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Ohio Environmental Protection Agency

Division of Surface Water

Biological and Water Quality Study of the Kokosing River and Selected Tributaries 2007

Watershed Assessment Units 05040003 010, 05040003 020, 05040003 030, and 05040003 040.

Knox, Morrow, Ashland, Coshocton and Richland counties

OHIO EPA Technical Report EAS/2010-05-09

Ted Strickland, Governor
Lee Fisher, Lt. Governor
Chris Korleski, Director

Biological and Water Quality Study of the Kokosing River Watershed 2007

Knox, Morrow, and Coshocton
Counties

May 13, 2010

OHIO EPA Technical Report EAS/2010-05-09

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NOTICE TO USERS

Ohio EPA incorporated biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish assemblage data, and the Invertebrate Community Index (ICI), which is based on macroinvertebrate assemblage data. Criteria for each index are specified for each of Ohio's five ecoregions (as described by Omernik 1987), and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the existing chemical and whole effluent toxicity evaluation methods and criteria, figure prominently in the monitoring and assessment of Ohio's surface water resources.

The following documents support the use of biological criteria by outlining the rationale for using biological information, the methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results:

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989a. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Since the publication of the preceding guidance documents, the following new publications by the Ohio EPA have become available. These publications should also be consulted as they represent the latest information and analyses used by the Ohio EPA to implement the biological criteria.

DeShon, J.D. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Ohio Environmental Protection Agency. 2008a. 2008 Updates to Biological criteria for the protection of aquatic life: Volume II and Volume II Addendum. Users manual for biological field assessment of Ohio surface waters. Div. of Surface Water, Ecol. Assess. Sect., Groveport, Ohio.

Ohio Environmental Protection Agency. 2008b. 2008 Updates to Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. of Surface Water, Ecol. Assess. Sect., Groveport, Ohio.

Ohio Environmental Protection Agency. 2006a. Methods for assessing habitat in flowing waters: Using the Qualitative Habitat Evaluation Index (QHEI). Ohio EPA Tech. Bull. EAS/2006-06-1. Revised by the Midwest Biodiversity Institute for Div. of Surface Water, Ecol. Assess. Sect., Groveport, Ohio.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.).

Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995. Policy issues and management applications for biological criteria, pp. 327-344. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

These documents and this report may be obtained by writing to:

Ohio EPA, Division of Surface Water
Ecological Assessment Section
4675 Homer Ohio Lane
Groveport, Ohio 43125
(614) 836-8772

Acknowledgments

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Study Area Description – Vince Mazeika
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Copies of this report are located on the Ohio EPA internet web page (http://www.epa.ohio.gov/dsw/document_index/psdindx.aspx) or may be available on CD from:

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FOREWORD

What is a Biological and Water Quality Survey?

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year Ohio EPA conducts biosurveys in 4-5 study areas with an aggregate total of 350-400 sampling sites.

