Total Maximum Daily Loads for Bokes Creek

Final Report

prepared by

Ohio Environmental Protection Agency
Division of Surface Water

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The TMDL in Brief:

Basin:
Bokes Creek in the Scioto Basin
Study Area:
Bokes Creek, headwaters to confluence with the Scioto River, selected tributaries; see pictorial at left
Goal:
Attainment of the appropriate Aquatic Life Use
Major Causes:
Nutrient enrichment, low dissolved oxygen, habitat alteration
Major Sources:
Agricultural runoff, failing septic systems, habitat alteration
Measure:
Total phosphorus, biological and habitat indices
Restoration Options:
Agricultural runoff controls and habitat protection and restoration

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ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

The Bokes Creek watershed encompasses 83.2 square miles in Logan, Union, and Delaware Counties in central Ohio. The Bokes Creek mainstem flows over 36 miles east-southeast from the headwaters originating in Logan County through Union County to its confluence with the Scioto River in Delaware County.

The Bokes Creek watershed was included on the 1998 303(d) list based upon a detailed chemical and biological water quality survey conducted in 1993. Since that time, Ohio EPA conducted an additional study on the watershed in 1999. The data collected during the 1999 survey is given greater weight in the water quality analysis as it is more reflective of current conditions.

Results of the 1999 water quality survey indicate that the entire Bokes Creek watershed is impacted by excessive concentrations of nutrients along with suspended solids, oxygen demanding substances, and bacteria which are often at overwhelming concentrations in the watershed. In many instances, these impacts are direct causes of water quality criteria violations or exceedences (pg. 39, Tables 13 and 14 in the 1999 Biological and Water Quality Study of Bokes Creek and Selected Tributaries). Manure spreading on agricultural fields is widespread in the basin, and runoff to streams via surface drainage or through field tiles in the area has negatively affected ambient water quality. Tile drainage has accelerated delivery of excess nutrients from agricultural fields where either waste manure application has occurred or inorganic fertilizers have been applied.

The Day Lay Egg Farms were a major source of nutrient and bacterial input to Powderlick Run and subsequently Bokes Creek. Storm water was particularly contaminated as it ran off of the Day Lay fields and facilities. This contamination was documented in the Powderlick Run headwaters from sampling during or soon after rain event(s).

Organic fertilizers/manure from two other concentrated animal feeding operations owned by Weaver's Heartland Egg Farm (one in eastern Logan County in headwaters of North Fork West Mansfield Tributary and another outside of the basin) likely have contributed to nutrient enrichment through land application of manure in the Bokes Creek drainage basin.

Headwaters and tributary areas are severely influenced by agricultural runoff including inorganic fertilizers from grain producing fields and manure from livestock operations. Failing on-site wastewater treatment systems are also problematic in the watershed (e.g., Magnetic Springs area). Modifications to the stream channels themselves (e.g., channelization, straightening, deepening) and the surrounding watershed (e.g., riparian corridor and wetland removal) have severely diminished the natural assimilative capabilities of this watershed.

Ohio's water quality standards include numerical biological criteria which form the basis of the numerical targets for the TMDLs. The success of the implementation actions resulting from the TMDLs will therefore be evaluated by observed improvements in biological scores. Intermediate nutrient targets were identified to complement the biocriteria and to help evaluate the impact of nutrient loadings. These nutrient targets were based on a recent Ohio EPA technical bulletin (Ohio EPA, 1999). Necessary loading reductions for the Bokes Creek TMDLs were estimated by comparing the instream 1999 summer concentrations to the desired targets.

Nutrient loading to the Bokes Creek watershed was simulated using the Generalized Watershed Loading Function or GWLF model (Haith et al., 1992). The complexity of this model falls between that of detailed, process-based simulation models and simple export coefficient models which do not represent variations over time. GWLF simulates precipitation-driven runoff and sediment delivery. Solids load, runoff, and ground water seepage can then be used to estimate particulate and dissolved-phase pollutant delivery to a stream, based on pollutant concentrations in soil, runoff, and ground water. GWLF has been used for TMDL development in Donegal Creek, Pennsylvania; Rock Creek Lake, Iowa; and Peña Blanca and Arivaca Lakes, Arizona and is a recommended model in U.S. EPA's Protocol for Developing Nutrient TMDLs (U.S. EPA, 1999).

Habitat was assessed using the Qualitative Habitat Evaluation Index (QHEI). The QHEI is a quantitative composite of six physical habitat variables used to 'score' a stream's habitat. QHEI targets supportive of the appropriate biocriteria have been developed based on statewide and ecoregional reference site data. The analysis of the QHEI provides a framework to develop habitat restoration and improvement strategies.

A stakeholder workgroup, the Bokes/Mill Creek Watershed Partnership, representing a variety of interests, areas, and expertise has been assisting the Ohio EPA with this project. The Bokes/Mill Creek Watershed Partnership, in conjunction with Ohio EPA, will be developing an implementation plan designed to achieve the TMDLs developed in this report during the summer and fall of 2002. The implementation plan will include agricultural runoff control strategies, septic system, point source improvements, habitat restoration, and public education strategies.

Table 1. Components of the Bokes Creek TMDL	
Study Area	Bokes Creek
1998 303(d) Listed Watersheds *(see Table 2 for segments)*	05060001 060 Scioto River (Above Bokes Creek to Above Mill Creek) 05060001 060 Bokes Creek 05060001 060 Powderlick Run
Target Identification	Nutrients and biological and habitat indices.
Applicable Water Quality Criteria	*OAC 3745-1-04* Free from suspended solids and other substances that enter the waters as a result of human activity and that will settle to form objectionable sludge deposits, or that will adversely effect aquatic life. Free from nutrients entering the waters as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae. Ecoregion Biocriteria, refer to Appendix A
Current Deviation from Target	Overall phosphorus levels exceed target values, a 19% reduction in phosphorus is necessary overall to meet targets. Biological communities fail to achieve biocriteria; refer to Appendix A.
Sources	Agriculture runoff, CAFOs, septic systems, channelization, and lack of riparian zones.
Load Allocation	Refer to Table 11
Critical/Season Conditions	The critical condition for low D.O. and algal blooms occurs when water temperatures are high and the flow is low. These conditions occur in the summer and are fueled by excessive nutrient loads. Loading reductions were determined using summer nutrient concentrations.
Safety Margin	Implicit in TMDL, refer to section 4.3
Implementation Plan	The implementation plan will involve agricultural runoff control strategies septic system and point source improvements, and habitat restoration strategies. The implementation plan will be developed in summer and fall of 2002. Conditions of a 319 grant require the preparation of a watershed action plan by the watershed coordinator by December, 2002.
Validation	Tiered approach to validation; assessment progression includes: 1. Confirmation of completion of implementation plan activities 2. Evaluation of attainment of chemical water quality criteria 3. Evaluation of biological attainment
Public Participation	Public information sessions, public notices of report, and a stakeholder group all have contributed to the public participation for this project.

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 every even-numbered year (40 CFR 130.7(d) did not require a 303(d) list submittal in the year 2000). The Ohio Environmental Protection Agency (Ohio EPA) identified the Bokes Creek watershed as a priority impaired water on the 1998 303(d) list. A summary of the Bokes Creek watershed portion of the 1998 303(d) list is included in Table 2. A general overview of Ohio's water quality standards is included in Table 5.

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. The process of formulating TMDLs for specific pollutants is, therefore, a method by which impaired water body segments are identified and restoration solutions are developed. 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.

This report serves to document the Bokes Creek TMDL process and provides for tangible actions to restore and maintain this water body. The main objectives of the report are to describe the water quality and habitat condition of Bokes Creek and to quantitatively assess the factors affecting non or partial attainment of WQS. The report is organized in sections forming the progression of the TMDL process.

The primary causes of impairment in the Bokes Creek watershed are nutrient enrichment, low instream dissolved oxygen, sedimentation, and habitat degradation. TMDLs were calculated for total phosphorus. Habitat degradation, siltation and dissolved oxygen depletion are not load based quantities; however, the regulations provide for these types of impairing causes and 'TMDL' numbers were calculated for these as well.

Table 2. Summary of the 303(d) listed waters included in this TMDL report

Waterbody Segment Description [Identification Number]	**303(d)[1] Status**		**Major causes 303(d)**	**Included in this report?[3]**	**Comments**
	1998	**2002**			
05060001 060	Scioto River (Above Bokes Creek to Above Mill Creek)				Impairment Rank[2] 8
Bokes Creek (Brush Run to Scioto River) [OH35 15]	✓		Nutrients	✓	Total phosphorus (limiting nutrient) only.
	✓		Unknown Toxicity	No	These causes were identified in the 1999 basin survey .
	✓		Siltation	✓	Not a load based parameter; activities implemented to meet nutrient targets will also address this cause.
		✓	Organic Enrichment/D.O .	✓	Low D.O. measured. Due to onsite WWT at Magnetic Springs and influences from Smith Run. Activities implemented to meet nutrient targets will also address this cause.
		✓	Habitat Alteration	✓	Not a load based parameter, allocations included.
		✓	Flow Alteration	✓	Not a load based parameter; activities implemented to meet nutrient targets that result in improvements to habitat will also address this cause
Bokes Creek (Headwaters to Brush Run) [OH35 18]	✓		Nutrients	✓	Total phosphorus (limiting nutrient) only.
	✓		Unknown Toxicity	No	These causes were identified in the 1999 basin survey data.
	✓		Habitat Alteration	✓	Not a load based parameter, allocations included.
	✓		Siltation	✓	Activities implemented to meet nutrient targets will also address this cause.
		✓	Organic Enrichment/D.O.	✓	Activities implemented to meet nutrient targets will also address this cause.
		✓	Flow Alteration	✓	Not a load based parameter; activities implemented to meet nutrient targets that result in improvements to habitat will also address this cause.
		✓	Ammonia	✓	Activities implemented in the headwaters to meet nutrient targets will also address this cause.
Powderlick Run [OH35 19]	✓		Nutrients	✓	Total phosphorus (limiting nutrient) only.
	✓		Habitat Alteration	✓	Not a load based parameter; allocations included.
	✓		Organic Enrichment/D.O.	✓	Activities implemented to meet nutrient targets will also address this cause.

Table 2. Summary of the 303(d) listed waters included in this TMDL report

Waterbody Segment Description [Identification Number]	303(d)[1] Status		Major causes 303(d)	Included in this report? [3]	Comments
	1998	2002			
		✓	Siltation	✓	Activities implemented to meet nutrient targets will also address this cause.
		✓	Flow Alteration	✓	Not a load based parameter; activities implemented to meet nutrient targets that result in improvements to habitat will also address this cause.
		✓	TDS/Salinity	✓	The point source discharge of filter backwash water from Day Lay Egg farm has been eliminated, thus the source has been removed.
		✓	Ammonia	✓	This cause is listed as a result of a spill of egg wash wastewater. Installation of improved egg wash wastewater handling technology has eliminated the source.
Tributary to Powderlick Run [OH35 19.1]		✓	Organic Enrichment/D.O.	✓	Activities implemented to meet nutrient targets will also address this cause.
		✓	Ammonia	✓	This cause is listed as a result of a spill of egg wash wastewater. Installation of improved egg wash wastewater handling technology has eliminated the source.
		✓	TDS/Salinity	✓	The point source discharge of filter backwash water from Day Lay Egg farm has been eliminated.
Brush Run [OH35 17]		✓	Organic Enrichment/D.O.	✓	Activities implemented to meet nutrient targets will also address this cause.
		✓	Nutrients	✓*	Total phosphorus (limiting nutrient) only. Target value based on upper Bokes Creek targets.
		✓	Siltation	✓	Activities implemented to meet nutrient targets will also address this cause.
West Fork West Mansfield Tributary [OH35 21]	✓		Organic Enrichment/D.O.	✓	Activities implemented to meet nutrient targets will also address this cause.
	✓		Habitat Alteration	✓	Not a load based parameter; allocations included.
		✓	Siltation	✓	Activities implemented to meet nutrient targets will also address this cause.
		✓	Nutrients	✓	Total phosphorus (limiting nutrient) only.
		✓	Flow Alteration	✓	Not a load based parameter; activities implemented to meet nutrient targets that result in improvements to habitat will also address this cause.

Table 2. Summary of the 303(d) listed waters included in this TMDL report

Waterbody Segment Description [Identification Number]	303(d)[1] Status 1998	303(d)[1] Status 2002	Major causes 303(d)	Included in this report? [3]	Comments
North Fork West Mansfield Tributary [OH35 20]		✓	Organic Enrichment/D.O.	✓	Attributed to a CAFO engaged in egg production. Activities implemented to meet nutrient targets will also address this cause.
		✓	Nutrients	✓	Attributed to a CAFO engaged in egg production. Total phosphorus (limiting nutrient) only.
		✓	Habitat alteration	✓	Not a load based parameter; allocations included.
		✓	Siltation	✓	Activities implemented to meet nutrient targets will also address this cause.
South Branch West Fork West Mansfield Tributary [OH35 21.1]		✓	Organic Enrichment/D.O.	✓	Attributed to a combination of the W. Mansfield WWTP spray field, on-site WWT at houses, and cattle. Habitat improvements are expected to deal with this cause.
		✓	Habitat Alteration	✓	Not a load based parameter, allocations included..
		✓	TDS/Salinity	✓	Attributed to a combination of the W. Mansfield WWTP spray field, on-site WWT at houses, and cattle. Habitat improvements are expected to deal with this cause.
		✓	Flow Alteration	✓	Improvements to meet habitat targets are expected to deal with this cause.
Smith Run [OH35 16]		✓	Organic Enrichment/D.O.	✓	Activities implemented to meet nutrient targets will also address this cause.
		✓	Nutrients	✓	Total phosphorus (limiting nutrient) only
		✓	Habitat Alteration	✓	Not a load based parameter; allocations included.
		✓	Flow Alteration	✓	Not a load based parameter; activities implemented to meet nutrient targets that result in improvements to habitat will also address this cause.
		✓	Siltation	✓	Activities implemented to meet nutrient targets will also address this cause.
Scioto River (Bokes Creek to Mill Creek) [OH35 12]	✓		Organic Enrichment/D.O.	☺	This segment is in full attainment, and will be delisted in the 2002 303(d).

Table 2. Summary of the 303(d) listed waters included in this TMDL report

Waterbody Segment Description [Identification Number]	303(d)[1] Status		Major causes 303(d)	Included in this report? [3]	Comments
	1998	2002			
White Sulphur Lake [OH35 12-106]	✓		Not described	☺	This segment is in full attainment, and will be delisted in the 2002 303(d).

1 The 1998 303(d) list was based on data collected in 1993 or before. This report also includes more current data collected in 1999 after the 1998 303(d) list was complete. These data will form the basis for future potential listing when the 2002 303(d) list is prepared, public noticed, and finalized.

2 The impairment rank is Ohio EPA's prioritization of the various impaired subwatersheds; refer to Ohio EPA's 1998 303(d) list available at: http://www.epa.state.oh.us/dsw/tmdl/303dnotc.html for more information.

3 TMDL numbers are included for total phosphorus. Low D.O. and altered habitat are not load based causes of impairment. Allocations for factors affecting instream D.O. (e.g. TP) and habitat (components of the QHEI scores) are included and are considered to be a parallel concept to a 'TMDL' for load-based parameters.

• The total phosphorus target for Brush Run is based on the target for the upper Bokes watershed. The sampling site was mostly dry during the water quality survey, data does not exist to calculate a specific target for this stream.

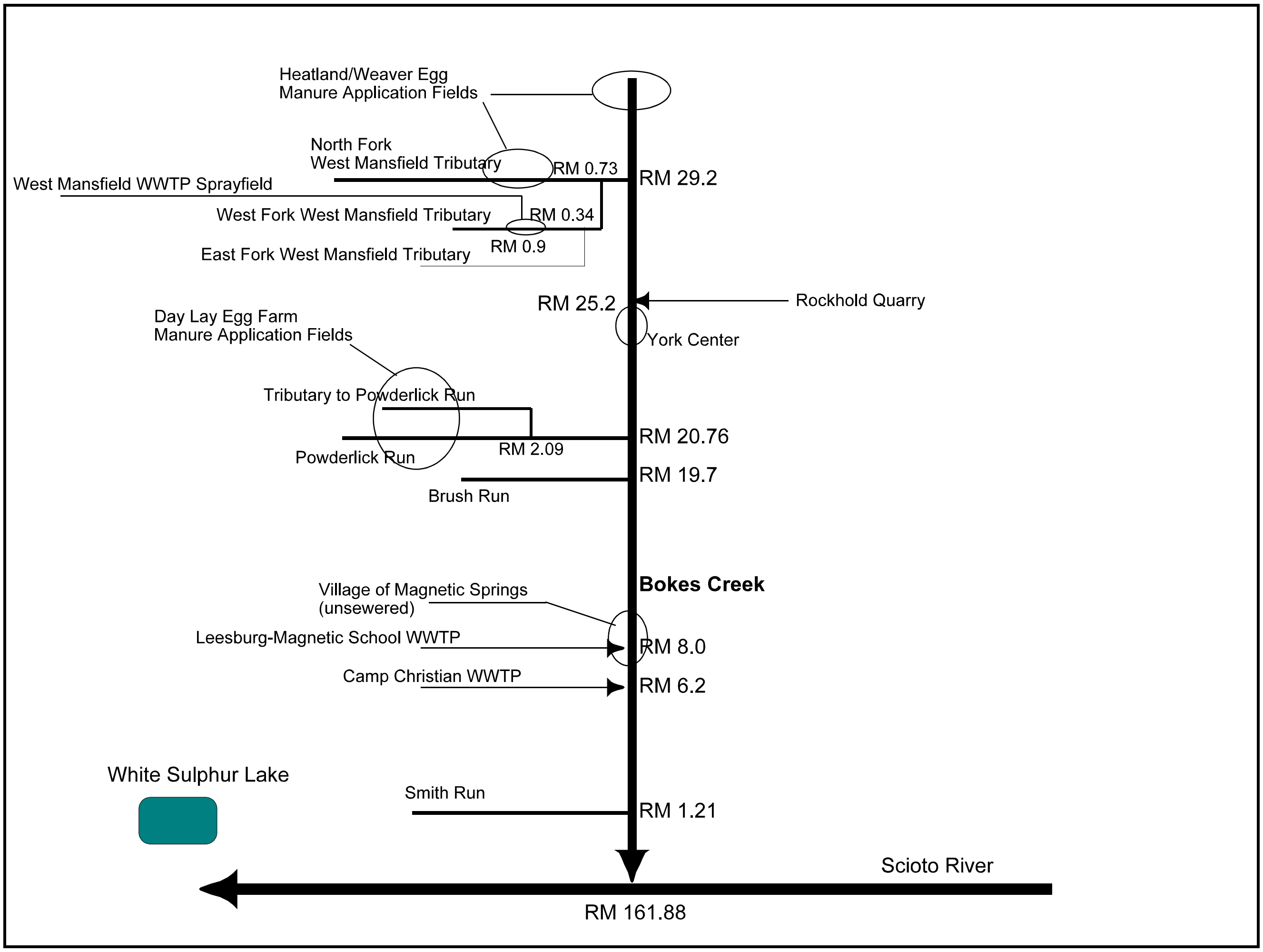


Figure 1. A schematic representation of the Bokes Creek Watershed.

2.0 WATERBODY OVERVIEW

2.1 Description of the Study Area

The Bokes Creek watershed encompasses 83.2 square miles in Logan, Union, and Delaware Counties in central Ohio. The Bokes Creek mainstem flows over 36 miles east-southeast from the headwaters originating in Logan County through Union County to its confluence with the Scioto River in Delaware County. The stream basin is entirely within the Eastern Corn Belt Plains ecoregion (Omernik, 1988). The stream's elevation decreases from approximately 1,050 feet above mean sea level (MSL) at its source to 872 feet above MSL at its mouth with an average 6.3 feet per mile gradient (ODNR, 1954). Local relief is generally less than 50 feet. Valleys are typically narrow and shallow. Bokes Creek's major tributaries are Smith Run, Brush Run, West Mansfield Tributary, and Powderlick Run. The gradient of these tributaries is generally much steeper than the mainstem (Table 3; Ohio DNR, 1954; Ohio EPA,1995b).

