State of Ohio
Environmental Protection Agency

Division of Surface Water

Total Maximum Daily Loads for the Nimishillen Creek Watershed

Middle Branch Nimishillen Creek upstream of Reifsynder Park

February 23, 2009
Draft Report for Public Review (Phosphorus)

Ted Strickland, Governor
Chris Korleski, Director

Table of Contents

	Page
Acknowledgements	vii
Executive Summary	viii
1.0 Introduction	**1**
2.0 Waterbody Overview	**2**
2.1 Description of Study Area	2
2.2 Water Quality Assessment	5
2.3 Causes and Sources of Impairment	23
3.0 Problem Statement	**31**
3.1 Target Identification	31
3.2 Identification of Current Deviation from Target	36
3.3 Source Identification	39
4.0 TMDL Development	**40**
4.1 Impairments addressed through this TMDL	40
4.2 Methods of TMDL Development	44
4.2.1 Nutrient/DO modeling – QUAL2K	45
4.2.2 Habitat alteration and sediment method	54
4.2.3 Pathogens	55
4.3 Critical condition and seasonality	60
4.3.1 Nutrients / dissolved oxygen	60
4.3.2 Habitat and sediment	60
4.3.4 Pathogens	60
4.4 Margin of Safety	60
4.4.1 Nutrients	61
4.4.2 Habitat and sediment	61
4.4.3 Pathogens	61
4.5 Future Growth	61

5.0 Watershed analysis, loading capacity, and allocations 62
5.1 Nutrient/Dissolved oxygen TMDL 62
5.2 Bacteria (Pathogen) TMDL 71
5.3 Habitat and sediment TMDLs 75
6.0 Public Participation 81
7.0 Water Quality Improvement Strategy 82
7.1 Implementation Approach and Rationale 83
7.1.1 Pathogens 83
7.1.2 Habitat 85
7.1.3 Nutrient and Sediment 98
7.1.4 Summary 101
7.2 Reasonable Assurances 101
7.2.1 Ohio EPA 102
7.2.2 Ohio Department of Natural Resources 105
7.2.3 Agricultural Services and Programs 108
7.2.4 Extension and Development Services 109
7.2.5 Agricultural Organizations and Programs 109
7.2.6 Local Health Departments 109
7.2.7 Local Zoning and Regional Planning 112
7.2.8 Phase II Storm Water Communities 112
7.2.9 Watershed Action Plan 114
7.2.10 Easements and Land Preservation 114
7.2.11 Muskingum Watershed Conservancy District 114
7.3 Process for Evaluation and Revision 115
7.3.1 Evaluation and Analyses 115
References 117

Figure	Title	Page
2-1	Nimishillen Creek watershed	3
2-2	Phosphorus concentrations in the Nimishillen Creek watershed	9
2-3	Nitrate concentrations in the Nimishillen Creek watershed	10
2-4	TDS concentrations in the Nimishillen Creek watershed	11
2-5	Phosphorus in Nimishillen Creek	12
2-6	Nitrate in Nimishillen Creek	12
2-7	Phosphorus in East Branch Nimishillen Creek	13
2-8	Nitrate in East Branch Nimishillen Creek	13
2-9	Phosphorus in West Branch Nimishillen Creek	14
2-10	Nitrate in West Branch Nimishillen Creek	14
2-11	Phosphorus in Middle Branch Nimishillen Creek	14
2-12	Nitrate in Middle Branch Nimishillen Creek	14
2-13	Manganese levels in Nimishillen basin	15
2-14	Iron levels in the Nimishillen basin	15
2-15	TSS concentrations for several streams in the Nimishillen Creek watershed	16
2-16	Fish community assessment results for Nimishillen Creek	17
2-17	IBI scores for Nimishillen Creek watershed by stream and river mile	18
2-18	MIwb scores for Nimishillen Creek watershed by stream and river mile	19
2-19	ICI scores for Nimishillen Creek watershed by stream and river mile	20
2-19a	Narrative macroinvertebrate ratings for all sites	21
2-20	ICI scores for East Branch Nimishillen Creek	22
2-21	Nimishillen Creek watershed land use map	27
2-22a	Point source loadings	28
2-22b	Point source loadings, cont'd	29
2-22c	Point source loadings, cont'd	30
3-1	Nimishillen Creek basin QHEI scores	37
3-2	Nimishillen basin QHEI scores by drainage area size	36
3-3	Phosphorus concentrations in the Nimishillen Creek watershed compared to target value	38
4-1	Segmentation scheme of a generic QUAL2K model	47
4-2	Reaches modeled with QUAL2K for the Nimishillen Creek TMDL	48
4-3	Calibration and observed D.O. on the Nimishillen QUAL2K model	50

Figure	Title	Page
4-4	Calibration and observed T.P. on the Nimishillen QUAL2K model	50
4-5	Calibration and observed NO3-NO2 on the Nimishillen QUAL2K model	51
4-6	Validation and observed D.O. on the Nimishillen QUAL2K model	52
4-7	Validation and observed T.P. for the Nimishillen QUAL2K model	52
4-8	Validation and observed NO3-NO2-N on the Nimishillen QUAL2K model	53
5-1	Model results at 5 mg/l effluent D.O.	64
5-2	Model results at 6 mg/l effluent D.O.	64
5-3	Phosphorus model results at current effluent quality and design flows	65
5-4	Phosphorus model results for the Louisville WWTP	66
5-5	Phosphorus model results for the Canton WPCF	67
5-6	Nimishillen Creek phosphorus @ Faircrest Road	68
5-7	Nimishillen Creek phosphorus @ Howenstine Drive	69
5-8	Fecal coliform LDC	75
5-9	SEV rating table	80
5-10	SEV scores for Nimishillen Creek	81
7-1	Graphical depiction of a two-stage ditch	88
7-2	Example of streamway	90
7-3	General model of relationship between stream health and imperviousness	93

Table	Title	Page
1-1	Summary of TMDLs for the Nimishillen Creek watershed	ix
2-1	Water Quality Standards summary	6
2-2	Violations and exceedances of Ohio water quality standards	7
2-3	Bacteria sample results	23
2-4	Land use distribution in the Nimishillen Creek basin	25
2-4a	Land use percentages by HUC 14	26
3-1	Nimishillen Creek basin biocriteria	32
3-2	Statewide total P targets for WWH	33
3-3	Statewide DO criteria for WWH	33
3-4	QHEI modified attributes	35
3-5	Targets of the habitat TMDL	35
3-6	Targets of the sediment TMDL	36
3-7	Bacteria water quality standards	36
4-1	Aquatic life use attainment causes of impairment and TMDL developed	42
4-2	Recreational use attainment impairment and TMDL assessment area	43
4-3	Low flow (Q7,10) for tributaries in the QUAL2K model	54
4-4	Summary of BIT bacteria TMDL development	56
4-5	Population growth figures for Nimishillen Creek watershed municipalities	62
5-1	Louisville WWTP's model results for total phosphorus at 2.0 MGD design flow	67
5-2	Canton WPCF's model results for total phosphorus at 39.0 MGD design flow	67
5-3	TMDL and allocations for total phosphorus	70
5-4	Total existing load, TMDL and allocations of fecal coliform loads	72
5-5	Point source fecal coliform loads	72
5-6	Existing and allocated fecal coliform loads for NPDES dischargers	73
5-7	Existing and allocated fecal coliform loads for non-NPDES dischargers	73
5-8	Nonpoint source fecal coliform loads	74
5-9	Sediment TMDLs	76
5-10	Habitat TMDLs	79
7-1	Summary of the cause/source associations for impaired recreational and/or aquatic life uses	83
7-2	Summary of the strategies for addressing each listed cause of impairment	85
7-3	Recommended loads for phosphorus	99

Appendices

Appendix A: Biological Attainment Tables

Appendix B: Use Designations for Nimishillen Creek (OAC 3745-1-24)

Appendix C: NPDES Discharges within the Nimishillen Creek Basin

Appendix D: Chemical Sample Results

Appendix E: Bacteria Sample Results

Appendix F: Fish Community Assessment Results

Appendix G: Macroivertebrate Community Assessment Results

Appendix H: QHEI Data

Appendix I: Response Summary to Public Comments on the Nimishillen Creek TMDL

Appendix Ia: Ohio EPA letter on the Industrial Excess Landfill

Appendix J: Pathogen Modeling Details

Appendix K: QUAL2K Model Data

ACKNOWLEDGEMENTS

The following Ohio EPA staff provided technical services for this project:

Biology and Chemical Water Quality	Brian Alsdorf, Dave Altfater, Jack Freda, Paul Anderson
Nonpoint Source Issues	Dan Bogoevski, Mark Bergman
Point Source Issues	Dean Stoll, Phil Rhodes
Project Leader	Bill Zawiski
Water Quality Standards	Chris Skalski
Modeling, Load Allocations	Paul Gledhill

The Nimishillen Creek Watershed Partners have provided a forum for discussion of the water quality issues in basin and are acknowledged for their contribution to the TMDL project. Special thanks to Eric Akin (Nimishillen Creek Watershed Coordinator) for his review and comments.

The Stark County SWCD and USDA-NRCS personnel who assisted with comments are also appreciated.

Acknowledgment is made of the property owners who allowed Ohio EPA personnel access to the study area.

EXECUTIVE SUMMARY

The Nimishillen Creek watershed is located in northeast Ohio, flowing through parts of Summit, Stark, and Tuscarawas Counties on its way to the Ohio River. This watershed appears on Ohio's 303(d) list (Ohio's impaired waters listing) based on findings from Ohio EPA's monitoring program. These findings indicate that organic enrichment, nutrients, flow alteration, metals, and pathogens are the primary causes of impairment. Major sources of impairment include municipal and industrial point sources, septic tanks and crop production.

Stream surveys were conducted in 2003, 2004 and 2005; impairments were found for biological communities as well as elevated phosphorus, nitrates and bacteria. Urban and suburban land use contributes nutrients to the Nimishillen Creek watershed along with the discharges from wastewater treatment plants and septic tanks. Ohio's water quality standards include numerical biological criteria that form the basis of the numerical targets for the TMDLs. The success of the implementation actions resulting from the TMDLs will be evaluated through further monitoring looking for changes in the biological scores. Nutrient targets complement the biocriteria and are used as a tool to help evaluate the impact of nutrient loadings. These nutrient targets were based on an Ohio EPA technical bulletin (Ohio EPA, 1999) that relates instream nutrient concentrations to aquatic community performance.

TMDLs were prepared for phosphorus, habitat (sediment), and bacteria.

Reasonable assurances proposed for the Nimishillen Creek watershed include a number of measures designed to address both point and nonpoint sources of pollution. The inclusion of phosphorus limits on larger municipal point sources will significantly reduce phosphorus loading to the system. Phase II of the storm water regulations will involve a portion of the watershed area and will be an essential part of water quality restoration. Riparian zones are also an important part of protecting current water quality as well as the restoration of impacted areas for implementing this TMDL. Protection of headwater streams is also recommended because of their importance to watershed integrity. This TMDL recommends that additional storm water controls be implemented by watershed communities, such as green roof design, rain barrels, rain gardens, and mechanisms to increase infiltration capacity on developed land. The intent of additional controls is to reduce instantaneous runoff peaks and their associated pollutants, which in part are attributed to existing and future additional impervious surface area.

Table 1-1. Summary of TMDLs for the Nimishillen Creek Watershed

Hydrologic Unit Code (14 digit)	Listed causes of impairment	TMDL action taken
Nimishillen Creek (05040001 050)		
010 020 030 040 050 060	Flow alteration, pathogens, metals, unionized ammonia, nutrients, pH, organic enrichment/DO, thermal modifications, unknown	TMDLs generated for nutrients (phosphorus), siltation (habitat) and bacteria. (See Tables 4-1 and 4-2 for additional details)

From: Appendix D.2. 2006 303(d) List of Prioritized Impaired Waters (Category 5) (Ohio EPA, 2006).

Assessment Unit: 05040001 050 Nimishillen Creek

Size (sq mi)	Aquatic Life Use Impairment	Recreational Use Impairment	Human Health Impairment (Fish Tissue)	AU Category	Priority Points	Next Field Monitoring	Projected TMDL
187.9	Yes	Yes	Yes	5	6	2017	2007

1.0 INTRODUCTION

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 waters (the section 303(d) lists) are made available to the public and submitted to the U.S. Environmental Protection Agency (U.S. EPA) in even-numbered years. The Ohio Environmental Protection Agency (Ohio EPA) identified the Nimishillen Creek watershed as a priority impaired water on the 2004 and 2006 303(d) lists. A general overview of Ohio's water quality standards is included in Table 2-1. Specific use designations for Nimishillen Creek (OAC 3745-1-24) are included in Appendix B.

The Clean Water Act and U.S. EPA regulations require that Total Maximum Daily Loads (TMDLs) be developed for all waters on the section 303(d) lists. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. Ultimately, the goal of Ohio's TMDL process is full attainment of biological and chemical Water Quality Standards (WQS) and, subsequently, removal of water bodies from the 303(d) list. The Ohio EPA believes that developing TMDLs on a watershed basis (as opposed to solely focusing on impaired segments within a watershed) is an effective approach towards this goal. Watershed-wide implementation of certain management practices (riparian protection, for example) is important when addressing streams with multiple nonpoint source related impacts.

This report documents the Nimishillen Creek TMDL process and provides tangible actions to restore and maintain this water body. The main objectives of the report are to 1) describe the water quality and habitat condition of the Nimishillen Creek Watershed and 2) quantitatively assess the factors affecting non or partial attainment of WQS. A draft implementation plan is also included. This plan identifies actions to address these factors and specifies monitoring to ensure actions are carried out and to measure the success of the actions prescribed. The report is organized in sections forming the progression of the TMDL process.

The primary causes of impairment in the Nimishillen Creek watershed are organic enrichment, nutrient enrichment, flow alteration, and pathogens. Nutrient enrichment and organic enrichment are closely tied to each other in the TMDL area. A number of wastewater treatment plants in the watershed contribute nutrients and other contaminants. Septic tanks contribute a majority of the bacteria load to the watershed. Runoff from both urban and suburban land is also an important source of nutrients, pathogens, and a cause of habitat degradation in the watershed. The implementation plan includes numerous actions which focus on point source and runoff issues.

TMDLs were calculated for phosphorus and bacteria. Although habitat degradation is not a load based quantity; TMDL numbers were calculated for these as well. Habitat survey methods used by Ohio EPA can identify high levels of sedimentation and assess overall habitat quality. Habitat improvements and reductions in siltation, are able to be

identified utilizing the QHEI. Additional discussion on habitat and siltation is found in sections 3.1 and 4.2.2.

2.0 WATERBODY OVERVIEW

2.1 Description of Study Area

The Nimishillen Creek watershed shown in Figure 2-1, is located in the northeastern portion of the Muskingum River watershed in the Ohio River drainage basin.

The headwaters of the Nimishillen Creek mainstem primarily originate in three distinct areas. The headwaters of the West Branch Nimishillen Creek are located to the west of the Village of Hartville and just south of the Akron-Canton Airport. Flowing south, the West Branch of Nimishillen Creek flows through the City of North Canton and the City of Canton to its confluence with the Nimishillen Creek mainstem near river mile (RM) 12.1. The headwaters of the Middle Branch Nimishillen Creek are located in Marlboro Township in northern Stark County. Flowing southwesterly, the Middle Branch Nimishillen Creek flows along the western portion of Plain Township, before entering the City of Canton where it combines with the East Branch to form the Nimishillen Creek mainstem at RM 15.0.

The headwaters of the East Branch Nimishillen Creek are located to the north, east and south of the City of Louisville. Flowing southwesterly, the East Branch Nimishillen Creek flows to the City of Louisville before entering the City of Canton and joining with the Middle Branch near RM 15.0 forming the mainstem. Continuing to flow south, the Nimishillen Creek mainstem flows through the City of Canton and the Village of East Sparta, prior to its confluence with Sandy Creek just south of the Stark and Tuscarawas County boundaries.

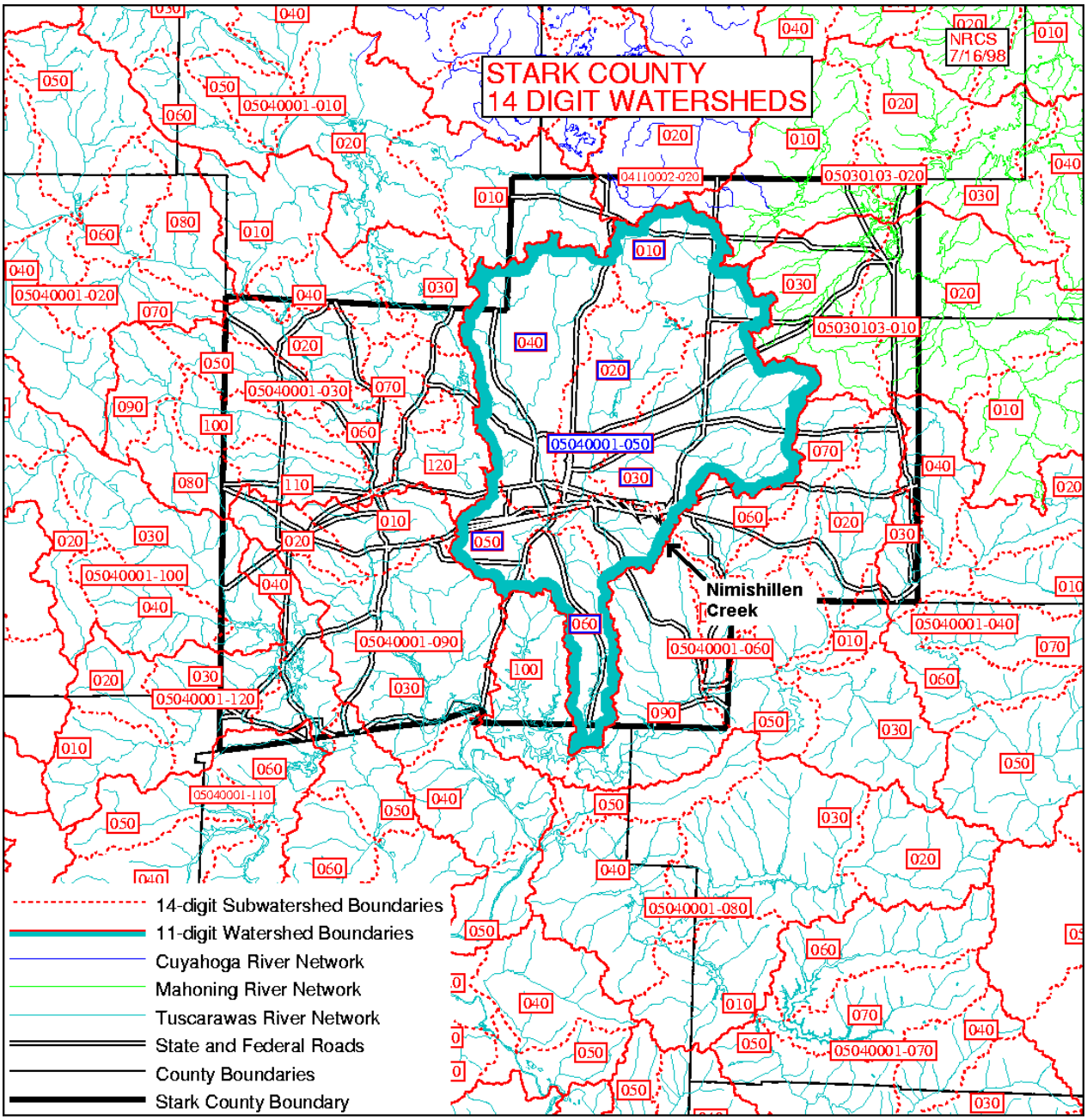


Figure 2-1. Nimishillen Creek watershed

Geology

The Nimishillen Creek Watershed, like the rest of Stark County, lies in two subdivisions of the Appalachian Plateau province. The northern two-thirds of the watershed resides in the glaciated section of the Appalachian Plateau, and the southern one third in the unglaciated section. The headwaters in the northern and central portions of the county have moderate relief and gentle slopes due to glacial actions and depositions. However, in the unglaciated southern portion of the watershed, the Nimishillen Creek mainstem has cut a narrow gorge through highlands resulting in steep sloping upland areas and broad flat expanses in the flood plains. As a result of glaciation, Nimishillen Creek

currently flows southwardly and drains a major portion (32 percent) of Stark County (NEFCO, 2003). The townships of Canton, Osnaburg, and Pike in the southern unglaciated section of the watershed have the most area affected by steep slopes. Consequently, the southern portion of the watershed has slower rates of development and urbanization in part due to poor conditions for home sewage treatment systems (HSTS).

Glacial History

Prior to glaciation, the topography of the entire watershed was similar to what is found in the southern portion today: steep sloped uplands with broad flat expanses in the lower lying areas. However, a succession of glaciers covered much of the area, and all but the southern portion of the land comprising the Nimishillen Creek Watershed was shaped and molded by glacial erosion and deposition. The watershed area had several glaciers come and go during the Illinoian and the Wisconsin age glaciers. The Wisconsin glacier, which began its advance nearly 20,000 years ago, swept away or buried most of the drift deposited by the earlier Illinoian glaciers, before receding nearly 12,000 year ago. The various Wisconsin glaciers advanced into the Nimishillen Creek Watershed area in two different lobes, melding nearly in the center of the watershed. The Killbuck lobe covered the western part of the glaciated watershed, while the Grand River lobe covered the eastern part. Because the two lobes did not advance at the same pace, there is a zone of overlap and outwash in an interlobate area that extends from Canton northward to Lake Township (Stark County Soil Survey, 1971).

Groundwater in the area does contribute to sustaining flow in the watershed. Glacial deposits in the basin provide a source of flow year-round. The ground water influence within the stream can be seen in the stream biology as evidenced by the presence of the mottled sculpin, a cold water species. During the most recent fish community surveys conducted by Ohio EPA, 41.1% of the individual fish in Nimishillen Creek were sculpins, the West Branch had 30.1%, while the Middle Branch had 16.15%.

Bedrock Geology

The Nimishillen Creek Watershed is underlain by bedrock from the Pennsylvanian era and the formations mainly consist of sandstone, siltstone, shale, coal, and limestone formed from sediments deposited sometime between 286 and 320 million years ago (Stark County Soil Survey, 1971).

The northern glaciated portion of the watershed has a diverse mix of Middle Kittaning Coal, Brookville Coal, and Mercer Limestone as the dominate bedrock types. Vast areas of bedrock are buried by glacial deposits of more than 60 feet, primarily along valleys of Nimishillen Creek and its major tributaries. In addition, the headwater areas of the Middle Branch of Nimishillen Creek also have bedrock buried by over 60 feet of glacial deposits.

The bedrock composition in the southern unglaciated portion of the watershed is dissimilar from the northern section. The dominant bedrock types are Mahoning Sandstone, Middle Kittaning Coal, and Brookville Coal. Thick glacial deposits only

reside in a narrow strip along the main stem of Nimishillen Creek near the Stark County - Tuscarawas County boundary.

2.2 Water Quality Assessment

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. Table 2-1 provides a brief description of Ohio's water quality standards. Further information is available in Chapter 3745-1 of the Ohio Administrative Code (OAC) or on the web at: (http://www.epa.state.oh.us/dsw/wqs/criteria.html).

In the Nimishillen Creek basin study area, the aquatic life use designations that currently apply to its segments are Warmwater Habitat (WWH), Modified Warmwater Habitat (MWH), and Limited Resource Water (LRW). Waters designated as WWH are capable of supporting and maintaining a balanced integrated community of warmwater aquatic organisms, while those designated MWH are waters that have been the subject of a use attainability analysis and have been found to be incapable of supporting and maintaining a balanced, integrated, adaptive community of warmwater organisms due to irretrievable modifications of the physical habitat. The LRW waters have been the subject of a use attainability analysis and have been found to lack the potential for any resemblance of any other aquatic life habitat as determined by the biological criteria in Ohio's water quality standards.

Attainment of WQS is measured utilizing both biological communities and chemical sample analysis. 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 insects: 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, and requires a TMDL, whereas a stream that meets all of the biocriteria benchmarks, is in "full attainment." A more detailed explanation of Ohio's biocriteria can be found in the Ohio EPA publication *The Role of Biological Criteria in Water Quality Monitoring, Assessment, and Regulation* (Ohio EPA, 1995).

Table 2-1. Water Quality Standards Summary

WQS Components	**Examples of:**	**Description**
Beneficial Use Designation	1. Water supply •Public (drinking) •Agricultural •Industrial 2. Recreational contact •Beaches (Bathing waters) •Swimming (Primary Contact) •Wading (Secondary Contact) 3. Aquatic life habitats (partial list): •Exceptional Warmwater (EWH) •Warmwater (WWH) •Modified Warmwater (MWH) •Limited Resource Water (LRW) •Cold Water Habitat (CWH) •State Resource Water	Designated uses reflect how the water is potentially used by humans and how well it supports a biological community. Every water in Ohio has a designated use or uses; however, not all uses apply to all waters (they are water body specific). Each use designation has an individual set of numeric criteria associated with it, which are necessary to protect the use designation. For example, a water that was designated as a drinking water supply and could support exceptional biology would have more stringent (lower) allowable concentrations of pollutants than would the average stream. Recreational uses indicate whether the water can be potentially used for swimming or if it may only be suitable for wading.
Numeric Criteria	1. Chemical	Represents the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. Laboratory studies of organism's sensitivity to concentrations of chemicals exposed over varying time periods form the basis for these.
	2. Biological *Measures of fish health:* • Index of Biotic Integrity • Modified Index of Well Being *Measure of macroinvertebrate health:* • Invertebrate Community Index	Indicates the health of the instream biological community by using these 3 indices (measuring sticks). The numeric biological criteria (biocriteria) were developed using a large database of reference sites.
	3. Whole Effluent Toxicity (WET)	Measures the harmful effect of an effluent on living organisms (using toxicity tests).
	4. Bacteriological	Represents the level of bacteria protective of the potential recreational use.
Narrative Criteria (Also known as the "Free Froms")	General water quality criteria that apply to all surface waters. These criteria state that all waters shall be free from sludge, floating debris, oil and scum, color and odor producing materials, substances that are harmful to human, animal or aquatic life, nutrients in concentrations that may cause algal blooms, and free from a public health nuisance.	
Antidegradation Policy	This policy establishes situations under which the director may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need. Refer to http://www.epa.state.oh.us/dsw/wqs/wqs.html for more information.	

Another designated use set forth in WQS is for recreational purposes. The recreational use for the Nimishillen Creek watershed study area is Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR). 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 a use attainment analysis that the combination of remoteness, accessibility, and depth makes full-body contact recreation by adults or children unlikely. In those cases, the Secondary Contact Recreation (SCR) designation is assigned. The attainment status of PCR and SCR is determined using bacterial indicators; the criteria for each are specified in the Ohio WQS. Ohio currently uses both fecal coliform bacteria and *E. coli* as measures of recreational attainment.

The Water Quality Standards designations applicable to the Nimishillen Creek watershed contained in Ohio Administrative Code Chapter 3745-1-24 are included as Appendix B.

The Nimishillen Creek basin was most recently surveyed by Ohio EPA in 2003, 2004, and 2005.

Water Quality

Overall, water quality in the Nimishillen Creek basin is considered fair in that it is not completely attaining water quality standards for several parameters including biological and bacteriological. Table 2-2 lists water quality chemical standard violations identified during the watershed survey. A brief discussion of water quality results during the most recent survey will follow for each stream section. Historical data will be used when necessary to illustrate long-term trends. A complete list of chemical sampling results is included as Appendix D.

Table 2-2. Violations and exceedances of Ohio Water Quality Standards for chemical parameters in the Nimishillen Creek watershed (Assessment Unit 05040001050) for the years 1998-2005. Ohio Water Quality Standards are specified in Chapter 3745-1 of the Ohio Administrative Code.

Stream (River Code)	Location (STORET Station ID)	River Mile	Date	Parameter	Observed Value (Water Quality Standard)
Nimishillen Creek (17-460)					
	8th Street	14.17	7/22/2003	Lead (µg/l)	11.7 (11.4)†—
	Munson Stadium	11.1	7/2/2003	Lead (µg/l)	13.0 (12.4)†—
	Howenstein Dr.	6.72	12/22/1998	Copper (µg/l)	13.0 (12.8)†—
				Lead (µg/l)	11.0 (10.3)†—
			5/18/2000	NH_3-N (µg/l)	1.94 (1.30)†r
			8/23/2000	Copper (µg/l)	17.0 (13.1)†—
				Lead (µg/l)	31.0 (10.7)†—

Table 2-2. Violations and exceedances of Ohio Water Quality Standards for chemical parameters in the Nimishillen Creek watershed (Assessment Unit 05040001050) for the years 1998-2005. Ohio Water Quality Standards are specified in Chapter 3745-1 of the Ohio Administrative Code.

Stream (River Code)	Location (STORET Station ID)	River Mile	Date	Parameter	Observed Value (Water Quality Standard)
				Zinc (µg/l)	174 (168)[†‡¯]
Middle Branch (17-462)					
	Martindale Rd. (Lower Crossing)	3.36	6/28/2005	Dissolved Oxygen (mg/l)	2.90 (4.0 min / 5.0 avg)[‡]
			7/19/2005	Dissolved Oxygen (mg/l)	1.54 (4.0 min / 5.0 avg)[‡]
			8/10/2005	Dissolved Oxygen (mg/l)	4.73 (4.0 min / 5.0 avg)[†]
East Branch (17-463)					
	Beck Rd.	4.20	8/20/1998	Total Dissolved Solids (mg/l)	1,920 (1,500)[†]
Hurford Run (17-468)					
	Mouth	0.1	7/30/1998	NH_3-N (mg/l)	6.78 (1.0)[†r]
			8/3/1998	NH_3-N (mg/l)	1.98 (1.8)[†r]
			8/10/1998	Total Dissolved Solids (mg/l)	1,510 (1,500)[†]
			8/5/2004	NH_3-N (mg/l)	2.43 (1.8)[†r]
Swartz Ditch (17-484)					
	Nimishillen Church Rd.	1.13	7/21/2003	Dissolved Oxygen (mg/l)	0.68 (4.0 min / 5.0 avg)[‡]

Key to symbols:

[†]Value exceeds the chronic (outside mixing zone average) water quality criterion.

[‡]Value in violation of the acute (outside mixing zone maximum) water quality criterion.

[¯]Water quality standard is dependent upon hardness as specified in Table 7-9 of OAC 3745-1-07.

[r]Water quality standard is dependent upon pH and temperature as specified in Tables 7-2 and 7-5 of OAC 3745-1-07.

Nimishillen Creek (HUC 05040001050-020, -050 and -060)

Water quality surveys in Nimishillen Creek identified several parameters which are showing elevated levels in addition to the violations identified in Table 2-2. The nutrients phosphorus and nitrate have been shown to be elevated in Nimishillen Creek. Figures 2-2, 2-3, and 2-4 depict average nutrient concentrations in the study area.

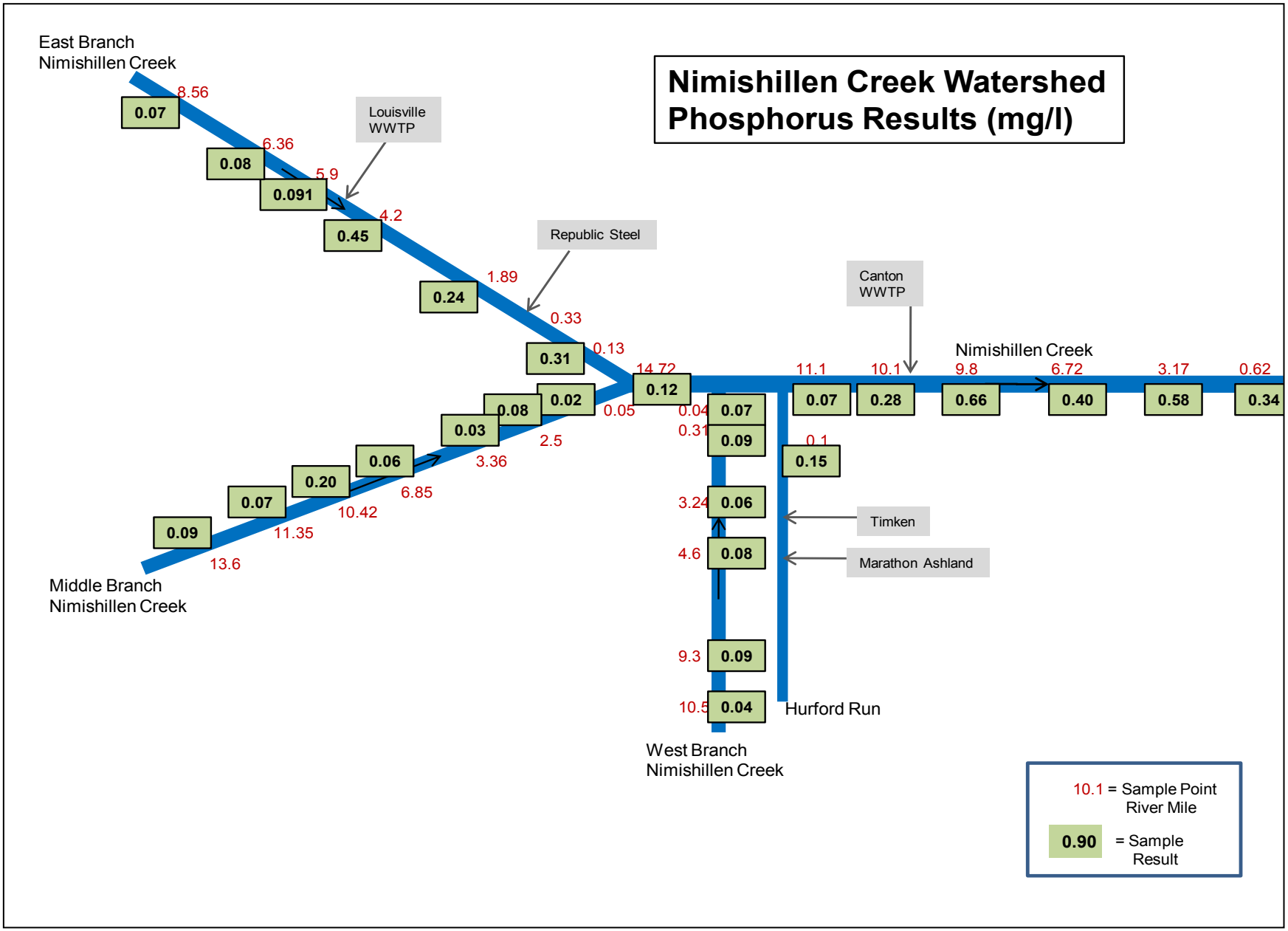


Figure 2-2. Phosphorus concentrations in the Nimishillen Creek watershed

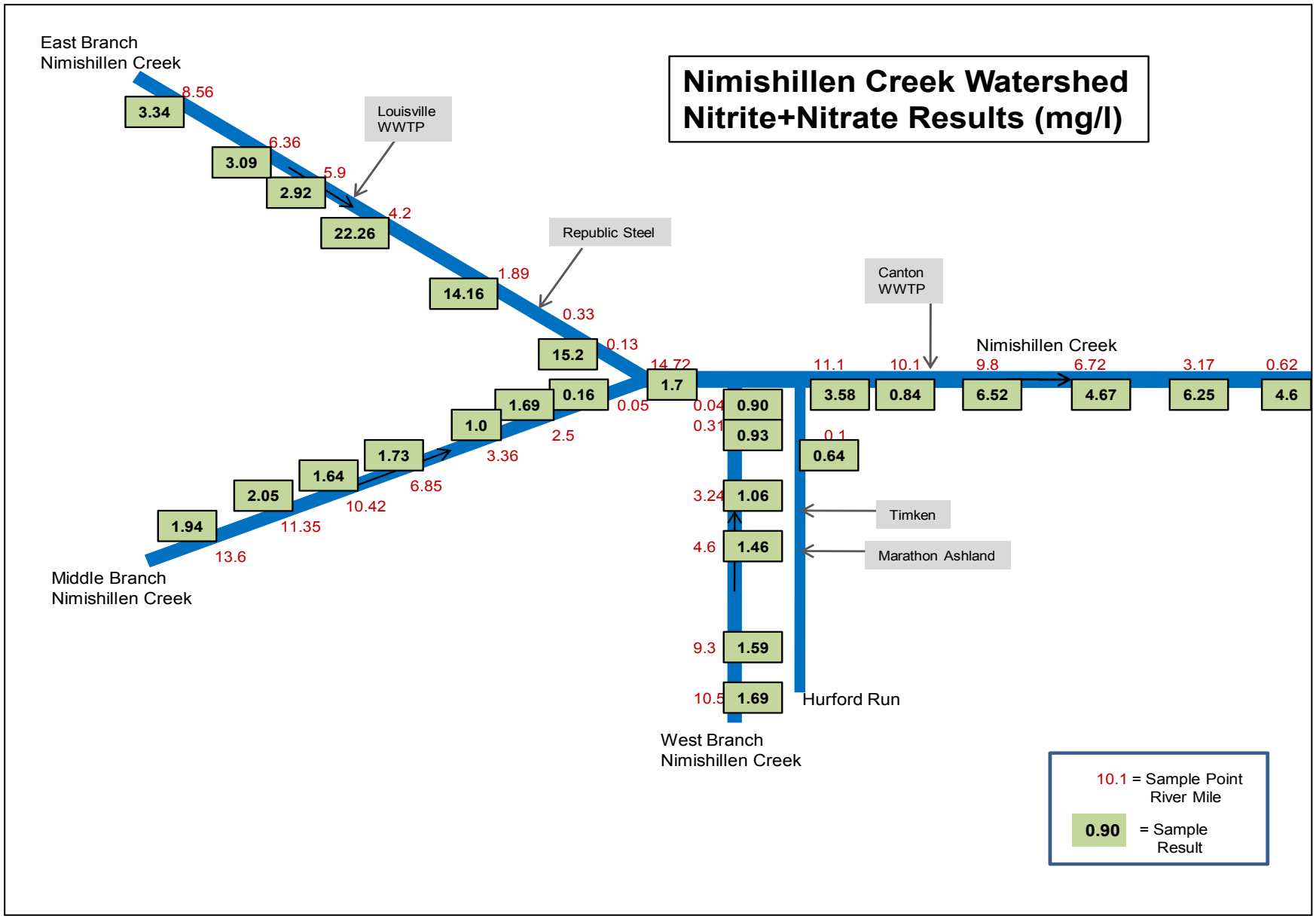


Figure 2-3. Nitrate concentrations in the Nimishillen Creek watershed.

