

Construction management must be carried out to control the volume and quality of runoff. Storm water permits for construction activities should be monitored and when appropriate, enforcement actions taken to ensure compliance. Phase II storm water permits for affected communities require local ordinances to address these issues.

Impoundments

Dams and their impoundments can cause water quality impairments on their own independent of other impacts. Dam removal alone is often sufficient to result in the attainment of the applicable designated use. Dam removal immediately and permanently eliminates the source and associated causes of impairment (with possible exception of siltation). Adverse impacts from dams can include a change in thermal and hydraulic regimes, chemical water quality degradation, and impaired habitat in the stream or river where they are located. A variety of impacts can result from the siting, construction, and operation of these facilities. Habitat quality expected in a healthy stream is degraded by impoundments by elimination of riffles, increased substrate sedimentation, and an overall decrease in QHEI scores. Dams also impede or block migration routes of native fish.

The primary benefits of dam removal are the increase in flow velocities and turbulence that corresponds to increased air entrainment and dissolved oxygen concentrations. Increased flow facilitates the movement of nutrients that are otherwise stagnated in a lake-like type of condition where impoundments exist. Algae and associated biomass accumulates in these stagnant areas resulting in poor water quality conditions (e.g., low dissolved oxygen). Habitat quality and diversity is impacted by impoundment and consequently impounded areas often can only support tolerant assemblages that have little biological diversity.

The Ohio EPA recommends that all dams within the watershed be evaluated for removal opportunities. The process will begin by compiling an inventory of all dams in the study area. The inventory shall be prioritized for removal opportunities based on ecological benefits of removal and feasibility. Impoundments providing public water supplies should still be evaluated in the context of this TMDL. It is acknowledged that removal cannot jeopardize public health and safety.

Wetlands Protection

Wetlands are an important part of the watershed and perform many useful functions which relate to water quality. Preservation and enhancement of wetlands in the Tuscarawas River TMDL area will help to improve water quality. All permits issued for impacts to Category 1, 2, and 3 wetlands should ensure that mitigation is conducted on-site if possible and at a minimum within the watershed area. If mitigation cannot be conducted on-site or within the watershed area, then a permit should not be issued for the proposed project.

Riparian Protection

Protection of riparian zones plays an important role in stream integrity. Small streams are able to maintain thermal regimes with riparian protection. Open streams lacking riparian protection are influenced by sunlight which, in addition to temperature increases, can stimulate algae and macrophyte growth. Additionally, protection and restoration of riparian zones along streams can help to mitigate some of the effects caused by increasing impervious area. Streambank protection afforded by riparian zones also helps to reduce sediment and nutrient loading.

Two mechanisms are proposed to promote riparian protection. The first mechanism proposed is the passage of stream setback ordinances. Another mechanism to promote riparian protection is comprehensive land use planning. Through the identification of sensitive natural areas communities can promote wise land use policy. These mechanisms are also promoted in the 208 plan.

Evaluation of all 401/404 permit applications for stream impacts in the Tuscarawas River TMDL area should require mitigation to be conducted on-site if possible and at a minimum within the watershed area. If mitigation cannot be conducted on-site or within the watershed area, then a permit should not be issued for the proposed project. Export of both wetland mitigation and stream mitigation out of the watershed is a threat to restoration and improvement of habitat in the watershed as well as long-term watershed health.

Headwater Streams

Headwater streams are a critical water resource within the Tuscarawas River watershed. They provide a source of perennial cold groundwater that maintains the summer base flow of larger downstream segments and can harbor many unique species of fish, amphibians, and benthic macroinvertebrates. The Ohio EPA has developed a three tiered classification scheme for the smallest headwater streams of watersheds, termed “primary headwater habitats” (PHWH).

Additional information may be found at:
http://www.epa.state.oh.us/dsw/wqs/headwaters/PHWHManual_2002_102402.pdf.

Class III PHWH streams are unique water resources that may be directly connected to groundwater springs with biological communities having a large number of cold to cool water adapted species not present in other types of environments. Vertebrate species of Class III-PHWH streams include fish such as mottled sculpins, redside dace, brook stickleback and salamander species with long-lived larval periods such as the spring salamander, red salamander, and two-lined salamander. A large number of cool water and pollution sensitive benthic macroinvertebrates such as mayflies, stoneflies, and caddisflies also are uniquely adapted to the habitat conditions provided by Class III-PHWH streams (Ohio EPA, 2002). It is a recommendation of this TMDL that the location of Class III-PHWH streams should be identified within small watershed units (e.g., the HUC-14 spatial level) for the entire basin using the Ohio EPA (2002) assessment techniques. Where Class III-PHWH streams are identified, all efforts should be made to ensure that their biological and hydraulic functions are protected and maintained. In situations where impacts to Class III-PHWH streams are required under Section 401 water quality certification, a high priority should be given to ensure that mitigation of impacts occurs within the local HUC-14 watershed unit. Impacts to other classes of PHWH streams should follow standard Section 401 mitigation protocols.