Soils in the Bokes Creek watershed reflect the influences of the original deciduous forest cover and continental glaciation. They are mainly a loamy calcareous glacial till, overlain by loess deposits in some southern portions of the ecoregion. Soil parent materials are comprised of glacial till, glacial outwash, or recent alluvium via in-stream post-glacial transport from gently rolling glacial till plain intersected by moraines, kames, and outwash plains (U.S. EPA, 1988).

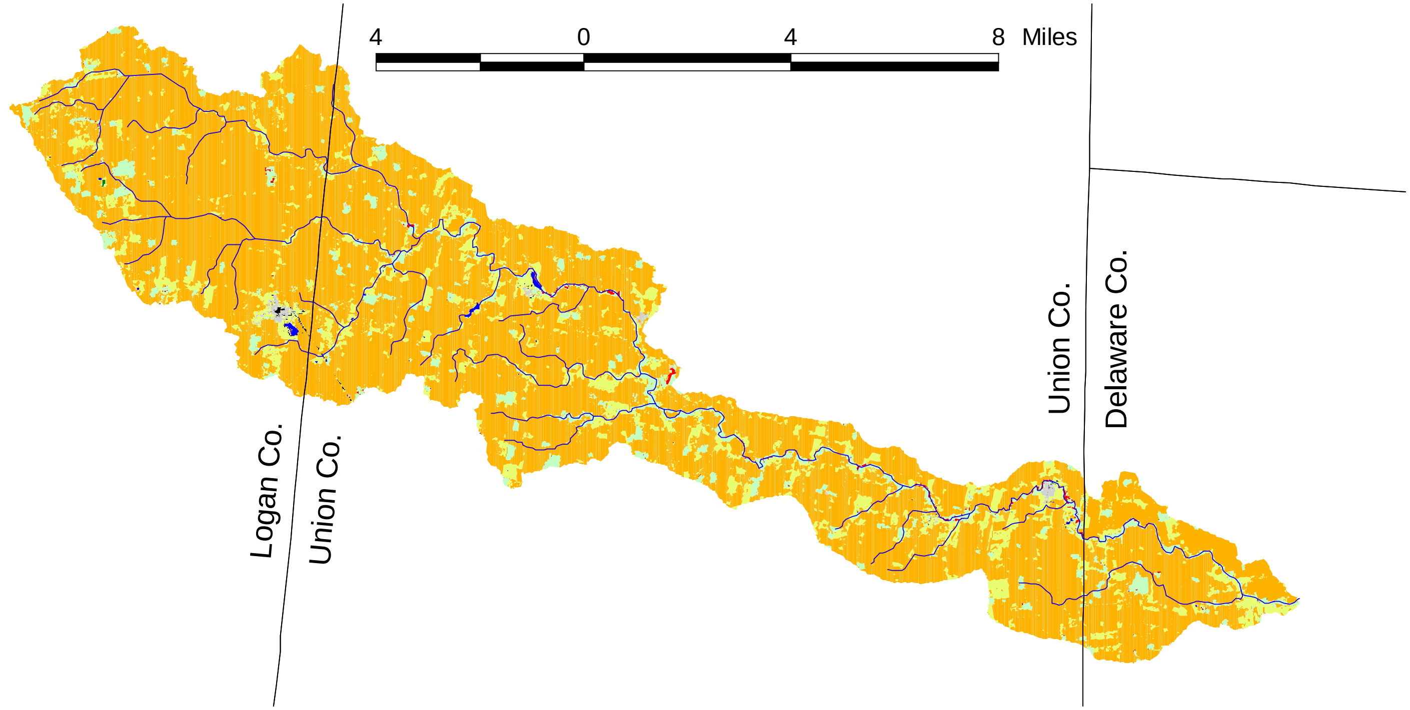
Artificial drainage augments the poor natural drainage in the Bokes Creek Basin, and portions of Bokes Creek itself as well as some of its tributaries were/are modified to promote drainage. Estimates from the United State Department of Agriculture (USDA) - Natural Resources Conservation Service (NRCS) indicate that greater than10 percent of the Bokes Creek watershed is considered Highly Erodible Land based on the 1982 National Resource Inventory data base (USDA, 1993).

The Bokes Creek watershed is used predominately for crop-based agriculture, with some livestock operations (Figure 2). Ohio EPA regulated facilities in the basin include the West Mansfield WWTP (land application of treated wastewater via sprayfield), Heartland Egg Farm (Weaver) in eastern Logan County (North Fork West Mansfield Creek and Bokes Creek), and Daylay and Mad River Egg Farms (Powderlick Run). The percentage of land in deciduous forests from the headwaters in Logan County downstream to the mouth decreases from 24 percent to 6 percent coverage. Rowcrop agriculture increases from 47 percent in the headwaters to 85 percent near the mouth (Ohio EPA, 1995b). Waste application from egg production is a major contributor to nutrient loads on agricultural fields in the watershed (especially the upper portion). Current land use trends have increased the potential for nonpoint source pollution of the stream system. Failing on-site septic systems in towns such as York Center and Magnetic Springs have likely contributed to nutrient enrichment in Bokes Creek (Ohio EPA, 1995a,1995b).

Table 3. Stream Characteristics of Bokes Creek Watershed

Stream Length	Length (miles)	Average Fall (feet per mile)	Drainage Area (square miles)
Bokes Creek	39.7	6.3	83.2
North Fork West Mansfield Tributary	8.8	12.5	8.8
West Fork West Mansfield Tributary	2.5	8.0	5.2
East Fork West Mansfield Tributary	2.67	15.0	1.6
South Branch West Fork West Mansfield Trib	2.40	24.4	2.8
Powderlick Run	5.1	16.8	3.84
Smith Run	4.9	11.0	5.94
Brush Run	3.2	25.3	3.38

Source: (Ohio DNR, 1954)



Categories	Acres	Percent
Open Water	71.0	0.1
Low Intensity Residential	168.0	0.3
High Intensity Residential	15.0	0.0
Commercial/Industrial/Transportation	36.0	0.1
Deciduous Forest	3447.	6.5
Evergreen Forest	8.0	0.0
Mixed Forest	0.2	0.0
Pasture/Hay	6167.	11.6
Row Crops	43148	81.0
Woody Wetlands	156.0	0.3
Emergent Herbaceous Wetlands	32.0	0.1

Figure 2. Land use in the Bokes Creek watershed.

Table 4. Streams and significant identified pollution sources in Bokes Creek study area

Stream Name	**Nonpoint Source Pollution Issues**	**Point Sources Present**
Bokes Creek	•Agriculture •Storm runoff nutrient inputs •Sedimentation •On-Site septic inputs from unsewered towns •Cattle encroachment	
West Fork West Mansfield Tributary	•Agriculture •Storm runoff nutrient inputs from WWTP application or egg farm nutrient application •Sedimentation •Cattle encroachment	West Mansfield WWTP (sprayfield application)
South Branch West Fork West Mansfield Tributary (and) Mayor Painter Ditch	•Agriculture •Storm runoff nutrient input from WWTP spray irrigation •Sedimentation •On-site septic systems	West Mansfield WWTP (sprayfield irrigation)
North Fork West Mansfield Tributary	•Agriculture •Storm runoff nutrient inputs from egg farm manure applications •Septic systems •Sedimentation •Cattle encroachment	Heartland Egg Farm (Weaver) Facility in headwaters in extreme eastern Logan County
East Fork West Mansfield Tributary	•Agriculture •Storm runoff nutrient inputs from egg farm manure applications •Sedimentation	
Powderlick Run	•Agriculture •Storm runoff nutrient inputs from egg farm manure applications •On-site septic systems •Sedimentation •Cattle encroachment	Daylay Egg Production Facilities #1, #2, and #3 Mad River Egg Facility
Brush Run	•Agriculture •Storm runoff nutrient inputs from egg farm manure applications •On-site septic systems •Sedimentation	
Smith Run	•Agriculture •Storm runoff nutrient inputs from egg farm manure applications •On-site septic systems •Sedimentation	

2.2 Water Quality and Biological 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 5 provides a brief description of Ohio's water quality standards. Further information is available in Chapter 3745-1 of the Ohio Administrative Code (OAC) (http://www.epa.state.oh.us/dsw/wqs/criteria.html).

In the Bokes Creek study area, the aquatic life use designations that apply to various 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 diverse warmwater aquatic organisms. Waters designated Modified Warmwater Habitat are incapable of supporting and maintaining a balanced, integrated community of diverse warmwater organisms due to irreversible physical habitat modifications. Modified Warmwater Habitat communities have low abundance or an absence of sensitive species and an increasing predominance of tolerant organisms comprising the community structure. Limited Resource Water designated streams have been found to lack the potential for supporting anything other than a limited, non-diverse biological community due to either natural background conditions or very altered habitat attributes as a result of human activity. The biological community in a LRW stream reach will have no sensitive species with low to very low number of species comprised primarily of tolerant organisms. The LRW designation is temporary, thus the stream reach will be reviewed periodically and can be subject to an upgrade in designation.

Attainment of aquatic life uses is measured in two ways. First, criteria in the WQS for various pollutants are compared to measurements taken from the water column to determine attainment for specific pollutants. Second, attainment is determined by directly measuring fish and aquatic bug populations to see if they are comparable to those seen in least impacted areas of the same ecological region and aquatic life use. 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 the stream biota do not achieve the biocriteria (fish: Index of Biotic Integrity (IBI) and modified Index of Well-being (MIwb); aquatic bugs: Invertebrate Community Index (ICI)) the stream is considered in "non attainment" of its designated use. If the fish and bug communities instream meet some of the biological criteria, but not others, the stream is in "partial attainment". A stream that is in "partial attainment" is not attaining its designated aquatic life use, whereas a stream that has a healthy, balanced biota, which meets all three of the biocriteria benchmarks, is in “full attainment” of its designated use.

Table 5. Summary of the components and examples of Ohio's Water Quality Standards

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) • 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 potentially be 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 bug (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 '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, and nutrients in concentrations that may cause nuisance algal blooms.	
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 type of beneficial use in the WQS is for recreational purposes. The recreational use for the Bokes Creek mainstem study area is Primary Contact Recreation (PCR). The two criteria for the PCR designation are a water depth of at least one meter over an area of at least 100 square feet or that canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion, the Secondary Contact Recreation (SCR) use applies. All sampled tributaries to Bokes Creek are designated as SCR. The attainment status of PCR and SCR is determined using bacterial indicators; the criteria for each are specified in the Ohio WQS.

For the Bokes Creek TMDL, Ohio EPA conducted a detailed assessment of chemical (water column, effluent, sediment), physical (flows, habitat), and biological (fish and aquatic bug) conditions in order to determine if streams and rivers in the study area were attaining their designated uses. The basis for the listing of Bokes Creek on the 303(d) list is the measurements that were obtained in an assessment conducted in 1993 (Ohio EPA, 1995a). Ohio EPA re-assessed the Bokes Creek study area in 1999 (Ohio EPA, 2000). This TMDL report addresses both the results in the 303(d) list based on 1993 data and the results of the 1999 assessment. However, greater weight is given to the 1999 data, as it is most reflective of current watershed conditions. An aquatic life use attainment table for the Bokes Creek study area is provided in Appendix A (Table A1).

2.2.1 Aquatic Life Use Attainment Status

Aquatic life use attainment status in Bokes Creek is shown in Figure 3. The detailed table that summarizes aquatic life use attainment status is included as Table A1 in Appendix A to this report.

2.2.1.1 Bokes Creek

The 1999 Bokes Creek study area included a mainstem reach beginning at river mile (RM) 36.3 (State Route 292) and extending downstream to the mouth and sites on six tributaries. Ambient mainstem water column chemical, physical and bacteriological sampling occurred at 10 stations; biological sampling occurred on 10 segments (Appendix A, Table A1). Based on the performance of biological communities with respect to ecoregional biocriteria, only 9.6 % (3.5 miles) of Bokes Creek was considered in Full attainment of the WWH aquatic life use designation (Figure 3). Partial attainment of the WWH use was demonstrated in 19.5 miles (53.4 %) of the stream, primarily in the middle and lower reaches of Bokes Creek. Non attainment of the WWH (and the short reach of MWH) use was documented in the headwaters and in the dissolved oxygen (D.O.) "sag zone" 2 to 4 miles downstream from the confluence of Powderlick Run for a total of 13.5 river miles (37.1 %). The narrative level of performance of the biological community was characterized as fair to marginally good.

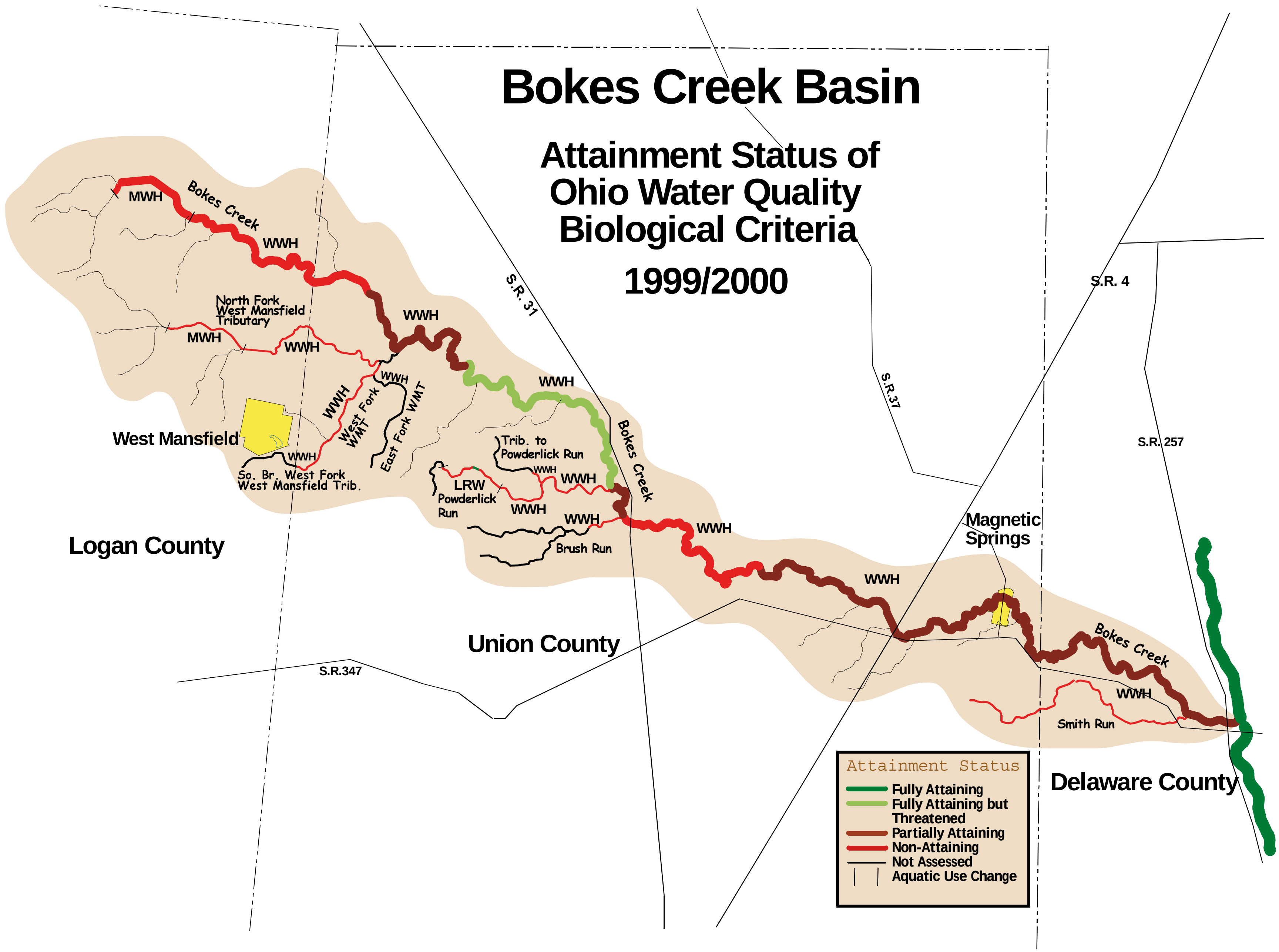


Figure 3. Aquatic Life Use Attainment Status in the Bokes Creek Basin

The non-attainment in the headwater reaches of Bokes Creek was related primarily to excessive agricultural nonpoint source pollution inputs, inadequate nighttime dissolved oxygen (D.O.) concentrations, and habitat deficiencies. Evidence of nutrient enrichment and some sedimentation was present throughout the Bokes Creek mainstem. Biological communities representative of WWH were present in most reaches except the headwaters. Physical habitat conditions were generally sufficient to support WWH biological communities in most areas except the headwaters. Where habitat conditions in Bokes Creek were marginally good to good (QHEI greater than 58-60) the biological community generally attained or partially attained the WWH biological criteria. The WWH stream use designation was retained for most of the Bokes Creek mainstem, except for an upper portion of the headwater reach, which was revised to MWH.

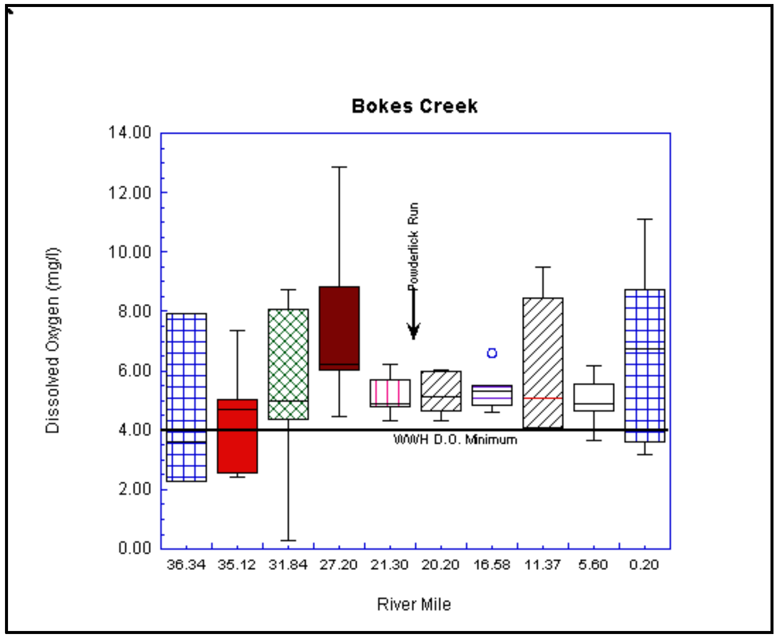


Figure 4. Dissolved oxygen in Bokes Creek

2.2.1.2 Tributaries

Biological samples were collected at 16 locations on various tributaries where water column chemical, physical and bacteriological data were recorded. These tributaries included North Fork West Mansfield Tributary, West Fork West Mansfield Tributary, South Branch West Fork West Mansfield Tributary, Powderlick Run, Unnamed Tributary to Powderlick Run (@ RM 2.0), Brush Run, and Smith Run. All tributary locations surveyed throughout the basin failed to meet the assigned WWH aquatic life use as determined by the applicable biological criteria. Eggwash wastewater spills, nonpoint source pollution (nutrients, manure, sediment runoff from agricultural operations), runoff from land application of treated municipal wastewater, malfunctioning on-site sewage treatment systems from unsewered communities, and habitat deficiencies all contributed to degradation of chemical water quality and the associated aquatic biological communities. The potential for a WWH biological community was present in the majority of the tributary stream reaches sampled based on habitat evaluations, so the WWH aquatic life use designations were retained in almost all of the segments.