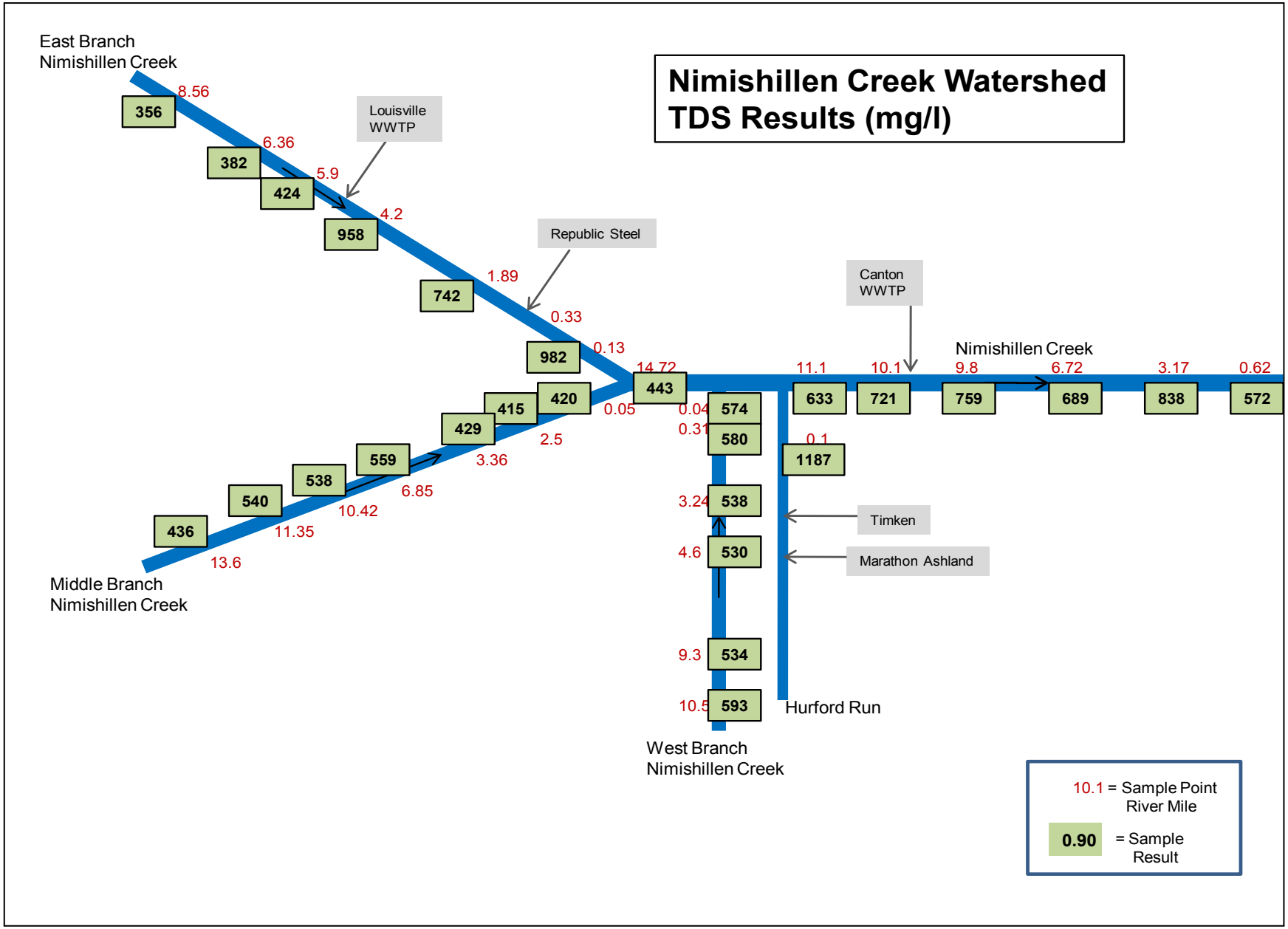


Figure 2-4. TDS concentrations in the Nimishillen Creek Watershed.

Both phosphorus and nitrate are elevated above target values in Nimishillen Creek.

The graph in Figure 2-5 shows average and maximum phosphorus values in the creek in comparison to the target level of 0.1 mg/l. Average levels are elevated immediately downstream of the Canton WWTP and remain elevated throughout the rest of the stream.

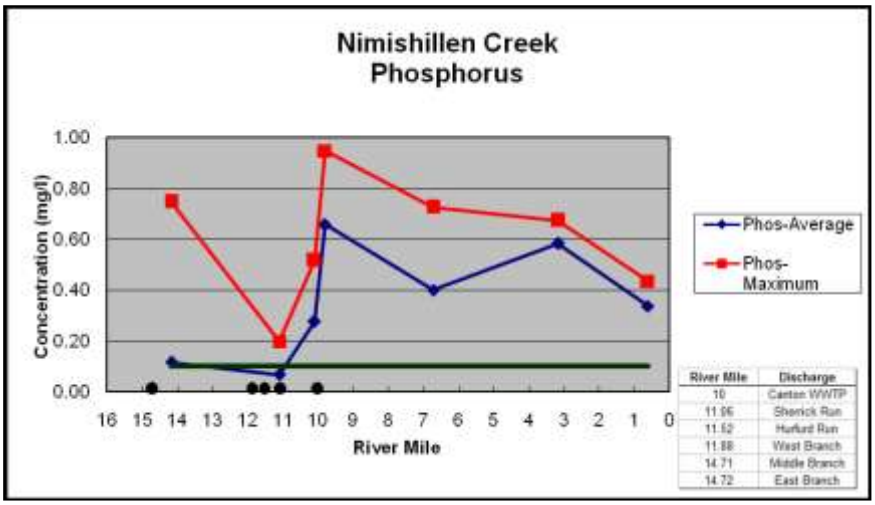


Figure 2-5. Phosphorus in Nimishillen Creek

Nitrate shows a similar trend as seen in phosphorus. Levels become elevated below the Canton WWTP and remain elevated in the stream. Figure 2-6 shows the nitrate levels in the stream. Nitrate levels are also elevated from upstream sources and are generally above the target concentration of 1.0 mg/l.

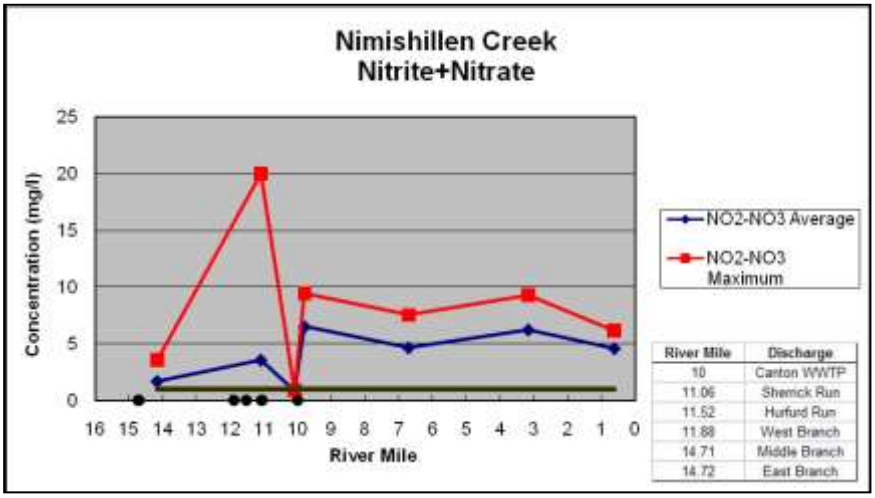


Figure 2-6. Nitrate in Nimishillen Creek

Total dissolved solids (TDS) have been shown to exert an influence on biological communities at levels below the WQS value of 1500 mg/l. TDS values in Nimishillen Creek are elevated when compared to other parts of the watershed lacking industrial or municipal dischargers. TDS concentrations in the watershed are shown in Figure 2-4.

<u>East Branch Nimishillen Creek (HUC 05040001050-030)</u>

Water quality in East Branch Nimishillen Creek has a number of parameters which are showing elevated levels in addition to the violations identified in Table 2-2. The nutrients phosphorus and nitrate have been shown to be elevated in East Branch Nimishillen Creek. Figures 2-2 and 2-3 depict average nutrient concentrations in the study area.

The graph in Figure 2-7 shows average and maximum phosphorus values in the creek in comparison to the target level of 0.1 mg/l. Average levels are elevated immediately

downstream of the Louisville WWTP (RM 4.6) and remain elevated throughout the rest of the stream. The discharges from J&L Specialty Products (RM 5.88) have been eliminated.

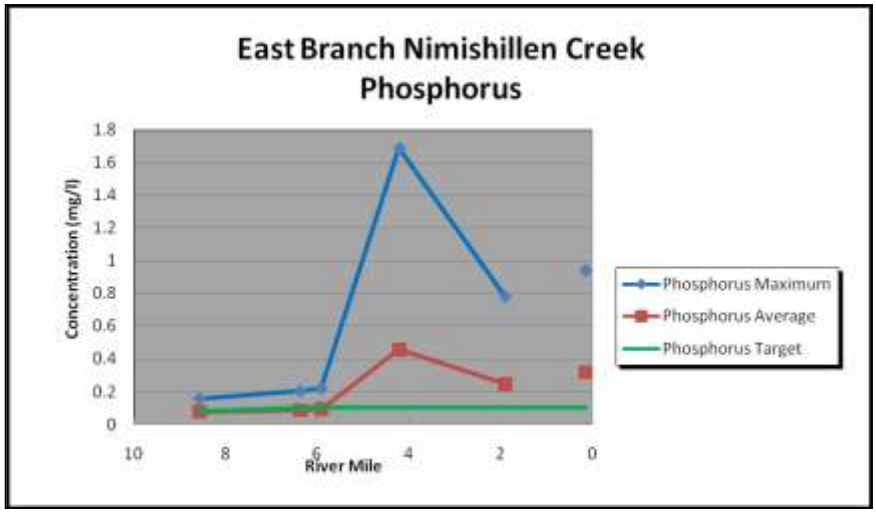


Figure 2-7. Phosphorus in East Branch Nimishillen Creek

Nitrate shows a similar trend as seen in phosphorus. Levels become very elevated below the Louisville WWTP and remain elevated in the stream. Figure 2-8 shows the nitrate levels in the stream. Nitrate levels are above the target concentration of 1.0 mg/l.

West Branch Nimishillen Creek (HUC 05040001050-040)

Water quality in West Branch Nimishillen Creek is generally of a higher quality than the Nimishillen or East Branch. Absent the large WWTPs, average phosphorus concentrations meet the target levels set in this TMDL. Figure 2-9 shows phosphorus levels in the West Branch. Maximum phosphorus concentrations do exceed the target concentration. This may be reflective of the higher percentage of residential development in the HUC 14 subwatershed when compared to others (see Table 2-2a).

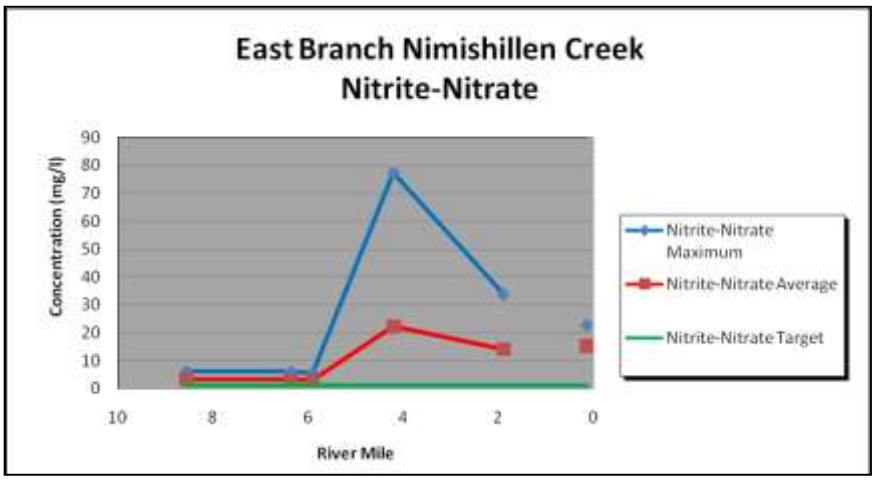


Figure 2-8. Nitrate in East Branch Nimishillen Creek

Nitrate concentrations also remain near the target level in this watershed. This also reflects the lack of a large municipal WWTP discharge. As shown in Figure 2-10, concentrations of nitrate are generally lower than those seen in the Nimishillen and West Branch.

Middle Branch Nimishillen Creek (HUC 05040001050-010, -020)

Water quality in Middle Branch Nimishillen Creek is also generally of a higher quality than the Nimishillen or East Branch. Similar to the West Branch, it does not have the

large WWTPs, as a result average phosphorus concentrations are lower, meeting the target at all sampled sites except one as shown in Figure 2-11.

Nitrate concentrations in the Middle Branch, Figure 2-12, are also lower than those seen in the Nimishillen and East Branch. Overall, the concentrations are slightly higher than those described above in the West Branch. This may be explained in part when evaluating land use in Table 2-2a. The dominant land use changes from residential in the West Branch to cultivated crops and pasture in the Middle Branch, and may reflect nutrients associated with farming.

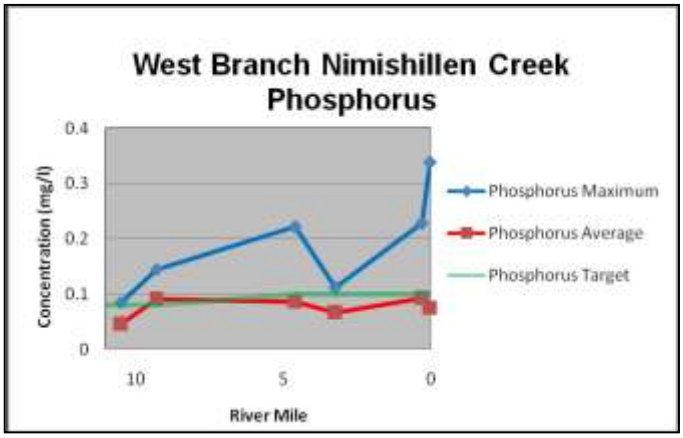


Figure 2-9. Phosphorus in West Branch Nimishillen Creek

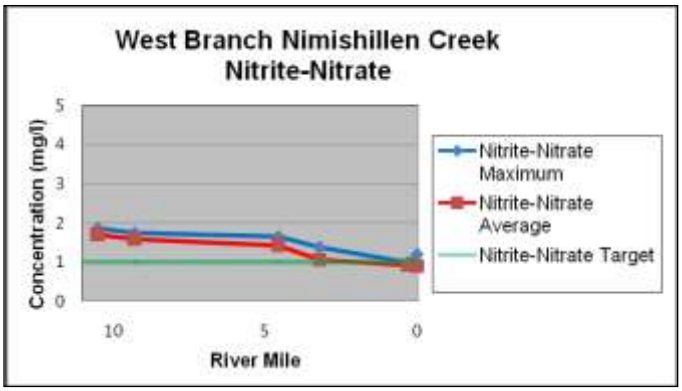


Figure 2-10. Nitrate in West Branch Nimishillen Creek

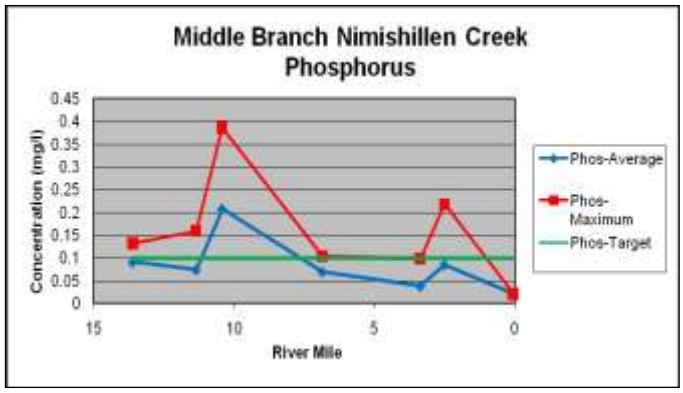


Figure 2-11. Phosphorus in Middle Branch Nimishillen Creek

Other Water Quality Sampling

While the above discussion focused mainly on nutrients, several other parameters will be discussed which show some interesting patterns when examined more closely.

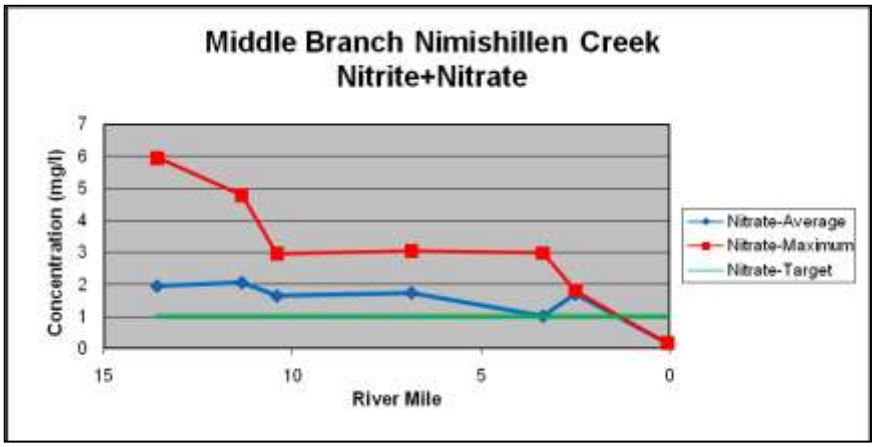


Figure 2-12. Nitrate in Middle Branch Nimishillen Creek

A total of 127 sites were sampled for chemical parameters during the most recent survey. Not every site was sampled for the full suite of parameters.

Manganese
Manganese is a metal commonly associated with groundwater and acid mine drainage. One stream in the survey area, Sherrick Run, is impacted by acid mine drainage. Figure 2-13 presents a summary of manganese results by stream. There is currently no water quality standard for manganese. A secondary drinking water standard for human consumption is set at 50 µg/l.

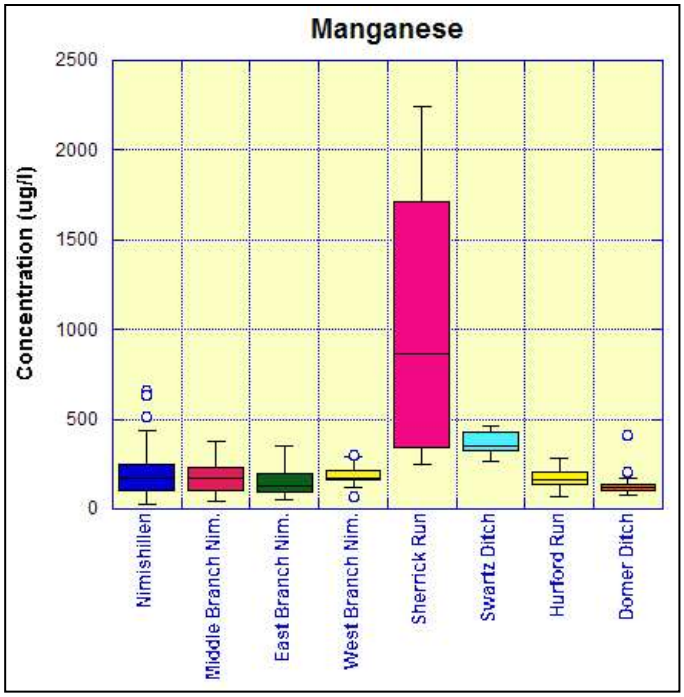


Figure 2-13. Manganese levels in the Nimishillen basin

Iron
Like manganese, iron is also commonly associated with groundwater and acid mine drainage. Iron is also found in discharges from iron and steel processing operations. Two major steel plant dischargers are currently located in the watershed, one on the East Branch Nimishillen Creek and another on Hurford Run. Ohio has a water quality standard for the protection of agricultural uses which is set at 5,000 µg/l and a outside mixing zone average standard set at 300 µg/l for the protection of drinking water supplies. A secondary drinking water standard for human consumption is set at 300 µg/l. Figure 2-14 presents a summary of iron results by stream.

The results indicate that on average, the Nimishillen Creek watershed exceeds the secondary drinking water standard in all monitored streams except for Hurford Run which has an average concentration of 294 µg/l (N=4). The highest value measured was 7830 µg/l in Nimishillen Creek. The highest average value was 1236 µg/l for the West Branch Nimishillen Creek. None of the streams sampled exceeded the agricultural use standard.

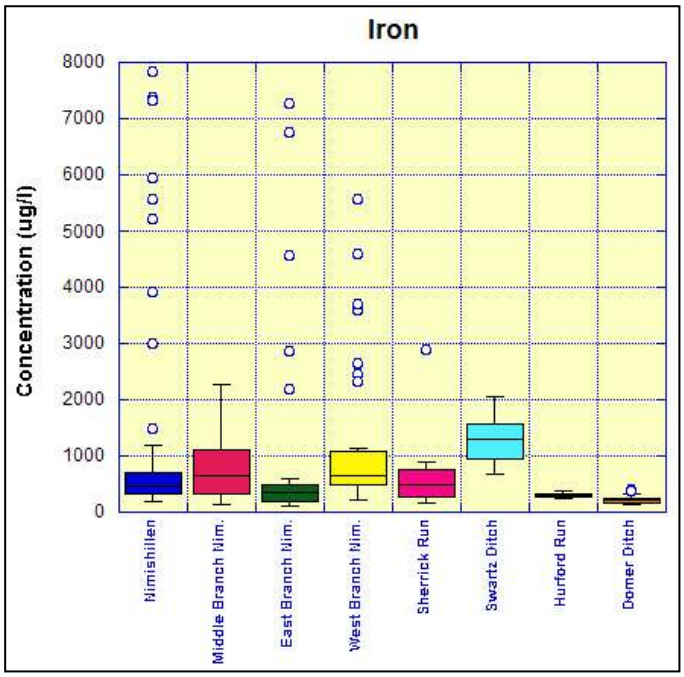


Figure 2-14. Iron levels in the Nimishillen basin

Total Suspended Solids
Suspended solids (TSS) concentrations in streams have been shown to be very important factors affecting biological communities in streams (Waters, 1995).

Suspended solids are considered a source of impairment in this watershed. A TMDL has been prepared to address habitat and siltation, both which are related to TSS concentrations.

Currently Ohio does not have a water quality standard for TSS. Research has shown TSS to become problematic at both lower concentrations over extended time periods, and high concentrations for shorter time periods. Decreases in both fish and macroinvertebrate community health have been shown to occur as a result of increased sediment loading to streams.

Figure 2-15 shows box plots of TSS concentrations for several streams in the watershed. Median concentrations of TSS are generally below 10 mg/l.

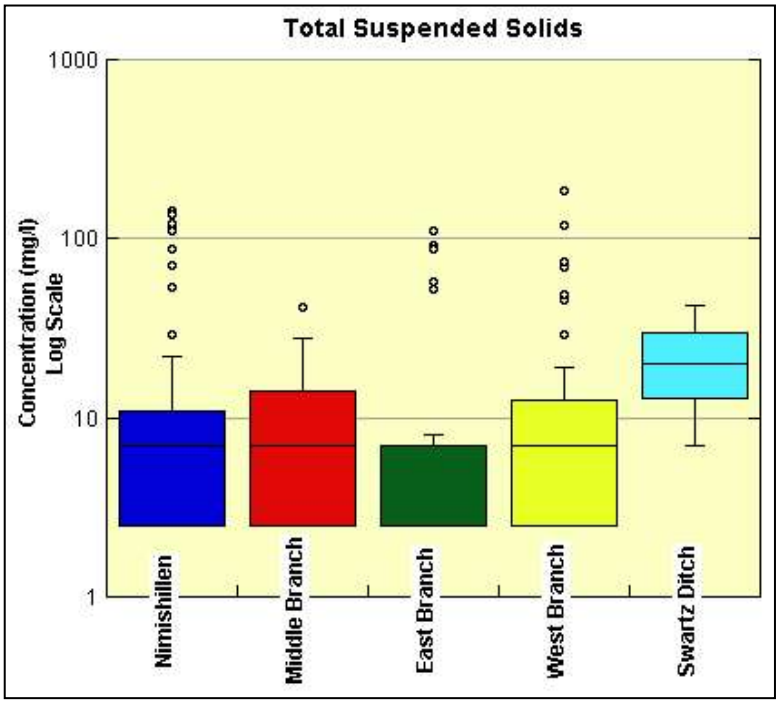


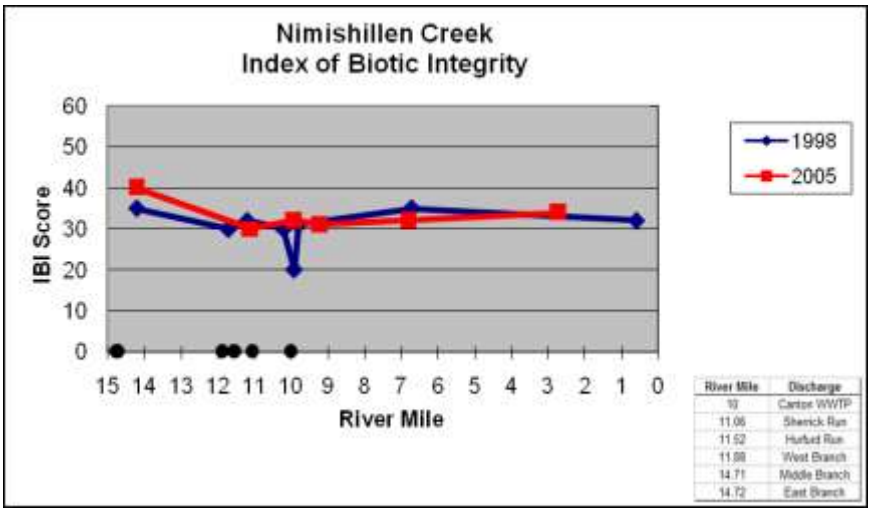
Figure 2-15. TSS concentrations for several streams in the Nimishillen Creek watershed

Biological Communities
As discussed previously in this section, Ohio EPA utilizes both fish and macroinvertebrate communities to evaluate the biological integrity of streams. Biocriteria values applicable to the Nimishillen Creek watershed are presented in Table 3-1.

Fish Community
Sampling results continue to indicate impairment of fish communities within the watershed. Figure 2-16 shows IBI and MIwb results for Nimishillen Creek. Comparison between 1998 and 2005 results indicate that scores have remained fairly consistent. Fish community impairments are also indicated by the higher percentages of tolerant species and omnivores and lower percentages of top carnivores, all indicative of impairments. The same patterns in fish community structure are seen in the other streams sampled in the basin. A complete listing of fish community assessment is included in Appendix F.

Figure 2-17 shows the IBI scores for all streams sampled in this survey and Figure 2-18 shows the MIwb scores for streams sampled in the survey.

Macroinvertebrate Community
As in the fish community assessment, macroinvertebrate communities are showing signs of impairment, although not of the same magnitude as those seen in fish communities. Figure 2-19 shows the ICI scores for all streams sampled in this survey.



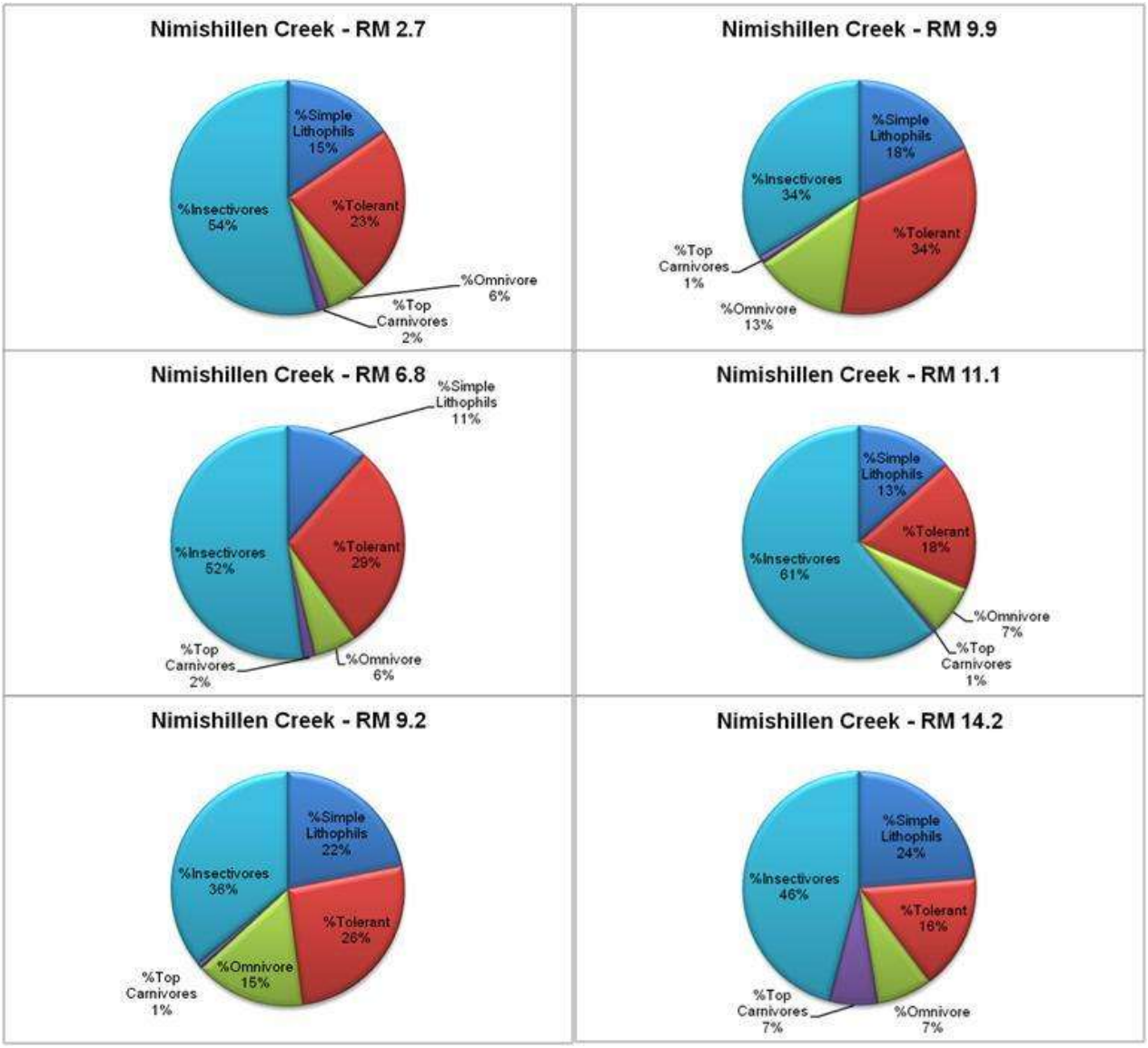


Figure 2-16. Fish community assessment results for Nimishillen Creek

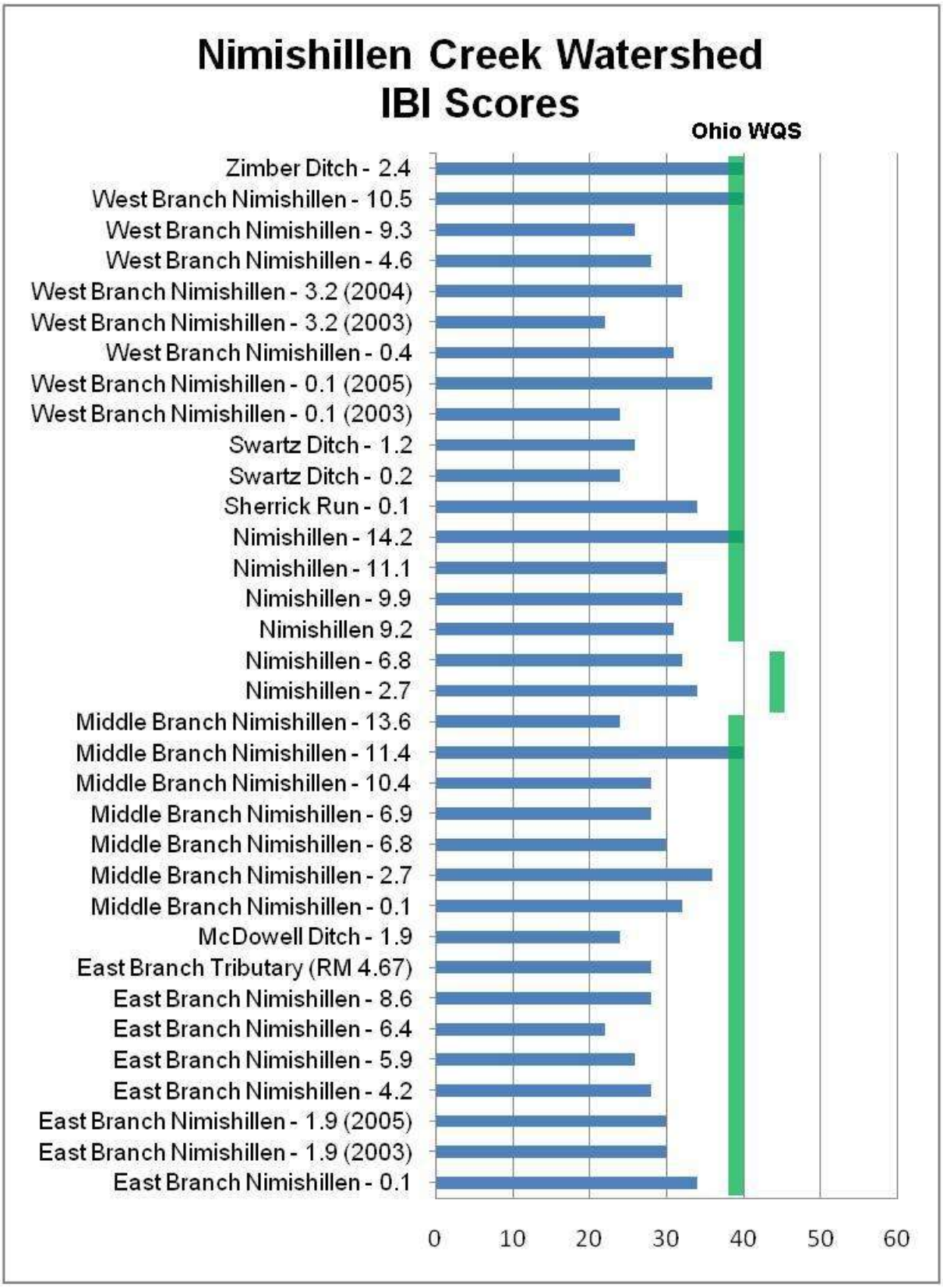


Figure 2-17. IBI scores for Nimishillen Creek watershed by stream and river mile

Figure 2-18. MIwb scores for Nimishillen Creek watershed by stream and river mile

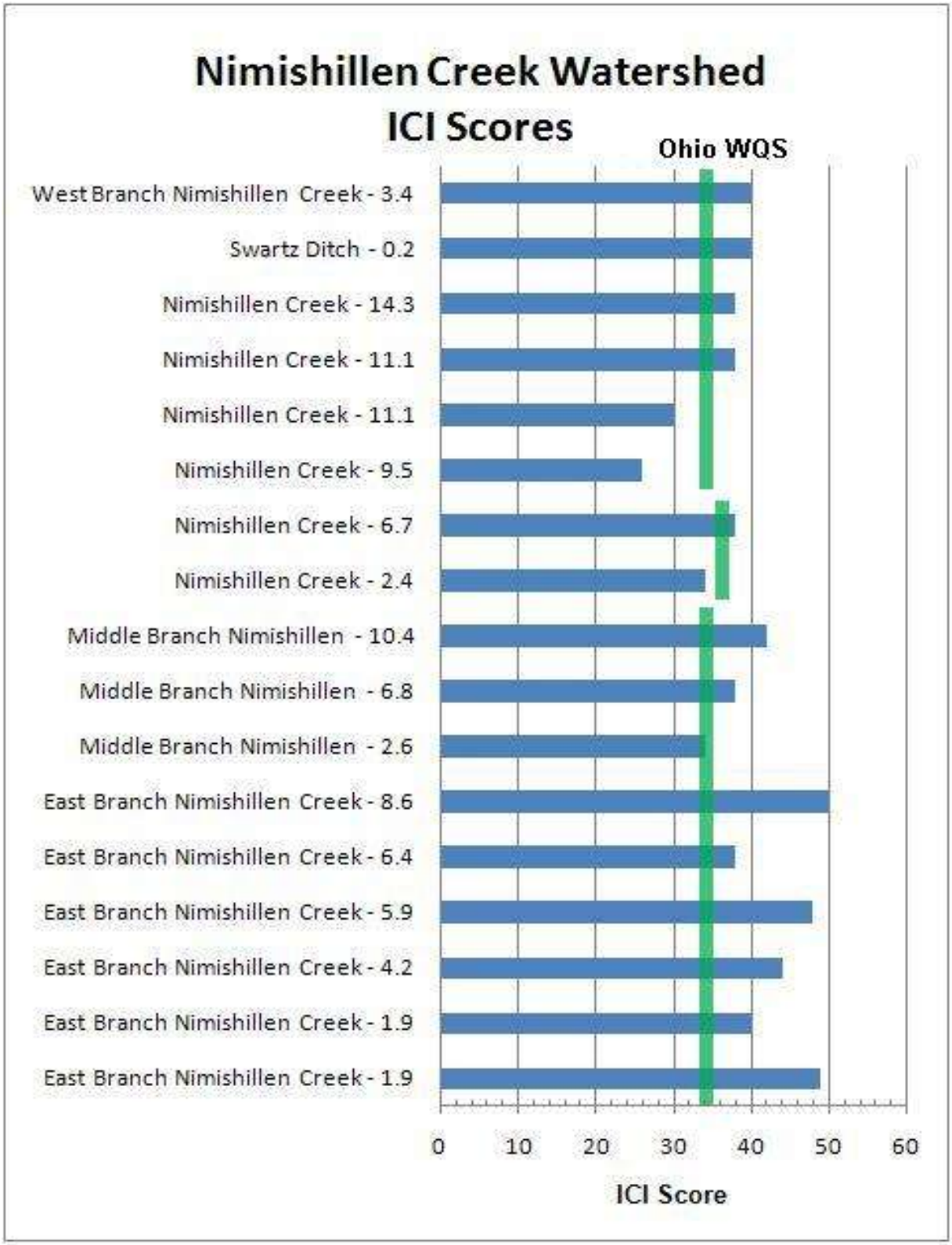


Figure 2-19. ICI scores for Nimishillen Creek watershed by stream and river mile

The sites evaluated for ICI scores are generally meeting the ICI standard. Additional sites were evaluated within the watershed for macroinvertebrate community health using a narrative rating based on a qualitative collection sample. These sites indicate impacted macroinvertebrate community health with 20 out of 22 sampled sited receiving a narrative evaluation of POOR or FAIR (below our narrative target of GOOD) and two sites receiving a narrative rating of MODERATELY GOOD. Figure 2-19a depicts all sampled sites based on the narrative rating.