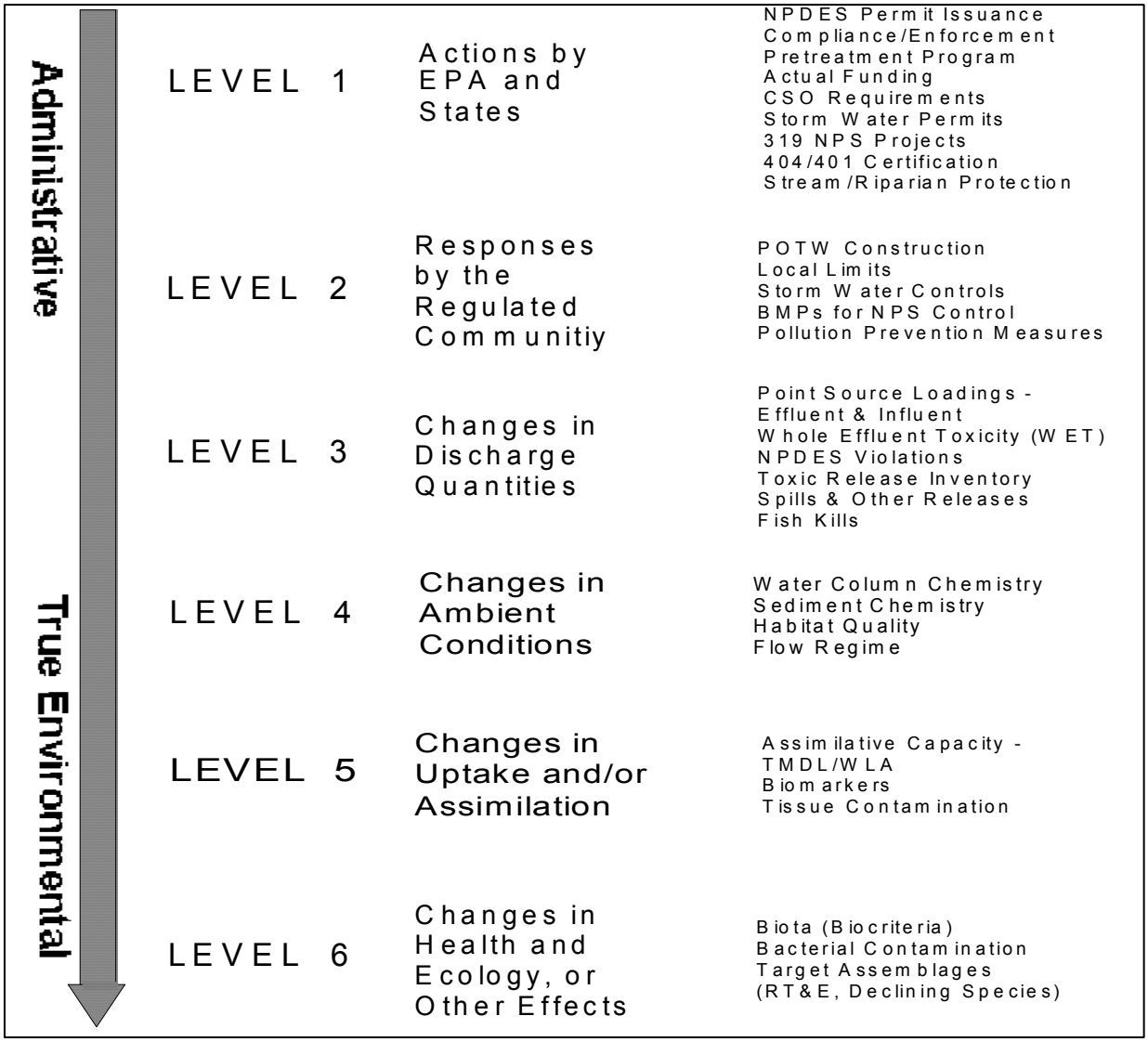
The Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (*e.g.,* NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1], Water Quality Permit Support Documents [WQPSDs]), and are eventually incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators consisting of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results.

Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach includes a hierarchical continuum from administrative to true environmental indicators (Fig. 1). The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4)



changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or

Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition. Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages, *i.e.,* rare, threatened, endangered, special status, and declining species or bacterial levels which serve as surrogates for the recreation uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Use

The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria designed to represent measurable properties of the environment that are consistent with the goals specified by each use designation. Use designations consist of two broad groups, aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting for aquatic life generally results in water quality suitable for all uses. The five different aquatic life uses currently defined in the Ohio WQS are described as follows:

1) *Warmwater Habitat (WWH)* - this use designation defines the "typical" warmwater assemblage of aquatic organisms for Ohio rivers and streams; *this use represents the principal restoration target for the majority of water resource management efforts in Ohio.*

2) *Exceptional Warmwater Habitat (EWH)* - this use designation is reserved for waters which support "unusual and exceptional" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (*i.e.,* declining species); *this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.*

3) *Coldwater Habitat (CWH)* - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic "runs" of salmonids during the spring, summer, and/or fall.

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned by state or federal law;* the representative aquatic assemblages are generally composed of species which

are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 mi^2 drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.,* true ephemeral streams), or other irretrievably altered waterways.

Chemical, physical, and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations employed in the Ohio WQS constitutes a "tiered" approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature, and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use can be having a water depth of at least one meter over an area of at least 100 square feet or, lacking this, where frequent human contact is a reasonable expectation. If a water body does not meet either criterion, the SCR use applies. Water quality criteria for determining attainment of recreational uses are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the presence or absence of bacteria indicators (*Escherichia coli*) in the water column.

Escherichia coli (*E. coli*) bacteria are microscopic organisms that are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour, 1977), but

there is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are becoming more feasible. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor every type of pathogen. Fecal indicator bacteria, including *E. coli*, by themselves are usually not pathogenic. However, some strains of *E. coli* can be pathogenic, capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, it invariably means that the water has received fecal matter from one source or another. Swimming or other recreational-based contact with water having a high *E. coli* count may result in ear, nose, and throat infections, as well as stomach upsets, skin rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The AWS and IWS use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this for AWS would be an urban area where there is no potential for livestock watering or irrigation, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health.