2.2.2 Conclusions from 1999 Water Quality Survey

The Bokes Creek mainstem supports fair to marginally good macroinvertebrate and fish communities. With the exception of headwater reaches and a 4-mile segment downstream from Powderlick Run, all 1999 mainstem sampling locations at least partially attained WWH ecoregional expectations.

Habitat conditions in Bokes Creek were fairly consistent with the biological performance except for the RM 17.0 site which was influenced biochemically by nutrient inputs from the Powderlick Run subbasin upstream. Better performance in the watershed was usually correlated with better habitat and wider riparian zones (more efficient nutrient and sediment absorption, assimilation, and buffering capacity).

The entire Bokes Creek watershed is impacted by excessive concentrations of nutrients along with suspended solids, oxygen demanding substances, and bacteria. Dissolved oxygen concentrations were very low, often below the minimum WQS of 4 mg/l (Figure 4). Bacterial exceedences in 1999 (Figure 5) confirmed an earlier Ohio Wesleyan University study that indicated high Salmonella and fecal coliform bacterial concentrations instream (Bowen et al, 1994). Also, an Ohio Wesleyan University plankton study found an excess diatom population and high cyanobacteria concentrations which indicated moderate nitrogen pollution and a eutrophic environment with high inorganic content (Ing Wei Khor, 1994). Nutrients, along with suspended solids, oxygen demanding substances, and bacteria are often at overwhelming concentrations in the watershed. In many instances, these impacts are direct causes of water quality criteria violations or exceedences (pg. 39, Tables 13 and 14 in the 1999 Biological and Water Quality Study of Bokes Creek and Selected Tributaries). Manure spreading on agricultural fields is widespread in the basin, and runoff to streams via surface drainage or through field tiles in the area has negatively affected ambient water quality (Figure 6). Tile drainage has accelerated delivery of excess nutrients from agricultural fields where either waste manure application has occurred or inorganic fertilizers have been applied.

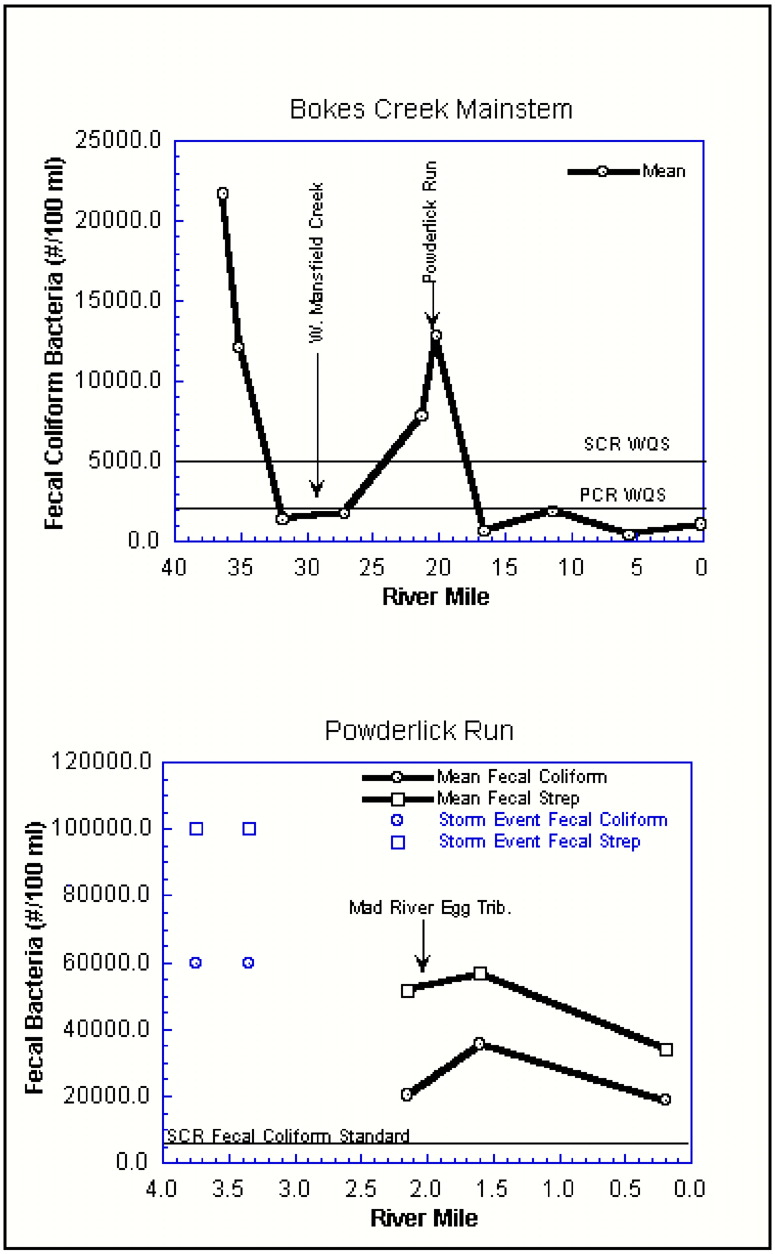


Figure 5. Bacteria levels measured in Bokes Creek and Powderlick Run.

The Day Lay Egg Farms were a major source of nutrient and bacterial input to Powderlick Run and subsequently Bokes Creek. Storm water was particularly contaminated as it ran off of the Day Lay fields and facilities. This contamination was documented in the Powderlick Run

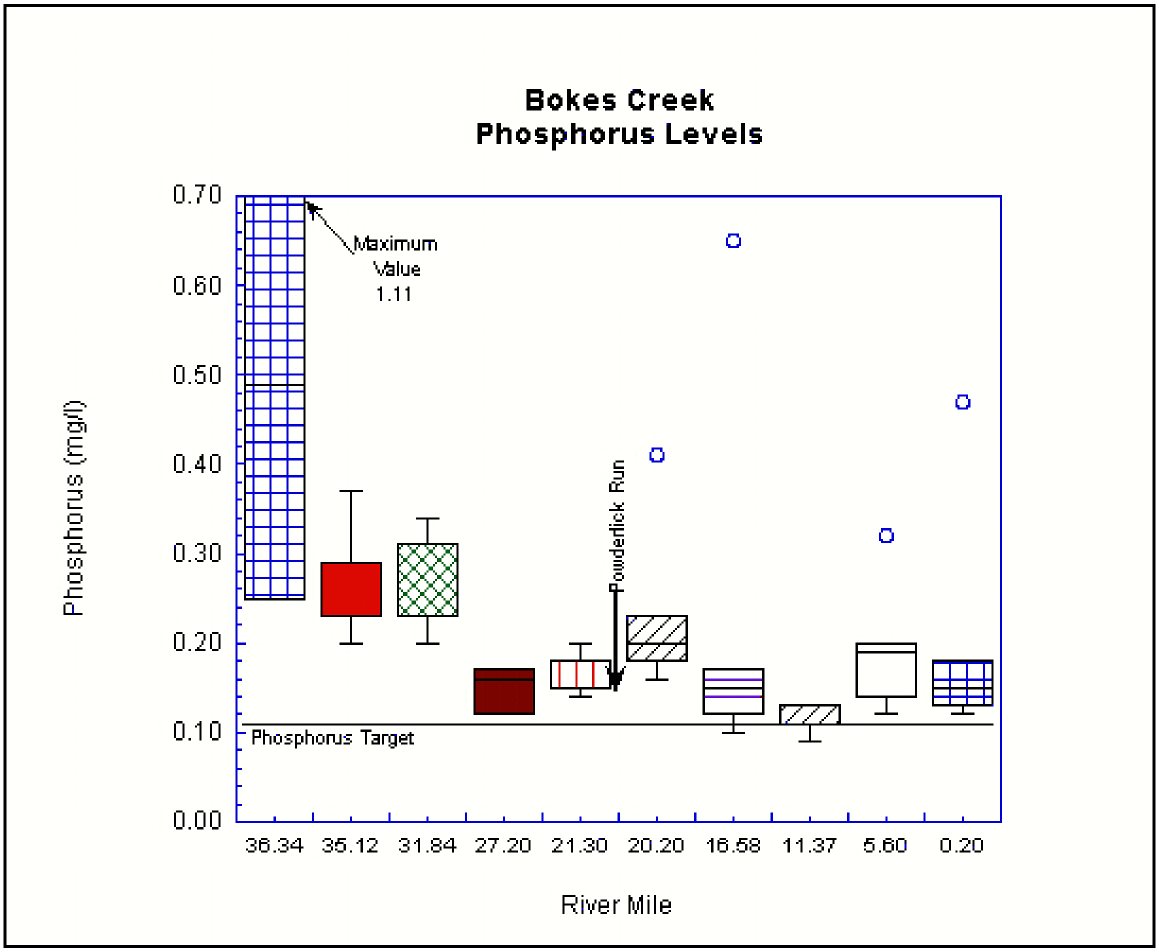


Figure 6. Phosphorus levels measured in Bokes Creek during the 1999 water quality survey.

headwaters from sampling during or soon after rain event(s) (Figure 5).

Organic fertilizers/manure from two other concentrated animal feeding operations owned by Weaver's Heartland Egg Farm (one in eastern Logan County in headwaters of North Fork West Mansfield Tributary and another outside of the basin) likely have contributed to nutrient enrichment through land application of manure in the Bokes Creek drainage basin.

Headwaters and tributary areas are severely influenced by agricultural runoff including inorganic fertilizers from grain producing fields and manure from livestock operations. Failing on-site wastewater treatment systems are also problematic in the watershed (e.g., Magnetic Springs area). Modifications to the stream channels themselves (e.g., channelization, straightening, deepening) and the surrounding watershed (e.g., riparian corridor and wetland removal) have severely diminished the natural assimilative capabilities of this watershed.

Similarly, according to an Ohio EPA Bokes Creek Water Chemistry Report and Phased TMDL Report (Ohio EPA, 1995b), "For the most part, animal influences in Bokes Creek are dominant at all flow levels." Human influence was most consistently apparent downstream of the community of Magnetic Springs, an unsewered area, and in the headwaters area (Hoover-Moffitt Rd.). Bokes Creek showed a high human influence at normal flows from improperly operating on-site sewage treatment system discharges. At high flows, agricultural runoff seemed to dominate.

Other pollutants that impacted the environmental quality in the Bokes Creek basin included silt/sedimentation, total dissolved solids (TDS) with related high hardness and conductivity, and, to a lesser extent, selected herbicides/pesticides and metals.

The Powderlick Run subbasin was unique among Bokes Creek tributaries for the number of egg production facilities and their impact on water quality to this stream and the Bokes Creek mainstem (two egg production facilities and three pullet production operations/facilities). Mad River Egg Farm and Day Lay Farm 3 are the only currently active egg production facilities. Day Lay Farm 1 and the two Pullet facilities in Logan County still raise pullets, Day Lay Farm 2 is not being operated and is in the process of being sold. Biological communities were documented to be poor or very poor at each site surveyed. No fish were collected downstream from the Mad River Egg Farm in the tributary to Powderlick Run or in Powderlick Run at RM 1.8. The ICI score was 0 at the associated macroinvertebrate sample site in Powderlick Run at RM 1.6. Egg wash water spills coupled with runoff from manure laden fields has destroyed the biological integrity of Powderlick Run and damaged it in Bokes Creek downstream of the confluence. Additionally, riparian forest removal has eliminated much of the nutrient assimilation ability of this subwatershed. Dredging and deepening of the channel in the downstream reach, performed in 1999, also destroyed what little habitat that was left. Dredge spoil disposal along the banks in the flood plain set the stage for additional degradation in Bokes Creek due to sedimentation upon experiencing heavy rain.

2.3 Causes and Sources of Impairment

The determination of impairment in rivers and streams in Ohio is straightforward – the numeric biocriteria are the principal arbiter of aquatic life use attainment and impairment. The rationale for using biocriteria has been extensively discussed elsewhere (Karr, 1991; Ohio EPA, 1987a,b; Yoder, 1989; Miner and Borton, 1991; Yoder, 1991).

Ohio EPA relies on an interpretation of multiple lines of evidence including water chemistry, sediment, habitat, effluent and land use data, biomonitoring results, and biological response to describe the causes (e.g., nutrients) and sources (e.g., agricultural runoff, municipal point sources, septic systems) associated with observed impairments. The initial assignment of the principal causes and sources of impairment that appear on the section 303(d) list do not necessarily represent a true "cause and effect" relationship. Rather they represent the association of impairments (based on response indicators) with stressor and exposure indicators whose links with the survey data are based on previous experience with similar situations and impacts. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified.

Table 6. Causes and Sources of Impairment in the Bokes Creek Basin

Waterbody Segment Description [Ident. Number]	Causes of Impact [1] *[(1998 303(d) list, (earlier surveys)]* Additional Causes of Impact (1999 Survey)	Sources of Impact (303(d) list / 1999 survey)	Aquatic Life Use Year	Miles of Attainment Status: Full	Full but Threatened	Partial	Non	No Assess-ment
Bokes Creek - Headwaters to Brush Run RMs 39.70-19.71 [OH35 18]	*Unknown Toxicity (H)* **Nutrients** (*M* / H) (T) **Siltation (M)** (T) **Habitat Alterations** (*M* /H)(T) Organic Enrichment/D.O. (H) Flow Alteration (M) Unionized Ammonia (S)	**Animal Holding / Mgmt. Areas (H)** (T) **Non-irrigated crop production (H)**(T) Channelization (H) Removal of Riparian Vegetation (H/M)(T) Flow Regulation / Modification (M) (T)	(MWH) /WWH	(RM 37.3-35.51) / RM 35.5 -19.71				
			1999	0.00	5.74	5.05	6.80	2.40 > RM 37.3
			WWH	RM 39.70 -19.71				
			1993	5.80	0.00	1.20	0.50	12.49
Comments: The biological community in Bokes Creek from the headwaters to Brush Run was impacted by nonpoint source pollution. Excess nutrients from runoff or drainage from fertilized fields (chicken/egg farm (organic) waste fertilizer or direct chemical fertilizer) on tributaries primarily and fields adjacent to mainstem. Channelized segments and riparian-removed reaches (some on mainstem/mostly on tribs.) allowed excess nutrient delivery and siltation to mainstem increasing algal production and diel D.O. sags. Ammonia (possibly hardness, and conductivity) was at high enough concentrations to likely contribute to chronic effects. Low D.O. (WQS exceedences)and high bacterial conc. (exceedences) contribute to chronic community stressors. Tile modified flow drainage has allowed more nutrients into streams. Threats: Yearsley Rd. area (RM 26.5-20.76) upst. from Powderlick Run threatened by nutrients & organic enrichment/D.O. & silt inputs from upst. tributaries and NPS storm runoff.								
Bokes Creek - Brush Run to Scioto River RMs 19.71 - 0.00 [OH35 15]	*Unknown Toxicity (H)* **Nutrients** (*M* / H) **Siltation (M)** **Habitat Alteration (S** / M **)** Organic enrichment / DO (H)	**Animal Holding / Management Areas (H)** **Non-irrigated crop production (H)** Removal of Riparian Vegetation (H/M) Flow Regulation / Modification (M) On-site Wastewater Systems (septic tanks) (M) Package Plants (small flows) (S) Pasture Land (S)	WWH	RM 19.71 - 0.00				
			1999	0.00	0.00	15.00	4.71	0.00
			WWH	RM 19.71 - 0.00				
			1993	0.00	0.00	19.60	0.0	0.11
Comments: The biological community in Bokes Creek from Brush Run to the mouth was impacted by nonpoint source runoff pollution (chiefly & primarily agricultural - Daylay Farm and runoff from fertilized fields but some localized additive effects from unsewered Magnetic Springs and possibly a small wastewater package treatment plant). Very elevated nutrient concentrations, high bacterial concentrations, high algal production, biochemical decay, & consequently chronically low dissolved oxygen concentrations and siltation inhibited community quality improvements. Generally the highest fish and macroinvertebrate diversity, IBI and ICI scores, and number of quality organisms (i.e., EPT taxa) occurred at site(s) upstream from Powderlick Run and Brush Run. Habitat alteration of tributaries (woody debris removal, field tiles, and loss of riparian corridor) and intensive fertilizer applications resulted in excess nutrients/organic fertilizer and sediment deposited in the lower mainstem.								

Waterbody Segment Description [Ident. Number]	Causes of Impact [1] *[(1998 303(d) list, (earlier surveys)]* Additional Causes of Impact (1999 Survey)	Sources of Impact (303(d) list / 1999 survey)	Aquatic Life Use Year	Miles of Attainment Status: Full	Full but Threatened	Partial	Non	No Assess-ment
Powderlick Run - RMs 5.90 - 0.00 [OH35 19]	**Nutrients (H)** **Habitat Alterations (H)** **Siltation (M** / H) Organic Enrichment /D.O. (H) Flow Alteration (M) Unionized Ammonia (M) Salinity/TDS/Chlorides (M/S)	*Feedlots (Confined Animal Feeding Operations.) (H)* Animal Holding / Management Areas (H) Non-irrigated crop production (H) Channelization (H) Removal of Riparian Vegetation (H) Dredging (H) Pasture Land (H/S) Flow Regulation / Modification (M) Septage Disposal (land application) (M) Channelization (M) Minor Industrial Point Source (H/M/S)	(LRW)/ WWH	(RM 5.10 - 3.01) / 3.0 - 0.00				
			1999/ 2000	0.30 (RM 3.9-3.6)	0.00	0.00	4.80	0.80 RM>5.1
			WWH	RM 5.90 - 0.00				
			1993	0.00	0.00	0.00	3.90	2.00

Comments: Excess nutrients from organic and NPS agriculture applications whose transfer from land application to the field and then to the stream is exacerbated by a lack of riparian vegetation, open canopy, and field tiles. These features allowed for gross nutrient enrichment with D.O.'s of zero mg/l (toxicity). Probable chronic ammonia toxicity (possibly acute toxicity) associated with NPS runoff and Mad River Egg Farm egg wash water spill was also evident via actual measurements and by the depauperate biota (no fish collected downstream from Mad River Egg Farm, ICI = 0). High TDS, conductivity and fecal coliform bacteria concentrations associated with Daylay Farms (particularly Mad River Egg Farm). Very poor to poor conditions will improve with decreasing nutrient inputs and improving the riparian corridor. Siltation affected Bokes Creek shortly after dredging in the lower reach of Powderlick Run. Siltation was a problem in most of Powderlick Run (lack of sufficient riparian habitat and /or unrestricted cattle access) and Bokes Creek (mostly delivery from tributaries). Recommended change use designation to LRW from RM 5.1 to RM 3.01. Rm 3.0 to mouth still WWH.

Waterbody Segment Description [Ident. Number]	Causes of Impact [1] *[(1998 303(d) list, (earlier surveys)]* Additional Causes of Impact (1999 Survey)	Sources of Impact (303(d) list / 1999 survey)	Aquatic Life <u>Use</u> Year	Miles of Attainment Status: Full	Full but Threatened	Partial	Non	No Assess-ment
West Fork West Mansfield Tributary RMS 2.32 - 0.00 [OH35 21]	**Organic enrichment/DO (H)** **Habitat Alterations** (*M* / H) Nutrients (H) Siltation (H) Flow Alteration (M)	**On-site Wastewater Systems (septic tanks)** (*M* / S) **Pasture Land** (*M* / S) Non-irrigated crop production (H) Removal of Riparian Vegetation (H) Septage Disposal (land application) (M) Flow Regulation / Modification (M) Channelization (S)	WWH	RM 2.32 - 0.00				
			1999	0.00	0.00	0.00	2.20	0.12
			WWH	RM 4.00- 0.00				
			1981	0.00	0.00	0.00	1.0	3.0
Comments: Combined impacts from agriculture (organic fertilizers and nutrients) with organically enriched runoff from West Mansfield land application fields caused nutrient enrichment / low diel D.O. problems (exceedences) via decay. High NH_3 , nitrogen, and phosphorus resulted in high algal production. High Total suspended solids (TSS) occurred in the form of algal production in suspension and/or sedimentation runoff. Excessive silt load, lack of riparian habitat and unimpeded cattle access limited the fish and macroinvertebrate habitat (not much hard substrates - mostly covered, silted, or embedded). These physical habitat limitations & chemical stressors resulted in tolerant fish populations.								
Scioto River Bokes Creek to Mill Creek [OH35 12]	*Organic Enrichment / D.O. (H)*	*Non-irrigated crop production (H)*	WWH	RM 161.88 - 155.40				
			1995	5.88	0.00	0.00	0.00	0.60
			WWH	RM 161.8 - 155.4				
			1991	0.00	0.00	6.5	0.00	0.00
Comments: The 1995 survey indicated the biological communities sampled at one station in this segment were performing in the good (fish - IBI, MIWB) to exceptional (macroinvertebrate - ICI) range. Earlier biological samples in 1991 and previous (1979) indicated only a minor departure for IBI. The lower 0.6 miles is at the upstream end of the narrow riverine O\Shaughnessy Reservoir and this portion was not evaluated, though it is drinking water supply and is generally good quality. Due to a database error while preparing the 1998 305(b) report, this segment should have been <u>delisted</u> in the present 1998 303(d) list.								