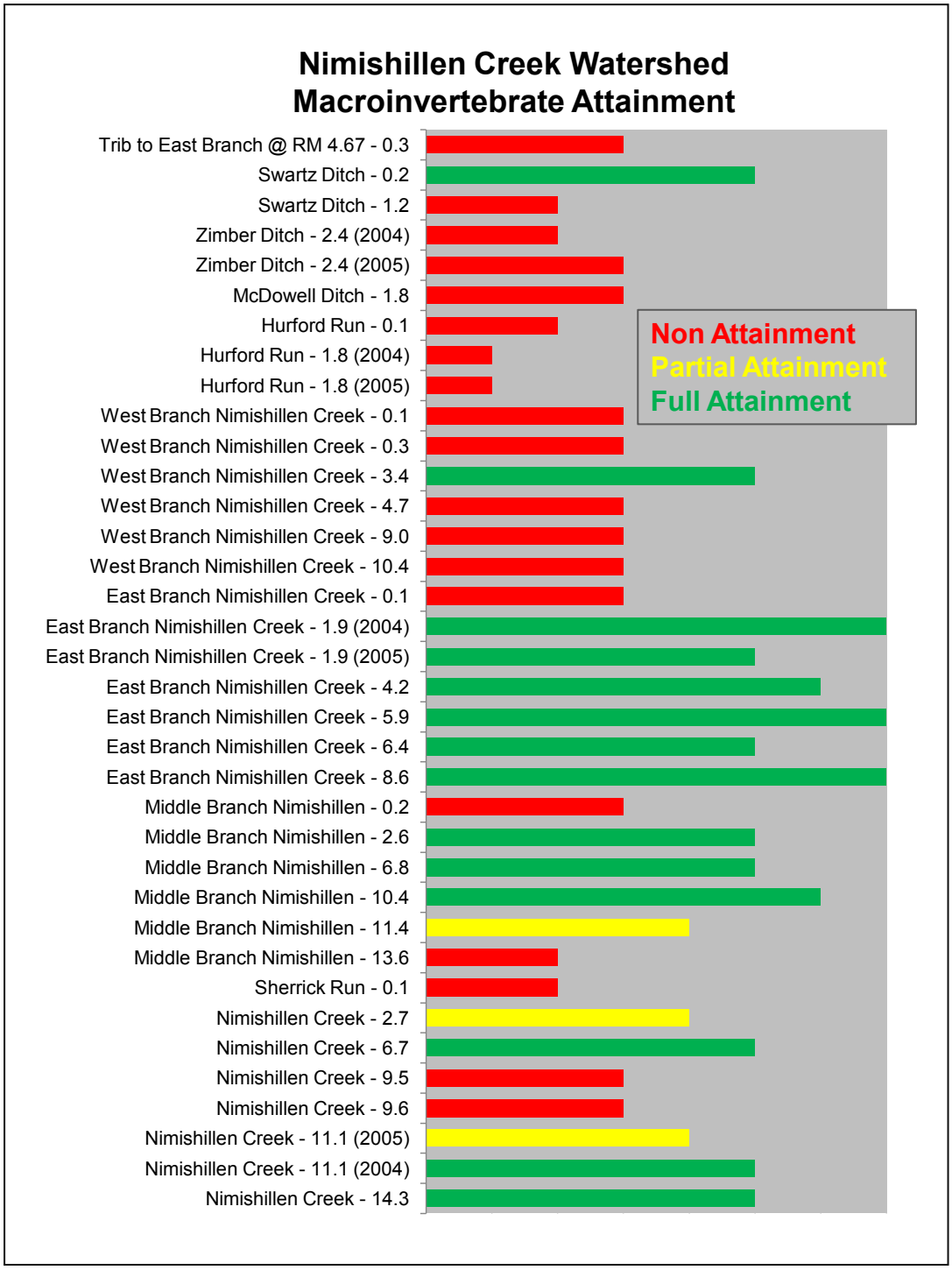


Figure 2-19a. Narrative macroinvertebrate ratings for all sites

The East Branch Nimishillen Creek has shown remarkable recovery from a 1993 evaluation to the current survey results. One major discharger has been eliminated which exerted a negative impact on the stream. J&L Specialty Product's former discharge negatively impacted stream biology and chemistry downstream from its point of discharge at river mile 5.8. In addition, water withdrawals made by J&L and the City of Louisville often resulted in the stream being limited to interstitial flow. As of 2001 J&L had eliminated all discharges and water withdrawals. As can be seen in Figure 2-20, recovery of the macroinvertebrate community was observed in the 1998 survey and continued improvement was noted in the most recent survey. Several sites are currently meeting the exceptional warmwater habitat standard of 46.

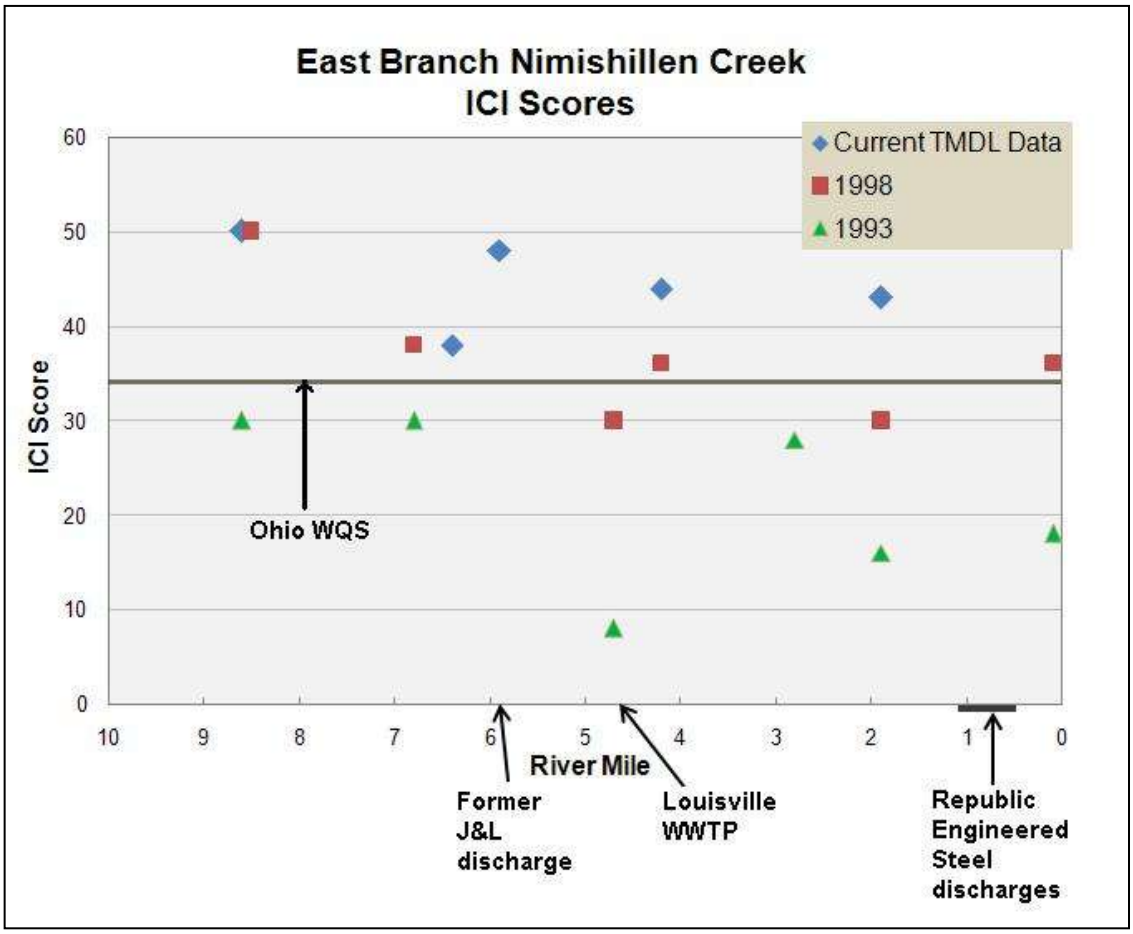


Figure 2-20. ICI scores for East Branch Nimishillen Creek

Bacteria

Bacteria data collected in 2003 and 2004 showed a difference in results attributable to the heavy rains experienced in 2003. Data analysis is presented in Table 2-3. Comparisons are made to Ohio Water Quality Standards Chapter 3745-1-07, Table 7-13. The results do not indicate a violation of the standard as requirement to collect five samples in a 30-day period was not met. Data does indicate that *E. coli* is a problem throughout the watershed. Bacteria sources are discussed further in Chapters 4 and 5 of this report. Sampling results are included in Appendix E.

Table 2-3. Bacteria Sample Results

	2003 Sample Results			
	Fecal Coliform Geometric Mean	Fecal Coliform 90%	*E. coli* Geometric Mean	*E. coli* 90%
Nimishillen Creek @ Howenstein Dr	3791	19400	3917	20400
Nimishillen Creek @ 8th St., dst East Branch	8653	81200	9454	88800
W. Br. Nimishillen Creek @ Market St.	2372	9060	1493	3120
Nimishillen Creek	5694	25200	4755	27400
M. Br. Nimishillen Creek	853	2500	805	2400
E. Br. Nimishillen Creek	13054	79000	13917	121000
W. Br. Nimishillen Creek	2450	8000	2230	7320
Watershed	3143	35600	2739	28800
	2004 Sample Results			
	Fecal Coliform Geometric Mean	Fecal Coliform 90%	*E. coli* Geometric Mean	*E. coli* 90%
Nimishillen Creek @ Howenstein Dr	749	1380	808	1328
Nimishillen Creek @ 8th St., dst East Branch	683	1229	757	1351
W. Br. Nimishillen Creek @ Market St.	573	1206	634	1373
Nimishillen Creek	839	1550	936	1750
M. Br. Nimishillen Creek	489	860	563	1040
E. Br. Nimishillen Creek	632	1570	895	2400
W. Br. Nimishillen Creek	692	1410	756	1610
Watershed	633	1470	741	1840

Value exceeds Ohio Water Quality Standard

2.3 Causes and Sources of Impairment

The primary determination of impairment in rivers and streams in Ohio is straightforward – the biocriteria standards are the principal arbiter of aquatic life use attainment and impairment.

Ohio EPA relies on an interpretation of multiple lines of evidence in ascribing what is causing aquatic life use impairment. This is done because biological communities are complex and affected by many different factors. Such lines of evidence include water and sediment chemistry, habitat quality, effluent chemistry, and land management information. The initial assignment of principal causes and sources of impairment that

appear on the section 303 (d) list do not necessarily reflect a true cause-effect relationship. However, the causes that are listed are based on years of data and field observations in which there is a well established correlation between various stressors (e.g. high nutrient concentrations) and predictable changes in structure and health of the aquatic community.

The Nimishillen Creek watershed is impacted by nonpoint sources (e.g., runoff from urban areas, septic tanks), point source discharges, and a number of habitat impairments (such as wetland loss, loss of riparian zones and channel alterations). There are currently 38 individual NPDES discharge permits within the watershed. A list of NPDES permits in the basin is included as Appendix C.

Physical habitat attributes in much of the free flowing main stem and tributaries show some characteristics of high quality that typically include natural stream morphology, coarse substrates and wooded riparian corridors. Urbanization in some areas of the watershed has resulted in altered stream hydrology, flashy flow regimes, stream banks denuded of riparian vegetation and has exacerbated nutrient enrichment and sediment production, which impacts aquatic life. This increase in sedimentation has been noted within the watershed during the recent comprehensive survey.

In addition to increasing volumes of sewage needing treatment, changing land use patterns are altering the types of nonpoint pollutants and the rates at which they are discharged within the watershed. The land use distribution for the watershed is shown in Figure 2-21 and Tables 2-4 and 2-4a.

Land cleared for construction can result in greatly accelerated rates of erosion and sedimentation of streams especially when sediment control measures are inadequate. Additionally, increased impervious surface area and storm water drainage systems typically follow new development and result in accelerated rates and volume of runoff that contribute a variety of pollutants including solids, nutrients, oils, increased temperature, and pesticides to streams.

Predicting the degree to which a specific source impairs water quality can be difficult in a watershed with multiple sources. Some impairments, such as dams, are more easily assigned a magnitude. A dam blocks fish passage for non-salmonids upstream. Removal of a dam can result in attainment if it is the source of impact and other upstream contributions are nonexistent or moderate in their impacts. Other sources and impairments are more difficult to assess.

Habitat changes associated with man-induced impacts can be substantial. Portions of this watershed have been channelized, bank surfaces hardened, and smaller tributaries culverted. These negative impacts continue today. Riparian vegetation is compromised or removed, which adds to channel destabilization and increased sediment production. Construction in the floodplain can also further impact the stream. In an effort to protect structures within in the floodplain the stream has been channelized or dredged. Dredging streams exacerbates problems associated with high flow events, often

creating additional flooding downstream. Ongoing, long-term maintenance of the dredged area is required. Dredged channels tend to incise more rapidly and cause bank failure, both of which add suspended material and bedload to a stream. By maintaining a healthy stream corridor and controlling impervious surface area, some storm water management issues can be addressed.

Development practices often result in the destruction of soil structure, which only intensifies urbanization impacts. Soil structure is an often overlooked, under-appreciated component of a watershed. The infiltration rate and storage capacity associated with an undisturbed site are much greater than those found in a typical compacted construction site. Natural infiltration will help to moderate high flow and maintain base flow. Urbanized streams lose some ability to self-regulate following storm events. The result of this rapid runoff, accelerated by increased impervious surface areas, is flash flows associated with a lower base flow. These extremes in high and low flows stress both physical habitat and biological communities. Long-term temperature changes can also occur in urbanized streams caused by decreased base flow and increases in heated runoff from pavements and storm ponds due to solar insolation and riparian removal. Instream sources of sediment are also significant within this watershed. Both hillslope failures and channel erosion contribute sediment. While this can be considered part of natural stream geomorphological processes, it is greatly accelerated by changing land use patterns and the resultant storm water runoff pattern changes.

Table 2-4. Land use distribution in the Nimishillen Creek Basin

Nimishillen Creek Land Use		
Data	Acres	Percentage
Open Water	842.4	0.7%
Developed, Open Space	23259.1	19.3%
Developed, Low Intensity	20037.3	16.6%
Developed, Medium Intensity	7826.0	6.5%
Developed, High Intensity	5147.8	4.3%
Barren Land (Rock/Sand/Clay)	12.2	0.0%
Deciduous Forest	17735.7	14.7%
Evergreen Forest	407.6	0.3%
Mixed Forest	57.4	0.05%
Shrub/Scrub	9.6	0.01%
Grassland/Herbaceous	2129.6	1.8%
Pasture/Hay	19003.6	15.8%
Cultivated Crops	23245.1	19.3%
Woody Wetlands	603.1	0.5%
Emergent Herbaceous Wetlands	38.7	0.03%
Total	**120355.2**	

Table 2-4a. Land use percentages by HUC 14

	East Branch Nimishillen Creek	Middle Branch Nimishillen Cr. below Swartz Ditch to above W. Branch [except E. Branch]	Middle Branch Nimishillen Cr. headwaters to below Swartz Ditch	Nimishillen Creek below Sherrick Run to Sandy Cr.	Nimishillen Creek below W. Branch to below Sherrick Run	West Branch Nimishillen Creek
Open Water	0.16%	1.49%	0.63%	1.47%	0.18%	0.75%
Developed, Open Space	16.92%	20.77%	10.17%	14.33%	19.05%	28.22%
Developed, Low Intensity	12.17%	26.36%	3.86%	9.25%	17.06%	25.66%
Developed, Medium Intensity	3.30%	9.48%	0.44%	1.59%	8.97%	12.26%
Developed, High Intensity	2.75%	5.17%	0.22%	0.95%	8.87%	6.70%
Barren Land (Rock/Sand/Clay)	0.01%	0.02%	0.00%	0.02%	0.02%	0.00%
Deciduous Forest	11.28%	6.70%	13.10%	39.64%	20.13%	9.96%
Evergreen Forest	0.23%	0.10%	0.62%	0.78%	0.21%	0.29%
Mixed Forest	0.00%	0.00%	0.30%	0.02%	0.01%	0.01%
Shrub/Scrub	0.00%	0.00%	0.00%	0.04%	0.00%	0.01%
Grassland/Herbaceous	1.46%	1.62%	2.07%	3.82%	1.76%	1.09%
Pasture/Hay	24.09%	12.63%	27.77%	14.33%	9.85%	6.35%
Cultivated Crops	27.23%	15.40%	40.27%	12.09%	13.28%	8.41%
Woody Wetlands	0.39%	0.24%	0.46%	1.58%	0.61%	0.26%
Emergent Herbaceous Wetlands	0.00%	0.00%	0.09%	0.08%	0.02%	0.03%

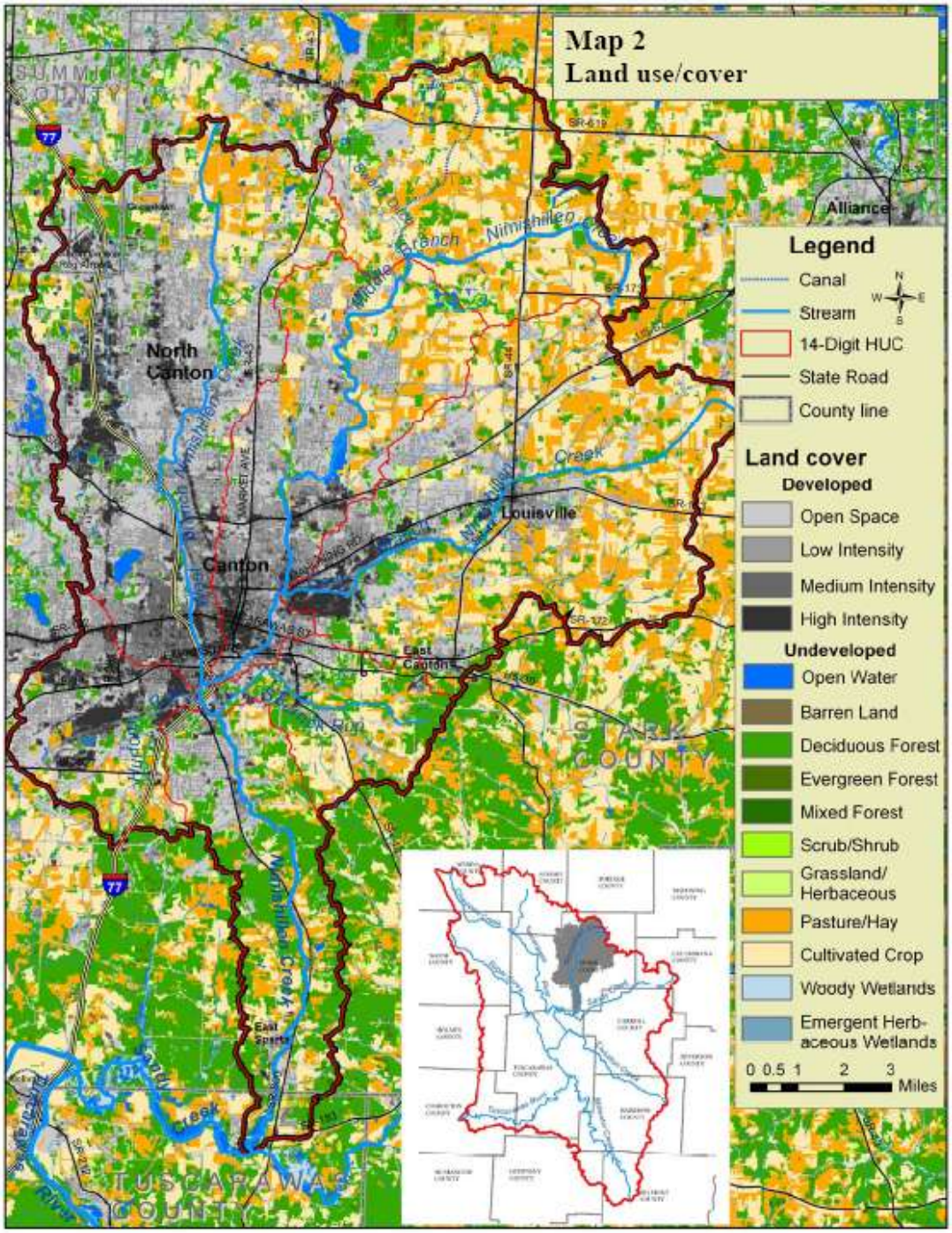
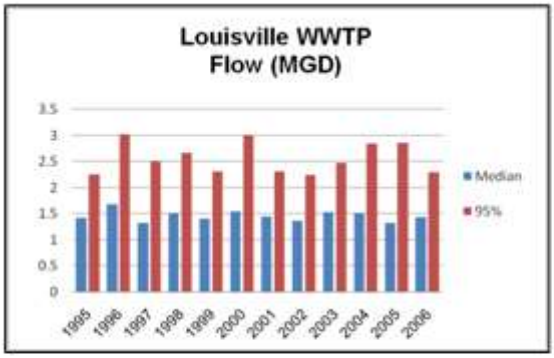
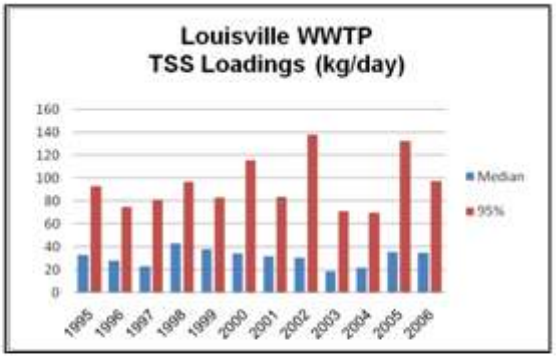


Figure 2-21. Nimishillen Creek watershed land use map

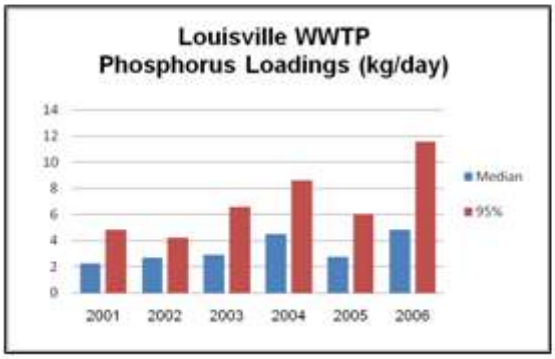
Point Source Loading

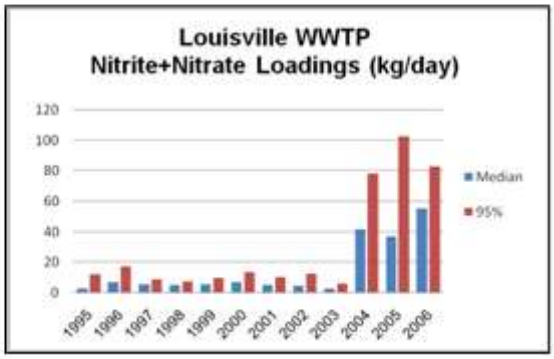
Loading graphs were generated for all major dischargers in the Nimishillen Creek study area, and also for one large WWTP operated by the county (Figures 2-22a, b, and c). In general, the major dischargers maintain NPDES permit compliance. Wastewater treatment plants within the basin have not had phosphorus permit limits in either their existing or previous NPDES permits.

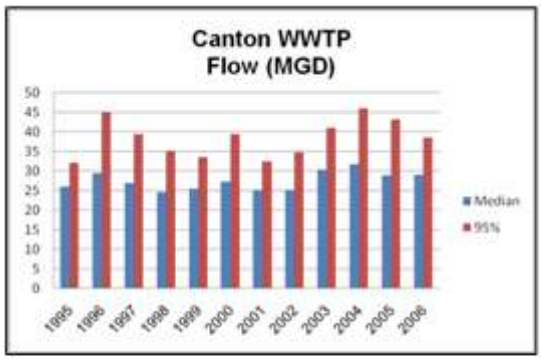


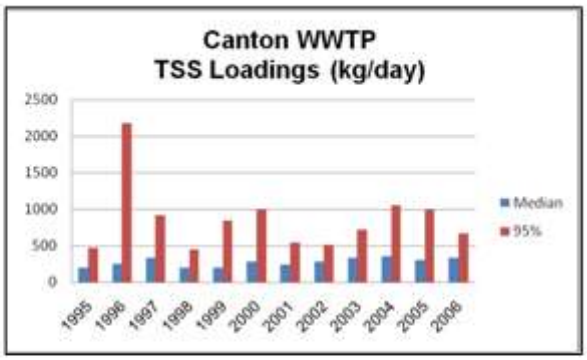


Louisville WWTP median and 95th percentile trend analysis for flow, TSS, phosphorus, and nitrate.

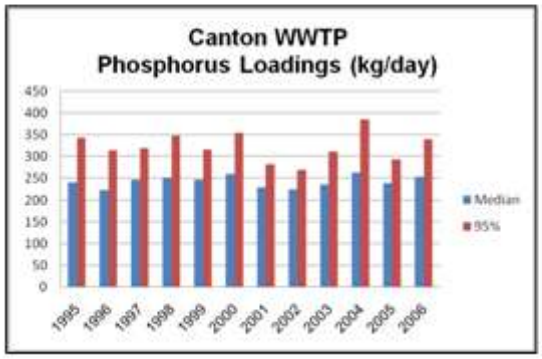








Canton WWTP median and 95th percentile trend analysis for flow, TSS, phosphorus, and nitrate.



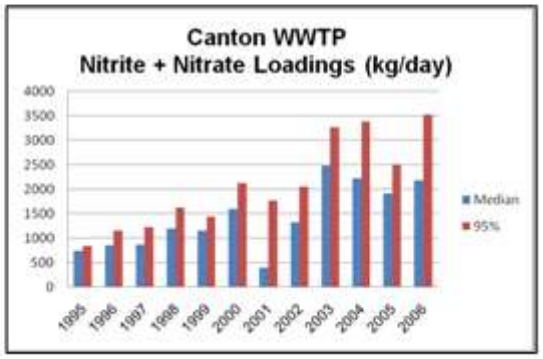
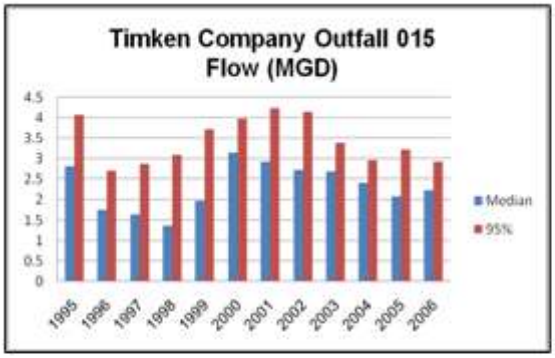
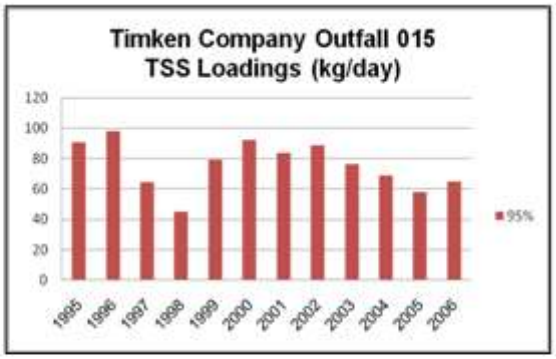
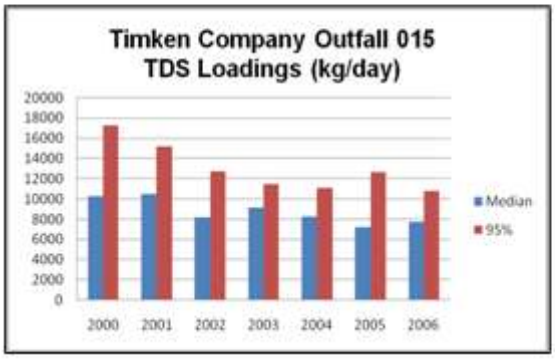


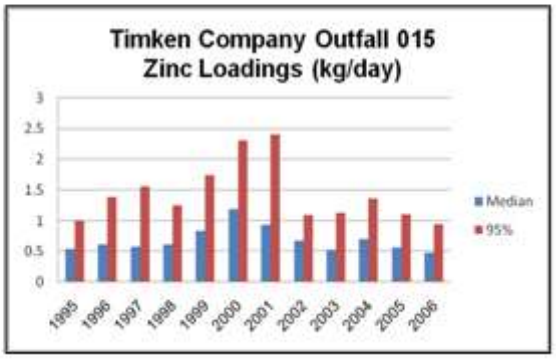
Figure 2-22a. Point source loadings

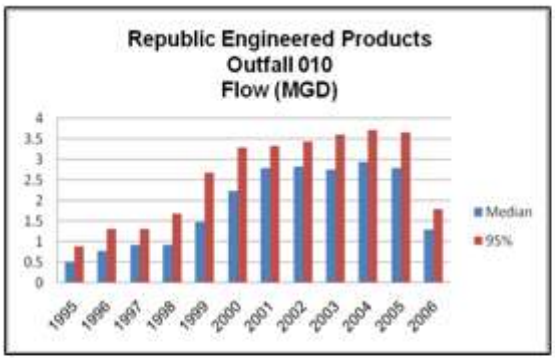


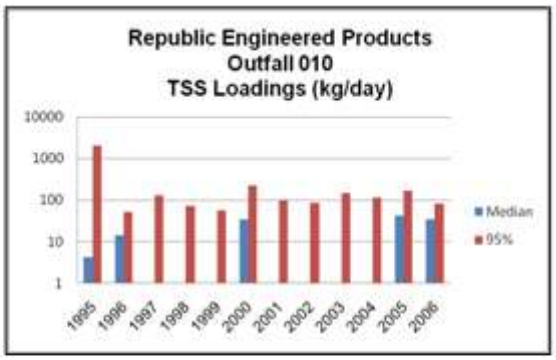


Timken outfall 015 median and 95th percentile trend analysis for flow, TSS, TDS, and zinc.

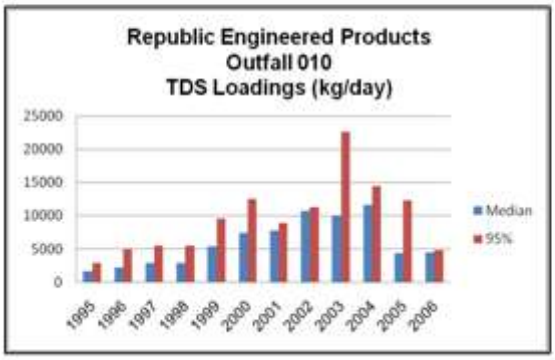








Republic Engineered Products outfall 010 median and 95th percentile trend analysis for flow, TSS, TDS, and zinc.