INTRODUCTION

As part of the Total Maximum Daily Load (TMDL) effort and the five year basin approach to monitoring, assessment, and the issuance of National Pollution Discharge Elimination System (NPDES) permits, ambient biological, water column chemical, sediment, and fish tissue sampling was conducted in the Kokosing River watershed from June through October, 2007. The entire Kokosing River watershed and every major tributary was included in the study area. Sample site locations and details are listed in Table 1.

Objectives of the study were to:

1) Monitor and assess the chemical, physical and biological integrity of water bodies within the Kokosing River watershed,

2) Evaluate the physical conditions in streams listed in the study plan to identify their potential to support aquatic biological communities,

3) Characterize the amount of aquatic resource degradation attributable to various land uses including agricultural practices, suburban community development, and urban expansion,

4) Evaluate the biological potential to support the WWH use designation, and

5) Determine any aquatic impacts from known point sources including wastewater treatment plants (WWTPs), and from unsewered communities.

The findings of this evaluation may factor into regulatory actions taken by the Ohio EPA (e.g., NPDES permits, Director's Orders, or the Ohio Water Quality Standards (OAC 3745-1)), and may eventually be incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report).

Executive Summary

The Kokosing River attracts anglers, canoers, kayakers, birders, waders and others who experience primary and secondary contact with the water column and recreate in a high quality public resource setting. Forty-one miles of the main branch of the Kokosing River and 6.5 miles of the North Branch of the Kokosing River have been given Scenic River status by the Director of the Department of Natural Resources. This designation means that the River is representative of a waterway that retains much of its natural character for the majority of its length. Shorelines are for the most part undeveloped, but the river may still exhibit signs of disturbances by human activities.

Study Sites and Aquatic Life Use Attainment

The 2007 watershed study consisted of 53 sites sampled from streams in the Kokosing River basin. Ambient biology, physical habitat quality, water column chemistry, bacteriological, and fish tissue data were collected (Table 9, pg. 46). Biological communities were assessed at 14 sites on the Kokosing River (from RM 54.7 to RM 0.1) and 39 sites on Kokosing River tributaries. Twelve (23%) sampling locations were impaired in the watershed. Eleven sites on the main stem fully met and three Kokosing River sample sites partially met designated or recommended aquatic life use criteria. Thirty Kokosing River tributaries fully met respective designated or recommended aquatic life use criteria. Five tributaries partially met and four tributaries did not meet designated or recommended aquatic life uses (Table 2, pg. 10).

Recreational Use Assessment

Bacteria samples collected during the survey were used to assess attainment with Ohio Water Quality Standards for stream recreation use. Attainment is assessed based on *E.coli* bacteria sample results. For the Kokosing River mainstem where recreational use activities are most common, the highest *E.coli* concentrations were typically observed after significant rainfall. Under normal or low flow conditions most *E.coli* results appeared satisfactory. Evaluation of *E.coli* results revealed that approximately 65% of all sites studied (including tributaries) failed to meet the applicable recreation use standard. Elevated bacteria concentrations were mostly likely due to a variety of sources including failing home sewage treatment systems (HSTS) and livestock access to streams. Summarized *E.coli* bacteria results are presented in Table 12, pg. 54.

Pollution Issues

Impairments to the aquatic community in the Kokosing River watershed were associated with livestock and agriculture, municipal discharges, hypolimnetic lake discharges (Apple Valley Lake), and urban runoff (Table 2, pg. 10). Aquatic communities in three locations impaired by agricultural land uses are the following: Kokosing River RM 50.5, East Branch Jelloway Creek RM 3.3, and South Branch Kokosing River RM 2.9. Livestock operations impaired Kokosing River (RM 39.3), East Branch Jelloway Creek (RM 3.3), and North Branch Kokosing River (RM 4.0). Municipal dischargers (WWTP's) impaired the following four aquatic sites: Kokosing River (RM 24.3), Jelloway Creek (RM 0.1), Little Jelloway Creek (RM 0.1), and East Branch Jelloway Creek (RM 0.1). Pollutants from the Apple Valley Lake discharge outlet impaired Little Jelloway Creek from the discharge outlet downstream to the mouth. The hypolimnetic discharge also impaired Jelloway Creek from the confluence of Little Jelloway downstream to the mouth. Urban and storm water runoff in Delano Run at RM 1.5 impaired the fish community. A detailed discussion of these impairments is contained in the summary of findings section.

Recommendations

Once a watershed's condition has been studied and any impairments identified, it is useful to examine ways to correct the problems. In this section, some general recommendations for the Kokosing River watershed are discussed. More specific, quantified recommendations may result from the Total Maximum Daily Load project.