Waterbody Segment Description [Ident. Number]	Causes of Impact [1] *[(1998 303(d) list, (earlier surveys)]* Additional Causes of Impact (1999 Survey)	Sources of Impact (303(d) list / 1999 survey)	Aquatic Life Use Year	Miles of Attainment Status: Full	Full but Threatened	Partial	Non	No Assessment
White Sulphur Lake 39.0 acres [OH35 106]	Not described	*Atmospheric Deposition (T)*[2] [2] These lists developed through citizen/user response questionnaires.	EWH 1993	39 acres 39.0[3]	0.00	0.0	0.0	0.0
				[3] Fully meets WQS but just wasn't the highest rating in all categories, but lake was not 'threatened' like in the stream segment category. Listing was an error.				
Comments: A quarry lake owned by the city of Columbus. Water pumped from quarry into Scioto River to augment flows only during extreme drought (~once/ 5 years). There is a Columbus city public water intake 12 miles downstream. Since Columbus owns it and controls the area surrounding it, there is minimal development pressure immediately around it. Since they are pumping water from it to the Scioto River upstream from their public water intake to supplement or augment flow, it must be higher quality, or else they would be compromising the public water supply. Chemistry results from 1995 survey indicated good water quality. **There was zero acres listed as impaired or threatened by acid deposition. No aquatic contamination issues were found and no PARTIAL or IMPAIRED assessments were found, which is what is supposed to relegate a lake to the 303(d) list. According to Ohio EPA officials involved in lake sampling, this lake should not have been listed. This situation does not appear to be a threat to water quality, and therefore, it is recommended that White Sulphur Lake be delisted from the 303(d) List.**								
Smith Run - RMs 4.90 - 0.00 [OH35 16]	Organic Enrichment /D.O. (H) Nutrients (H) Siltation (M) Habitat Alterations (M) Flow Alteration (M)	Non-irrigated crop production (H) Flow Regulation / Modification (M) Removal of Riparian Vegetation (M)	WWH 1999	RM 4.90 - 0.00 0.00	0.00	0.00	4.90	0.00
Comments: Widen riparian corridor in upper reach to intercept/absorb excess nutrients/organic fertilizers to decrease inputs into the stream, stabilize banks and decrease silt loads. Substrate embeddedness inhibited fish and macroinvertebrate populations. Low diel D.O. concentrations (2.7 mg/l -toxic or avoidance) from decaying organic matter (algal production / decay) impacted the aquatic community. High nutrients converted to algal biomass and/or high siltation was illustrated and confirmed by parallel high total suspended solids (TSS). Field tiles allowed quicker nutrient delivery through thinly canopied upper stream affecting all portions of stream (Smith Run had better riparian corridor in lower portions). High nutrient loads & low oxygenated, poor quality water sent to Bokes Creek.								

<table>
<tr><th rowspan="2">Waterbody Segment Description [Ident. Number]</th><th rowspan="2">Causes of Impact [1]
[(1998 303(d) list, (earlier surveys)]
Additional Causes of Impact (1999 Survey)</th><th rowspan="2">Sources of Impact

(303(d) list / 1999 survey)</th><th rowspan="2">Aquatic Life <u>Use</u> Year</th><th colspan="5">Miles of Attainment Status</th></tr>
<tr><th>Full</th><th>Full but Threatened</th><th>Partial</th><th>Non</th><th>No Assess-ment</th></tr>
<tr><td rowspan="2">Brush Run -

RMs
3.20 - 0.00

[OH35 17]</td><td rowspan="2">Organic Enrichment /D.O. (H)
Nutrients (H)
Siltation (M)</td><td rowspan="2">Non-irrigated crop production (H)
Pasture Land (H)
Removal of Riparian Vegetation (H)
Streambank Modification / Destabilization (H)
On-site Wastewater Systems (septic tanks) (M)</td><td>WWH</td><td colspan="5">RM 3.20 - 0.00</td></tr>
<tr><td>1999/ 2000</td><td>0.00</td><td>0.00</td><td>0.00</td><td>1.00</td><td>2.20</td></tr>
<tr><td colspan="9">Comments: Nutrients and organic fertilizers from field applications runoff and exposed streams and banks from riparian removal and/or bank destabilization (nonirrigated crop production upstream and/or cattle access) allowed excess nutrients to trigger primary production, subsequent increased algal biomass decay, and lower diel D.O. concentrations. Siltation and sedimentation from erosion of open, unstable streambanks embedded substrates and limited fish and macroinvertebrate habitats, decreasing diversity. Tolerant fish community present indicated poor water quality conditions.</td></tr>
<tr><td rowspan="2">Trib. to Powderlick Run (confluence @ RM 2.08)
RMs
1.77 - 0.00
[OH35 19.1]</td><td rowspan="2">Organic Enrichment /D.O. (H)
Unionized Ammonia (H)
Salinity/TDS/Chlorides (H)</td><td rowspan="2">Minor Industrial Point Source (H)
Spills (H)
On-site Wastewater Systems (septic tanks) (M)</td><td>WWH</td><td colspan="5">RM 1.77 - 0.00</td></tr>
<tr><td>1999</td><td>0.00</td><td>0.00</td><td>0.00</td><td>0.30</td><td>1.47</td></tr>
<tr><td colspan="9">Comments: Mad River Egg Farm Process egg wash water spilled from holding lagoons into a Trib. to Powderlick Run affecting the biological community in the Trib. to Powderlick Run and in Powderlick Run downstream. <u>No fish</u> were collected during fish survey - in the Trib. to Powderlick Run or at RM 1.8 in Powderlick Run (dst. of confluence with Trib. to Powderlick Run) though habitat supported a fish community presence (fish kill and / or fish avoidance). ICI was a <u>zero</u> at RM 1.6 in Powderlick Run - downstream from the Trib to Powderlick Run and Mad River Egg Farm with only tolerant organisms present.</td></tr>
</table>

Waterbody Segment Description [Ident. Number]	Causes of Impact [1] *[(1998 303(d) list, (earlier surveys)]* Additional Causes of Impact (1999 Survey)	Sources of Impact (303(d) list / 1999 survey)	Aquatic Life Use Year	Miles of Attainment Status				
				Full	Full but Threatened	Partial	Non	No Assess-ment
North Fork West Mansfield Tributary RMs 8.80 - 0.00 [OH35 20]	Organic Enrichment /D.O. (H) Nutrients (H) Habitat Alterations (H) Siltation (H/M)	Non-irrigated crop production (H) Removal of Riparian Vegetation (H/M) Pasture Land (H) Flow Regulation / Modification (M) Channelization (M)	(MWH)/ WWH	RM (6.1 - 4.51)/ 4.5 - 0.00				
			1999	0.00	0.00	0.00	5.30	3.50 RM > 6.1, RM < 0.8
Comments: Land applied organic fertilizers and nutrient applications (i.e. Phosphorus or anhydrous ammonia) to fields without adequate riparian cover or width and field tiles caused excess nutrient enrichment, algal production, decay, and low diel D.O. concentrations (D.O. under 1 mg/l - toxic or avoidance). Excessive siltation with embedded and covered substrates limited fish and bug habitat. Open canopy (riparian removal) and some channelization allowed more primary production, increased BOD and consequently low D.O.								
South Branch West Fork West Mansfield Tributary RMs 2.42 - 0.00 [OH35 21.1]	Organic enrichment/DO (H) Habitat Alterations (M) Salinity/TDS/Chlorides (M) Flow Alteration (M) Siltation (S)	Non-irrigated crop production (H/M) Septage Disposal (land application) (H) Flow Regulation / Modification (M) Removal of Riparian Vegetation (M) Dam Construction (S)	WWH	RM 2.42 - 0.00				
			1999/ 2000	0.00	0.00	0.00	1.00	1.42 RM>1.0
Comments: Organic nutrients were getting into stream from fertilized field runoff (at WWTP waste - applied fields and other fields). Where no riparian vegetation (open canopy), excess nutrients caused higher primary production and impacts from lower D.O. concentrations via decay. Possible anhydrous NH_3 runoff after field applications or sewage source, bacterial contamination & high Cond./TDS/hardness likely contributed to impacts in biological community. Siltation limiting habitat in parts of stream.								

[1] Causes and sources of impairment in **bold** type are listed in the 1998 303(d) list and were also identified during the 1999 Biological and Water Quality Study of the Bokes Creek Basin; items in *italics* are listed in the 1998 303(d) list only; items in plain type were identified during the 1999 Biological and Water Quality Study of the Bokes Creek Basin. The magnitude (i.e. relative contribution) of the cause or source of impairment is estimated as follows:
H-High magnitude M-Moderate magnitude S-Slight Magnitude T-identifies a threat

Table 7. Point source dischargers in the Bokes Creek Basin

Entity	Receiving Stream (RM of discharge)	Design Flow (MGD)
Camp Christian WWTP	Bokes Creek (RM 6.2)	0.015
Rockhold Quarry	Bokes Creek (RM 25.2)	0.077
Leesburg-Magnetic School	Bokes Creek (RM 8.0)	0.001
West Mansfield WWTP*	South Branch West Fork West Mansfield Tributary (RM 0.9)	0.100

* West Mansfield is an NPDES regulated facility. However, they land apply all effluent from their facility, so they are not strictly considered a point source discharge. West Mansfield is included in this table to clarify the status of their wastewater treatment system.

3.0 PROBLEM STATEMENT

The goal of the TMDL process is full attainment of the Water Quality Standards including attainment of numeric biological criteria (see Table 5). As described in Section 2 the water quality and biological assessment of the Bokes Creek watershed indicates that the non-attainment of WQS is primarily due to nutrient and organic enrichment, sedimentation and habitat degradation. These issues combine to result in non-attainment of the criteria for dissolved oxygen and the numeric biocriteria.

Nutrients, except under unusual circumstances, rarely approach concentrations in the ambient environment that are toxic to aquatic life. U.S. EPA (1976) concluded that “levels of nitrate nitrogen at or below 90 mg/l would not have [direct] adverse effects on warmwater fish." However, nutrients, while essential to the functioning of healthy aquatic ecosystems, can exert negative effects at much lower concentrations by altering trophic dynamics, increasing algal and macrophyte production (Sharpely, et al., 1994), increasing turbidity (via increased phytoplanktonic algal production), decreasing average dissolved oxygen concentrations, and increasing fluctuations in diel dissolved oxygen and pH. Such changes are caused by excessive nutrient concentrations resulting in shifts in species composition away from functional assemblages of intolerant species, benthic insectivores and top carnivores (e.g., darters, insectivorous minnows, redhorse, sunfish, and black basses) typical of high quality warmwater streams towards less desirable assemblages of tolerant species, niche generalists, omnivores, and detritivores (e.g., creek chub, bluntnose minnow, white sucker, carp, green sunfish) typical of degraded warmwater streams (Ohio EPA, 1999). Nutrient concentrations in the Bokes Creek watershed are excessive in comparison with statewide data reflecting appropriate ranges of biological performance (as the IBI). Further, depressed dissolved oxygen levels (Figure 4) and wide diel swings (for example, Figure 7), excessive algae, and trophic species shifts have been documented which also indicate a nutrient enrichment problem.

The effects of nutrient enrichment are exacerbated by poor physical habitat; conversely, high quality habitat can mitigate those effects. High quality riverine habitats with intact riparian zones and natural channel morphology may decrease the potentially adverse effects of nutrients by assimilating excess nutrients directly into plant biomass (e.g., trees and macrophytes), by sequestering nutrients into invertebrate and vertebrate biomass, by "deflecting" nutrients into the immediate riparian zone during runoff events (see reviews by Malanson 1993; Barling and Moore 1994), and by reducing sunlight (a principal limiting factor in algal production) through shading. Also, high quality habitats minimize nutrient retention time in the water column during low flows because they tend to have high flow velocities in narrow low flow channels (e.g., unbraided vs. braided riffles), and coarse substrates with little potential for adsorption. Additionally, a healthy community of aquatic organisms typical of high quality habitats process and utilize nutrients very efficiently.

Poor quality habitat with reduced or debilitated riparian zones (either no riparian zone is present or runoff bypasses the zone via field tiles) and simplified channel morphology generally exacerbate the deleterious effects of nutrients by reducing the riparian uptake and conversion

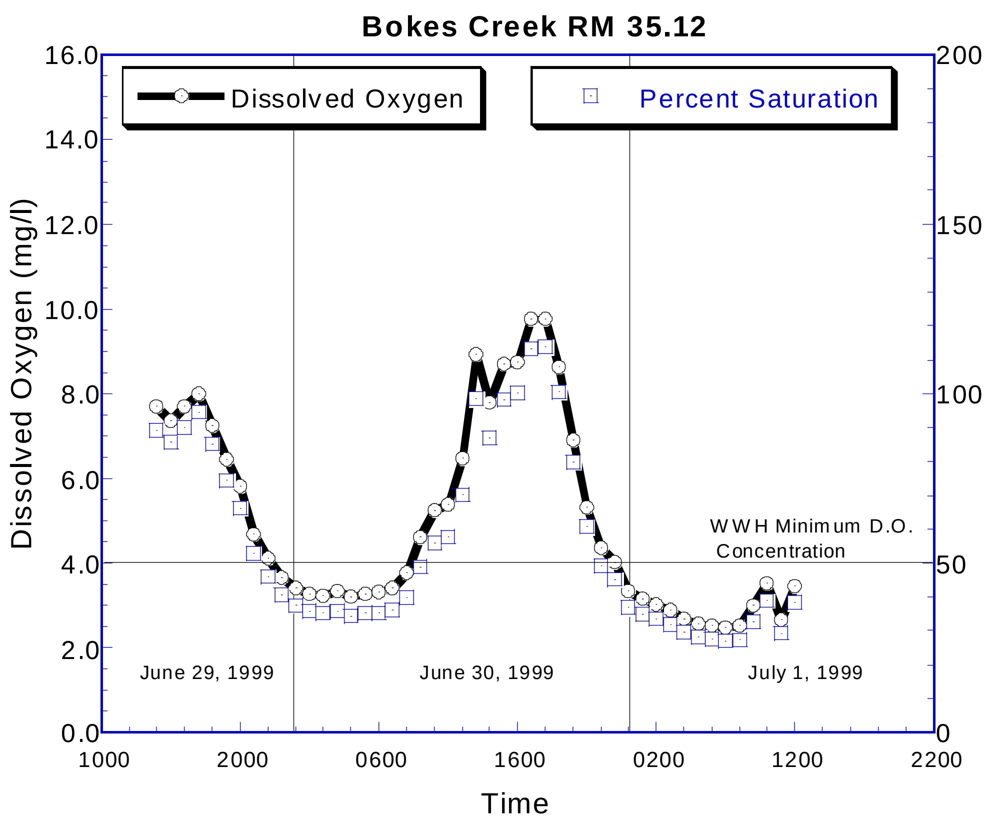


Figure 7. Diel dissolved oxygen concentration readings recorded over 48-hr. period using a continuous sampler in Bokes Creek at RM 35.12 from 29 June to 1 July, 1999.

of nutrients, by increased retention time through increased sediment-water column interface via a wide channel and subsequent loss of low flow energy (e.g., increased intermittency), retention of nutrients within the channel due to diminished filtering time during overland flow events, and by allowing full sunlight to stimulate nuisance growths of algae. These factors also interact to increase the retention of nutrients in the most available dissolved forms, attached to fine sediments (especially clays and silts) and in planktonic and attached algae (Ohio EPA, 1999).

The habitat quality in the Bokes Creek watershed ranges from poor to good. In general, however, the habitat quality is degraded in many of the headwater streams in the watershed. Headwater habitat quality is a critical component of the assimilative capacity for the protection of downstream uses; poor headwater habitat quality significantly reduces the capacity of a stream to assimilate nutrients and the effect of this is perpetuated throughout the stream system (Figure 8).

The parameter selected for Total Maximum Daily Load development is total phosphorus (the limiting nutrient; see Appendix C). In conjunction with modeling the loads for this parameter, instream dissolved oxygen concentration and stream habitat have also been evaluated. Although not expressed as loads per se, allocations for the factors affecting instream dissolved

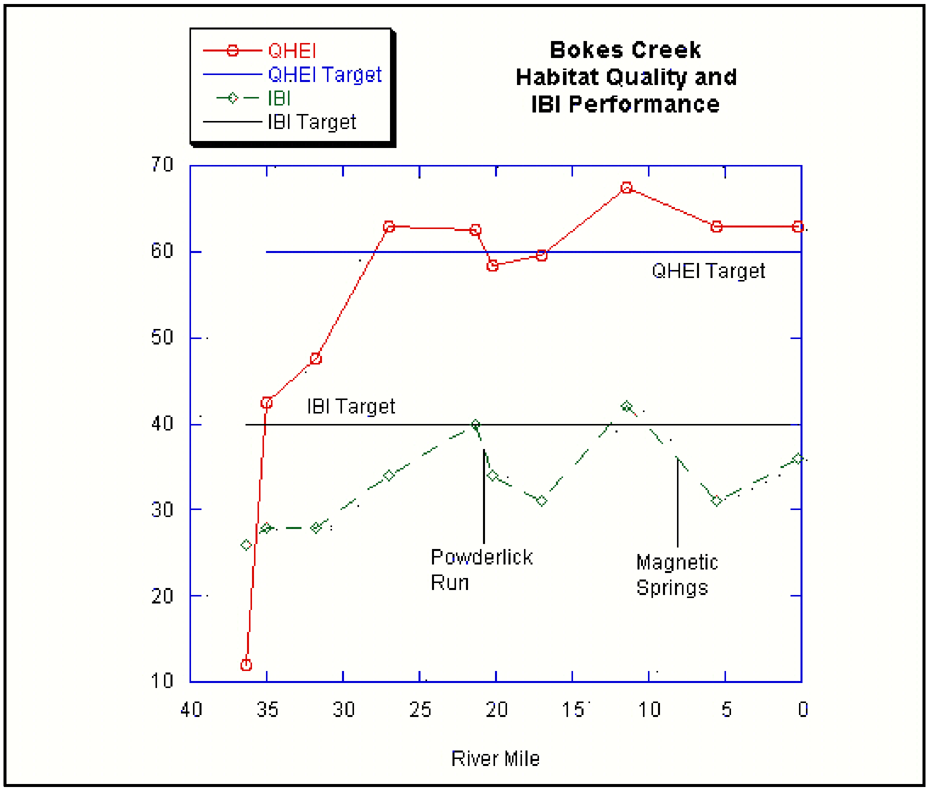


Figure 8. Comparison of habitat quality and IBI performance as measured in the 1999 Bokes Creek Intensive Survey.

oxygen and stream habitat have been included analogous to the "TMDL" numbers for total phosphorus.