6.1.3 Nutrient and Sediment

Nutrient and sediment loads in the Tuscarawas River watershed are primarily due to point source discharges, polluted runoff from row crop agriculture and livestock, storm water runoff, home sewage treatment systems, and channel degradation. NPDES permit revisions for point source dischargers will be carried out according to recommendations in this report. Other sources include failing HSTS and livestock manure, and abatement strategies for these sources of nutrients and solids are identical to those discussed earlier (see Section 6.1.1). In the urban and developing areas of the watershed, polluted runoff from residential and commercial land uses are creating elevated nutrient loads. Stream instability and landscape sediment loads will potentially threaten or impair the quality of the water resource as a result of any further development in the watershed which fails to address this cause and source of pollution.

Point Source Discharges
Changes in permit conditions are the most straightforward means to achieve the necessary reductions in nutrients from point sources. It is therefore recommended that permits be modified and/or renewed with reduced load limits for phosphorus. It is initially recommended that all wastewater treatment plants discharging greater than 100,000 gallons per day receive an initial phosphorus limit of 1 mg/l. Phosphorus limits for smaller plants will be evaluated on a case-by-case basis in relation to the specific dischargers potential to impact the watershed both locally and further downstream.

Sources from Agricultural Runoff and Drainage Infrastructure
Many management practices abate sediment and nutrient loading to surface waters from crop fields. Examples include vegetated buffer strips, grassed waterways, nutrient management, conservation tillage, conservation crop rotations, wetland restoration, and water table management. For decades conservation professionals have researched these practices, improved their effectiveness, and worked with private landowners to implement them. Programs currently funded under the Farm Bill provide cost share and dollar incentives for land set asides and structural and management conservation practices.

Vegetative buffer strips have been shown to be very effective at reducing overland loading of nutrients and sediment in scientific literature (Peterjohn and Correll, 1986; Osborne and Kovacich, 1993). Vegetated buffer strips (e.g., riparian trees or grass filter strips) slow the velocity of overland surface flow allowing sediment particle to fall out of suspension. Buffers also increase infiltration of surface water due to better soil structure, macropores created by roots and soil invertebrates, and reduced surface crusting (Prichard, 1998). Greater infiltration reduces surface discharges and the associated sediment and nutrient loads (Prichard, 1998). However, the effectiveness of buffers decreases dramatically when small concentrated flow paths allow water to rapidly move across them. Such flow paths typically develop at low points along the fields/buffer border or where the vegetation of the buffer is disturbed. These situations should be corrected as they are identified by landowners, farm operators, and conservation professionals (e.g., NRCS/SWCD staff). Sub-surface drainage creates a by-pass to the buffer strips where there is no contact between the vegetation and the drainage water and flow is not slowed. However, water table management (e.g., NRCS practice 554) is a means to reduce the volume and/or rate of discharging sub-surface drainage water thereby counteracting the short circuiting that occurs through buffer strips.

Benefits of buffer strips that go beyond improving chemical water quality of surface runoff are related to channel stability, structural habitat, light availability, stream temperature, and food resources. Providing a stream buffer may reduce the need and/or importance for stream bank management and erosion control as crop losses would not be occurring. In some cases armoring stream banks to minimize erosion prevents the naturalization of the stream's geomorphology (i.e., channel evolution) and perpetuates stream instability. Additionally, tree cover shades streams which may limit algal growth and reduce stream temperatures. Temperature is inversely proportional to the stream's capacity to hold dissolved oxygen, and high temperatures can severely impact aquatic life. Woody debris and detritus contributed to the stream system by riparian trees also have a significant role in the quality and diversity of habitat and food resources of the aquatic ecosystem (Ward, 1992; Wallace et al., 1997; Baer et al., 2001). These factors have a significant impact on the aquatic biological community and therefore the capacity for the system to attain its designated aquatic life use.