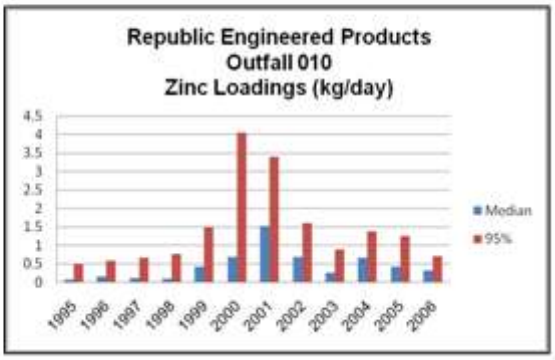
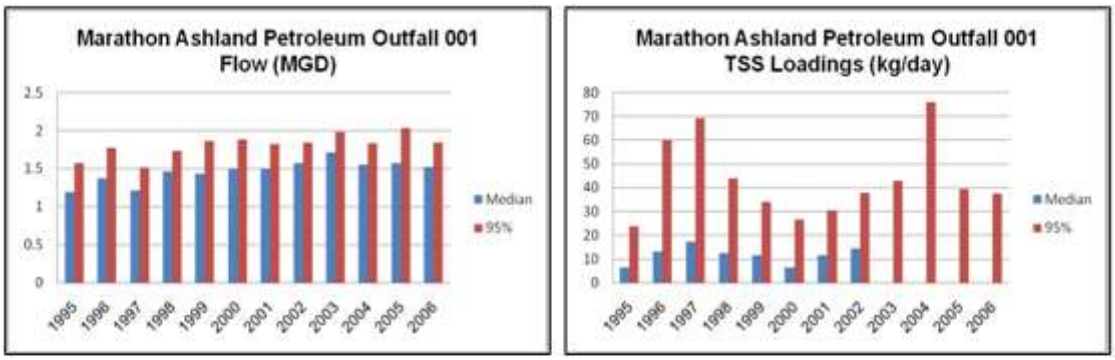
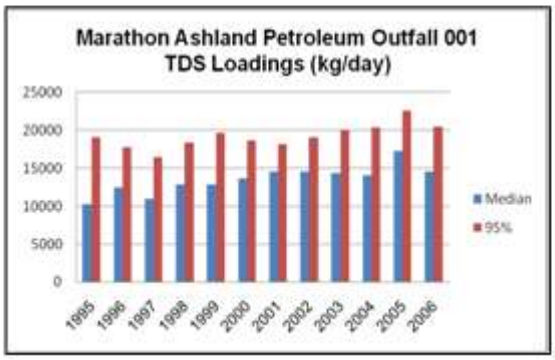
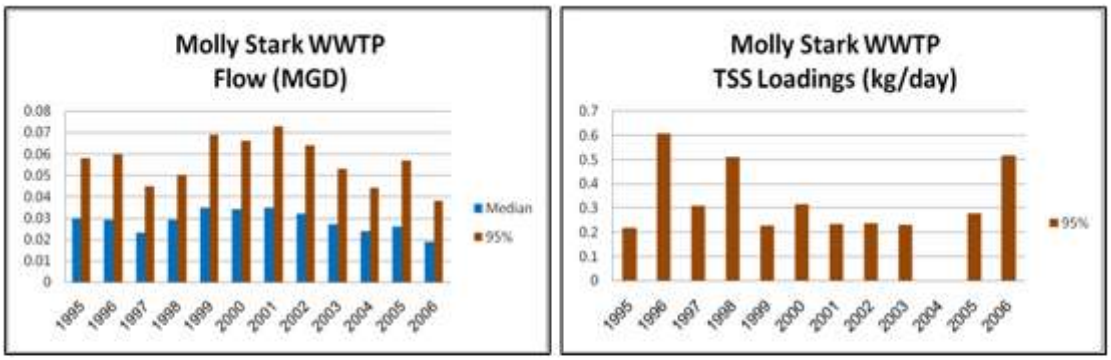


Figure 2-22b. Point source loadings



Marathon Ashland Petroleum outfall 001 median and 95th percentile trend analysis for flow, TSS, and TDS.





Molly Stark Hospital WWTP median and 95th percentile trend analysis for flow, TSS, and phosphorus.

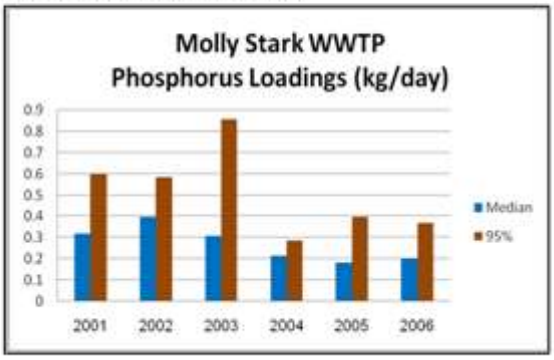


Figure 2-22c. Point source loadings cont'd

3.0 PROBLEM STATEMENT

This chapter outlines the causes of impairment and the TMDL targets that are developed for each impairment.

From 2003 through 2005 Ohio EPA staff surveyed the Nimishillen Creek 11-digit Hydrologic Unit Code (HUC), 05040001050. Designated water resource uses related to recreation and aquatic life were evaluated to determine if minimum quality standards are being achieved. For waterbodies that do not meet water quality standards, the causes of impairment and the associated pollution sources were determined. Causes of impairment addressed by this report are nutrient enrichment, habitat and flow alteration, sedimentation of the stream and pathogens.

Some causes of impairment that are listed in Chapter 2 in this report in certain streams are not quantified in terms of the magnitude of the problem and/or the needed abatement for the stream. In most cases the reason for this is because those causes of impairment will be adequately abated through actions that address another cause of impairment that is being quantified. For example, nutrient enrichment is one of the causes of impairment at one of the several West Branch Nimishillen Creek assessment sites. A nutrient TMDL is not developed for West Branch Nimishillen Creek however. This is because the pathogen TMDL for this stream sufficiently addresses the sources of nutrients which are the same as the sources of pathogens. Causes of impairment that are not addressed directly with a TMDL are discussed in Chapter 5 of this report.

The following sub-sections describe the numeric targets used to develop 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.

The goal of the TMDL process is full attainment of the WQS, and in particular attainment of the numerical biological criteria. As described in Section 2, the water quality and biological assessment of the Nimishillen Creek watershed indicates that the nonattainment of WQS is primarily due to organic enrichment, flow alteration, and habitat degradation. These correspond to nonattainment of the numeric biocriteria.

3.1 Target Identification

The establishment of load reduction and habitat improvement goals (or targets) is a significant component of the TMDL process. The TMDL identifies the load reductions and other actions that are necessary to meet the target, resulting in the attainment of applicable water quality standards.

Numeric targets are derived directly or indirectly from state narrative or numeric WQS (OAC 3745-1). In Ohio, applicable biocriteria are appropriate numeric targets (see Section 2.2). Determinations of current use attainment are based on a comparison of a

stream's biological scores to the appropriate criteria, just as the success of any implementation actions resulting from the TMDLs will be evaluated by observed improvements in biological scores.

Biocriteria

Biocriteria are the final arbiter of attainment of a use designation. Once control strategies have been implemented, biological measures including the IBI, ICI, QHEI and MIwb will be used to validate biological improvement and biocriteria attainment. The current attainment status of the biocriteria is listed in Appendix A. Applicable biocriteria for the Nimishillen Creek basin are included in Table 3-1. The lower approximately seven miles of the Nimishillen Creek are in the Western Allegheny Plateau Ecoregion. Biological criteria for this region are slightly different than those sites in the Erie/Ontario Lake Plain Ecoregion.

Table 3-1. Nimishillen Creek Basin Biocriteria (EOLP/WAP)

Index – Site Type	Modified WWH	WWH
IBI - Headwaters	24	40 / 44
IBI - Wading	24	38 / 44
IBI - Boat	24	40
Mod. Iwb – Wading	6.2	7.9 / 8.4
Mod. Iwb – Boat	5.8	8.7 / 8.6
ICI	22	34 / 36

Nutrient enrichment/ Organic enrichment

Nutrient enrichment is identified as a major cause of impairment in several streams in the Nimishillen Creek watershed. For the purpose of this TMDL, excessive nutrient loading is analyzed at low flow with primary focus on total phosphorus (total P). This nutrient 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 P targets used in this report are shown in Table 3-2. It is important to note that these nutrient targets are not codified in Ohio's water quality standards; therefore, there is a certain degree of flexibility as to how they can be used in TMDL development. This flexibility considers the feasibility of measures necessary to meet the target and best professional judgment regarding if load reductions meeting the target would acceptably address stream impairments.

Table 3-2. Statewide total P targets for Warm Water Habitat (WWH)

Use designation	Watershed size	Total P (mg/l)
WWH	Headwaters (drainage area < 20 mi^2)	0.08
	Wadable (20 mi^2 < drainage area < 200 mi^2)	0.10
	Small River (200 mi^2 < drainage area < 1000 mi^2)	0.17

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.

The modeling method employed for nutrient enrichment simulates many stream chemistry parameters including dissolved oxygen (DO). Some recommendations regarding stream DO at low flow are included in this report. This is because the state of Ohio has specific water quality standards for DO (OAC Rule 3745-1-07 Table 7-1) for the protection of aquatic life. Table 3-3 of this report lists these criteria.

Table 3-3. Statewide dissolved oxygen criteria for Warm Water Habitat (WWH)

Use designation		DO (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

It has been shown that habitat quality also influences a stream's ability to process nutrients. This TMDL also focuses on habitat quality, both instream and riparian. It is anticipated that improvements in habitat coupled with phosphorus and nitrate reductions toward the target level will result in aquatic biological community attainment.

Habitat, flow alteration and sediment

<u>Habitat</u>

Habitat alteration is a cause of impairment throughout the Nimishillen Creek watershed. Poor habitat quality is an environmental condition, rather than a pollutant load, so development of a load-based TMDL to address this cause of impairment is not possible. However, the Qualitative Habitat Evaluation Index (QHEI) is a tool that provides a numeric value, which is assigned to a particular stream segment based on the quality of its habitat. The QHEI evaluates six general aspects of physical habitat that include

channel substrate, instream cover, riparian characteristics, channel condition, pool/riffle quality, and gradient and drainage area.

The numeric value assigned to a stream segment through the QHEI is qualitatively derived, however it is based on the presence and absence and relative abundance of unambiguous habitat features. QHEI scores can range from 12 to 100. The appropriate QHEI habitat target score is determined by statistical analysis of Ohio's statewide database of paired QHEI and IBI scores. Simple linear and exponential regressions and frequency analyses of combined and individual components of QHEI metrics in relation to the IBI have been examined. The regressions indicate that the QHEI is significantly correlated with the IBI. QHEI scores greater than 75 indicate excellent stream habitat. Scores between 60 and 75 indicate good habitat quality and scores less than 45 demonstrate habitat not conducive to warm water habitat (WWH) (Ohio EPA, 1999). The Warmwater Habitat use designation QHEI target is 60. In addition, since habitat is strongly correlated with the IBI biocriteria, the QHEI provides a target and format to evaluate how habitat issues and impairments affect attainment of the aquatic use designations. Degraded habitat has been identified as a contributing cause of nonattainment in several stream segments within the TMDL area. Targets for habitat characteristics for the Nimishillen Creek watershed are presented in Table 3-4 and have been taken from the technical report entitled *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA, 1999). Ohio EPA QHEI data are presented in Appendix H. Additional discussion of the Ohio EPA's QHEI methodology can be found in *The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application(Ohio EPA, 1989) web link:* http://www.epa.state.oh.us/dsw/documents/BioCrit88_QHEIIntro.pdf*),* and the 2006 updated manual found at the web link: http://www.epa.state.oh.us/dsw/documents/QHEIManualJune2006.pdf.

The analysis of the QHEI components as they relate to IBI scores led to the development of a list of attributes that are associated with degraded communities. These attributes are modifications of natural habitat and are listed in Table 3-4. Modified attributes are further divided into high influence and moderate influence attributes based on the statistical strength of the relationships. The presence of these attributes can strongly influence the aquatic biology, and the QHEI score itself may not reflect this effect. Since other, less influential, habitat components are present, a QHEI score can be above 60 though habitat is impaired. Because of this, an accumulation of four modified attributes corresponds to fewer than 50% of sites achieving a WWH target IBI score of 40. High influence modified attributes are particularly detrimental. The presence of one is likely to result in impairment, and two will likely preclude a site from achieving an IBI of 40. The QHEI score of 60 or greater is correlated with IBIs of 40 or greater. These three factors appear to have about an equal weight. A complete habitat TMDL needs to reflect both a good QHEI score and the relative absence of these modified attributes (Ohio EPA, 1999).

The habitat TMDL equation presented in Table 3-5 reflects the relationship between the QHEI score, modified attributes and aquatic community performance. The TMDL is

based upon a total score of three (3), and is the sum of three component scores each worth one point.

Table 3-4. QHEI modified attributes

QHEI categories	Modified attributes	
	High influence	Moderate modified attributes
QHEI Score	- Channelized or No Recovery - Silt/Muck Substrate - Low Sinuosity - Sparse/No Cover - Max Pool Depth < 40 cm (Wadable 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

Table 3-5. Targets of the habitat TMDL

Scores for the TMDL							
QHEI score >= 60	**+1**	One or less of the high influence attributes present	**+1**	Four or less of the modified attributes present (high and moderate influence together)	**+1**	**=**	3

Flow alteration

Habitat alteration can result in flow alteration, which is a listed cause of impairment in the Nimishillen Creek watershed. Under certain circumstances flow alteration can be viewed as the hydrological consequences of habitat alteration. For example, in an agricultural setting, channelization of streams to facilitate drainage often exacerbates hydrological extremes; high flows get higher and low flows get lower. The high flows contribute to entrainment of excess sediment in the stream system, and the low flows exhibit low dissolved oxygen and high temperatures (U.S. EPA, 2007). For stream assessment areas where flow alteration is identified as the cause of impairment, the habitat QHEI is carried out in this report. An examination of actual QHEI score's metrics that relate to stream flow is presented in Chapter 5 wherever this is applied.

Sediment

In the Nimishillen Creek watershed, three assessment areas have some type of sedimentation listed as a cause of impairment in addition to habitat alteration. In order to address this, numeric targets for sediment are also based upon the QHEI metrics. The QHEI substrate, riparian characteristic, and channel metrics all evaluate stream attributes related to sediment. Each of these factors influences the degree to which sediment affects a stream, and cumulatively serves as its numeric target.

The substrate metric evaluates the dominant substrate materials (i.e., based on texture size and origin) and the functionality of coarser substrate materials in light of the amount of silt cover and degree of embeddedness. This is a qualitative evaluation of the

amount of excess fine material in the system and the degree to which the channel assimilates (i.e., sorts) the loading. The channel morphology metric considers sinuosity, riffle and pool development, channelization and channel stability. Except for stability each of these aspects are directly related to channel form and consequently how sediment is transported, eroded and deposited within the channel itself (i.e., this is related to both the system's assimilative capacity and loading rate). Stability reflects the degree of channel erosion which indicates the potential of the stream as being a significant source for the sediment loading. The bank erosion and riparian zone metric also reflects the likely degree of in-stream sediment sources. Finally, the evaluation of floodplain quality is related to the capacity of the system to assimilate sediment loads.

The individual components of the sediment TMDL are QHEI metric scores for substrate, channel and riparian. These metric target scores are based on the same associations made between QHEI and IBI results as explained in the habitat TMDL above (Ohio EPA, 1999). Table 3-6 show the minimum scores expected for the sediment TMDL.

Table 3-6. Targets of the sediment TMDL

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

Bacteria
Targets for bacteria are contained in Ohio WQS, OAC 3745-1-07, Table 7-13. Standards exist for both fecal coliform bacteria and *E. coli*. All designated streams in the Nimishillen Creek are listed as PCR. The standards for this designation are listed in Table 3-7. Individual stream designations are also included in Appendix B.

Table 3-7. Bacteria Water Quality Standards

Parameter	**Bathing Waters**		**Primary Contact**		**Secondary Contact**
	Geometric Mean	**Instantaneous**	**Geometric Mean**	**Instantaneous**	**Instantaneous**
Fecal Coliform	200/100 ml	400/100 ml	1,000/100 ml	2,000/100 ml	5,000/100 ml
E. coli	126/100 ml	235/100 ml	126/100 ml	298/100 ml	576/100 ml

3.2 Identification of Current Deviation from Target

Habitat
Deviations from habitat goals are those QHEI values less than 60 for WWH streams. Figure 3-1 shows Nimishillen Creek basin QHEI scores. Of the 33 sites assessed, ten (30%) failed to meet the QHEI target of 60. Further breakdown of the scores into three groups based on drainage area reveals a pattern of impact which is greater at the smaller watershed sizes.

When data is analyzed for the watershed sizes: headwaters (<20 mi^2), small streams (20 – 50 mi^2), and streams >50 mi^2, it is apparent that the smaller streams are seeing a disproportionate level of habitat impact. The headwater streams show 54% of the sites below the QHEI target, the smaller streams show 21% of the sites below the target, and the streams over 50 mi^2 do not have any sites below the QHEI target. QHEI scores for this analysis are depicted in Figure 3-2.

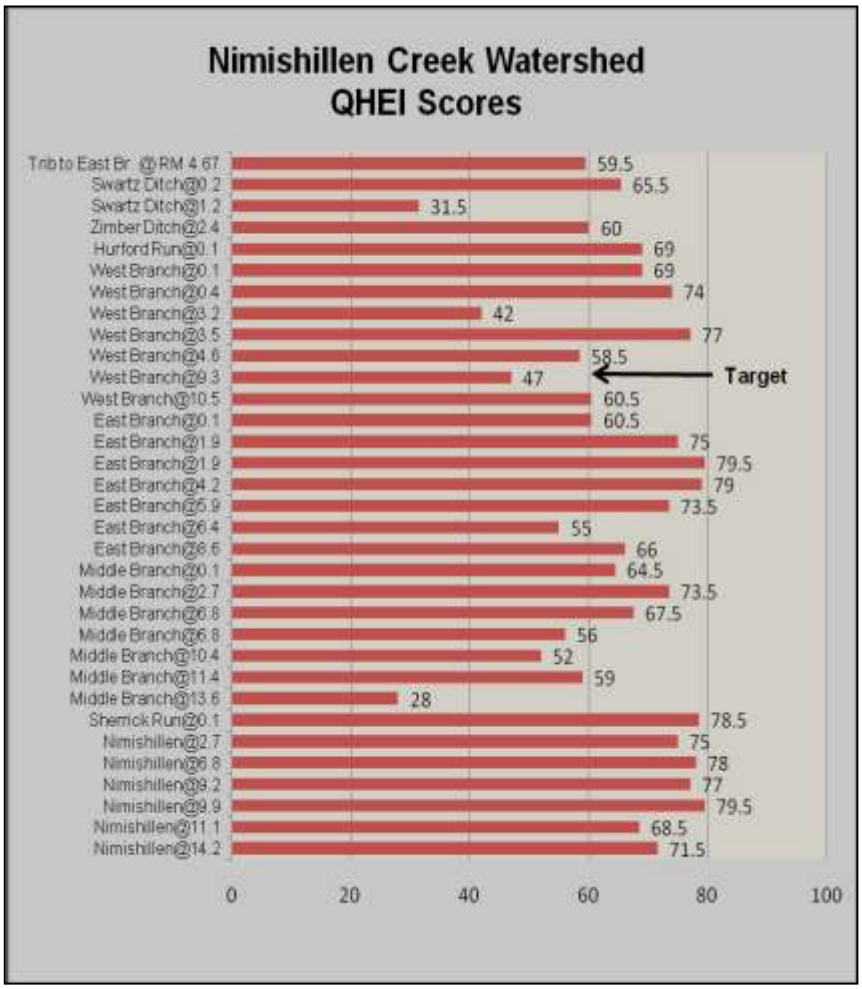


Figure 3-1. Nimishillen Creek basin QHEI scores (Target = 60)

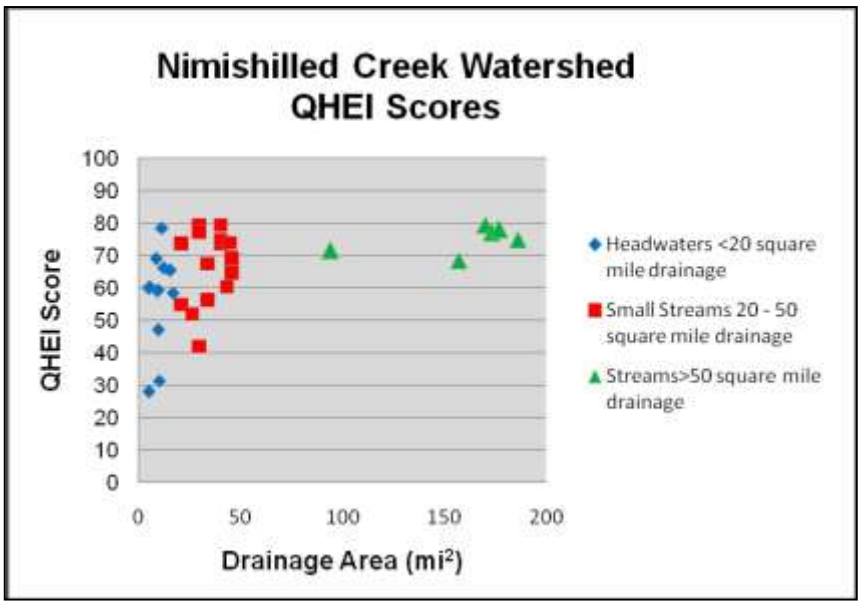


Figure 3-2. Nimishillen Creek basin QHEI scores by drainage area size

Phosphorus

Target phosphorus values are discussed in Section 3.1 and presented in Table 3-2, deviations from the target phosphorus concentration is illustrated in Figure 3-3. Achieving this TMDL target, in conjunction with recommended habitat improvements, dam removals, and the implementation of Phase II storm water programs, should result in attainment of applicable biocriteria standards.

Pathogens

Elevated bacteria loading is the cause of recreational use impairment for several streams in the Nimishillen Creek watershed. The

proportion of pathogenic organisms present in assessed waters is generally small compared to non-pathogenic organisms. For this reason most pathogenic organisms are difficult to isolate and identify. Additionally, pathogenic organisms are highly varied in their characteristics and type which also makes them difficult to measure.

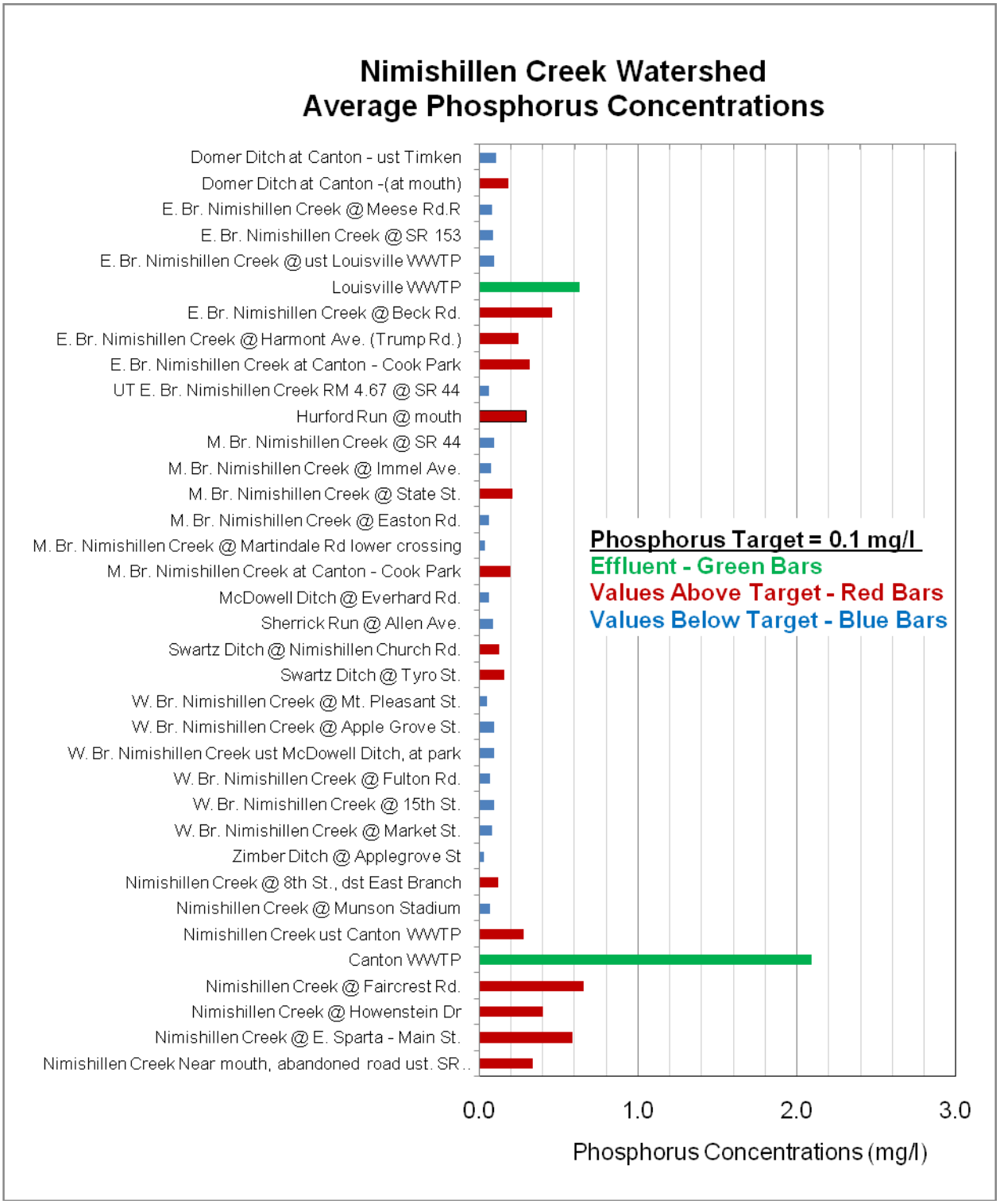


Figure 3-3. Phosphorus concentrations in the Nimishillen Creek watershed compared to target value

Nonpathogenic bacteria that are associated with pathogens transmitted by fecal contamination are more abundant and are, therefore, monitored as surrogates because of the greater ease in sampling and measuring. These bacteria are called indicator organisms. There are promulgated water quality standards for the maximum geometric mean concentration and the ninetieth percentile concentration for fecal coliform bacteria (OAC 3745-1-07). These values serve as the targets used in the development of the TMDLs that address recreation use impairments.

Numeric targets for fecal coliform are derived from bacteriological water quality standards. The criterion for fecal coliform specified in OAC 3745-1-07 are applicable outside the mixing zone and vary for waters determined primary contact recreation (PCR). 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.

TMDLs are developed to reflect the chronic parts of the PCR standard using a loading (watershed) model and the acute part in a more empirical manner using load duration curve (see Chapter 4).

3.3 Source Identification

Failing or malfunctioning home sewage disposal systems are identified as a source contributing to nonattainment in the watershed. Home sewage disposal systems consist of both on-lot (e.g., septic tanks and tile field) and off-lot discharges.

In addition to the above, urbanization and suburbanization also contribute to non attainment. Discharges from storm sewer systems carry oxygen demanding substances, nutrients, suspend solids, and bacteria.

Dams also cause water quality impacts in the Nimishillen Creek TMDL area. Adverse impacts from dams can include a change in thermal and hydraulic regime, chemical water quality degradation, and impaired habitat in the stream. Dams also impede or block migration routes of native fish. All dams in the watershed should be evaluated and prioritized for removal.

Changes in the watershed have also impacted the hydrology and nature of runoff events. Increases in impervious surfaces coupled with riparian zone impacts have created a stream system subject to rapid fluctuations in flow volume. This flashiness can accelerate stream bank degradation and create additional hydrologic problems. Responses to changes in runoff patterns including channelization often serve to exacerbate the magnitude of problems and cause an accumulation of downstream impacts such as excess sediment resulting in siltation.

The large municipal WWTPs are a source of nutrients to the watershed. Discharges

contribute phosphorus and nitrates as well as TDS. WWTPs are also being identified as sources for a group of contaminants know as PPCPs (pharmaceuticals and personal care products). As research into this emerging area continues many commonly used household products and medicines are found in the discharges of WWTPs. Impacts to the biological community are often not immediately toxic but will cause shifts in population sex ratios and a condition known as intersex where fish of either sex will also show characteristics of the opposite sex. At this time specific analyses on the effluents from WWTPs in this watershed have not been conducted but nationwide an ever growing body of scientific literature indicates that they are ubiquitous in similar discharges. Biological impairments are potentially associated with these pollutants.

Other NPDES permit holders contribute metals and TDS to the basin.

Another source of impairment to the East Branch Nimishillen Creek has been the withdrawal of water, which has caused the stream to become interstitial during drier parts of the year.

A final source of pollutants consists of farming activities within the basin. Contributions of nutrients and sediment as well as habitat impacts are associated with farming in the watershed.

4.0 TMDL Development

4.1 Impairments addressed through this TMDL

This section outlines which causes of impairment will be addressed through the development of a TMDL for particular assessment areas in the Nimishillen Creek watershed.

Table 4-1 addresses aquatic life use impairment. This table shows each assessment unit's cause(s) of impairment and the TMDL approach(s). The methods of each of these TMDL approaches are explained in the next section. As mentioned in Chapter 3, some causes of impairment are indirectly addressed and do not receive an explicit TMDL. Table 4-1 shows the causes that are indirectly addressed. Most of them are nutrient impairment on stream sections that were not included in the low flow QUAL2K modeling. These excessive nutrients are addressed indirectly via the bacteria/pathogen TMDL that these watersheds are receiving. Each 14-digit HUC with a cause of impairment indirectly addressed is discussed individually in Chapter 5.

Table 4-2 shows which subwatersheds require recreational use impairment TMDLs. The fecal coliform data were collected in the recreational seasons of 2003 and 2004. These data are being used to approximate recreational use attainment status shown here for each assessment site.

Modeling of bacteria watershed loading is included in this TMDL to examine the chronic (geometric mean) aspect of the primary contact recreational use standard. The geographic breakdown of areas with this modeling applied is presented in Table 4-2. When practical, if the average of a 14-digit HUC's bacteria data show impairment then the 14-digit HUC is modeled as one geographic unit (as in the HUCs 010, 030, 040 and 060). The 14-digit HUC 050, which includes Sherrick Run, Hurford Run and a small part of the mainstem Nimishillen Creek, is an example of a 14-digit HUC not practical to be modeled as one unit. This is because the two tributaries are very different from each other. Hurford Run drains a large area with industrial land use practices and much of its flow is treated industrial wastewater. Evident from Table 4-2 Hurford Run has no recreational use impairment. Sherrick Run however does have impairment and is modeled independent of the rest of the 14-digit HUC.

Table 4-2 also shows that the assessment site on the mainstem Nimishillen Creek in the 050 14-digit HUC and the mainstem assessment site in the 020 subwatershed have recreational use impairment. However there is very little area that actually drains directly to the mainstem at these sites. The elevated bacteria values sampled at these two sites are sourced in the tributaries draining to them (mostly East Branch Nimishillen Creek). Since 1) these tributaries are being considered for their own bacteria TMDL and 2) the watershed loading model method would be impractical for such small drainage areas, no direct modeling is employed for these impaired sites. The pathogenic sources are considered indirectly addressed due to the tributary TMDLs.

In Chapter 5, a load duration curve (LDC) has been created for the mainstem Nimishillen Creek in the lower, 060, 14-digit HUC. In this report this curve will be used to examine the acute (90th percentile) aspect of the primary contact recreational use standard.

Table 4-1. Aquatic life use attainment causes of impairment and TMDL developed

14-digit HUC	Description	River mile	Causes	TMDL				
				QUAL2K nutrient/DO	QHEI habitat/flow	QHEI sediment	Indirectly addressed	Not addressed
010	Middle Branch Nimishillen Creek	13.6	Habitat alteration		X			
			Siltation			X		
	Swartz Ditch	1.2	Org. enrichment/DO				X	
			Habitat alteration		X			
020	Middle Branch Nimishillen Creek	10.4	Habitat alteration		X			
			Siltation			X		
		6.8 and 0.1/0.2	Nutrients				X	
			Flow alteration		X			
	Nimishillen Creek	14.2/14.3	Nutrients	X				
			Flow alteration		X			
030	East Branch Nimishillen Creek	8.6	Unknown					X
		6.4	Org. enrichment/DO				X	
		5.9	Nutrients				X	
			Unknown					X
		4.2 and 1.9	Nutrients	X				
			Ammonia	X				
		0.1	Nutrients	X				
			Flow alteration		X			
	Unnamed trib to EB @ RM 4.67	0.3	Nutrients				X	
040	West Branch Nimishillen Creek	10.5/10.4	Habitat alteration		X			
			Sediment			X		
		9.3/9.0	Habitat alteration		X			
			Nutrients				X	
		4.6, 3.5, 0.4, 0.1	Flow alteration		X			
	McDowell Ditch	1.9/1.8	Flow & habitat alt		X			
	Zimber Ditch	2.4	Flow & habitat alt		X			
			Unknown					X
050	Hurford Run	1.8 and 0.1	Thermal				X	
			Ammonia				X	
			pH and unknown					X
	Sherrick Run	0.1	Acid mine drainage					X
			Flow alteration		X			
	Nimishillen Creek	11.1	Nutrients	X				
			Flow alteration		X			
			Unknown					X
060	Nimishillen Creek	9.9, 9.2, 6.8, 2.7	Nutrients	X				
			Flow alteration		X			

Note that assessment sites in full attainment of aquatic life use are not shown on this table.

Table 4-2. Recreational use attainment impairment and TMDL assessment area

Pathogen assessment breakdown	Target Parameter *units*		Target
	Fecal Coliform *cfu/100 ml* (based on the concentrations used in the water quality standard)	Geometric mean	1000
		90th percentile	2000

Site	RM	Observed Condition		Impaired	Area of TMDL
05040001-050-010 Middle Branch Nimishillen Creek headwaters to below Swartz Ditch					
M. Br. Nimishillen Creek @ SR 44	13.6	Geometric mean	858	No	Full 14-digit HUC
		90th Percentile	1950		
Swartz Ditch @ Nimishillen Church Rd.	1.13	Geometric mean	977	No	
		90th Percentile	1630		
M. Br. Nimishillen Creek @ Immel Ave.	11.35	Geometric mean	988	Yes	
		90th Percentile	2400		
Swartz Ditch @ Tyro St.	0.26	Geometric mean	605	No	
		90th Percentile	901		
05040001-050-020 MB Nim. Cr. below Swartz D. to mainstem Nim. Ck above W. Branch [except E. Branch]					
M. Br. Nimishillen Creek @ Martindale Rd lower crossing	3.36	Geometric mean	278	No	None
		90th Percentile	1325		
M. Br. Nimishillen Creek @ Easton Rd.	6.85	Geometric mean	729	No	
		90th Percentile	1300		
M. Br. Nimishillen Creek @ State St.	10.42	Geometric mean	749	No	
		90th Percentile	1470		
Nimishillen Creek @ 8th St., dst East Branch	14.17	Geometric mean	1836	Yes	See section above
		90th Percentile	14000		
05040001-050-030 East Branch Nimishillen Creek					
E. Br. Nimishillen Creek @ Harmont Ave. (Trump Rd.)	1.89	Geometric mean	1887	Yes	Full 14-digit HUC
		90th Percentile	32400		
E. Br. Nimishillen Creek @ Beck Rd.	4.2	Geometric mean	2816	Yes	
		90th Percentile	41600		
E. Br. Nimishillen Creek @ ust Louisville WWTP	5.9	Geometric mean	3276	Yes	
		90th Percentile	68890		
E. Br. Nimishillen Creek @ SR 153	6.36	Geometric mean	3592	Yes	
		90th Percentile	30800		
E. Br. Nimishillen Creek @ Meese Rd.R	8.56	Geometric mean	1551	Yes	
		90th Percentile	33000		
UT E. Br. Nimishillen Creek RM 4.67 @ SR 44	0.22	Geometric mean	2069	Yes	
		90th Percentile	26990		

Table 4-2 (cont.). Recreational use attainment impairment and TMDL assessment area

Site	RM	Observed Condition		Impaired	Area of TMDL
05040001-050-040 West Branch Nimishillen Creek					
W. Br. Nimishillen Creek @ Mt. Pleasant St.	10.5	Geometric mean	1037	Yes	Full 14-digit HUC
		90th Percentile	3170		
W. Br. Nimishillen Creek @ Apple Grove St.	9.3	Geometric mean	691	Yes	
		90th Percentile	3860		
W. Br. Nimishillen Creek ust McDowell Ditch, at park	4.6	Geometric mean	1619	Yes	
		90th Percentile	5960		
Zimber Ditch @ Applegrove St	2.4	Geometric mean	601	Yes	
		90th Percentile	2052		
W. Br. Nimishillen Creek @ Market St.	0.04	Geometric mean	862	Yes	
		90th Percentile	3180		
W. Br. Nimishillen Creek @ Fulton Rd.	3.24	Geometric mean	1440	Yes	
		90th Percentile	5990		
McDowell Ditch @ Everhard Rd.	1.88	Geometric mean	1347	Yes	
		90th Percentile	5590		
W. Br. Nimishillen Creek @ 15th St.	0.31	Geometric mean	1853	Yes	
		90th Percentile	5620		
05040001-050-050 Nimishillen Ck below West Branch to below Sherrick Run					
Sherrick Run @ Allen Ave.	0.1	Geometric mean	738	No	Sherrick Run TMDL
		90th Percentile	4730		
Nimishillen Creek @ Munson Stadium	11.1	Geometric mean	1239	Yes	See section above
		90th Percentile	21000		
Hurford Run @ mouth	0.1	Geometric mean	197	NO	No TMDL
		90th Percentile	428		
05040001-050-060 Nimishillen Creek below Sherrick Run to Sandy Cr.					
Nimishillen Creek @ Howenstein Dr	6.72	Geometric mean	1755	Yes	Full 14-digit HUC
		90th Percentile	16860		
Nimishillen Creek @ Faircrest Rd.	9.8	Geometric mean	1413	Yes	
		90th Percentile	10520		
Nimishillen Ck Near mouth, abandoned road ust. SR 183	0.62	Geometric mean	4409	Yes	
		90th Percentile	17610		

Note that this table contains all sites sampled for bacteria in the 2003 and 2004 recreational seasons.