Recommendations are not limited to this chapter. Recommendations for changes at specific locations that would benefit stream resource quality (for example, riparian and streamside buffer practices and landuse changes) are interspersed throughout this document. Another type of recommendation, pertaining specifically to revisions to stream use designations, are contained in the aquatic life use designation section, page 6. The Kokosing Scenic River Watershed Plan on page 35 lists specific objectives or "action items" which address stream restoration, water quality protection and public resource stewardship.

Managing Storm Water

The Kokosing River watershed and the overall water quality downstream to the Walhonding River are directly affected by storm water drainage and the ways the watershed is buffered from precipitation events. Reduction of sediment, nutrients, fertilizers/chemicals, erosion, and hydrologic modifications can be accomplished through proper storm water management. Agricultural drainage was responsible for storm water pollution in the Kokosing River (RM 50.5), E. Br. Jelloway Creek (RM 3.3) and South Branch Kokosing River (RM 2.9). Sediment runoff due to eroded and trampled stream banks caused by livestock with unrestricted instream access was found to cause pollution in the Kokosing River (RM 39.3), E. Br Jelloway Creek (RM 3.3), and Tributary to N. Br. Kokosing River (RM 9.99) at RM 4.0 (Table 2, pg. 10).

Increased surface area covered by impervious surfaces (urbanization) was problematic in the middle portion of the watershed at Delano Run (RM 1.5). Delano Run was surrounded by impervious surfaces, including: urban housing, industry, and a state route. Physical evidence of storm water runoff such as litter was apparent. Substrates were covered with fine silt and other sediment from the associated storm water runoff. Downstream Delano Run is impounded, forming a small reservoir on the east side of State Route 13.

Re-establishing natural riparian buffers (wetland and wooded riparian corridors) in the watershed to help slow storm water and filter pollutants before they reach the surface waters are positive mechanisms to reduce storm water pollution. In addition to restoring riparian buffers an effort should be made to take advantage of the stream's natural assimilative capacities. Natural development of stream channels provides an array of beneficial services including settling fine sediments into adjacent floodplains, processing of nutrients into productive biomass instead of nuisance algae, improved water quality, creation of natural instream habitats to increase carrying capacity of biomass, and ultimately and most importantly evolution into a stable channel and the slowing of erosion.

Providing out of stream watering areas for livestock and fencing livestock out of streams and riparian corridors will allow the natural vegetative riparian zone to re-establish and help buffer the stream banks from storm water erosion. Another benefit fencing out livestock is to protect the chemical water quality from elevated bacteria and nitrate levels associated with livestock defecation and urination.

Apple Valley Lake

The Apple Valley Lake Committee was eager to remedy the problems associated with the hypolimnetic lake discharge and expeditiously took measures to shut off the bottom discharge after meeting with the Ohio EPA about the issue. Researching more environmentally friendly lake discharge methods was next on the agenda for the lake's committee members and the Ohio EPA.

Nutrient Enrichment and Bacteria

Nutrient enrichment was a problem detected in this watershed study. Methodologies describing ways to reduce nutrient contributions from the general landscape (livestock, agricultural drainage, and urban storm water) were described above. Wastewater treatment plants (WWTP's) contributed to nutrient enrichment. The sources of nutrient enrichment in each subwatershed were different and the resolution to these problems should be tailored to benefit each subwaterhsed.

Improve Habitat Quality

Some of the streams of the Kokosing River watershed have been physically altered. Small watercourses, generally < 20 $mi.^2$ in drainage area, have been legally petitioned under the provisions of the County Ditch Law to facilitate drainage. They will be maintained in this condition in perpetuity or until their petitions are revoked. Other streams have been altered by individual landowners or under provisions of older ditch laws. Regardless, channelization has lowered habitat quality in those portions of the Kokosing River watershed.

To remedy these problems an effort should be made to restore these modified streams to their natural morphological state. Natural stream channels have a greater capacity to assimilate nutrients and fine sediments by flushing them into adjacent floodplains, thereby processing nutrients into productive biomass rather than nuisance algae, which improve water quality. Natural stream channels also support diverse instream habitats, and ultimately – and most importantly for adjacent landowners – possess stable channels. Many of the current causes and sources of stress within this watershed could be reduced by allowing riparian vegetation to re-establish and the stream channel to evolve. Removing the remaining dams, restoring manmade cutoff channels, restoring wetlands and moving dikes and levees away from the active stream channel will foster this process.