Sources from Urban and Residential Runoff

The relatively high volume of runoff generated in urban and high density residential areas increases the potential for pollution. Sediment and nutrient residues on surfaces that are impervious or poorly pervious (e.g., compacted lawns, gravel drives, etc.) are more easily transported in this higher volume of runoff and negligible attenuation of the loading occurs due to infiltration. Reducing imperviousness and improving on-site retention and infiltration can abate sediment and nutrient loading by reducing the runoff discharge.

Lawn care and yard maintenance that limits the application of nutrients and increases the likelihood of uptake and retention is recommended. This includes reducing the amount and/or frequency of fertilizer applications. The timing of application should be such that it is unlikely immediately preceding a runoff event (e.g., precipitation or irrigation). More stable alternatives to chemical fertilizers should be adopted such as organic based materials (e.g., composts and manures). Organic materials also provide carbon which improves soil structure and increases permeability (i.e., leads to greater storm water infiltration).

The NRCS in collaboration with the National Association of Conservation Districts (NACD) and the Wildlife Habitat Council (WHC) developed a backyard conservation manual that highlights ten activities that collectively are designed to improve water and soil quality and wildlife habitat.

This document can be found on the world-wide web at http://www.nrcs.usda.gov/feature/backyard/.

Assimilative Capacity
Increasing the assimilative capacity of the stream system itself is a viable means to help achieve water quality goals. Such an increase can help abate pollutant loads in the event that controls for landscape based and point sources are inadequate. One of the most important ways to increase the assimilative of the system is to provide and/or preserve floodplain connection. Other means include ensuring high quality substrate (i.e., an adequate hyporheic zone), and appropriate channel morphology (e.g., sinuosity, width depth relationships). A sufficient source of carbon is needed to support many of the organisms that are critical for instream biological processing; therefore detritus from riparian trees and floodplains is important (Wallace et al., 1997; Baer et al., 2001; Crenshaw et al., 2002).

6.1.4 Summary

The diverse sources of impairment in the Tuscarawas River watershed related to land uses require a number of various implementation actions. The basic principles of providing floodplain connectivity, stable stream morphology and watershed hydrology that approximates natural conditions (i.e., there is adequate infiltration) are applicable to the agricultural, developing, and urban areas of the watershed. Likewise stream buffers are appropriate for all land use types in the watershed.

Point source reductions are needed at a number of facilities throughout the basin. Home Sewage Treatment Systems (HSTS) must be addressed in rural, urban, and developing areas. Overland sediment loading is primarily a concern in the agricultural areas and where residential and commercial development is rapid. Nutrient loading resulting from agrochemicals and manure sources should be addressed by conservation and management practices promoted by NRCS. Residential, commercial and otherwise urban areas can reduce overland loading by reducing the application rate of fertilizers and improved timing. Reduction in runoff volume through onsite storm water management will also reduce loading from urban areas and improve watershed hydrology and consequently stream stability.

6.2 Reasonable Assurances

The recommendations made in this TMDL report will be carried out if the appropriate entities work to implement them. In particular, activities that do not fall under regulatory authority require that there be a committed effort by state and local agencies, governments, and private groups to carry out and/or facilitate such actions. The availability of adequate resources is also imperative for successful implementation.

The following discusses organizations and programs that have an important role or can provide assistance for meeting the goals and recommendations of this TMDL. This section establishes why it is reasonable to be assured of successful implementation.

6.2.1 Ohio EPA

The several programs that Ohio EPA Division of Surface Water administers are designed to control pollution from point sources and certain storm water discharges as well as provide assistance for abating nonpoint sources of pollution. Other divisions within the Ohio EPA provide assistance such as funding, technical assistance, and education for water resource related issues. Information regarding the specific programs within the Ohio EPA Division of Surface Water (DSW) can be found on the web at http://www.epa.state.oh.us/dsw/, and information about the Division of Environmental and Financial Assistance (DEFA) at http://www.epa.state.oh.us/defa/. What follows are programs within the agency that are especially important for the implementation of this TMDL.

NPDES Program

National Pollution Discharge Elimination System (NPDES) permits authorize the discharge of substances at levels that meet the more stringent of technology or water-quality-based effluent limits and establish requirements related to combined sewer overflows, pretreatment, and sludge disposal. All entities that wish to discharge to the waters of the state must obtain a NPDES permit and both general and individual permits are available for coverage. Through the NPDES Program (http://www.epa.state.oh.us/dsw/permits/permits.html), the Ohio EPA will use its authority to ensure that recommended effluent limits are applied to the appropriate permit holders within the Tuscarawas River watershed. Ohio EPA staff in the NPDES Program can provide technical assistance for permitted entities when needed. Permits issued under the NPDES Program must be consistent with the point source recommendations in a TMDL that has been approved by the U.S. EPA.