4.2 Methods of TMDL development

A TMDL is a tool for implementing water quality standards, and is based on the relationship between pollution sources and in-stream water quality conditions. TMDLs establish allowable loadings or other quantifiable parameters for a waterbody, and thereby provide the basis for states to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.

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 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.

TMDL development requires the definition of the existing load, calculation of the loading capacity and allocation of the TMDL. The existing load is the quantity of a pollutant that, prior to TMDL implementation, is contributed to a waterbody. The existing load includes contributions from all sources, including point, non-point, and natural. 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.

4.2.1 Nutrient/DO modeling – QUAL2K

The lower section of the East Branch Nimishillen Creek and all of the mainstem Nimishillen Creek do not meet their aquatic life use designation of warm water habitat. Nutrients are a cause of impairment in all of these sites with major municipal wastewater treatment plants and urban runoff as the main sources of these nutrients. Times of low stream flow in warmer months are believed to be the critical condition in which these nutrients cause the most detriment to aquatic life. This is generally based on the fact that the nutrient rich discharge from municipal waste water treatment plants on both East Branch Nimishillen Creek and the mainstem dominates stream flow during these events. Nutrients, and dissolved oxygen (DO), are assessed using the QUAL2K model, version 2.04 (Chapra, 2006).

As explained in Chapter 3, total phosphorus (T.P.) is used as the nutrient target for this TMDL due to its importance in stream processes, including nuisance algae problems. QUAL2K simulates the decay of organic and inorganic phosphorus in the stream. This is an important level of complexity because excessive inorganic phosphorus is most conducive to excessive algae growth. Since DO is an integral aspect of the QUAL2K model and to aquatic stream life, it is assessed with the nutrients in this modeling. Model calibration and validation is developed using data collected by the Ohio EPA

during August 15-17 and September 6-7 of 2006. 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. Calibrated and validated model rates are then used to run scenarios of critical condition flow and wastewater treatment plant discharge concentrations. Results from these scenarios are compared to the TP targets and DO water quality standards, explained in Chapter 3, to allow for practical TMDL decisions to be made.

QUAL2K model description

QUAL2K is a one-dimensional, steady-state model which is used to simulate DO, CBOD, organic and 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 requires the user to determine stream reaches that represent stretches of river that have consistent hydraulic characteristics (e.g., slope, bottom width, etc.). The model 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. Therefore each element, equal length subdivisions within the reaches, is the unit that all of the model's calculations are carried out on. Each element is a separate system which has an initial external input and internal interactions that either add to or reduce the dissolved oxygen. All of an element's outputs are a sum of the input and these interactions. Each element's output represents the input of the next element.

For this TMDL one QUAL2K model was created starting just upstream the Louisville WWTP on East Branch Nimishillen Creek (RM 4.68). The model flows downstream to near the mouth of the mainstem Nimishillen Creek at RM 0.68. The main stem Nimishillen Creek begins at the confluence of East Branch and Middle Branch Nimishillen creeks. The QUAL2K model allows the addition of 1) tributaries, 2) point sources inputs and withdrawals and 3) nonpoint source discharges and withdrawals. QUAL2K allows for tributaries to either 1) contain their own reaches, with computational elements similar the main stream being modeled, or 2) be treated like point source discharges. All tributaries in the Nimishillen model (except for East Branch Nimishillen Creek) are treated like point sources. Figure 4-1 shows a generic QUAL2K segment and its possible components. The reaches are numbered in ascending order starting from the most upstream reach.

Figure 4-2 shows a schematic of the Nimishillen model segment that was simulated with QUAL2K, including divisions of each reach. The full model area consisted of 14 reaches totaling 18.8 river miles with 7 tributaries and 5 direct point sources considered. Also nonpoint source ground water is added to the stream when low flow simulations are carried out. No withdrawals are included in the Nimishillen QUAL2K model.

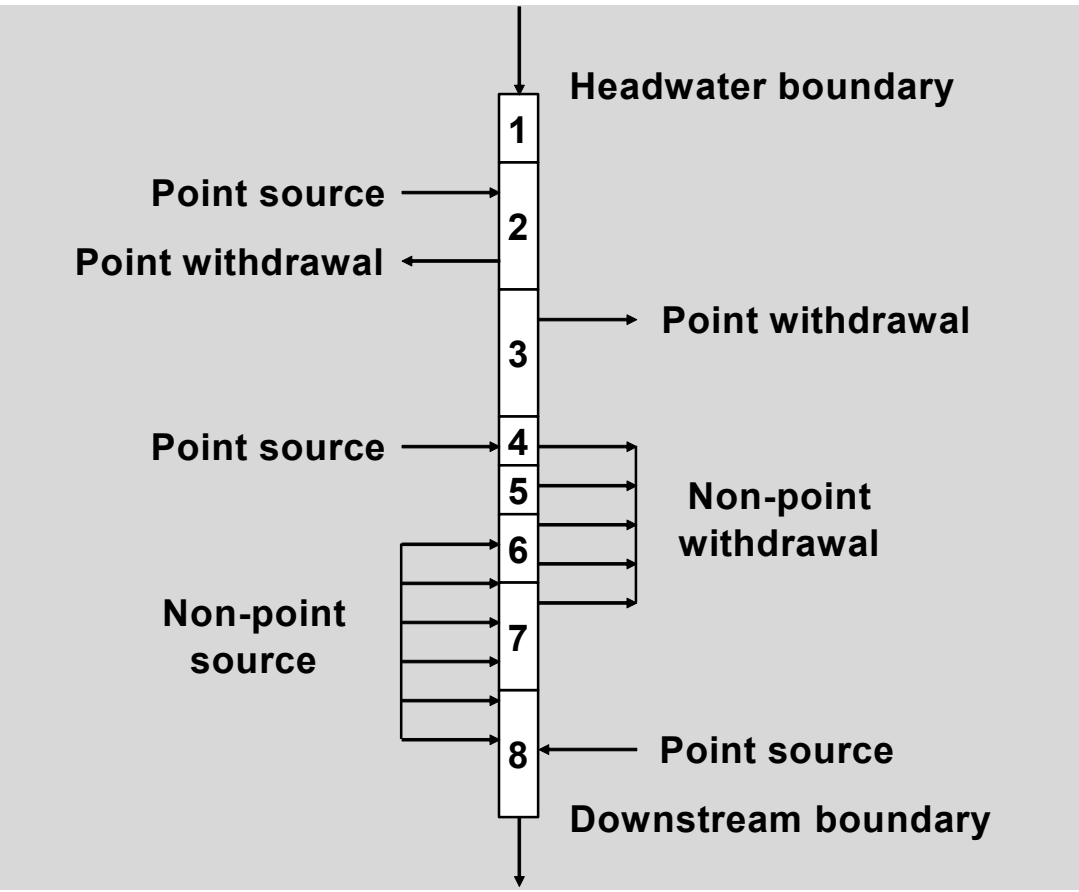
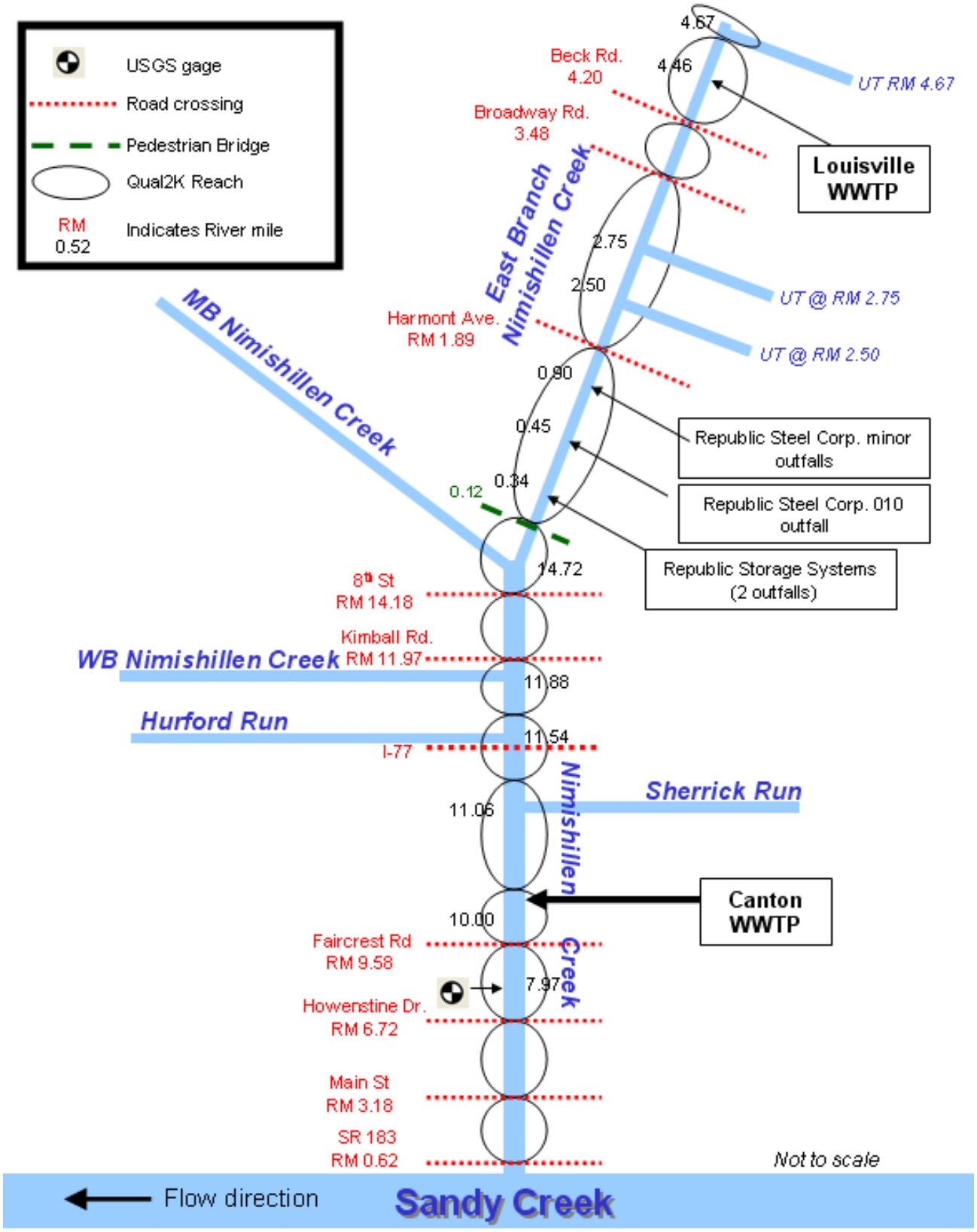


Figure 4-1. Segmentation scheme of a generic QUAL2K model

Figure 4-2. Reaches modeled with QUAL2K for the Nimishillen Creek TMDL



Model calibration

The Nimishillen Creek QUAL2K model was calibrated primarily using data collected by Ohio EPA on 15-17 August 2006. Some older Ohio EPA collected hydraulic data and some of the special data parameters collected during a 6-7 September 2006 were also used in calibration. Calibration included running the model at similar conditions (i.e., similar hydraulics, meteorology and effluent and tributary water quality) as measured on 16 August, 2007.

Reaeration coefficients were determined using the Parkhurst-Pomeroy, Tsivoglou-Neal and Thackston-Krenkel equations recommended by Ohio EPA guidelines for the calculation of reaeration coefficients for Ohio streams, based on the stream's average slope (Skalsky, 1984). Model results were compared to observed data. Adjustments were made primarily by altering model constituent reaction rates, within reason, in order to better fit the model's predictions to the observed data. Over 85 model runs were carried out to fine tune the calibration. Figures 4-3, 4-4, and 4-5 show the results of the dissolved oxygen, T.P and nitrate + nitrite-N calibration respectively. These figures include observed (boxes) and model predicted (lines) data. Figure 4-3, which shows dissolved oxygen, contains the diel maximum and minimum of observed and predicted data. Data used in this model are included as Appendix K.

Figure 4-3. Calibration and observed DO on the Nimishillen QUAL2K model

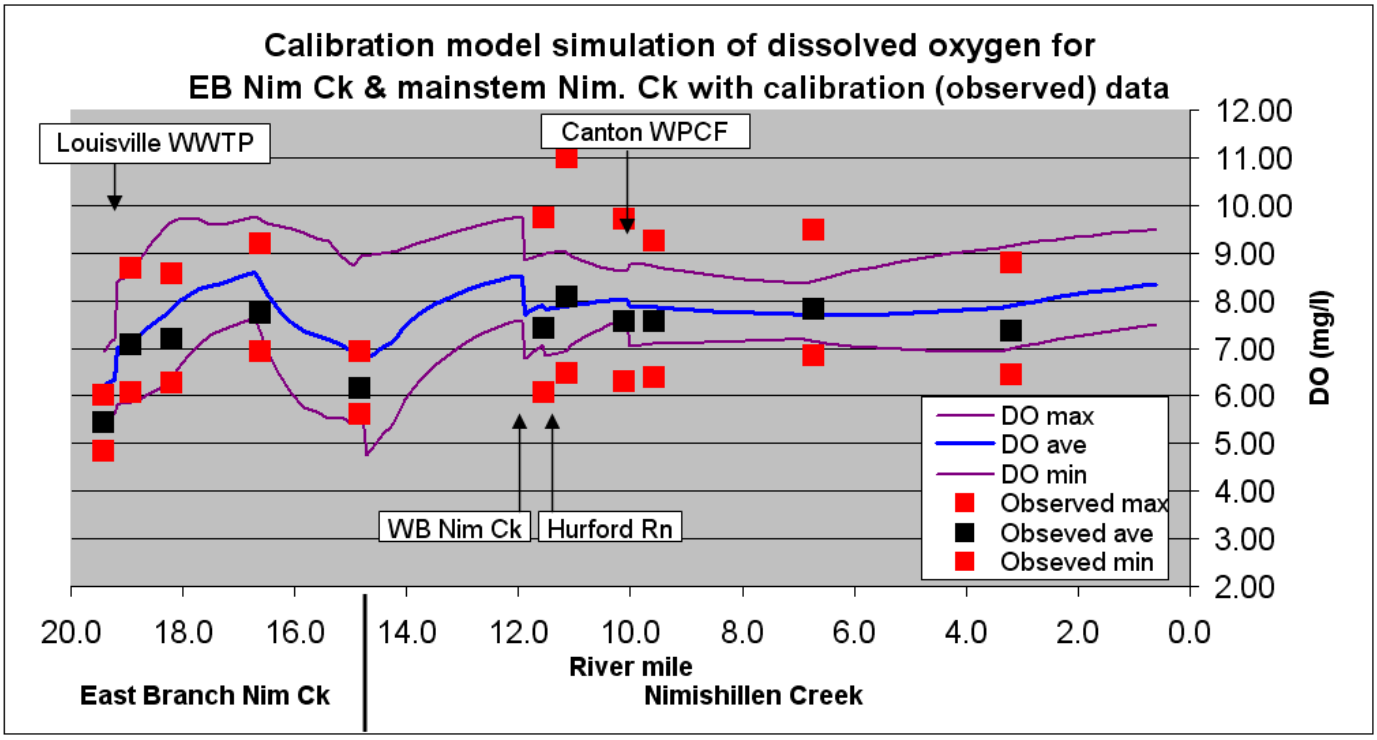


Figure 4-4. Calibration and observed T.P. on the Nimishillen QUAL2K model

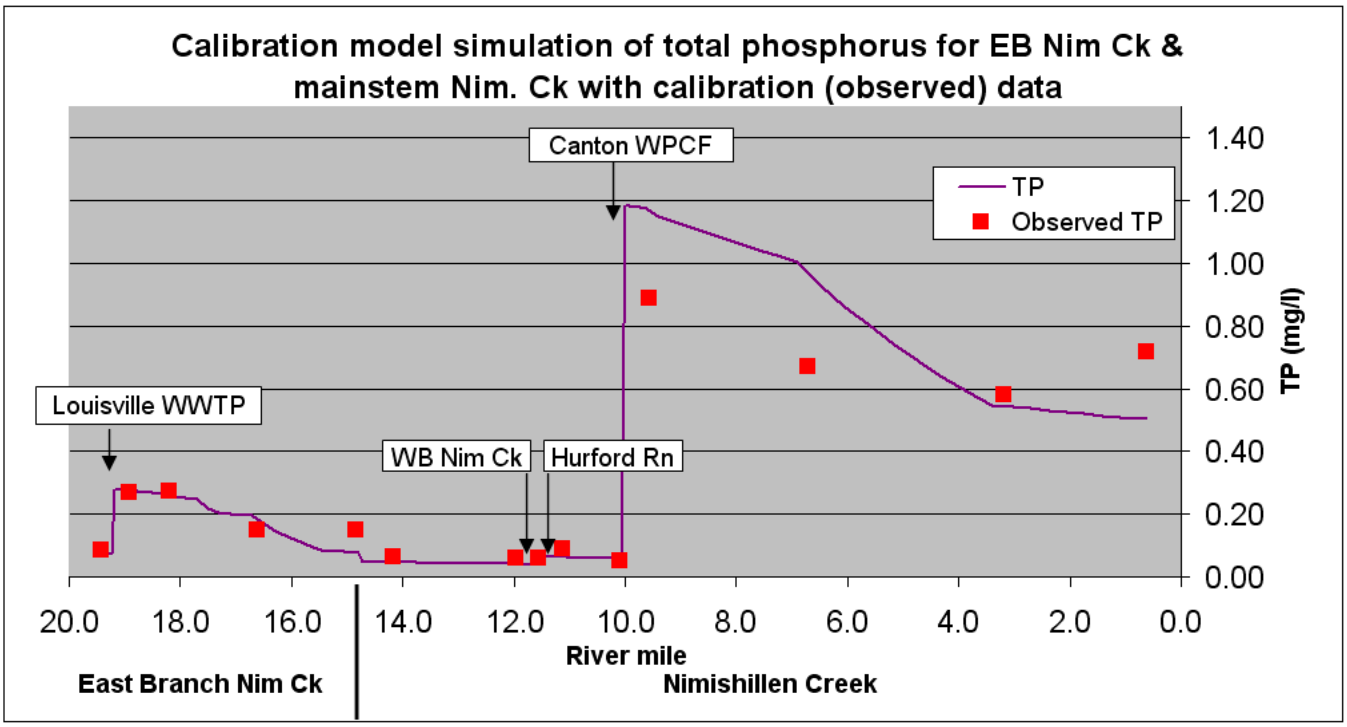
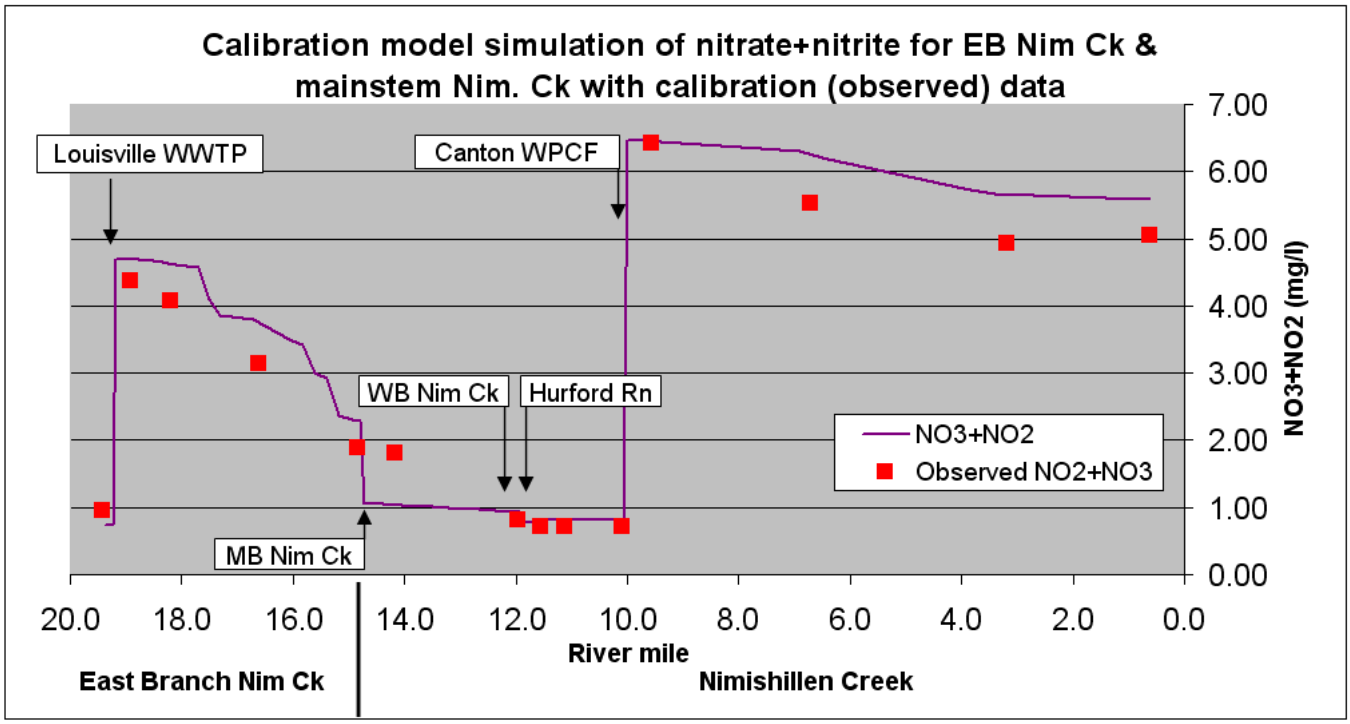


Figure 4-5. Calibration and observed NO3+NO2-N on the Nimishillen QUAL2K model



Model validation

Model validation is the, "comparison of model results with an independent data set without further adjustments" (Reckhow, 1983). The Nimishillen QUAL2K model was validated for 6-7 September 2006. This was a period in which some additional water quality data was collected throughout the Nimishillen Creek watershed. No alteration of the reaction rates were made for this effort. The observed meteorological conditions that occurred for the validation period and upstream, tributary and point source flows were input into the model.

The model was run one time to examine how close it came to predicting observed data. Figures 4-6, 4-7 and 4-8, show the results of the dissolved oxygen, T.P and nitrate + nitrite-N calibration respectively. The layout of these figures is the same as Figures 4-2 thru 4-5 above. The observed data being used for this validation is not quite as robust in quantity or quality as the data used for calibration. Quantity is reduced because fewer sites were assessed. Lesser quality is because only grab (instantaneous) samples were collected for most parameters (not the dissolved oxygen however) rather than 24-hour composite samples which were used for the calibration data. Considering these limitations, the validation fit is acceptable.

Figure 4-6. Validation and observed DO on the Nimishillen QUAL2K model

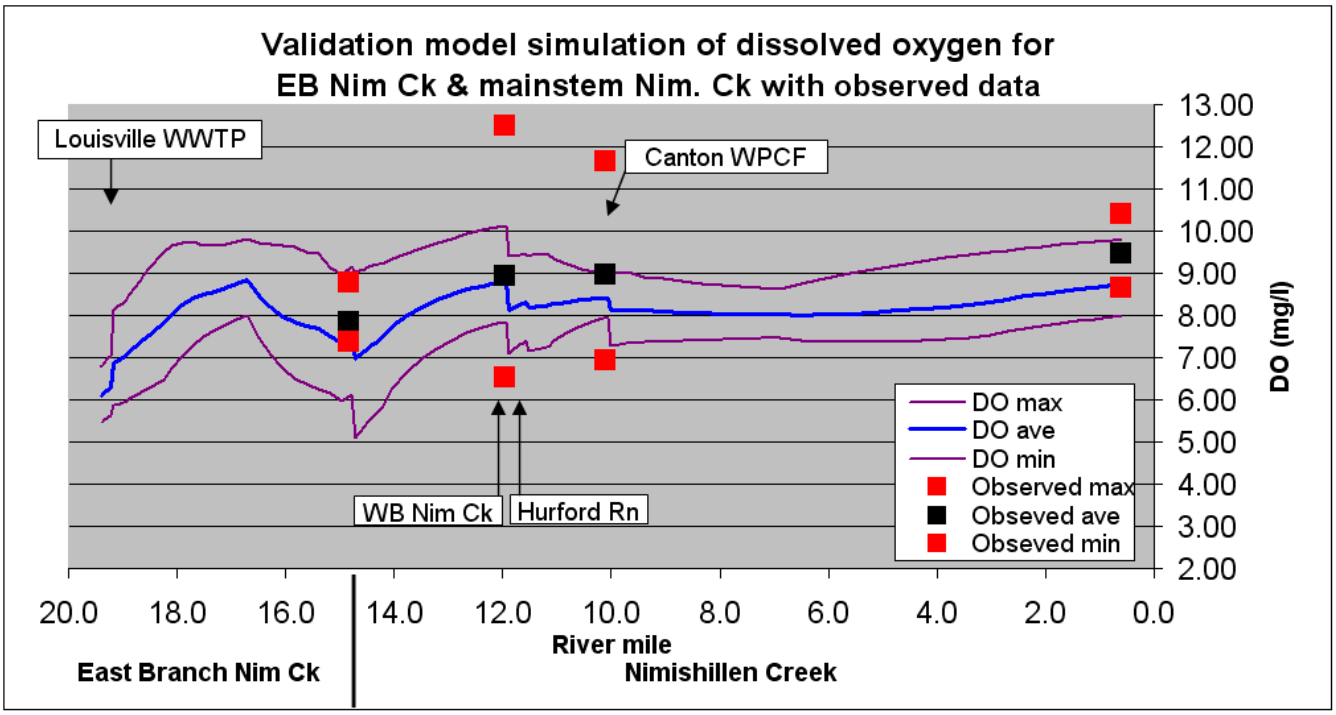


Figure 4-7. Validation and observed T.P. on the Nimishillen QUAL2K model

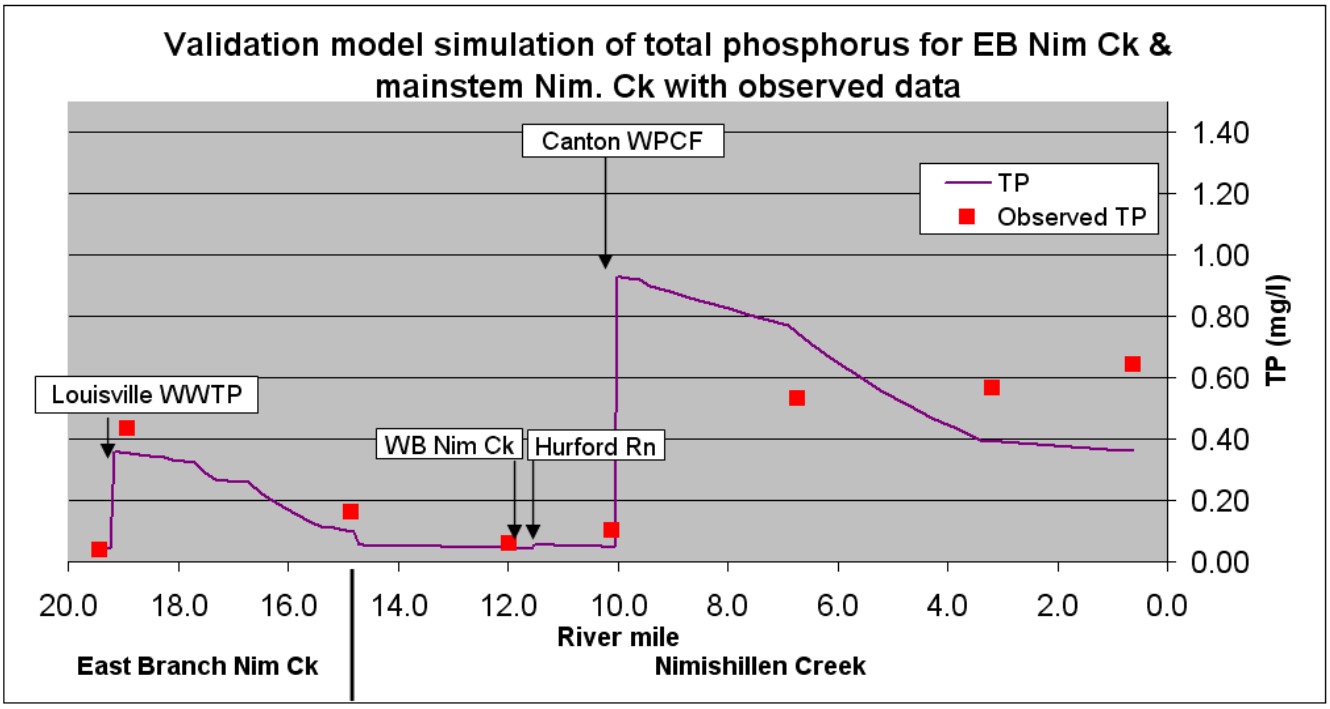
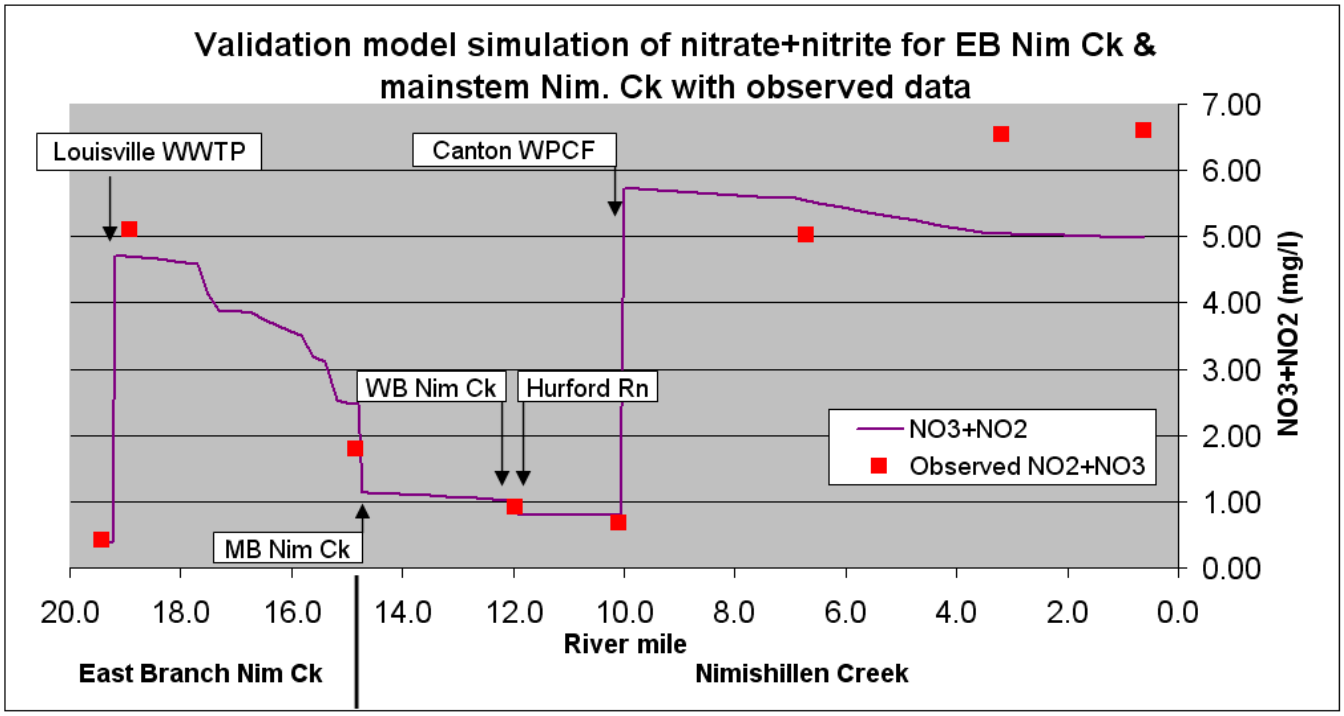


Figure 4-8. Validation and observed NO3+NO2-N on the Nimishillen QUAL2K model



Modeling critical condition

Once the QUAL2K model was calibrated and validated a critical condition was simulated. Since hydro-modifications due to urban land uses and major municipal wastewater treatment plants are sources of impairment for these stream reaches, a summer low flow critical condition was simulated. The weather conditions of a typical hot summer day, August 2, 2006, was selected to be used for the critical condition.

The 7-day average streamflow with a 10-year recurrence interval ($7Q_{10}$) for all of the tributaries are considered for this modeling simulation, and presented in Table 4-3. This is the critically low-flow statistic that is used by Ohio EPA to make low flow determinations for many parameters, including DO. Low flow $7Q_{10}$ values are determined by USGS for most of their streamflow gages (USGS, 2001). Ohio EPA uses watershed area weighting of published gage low flows to calculate the values for watersheds that do not have a gage on them. Furthermore, considerations are made for continuous discharges that may or may not be present altering streamflow. For the Nimishillen Creek QUAL2K model, many of these considerations were made to determine a $7Q_{10}$ value for each tributary.

The point sources that discharge to the QUAL2K modeled reaches are considered in this critical condition. The design flows of the facilities are used in this simulation. Design flows are the discharge flow rates each facility is permitted to discharge at. For the first model run simulation of this critical condition, water quality parameters for the permitted facilities are set to either the facilities permitted limit or some calculated average levels if no limits exist. Calculated average projected effluent quality (PEQ)

values are used for nutrient parameters that do not currently have limits. These concentration calculations are mostly based on the facility's monthly operating reports which are self-monitoring data submitted to Ohio EPA. Some effluent concentrations of the NPDES facilities are altered in the subsequent modeling runs to simulate various pollutant reduction approaches. These simulation results are discussed in Chapter 5.