3.1 Target Identification

The establishment of instream numeric targets is a significant component of the TMDL process. The numeric targets serve as a measure of comparison between observed instream conditions and conditions that are expected to restore the designated uses of the segment. The TMDL identifies the load reductions and other actions that are necessary to meet the target, thus resulting in the attainment of applicable water quality standards.

3.1.1 Nutrients

Numeric targets are derived directly or indirectly from state narrative or numeric water quality standards (OAC Chapter 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.

Ohio EPA currently does not have statewide numeric criteria for nutrients but potential targets have been identified in a technical report entitled *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 assemblages of Ohio streams and rivers. The study reaches a number of conclusions and stresses the importance of habitat and other factors, in addition to instream nutrient concentrations, as having an impact on the health of biologic communities. The study also includes proposed targets for nitrate+nitrite concentrations and total phosphorus concentrations based on observed concentrations associated with acceptable ranges of biological community performance within each ecoregion. The total phosphorus targets are shown in Table 8. 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 a TMDL setting.

Table 8. Total Phosphorus Targets

Eastern Corn Belt Plains Criteria	**TP (mg/l)**	
Watershed Size	EWH	WWH
Headwaters (drainage area < 20 mi^2) (**H**)	0.05	0.07
Wadeable (20 mi^2 < drainage area < 200 mi^2) (**W**)	0.08	0.11
Small Rivers (200 mi^2 < drainage area < 1000 mi^2) (**SR**)	0.17	0.17

Ohio's standards also include narrative criteria which limit the quantity of nutrients which may enter 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 nonattainment of biological criteria may fall under <u>either</u> OAC Rule 3745-1-04 (D) or (E) prohibitions.

3.1.2 Dissolved Oxygen

The instream dissolved oxygen (D.O.) is not fully attaining WQS in some areas of Bokes Creek. The D.O. criteria for the Warmwater Habitat segments is a 5.0 mg/l average over a 24-hour period and a 4.0 mg/l minimum at any time.

3.1.3 Ammonia-N

Ohio's water quality standards for ammonia nitrogen are based on the stream's designated use, pH and temperature. The standards are tabularized and can be found in OAC Rule 3745-1-07, Tables 7-2 through 7-8 and are protective of aquatic toxicity. There are localized areas in Bokes Creek headwaters and in the Powderlick Run watershed where ammonia-N is problematic. See Section 3.2 for a more complete discussion of the applicable ammonia-N criteria.

3.1.4 Sedimentation and Habitat

Sedimentation was identified as a cause of impairment in nearly every listed segment in the Bokes Creek watershed. OAC Rule 3745-1-04 (A) states that all waters of the state shall be free from suspended solids and other substances that enter the waters as a result of human activity and that will settle to form objectionable sludge deposits, or that will adversely affect aquatic life. However, no statewide numeric criteria have been developed specifically for sediment or Total Suspended Solids (TSS). In part, the reason that there are not numeric criteria for TSS or sediment is that it is difficult to directly associate these pollutants with toxicity to aquatic life. Rather, the effect on aquatic life is that sediment smothers bottom dwelling (benthic) organisms, or chokes the habitat such that there is no place for aquatic organisms to live. In addition, it is difficult to associate water quality measurements of TSS on any given day with the amount of sediment that can get deposited over a given period of time (e.g., a year).

Since excessive sedimentation often correlates with poor habitat quality (Ohio EPA, 1996), target Qualitative Habitat Evaluation Index (QHEI) scores, based on reference data sites for some of the aquatic life use designations, can be used as surrogates. The QHEI is a quantitative composite of six physical habitat variables used to 'score' a stream's habitat. The variables are: substrate, instream cover, riparian characteristics, channel characteristics, pool/riffle quality, and gradient and drainage area. It can be used to assess and evaluate a stream's aquatic habitat, and determine which of the six habitat components need to be improved to reach the QHEI target score. The substrate variable incorporates sediment quality and quantity and therefore, provides a numeric target for sedimentation. The advantage of using the QHEI is that it assesses both the condition of the riparian corridor (i.e. the source of the sediment) and the effects on the stream itself (i.e. the historic sediment deposition). Therefore it is an appropriate measure to use as a TMDL target to assess the indirect effects of sediment on an aquatic system. The Warmwater Habitat use designation QHEI target is greater than or equal to 60. In addition, since habitat is strongly correlated with biological community performance (as measured by the IBI), the QHEI provides a target and format to evaluate how habitat issues and impairments affect attainment of the aquatic use designations.

3.1.5 Biocriteria

The biocriteria are the final arbiter of attainment of an aquatic life use designation. After the control strategies have been implemented, biological measures including the Index of Biotic Integrity (IBI), Invertebrate Community Index (ICI), QHEI and Modified Index of Well-being (MIWB) will be used to validate biological improvement and biocriteria attainment. The current attainment of the biocriteria along with the applicable standards is listed in Appendix A, Table A1.

3.1.6 Total Dissolved Solids (TDS)

In Powderlick Run, discharges of water filtration backwash water from Day Lay Egg Farm operations were a source of Total Dissolved Solids (TDS). These sources had difficulty meeting their NPDES permit limitations, and in order to eliminate the violations, Day Lay Egg Farm decided to eliminate these discharges in favor of land application of the waste. Subsequently, Day Lay has been able to eliminate the generation of filter backwash wastewater through adjustments to their watering system. The water quality standard for TDS is 1500 mg/l as a 30-day average.

3.2 Current Deviation from Target

3.2.1 Nutrients (Total P)

As described in the preceding section, target values for total phosphorus are based upon the drainage area, use designation, and ecoregional characteristics of a given stream segment. Table 9 illustrates the median concentrations compared to the target values for the nutrients, and lists the amount of deviation from the target value that was recorded in the 1999 water quality survey. For most of the Bokes Creek watershed, the target value for phosphorus will be 0.11 mg/l of Total Phosphorus.

3.2.2 Dissolved Oxygen

Dissolved oxygen data were collected under various flow and loading conditions during the intensive survey conducted in 1999. Dissolved oxygen was measured at low levels in some segments, and is attributable to the combined effects of nonpoint source nutrient enrichment and inputs from failing onsite wastewater treatment systems (also a nonpoint source contribution). Figures 4 and 7 are graphs of the data from the 1999 survey for Bokes Creek showing low dissolved oxygen conditions. Dissolved oxygen excursions below the 4.0 mg/l minimum were recorded in the survey data at three headwaters sites and are attributable to nonpoint source impacts (Chapter 2, Table 6). Dissolved oxygen excursions in the lower segments of Bokes Creek are attributed to residual effects from Powderlick Run, inputs from onsite wastewater treatment systems in Magnetic Springs, and additional enrichment emanating from Smith Run upstream from the most downstream site.

3.2.3 Ammonia-N

Ammonia-nitrogen (ammonia-N) was elevated at only one site on the Bokes Creek mainstem, the most upstream site. The elevated ammonia-N was attributed to nonpoint source impacts in the segment of Bokes Creek upstream of Brush Run and resulted in only one minor violation of the MWH WQS for ammonia-N (3.4 mg/l recorded vs. WQS of 3.3 mg/l ammonia-N). Therefore, in spite of contributing to the overall nutrient excess in the upper Bokes Creek watershed, as well as to the low dissolved oxygen situation, the ammonia-N levels recorded do not appear to be a dominant source of impact at this uppermost site.

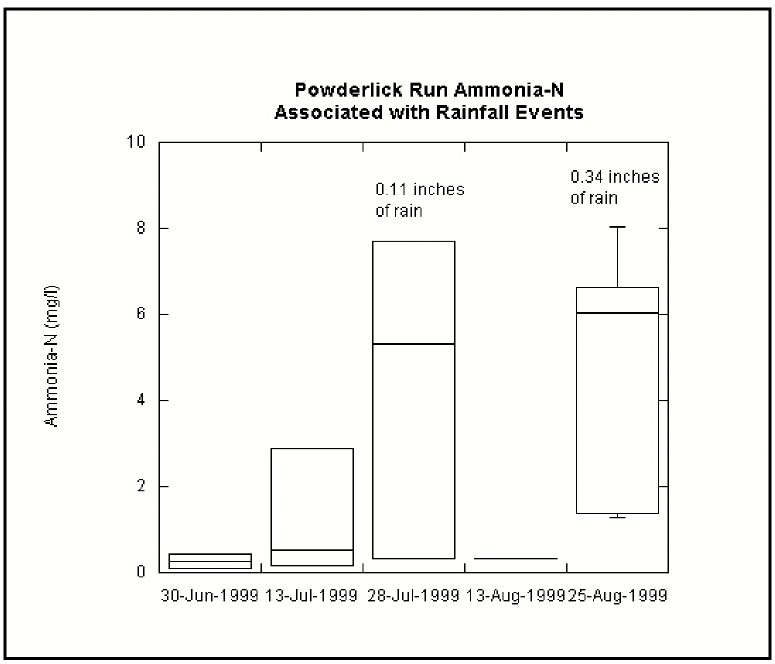


Figure 9. Ammonia levels in Powderlick Run associated with rainfall and non-rainfall events from the 1999 survey data.

Ammonia-N was also found to be elevated in Powderlick Run in levels that exceed applicable WQS. Based on pH and temperature at the time of the survey, WQS for 30 day average ammonia-N criteria were approximately 2.2 mg/l, whereas monthly average ammonia-N levels in Powderlick Run ranged from less than the criteria (average of 0.235 mg/l) to a high average of 5.3 mg/l. Elevated ammonia-N appears to be associated with rainfall events in Powderlick Run (data in Ohio EPA, 2001) and as a result of nonpoint sources (Figure 9). Based on the data from wet weather events in lower Powderlick Run, ammonia-N is 67% higher than the WQS for ammonia-N.

3.2.4 Sedimentation, Habitat, & Biocriteria

As previously noted, the deviation or the attainment of the IBI, ICI, MIWB and QHEI is detailed in Appendix A, Table A1. Habitat deficiencies in the Bokes Creek mainstem are shown in Figure 8. In addition, many of the tributaries to Bokes Creek have habitat impacts that will influence the ability of the tributaries to achieve nutrient reduction targets in the absence of a general improvement of the habitat. Figures 12 and 13 (Chapter 4) show the deviation of the QHEI from the WWH target of 60 in Bokes Creek tributaries. Habitat improvements that will result in the improvement of QHEI scores will enhance the ability of both the Bokes Creek mainstem and the tributaries to ultimately attain WQS as measured by the biocriteria.

3.2.5 Total Dissolved Solids (TDS)

The WQS for Total Dissolved Solids (TDS) is a 30 day average of 1500 mg/l TDS. In lower Powderlick Run, a summer average of 4758 mg/l was recorded at RM 1.6, and 4280 mg/l at RM 0.2. For the period of June through August of 1999, TDS discharges from the Day Lay Egg Farm (4IN00183*AD) averaged 8678.6 mg/l TDS, almost 6 times the ambient water quality criterion. Reductions in the level of TDS in Powderlick Run have been achieved by the elimination of the point source discharge of filter backwash water from the Day Lay Egg Farm. Ohio EPA expects this elimination to result in attainment of the TDS criterion in Powderlick Run.

Table 9. Median and Target Values of Total Phosphorus in the Bokes Creek Basin (1999 survey)[4]

Waterbody Segment Description [Identification Number]	**Aquatic Life Use Designation** [1]	**Drainage Area** [2]	**Median** - mg/l (# samples)	**Target** [3] - mg/l	**Deviation** - mg/l
Bokes Creek (Brush Run to Scioto River) [OH35 15]	WWH	W	0.14 (20)	0.11	0.03
Bokes Creek (Headwaters to Brush Run) [OH35 18]	MWH / WWH WWH	H W	0.49 (4) / 0.23 (10) 0.17 (14)	0.58 / 0.07 0.11	-0.09 / 0.16 0.06
Powderlick Run [OH35 19]	LRW / WWH	H	1.32 (2) / 0.83 (13)	— / 0.07	— / 0.76
Tributary to Powderlick Run [OH35 19.1]	WWH	H	—	0.07	—
Brush Run [OH35 17]	WWH	H	—	0.07	—
West Fork West Mansfield Tributary [OH35 21]	WWH	H	0.45 (5)	0.07	0.38
North Fork West Mansfield Tributary [OH35 20]	MWH / WWH	H	0.23 (2) / 0.36 (10)	0.58 / 0.07	-0.35 / 0.29
South Branch West Fork West Mansfield Tributary [OH35 21.1]	WWH	H	0.16 (1)	0.07	0.09
Smith Run [OH35 16]	WWH	H	0.12 (7)	0.07	0.05

1 Aquatic Life Use Designations are based on the proposed/recommended use designations as determined by the 1999 biological and water quality survey of the Bokes Creek Basin.

2 Source: Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA Technical Bulletin MAS/1999-1-1) H=Headwater (0-20 mi^2) W=Wadeable (>20-200 mi^2) SR=Small River(>200-1000 mi^2) LR=Large River (>1000 mi^2)

3 Source: Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (Ohio EPA Technical Bulletin MAS/1999-1-1): ECBP (Eastern Corn Belt Plains) Ecoregion Criteria -- Table 2 - TP

4 The biocriteria and chemical criteria determine the impairment not the total phosphorus target. Therefore, the target may be exceeded yet the segment be in attainment if the biocriteria attains; or, the target may be met but the biocriteria does not so the segment is considered impaired. The target is a guideline to meet biocriteria, not an absolute reference.

3.3 Source Identification

Nonpoint sources are the predominant source of nutrients on a yearly average basis and are the largest source of sediment resulting in siltation and sedimentation. Lack of riparian cover and channelization, particularly in the upper reaches, also contributes to non-attainment. Source identification is covered in more detail in Chapter 2 especially in Table 6. Allocation of loads follows in Chapter 4.

At the commencement of this TMDL project, Ohio EPA was not aware of the presence of any point source dischargers in the Bokes Creek watershed. As the project progressed, Ohio EPA became aware of three unpermitted dischargers, a quarry and two small discharges of sanitary waste, from a camp and a school. NPDES permit applications have been obtained, or are being obtained, and Ohio EPA will issue NPDES permits to these point source dischargers in accordance with Ohio EPA regulations (including antidegradation). The cumulative loading from these sources is negligible, and a specific point source allocation was not performed. NPDES permit limits will be set at Best Available Demonstrated Control Technology (BADCT) limits per OAC Rule 3545-05 for the sanitary discharges. These effluent limits represent advanced treatment limits(10 mg/l $CBOD_5$, 1.0 mg/l ammonia-N, and 6.0 mg/l D.O.) and will also be protective of water quality standards. The discharge from the quarry will be regulated for pH and Total Suspended Solids (TSS); it appears that the stream benefits from the augmented flow provided by the quarry.

4.0 TOTAL MAXIMUM DAILY LOADS

A TMDL is a means for recommending controls needed for the attainment and maintenance of water quality standards (U.S. EPA, 1991). 40 CFR 130.2(i) states that a TMDL calculation is the sum of the individual wasteload allocations for point sources and the load allocations for nonpoint sources and natural background in a given watershed, and that TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. Aquatic organisms are affected by a combination of variables that are not limited to load based pollutants. Therefore, the attainment of WQS in Ohio requires that both pollutant loads and environmental conditions (pollution, or non-load based parameters such as habitat) be addressed when identified as impairing causes.

Phosphorus, one of the identified impairing causes in this watershed, is a load based parameter and a TMDL is calculated for it (see Table 11). Dissolved oxygen is a condition of the water column and is not a load based parameter; however, a low level of dissolved oxygen is an impairing cause particularly during the low flow, high temperature summer months. The TMDL numbers proposed for phosphorus will improve the level of D.O. by reducing algal growth (see Ohio EPA, 1999 for the relationship between nutrients and D.O.). In addition, D.O. levels can be increased by improving various aspects of the stream and stream corridor itself. Certain improvements to the stream habitat can have the additional benefit of increasing the level of D.O. in the stream (e.g., riffles). The combination of reducing algal growth and increasing the capacity of the stream to hold dissolved oxygen is a means for recommending controls to meet the D.O. water quality criteria and is, therefore, a D.O. ‘TMDL’.

Degraded or poor habitat is another non-load based impairing cause in the Bokes Creek watershed. Identification of which aspects of the habitat are degraded at particular points in the watershed is provided in this report as are benchmarks which can be used to set habitat goals. This is analogous to allocations of loads for pollutants. These recommended habitat ‘allocations’ are necessary to meet biological and chemical water quality standards (in combination with the other TMDLs described above) and as such are a habitat ‘TMDL’.

The TMDL calculation must also include either an implicit or explicit margin of safety that accounts for the uncertainty concerning the relationship between pollutant load or the pollution (the non-load causes of impairment) and water quality. The calculations, then, provide a numeric basis for addressing the impairing causes.

4.1 Method of Calculation

Two different analysis techniques were selected; each to address the following two issues:

1. Determine the nonpoint and point source loading contributions to the stream network. Predict future loadings based on implementation actions. This method determined the

existing total phosphorus loads to the system.
2. Establish current habitat conditions and quantify desired habitat goals.

Multiple methods were needed given resource constraints (time and data availability) and applicability. A model which incorporated both of the above issues would have had exhaustive data requirements while providing little or no additional benefit to the process. The techniques selected are the most appropriate and applicable available methods for the goals and needs of this project. Table 10 summarizes the modeling approach selected for this TMDL project.

Table 10. Modeling Approach Summary

Model or Method	**Parameters Analyzed**	**Goals**	**How was it used?**
Generalized Watershed Loading Functions (GWLF)	• Phosphorus • Sediment • Nitrogen (not included as a TMDL)	Quantify the total phosphorus and sediment loads to the receiving streams in the study area. Evaluate and compare nutrient loadings between sub-watersheds and between point and nonpoint sources. Evaluate the effect of land use changes on loadings during the implementation plan phase.	• Quantify the existing loads from both point and nonpoint sources. • Using the workgroup's input, vary the land use and other factors to simulate control actions to determine when targeted load value is achieved.
Ecological Assessment Techniques and Models	• Phosphorus • TSS • IBI • ICI • QHEI 1. Substrate 2. Instream cover 3. Riparian quality	Establish targets for parameters with no criteria. Evaluate parameters which are not directly incorporated in the other models. **Directly address the biocriteria impairment issues.**	• Determine numeric targets for phosphorus and habitat where no criteria exist. • Compare attaining reference sub-watersheds to impaired sub-watersheds in the Bokes Creek basin. Assist in determining needed changes in the impaired sub-watershed. • Determine effects of habitat characteristics on instream concentrations of nutrients, TSS, and dissolved oxygen.

4.1.1 Loads to the stream

Nutrient loading to the Bokes Creek watershed was simulated using the Generalized Watershed Loading Function or GWLF model (Haith et al., 1992). The complexity of this model falls between that of detailed, process-based simulation models and simple export coefficient models which do not represent variations over time. GWLF simulates precipitation-driven runoff and sediment delivery. Solids load, runoff, and ground water seepage can then be used to estimate particulate and dissolved-phase pollutant delivery to a stream, based on pollutant concentrations in soil, runoff, and ground water. GWLF has been used for TMDL development in Donegal Creek, Pennsylvania; Rock Creek Lake, Iowa; and Peña Blanca and Arivaca Lakes, Arizona and is a recommended model in U.S. EPA's Protocol for Developing Nutrient TMDLs (U.S. EPA, 1999) and the Upper Little Miami River TMDL in Ohio (Ohio EPA, 2002).

GWLF simulates runoff and streamflow by a water-balance method, based on measurements of daily precipitation and average temperature. Precipitation is partitioned into direct runoff and infiltration using a form of the Natural Resources Conservation Service's (NRCS) Curve Number method (SCS, 1986). The Curve Number determines the amount of precipitation that runs off directly, adjusted for antecedent soil moisture based on total precipitation in the preceding five days. A separate Curve Number is specified for each land use by hydrologic soil grouping. Infiltrated water is first assigned to unsaturated zone storage where it may be lost through evapotranspiration. When storage in the unsaturated zone exceeds soil water capacity, the excess percolates to the shallow saturated zone. This zone is treated as a linear reservoir that discharges to the stream or loses moisture to deep seepage, at a rate described by the product of the zone's moisture storage and a constant rate coefficient.