Storm Water Program

On December 8, 1999, U.S. EPA promulgated the expansion of the existing National Pollutant Discharge Elimination System (NPDES) Storm Water Program by designating additional sources of storm water for regulation to protect water quality. Entities were required to obtain permit coverage by March 10, 2003.

Municipalities located in urbanized areas and that operate municipal separate storm sewer systems (MS4s) are included in the program in the State of Ohio. Pollutants from MS4s include floatables, oil and grease, as well as other pollutants from illicit discharges.

Operators of small MS4s will be required to develop a storm water management program that implements six minimum measures (listed below) which focus on a Best Management Practice (BMP) approach. The BMPs chosen by the MS4 must significantly reduce pollutants in urban storm water compared to existing levels in a cost-effective manner.

The six minimum control measures:

- Public education and outreach program on the impacts of storm water on surface water and possible steps to reduce storm water pollution. The program must be targeted at both the general community and commercial, industrial and institutional dischargers.
- Public involvement and participation in developing and implementing the Storm Water Management Plan.
- Elimination of illicit discharges to the MS4.
- Construction site storm water runoff ordinances that require the use of appropriate BMPs, pre-construction review of Storm Water Pollution Prevention Plans (SWP3s), site inspections during construction for compliance with the SWP3, and penalties for non-compliance.
- Post-construction storm water management ordinances that require the implementation of structural and non-structural BMPs within new development and redevelopment areas, including assurances of the long-term operation of these BMPs.

- Pollution prevention and good housekeeping for municipal operations such as efforts to reduce storm water pollution from the maintenance of open space, parks and vehicle fleets.

Storm water control measures will help to improve water quality in the Tuscarawas River watershed. Reduction in the sediment load will improve both habitat and chemical water quality. Identification of illicit discharges to storm sewer systems will also improve water quality.

Staff within the Storm Water Program provides technical assistance to permitted entities when needed. District Office staff within the Storm Water Program responds to and investigate complaints received by individuals and organizations.

401 Water Quality Certification Program
In Ohio, anyone wishing to discharge dredged or fill material into the waters of the United States, regardless of whether on private or public property, must obtain a Section 404 permit from the U.S. Army Corps of Engineers (Corps) and a Section 401 Water Quality Certification (WQC) from the state.

Stream and wetland mitigation is used as a condition for granting 401 certificates and is the means of ensuring that water resources do not experience a net decline in quality. When a wetland or stream segment is impacted, an appropriate mitigation is required such that there is no net loss of wetlands or unimpaired stream length. Restoration, creation, or other forms of enhancement are required at a level that depends upon the original quality of the resource.

Currently there are proposed rule changes to the 401 Program that are designed to provide a more scientific basis for determining appropriate criteria for 401 permit decisions (i.e., acceptance or denial) as well as mitigation stipulations for the respective projects (http://www.epa.state.oh.us/dsw/401/401Section.html). These rule changes are expected to be finalized in the near future. Ohio EPA staff will conduct reviews and issue permits to provide the most reasonable protections and improvements, where possible, of surface waters in the Tuscarawas River watershed.

Wetland Protection Program
House Bill 231 established a permanent permitting process for isolated wetlands. Reviewers in the 401 Water Quality Certification Section are responsible for the isolated wetland permits required by this state law. Ohio EPA staff will conduct reviews and issue permits to provide the most reasonable protections and improvements of surface waters in the Tuscarawas River watershed.

Enforcement Program
When Ohio EPA is unable to resolve continuing water quality problems due to violations of permitting rules or laws, the Division of Surface Water may recommend that enforcement action be taken. The enforcement and compliance staffs work with Ohio EPA attorneys, as well as the Attorney General's Office, to resolve these cases. Where possible, an added emphasis and priority are given to actions in sensitive watersheds. All completed enforcement actions are posted on the DSW web page.

208 Program (State Water Quality Management Plans)
Ohio EPA oversees the State Water Quality Management (WQM) Plan. The State WQM Plan is like an encyclopedia of information used to plot and direct actions that abate pollution and preserve clean water. A wide variety of issues is addressed and framed within the context of

applicable law and regulations. The Tuscarawas River TMDL becomes a part of the State WQM Plan when it is approved by the U.S. EPA and the recommendations found herein align with and support the state's overall plan for clean waters. More importantly, the requirement and intention to review and update the State Water Quality Management Plan on an annual basis creates an avenue to apply adaptive management and make adjustments in these recommendations as necessary.