Table 4-3. Low flow ($Q_{7,10}$) for tributaries in the QUAL2K model

Tributary	Flow (cfs)
East Branch Nimishillen Creek upstream RM 4.67	0.00*
UT to East Branch Nimishillen Creek @ RM 4.67	0.66
UT to East Branch Nimishillen Creek Ck @ RM 2.75	0.28
UT to East Branch Nimishillen Creek RM 2.50	0.30
UT to East Branch Nimishillen Creek Ck @ RM 1.89	0.11
Ground water on East Branch Nimishillen Creek as a diffuse source	0.42
Middle Branch Nimishillen Creek	1.65
West Branch Nimishillen Creek	6.04
Hurford Run (includes Marathon Ashland Petroleum (001), Timken (015) at PSD flows)	8.87
Sherrick Run @ Nimishillen Ck RM 11.06	0.74
Ground water on mainstem upstream of Canton as a diffuse source	0.62
Ground water on mainstem downstream of Canton as a diffuse source	1.21

* This zero low flow has been determined in pervious modeling efforts of East Branch Nimishillen Creek and is due natural conditions exacerbated by groundwater pumping for industrial reasons.

4.2.2 Habitat alteration and sediment method

As explained in Chapter 3, aspects of the Qualitative Habitat Evaluation Index (QHEI) are used for the habitat and sediment TMDLs in this report. This subsection contains explanations of the QHEI and the development of using it as TMDLs.

Qualitative Habitat Evaluation Index (QHEI)

The QHEI is a quantitative expression of a qualitative, visual assessment of habitat in free flowing streams, and was developed by the Ohio EPA to assess available habitat for fish communities (Rankin, 1989, 1994). The QHEI is a composite score of six physical habitat categories: 1) substrate, 2) in-stream cover, 3) channel morphology, 4) riparian zone and bank erosion, 5) pool/glide and riffle/run quality and 6) gradient. Each category is subdivided into specific attributes that are assigned a point value reflective of the attribute's impact on the aquatic life. The highest scores are assigned to the attributes correlated to streams with high biological diversity and integrity, and lower scores are progressively assigned to less desirable habitat features. QHEI evaluations are carried out in field by trained staff. Each of the components are evaluated on site and recorded on the QHEI form. The totaled score is later analyzed in an electronic database. The evaluation form is available on line at the following website: http://www.epa.state.oh.us/dsw/bioassess/QHEIFieldSheet062401.pdf.

The QHEI is a macro-scale approach that measures the emergent properties of habitat (sinuosity, pool/riffle development), rather than the individual factors that shape these properties (current velocity, depth, substrate size). The QHEI is used to evaluate the characteristics of a short stream segment, as opposed to the characteristics of a single sampling site. Individual sites may have poor physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. In these cases the area of high quality habitat is most likely a source of organisms to the adjacent, poorer quality habitats. Organisms migrate out of high quality habitats in response to ecological pressures within those habitats that are associated with resource availability, species competition, and other species interactions.

The QHEI evaluation is somewhat subjective and requires the evaluator to be experienced in the use of the index. The variability between evaluations from different trained investigators and the variability in time at a particular site have been determined to be minimal within the same season provided that the investigators are experienced with the method (Rankin, 1989).

TMDL using QHEI components

The empirical nature of the QHEI and the data that underlie it provide measurable targets that are parallel concepts to a loading capacity for a pollutant. By the scoring of metrics the QHEI provides a way to evaluate whether habitat is a limiting factor for the fish community, and by listing modified attributes the QHEI shows what are the likely stressors. These attributes could account for probable sources of sediment (riparian corridor, bank stability) and the effects on the stream itself (i.e., the historic sediment deposition). Because of this, the QHEI has aspects of both a loading model and a receiving stream model. When used with biological indices, the numeric measurability of the QHEI provides a means to monitor progress when implementing a TMDL and to validate that a target has been reached.

Application

The QHEI targets described for the habitat and sediment TMDLs are outlined in Chapter 3. There, Tables 3-4 and 3-5 show the habitat and sediment TMDL equations used respectively.

4.2.3 Pathogens

A watershed loading method using the Bacteria Indicator Tool (BIT) is employed for watersheds of a 14-Digit HUC size or smaller (approximately 10-30 square miles) with recreational use impairment. This modeling addresses the chronic or geometric mean portion of the primary contact recreational use standards. The acute, 90th percentile aspect of these standard is addressed by use of a load duration curve. Both TMDL methods use fecal coliform as the indicator for pathogen presence.

The Bacteria Indicator Tool Method

Recreational use impairments are summarized in Section 4.1. Table 4-4 provides a summary of this TMDL method of development. Additional discussion of bacterial modeling is included as Appendix J.

Table 4-4. Summary of BIT bacteria TMDL development

Development step	Source		Method
Existing load	Point Source w/ NPDES		Product of discharger design flow and the fecal coliform average standard currently in place.
	Point Source w/o NPDES		Product of discharger design flow and the fecal coliform average standard.
	Surface runoff		Determined with the BIT tool and a spreadsheet watershed washoff model.
	HSTS		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.
	Cows in stream		Cattle in stream bacteria loads are determined using the BIT tool.
Calculation of loading capacity	-		Product of the average recreation season discharge volume from each sub-basin and the fecal coliform geometric mean concentration.
Suggested allocation	WLA	Point Sources w/ NPDES	Product of discharger design flow and the fecal coliform average standard currently in place.
		Point Sources w/o NPDES	Product of discharger design flow and the fecal coliform average standard.
		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	LA is equal to the sum of all WLAs (except for MS4 runoff) subtracted from the assimilative capacity.
		HSTS	Failing home sewage treatment systems are allocated a fecal coliform load of zero.
		Cows in stream	Cattle grazing in streams are allocated a fecal coliform load of zero.

<u>Existing loads</u>

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 should no washoff occur. 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 spend 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 ™ satellite imagery circa 2001 (Homer, 2004). 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 was obtained from Ohio Agricultural Statistics Service published data. Communication with the Stark County Natural Resources Conservation Service's District Conservationist took place in order to learn approximate locations of livestock farms in Stark County. The county total of livestock and basic livestock operations locations were combined to estimate the amount of livestock in each of the modeled watersheds.

- Information regarding wildlife populations was obtained from Ohio Department of Natural Resource census data. For the distribution of wildlife populations the total number of animals within the county was divided by the total number of acres of relevant land use in the county. The resulting animal densities (animals per acre) were used to estimate the wildlife populations within each watershed.

When all values were entered, BIT predicts the maximum surface accumulation rate of fecal coliform and the asymptotic limit of accumulation should no washoff occur. Additionally, BIT predicts the fecal coliform load contributed directly to the stream from cattle with stream access. A spreadsheet method was 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 was 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. Daily bacteria washoff was modeled for the most recent ten recreational seasons (1997-2006) for each subwatershed. The average total recreational season bacteria load was determined to represent the bacteria that washes off of the various land uses.

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. Several non-permitted facilities with much lower effluent flow are known to exist in the subwatersheds modeled. These facilities have no NPDES permit and do not report their effluent quantity and quality values. Therefore effluent flow values were estimated. Like the permitted dischargers, these facilities were assumed to be continuously discharging fecal coliform effluent concentrations of 1000 cfu per 100 ml.

The number of HSTS and the percentage of those which are failing are determined via county supplied information and GIS analysis. These calculations were made without the use of BIT. The Stark County Health Department was able to supply street addresses for all of the homes with HSTSs. Using GIS these addresses were able to be geo-coded and turned into spatial data. Simple GIS analysis was then used to determine how many HSTSs were in each subwatershed being considered for a bacteria TMDL. 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 this TMDL, a system considered failing is a one that is non-functional with untreated effluent being discharged to streams in the considered subwatersheds. 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 (Metcalf & Eddy, 1991) and representative wastewater-quality information (U.S. EPA, 2002).

Bacteria loading is often difficult to quantify because there is 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 such literature and default values results in considerable 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. Assessing the accuracy of these assumptions is beyond the scope of this report.

<u>Loading capacity and TMDL</u>

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 determined by averaging the 10 years of modeled hydrology for May through October 15. Stream flow was calculated by summing both

the contribution of flow resulting from overland runoff and groundwater (baseflow) to the stream. Runoff was calculated concurrently with the existing bacteria overland washoff in the spreadsheet method used and described above. Baseflow for each subwatershed was calculated by applying a watershed area weighting factor to a nearby USGS daily stream flow gage's baseflow. The baseflow of the gages was determined by applying a watershed area yield value. This value was determined by applying a stream flow separator method to the daily stream flow records of the Nimishillen Creek at North Industry gage (USGS 03118500) and the Middle Branch Nimishillen Creek at Canton gage (USGS 03118000). The geometric mean target is 1000 cfu per 100 ml for all primary recreational use streams and is described in Section 3.3. The loading capacity calculation accounts only for dilution as a means of assimilation. Not considering instream processing and decay of fecal coliform is a wasteload conservative measure representing an implicit margin of safety.

Suggested allocations

Existing fecal coliform loads are allocated for each subwatershed to meet the seasonal TMDL based on the BIT-washoff loading, geometric mean method described in this subsection (and presented in Chapter 5). These allocations are a suggested manner by which various implementation practices can be used to meet the TMDLs. Loads modeled as coming from unmanaged lands are first taken out of the loading capacity with no reduction. Since all permitted NPDES dischargers currently have limits equal to the geometric mean fecal coliform standard, the same load calculated as in the existing load is removed. This is also how the non-NPDES dischargers are treated since there are no data to indicate these sources' effluent contains concentrations greater than the geometric mean standard. Since the load from failing HSTSs are considered to be direct discharges (failing aeration systems, leach fields that are discharging to an outlet or short-cutted septic tank effluent being drained) no effluent is allowed in these suggested allocations. Therefore fecal coliform load from HSTSs are allocated to zero. Fecal coliform from cows grazing in streams are also allocated a load of zero as well. The remaining loading capacity is allocated equally to nonpoint and MS4 sources of runoff. This results in an equal proportion of required reduction from all nonpoint and MS4 runoff source areas.

Load duration curve

A load duration curve (LDC) has been developed for Nimishillen Creek at Howenstine Road. A load duration curve is generated by plotting 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.

The LDC 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 non-point sources are having a greater impact on the overall pollutant loading of the system.

This graph is being used to examine the acute, 90th percentile aspect of the recreational use primary contact standard as is explained in Chapter 5.

4.3 Critical condition and seasonality

4.3.1 Nutrients / dissolved oxygen

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. As phosphorus readily attaches to sediment, detachment of adsorbed phosphorus in bottom sediments can lead to elevated instream concentrations 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 on an annual basis. The TMDLs are therefore reflective of all conditions, rather than a single critical condition.

4.3.2 Habitat and sediment

The critical condition for the habitat and sediment TMDLs 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.

4.3.3 Pathogens

The critical condition for pathogens is the summer dry period when flows are lowest, and thus the potential for dilution is the lowest. Summer is also the period when the probability of recreational contact is the highest. For these reasons recreational use designations are only applicable in the period May 1 to October 15. Pathogen TMDLs are developed for the same May to October 15 time-period in consideration of the critical condition, and for agreement with Ohio WQS.

4.4 Margin of Safety

Margin of safety (MOS) is a required component of TMDLs in order to account for the uncertainty concerning the relationship between pollutant loads and of the quality of receiving waterbodies and the accuracy of the load calculations. The MOS can be incorporated implicitly by the conservative assumptions in the development of TMDLs. They can also be incorporated explicitly by quantitatively allocating a portion of the loading capacity specifically for the MOS.

4.4.1 Nutrients

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. Since most of the treatment plants discharge effluent of a quality better than their permit limits, and are typically discharging below design flows, this represents a built-in margin of safety.

4.4.2 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. Using an IBI score of 40 as 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. The difference between the habitat and sediment targets and the levels at which attainment actually occurs is an implicit margin of safety.

4.4.3 Pathogens

A margin of safety is implicitly incorporated into the pathogen TMDL. Loading of fecal coliform to each 14-digit HUC (or smaller watershed) 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. No attempt is made to link downstream loading capacity with upstream loading via instream processing. Only die-off of land accumulated bacteria prior to wash off 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.

4.5 Future Growth

Table 4-5 presents population data and growth rates for Stark County, of which the majority of the Nimishillen Creek watershed lies in. These data indicate that population growth is fairly stable on a county-wide basis.

Table 4-5. Population growth figures for Nimishillen Creek watershed municipalities

County	Population		2000-2005 % change
	2000†	2005‡	
Stark	**378,098**	**380,608**	**0.66**
Pike Township	4,088	4,295	5.06
Perry Township	29,167	28,560	-2.08
Canton Township	13,882	13,668	-1.54
Osnaburg Township	5,886	6,131	4.16
Paris Township	5,969	6,190	3.70
Jackson Township	37,744	40,276	6.71
Plain Township	51,997	51,267	-1.40
Nimishillen Twp.	9,098	9,172	0.81
Washington Twp.	4,791	4,942	3.15
Lake township	25,892	25,880	-0.05
Marlboro township	4,227	4,498	6.41
Canton, city	80,806	79,478	-1.64
East Canton, city	1,629	1,619	-0.61
East Sparta, village	806	786	-2.48
Hartville, village	2,174	2,389	9.89
Hills and Dales, village	260	262	0.77
Louisville, city	8,904	9,367	5.20
Meyers Lake, village	565	561	-0.71
North Canton, city	16,369	16,780	2.51

† US Census Bureau, 2000
‡ US Census Bureau, 2005

5.0 Watershed analysis, loading capacity, and allocations

5.1 Nutrient/Dissolved oxygen TMDL

As explained in Chapter 4, the QUAL2K model examines several parameters including dissolved oxygen and total phosphorus. Summer low flow conditions were simulated to examine these parameters. The reach modeled starts in the downstream section of East Branch Nimishillen Creek and continues downstream to just upstream of the mouth of Nimishillen Creek (river mile 0.62). East Branch is joined by Middle Branch Nimishillen Creek to form the mainstem Nimishillen Creek at the mainstem's river mile (RM) 14.72. This model is built to consider the East Branch and mainstem as one stream with the Middle Branch as a tributary (as seen in Figure 4.2 in Chapter 4). The RMs shown on the figures in this section consider the RMs for East Branch as a continuation of the mainstem's RM (i.e., add 14.72 to the East Branch's RM to determine the model RM).

Two municipal wastewater treatment plants and one industrial discharger are included in this modeling reach's critical low flow simulations. The Nimishillen QUAL2K model begins just upstream of the Louisville WWTP (3PD00033) discharge at East Branch RM 4.46 (Nimishillen QUAL2K RM of 19.18). Louisville WWTP has a 3.09 cubic feet per second (cfs) design flow. The industrial facility Republic Technologies International (RTI, 3ID00000) has several discharges to East Branch Nimishillen Creek between East Branch RM 1.09 and 0.45 (or model RMs of 15.81 and 15.17). Only three of RTI's outfalls are considered to be discharging during low flow conditions: 003, 011 and 010. Outfall 010 has the highest design flow of 4.24 cfs while the other two combined are considered to be 0.47 cfs. Republic Storage Systems (3ID00007) is not considered for the low flow runs of the Nimishillen QUAL2K model because its outfalls are intermittent. The Canton Water Pollution Control Facility (3PE00000), discharging on the mainstem Nimishillen Creek's RM 10.0, has the highest design flow considered in the model at 60.34 cfs.

No other permitted dischargers on the Nimishillen QUAL2K modeled stream section are considered to be flowing in a low flow critical condition. No storm water is considered to occur during this low flow period. Because of this, no MS4 (permitted municipal storm water) is included in this critical condition or in the D.O. and T.P. pollutant allocations. Dischargers on tributaries that are considered to be flowing on any given day, such as the outfall 015 of the Timken Company on Hurford Run, with a design flow of 5.42 cfs, are included in the low flow model simulations. Complete records of the low flow considerations and calculations and water quality inputs can be reviewed upon request.

Dissolved oxygen

Figure 5-1 shows the dissolved oxygen (D.O.) in the Nimishillen QUAL2K model by river mile for the first model run. This shows the model predictions of D.O. under low flow conditions when the both Louisville WWTP and Canton WPCF are discharging at their design flow effluent with a quality of 5.0 mg/l D.O. This is the minimum limit currently in place for both of these facilities. The model predicted diel average, maximum and minimum D.O. are shown on this figure. Also included are lines showing the average and minimum D.O. water quality standards for the warm water habitat aquatic life use, 5.0 and 4.0 mg/l respectively. Seen on this figure, the model predicts both an average and minimum D.O. water quality standard violation downstream of the Louisville WWTP and an average violation downstream of the Canton WPCF. Both of these areas of low D.O. occur downstream the WWTPs, showing the typical D.O. sag expected below enriched WWTP effluent (Chapra, 1997). There is also a shaded area that includes a minimum D.O. that is very low. This is an area of uncertainty and the low D.O. has been determined not to be due to Louisville WWTP's effluent. This low D.O. exists in the model due to increased amount of sediment oxygen demand (SOD) that was added to this reach during model calibration. This specific stream reach has been unassessed by Ohio EPA and therefore its predicted D.O. violation is not considered further.

Figure 5-2 shows a model simulation of the Nimishillen QUAL2K that considers both Louisville WWTP and Canton WPCF effluent to be discharging at a constant D.O. level of 6.0 mg/l. As can be seen in this figure, no instream D.O. violations would occur in the

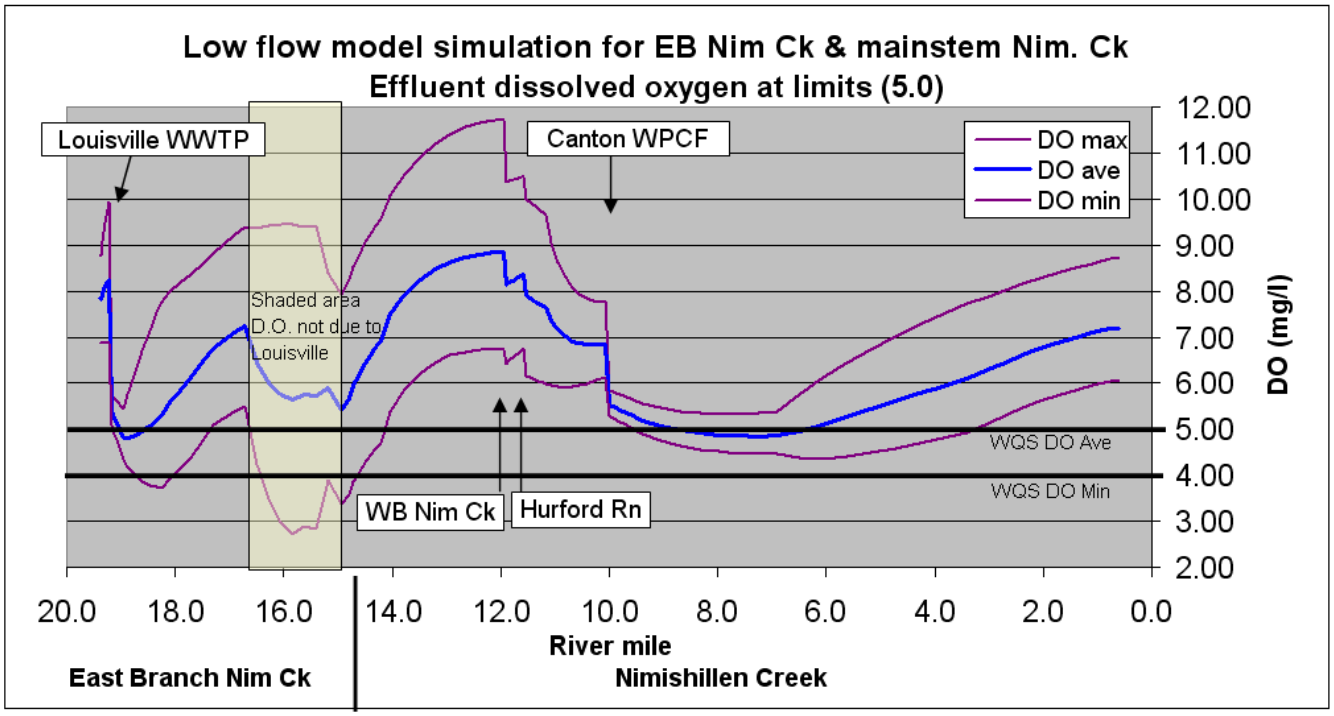


Figure 5-1. Model results at 5 mg/l effluent D.O.

stream were these limits put into place. Based on a review of both plant's self monitoring monthly operating records it appears both plants are in general already discharging effluent at or higher than 6.0 mg/l. Since this limit adequately addresses any instream D.O., there are no further recommendations based on the D.O. targets.

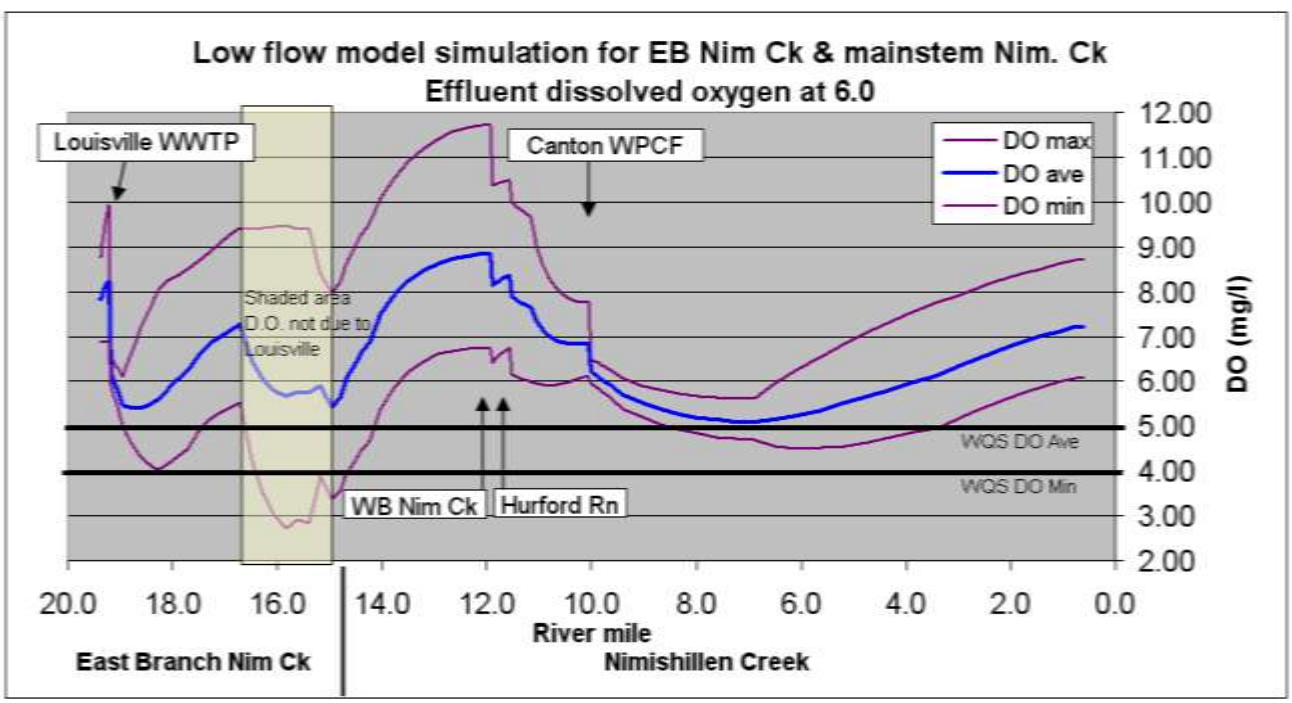


Figure 5-2. Model results at 6 mg/l effluent D.O.

Total phosphorus

Total phosphorus (T.P.) was examined using the Nimishillen QUAL2K model at the same low flow critical condition as was D.O. Because of the complexity of the interaction of total phosphorus in the model among various inputs and assimilation and decay over time and distance, it is helpful to establish a "point of compliance" as a means to determine whether the target is being met. Such a compliance point also may have utility as a monitoring location if water quality trading is pursued as an implementation option. Ohio EPA is identifying a compliance point for each of the streams being modeled:

- East Branch Nimishillen Creek at RM 0.05 (pedestrian bridge in Cook Park)
- Nimishillen Creek at RM 0.62 (SR 183).

Figure 5-3 shows the T.P. throughout the model reach when simulated at critical condition with the WWTPs discharging at their design flows. Neither WWTP currently has a T.P. limit however both monitor effluent T.P. Using that self monitoring data the average projected effluent quality (PEQ) was calculated for the last 5 years of data. The Louisville WWTP's average PEQ for T.P. is 1.06 mg/l with 242 observations and the Canton WPCF's average PEQ for T.P. is 2.52 mg/l with 521 observations. Figure 5-3 shows the T.P. warm water target, 0.1 mg/l. It can be seen on this figure that the target T.P. concentration is not met on the East Branch Nimishillen Creek downstream of Louisville WWTP. The main stem Nimishillen Creek only meets the target upstream of the Canton WPCF between its formation (at the confluence of East Branch and Middle Branch Nimishillen creeks) and Hurford Run.

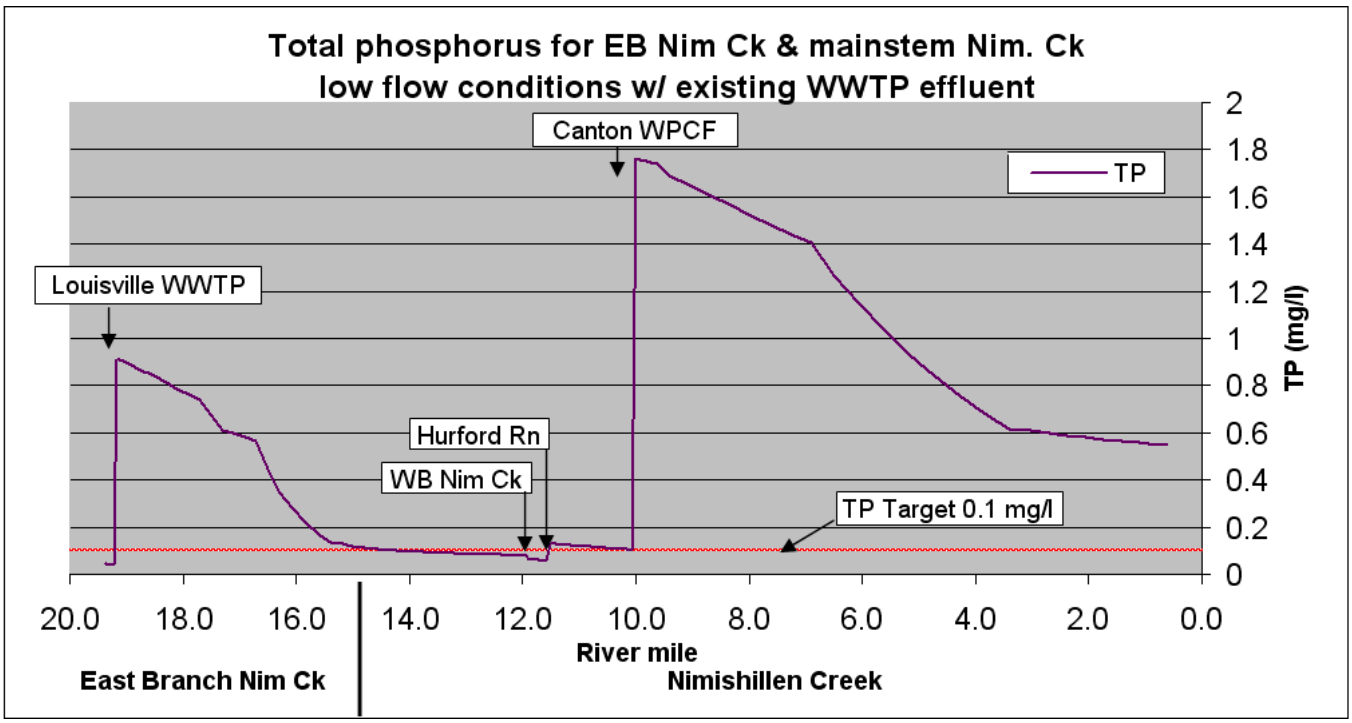


Figure 5-3. Phosphorus model results at current effluent quality and design flows

Model simulations examining alternative effluent levels were carried out for Louisville WWTP and Canton WPCF. Figure 5-4 shows the portion of the Nimishillen QUAL2K model of the East Branch Nimishillen Creek and upper section of the main stem Nimishillen Creek. This figure shows the T.P. at the existing WWTP effluent (as in Figure 5-3) in addition to the T.P. if the WWTP discharges at a T.P. concentration of 1.0 mg/l. Note that the T.P. target of 0.1 mg/l is met at the East Branch Nimishillen Creek compliance point. A T.P. limit of 1.0 mg/l for Louisville WWTP is appropriate as a first step to reducing the stream's nutrient loads. With a T.P. limit of 1.0 mg/l future biological assessment of East Branch Nimishillen Creek could be carried out to examine if this reduction is adequate in restoring the stream's attainment status.

Figure 5-5 shows several modeling simulations of the Nimishillen QUAL2K model with Canton WPCF set at various T.P. effluent concentrations for the low flow critical condition. Each line represents the model's predicted instream T.P. concentration. The line showing the greatest concentration is the modeling run representing existing concentration at design flows (the same data shown in Figure 5-3). Here it can be seen that were Canton WPCF limited to a T.P. effluent concentration of 1.0 mg/l, the T.P. target of 0.1 mg/l will not be met at the Nimishillen Creek compliance point. A T.P. effluent concentration of 0.4 mg/l would be needed to meet the 0.1 mg/l target at the compliance point.

Tables 5-1 and 5-2 summarize the modeling simulations described in this section for Louisville WWTP and Canton WPCF. These tables also include the daily pollutant loads of the effluent sources and total stream pollutant load for this critical low flow condition.

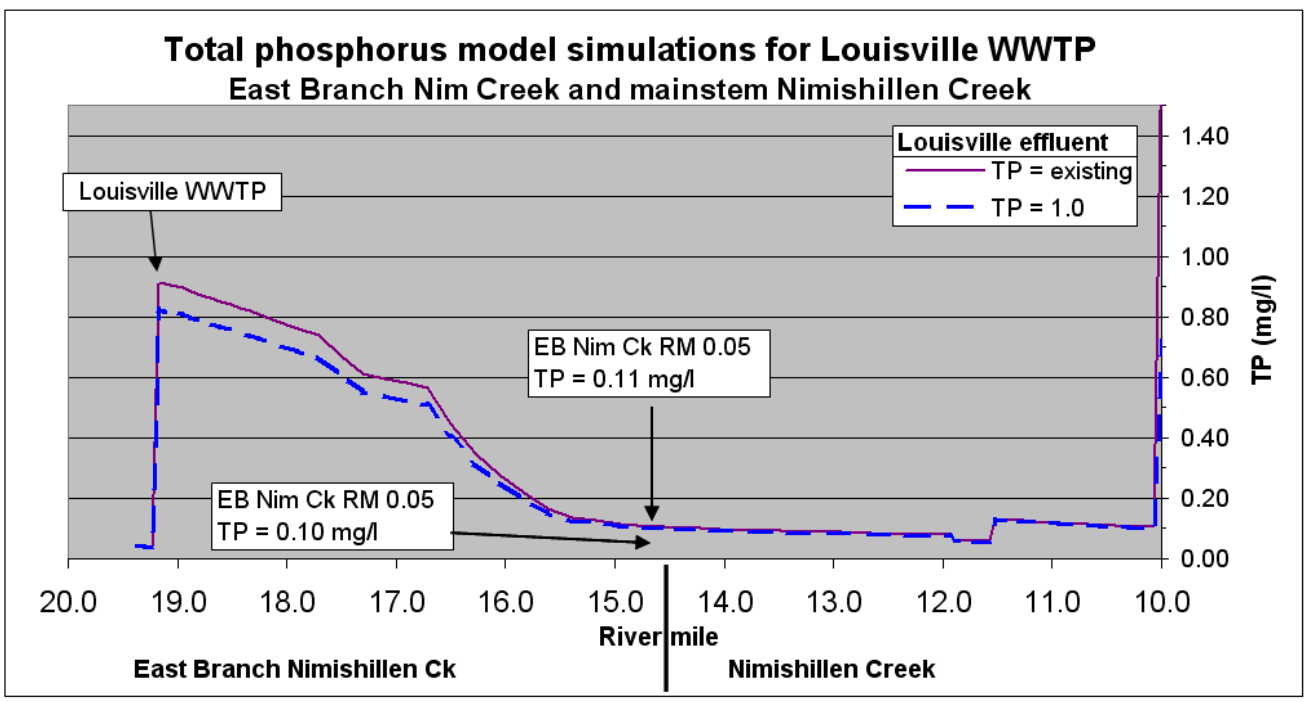


Figure 5-4. Phosphorus model results for Louisville WWTP

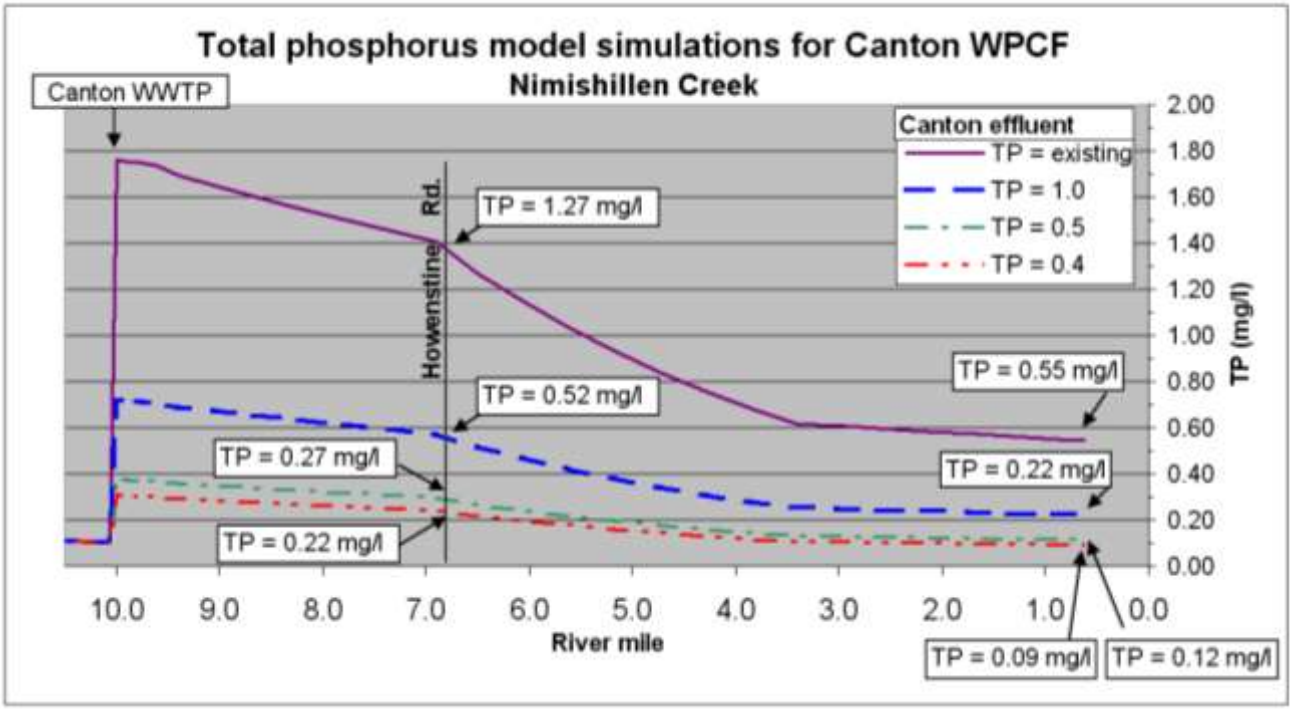


Figure 5-5. Phosphorus model results for Canton WPCF

Table 5-1. Louisville WWTP's model results for total phosphorus at 2.0 MGD design flow

Modeling Scenario	Effluent		East Branch Nimishillen Creek at Compliance Point (RM 0.05)	
	Concentration[1]	Load[2]	Concentration[1]	Load[2]
Current	1.62	12.3	0.11	2.6
Proposed	1.0	7.56	0.10	2.3

[1] All concentrations are in mg/l
[2] All loads are in kg/d

Table 5-2. Canton WPCF's model results for total phosphorus at 39.0 MGD design flow

Modeling Scenario	Effluent		Nimishillen Creek at Howenstine Dr (RM 6.72)	Nimishillen Creek at Compliance Point (RM 0.62)	
	Concentration[1]	Load[2]	Concentration[1]	Concentration[1]	Load[2]
Current	2.52	372.0	1.27	0.55	119.8
Level 1	1.0	147.6	0.52	0.22	47.9
Level 2	0.5	73.8	0.27	0.12	26.1
Level 3	0.4	59.1	0.22	0.09	20.5

[1] All concentrations are in mg/l
[2] All loads are in kg/d

While the recurrence of the critical condition stream flow is rare, T.P. is clearly above the target in the Nimishillen Creek watershed throughout the stream's flow regime. Figures 5-6 and 5-7 compare concentration duration curves with results from sampled T.P. data collected at Faircrest Road by Canton WPCF and at Howenstine Drive by Ohio EPA, respectively. In each of these figures the abscissa shows percentile of stream flow exceedance or the flow duration interval. The ordinate shows log T.P. concentration. Both of these plots indicate that T.P. is 1) consistently above the target concentration of 0.1 mg/l and 2) generally increasing with decreasing stream flows. With T.P. concentrations increasing at lower flows, it is clear that the dry-weather point sources' T.P.-rich effluent makes up an increased proportion of the stream flow.