Aquatic Life Use Designations

Table 1. Stream use designations for water bodies in the Kokosing River watershed based on sampling conducted during 2007.

Use designations based on Ohio EPA biological field assessments appear as a plus sign (+). Use designations based on the 1978 and 1985 standards are displayed with an asterisk (*). Use designations based upon results other than Ohio EPA biological data are marked with a circle (o). The delta symbol (Δ) indicates a new use designation based upon the findings of this report.

Water Body Segment	Use Designations												Comments
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Kokosing river - North branch (RM 29.66) to the mouth			+						+	+		+		
- all other segments		+	Δ						+	+		+		
Singer run		*							*	*		*		
Brush run		*				Δ			*/+	*/+		*/+		
Honey run		*							*	*		*		

Water Body Segment	Use Designations												Comments
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Jelloway creek –Ireland Creek (RM 9.35) to Fredericktown Amity Rd. (RM 5.18)			+			Δ			+	+		+		
Jelloway creek (RM 4.9) to the mouth			+						+	+		+		
Little Jelloway creek			+			Δ			+	+		+		
East branch -from headwaters to US Route 62 (RM 2.4)			+			Δ			+	+		+		
East branch (RM 2.4 to mouth)			+											
Sapps run		*							*	*		*		
Dowd creek		*							*	*		*		
Shadley Valley creek		*							*	*		*		
Ireland creek		*							*	*		*		
Barney run		*							*	*		*		
Schenck creek			+			Δ			+	+		+		
Coleman branch		*							*	*		*		
Little Schenck creek (from headwaters to RM 3.5)		*	Δ			Δ			*/+	*/+		*/+		
Little Schenck creek (RM 3.49 to mouth)		*	Δ						*/+	*/+		*/+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Mud run		*							*	*		*		
Indianfield run		*	Δ						*/+	*/+		*/+		
Big run		*/+							*/+	*/+		*/+		
Elliott run		*/+							*/+	*/+		*/+		
Wolf run		*							*	*		*		
Center run		*	Δ			Δ			*/+	*/+		*/+		
Dry creek -from headwaters to unnamed trib. (RM 4.74)		*	Δ			Δ			*/+	*/+		*/+		
Dry creek- unnamed trib. (RM 4.74) to Dry Run (RM 1.05)		*				Δ			*/+	*/+		*/+		
Dry creek-Dry Run (RM 1.05) to the mouth		*/+							*/+	*/+		*/+		
Dry run		*							*	*		*		
Armstrong run		*	Δ			Δ			*/+	*/+		*/+		
North branch-from headwaters to unnamed trib. (RM 10.8)		+	Δ			Δ			+	+		+		
North branch-unnamed trib. to East Branch (from RM 10.8 to 6.32)		+							+	+		+		
North branch-East Branch to mouth (from RM 6.32 to mouth)		+	Δ						+	+		+		
Job run		*	Δ			Δ			*/+	*/+		*/+		

Water Body Segment	Use Designations												Comments
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
East branch (from headwaters to Mishey Rd. at RM 4.82)		*				Δ			*/+	*/+		*/+		
East branch (downstream Knox Lake (RM 1.0) to mouth)		*	Δ						*/+	*/+		*/+		
Isaacs run		*							*	*		*		
Markley run		*							*	*		*		
Toby run		*							*	*		*		
Lost run		*							*	*		*		
Granny creek		*	Δ			Δ			*/+	*/+		*/+		
Mile creek		*							*	*		*		
South branch		*/+							*/+	*/+		*/+		
Delano Run		Δ							Δ	Δ		Δ		
North branch trib., at RM 9.9		Δ							Δ	Δ		Δ		
Sylvester run		*							*	*		*		

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat; MWH = modified warmwater habitat; SSH = seasonal salmonid habitat; CWH = coldwater habitat; LRW = limited resource water; PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply; BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.

Aquatic Life Use Attainment Status

The overall aquatic life use attainment status for the Kokosing River watershed was good. Only twenty three percent (12 out of 53 sites) of the sampling locations were not meeting or only partially meeting their designated aquatic life uses (Table 2).

Table 2. Aquatic life use attainment status for stations sampled in the Kokosing River basin based on data collected June-October 2007. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community.