Nonpoint Source Program

The Ohio Nonpoint Source (NPS) program focuses on identifying and supporting implementation of management practices and measures that reduce pollutant loadings, control pollution from nonpoint sources and improve the overall quality of these waters. Ohio EPA receives federal Section 319(h) funding to implement a statewide nonpoint source program, including offering grants to address nonpoint sources of pollution. Staff from the NPS program works with state and local agencies, governments, watershed groups, and citizens.

In addressing sources of impairment related to agricultural activities, NPS staff will correspond with ODNR to promote BMPs as well as cost-share and incentive based conservation programs. In particular, Ohio EPA will encourage the ODNR to continue to work with Farm Service Agency personnel and staff from local SWCD and NRCS offices. NPS staff will also provide assistance to agencies and groups actively promoting conservation as well as direction to other appropriate resources within the Ohio EPA.

NPS staff will continue to work with watershed groups that are active in the Tuscarawas River basin. Local NPS implementation is critical to achieving state environmental targets. Additionally, there is a reliance on watershed management plans to identify and outline actions to correct water quality problems caused by NPS pollution.

Section 319(h) grants are expected to be directed to projects that eliminate or reduce water quality impairments caused by nonpoint sources of pollution. Applicants may apply for a maximum of $500,000 for a three year period. Each project funded must provide an additional 40% matching share and the total federally funded share of project costs may not exceed 60%. Areas with approved TMDLs will receive special consideration for funding.

Division of Environmental and Financial Assistance

The Division of Environmental and Financial Assistance (DEFA) provides incentive financing, supports the development of effective projects, and encourages environmentally proactive behaviors through the Ohio Water Pollution Control Loan Fund (WPCLF). Municipal wastewater treatment improvements – sewage treatment facilities, interceptor sewers, sewage collection systems and storm sewer separation projects – are eligible for financing. Nonpoint pollution control projects that are eligible for financing include:

- Improvement or replacement of on-lot wastewater treatment systems
- Agricultural runoff control and best management practices
- Urban storm water runoff
- Septage receiving facilities
- Forestry best management practices.

The Water Resource Restoration Sponsor Program (WRRSP) is a part of the WPCLF and directs funding towards stream protection and restoration projects. The primary focus of this program is to improve and protect stream habitat. Like Section 319 (h) grants, proposals for stream improvements within the Tuscarawas River watershed will receive special consideration.

6.2.2 Ohio Department of Natural Resources

The Ohio Department of Natural Resources (ODNR) works to protect land and water resources throughout Ohio. A specific objective in regards to water resources is to *"Lead in the development and implementation of stream and wetlands conservation initiatives, applying advanced science, technology and research to restore and protect stream and wetlands habitats"*. This commitment attests that the ODNR will be a reliable partner in addressing causes and sources of impairment in the watershed.

The following are programs and divisions within the ODNR that are particularly instrumental in protecting and improving water resources within the Tuscarawas River watershed.

Pollution Abatement Program
Under Ohio's Pollution Abatement Rules (OAC 1501) the ODNR is required to respond to written and non-written complaints regarding agricultural pollution. As defined by OAC 1501, agricultural pollution is the "failure to use management or conservation practices in farming or silvicultural operations to abate wind or water erosion of the soil or to abate the degradation of waters of the state by animal waste or soil sediment including substances attached thereto." In cooperation with Soil and Water Conservation Districts (SWCD), an investigation is begun within five days of receipt of the complaint and a Pollution Investigation Report (PIR) is generated within ten days. Resource management specialists from ODNR within the Division of Soil and Water Conservation (DSWC) typically become involved with pollution abatement cases in their respective areas of the state.

If it is determined necessary, an operation and management plan will generated to abate the pollution. This plan is to be approved by the SWCD or ODNR and implemented by the landowner. Cost share funding may be available to assist producers in implementing the appropriate management practices to abate the pollution problems and such practices may be phased in if necessary. If a landowner fails to take corrective action within the required timeframe, the Chief of the Division of Soil and Water Conservation (ODNR) may issue an order such that failure to comply is a first degree misdemeanor. This program safeguards against chronic problems that lead to the degradation of water quality within the Tuscarawas River watershed.