Flow in streams may come from surface runoff during precipitation events or from ground water pathways. The amount of water available to the shallow ground water zone is strongly affected by evapotranspiration, which GWLF estimates from available moisture in the unsaturated zone, potential evapotranspiration, and a cover coefficient. Potential evapotranspiration is estimated based on mean daily temperature and the number of daylight hours.

The user of the GWLF model must divide land uses into "rural" and "urban" categories that determine how the model calculates loading of sediment and nutrients. For the purposes of modeling, "rural" land uses are those with predominantly pervious surfaces, while "urban" land uses are those with predominantly impervious surfaces. It is often appropriate to divide certain land uses into pervious ("rural") and impervious ("urban") fractions for simulation. Monthly sediment delivery from each "rural" land use is computed from erosion and the transport capacity of runoff, whereas total erosion is based on the universal soil loss equation (USLE) (Wischmeier and Smith, 1978), with a modified rainfall erosivity coefficient that accounts for the precipitation energy available to detach soil particles (Haith and Merrill, 1987). Thus, erosion can occur when there is precipitation, but no surface runoff to the stream; delivery of sediment, however, depends on surface runoff volume. Sediment available for delivery is accumulated over a year, although excess sediment supply is not assumed to carry over from one year to the next. Nutrient loads from rural land uses may be dissolved (in runoff) or solid-phase (attached to sediment loading as calculated by the USLE).

For 'urban' land uses, soil erosion is not calculated, and delivery of nutrients to the water bodies is based on an exponential accumulation and washoff formulation. All nutrients loaded from urban land uses are assumed to move in association with solids.

The GWLF model was calibrated to streamflow data in the Bokes Creek watershed using gaging station data at the mouth of Bokes Creek from April 1990 through September 1997. The value of R^2 is about 0.71 for the period of record, but improves substantially in the later years of the simulation (0.90 for the last two years of gage record). Ohio EPA attributes this improvement to better correlation of the current land use model inputs to recent stream characteristics than to the historic land use in the watershed and the associated effects on stream characteristics. Soil and Water Conservation personnel and Ohio State University Extension representatives have observed that land use in the watershed has changed significantly in the period 1993 to present. Thus, the improvement in the R^2 values should not be surprising. The monthly and annual nutrient loading for the three subwatersheds, chosen because they coincide with the 303(d) listed segments, compares reasonably well to the concentrations recorded in July 1999. The model was then used to predict average loadings using 1990 to 2000 meteorological data from the Marysville weather station. These loadings are summarized in Table 11.

Refer to Appendix C for more details on the GWLF modeling.

Table 11. TMDLs and Allocations for the Bokes Creek Watershed[1]

Subwatershed	Existing Loads			Reduction %	TMDL[2]	TMDL Allocations[3]		
	NPS[4]	PS	Total			Natural	WLA	LA
Total Phosphorus (*kg/day*)								
Entire Area	57	0.3	58	19	**47**	**2.1**	**0.3**	**44**
Bokes Creek u/s Brush Run	32	0.0	32	35	21	1.2	0.0	19
Powderlick Run	5	0.0	5	92	0.4	0.1	0.0	0.3
Bokes Creek d/s Brush Run	21	0.3	21	19	17	0.8	0.3	16

1 NPS = Nonpoint Source; PS = Point Source; TMDL = Total Maximum Daily Load; WLA = Wasteload Allocation (i.e., point source allocation); LA = Load Allocation (nonpoint source allocation less the natural background); Natural = Background.

2 TMDL = (1 - (% Reduction/100)) * Existing total load

3 LA = TMDL - Natural - WLA

4 The existing NPS load includes the existing natural background load.

4.1.2 Habitat Goals

Physical habitats were evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin, 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine a QHEI score from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer 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. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas scores less than 45 *generally* cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently typify habitat conditions having the ability to support exceptional warmwater faunas.

The two methods selected were used in conjunction to determine the load(s) and the habitat condition(s) that need to exist in order to attain the WQS. GWLF was used to calculate non-point source loads and to determine the impact of strategies to reduce loads. The QHEI was used as a guide to direct restoration efforts for habitat and provides a monitoring tool to measure progress towards habitat goals.

4.2 Critical Conditions and Seasonality

TMDL development should specify the environmental conditions assumed to define allowable loads. Determinations of TMDLs must take into account critical conditions for stream flow, loading, and water quality parameters (40 CFR 130.7(c)(1)). The critical condition is defined as the set of environmental conditions that, if controls are designed to be protective of them, will ensure attainment of objectives for all other conditions. For example, the critical condition for control of a continuous point source discharge is the drought stream flow. Point source pollution controls designed to meet water quality standards for drought flow conditions will ensure compliance with standards for all other conditions. The critical condition for a wet weather-driven source may be a particular rainfall event, coupled with the stream flow associated with that event.

Nutrient sources in the Bokes Creek watershed arise primarily from wet weather-driven sources; nutrient loadings from the small WWTPs in the basin are minimal. The critical condition for dissolved oxygen and nutrient instream concentrations is expected to be the summer low-flow period. This is the period that is most conducive to algal growth, instream temperatures are high, and the stream flows are low. Therefore, the observed summer concentrations have been compared to the targets and used to estimate the necessary loading reductions.

Seasonality is addressed in the TMDL by using the GWLF model to predict monthly and annual loadings over a multi-year period using actual weather conditions. The estimated loads are therefore reflective of seasonal changes in weather and other conditions that can vary over the course of a year (e.g., agricultural practices).

4.3 Margin of Safety

The statute and regulations require that a TMDL include a margin of safety to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA § 303(d)(1)(C), 40 C.F.R. § 130.7(c)(1)). EPA guidance explains that the margin of safety (MOS) may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is explicit, the loading set aside for the MOS must be identified.

A margin of safety is incorporated implicitly into these TMDLs. There are several areas where an implicit margin of safety is incorporated including the 303(d) listing process and the target development process. An explanation for each of these areas is provided below.

4.3.1 TMDL Priority 303(d) Listing

It is important to keep in mind during the evaluation of the TMDL a major difference in Ohio's program from other regional programs. In Ohio, one way a stream segment is listed on the 303(d) list is for failure to attain the appropriate aquatic life use as determined by direct measurement of the aquatic biological community. Many other regional or state programs rely solely on chemical samples in comparison to chemical criteria to determine water quality and designated use attainment. However, relying solely on chemical data does not take into account any of the parameters or other factors for which no criteria exist but that affect stream biology nor does it account for multiple stressor situations. Therefore, the chemical specific approach misses many biologically impaired streams and may not detect a problem until it is severe. Ohio's approach incorporates an increased level of assurance that Ohio's water quality problems are being identified. Likewise, delisting requires attainment of the aquatic life use determined by the direct measurement of the aquatic biological community. This provides a high level of assurance (and an implicit margin of safety) that if the TMDL allocations do not lead to sufficiently improved water quality then the segments remain on the list until true attainment is achieved.

4.3.2 Target Development

The use of nutrient targets that are based on data from relatively unimpacted reference sites provides an additional implicit safety factor. These data constitute a background concentration of nutrients in a stream; unimpacted streams generally have nutrient levels well below those needed to meet biological water quality standards. As the stream becomes impacted, nutrient levels can rise, but the stream can still meet the water quality standards based on other factors such as the presence of good habitat. Once the nutrient levels rise high enough or other factors change which no longer mitigate the effects of nutrients then the biological community is impacted, and the stream is impaired. By using nutrient targets based on data from relatively unimpacted sites (or sites that are conservatively in attainment of biological water quality criteria) the targets themselves are set at a conservative level. In other words, water quality attainment is likely to occur at levels higher than these targets and the difference between this actual level where attainment can be achieved and the selected target is an implicit margin of safety.

A further conservative assumption implicit in the target development lies in the selection of the statistic used to represent the phosphorus target which corresponds to an unimpaired biological community. Since Ohio EPA's evaluation of phosphorus data for generating target values is based on measured performance of aquatic life and since full attainment can be observed at concentrations above this target (reinforcing the concept that habitat and other factors play an important role in supporting fully functioning biological communities), it would be valid to argue that a 95th percentile of these values (to exclude outliers) would be protective of the respective aquatic life use. Instead, Ohio EPA selected the median value associated with measured aquatic life performance. The selection of this statistic is an implicit margin of safety in these TMDLs. Refer to Appendix B for more information on how the nutrient targets were derived.

The habitat targets were selected using a method analogous to the nutrients method. The habitat targets and the specific aspects of the habitat that are degraded as provided with the QHEI model combine to add another layer of potential protection to achieving the WQS by providing additional guidance on an alternate means to reduce the nutrient load to the stream, mitigate the impacts of the nutrients in the stream, and directly improve an aspect of stream ecology vital to the biological community. Ohio EPA's ability to add habitat targets, and provide guidance on the improvement of the habitat is an implicit margin of safety made possible through extensive ecosystem monitoring and analysis, and should be recognized as a margin of safety in these TMDLs.

4.4 TMDL Calculations

4.4.1 Load-based calculations: total phosphorus

Necessary loading reductions were estimated by comparing the median instream summer 1999 concentrations in Bokes Creek to the appropriate target (see Table 9). The overall needed phosphorus reduction basin-wide was estimated to be about 20% based on the difference between the appropriate target (0.11 mg/l) and the median observed concentration (0.14 mg/l) at the most downstream point. This is the deviation from the phosphorus target as listed in Table 9 for the waterbody segment Bokes Creek from Brush Run to the Scioto River. The Upper Bokes basin was calculated to need a 35% reduction, while the figure for Powderlick Run was about 90%. Generally, the smaller tributaries deviated from the total phosphorus target usually more than the targeted reduction for the Bokes Creek main stem and this could be used to assist guiding implementation actions; however, from a watershed perspective, a 20% reduction is a desirable and attainable reduction. This reduction in combination with the other recommendation of this report (improved habitat) should attain standards in all segments.

This approach assumes a direct relationship between loadings and concentrations and a constant assimilation factor (i.e., the instream concentrations of total phosphorus will respond to future changes in loading in the same manner as they respond to current loads). These simplifying assumptions are warranted by the fact that it is the cumulative, rather than the acute, loadings of nutrients that are impairing the biologic communities. Please refer to *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA, 1999) for a full discussion of the cumulative impacts of nutrients on Ohio rivers and streams (Appendix B).

All listed segments in the study area are included in one of the three subwatersheds. Unlisted and attaining stream segments are also included because they are sources of load regardless if they are locally impaired or not. Attainment of Ohio's WQS cannot be reached if a stream segment by stream segment approach to TMDL projects is taken.

Table 11 lists the existing loads, the needed reduction, the TMDL value, and the allocations for total phosphorus and sediment for the entire watershed and per subwatershed; Figure 10 shows a graphic representation of these quantities for total phosphorus. The existing nonpoint source (NPS) category covers agricultural, urban, groundwater and natural background inputs. The TMDL was divided up based on the background conditions (natural), waste load allocations (WLA) for point sources and load allocations (LA) for nonpoint sources. The background or natural conditions were calculated by modeling a 'pristine' or non-impacted condition in the subwatershed. All point sources and septic inputs were removed, and urban and row crop land uses were converted to forest or pastureland. The (minor) point source nutrient allocation was based on the calculated existing total phosphorus load. The rest of the TMDL was then allocated to nonpoint sources.

GWLF sediment results are based on sheet and rill erosion and are calculated using a sediment delivery ratio (the percentage of eroded sediment that is actually delivered to a stream). The total nonpoint source sediment load to the stream would also include bank and gully erosion. GWLF does not have the ability to calculate this part of the sediment load and the data needed to quantify it using another method was not available. The QHEI does take this type of erosion into account and will be used to guide implementation actions to address bank and gully erosion.

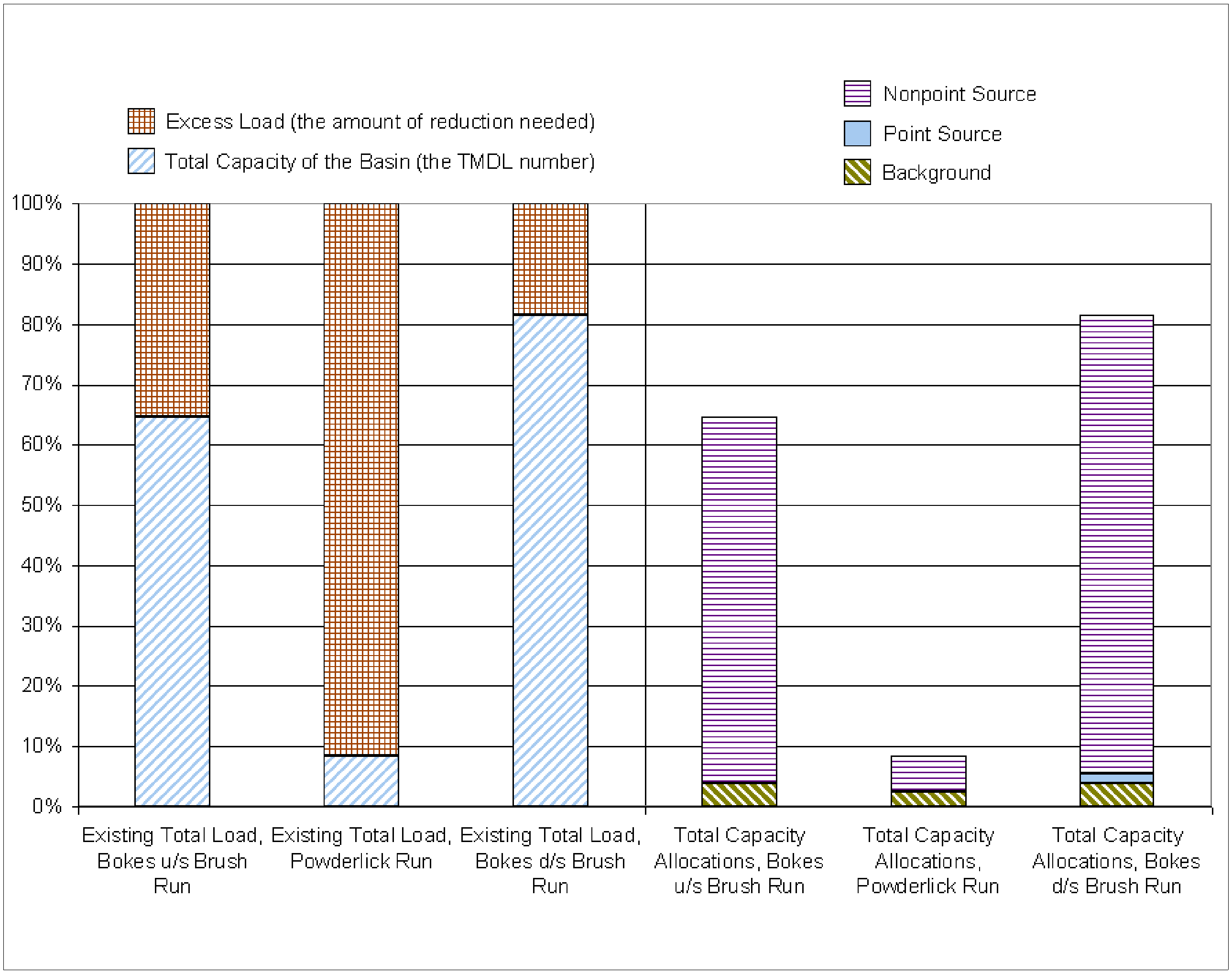


Figure 10. Graphical representation of the total phosphorus existing load and TMDL allocations.

4.4.2 Habitat Calculations for Aquatic Life

The detailed QHEI results are presented in Appendix D, and the QHEI scores per river mile are shown graphically in Figures 11 through 13. These three figures show the cumulative QHEI score in the top graphic and the deviation of the QHEI score from the target in the bottom graph per sampling site. Figure 11 presents the information for the Bokes Creek mainstem from the headwaters to just upstream of the Scioto River. Figures 12 and 13 present this information for the tributaries with Figure 12 showing Powderlick Run and Figure 13 depicting West Mansfield tributary and Smith Run . These figures highlight where the habitat is degraded and to what extent. The detailed results (Appendix D) show that good quality stream macrohabitats were present at locations downstream from Phelps Rd. (RM 27.0) while poor quality habitat was observed upstream. QHEI scores in the lower reach averaged about 62. The three upstream sites averaged a poor QHEI score of 34.0. The most upstream location existed as a shallow, pooled, deeply entrenched, straight, grass flanked ditch. The next two downstream locations were also limited by flow and the riffles at these sites lacked function. Furthermore, inadequately treated residential sewage was being discharged to Bokes Creek at these sites (RM 35.1 and RM 31.8) and unrestricted cattle access occurred at RM 31.8. Substrates at all three upstream sites were limiting with extensive amounts of silt, little interstitial volume, and if present, mostly embedded gravel, cobble or larger substrates. Functional woody debris occurred only at the RM 31.8 upstream site.

Impaired tributaries included Powderlick Run and the West Mansfield tributary. Powderlick Run was extensively embedded and heavy layers of silt were common. Excepting the site at RM 1.8 where a moderate amount of cover was available, all other sites contained little important instream habitat elements such as deep pools, rootwads, boulders, etc. Additionally, except for the RM 1.8 site, the riffles in Powderlick Run had extremely limited functional influence due to extensive embeddedness.

A poor QHEI score was determined at RM 1.0 at a single West Fork West Mansfield Tributary site. Intermittent flow, entrenched channel, silty, sandy, pea gravel substrates and nonfunctional riffles were considered likely to influence biological performance. The South Branch of the West Fork West Mansfield Tributary was evaluated for habitat quality in 2000 at RM 0.1 where a fair QHEI was determined. More groundwater recharge was evident here than at other area streams which resulted in slightly better QHEI attribute scores. Habitat quality in the North Fork West Mansfield Tributary improved from upstream channelized conditions to downstream where natural attributes were prevalent. At RM 5.6, a very poor QHEI score (15.0) reflected conditions which were not capable of supporting a WWH aquatic community. At RM 3.8, the stream passed through a cattle pasture where livestock had trampled the stream banks and denuded the riparian vegetation. A poor QHEI score (30.5) was recorded here. Both of these upstream locations lacked functional riffles, were intermittent, and had minimal instream cover. At RM 1.3, the stream remained intermittent but deeper pools and better substrate conditions resulted in a fair QHEI value (51.0).