River Mile Fish/Invertebrate	IBI	MIwb	ICI	QHEI	Attainment Status	Causes	Sources
Kokosing River - (17650) Erie Ontario Lake Plain Ecoregion WWH existing, recommended EWH							
54.7/54.6[H]	50	NA	VG[ns]	65.5	**Full**		
50.5/49.8 [H]	44*	NA	44[ns]	57.5	**Partial**	Sedimentation/Siltation	Agriculture
45.4[W]	46[ns]	9.2[ns]	48	46.0	**Full**		
39.3/39.2[W]	39*	9.2[ns]	46	55.5	**Partial**	Sedimentation/Siltation	Unrestricted Cattle Access
32.6/32.5[W]	47[ns]	9.4	48	75	**Full**		
Kokosing River - (17650) Erie Ontario Lake Plain Ecoregion – EWH existing							
28.6/28.7 [W]	48[ns]	9.3[ns]	52	82.0	**Full**		
25.3/25.1 [W]	56	9.9	52	82.5	**Full**		
24.3/24.5 [W]	54	8.9[ns]	38*	87.5	**Partial**	Nutrient/Eutrophication,Phosphorus	Municipal Point Source Discharge
20.9/22.1 [W]	49[ns]	9.0[ns]	42[ns]	82.5	**Full**		
18.9 [W]	53	10.0	52	82.0	**Full**		
11.6[B]	53	9.15[ns]	E	81.0	**Full**		
6.2[W]	48[ns]	9.4	52	87.0	**Full**		
2.7[B]	52	9.3[ns]	50	88.0	**Full**		
0.1[B]	55	9.1[ns]	E	81.0	**Full**		

River Mile Fish/Invertebrate	IBI	MIwb	ICI	QHEI	Attainment Status	Causes	Sources
Brush Run (17652) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended CWH							
0.9[H]	48	NA	G	65.5	**Full**		
Jelloway Creek (17654) Erie Ontario Lake Plain Ecoregion – EWH existing, recommended CWH and EWH							
8.9[H]	52	NA	E	74.0	**Full**		
Jelloway Creek (17654) Erie Ontario Lake Plain Ecoregion – EWH existing							
4.3[W]	49[ns]	9.1[ns]	48	73.5	**Full**		
0.1[W]	53	9.25[ns]	G*	81.5	**Partial**	Nutrient/Eutrophication Biological Indicators; Organic Enrichment (sewage) Biological Indicators	WWTP Discharge, Dam bottom discharge; agriculture
Little Jelloway Creek (17655) Erie Ontario Lake Plain Ecoregion – EWH existing, recommended CWH and EWH							
7.0/6.9[H]	54	NA	VG[ns]	67.0	**Full**	Threatened by open pasture upstream and adjacent row-crops	
0.8/0.9[H]	36*	NA	28*	71.0	**NON**	Flow Alteration	Apple Valley Lake Dam bottom discharge
0.1[W]	44*	8.8*	LF*	71.0	**NON**	Nutrient/Eutrophication Biological Indicators; Organic Enrichment (sewage) Biological Indicators ammonia-nitrogen	Small flow WWTP Discharge Apple Valley Lake Dam
E. Br. Jelloway Creek (17656) Erie Ontario Lake Plain Ecoregion – EWH existing, recommended CWH and EWH							
3.3[H]	40*	NA	44[ns]	61.5	**Partial**	Sedimentation/Siltation	Agriculture, Unrestricted Cattle Access
E. Br. Jelloway Creek (17656) Erie Ontario Lake Plain Ecoregion – EWH existing							
1.0/1.1[H]	24*	NA	52	46.0	**NON**	Total Phosphorus, Total Ammonia	Danville WWTP
Schenck Creek (17662) Erie Ontario Lake Plain Ecoregion – EWH existing, recommended CWH and EWH							
8.7/8.8[H]	46[ns]	NA	E	80.5	**Full**		
2.6[W]	47[ns]	9.3[ns]	E	83.5	**Full**		
0.6/0.5[W]	50	9.3[ns]	E	76.0	**Full**		
Little Schenck Creek (17664) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended CWH and EWH							
4.5[H]	50	NA	E	91.5	**Full**		