SWCD Program
ODNR-DSWC has a cooperative working agreement with the Soil and Water Conservation Districts throughout Ohio and the NRCS. According to the agreement ODNR-DSWC is responsible to "provide leadership to Districts in strategic planning, technical assistance, fiscal management, staffing, and administering District programs." The Division also provides "training and technical assistance to District supervisors and personnel in their duties, responsibilities, and authorities." Program Specialists from ODNR work with the SWCDs to identify program needs and training opportunities. ODNR also ensures that program standards and technical specifications are available to SWCDs and NRCS personnel. State matching dollars from the ODNR constitute roughly half of the annual operating budgets of SWCDs.

Through the partnership established by the working agreement and their history of collaboration, ODNR can communicate the goals and recommendations highlighted in this TMDL to SWCDs and provide guidance to actively promote conservation efforts that are consistent with those goals.

Urban Storm Water Program
ODNR staff provides technical expertise regarding storm water management and controls as well as administers urban storm water related grants. The urban storm water program has been responsible for the development and maintenance of the Rainwater Manual for the State of Ohio which provides guidance regarding storm water management and sediment and erosion control measures.

Staff from the urban storm water program will be an important resource for communicating with the development community and promoting storm water management that is consistent with recommendations and goals of this TMDL.

Mineral Resources Management (Acid Mine Drainage)
The Ohio legislature established the Acid Mine Drainage Abatement and Treatment (AMDAT) fund in March 1995. The Division transfers up to 10% of the annual federal Abandoned Mine Land (AML) grant into the AMDAT fund. Based upon present AML grant levels the Division transfers approximately $500-600 thousand into the fund annually. Grant moneys placed into the AMDAT fund, pursuant to ORC 1513.37 (E) will be utilized to abate mine drainage problems within watersheds that have been approved as hydrologic units. Priority will be given to the expenditure of AMDAT funds whenever other sources of funding can be leveraged through the expenditure of AMDAT moneys (the AMDAT funds are considered “state money” and can therefore be used to match federal funds from other programs). It is the purpose of the AMDAT fund to provide for the long-term clean up of watersheds impacted by AMD in accordance with the criteria established in ORC 1513.37 (E) for hydrologic units.

Local community watershed groups and other governmental agencies may request assistance from the ODNR Division of Mineral Resources Management (MRM) in developing watershed abatement plans, such that AMDAT funds can be expended for AMD abatement. The MRM can provide assistance in the form of subsurface drilling, development of watershed monitoring plans, laboratory analysis of water samples, matching funding for water monitoring, hydrology and engineering technical assistance, construction contract administration, and construction oversight. Once watershed restoration plans are developed for a hydrologic unit or for a subwatershed within a hydrologic unit, the MRM may also provide matching funding for the purpose of construction of an abatement project. Individual projects are eligible to receive matching funds through AMDAT if such projects are within an approved hydrologic unit (subject to approval by the U.S. Dept. of the Interior, Office of Surface Mining) and the project has been demonstrated to be a priority component of a watershed restoration plan.

In March 1999 the Ohio MRM gained the authority to grant money from the AMDAT fund directly to watershed groups in accordance with the following criteria:

- The watershed group meets the criteria for a charitable organization as defined in ORC 1716.01;
- The watershed group provides matching funding, including in-kind services, for 50% of the cost of the proposed project.

The funds may be used for the following: data collection and analysis necessary to qualify a watershed as a hydrologic unit; monitoring of water quality changes resulting from an abatement project; engineering design and construction costs for a priority reclamation project in the qualified hydrologic unit.

Division of Forestry
The mission of the Division of Forestry is to promote sustainable use and protection of forests on public and private lands. The division provides technical expertise and other forms of assistance regarding riparian forest establishment and protection.

Division of Wildlife
Through efforts to increase the amount of habitat for game birds and other forms of wildlife, private lands biologists actively promote the establishment of warm season grass in buffer strips and on cropland set asides. Private lands biologists come into contact with private landowners and conservation groups to educate and provide assistance regarding these types of habitat improvements.

6.2.3 Agricultural Services and Programs

Local Soil and Water Conservation District (SWCD), Natural Resource Conservation Service (NRCS), and Farm Service Agency (FSA) offices often work to serve the county's agricultural community. Staff from these offices establishes working relationships with private landowners and operators within their county, which are often based on trust and cooperation.

SWCD and NRCS staff is trained to provide sound conservation advice and technical assistance (based on standard practices) to landowners and operators as they manage and work the land. Sediment and erosion control and water quality protections make up a large component of the mission of their work. SWCD and NRCS activities also include outreach and education in order to promote stewardship and conservation of natural resources. SWCD and NRCS staff also serves county residents not associated with agricultural and some districts have well-developed urban conservation programs.