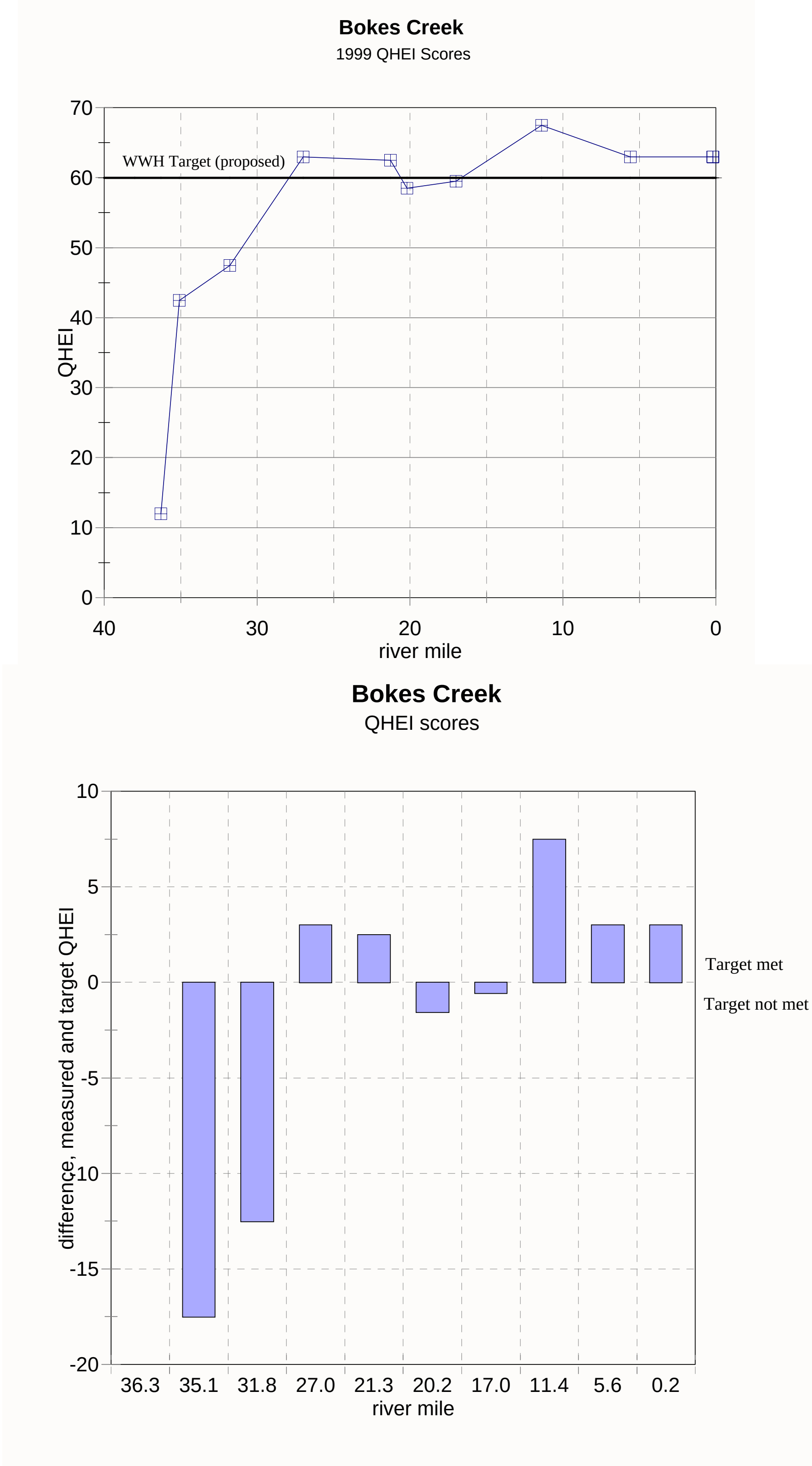
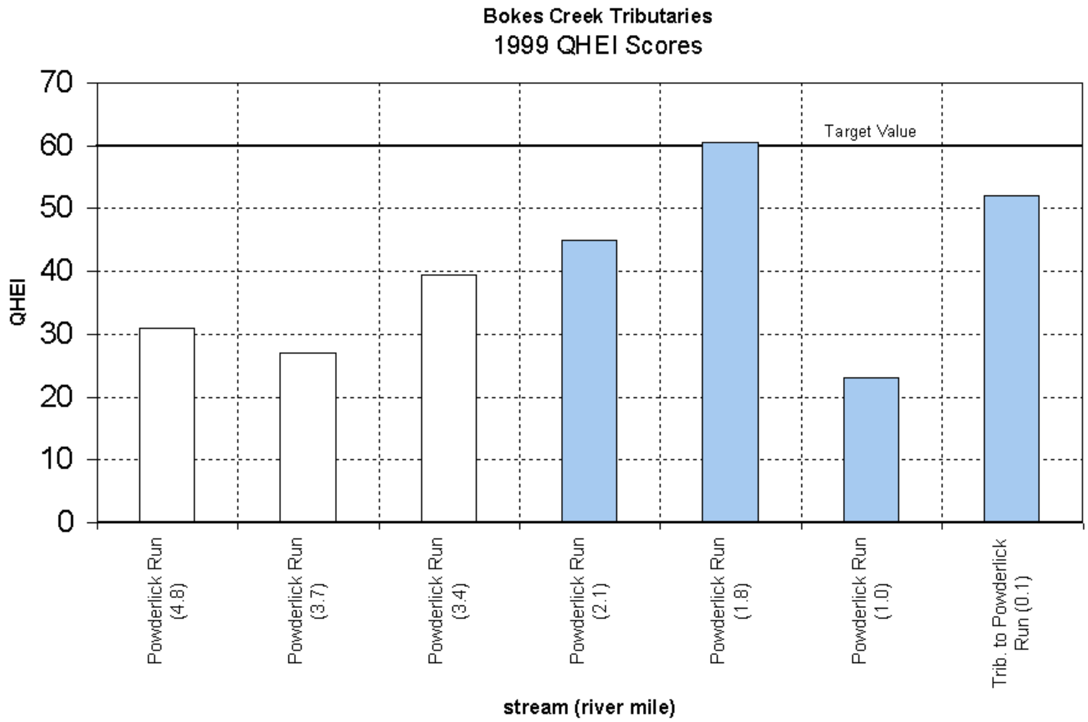


Figure 11. QHEI scores and deviation from the target for Bokes Creek (mainstem).



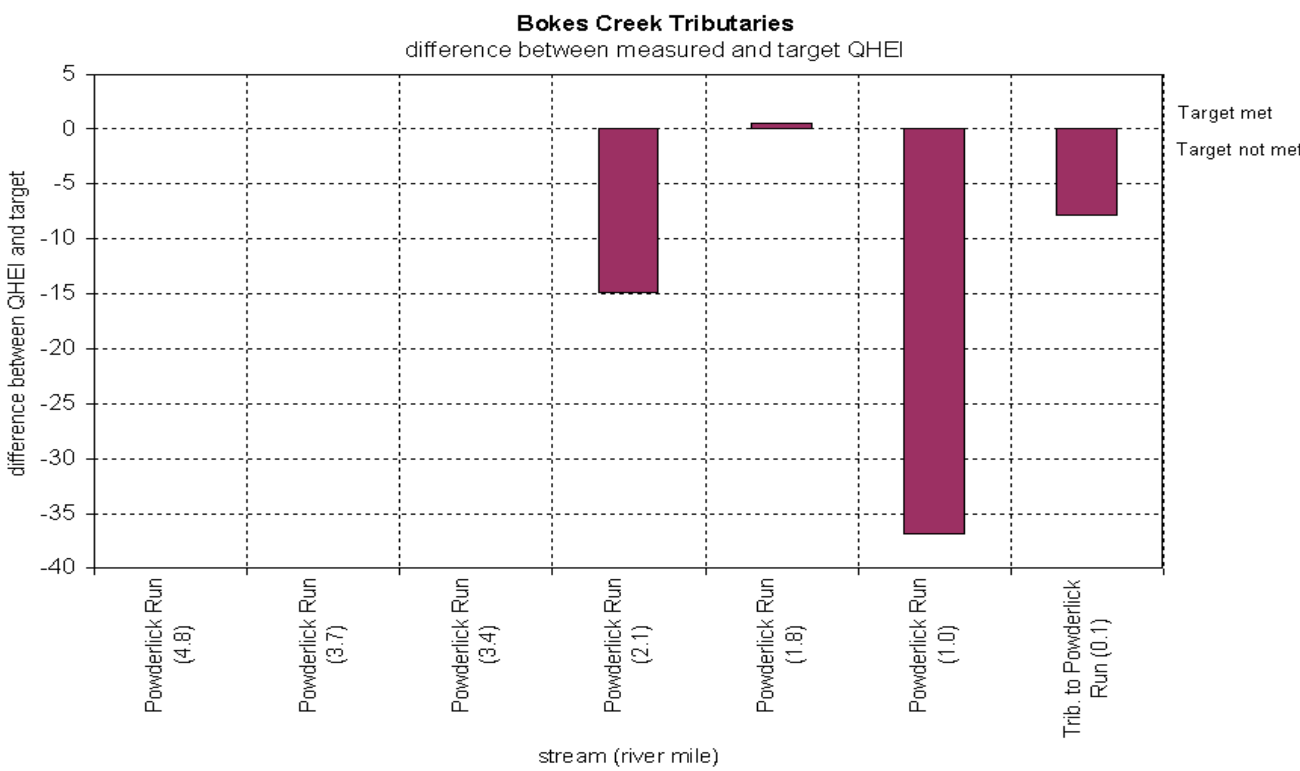
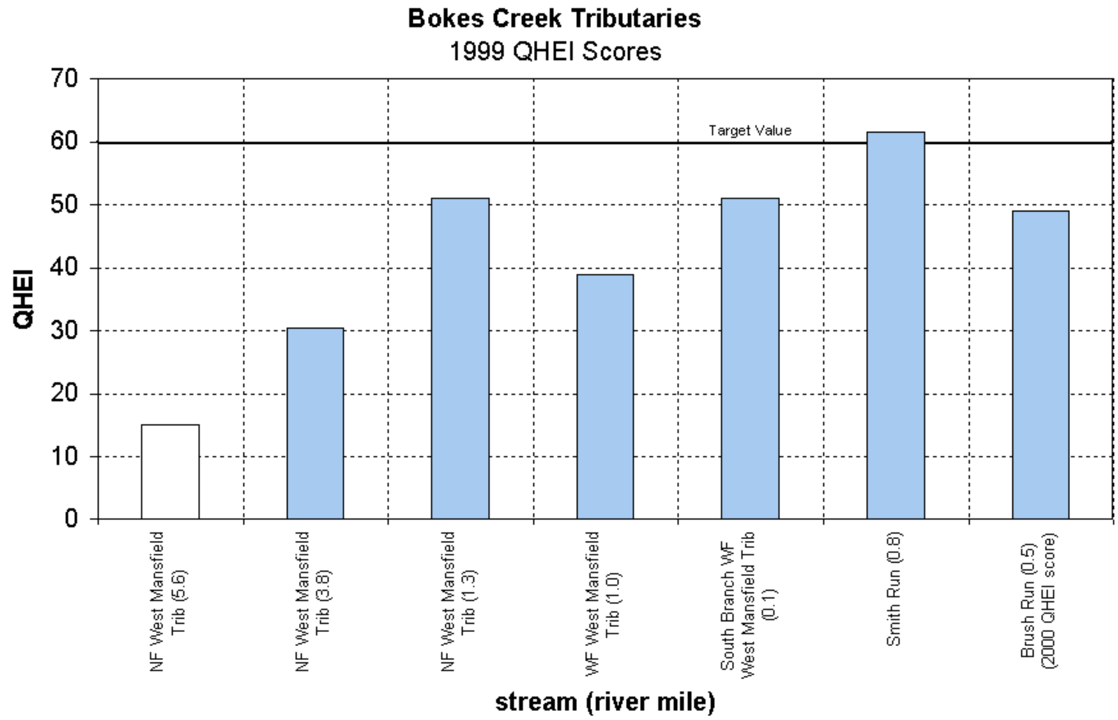


Figure 12. QHEI scores and deviation from the target for the Powderlick Run sub-basin.



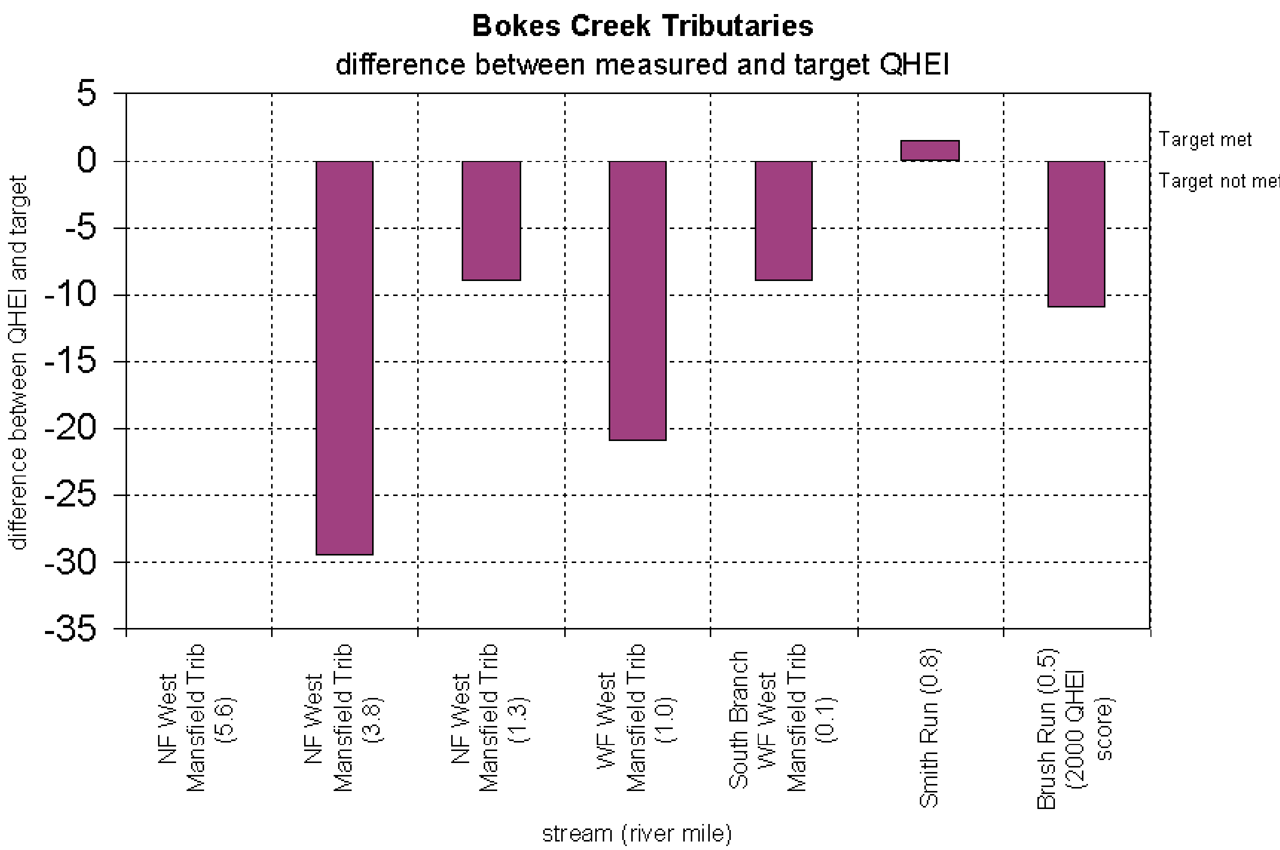


Figure 13. QHEI and deviation from target in Smith Run and the West Mansfield Tributaries.

5.0 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 its findings and recommendations.

Public participation associated with the Bokes Creek TMDL project began with the hiring of a local watershed coordinator funded in part by a 319 grant. The grant was awarded in August 2000, and the watershed coordinator started soon thereafter, under the sponsorship of the Union County Soil and Water Conservation District Board of Supervisors. The watershed coordinator position has served as an essential local link between Ohio EPA and local government and citizens throughout the TMDL project, and will continue to serve in that capacity through implementation of the TMDL.

Consistent with Ohio's current Continuing Planning Process (CPP), Ohio EPA involved the public in the Bokes Creek TMDL project by soliciting input and recommendations for action from many local parties. Although there was no organized watershed advocacy group existing in the Bokes Creek watershed, after holding some initial meetings to solicit public involvement, the Bokes/Mill Creek Watershed Partnership was formed. The Bokes/Mill Creek Watershed Partnership is comprised of private citizens/landowners, agricultural community (farmers), municipal officials, government entities, environmental interest/advocacy groups and the industrial community. The Bokes/Mill Creek Watershed Partnership is serving the purpose of providing a body representative of local interests that could interact with Ohio EPA during the TMDL project and on other watershed issues. This group will continue to serve as a focal point for local citizen and government input to the TMDL project as the implementation process goes forward.

To better identify stakeholder concerns and problems affecting the watershed, the Bokes/Mill Creek Watershed Partnership originally developed five subcommittees (Administrative, Nonpoint Source Pollution, Point Source Pollution, Stream Flow/Habitat and Water Supply). Through these subcommittees, water quality/watershed concerns have been documented, including high levels of atrazine, high nutrient levels and the presence of log jams. The Nonpoint Source Pollution and the Stream Flow/Habitat subcommittees list log jams as the highest priority concern, so the decision was made to merge the two subcommittees.

Public outreach activities also include a public comment period associated with the review of the draft TMDL report prior to its submittal to U.S. EPA Region 5. The draft TMDL report was public noticed on May 6, 2002, and a copy of the report was posted on Ohio EPA's web page (http://www.epa.state.oh.us/dsw/tmdl/index.html). In addition, copies of the report were distributed to local libraries. A summary of the comments received and the associated responses is included in Appendix G. The Union Soil and Water Conservation District, Bokes/Mill Creek Watershed Partnership and watershed coordinator also facilitated the public notification and review of the draft TMDL report.

The 1998 303(d) list public comment period, and the selection of Bokes Creek as a priority watershed for TMDL development, provided an additional opportunity for public input concerning information contained in the list (e.g., causes and sources of impairment, priority, restorability).

Public involvement is the keystone 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 this section of the Bokes Creek watershed into attainment. The local leadership provided by the Bokes/Mill Creek Watershed Partnership and subcommittees will be instrumental in promoting further public involvement and implementation of the TMDL project.

Table 12. Bokes Creek/Mill Creek Watershed Partnership and other Public Participation

Date	Time	Subject(s)
11/8/00	9:30 a.m.	TMDL Project kick-off meeting, attended by local watershed coordinator
2/15/01	8:00 a.m.	Tour of the Bokes Creek watershed.
2/21/01	2:00 p.m.	Initial public meeting concerning TMDL project; solicitation of items important to the public in terms of water quality.
6/5/01	9:30 a.m.	Second public meeting concerning TMDL project; solicit public's ideas for possible watershed committee structure.
9/5/01	3:00 p.m.	Third public meeting concerning TMDL project; establish structure and membership of Watershed Partnership.
9/12/01	3:00 p.m.	Initial meeting of Bokes/Mill Creek Watershed Partnership.
10/10/01	9:00 a.m.	Bokes/Mill Creek Watershed Partnership meeting. Organization; establish subcommittee structure and draft mission statement.
11/14/01	9:15 a.m.	Bokes/Mill Creek Watershed Partnership meeting. Subcommittee reports, TMDL issues on Bokes, Mill, and Blues Creeks.
11/28/01	4:15 PM	Administrative (Education) subcommittee meeting.
12/4/01	7:30 p.m.	Nonpoint Source subcommittee meeting.
12/11/01	7:00 p.m.	Stream Flow/Habitat subcommittee meeting.
12/12/01	9:15 a.m.	Bokes/Mill Creek Watershed Partnership meeting. Subcommittee reports, TMDL issues on Bokes, Mill and Blues Creeks.
12/19/01	4:15 p.m.	Administrative subcommittee meeting.
1/3/02	7:30 p.m.	Nonpoint Source subgroup meeting.
1/7/02	1:00 p.m.	Water Supply subcommittee meeting.

Date	Time	Subject(s)
1/9/02	9:15 a.m.	Bokes/Mill Creek Watershed Partnership meeting. Subcommittee reports and discussion, review of TMDL report structure and timing.
1/21/02	7:00 p.m.	Stream Flow/Habitat subcommittee meeting
1/23/02	1:30 p.m.	Initial Point Source subcommittee meeting.
1/24/02	3:45 p.m.	Administrative subcommittee meeting.
2/5/02	7:30 p.m.	Nonpoint Source subcommittee meeting.
2/7/02	1:00 p.m.	Water Supply subcommittee meeting.
2/13/02	9:15 a.m.	Bokes/Mill Creek Watershed Partnership meeting. Discussion of pollutants to be handled in the TMDL.
3/5/02	7:30 p.m.	First meeting of the combined Nonpoint Source and Stream Flow/Habitat subcommittee.
3/13/02	9:30 a.m.	Bokes/Mill Creek Watershed Partnership meeting. Discussion of results of TMDLs, and by-laws.
3/27/02	9:30 a.m.	Farmers breakfast. Presentations on TMDLs, results of TMDLs, and natural channel design.
4/10/02	9:30 a.m.	Bokes/Mill Creek Watershed Partnership meeting. Update on TMDL status and by-laws.
The Bokes/Mill Creek Watershed Partnership continues to meet the 2nd Wednesday of each month		

Log Jams and Water Quality Issues

As a consequence of the public participation efforts on the Bokes Creek TMDL project, Ohio EPA was exposed to issues that are very important to local stakeholders, but were not immediately apparent to Ohio EPA. The issue of log jams, and their effect on Bokes Creek is a significant local issue. Careful reference to Figure 2 will reveal that there are log jams of sufficient magnitude on Bokes Creek that satellite imagery identifies the area as a wooded wetland (red markings in the Bokes Creek mainstem). In discussion of this important local issue, Ohio EPA has maintained that it has no data to support the supposition that log jams are a water quality problem.