Additionally in Figures 5-6 and 5-7, the Faircrest Road data (Figure 5-6) shows a general, slightly higher concentration of T.P. at various flow regimes compared to Howenstine Drive (Figure 5-7). Since Howenstine Drive is 2.95 river miles downstream of Faircrest Road this confirms the longitudinal T.P. decay predicted by the QUAL2K modeling.

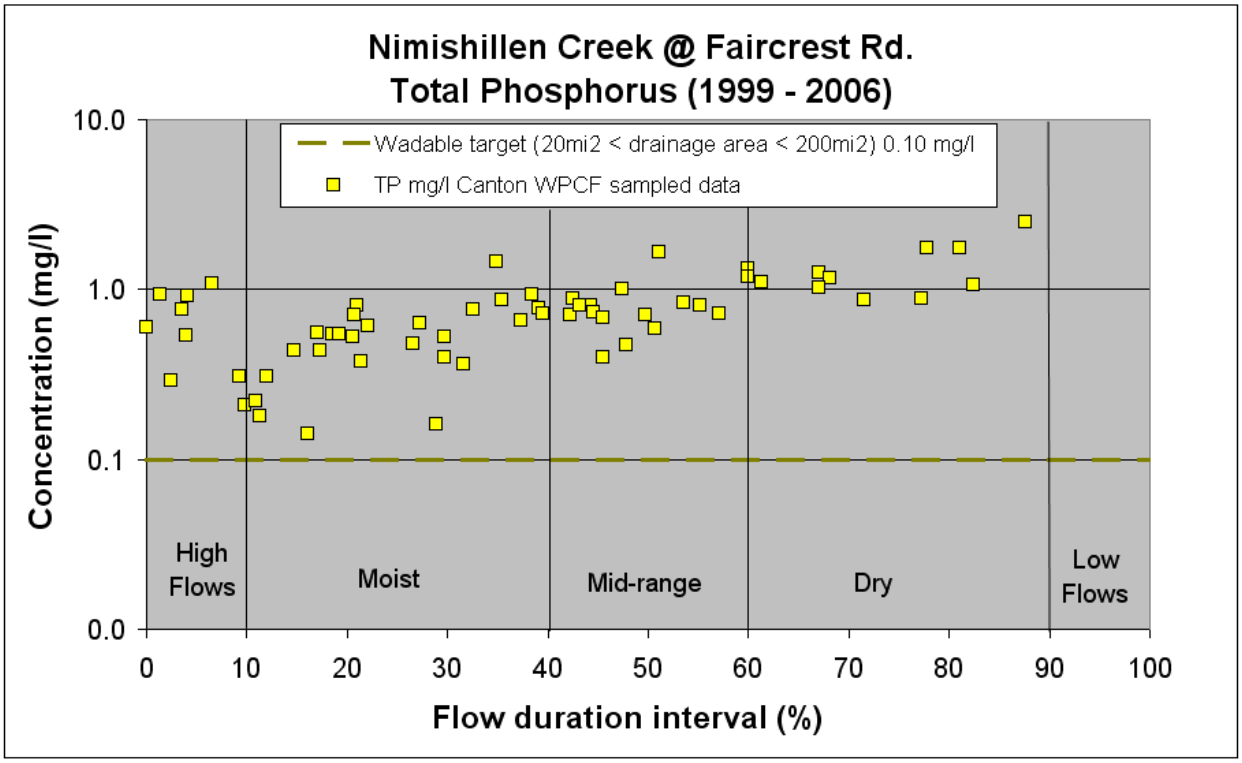


Figure 5-6. Nimishillen Creek phosphorus @ Faircrest Road

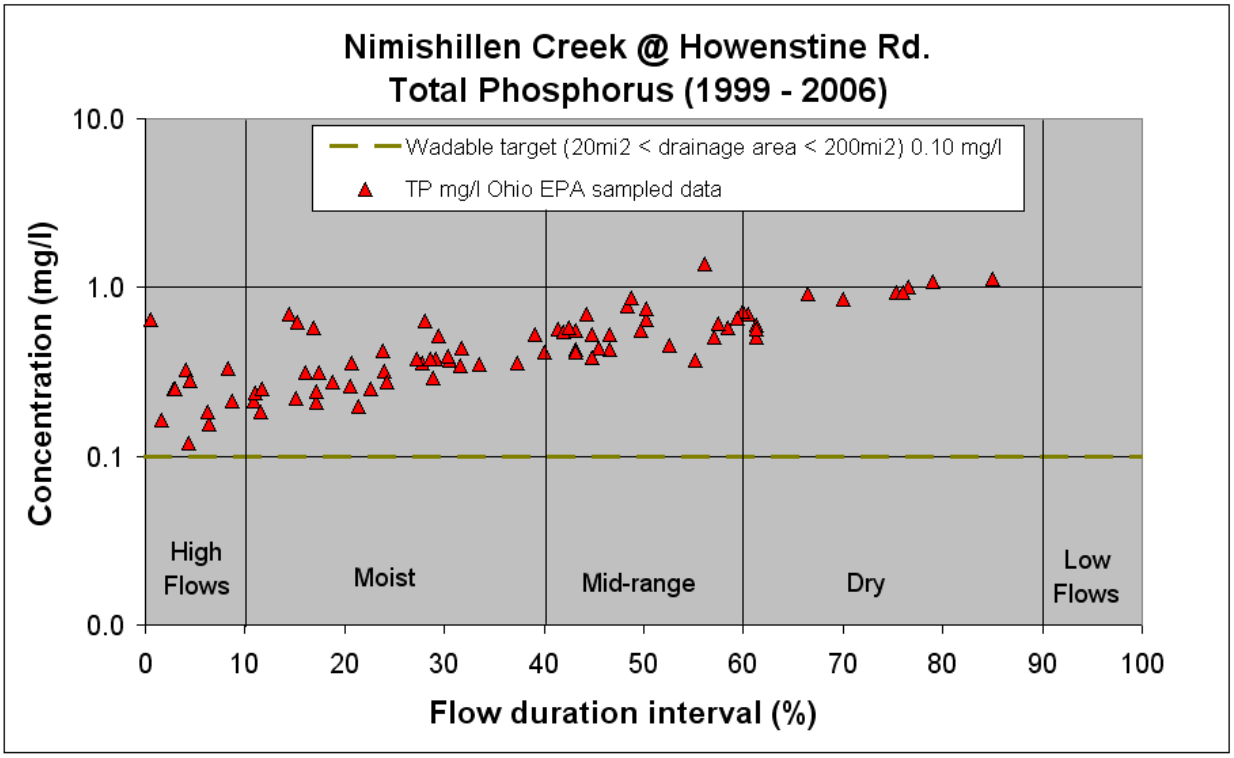


Figure 5-7. Nimishillen Creek phosphorus @ Howenstine Drive

TMDL allocations for phosphorus are summarized in Table 5-3. As discussed earlier, Ohio EPA established compliance points on each of the streams being modeled. Since the model simulates instream T.P. decay in a manner similar to natural conditions, the distance from a point source to a compliance point must be taken into consideration. The greater the distance from point sources to the compliance points the more assimilation of that source's T.P. is expected. The TMDL for each compliance point is the total critical condition flow at that point times the instream target concentration (0.1 mg/l T.P.). As shown in Figures 5-4 and 5-5, the allocated loads outlined in Table 5-3 decay to the target concentration of 0.10 mg/l at the compliance point in East Branch Nimishillen Creek and on the mainstem Nimishillen Creek. Thus, the T.P. loads allocated to the sources (the load and wasteload allocations) do not explicitly add up to the TMDL.

Effluent concentrations outlined in Table 5-3 for Louisville WWTP and Canton WWTP are determined via modeling described above. The T.P. concentration for the other facilities represents their current observed or assumed values. Since all of these are well below 1.0 mg/l already, these allocations represent no expected reductions.

Table 5-3. TMDL and allocations for total phosphorus

	Design Flow (MGD)	Phosphorus WLA/LA at Source		Phosphorus Loads at Compliance Points[1] (kg/d)		
		Conc (mg/l)	Load (kg/d)	TMDL[2]	WLA[2]	LA[2]
East Branch Nimishillen				2.34	2.315	0.026
Louisville WWTP	2.00	1.00	7.56			
Republic Steel Corp. 010 outfall	2.74	0.16	1.66			
Republic Steel Corp. other outfalls	0.30	0.08	0.09			
Nonpoint sources	-	-	0.11			
Nimishillen Creek				21.78	21.368	0.416
Canton WPCF	39.00	0.40	59.05			
Canton Water Dept. NE Plant	0.16	1.00	0.60			
Marathon Ashland Petroleum	1.67	0.27	1.70			
Timken Company	3.50	0.27	3.58			
Nonpoint sources	-	-	1.34			

1 Compliance point is at RM 0.05 on East Branch Nimishillen Creek and at RM 0.62 on Nimishillen Creek. The allocations for the Nimishillen Creek compliance point reflect the sum of the loads contributed in Nimishillen Creek. The allocations for the East Branch compliance point reflect the sum of the loads contributed in East Branch. The loads contributed upstream of the East Branch compliance point are included in the model and are reflected in the Nimishillen compliance point.

2 The loads contributed to the streams decay and assimilate so that the TMDL is met at both compliance points.

As shown in Figures 5-6 and 5-7 the effluents from the point sources are rich in total phosphorus during the critical low flow period. Therefore, a T.P. limit of 1.0 mg/l is recommended for all WWTPs in the watershed with design flows at or greater than 100,000 gallons per day. While the QUAL2K modeling results indicate that this limit will not meet the T.P. target concentration at the compliance point during critical low flow events, it does represent a significant (approximately 60%) reduction in T.P. load from the Canton WPCF. Applied on an annual basis, this limit should provide enough instream nutrient reduction to improve aquatic life throughout the watershed while imposing achievable NPDES limits. Any further reduction in effluent limits should be evaluated after these limits are being attained and an evaluation of the biological condition of the streams has been completed.

Indirectly addressed nutrient impairment, nonpoint sources reduction

Impairment is caused by nutrients and/or organic enrichment in several stream reaches that are not assessed by the QUAL2K modeling in the Nimishillen Creek watershed. These are outlined in Table 4-1 of Chapter 4.

Nutrient and organic enrichment causes of impairment are addressed indirectly in this TMDL for watersheds of Swartz Ditch, the upper East Branch Nimishillen Creek including its unnamed tributary at RM 4.67 and the West Branch Nimishillen Creek. The bacteria TMDLs calculated for these watersheds addresses the primary sources of nutrient and organic enrichment. This is because the recommended pollutant allocations for these watersheds to meet their determined bacteria TMDL calls for reductions of fecal coliform sourced from 1) cows grazing in the streams, 2) runoff from managed lands and 3) failing home sewage treatment systems. Limiting livestock and human waste from being directly discharged to streams will reduce all nutrients associated with that waste. Implementation efforts that reduce the amount of fecal coliform bacteria that runs off the land, such as filter strips in grazing lands and better pet waste removal practices in urban lands, will also directly reduce the amount of nutrients that are washed off into the streams.

The lower 14-digit HUC of Middle Nimishillen Creek (020) has 2 assessment sites that are also impaired by nutrients. These are sites on the Middle Nimishillen Creek itself, and not the mainstem Nimishillen Creek. No bacteria TMDL was necessary for this 14-digit HUC because these sites meet the primary recreational use standards (this is a more highly urbanized subwatershed). This 14-digit HUC is downstream of the 14-digit HUC 010 (upper Middle Nimishillen Creek). That entire 14-digit HUC (which includes Swartz Ditch) receives a bacteria TMDL in this report. For the same argument as explained in the previous paragraph, this bacteria TMDL should be adequate to reduce nutrients in the 14-digit HUC 020.

While the indirect manner of addressing nutrient and organic enrichment impairment for the stream reaches explained in this subsection does not fulfill expectations of a full TMDL, the bacteria TMDLs and their recommended allocations should act as a surrogate for adequately addressing these causes of impairment.

5.2 Bacteria (Pathogen) TMDL

The tables that follow (5-4 through 5-8) show the main bacteria modeling for the bacteria TMDL. These address the geometric mean (chronic) portion of the primary contact recreational use attainment, fecal coliform of 1000 cfu/100 ml. Allocation recommendations are provided. Loads for these recommendations are provided to quantitatively facilitate implementation efforts in order to meet the established TMDLs.

Table 5-4. Total existing load, TMDL and allocations of fecal coliform loads (for the recreation season)

14-Digit HUC	Subwatershed	Existing Loads[1]			TMDL[1]	% Reduction	Allocations[1]	
		PS	NPS	Total			WLA	LA
010	upper Middle Branch Nim. Ck	467.8	141.4	609.2	74.8	87.7	0.09	74.7
030	East Branch Nim. Ck	1404.0	286.3	1690.3	164.2	90.3	1.6	162.6
040	West Branch Nim. Ck	2246.7	41.1	2287.8	143.6	93.7	113.3	30.4
050	Sherrick Run[2]	560.3	6.03	566.4	35.1	93.8	29.1	6.03
060	lower mainstem Nim Ck	664.3	2.49	666.8	94.6	85.5	92.1	2.49

[1] cfu * 10^{13} * $season^{-1}$ (for cfu * 10^{13} * day^{-1} divide each value by 138)
[2] Sherrick Run is only part of this 14-digit HUC

Table 5-5. Point source fecal coliform loads. This includes existing, percent reduction required, and wasteload allocation (WLA) by source.

14-Digit HUC	Sub-Watershed	Point Source Loads[1]				
			NPDES Discharger	MS4	HSTS	**Total WLA**
010	upper Middle Branch Nimishillen Ck	Existing	0.08	0.015	467.78	467.8
		% reduction	0	24.2	100	
		Allocation	0.08	0.011	0	0.09
030	East Branch Nimishillen Ck	Existing	1.38	0.36	1402.2	1404.0
		% reduction	0	30.2	100	
		Allocation	1.38	0.25	0	1.6
040	West Branch Nimishillen Ck	Existing	0.20	0.78	2245.7	2246.7
		% reduction	0	0	95.0	
		Allocation	0.20	0.78	112.29	113.3
050	Sherrick Run[2]	Existing	0.01	0.05	560.27	560.3
		% reduction	0	0	94.8	
		Allocation	0.01	0.05	28.99	29.1
060	lower mainstem Nimishillen Ck	Existing	24.82	0.07	639.39	664.3
		% reduction	0	0	89.5	
		Allocation	24.82	0.07	67.20	92.1

[1] cfu * 10^{13} * $season^{-1}$ (for cfu * 10^{13} * day^{-1} divide each value by 138)
[2] Sherrick Run is only part of this 14-digit HUC

Table 5-6. Existing and allocated fecal coliform loads for NPDES dischargers

14-Digit HUC	Sub-watershed	Facility (NPDES permit number & name)	Existing (permitted) load[1]	% reduction	Allocated load[1]
010	upper Middle Branch Nimishillen Ck	3PR00373 Cutty's Sunset Camping Resort STU 1	0.045	0	0.045
		3PB00019 Hartville WWTP	0.029	0	0.029
		3PV00123 Shady Knoll MHP	0.004	0	0.004
030	East Branch Nimishillen Ck	3PR00279 Canaan Acres Christian	0.009	0	0.009
		3PR00273 Cornerstone Foursquare WWTP[2]	0.002	0	0.002
		3PR00336 Hot Laps Sports Bar Inc.	0.003	0	0.003
		3PR00363 Louisville Health Center	0.010	0	0.010
		3PD00033 Louisville WWTP	1.272	0	1.272
		3PG00108 Molly Stark Hospital WWTP	0.064	0	0.064
		3PT00112 North Nimishillen Elem Sch	0.004	0	0.004
040	West Branch Nimishillen Ck	3PG00082 Bob-O-Link Allt STP	0.191	0	0.191
050	Sherrick Run[3]	3PT00113 Walker Elem Sch	0.005	0	0.005
060	lower mainstem Nimishillen Ck	3PE00000 City of Canton WPCF	24.802	0	24.802
		3IN00035 US Ceramic Tile Co.	0.009	0	0.009

[1] cfu * 10^{13} * $season^{-1}$ for cfu * 10^{13} * day^{-1} divide each value by 138
[2] This facility is not currently discharging; however it has an active NPDES permit
[3] Sherrick Run is only part of this 14-digit HUC

Table 5-7. Existing and allocated fecal coliform loads for non-NPDES dischargers (estimated)

14-Digit HUC	Sub-watershed	Facility name	Existing estimated load[1]	% reduction	Allocated load WLA[1]
030	East Branch Nimishillen Ck	Bud's Corner Tavern	0.002	0	0.002
		Carriage House	0.005	0	0.005
		Elm Inn	0.003	0	0.003
		Robert Apartments	0.004	0	0.004
		Thompson Dairyland	0.004	0	0.004
		VFW	0.002	0	0.002
		Northmark Inc	0.002	0	0.002
040	West Branch Nimishillen Ck	Leno's Restaurant	0.004	0	0.004
		North Market Home Sales	0.002	0	0.002
		Whipple Center Building	0.002	0	0.002
050	Sherrick Run[2]	Arvilla Well Services Inc	0.002	0	0.002
		Roadside Tavern	0.002	0	0.002
		True Vine Ministries	0.002	0	0.002
060	lower mainstem Nimishillen Ck	Adams Fabricating	0.002	0	0.002
		Barb Huff Apartments	0.002	0	0.002
		Stanley Miller	0.002	0	0.002

[1] cfu * 10^{13} * $season^{-1}$ for cfu * 10^{13} * day^{-1} divide each value by 138
[2] Sherrick Run is only part of this 14-digit HUC

Table 5-8. Nonpoint source fecal coliform loads. These include existing, percent reduction required, and load allocation (LA) by source.

14-Digit HUC	Sub-Watershed		Non-Point Source Loads[1]					
			Cropland	Pasture	Forest	Urban[2]	Cattle in stream	Total LA
010	upper Middle Branch Nimishillen Ck	Existing	31.44	66.74	0.18	0.11	42.91	141.4
		% Reduction	24.2	24.2	0	24.2	100	
		Allocation	23.85	50.61	0.18	0.08	0	74.7
030	East Branch Nimishillen Ck	Existing	65.20	166.64	0.72	0.12	53.64	286. 3
		% Reduction	30.2	30.2	0	30.2	100	
		Allocation	45.49	116.27	0.72	0.09	0	162.6
040	West Branch Nimishillen. Ck	Existing	12.96	17.01	0.24	0.17	10.73	41.1
		% Reduction	0	0	0	0	100	
		Allocation	12.96	17.01	0.24	0.17	0	30.4
050	Sherrick Run[3]	Existing	4.37	1.29	0.32	0.05	0	6.03
		% Reduction	0	0	0	0	-	
		Allocation	4.37	1.29	0.32	0.05	0	6.03
060	lower mainstem Nimishillen Ck	Existing	0.77	0.64	0.98	0.09	0	2.49
		% Reduction	0	0	0	0	-	
		Allocation	0.77	0.64	0.98	0.09	0	2.49

[1] cfu * 10^{13} * $season^{-1}$ (for cfu * 10^{13} * day^{-1} divide each value by 138)
[2] This is non-MS4 urban
[3] Sherrick Run is only part of this 14-digit HUC

Load duration curve

Figure 5-8 is a load duration curve showing the bacteria load at various stream flows for the Nimishillen Creek at Howenstine Rd. This site is in the 060 14-digit HUC; the most downstream HUC of the Nimishillen Creek. This site is also the only site in the watershed with adequate data points throughout various stream flow levels (n= 61) for an LDC.

The curve on this plot shows the fecal coliform bacteria load for the acute, 90th percentile portion of the primary contact recreation use standard. Actual load data points, shown as pink triangles, that are above the curve indicate concentrations that exceed this maximum aspect of the target. Note that the majority of the high flow data points exceed the standard. Other exceedances are spread throughout the flow duration interval, but less in frequency in the drier conditions. Based on this plot, bacteria loading reduction implementation efforts in order to meet this aspect of the recreation use standard should be focused on the sources expected during times of higher stream flow. These sources are non point sources that come from runoff, such grazing lands and pets, and any high flow sewage treatment control issues, such as waste water treatment plant releases. While implementing management practices to meet the recommended load allocations outlined in the geometric mean portion of this TMDL, this curve supports further emphasis placed on such high flow controls.

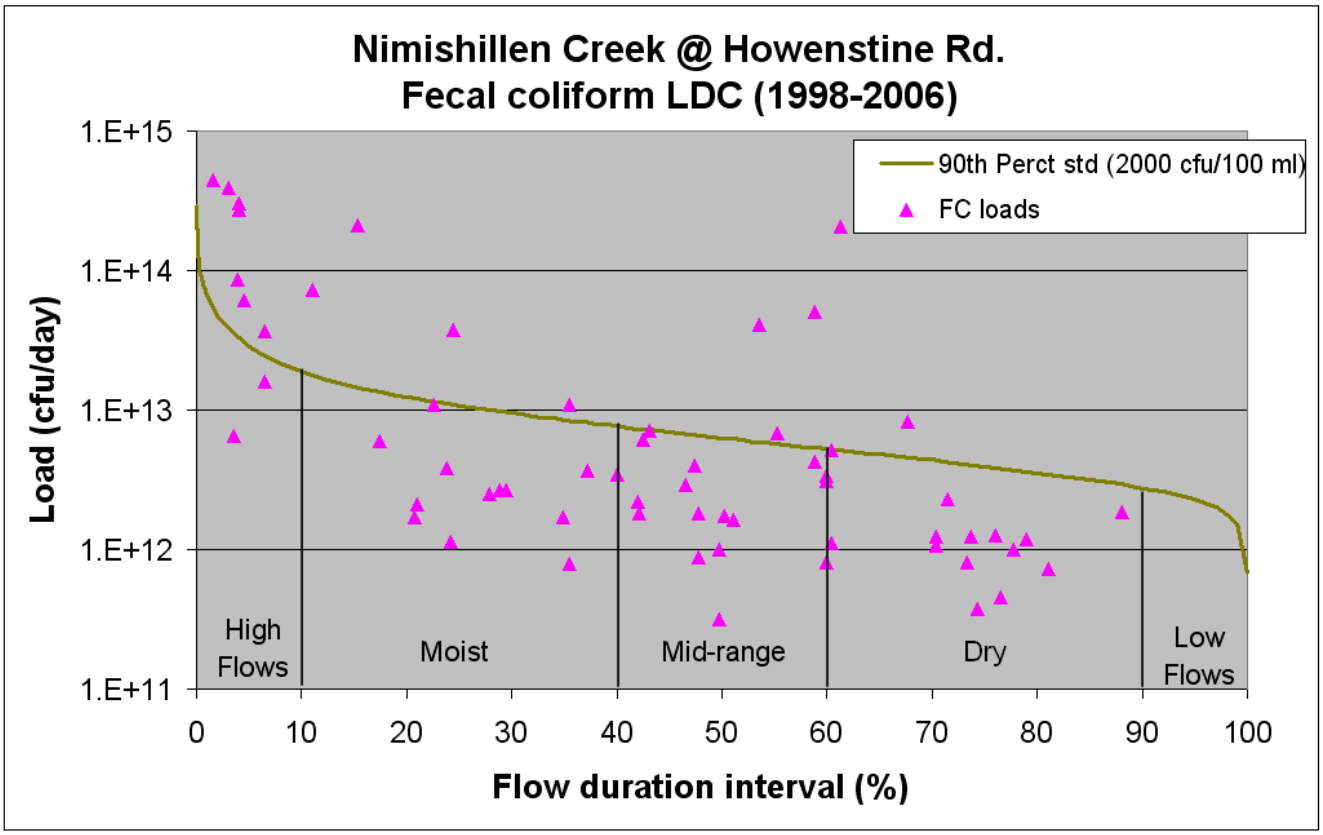


Figure 5-8. Fecal coliform LDC.

5.3 Habitat and sediment TMDLs

The following tables, 5-9 and 5-10, show the sediment and habitat TMDLs respectively. The TMDL targets are included in each table above the watershed data.

The sediment TMDL, Table 5-9, shows the three stream assessment sites that are impaired by siltation or sediment. The two sites on Middle Branch Nimishillen Creek fail to meet the expectations of the sediment TMDL. Both sites' substrate metric deviates greatest from the target. Implementation efforts targeting sediment runoff and eroding stream channel banks are appropriate to address this impairment. The West Branch Nimishillen Creek site impaired by sediment meets the sediment TMDL used in this report. That site does however fail to meet the substrate metric target. The riparian metric aspect of this TMDL was great enough to make up for the deviation in the substrate metric. The channel metric just meets the expectations of warm water habitat at this site. Based on these results, sediment is a contributing factor to this site's non attainment of warm water habitat however it may not be the most important cause of impairment in need of mitigating efforts.

Table 5-9. Sediment TMDLs

TMDL Target For WWH		Sediment TMDL					
		QHEI Categories			TOTAL TMDL SCORE		
		Substrate	Channel	Riparian			
		Allocations					
		≥ 13	≥ 14	≥ 5	32		
Existing Scores Stream/River (Use)	**River mile**	**QHEI Categories**			**Total Sediment Score**	**Deviation from target (%)**	**Main impairment category**
		Substrate	**Channel**	**Riparian**			
010 upper Middle Branch Nimishillen Creek							
Middle Br Nim. Ck	13.6	1	4	3	8	75.0	substrate
020 Middle Branch Nimishillen Creek downstream Swartz Ditch to upstream the confluence of Nimishillen Creek and West Brach Nimishillen Creek							
Middle Branch Nimishillen Creek	10.4	5.5	8	6.5	20	37.5	substrate
040 West Branch Nimishillen Creek							
West Branch Nimishillen Creek	10.5/10.4	12	14	6.5	32.5	☺	substrate

☺ Indicates the stream sites meets the TMDL.

Table 5-10 shows the habitat TMDL results. All six 14-digit HUCs in the Nimishillen Creek watershed have some habitat impairment. Each subwatershed will be discussed individually in the following paragraphs.

In the 010 14-digit HUC, the upper Middle Branch Nimishillen Creek subwatershed, two stream sites are assessed. The Middle Branch site at river mile 13.6 scores 0 out of the required 3 to meet the habitat TMDL. This site shows recent signs of channelization, exhibits all high influence attributes of modification that are possible to be scored and has the lowest total QHEI score of all sites assessed in this survey. Swartz Ditch at river mile 1.2 is also included in this table. Note that this tributary is classified as modified warm water habitat. Since this habitat TMDL is only developed for warm water habitat stream it is not fully appropriate to include Swartz Ditch here. However with the source of Swartz Ditch's impairment the same as upper Middle Branch Nimishillen Creek, channelization, implementation efforts improving the poor instream habitat of this subwatershed should be suitable to address non attainment in both streams.

Two sites on the Middle Branch Nimishillen Creek and one mainstem Nimishillen Creek site in the 020 14-digit HUC have flow alteration as a cause of impairment. All three of these sites fail to meet the habitat TMDL. Also all three sites have substrate embeddedness with moderate to heavy silt present. The Middle Branch Nimishillen Creek sites have much poorer overall habitat than the mainstem Nimishillen Creek site. Middle Branch's river mile 10.4 site shows signs of recent channelization and contains a predominant silt and/or muck substrate. The Middle Branch assessment site at river mile 6.8 shows similar modified attributes to the mainstem at river mile 14.2/14.3 however the mainstem sites contains much more positive, warm water attributes. Addressing the sources that deliver sediment to these stream assessment sites in the

upstream 010 14-digit HUC may be adequate to improve in-stream habitat. Additionally, sediment erosion controls that slow the runoff of water should also help in addressing the flow alteration cause of impairment at these sites.

Only one site in the East Branch Nimishillen Creek, 030, 14-digit watershed receives a habitat TMDL. The most downstream site, river mile 0.1, has flow alterations as a cause of impairment. This site fails to meet the habitat TMDL with 2 out of the 3 points needed. The assessment shows signs of moderate to heavy substrate/riffle embeddedness, as well as poor channel sinuosity. Occasional dewatering of this stream is not addressed by the QHEI assessment used in this habitat TMDL, but may also be a factor in this site's flow alteration cause of impairment. Addressing the nutrient cause of impairment in East Branch Nimishillen Creek subwatershed may be a more appropriate first step in implementing actions to result in full aquatic life use attainment.

The West Branch Nimishillen Creek 040 14-digit HUC fails to attain warm water habitat expectations at all of the assessment sites. The two most upstream assessment sites at river miles 10.5/10.4 and 9.3/9.0 have habitat alteration as their cause of impairment. The habitat TMDL is met at the river mile 10.5/10.4 site receiving all three allocation points narrowly. The river mile 9.3/9.0 site fails to pass the TMDL receiving 0 points. While both sites showed signs of substrate embeddedness, the 9.3/9.0 site has much poorer channel development and vegetation cover. Implementation efforts that improve the in-stream habitat at both of these sites will likely help to overcome non attainment.

The four assessment sites on the lower section of West Branch Nimishillen Creek all have flow alterations as their cause of impairment. Stream assessment indicates that the flashy nature of these streams due to urban imperviousness is the primary source of this flow alteration. Half of these sites' habitat TMDLs meet expectations, however this TMDL is not primarily focused on this type of flow alteration. Implementation that addresses stream flashiness is appropriate for the lower section of this subwatershed.

Two tributaries in the West Branch Nimishillen Creek subwatershed receive habitat TMDLs. Both McDowell Ditch and Zimber Ditch have habitat alteration and flow alteration listed as causes of impairment. McDowell Ditch is designated a modified warm water habitat stream that does not meet its aquatic life use expectations. The habitat TMDL, which is only developed for warm water habitat streams, is applied to McDowell Ditch in this report. This is done to help show the areas needing improvement at this stream assessment site. Poor channel development, especially sinuosity is the primary modified attribute of this site. The presence of a fine material substrate with embeddedness is also noted. Addressing the poor channel development in addition to reducing the flashiness of this stream due to urban runoff should help it reach attainment of modified warm water expectations. Zimber Ditch fails to meet the habitat TMDL with 2 out of the 3 needed points. Addressing habitat and flow issues in this stream as a part of implementing practices throughout the West Branch Nimishillen Creek subwatershed should improve the aquatic life in this stream. However Zimber Ditch also has an unknown cause of impairment that was not identified during the

stream assessment. Further assessment may be needed on this small tributary if other measures do not yield an acceptable aquatic life community improvement.

The 050 14-digit HUC includes one Sherrick Run site and one mainstem Nimishillen Creek site that receives a habitat TMDL in this report. The Sherrick Run site, at river mile 0.1, has flow alteration and acid mine drainage as its causes of impairment. This stream passes the habitat TMDL indicating that flow alterations are due to upstream and likely upland (i.e., not in stream channel) causes. The acid mine drainage cause of impairment is not modeled in this report, however any subsurface mine seeps contributing polluted flow to Sherrick Run may be the most effective means of remedial implementation for this tributary. The main stem Nimishillen Creek site, at river mile 11.1, included in this 14-digit HUC is impaired due to flow alteration. For this site refer to the discussion of the next 14-digit, 060, as it can easily be grouped with these sites.

All assessment sites on the most downstream 14-digit HUC in the Nimishillen Creek watershed, 060, have flow alteration as a cause of impairment. While urban runoff is the major source of this impairment, the habitat TMDL has been applied to these sites to examine their habitat attributes. Including the Nimishillen Creek site at river mile 11.1, which is in the next subwatershed upstream, these mainstem sites all have relatively similar habitat. All sites have total QHEI scores indicating healthy habitat; above 68 with the three downstream sites above 75. All sites have extensive to moderate substrate and riffle embeddedness. The two upper sites discussed here, at river miles 11.1 and 9.9, do not pass the habitat TMDL due to having too many modified attributes. In spite of this, the flashy nature of the urban runoff from contributing subwatersheds upstream are the most likely stressor and should be focused on in any implementation efforts.

Table 5-10. Habitat TMDLs

Habitat TMDL		Allocations						TMDL
		QHEI Score	# of High Influence Attributes	Total # of Modified Attributes				
TMDL Targets		≥ 60= *1 pt*	< 2 = *1 pt*	< 5 = *1 pt*				*3 pts*
					Sub-score			
Existing Scores Stream/River (Use)	**River mile**	**QHEI Score**	**# of High Influence Attributes**	**Total # of Modified Attributes**	**QHEI Score**	**High Influence**	**Tot # Mod**	**Total Habitat Score**
010 upper Middle Branch Nimishillen Creek								
Middle Br Nimishillen Ck	13.6	28	5	10	0	0	0	0
Swartz Ditch (MWH)	1.2	31.5	3	8	0	0	0	0*
020 Middle Branch Nimishillen Creek downstream Swartz Ditch to upstream the confluence of Nimishillen Creek and West Brach Nimishillen Creek								
Middle Branch Nimishillen Creek	10.4	52	2	8	0	0	0	0
	6.8	56	1	7	0	1	0	1
Nimishillen Creek	14.2/14.3	71.5	1	7	1	1	0	2
030 East Branch Nimishillen Creek								
East Branch Nimishillen Ck	0.1	60.5	1	6	1	1	0	2
040 West Branch Nimishillen Creek								
West Branch Nimishillen Creek	10.5/10.4	60.5	1	4	1	1	1	☺
	9.3/9.0	47	3	9	0	0	0	0
	4.6/4.7	58.5	1	6	0	1	0	1
	3.2	77	0	1	1	1	1	☺
	0.4/0.3	74	0	3	1	1	1	☺
	0.1	69	1	5	1	1	0	2
McDowell Ditch (MWH)	1.9/1.8	67.5	1	5	1	1	0	2*
Zimber Ditch	2.4	60	1	5	1	1	0	2
050 Nimishillen Creek downstream of West Brach Nimishillen Creek to downstream Sherrick Run								
Nimishillen Creek	11.1	68.5	1	5	1	1	0	2
Sherrick Run	0.1	78.5	0	0	1	1	1	☺
060 Nimishillen Creek downstream Sherrick Run to mouth								
Nimishillen Creek	9.9	79.5	0	6	1	1	0	2
	6.8/6.7	78	0	3	1	1	1	☺
	2.7	78	0	3	1	1	1	☺

☺ Indicates the stream sites meet the TMDL.
* Note that these two streams are designated MWH.

Another potential tool to better understand the effects of TSS on fish communities, is a dose-response model using a severity of ill effect scale (Newcombe & Jensen, 1996). The model uses data gathered from the literature to assign a score, the scale of severity (SEV), based on TSS concentrations and duration of exposure. The intent of this model is to enable the user to assign a potential effect attributable to suspended sediment in

the stream. Use of this model was discussed and considered useful in a U. S. EPA review of biological effects of sediment (Berry et al., 2003). The rating scale is included here as Figure 5-9. The TMDL equivalent target for this scale would ideally be a SEV score of 0, meaning the fish community is experiencing no effects from suspended sediment.

An analysis of data for Nimishillen Creek was completed utilizing the model for the years 1997, 1998, 1999, 2003, 2004, and 2005. Experimentation with the model indicated that some of the constants used in the predictive models did not reflect fish community observations in Nimishillen Creek and may be too conservative. Constants used in this analysis were still based on those presented in Table 3 of the paper (Newcombe & Jensen, 1996), and appeared to present a severity index more representative of what had been observed in Nimishillen Creek, they are still conservative in that they were developed for adult and juvenile salmonids. It should be noted that the addition of more data to the model would help to refine its predictive ability, pointing out a need for additional research in this area.