The close working relationships that SWCD and NRCS staff typically maintains with local land owners and producers make them well suited for promoting both widely used conservation practices as well as some that are more innovative.

Federal Farm Bill programs are administered by the local NRCS and FSA offices. NRCS is responsible for the Environmental Quality Incentives Program (EQIP) and the Wetland Reserve Program (WRP), while FSA is responsible for the set-aside programs the Conservation Reserve Program (CRP) and the Conservation Reserve Enhancement Program (CREP).

Environmental Quality Incentives Program
The Environmental Quality Incentives Program (EQIP) is an incentive based, voluntary program designed to increase the use of agriculturally related best management and conservation practices. EQIP is available to operators throughout the watershed irrespective of whether they own or rent the land that they farm. Through this program operators receive cost share and/or incentive payments for employing conservation management practices. Contracts are five years in length.

Eligible conservation practices cover broad categories such as nutrient and pesticide management, conservation tillage, conservation crop rotation, cover cropping, manure management and storage, pesticide and fertilizer handling facilities, livestock fencing, pastureland management, and drainage water management among others. However, funding for these practices is competitive and limited to the allocations made to any respective county in Ohio. Each county in receives a minimum of $100,000 per year and may receive more depending on state priorities for that year. More information on this program is available on the NRCS website at www.nrcs.usda.gov.

Conservation Reserve Program and Wetland Reserve Program
The Conservation Reserve and Wetland Reserve Programs (CRP and WRP respectively) are set aside programs. The goals of these programs are to protect environmentally sensitive lands (e.g., highly erodible soils) and improve water quality and wildlife habitat.

Set aside programs are voluntary and incentive-based and provide compensation to farmers for establishing and maintaining buffers, wetlands, grasslands or woodlands on land that would otherwise be used for agricultural production. Compensation is restricted to the timeframe established in the contract agreement. Incentive payments for these two programs are lower than the enhanced versions (i.e., CREP and WREP), which are limited to areas that have been approved by the USDA for the additional funding. These programs can assist in creating land use changes that improve water resource quality in the Tuscarawas River watershed.

6.2.4 Extension and Development Services

Each county in Ohio has an extension agent dedicated to agricultural and natural resource issues. The primary purpose of extension is to disseminate up-to-date science and technology so it can be applied for the betterment of the environment and society. Like SWCD and NRCS staff, extension agents provide technical advice to landowners and operators and often develop strong relationships with the local community. Local extension agents are particularly well suited for promoting innovative conservation measures that have not yet been established in the standard practices developed by NRCS.

6.2.5 Agricultural Organizations and Programs

Agricultural organizations are working to address water quality problems associated with traditional farming practices. The Ohio Farm Bureau Federation (OFBF) seeks to improve water quality through the employment of scientifically-based economically sound conservation management practices (http://www.ofbf.org). In order to pursue this mission, OFBF initiated programs aimed at engaging producers in voluntary water quality protection and improvement efforts. At the local level county Farm Bureau Public Policy Action Teams have the opportunity to administer OFBF programs related to environmental quality. The Public Policy Action Team leader works with the county's Organizational Director, who is a staff member of the OFBF, to implement program initiatives.

OFBF's Agricultural Watershed Awareness and Resource Evaluation (AWARE) program promotes water quality monitoring and education so that producers have more information when making resource conservation decisions regarding their operations. In collaboration with other conservation and commodity organizations, OFBF led the development of a producer self-assessment program designed to evaluate the potential for off-site environmental impact and develop strategies to reduce those risks. OFBF also offers assistance to producers to better understand and comply with new and existing environmental regulations.

To help Ohio's livestock, poultry and equine producers identify and address key management issues affecting environmental quality, the Ohio Livestock Coalition (OLC) developed the Livestock Environmental Assurance Program (LEAP). LEAP is a voluntary and confidential environmental assurance program that provides producers the opportunity to take a proactive approach in blending sound production economics with concern about environmental quality.

LEAP helps producers profitably manage environmental challenges that are critically important to the success of the business and effectively assess how farmstead practices affect water quality.

6.2.6 Local Health Departments

Under OAC 3701-29 local health departments are responsible for code enforcement, operational inspections, and nuisance investigations of household sewage treatment systems serving 1, 2, or 3 family dwellings. The Ohio Department of Health works with locals health departments and provides technical assistance and training.