Dependant upon resource levels during the summer of 2002, Ohio EPA will evaluate attempting to establish a link between water quality and the log jams in Bokes Creek.

6.0 IMPLEMENTATION AND MONITORING RECOMMENDATIONS

6.1 Implementation Strategies

The major causes of impairment in the Bokes Creek basin are nonpoint source in nature. Land application of manure from egg production facilities in the headwaters and on tributaries, coupled with habitat degradation, other agricultural operations, and failing or inadequate onsite sewage treatment facilities have resulted in impaired biological community performance in Bokes Creek. Sections 3 and 4 of this report identify pollutant reduction and other targets that are expected to allow restoration of the aquatic life uses of the Bokes Creek basin

Restoration methods to bring an impaired waterbody into attainment with water quality standards generally involve an increase in the waterbody's capacity to assimilate pollutants, a reduction of pollutant loads to the waterbody, or some combination of both. As described in Section 2.0, the causes of impairment in the Bokes Creek are primarily nutrient enrichment, sedimentation, and stream habitat degradation. Therefore, an effective restoration strategy would include habitat improvements and reductions in pollutant loads potentially combined with some additional means of increasing the assimilative capacity of the stream.

6.1.1 Powderlick Run Implementation Activities

The Powderlick Run sub-basin of the Bokes Creek watershed is a target area for restoration actions for the reasons summarized below:

- Non-attainment of WQS in the Powderlick Run sub-basin is causing a DO sag zone for 2-4 miles downstream of the confluence of Powderlick Run with Bokes Creek at RM 20.76;
- Wet weather ammonia-N is elevated to levels that exceed WQS; a 67% reduction in wet weather ammonia-N is needed to maintain WQS in this sub-basin;
- A 91.6% reduction in total phosphorus loadings is needed to meet nutrient targets in the Powderlick Run sub-basin;
- Effects of nutrient enrichment are exacerbated by poor physical habitat; specifically, Powderlick Run contains the only LRW designation in the entire watershed, with biological community scores of zero (0), QHEI scores below 45 and as low as 25; in stream conditions are characterized as extensively embedded, with heavy patches of silt common and lacking in important instream habitat elements; channelization of the downstream section in 1999 destroyed what little habitat was left in that segment;

Implementation actions to address the water quality issues noted above have begun in the Powderlick Run sub-basin. They are summarized below.

Daylay Egg farm has eliminated their active NPDES discharges. In addition, Daylay Egg Farm has eliminated the necessity to produce the problematic filter backwash water through adjustments to their watering system. Future Daylay implementation plans call for installing storm water ponds and wetlands to help control storm water discharges. Daylay Egg Farm enrolled their farm in a USDA Conservation Plan and agreed to meet the USDA Federal 590

Standard that uses phosphorus as a limiting nutrient for land application of manure. Daylay also has installed over 25 acres of switchgrass filter strips along Powderlick Run and Brush Run.

A 319 implementation project (#EPA-01(h)-22), the Bokes Creek Water Quality Enhancement Project, will begin in spring 2002 and be completed in 2005. The 319 grant provides $189,000 and will be matched with $142,750 in local in-kind and cash contributions, for a total project cost of $331,750. This project will also focus restoration efforts in the Powderlick Run sub-basin. The project is expected to increase the assimilative capacity of Powderlick Run and restore in stream and stream bank habitat conditions in select locations downstream of the Daylay Egg Farm and upstream of the segment that was channelized in 1999. The implementation of this project will provide an important, local, "on the ground" example to local stakeholders in the watershed that habitat improvement and effective drainage can be accomplished at the same time. Specifics of the project are outlined below:

- A two-stage (low flow + floodplain) channel will be constructed in a 2000 lineal foot (LF) segment of Powderlick Run; the two-stage channel will allow for flow and instream habitat during summer low flow conditions, as well as providing a floodplain for sediment deposition during high flow wet weather conditions. In stream habitat features (riffles, boulders, woody debris, log vanes, root wads, etc.) will be placed in the 2-stage channel to restore habitat features.
- A twenty-six acre permanent conservation easement will be purchased adjacent to the two-stage channel to insure the long-term integrity of the restoration work;
- A 1,000 LF segment of headwater channel tributary to Powderlick Run will be restored by returning channel morphology to "natural" contours and providing a wooded corridor adjacent to the new channel;
- A preliminary field assessment of nine sites will be conducted to compare current Powderlick Run conditions to those of "natural" reference sites to provide the basis for design of the two-stage channel; the assessment will include data about physical and morphological characteristics, substrate analysis, QHEI, macroinvertebrates, water quality monitoring for NO3, DO pH, temperature, and a hydraulic analysis;
- Post-construction QHEI and chemical water quality data will be collected to determine WQ impacts and to estimate loading reductions resulting from project implementation;
- An additional 1500 LF of in stream habitat enhancements will be implemented in a headwater area of the Powderlick Run sub-watershed to include (riffles/pools, boulders, woody debris, overhanging cover, bank stabilization, and/or stabilization of tile and waterway outlets;
- A series of field days, workshops, public meetings, newsletter and newspaper articles will be used to educate the public about the project and to promote implementation of similar practices elsewhere in the watershed.

6.1.2 Watershed Action Plan

Through a FY 2000 319 grant (#EPA-00(h)-04), a watershed coordinator has been hired to complete a community-based watershed action plan (WAP) for the entire Bokes Creek watershed by December 2002. The WAP will build upon both the TMDL work completed to date and the implementation efforts that have already begun in the Powderlick Run sub-basin. The WAP will link local and state priorities for action in the watershed with the identified water quality targets outlined in the TMDLs. A key component of the WAP will be an estimate of the loading reductions and habitat improvements that can be expected as a result of implementing the recommended restoration actions.

Through the development of the WAP, the watershed coordinator will assist the watershed steering group with identification of strategies and setting of goals, coordinate implementation, and develop a monitoring program to ensure local efforts are sustained to improve water quality. The WAP will identify local project sponsors for recommended restoration actions and will provide the road map for future project applications to the two major funding sources for implementation ----- the 319 grant program and the Water Pollution Control Loan Fund (WPCLF). Both sources of funding provide for voluntary implementation of agricultural best management practices, upgrades/replacements of failing home sewage treatment systems (HSTSs), and stream restoration. However, the amount of funding available through the 319 grant program is far smaller (approximately $7M annually for the entire program), is available only once per year on a competitive basis, and is subject to funding caps per project ($500,000 in FY 2002). In contrast, approximately $200M of low interest loan funding is available annually through the WPCLF. WPCLF funding is available throughout the year and there are no funding caps per project. In addition, WPCLF funding is available to solve both point and nonpoint source pollution problems.

6.2 Reasonable Assurances

U.S. EPA guidance calls for reasonable assurances when TMDLs are developed for waters impaired by both point and nonpoint sources and for waters impaired solely by nonpoint sources. The purpose of the reasonable assurances requirement is for U.S. EPA to be comfortable that the identified activities will in fact be implemented. Reasonable assurances for reductions in nonpoint source loadings may be non-regulatory, regulatory, or incentive based, and should be consistent with applicable laws and programs. Because Ohio EPA does not have direct authority/jurisdiction over many of the identified nonpoint sources, it will be important to coordinate activities with those governmental agencies that do (e.g., county health departments, municipalities, county soil and water conservation districts, local NRCS offices).

Existing federal regulations do not require implementation planning for an approvable TMDL, however implementation of the TMDL project is important to effect positive change in water quality. As mentioned in the previous section, a mechanism to ensure implementation planning for the Bokes Creek TMDL is in place. Local leadership provided by the Bokes Creek watershed coordinator coupled with grant requirements for the completion of a watershed action plan will ensure that implementation planning is performed. Once implementation planning has been completed, projects can be developed based on that plan that will accomplish the needed load reductions and habitat improvements identified in this TMDL project.

Ohio EPA initiated the TMDL process in this watershed in the early 1990s, and produced a 1995 report entitled the "Bokes Creek Water Chemistry Report and Phased TMDL" (Ohio EPA, 1995b). This report identified several problem areas in Bokes Creek, some of which are still identified in this TMDL. The critical link that is present in this TMDL as opposed to the previous one is the local watershed coordinator with a responsibility to prepare an action plan. In the absence of this link, local implementation of the 1995 Bokes Creek phased TMDL has occurred in an *ad hoc* fashion. However, due to local leadership by the Scioto River Valley Federation, Day Lay Egg Farm, the Union County Soil and Water Conservation District, Oxbow River and Stream Restoration Company and the City of Columbus, a 319 grant project will be commencing in 2002 which will serve to address some of the impairments that are identified in this TMDL process.

The Bokes Creek Water Quality Enhancement Project is designed to address habitat impairments in the Powderlick Run watershed, with concomitant improvements in assimilative capacity and reductions in nutrient loadings. As discussed in chapter 6.1.1, the project is intended to demonstrate natural channel design theory on a highly modified section of stream, as well as to provide a demonstration of two stage channel design, which allows for a natural low flow channel to be augmented by a second stage high flow channel. The implementation of this project will provide an important, local, "on the ground" example to other stakeholders in the basin that habitat improvement and effective drainage can be accomplished at the same time.

The Bokes Creek Water Quality Enhancement Project provides a good example of the flow of water quality information to the planning of a project to implement the improvements necessary to restore water quality. Ohio EPA expects that the addition of the watershed coordinator to this process will allow for a more efficient transition from the implementation planning stage to the project stage (as represented by applications for 319 grant funding). Ohio EPA expects to dedicate future 319 grant funding to accomplishing the water quality goals outlined by this TMDL project.

6.3 Process for Monitoring and Revision

Monitoring of the Bokes Creek watershed will be necessary to ensure that the pollutant reduction targets and habitat improvements are accomplished so as to ultimately result in attainment of the Biological Criteria, which will result in restoration of the aquatic life uses in this basin. A tiered approach to monitoring progress and validating the TMDL will be followed:

1. Confirmation of completion of implementation plan activities
2. Evaluation of attainment of chemical water quality criteria
3. Evaluation of biological attainment.

A TMDL revision will be triggered if any one of these three broad validation steps is not being completed or if the WQS are not being attained after an appropriate time interval. Following development of the implementation plan, if the planned activities are not being carried forth within a reasonable time frame as specified in the implementation plan then an intercession by the Bokes/Mill Creek Watershed Partnership or other appropriate parties would be needed to keep the implementation activities on schedule. Once the majority of or the major implementation plan items have been carried out and/or the chemical water quality has shown consistent and stable improvements then a full scale biological and chemical watershed assessment would be completed to evaluate attainment of the use designations. If chemical water quality does not show improvement and/or waterbodies are still not attaining water quality standards after the implementation plan has been carried out, then a TMDL revision would be initiated. The Ohio EPA would initiate the revision if no other parties wish to do so.

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Appendix A - Aquatic Life Use Attainment Table

This aquatic life use attainment table for the Bokes Creek study area is based on the 1999 sampling results; these data were not available for the 1998 303(d) list but will be used in the next listing cycle. The table is arranged from upstream to downstream and includes sampling locations indicated by river mile (RM), the applicable biocriteria indices, the use attainment status (i.e. full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI) (an indicator of habitat quality), and comments for the sampling location. Where the aquatic life use designation (WWH, MWH or LRW), as determined by the1999 assessment, is different than the use designation in effect prior to the1999 survey, Table A1 provides the attainment status for the existing or the recommended use designation. The recommended use designations became official standards as of June, 2001.

Table A1. Aquatic life use attainment status of sites sampled in the Bokes Creek basin from June- October, 1999. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and the Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) measures the ability of the physical habitat to support a biotic community. Aquatic life uses for the Bokes Creek basin were based on biological sampling conducted during June - October 1999.

RIVER MILE Fish/Invert.	IBI	MIwb	ICI[a]	QHEI	Attainment Status[b]	Site Location
Bokes Creek (02-138) 1999	Eastern Corn Belt Plains (ECBP) - Modified Warmwater Habitat (MWH) Use Designation (**recommended**)					
36.3	26	NA	P*	12.0	**NON**	at SR 292
Bokes Creek (02-138) 1999	*Eastern Corn Belt Plains (ECBP) - WWH Use Designation (existing)*					
35.1 / 35.0	28*	NA	F*	42.5	**NON**	dst. Logan Co Rd. 120
31.8 / 31.9	28*	NA	F*	47.5	**NON**	West Mansfield - Mt. Victory Rd.
27.0 / 27.3	34*	8.6	F*	63.0	PARTIAL	dst./ust. Phelps Rd.
21.3 / 21.2	40	8.1_{ns}	36	62.5	FULL	Yearsley Rd. (ust. Powderlick Run)
20.2 / 20.4	34*	7.2*	34^{ns}	58.5	PARTIAL	Adj. SR 31 (dst. Powderlick Run)
17.0 / 16.8	31*	5.7*	MG^{ns}	59.5	**NON**	ust. Reed Ford Rd.
11.4	42	7.2*	MG^{ns}	67.5	PARTIAL	ust. SR 4
5.6 / 5.4	31*	5.9*	G	63.0	PARTIAL	ust./dst. Brown Rd.
0.2	36_{ns}	6.5*	MG^{ns}	63.0	PARTIAL	dst. SR 257 (near mouth)
Bokes Creek 1993						
27.2 / 26.2	40	8.5	42	56.0	FULL	
21.4	34*	6.7*	40	44.0	PARTIAL	
20.2	34*	5.7*	---	63.5	(**NON**)	
14.8	31*	6.2*	38	72.0	PARTIAL	
5.6	34*	7.4*	32^{ns}	64.0	PARTIAL	
0.3	41	7.3*	---	68.0	(PARTIAL)	
Bokes Creek 1992						
27.5 / 26.2	32*	6.3*	44	43.5	PARTIAL	
21.3 / 21.4	30*	6.2*	50	59.0	PARTIAL	
20.2 / 20.5	29*	5.2*	34^{ns}	45.0	**NON**	
14.8	37^{ns}	7.6*	40	78.0	PARTIAL	
5.5 / 5.6	37^{ns}	6.5*	42	68.0	PARTIAL	
0.3 / 0.2	49	9.1	44	81.5	FULL	
Bokes Creek 1990						
27.2 / 27.5	28*	7.5*	30*	61.0	**NON**	
21.3 / 21.4	34*	6.6*	40	58.5	PARTIAL	
13.2 / 14.8	32*	6.3*	38	82.5	PARTIAL	
5.6	36^{ns}	5.6*	32^{ns}	65.5	**NON**	

RIVER MILE Fish/Invert.	IBI	MIwb	ICI[a]	QHEI	Attainment Status[b]	Site Location
Bokes Creek 1981						
30.6 A	24*	NA	F*	---	**NON**	
30.6 B	28*	NA	MG^{ns}	---	PARTIAL	
28.4 A	18*	NA	F*	---	**NON**	
28.4 B	24*	NA	MG^{ns}	---	**NON**	
26.1 /25.9 A	12*	--	F*	---	**NON**	
26.1 /25.9 B	34*	--	MG^{ns}	---	PARTIAL	
23.2 A	--	--	G	---	(FULL)	
23.2 B	--	--	G	---	(FULL)	
Smith Run (02-138) 1999	ECBP - WWH Use Designation					
0.8	20*	NA	F*	61.5	**NON**	Brindle Rd.
Powderlick Run (02-144) 1999	ECBP-Limited Resource Water (LRW) Use Designation (**recommend**)					
4.8c/4.8	22	NA	VP*	31.0	**NON**	Storms Rd. (dst. Daylay Egg Farm #3)
3.7c/3.7	24	NA	P	27.0	FULL	Easternmost crossing at Davis Rd. (recovery / ust. Daylay Farm #2)
3.4 / 3.3	18	NA	VP*	39.5	**NON**	St. Rt. 739 (dst. Daylay Farm #2/ upstream Daylay Farm #1 - pullets)
Powderlick Run (02-144) 1999	ECBP - WWH Use Designation					
2.1	24*	NA	P*	45.0	**NON**	West crossing at Powderlick Rd. (dst Daylay Farms /ust Mad River Egg Farm)
1.8/1.6	12*	NA	0*	60.5	**NON**	Ust. Powderlick Rd. just west of Fawley Rd. (dst. tributary draining Mad River Egg Farm)
1.2	--	NA	4*	---	(**NON**)	Dst. Powderlick Rd. E of Fawley Rd.
1.0/0.9	18*	NA	6*	23.0	**NON**	Dst. recovery / ust. cattle farms
Powderlick Run (02-144) 1993	*ECBP - WWH Use Designation*					
0.2	28*	NA	--	34.0	(**NON**)	
1.6	22*	NA	--	60.5	(**NON**)	
0.2 / 0.1	25*	NA	30*	49.5	**NON**	
Trib. to Powderlick Run (@ RM 2.0) (02-330) 1999	ECBP - WWH Use Designation					
0.1	12*	NA	--	52.0	(**NON**)	dst. Mad River Egg Farm in trib.
West Fork West Mansfield Tributary (02-194) 1999	ECBP - WWH Use Designation					
1.0 /0.8	26*	NA	MG^{ns}	39.0	**NON**	ust. St. Rt. 47
West Fork West Mansfield Tributary 1981						
0.8A	14*	NA	F*	59.0	**NON**	
0.8B	34*	NA	F*	59.0	**NON**	

RIVER MILE Fish/Invert.	IBI	MIwb	ICI[a]	QHEI	Attainment Status[b]	Site Location
S. Br. West Fork West Mansfield Tributary (02-331) 1999 ECBP-WWH Use Designation						
0.1	--	NA	P*	51.0	(**NON**)	adj. Newton-Perkins Rd. near mouth
East Fork West Mansfield Tributary (02-195) 1981						*ECBP-WWH Use Designation*
0.3A	20*	NA	--	---	(**NON**)	adj. St. Rt. 47
0.3B	28*	NA	--	---	(**NON**)	adj. St. Rt. 47
North Fork West Mansfield Tributary (02-227) 1999						ECBP-MWH Use Designation (**recommended**)
5.6	12*	NA	P*	15.0	**NON**	farm rd. off Logan Co. Rd 26
North Fork West Mansfield Tributary (02-227) 1999						ECBP - WWH Use Designation
3.8/4.0	30*	NA	P*	30.5	**NON**	Co. Rd. 142 (Logan Co.)
1.3	32*	NA	F*	51.0	**NON**	January Rd.
Brush Run (02-228) (2000) ECBP - WWH Use Designation						
0.5[c]	24*	NA	--	49.0	(**NON**)	Yearsley Rd.

Biological Criteria for Eastern Corn Belt Plains (ECBP)

Site Type INDEX	IBI Headwaters	IBI Wading	IBI Boat	MIWB Wading	MIWB Boat	ICI (all sites)
WWH	40	40	42	8.3	8.5	36
MWH	24	24	24	6.2	5.8	22
LRW	18	18	18	4.0	4.0	8

* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
ns Nonsignificant departure from biocriterion (<4 IBI or ICI units; <0.5 MIwb units).
a Narrative evaluation used in lieu of ICI (E=Exceptional; G=Good; MG=Marginally Good; F=Fair; P=Poor).
b Use attainment status based on one organism group is parenthetically expressed.
c Sampled or evaluated in 2000.
NA Not Applicable. The MIwb (Modified Index of Well-being) is not applicable to headwater sites.