TABLE 1.—Scale of the severity (SEV) of ill effects associated with excess suspended sediment.

SEV	Description of effect
	Nil effect
0	No behavioral effects
	Behavioral effects
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
	Sublethal effects
4	Short-term reduction in feeding rates; short-term reduction in feeding success
5	Minor physiological stress; increase in rate of coughing; increased respiration rate
6	Moderate physiological stress
7	Moderate habitat degradation; impaired homing
8	Indications of major physiological stress; long-term reduction in feeding rate; long-term reduction in feeding success; poor condition
	Lethal and paralethal effects
9	Reduced growth rate; delayed hatching; reduced fish density
10	0–20% mortality; increased predation; moderate to severe habitat degradation
11	>20–40% mortality
12	>40–60% mortality
13	>60–80% mortality
14	>80–100% mortality

Figure 5-9. SEV Rating Table (from Newcombe & Jensen, 1996)

The results of this model are presented in Figure 5-10. As can be seen, Nimishillen Creek is generally showing severity levels greater than 7 but less than 9 (except for results based on average TSS concentration for 2003). The scores indicate that habitat degradation has occurred and some stress is being experienced by the fish community. Elevated levels of severity were found for the 2003 sampling year, which experienced significant flooding. This is in concurrence with the TMDLs prepared for siltation and habitat. The Nimishillen Creek main stem also represents the total sediment load being exported from upstream tributaries, and not necessarily generated from either instream sources or point sources in the stream.

A recent publication (Manolakos et al. 2007) indicates that habitat quality is highly correlated with fish community health, based on evaluation of Ohio EPA data. In this study, embeddedness was shown to be strongly associated with poor fish community scores (IBI). Embeddedness is also associated with siltation and TSS, lending additional importance to this source of impairment and strengthening its need to be addressed.

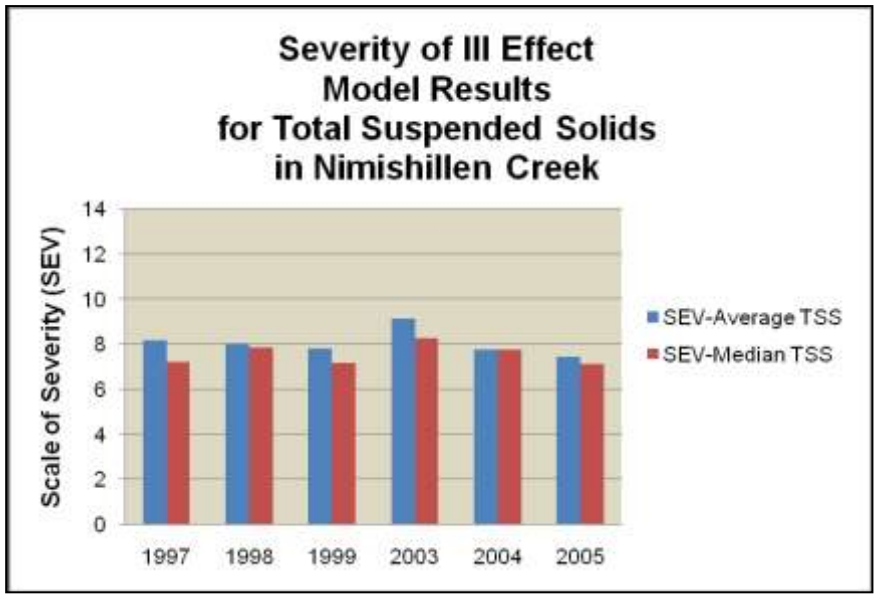


Figure 5-10. SEV scores for Nimishillen Creek

6.0 Public Participation

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 met multiple times over eighteen months and in July, 2000, issued a report to the Director of Ohio EPA on their findings and recommendations. The Nimishillen Creek watershed TMDL project has been completed utilizing the process endorsed by the advisory group.

The initial Nimishillen Creek TMDL stakeholders public meeting was held on July 18, 2007. The meeting was held in conjunction with the Nimishillen Creek Watershed Partners.

A meeting was held on November 9, 2007, at the City of Canton WWTP to discuss the implementation plan for this TMDL. The meeting was held in conjunction with the Nimishillen Creek Watershed Partners.

A meeting was held on November 29, 2007, at the Stark County SWCD to discuss USDA and SWCD involvement and recommendations for the implementation plan. The meeting was held in conjunction with the Nimishillen Creek Watershed Partners.

A meeting was held on December 4, 2007, at the City of Canton WWTP to discuss results of computer modeling completed for this TMDL. The meeting was held in conjunction with the Nimishillen Creek Watershed Partners.

A meeting on the Draft TMDL report was held on July 1, 2008. Ohio EPA issued a news release on May 38, 2008, providing notification of the meeting and the availability of the draft report.

Consistent with Ohio's continuous planning process, the public outreach activities also included a public comment period associated with the review of the preliminary TMDL report prior to its submittal to U.S. EPA Region 5. A copy of the draft report was posted on Ohio EPA's web page. A response summary to the public comments received will be included as Appendix I in the final report.

Public involvement is key to the success of this TMDL project. Ohio EPA will continue to support the implementation process and will facilitate to the fullest extent possible an agreement acceptable to the communities and stakeholders in the study area and Ohio EPA. Ohio EPA is reluctant to rely solely on regulatory actions and strongly upholds the need for voluntary actions to bring these sections of the Nimishillen Creek watershed into attainment.

7.0 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 remainder of 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

7.1 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. Recommendations being made for specific locations will be discussed in the following section, and a more detailed discussion regarding causes and sources of impairment can be found in Chapter 2 of this report.

Table 7-1. Summary of the cause/source associations for impaired recreational and/or aquatic life uses.

Watershed	Major cause of impairment addressed by reasonable assurances	
Nimishillen Creek HUC 05040001-050	• Flow Alteration • WWTP discharges • Nutrients • Crop Production	• Habitat • Siltation • Septic tanks

7.1.1 Pathogens

Recreation use impairments in the Nimishillen Creek 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 7-2. Summary of the strategies for addressing each listed cause of impairment in the Tuscarawas River watershed.

PATHOGENS	

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

HABITAT	

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

TOTAL PHOSPHORUS	

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

SEDIMENT	

• Reduce overland source loading
  ○ Reduce potential for surface erosion
  ▪ Protective cover
  ▪ Conservation tillage
  ○ Provide stream side buffering
	• Reduce in-stream erosion
	  ○ 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	

7.1.2 Habitat

In the Nimishillen Creek 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 however, 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.

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 7.2.3. 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 have 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 in-stream 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. Stream restoration generally entails greater 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 7-1 for depictions of a two-stage ditch.

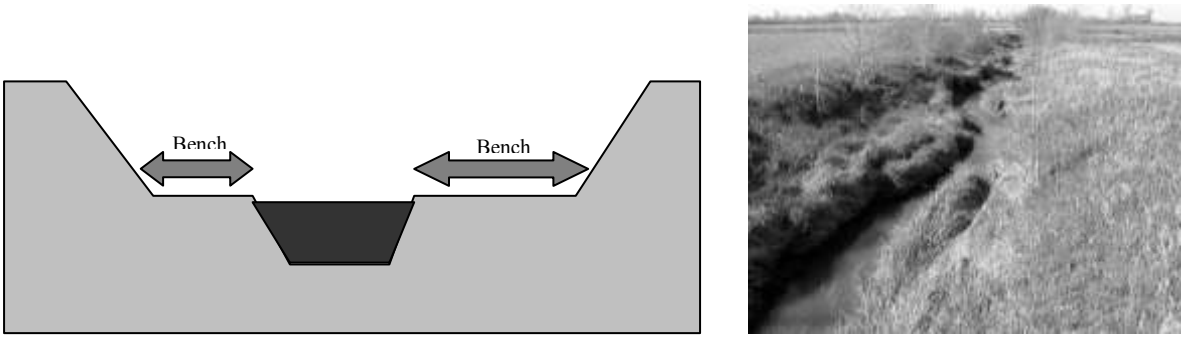


Figure 7-1. Graphical depiction of a two-stage ditch (left) and photo (right) taken in Wood County, Ohio. Notice the slight meander pattern along the ditch bottom in the picture.

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 in-stream 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 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 with whom it is particularly important to communicate 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.

Floodplains

Another very important and often overlooked mechanism to preserving and restoring healthy, stable streams is to maintain or restore adequate floodplain width at or below the elevation of the bankfull channel stage. The bankfull channel stage corresponds to the discharge that would just fill the channel to the top of its banks and be at a point where water begins to overflow onto a floodplain. This description of bankfull channel stage considers that the stream is natural and has not been disturbed by man (i.e. ditching or downcutting). The bankfull discharge associated with the bankfull stage is near the 1.5-year reoccurrence interval using the annual peak series, but may vary from a 1.1- to 1.8-year reoccurrence interval (Rosgen, 1996). Natural floodplain width varies due to geologic history, but lower gradient healthy, stable streams generally require a floodplain width of five (5) times the bankfull width of the channel and many streams prefer a floodplain width of ten (10) times the bankfull width of the channel or more (Williams, 1978) (Figure 7-2). The bankfull width of the channel is measured at the bankfull stage at the crest of the riffle.

The Federal Emergency Management Agency's (FEMA) National Flood Insurance Program (NFIP) regulations are a key part of preserving and maintaining the natural benefits of floodplains. In fact, this is one of two fundamental requirements of the NFIP. Unfortunately the minimum NFIP floodplain regulations, which most communities use, are not sufficient to preserve and maintain the natural benefits and functions of floodplains. The minimum NFIP floodplain regulations focus on the 100-year flood elevation and provide for an arbitrary 1.0-foot allowable rise in the 100-year flood elevation. This allowable rise actually encourages the filling of floodplains and the subsequent loss of flood storage volume, which increases downstream flooding and promotes local stream instabilities. Higher floodplain standards are necessary. The higher standards need to focus on the natural benefits and functions of floodplains, which can be done by each community updating their floodplain regulations to higher standards that include items such as:

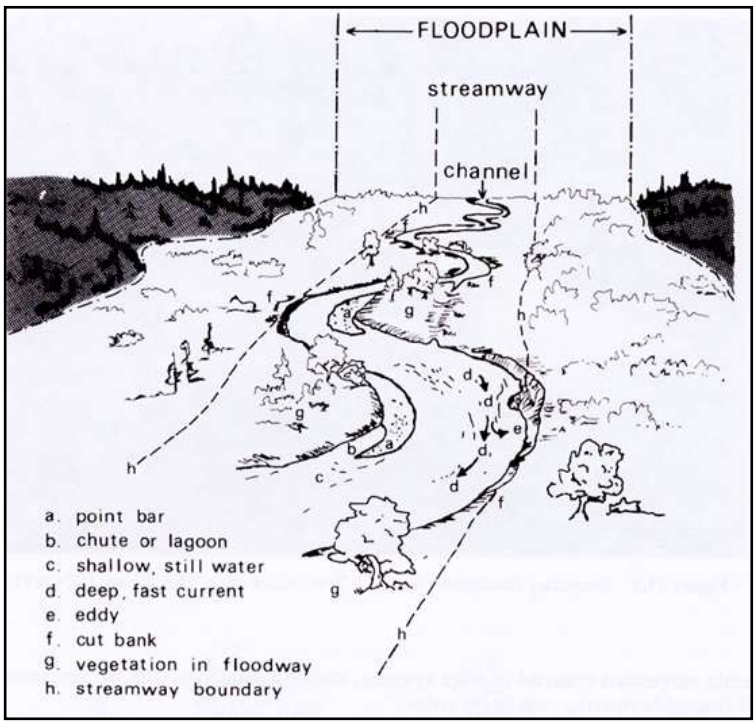


Figure 7-2. Example of streamway (minimum of 5 x bankfull width of channel and preferably larger (e.g., 10 x).

1. Reducing the allowable rise in the 100-year floodplain elevation to zero;
2. Preserving floodplain width or streamway (see Figure 7-2) of at least five (5) times the bankfull width of the channel and preferably ten (10) times the bankfull width of the channel;
3. Requiring a riparian buffer (important to reduce downstream flooding, and improves stream stability and water quality); and/or
4. Extending floodplain regulations to drainage areas of 0.25 square miles (typically floodplain regulations stop at drainage areas of about 1 square mile, but can stop at drainage areas as large as 10 square miles).

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 Nimishillen Creek watershed an effort should be made to protect, maintain, create, or facilitate the development of floodplains.

<u>Agricultural Areas</u>

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, 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 7-3.

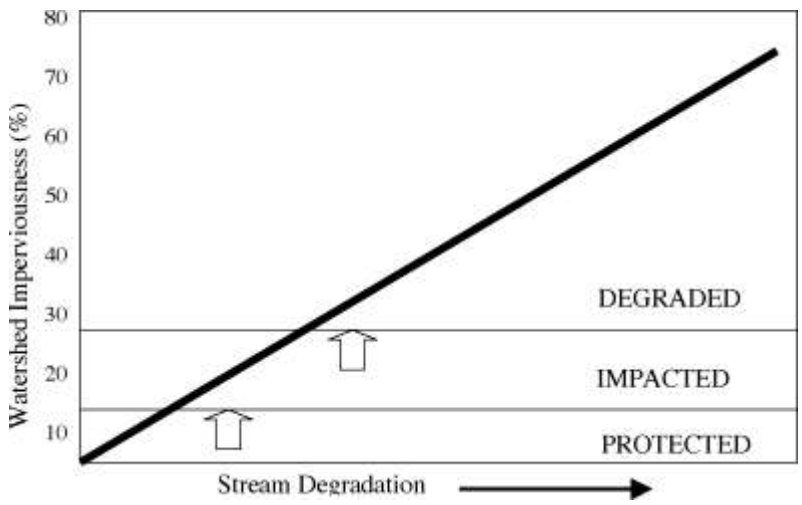


Figure 7-3. General model of relationship between stream health and imperviousness. (adapted from Schueler)

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 run off 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 watershed 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 Nimishillen Creek 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 business 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. 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 Department of Natural Resources lists a single lowhead dam on the Middle Branch Nimishillen Creek, but it is likely that other dams are in the watershed.

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 can not 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 Nimishillen Creek 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 Nimishillen Creek 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 Nimishillen Creek 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.

7.1.3 Nutrient and Sediment

Nutrient and sediment loads in the Tuscarawas River watershed are primarily due to point source discharges, polluted run-off 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 7.1.1). In the urban and developing areas of the watershed, polluted run-off 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.

While the modeling conducted for Nimishillen Creek indicated an effluent phosphorus concentration of 0.4 mg/l was needed to meet the target concentration, it did not view the watershed holistically. Although computer simulations indicate the target would be met, at this time phosphorus is not a parameter for which Ohio has a water quality standard. From a water quality standard point of view the nonattainment exists for biological criteria and bacteria. Achieving a zero phosphorus load will not ensure that the biological standard is met because of the number of other forces also acting on the biological community such as habitat, embeddedness, and flow alteration. Without addressing all impairments, complete restoration is unlikely.

The initial load reduction achieved at Canton will be 60%, with an effluent limit of 1 mg/l. Reassessment of the biological communities will be the final determinant of watershed restoration effectiveness. Effluent load allocations for phosphorus are included in Table 7-3.

Where an entity cannot immediately meet the 1 mg/l effluent limit, the discharge permit will contain a compliance schedule. The schedule will contain milestones and a time table for design, construction, and final compliance. A general schedule would involve a period of up to three years for completion of construction and final compliance. Depending on the nature and extent of work needed at an entity, the schedule can be adjusted to reflect specific milestones and time tables. An entity may elect to achieve load reductions through a water quality trading plan approved pursuant to Ohio Administrative Code Chapter 3745-5.

Table 7-3. Recommended loads of phosphorus

Facility	NPDES	Effluent Load (kg/day)
Louisville WWTP RM *	3PD00033	7.56
Republic Steel Corp. 010 outfall *	3ID00000	1.66
Republic Steel Corp. other outfalls *	3ID00000	0.09
Canton WPCF	3PE00000	147.63
Canton Water Department NE Plant	3IY00011	0.60
Marathon Ashland Petroleum	3IG00000	1.70
Timken Company	3ID00021	3.58
	Total	**162.82**

* These facilities discharge into the East Branch Nimishillen Creek watershed.

Sources from Agricultural Run-off 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 stability issues. 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 Run-off

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 are recommended. This includes reducing the amount and/or frequency of fertilizer applications. The timing of application should be such that it is unlikely immediately precede 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 in-stream biological processing therefore detritus from riparian trees and floodplains is important (Wallace et al., 1997; Baer et al., 2001; Crenshaw et al., 2002).

7.1.4 Summary

The diverse sources of impairment in the Nimishillen Creek 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 sources 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.

7.2 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.

7.2.1 Ohio EPA

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 Nimishillen Creek 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) will be 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:

1. 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.
2. Public involvement and participation in developing and implementing the Storm Water Management Plan.
3. Elimination of illicit discharges to the MS4.
4. Construction site storm water runoff ordinances that requires 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.
5. Post-construction storm water management ordinances that requires the implementation of structural and non-structural BMPs within new development and redevelopment areas, including assurances of the long-term operation of these BMPs.
6. 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 provide technical assistance to permitted entities when needed. District Office staff within the Storm Water Program respond 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 is required at a level that depends upon the original quality of the resource.

Currently there are proposed rules 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 Nimishillen Creek 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 Nimishillen Creek 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 is 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 Nimishillen Creek TMDL becomes a part of the State WQM Plan when it is approved by the U.S. EPA and the recommendation 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 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 work with state and local agencies, governments, watershed groups, and citizens.

In addressing sources of impairment related to agricultural activities, NPS staff will correspond with Ohio DNR to promote BMPs as well as cost-share and incentive based conservation programs. In particular, Ohio EPA will encourage the Ohio DNR 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 the Nimishillen Creek Watershed Partners and other interested parties active in the Nimishillen Creek 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.

7.2.2 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 Ohio DNR will be a reliable partner in addressing causes and sources of impairment in the watershed.

The following are programs and divisions within the Ohio DNR that are particularly instrumental in protecting and improving water resources within the Nimishillen Creek

watershed.

Pollution Abatement Program
Under Ohio's Pollution Abatement Rules (OAC 1501) the Ohio DNR 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 Ohio DNR 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 Ohio DNR 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 (Ohio DNR) 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 Nimishillen Creek watershed.

SWCD Program
Ohio DNR-DSWC has a cooperative working agreement with the Soil and Water Conservation Districts throughout Ohio and the NRCS. According to the agreement Ohio DNR-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 Ohio DNR work with the SWCDs to identify program needs and training opportunities. Ohio DNR also ensures that program standards and technical specifications are available to SWCDs and NRCS personnel. State matching dollars from the Ohio DNR constitute roughly half of the annual operating budgets of SWCDs.

Through the partnership established by the working agreement and their history of collaboration, Ohio DNR 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
Ohio DNR 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.

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 Ohio DNR 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 US 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 RC 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.

7.2.3 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 are 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 serve 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 maintain 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), while FSA is responsible for set-aside programs such as the Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), and the Wetland Reserve Program (WRP).

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.

Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program for people who want to develop and improve wildlife habitat primarily on private land. Through WHIP USDA's Natural Resources Conservation Service provides both technical assistance and up to 75 percent cost-share assistance to establish and improve fish and wildlife habitat. WHIP agreements between NRCS and the participant generally last from 5 to 10 years from the date the agreement is signed.

WHIP has proven to be a highly effective and widely accepted program across the country. By targeting wildlife habitat projects on all lands and aquatic areas, WHIP provides assistance to conservation minded landowners.

The Farm Security and Rural Investment Act of 2002 reauthorized WHIP as a voluntary approach to improving wildlife habitat. Program administration of WHIP is provided under the Natural Resources Conservation Service. More information on this program is available on the NRCS website at: http://www.nrcs.usda.gov/programs/whip/.

Conservation Reserve Program and Wetland Reserve Program

The Conservation Reserve and Wetland Reserve Programs (CRP and WRP, respectively) are set aside programs much like the CREP (see below), which is the enhanced version of CRP. 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 Nimishillen Creek watershed.

7.2.4 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.

7.2.5 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 which 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.

7.2.6 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.

The Stark County Health Department has provided the following information:

Longest-term outcome statement.
The County Health Department, within its jurisdictional boundaries, will evaluate the HSTS's within the urbanized area of the county within the next ten years. When failing systems are documented, they will be required to upgrade to meet current standards. However, when an area-wide failure of HSTS's is recognized, solutions will be sought that will address the affected community as a whole.

In addition, real estate transfer inspections will be conducted county-wide, by the Health Department or registered service providers. Again, when failing systems are documented, they will be required to upgrade to meet current standards

(Both goals are in addition to county-wide nuisance complaint investigation, home addition inspections, and self-help inspections already conducted by the Health Department.)

Rationale
In accordance with the requirements of the Phase II Stormwater Program (Clean Water Act) and Ohio EPA's findings in the 2008 TMDL for Nimishillen Creek, HSTS failures are recognized as a significant source of pollution causing illicit discharges into the Waters of the State. The urbanized areas of Stark County, due to the density of aging housing utilizing HSTS's, poses the highest potential impacts. It is estimated that there are approximately 17,000 HSTS's in the urbanized area of the county. Though estimations of failure rate vary widely, using a failure rate of 25% would equate to approximately 4200 failing systems, with the capacity to discharge an average of 765,000 gallons of untreated sewage per day. Stream segments affected by such discharges will likely exhibit unacceptable levels of bacteria, BOD, TSS, DO, and nutrients.

Real estate transfer inspections are an ideal time to upgrade failing systems, since funds can be easily allocated for the correction during the transfer. It also protects buyers from the financial burden they may encounter if the system is found to be failing later, if an inspection had not been conducted. Lastly, it gives the buyer an opportunity to become educated on how to properly maintain the system, improving system longevity.

The removal of illicit discharges and the correction of failing HSTS's will decrease the risk of disease transmission and improve water quality. The requirements of the Phase II Stormwater Program are satisfied and progress

is made toward attainment of TMDL standards. The bottom-line: the waters of Stark County make headway toward becoming once again fishable and swimmable.

7.2.7 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 have 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.

7.2.8 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 7.2.1.

Specific to this TMDL are revisions to Section 620 of the Stark County Subdivision Regulations which went into effect on October 4, 2005. The revised regulations were approved for adoption by the Stark County Planning Commission at its' regular monthly meeting on August 9, 2005 and adopted by the Board of Stark County Commissioners at their regular bi-weekly meeting on October 4, 2005. The revised regulations were reviewed and approved by the local engineering firms, the BIA, the Stark County Prosecutors Office, Stark County Soil & Water, the Stark County Engineer's office, the Stark County Drainage Task Force and Dave Thorley, legal counsel for the Stark County Regional Planning Commission.

Section 620 pertains to the design and construction requirements for storm water conveyance systems and storm water runoff control in new allotments as well as in new commercial and industrial developments. The Stark County Erosion and Sediment Control Regulations will continue to be the requirements pertaining to water quality standards in new allotments as well as in new commercial and industrial developments. These revisions were adopted for the following reasons:

a. *Provided a defined engineering standard or set of requirements for the development of land. The past regulations were vague and did not list specific engineering requirements for either the conveyance of storm water or for the control of storm water runoff. The*

wording given in the past regulations could be interpreted to mean different things to different people.

b. *As many parts of Stark County continue to develop into more densely populated urbanized areas, a defined standard for storm water management design was badly needed. The revised regulations do not impose unnecessary requirements or costs on Developers, but will better protect downgrade and downstream property owners as well as preventing new developments from making existing flooding problems worse or create new flooding problems.*

c. *While the Stark County Erosion and Sediment Control Regulations pertain to water quality standards, it was not possible to achieve water quality without first achieving control of storm water runoff, which the revised regulations address.*

A brief summary of some of the main requirements of the revised regulations is as follows:

a. Storm Water Collection Systems - For storm sewers, open water carriers, culverts and pavement drainage, the revised regulations refer to ODOT's Location And Design Manual Volume Two and ODOT's Construction and Material Specifications as the standard. For bridges, the revised regulations refer to ODOT's Bridge Design Manual and ODOT's Construction and Material Specifications as the standard.

b. Storm Water Runoff Control - The flow rate of storm water from a developed site must be controlled so that the following criteria are met:

1. *The peak flow of storm water from the developed site at an appropriately selected point of analysis on the earth's surface shall not exceed the peak flow of storm water from the pre-developed site at the same point of analysis for the same year frequency storm. This requirement applies for all storms with a frequency of 100 years and less.*

2. *The peak flow of storm water from the site during construction at an appropriately selected point of analysis on the earth's surface shall not exceed the peak flow of storm water from the pre-developed site at the same point of analysis for the same year frequency storm. This requirement applies for all storms with a frequency of 10 years and less. When determining the area of land disturbed during construction, an allowance shall be included for lots that are also under construction at the same time the streets are being constructed.*

3. *The flow of storm water from the developed site shall be drained to an adequate outlet. This outlet must be approved by the Subdivision Engineer and will consist of a ditch, stream, river, storm sewer, pond or lake having sufficient capacity to accommodate flow from the developed site.*

4. *The flow of storm water from the developed site must not cause flooding to proposed buildings within the development or to existing downstream homes, buildings, places of business or other structures.*

5. *Surface water draining from an existing watershed area cannot be diverted, channeled, piped or otherwise rerouted into another watershed area unless approved by the Stark County Subdivision Engineer.*

Control of storm water runoff from a developed site may be accomplished using a control structure such as a storm water management basin, underground storage tanks or pipes, storage on pavement areas, storage on roof areas or a combination of these types of control measures. The primary purpose of any storm water runoff control structure is to temporarily store water during a storm and release it at a rate that meets the runoff control criteria given previously. For new subdivisions, only detention, retention or infiltration basins may be used. The use of anything else such as an underground tank is not economically feasible and would require much larger maintenance costs than a basin. The design and construction of basins refer to the Ohio Natural Resources Conservation Service's Standard 378 as the standard and as modified in the proposed regulations.

Erosion control and water quality measures shall continue to be designed and constructed in accordance with the Stark County Erosion/Sediment Control Regulations.

c. Easements for Drainage Purposes - The main revision require public drainage for an open channel through a new subdivision that drains an area greater than ½ square mile. This easement has to have a sufficient width to contain the top width of the channel plus 20 feet along one side and 30 feet along the other side. The past regulations simply require a 75-foot wide easement for all open channels and do not address the case where the width of an open channel might take up most of the 75-foot width.

d. The revised regulations refer to ODOT's Location and Design Manual Volume Three as the general standard for construction plans.

7.2.9 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. A Watershed Action Plan for Nimishillen Creek was fully endorsed on March 16, 2007. The complete plan may be found on the Upper Tuscarawas River Region Watersheds web site at: http://www.uptuscwatershed.org/nim_state_action_plan.htm.

7.2.10 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.

7.2.11 Muskingum Watershed Conservancy District

The Muskingum Watershed Conservancy District (MWCD) 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 discusses, 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.

7.3 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 (WQS).

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

7.3.1 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., in-stream 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 (OEPA, 2006). There is one Ohio EPA ambient water quality monitoring site located within the watershed, Nimishillen Creek at North Industry. The USGS also maintains a flow gaging station at this site. Additional monitoring is also conducted as part of the NPDES permit program. Wastewater treatment plants in the watershed (Canton, Louisville, Bob-O-Link) contain upstream and downstream monitoring requirements in their discharge permits. This data will continue to be utilized as part of Ohio EPAs ongoing monitoring.

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.

Citizen monitoring of the watershed will also prove useful. Tools such as the use of sediment sticks and the ODNR Scenic River stream survey methods will help to further increase our understanding of the Nimishillen Creek watershed. In addition to providing data, more frequent stream observations can help to alert Ohio EPA and other regulatory agencies to observed water quality impacts, enabling quicker response times to potential impacts.

References:

Baker, R., P. Richards, T.L. Loftus, and J. W. Kramer. 2004. *A New Flashiness Index: Characteristics and Applications to Midwestern Rivers and Streams.* Journal of the American Water Resources Association. April, 2004

Berry, W., N. Rubenstein, B. Melzian, and B. Hill. 2003. *The Biological Effects of Suspended Sediment (SABS) in Aquatic Systems: A Review*. U.S. EPA Internal Report. August 20, 2003.

Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr., T.H. Jobes, and A.S. Donigian, Jr. 2001. Hydrological Simulation Program - Fortran (HSPF). User's Manual for Release 12. U.S. EPA National Exposure Research Laboratory, Athens, GA, in cooperation with U.S. Geological Survey, Water Resources Division, Reston, VA.

Chapra, S.C., G.J. Pelletier, and H. Tao. 2005. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.02: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Cleland, B. 2005. TMDL Development Using Duration Curves. Update & Habitat TMDL Applications. Presentation made at Region 5 TMDL Practitioners' Workshop Hickory Corners, MI. November 15, 2005.

Dai, T., R.L. Wetzel, T.R.L. Christensen, and E.A. Lewis. 2000. BasinSim 1.0: A Windows-Based Watershed Modeling Package, User's Guide. Virginia Institute of Marine Science and School of Marine Science, College of William & Mary, Gloucester Point, VA.

EPA BASINS Technical Note 6; Estimating Hydrology and Hydraulic Parameters for HSPF. 2000, Office of Water, Unites States Environmental Protection Agency

Foos, A. F. Smith, L. R. Baird, B. A. Clark-Thomas, D. W. Conner, T. E. Conte, J. N. Dennison, C. M. Indriolo, W. K. Laine, A. W. Landaw, F. G. Larkin, K. J. Lobur, J. D. Naus, and C. J. Ulle. 2000. Soil Characteristics and Vascular Plant Diversity of disturbed lands; PPG Lime Lakes in Barberton OH, and abandoned coal mines in Stark County, OH. Ohio Academy of Science.

Haith, D.A., R. Mandel, and R.S. Wu. 1992. GWLF, Generalized Watershed Loading Functions, Version 2.0, User's Manual. Department of Agricultural & Biological Engineering, Cornell University, Ithaca, NY.

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 National Land-Cover Database for the United States. *Photogrammetric Engineering & Remote Sensing* 70:7 July 2004, pp. 829–840.

Hynes, H.B.N., 1970, *The Ecology of Running Waters*, University of Toronto Press.

Low-Impact Design Strategies: An Integrated Design Approach, Prince George's County Maryland Department of Environmental Resources, June 1999.

Manolakos, E., H. Virani, and V. Novotny. 2007. *Extracting knowledge on the lilnks between the water body stressors and biotic integrity*. Water Research. 41:4041-4050.

Metcalf & Eddy. 1991. Wastewater Engineering: Treatment, Disposal, Reuse. McGraw-Hill, Inc. New York, NY.

Mostaghimi, S., T.M Younos, and U.S. Tim. 1992. Effects of sludge and chemical fertilizer application on runoff water quality. *Water Res. Bull.* 28, 545–552.

NEFCO. Northeast Ohio Four County Regional Planning and Development Organization. 2006. Nimishillen Creek Watershed - State Action Plan

Nelson, E. & D. Booth. 2002. *Sediment sources in an urbanizing, mixed land-use watershed*. Journal of Hydrology. 264, 51-68.

Newcombe, C.P. and J.O. Jensen. 1996. *Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact*. North American Journal of Fisheries Management. 16: 693-727.

Ohio Department of Development. 2003. Published material on website (http://www.odod.state.oh.us/research/). Office of Strategic Research.

Ohio EPA, 1989, *The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application*

Ohio EPA, 1995, *The Role of Biological Criteria in Water Quality Monitoring, Assessment, and Regulation*, Ohio EPA Technical Report MAS/1995- I-3

Ohio EPA. 1999. *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams*. Ohio EPA Technical Bulletin MAS/1999-1-1. Columbus, OH.

Ohio EPA. 2006. *Ohio 2006 Integrated Water Quality Monitoring and Assessment Report*. Division of Surface Water, Columbus, OH.

Pavey, R.R., R.P. Goldthwait, C.S. Brockman, D.N. Hull, E.M. Swinford, and R.G. Van Horn. 1999. Quaternary Geology; GIS Map Data. Ohio Division of Geological Survey, Columbus, Ohio

Quilbé, R., C. Serreau, S. Wicherek, C. Bernard, Y. Thomas, and J.-P. Oudinet. 2005. Nutrient Transfer by Runoff from Sewage Sludge Amended Soil under Simulated

Rainfall. *Environmental Monitoring and Assessment* (2005) 100: 177–190.

Rankin, E. T. 1989. The qualitative habitat evaluation index (QHEI), rationale, methods, and application. Ecological Assessment Section, Division of Water Quality Planning and Assessment, Ohio Environmental Protection Agency, Columbus, OH.

Rankin, E. T. 1995. The use of habitat indices in water resource quality assessments, pp. 181- 208 in Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Davis, W.S. and Simon, T.P. (eds.), Lewis Publishers, Boca Raton, FL.

Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology. Colorado, USA.

Sablak G. 2004. Link between macroinvertebrate community, riparian vegetation and channel geomorphology in agricultural drainage ditches. Master's Thesis. Ohio State University, Columbus, Ohio.

Sharpley, A.N., T. Daniel, T. Sims, J. Lemunyon, R. Stevens, and R. Parry. 2003 Agricultural Phosphorus and Eutrophication, Second Edition. ARS-149. Agricultural Research Service, United States Department of Agriculture.

Skalsky, D., L. Fischer, M. Eggert, J. Youger, 2000, Reaeration Measurement Field Methodology Using the Modified Trace Technique and Analytical Methods for Determining Reaeration Coefficients, (unpublished report). Division of Surface Water, Ohio Environmental Protection Agency.

Survey of Northeast Ohio Home Sewage Disposal Systems and Semi-Public Sewage Disposal Systems, April 2001. The report was prepared for NOACA by CT Consultants of Willoughby.
to Control Nonpoint Source Pollution from Hydromodification. EPA 841-B-07-002. Nonpoint Source Control Branch Office of Wetlands and Oceans and Watersheds Office of Water, United States Environmental Protection Agency, Washington, DC.

U.S. Census Bureau. 2000. Census 2000. Population Division, United States Census Bureau.

U.S. Census Bureau. 2005. Published material on website (http://www.census.gov/popest/estimates.php). Population Division, Projections Branch, United States Census Bureau.

U.S. Department of Agriculture. 1986. Urban Hydrology for Small Watersheds. Technical Release No. 55 (second edition). Natural Resources Conservation Service (formerly Soil Conservation Service), United States Department of Agriculture, Washington, DC.

U.S. Department of Agriculture. 1994. State Soil Geographic (STATSGO). Natural Resources Conservation Service, National Cooperative Soil Survey, United States Department of Agriculture.

U.S. Department of Agriculture. 2000. Predicting Rainfall Erosion Losses, Revised Universal Soil Loss Equation (RUSLE). From the Electronic Field Office technical Guide (http://www.nrcs.usda.gov/technical/efotg/).Ohio Natural Resources Conservation Service, United States Department of Agriculture.

U.S. Department of Agriculture. 2004. SSURGO Geographic Soil Survey. Various counties. Natural Resources Conservation Service, United States Department of Agriculture, Fort Worth, Texas.

U.S. Environmental Protection Agency. 1999. Protocol for Developing Nutrient TMDLs. First Edition. EPA 841-B-99-007. Office of Water (4503F), United States Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency. 2000. Bacterial Indicator Tool Users Guide. EPA-823-B-01-003. Office of Water, United States Environmental Protection Agency, Washington DC.

U.S. Environmental Protection Agency. 2001. Protocol for Developing Pathogen TMDLs. First Edition. EPA 841-R-00-002. Office of Water (4503F), United States Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency. 2002. Onsite Wastewater Treatment Systems Manual. EPA/625/R-00/008. Office of Water and Office of Research and Development, United States Environmental Protection Agency.

U.S. Environmental Protection Agency. 2007. National Management Measures

U.S. Geological Survey. 1996. USGS Digital Raster Graphics. EROS Data Center. United States Geological Survey, Sioux Falls.

Zhang, L. M., J.L. Morel and E. Frossard. 1990. Phosphorus Availability in Sewage Sludges, *Proceedings of the First Congress of the European Society of Agronomy*, Paris.