6.2.7 Local Zoning and Regional Planning

Developing local land use planning in the watershed is very important. In general, land use is a decision left up to local governments. Decisions to utilize zoning or other forms of guidelines can have direct impacts on a watershed. Local ordinances for stream setbacks are very important to both the long term stability of the watershed and also to its recovery. Their importance to habitat protection and water quality cannot be overstated. In addition, habitat protection and floodplain management can have direct impacts on citizens and businesses within the watershed. Flooding is a natural process which can be extremely influenced by human activities.

This TMDL recommends that local jurisdictions develop comprehensive plans, floodplain management plans, and sediment and erosion control plans. The plans should encompass economic as well as ecological concerns in relation to watershed development. These plans should also be consistent with requirements of NPDES Storm Water permits.

6.2.8 Phase II Storm Water Communities

Phase II storm water communities must develop storm water management plans that include controls for the six minimum control measures outlined by the U.S. EPA (www.epa.state.oh.us/dsw/storm/ms4.html), and included in Section 6.2.1.

6.2.9 Watershed Action Plan

A watershed action plan is an itemization of the problems, priorities and activities the local watershed group would like to address. To access funding from U.S. EPA, Ohio EPA or ODNR, the overall purpose of the watershed plan is to restore and maintain the chemical, physical and biological integrity of waterbodies within the watershed, an objective of the Clean Water Act of 1972. Currently, portions of the Tuscarawas River watershed have a funded Watershed Coordinator and a Watershed Action Plan is being developed (a WAP for Wolf Creek has been approved). The process will follow guidance set forth in the Ohio EPA document: *A Guide to Developing Local Watershed Action Plans in Ohio* which may be found on Ohio EPA's website, http://www.epa.state.oh.us/dsw/nps/wsguide.pdf. Additions to the plan requirements (Appendix 8) can be found at: http://www.epa.state.oh.us/dsw/nps/NPS_WAP_APP8.pdf.

6.2.10 Easements and Land Preservation

The preservation and protection of high quality riparian acres is advanced by multiple private and public entities throughout the watershed. This TMDL encourages the use of easements and outright land purchase for conservation. By targeting riparian areas and high quality wetlands, the watershed will gain a level of protection which can lead to restoration in those areas currently impaired. Protection of headwater streams should be considered a high priority for watershed protection and restoration.

The Western Reserve Land Conservancy (WRLC) works in the northern part the Tuscarawas River watershed, including Stark, Portage, Summit, Medina and Wayne counties. WRLC has several programs aimed at facilitating the preservation of land and public education that stresses the importance of preservation for the protection of natural resources. More information can be found on the WRLC website (http://www.wrlc.cc/).

6.2.11 Muskingum Watershed Conservancy District

The Muskingum Watershed Conservancy District was formed in 1933 to address flooding concerns within the watershed, the largest watershed wholly within Ohio's boundaries. The district operates a series of dams, often with other agencies, to control river flows and manage several reservoirs. In addition to flood control, the impoundments offer a number of recreational opportunities. As has been previously discussed, dams and their impounded areas do cause water quality problems resulting in biological, chemical, and physical degradation of the water resource. It is hoped that this TMDL will encourage and foster a working relationship between all watershed stakeholders to encourage ecologically appropriate management strategies whenever possible. Ohio EPA encourages preservation and conservation of headwater streams and smaller tributaries as an alternative to dredging of larger streams. Prior to implementing any dredging program, the entire watershed and its hydrology should be considered. Preservation and conservation along with enhancement and restoration of upstream storage capacities may prove to be a more economical and sustainable management measure.

6.3 Process for Evaluation and Revision

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

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

6.3.1 Evaluation and Analyses

Aquatic life and recreational uses are impaired in the watershed, therefore monitoring that evaluates the river system with respect to these uses is a priority to the Ohio EPA. The degree of impairment of aquatic life use is exclusively determined through the analysis of biological monitoring data. Recreational use impairment is determined through bacteria counts from water quality samples. Ambient conditions causing impairment include high phosphorus and sediment concentrations (or loads) and degraded habitat. This report sets targets values for these parameters (e.g., instream concentrations or loads and habitat features), which should also be measured through ongoing monitoring.

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

Past and Ongoing Water Resource Evaluation
The most recent sampling in this watershed occurred during the 2003, 2004, and 2005 sampling seasons. The Ohio EPA is scheduled to perform biological, water quality, habitat, and sediment chemistry monitoring in the basin in 2017 (Ohio EPA, 2006).

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

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