River Mile Fish/Invertebrate	IBI	MIwb	ICI	QHEI	Attainment Status	Causes	Sources
River Mile 3.5 (Carson Rd) – Downstream end of CWH and EWH, Begin EWH from RM 3.49 to the mouth							
Little Schenck Creek (17664) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended EWH							
0.2[H]	46[ns]	NA	E	72.0	**Full**		
Indianfield Run (17666) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended EWH							
2.7/2.8[H]	54	NA	VG[ns]	73.0	**Full**		
Big Run (17667) Erie Ontario Lake Plain Ecoregion –WWH existing							
4.4/4.5[H]	50	NA	MG[ns]	65.0	**Full**		
0.7/0.6[W]	44	8.6	50	70.5	**Full**		
Elliot Run (17668) Erie Ontario Lake Plain Ecoregion – WWH existing							
1.1/1.0[H]	44	NA	MG[ns]	32.0	**Full**		
0.2 [H]	54	NA	VG	47.5	**Full**		
Center Run (17670) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended CWH and EWH							
1.7[H]	48[ns]	NA	E	60.5	**Full**		
Dry Creek (17671) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended CWH and EWH							
10.7/10.8[H]	56	NA	E	78.0	**Full**		
9.2[H]	54	NA	VG[ns]	81.5	**Full**		
Dry Creek (17671) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended CWH							
4.5[W]	42	7.5[ns]	48	69.5	**Full**		
Dry Creek (17671) Erie Ontario Lake Plain Ecoregion – WWH existing							
1.0 [W]	46	8.95	44	61.0	**Full**		
Armstrong Run (17673) Erie Ontario Lake Plain Ecoregion –WWH existing, recommended CWH and EWH							
1.1/1.6[H]	48[ns]	NA	E	71.5	**Full**		
N. Br. Kokosing River (17674) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended CWH and EWH							
17.8/17.77 [H]	50	NA	E	71.0	**Full**		
14.0 [H]	54	NA	E	82.5	**Full**		
N. Br. Kokosing River (17674) Erie Ontario Lake Plain Ecoregion – WWH existing							
9.2/8.7	40	7.5[ns]	42	66.0	**Full**		

River Mile Fish/Invertebrate	IBI	MIwb	ICI	QHEI	Attainment Status	Causes	Sources
N. Br. Kokosing River (17674) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended EWH from RM 8.5 to the mouth							
6.2 [W]	55	9.9	50	82.5	**Full**		
5.4/5.5 [W]	52	9.9	E	65.0	**Full**		
0.1 [W]	52	10.0	52	85.0	**Full**		
Job Run (17675) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended EWH and CWH							
0.1 [H]	48[ns]	NA	E	46.5	**Full**		
E. Br. North Br. Kokosing River (17676) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended CWH							
6.1/6.0 [H]	42	NA	G	23.0	**Full**		
E. Br. North Br. Kokosing River (17676) Erie Ontario Lake Plain Ecoregion – WWH existing, recommended EWH							
0.1 [W]	51	9.7	VG[ns]	87.5	**Full**		
***Granny Creek (17681) Erie Ontario Lake Plain Ecoregion – WWH existing*, recommended EWH and CWH**							
4.3 [H]	52	NA	VG[ns]	79.0	**Full**		
Mile Run (17682) Erie Ontario Lake Plain Ecoregion – WWH existing							
4.8/4.6 [H]	50	NA	MG[ns]	57.5	**Full**		
S. Br. Kokosing River (17683) Erie Ontario Lake Plain Ecoregion – WWH existing							
2.9/3.0 [H]	38[ns]	NA	HF*	57.5	**Partial**	Nutrient/Eutrophication, Ammonia, Low Dissolved Oxygen (DO)	Agriculture
Delano Run (17690) Erie Ontario Lake Plain Ecoregion –Undesignated, WWH recommended							
1.5/1.6 [H]	30	NA	G	53.5	**Partial**	Sedimentation/Siltation	Urban Runoff/Storm Sewers
N. Br. Kokosing Tributary, River Mile 9.9 (17691)) Erie Ontario Lake Plain Ecoregion – Undesignated, recommended WWH							
4.0/3.9 [H]	32*	NA	MG[ns]	57.0	**Partial**	Sedimentation, Low DO, Organic enrichment	Unrestricted Cattle Access

Ecoregion Biocriteria for Erie-Ontario Lake Plain

	IBI			MIwb			ICI		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	20	H	H	H	34	46	22
Wading	38	50	22	7.9	9.4	5.6	34	46	22
Boat	40	48	20	8.7	9.6	5.7	34	46	22

H - Headwater site, MIwb is not applicable.

W - Wading site.

B - Boat site.

a - MIwb is not applicable to headwater streams with drainage areas $\leq$ 20 mi^2.

[b] - A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, HF=High Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional

c - Attainment status is given for the existing or if a change is proposed then the proposed use designations.

NA Not applicable

ns - Nonsignificant departure from biocriteria ($\leq$4 IBI or ICI units, or $\leq$0.5 MIwb units).

* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

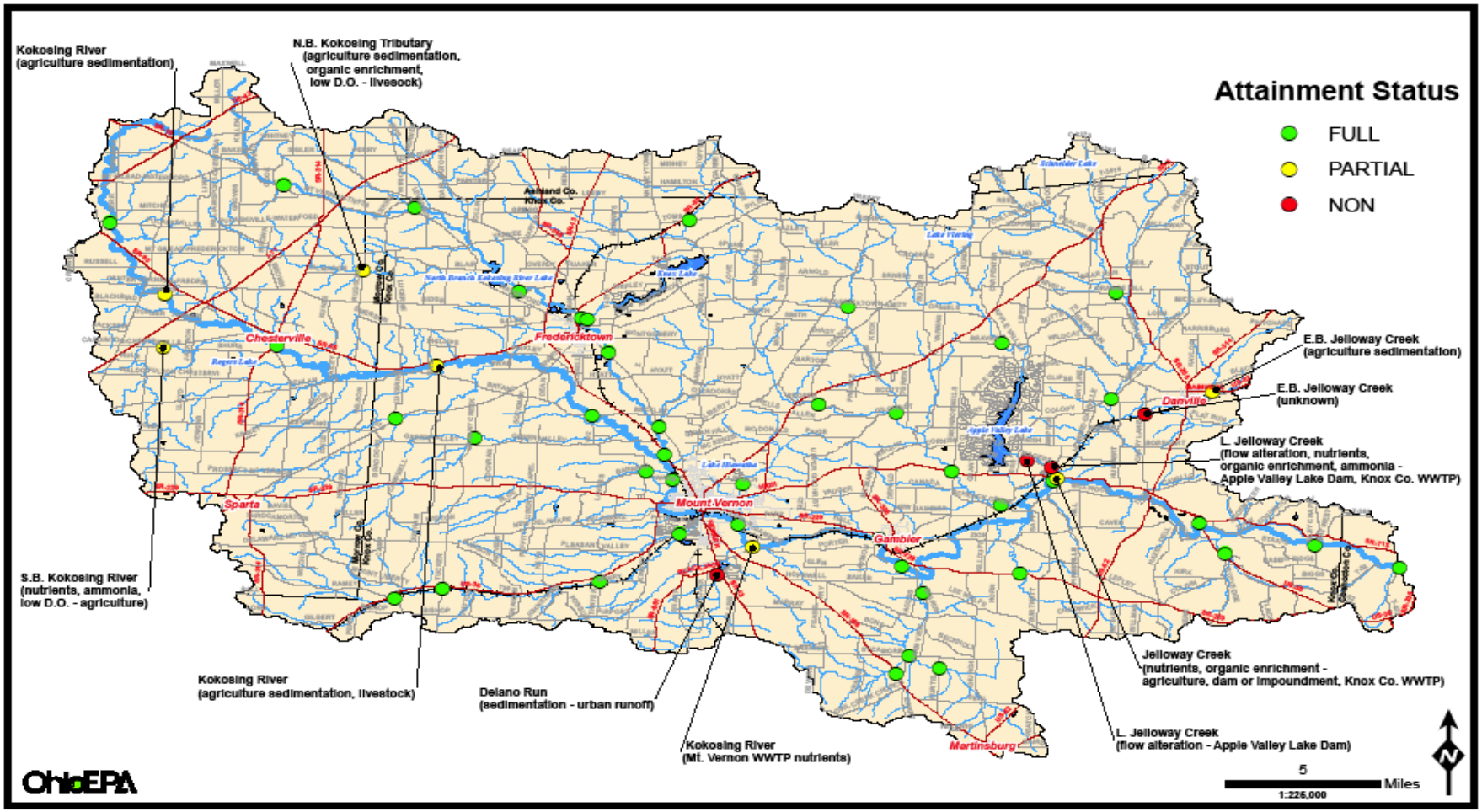


Figure 2. Kokosing River watershed aquatic life use attainment map, 2007.

Kokosing River Fish Tissue Advisory Summary, 2007

Reach Examined: RM 29.7-0.2

Advisory Recommendations

Meals of rock bass 8" and over and smallmouth bass 15" and over should be restricted to one meal per month due to mercury levels in the stream segment from County Road 13/Green Valley Road (Mount Vernon) to the mouth (Walhonding River). Mercury and PCB concentration levels detected in seven commonly eaten fish species are listed in Table 3 and Table 4.

Other Metals

Arsenic, average 22 ppb, maximum 43 ppb
Cadmium, average 5 ppb, maximum 19 ppb
Lead, average 52 ppb, maximum 633 ppb

Pesticides

DDE was detected in samples in the unrestricted consumption range.

Previous Advisories

None.

Table 3. Mercury concentrations found in Kokosing River fish tissue samples listed by species, 2007.

Species	Ave. Length (inches)	Ave. Conc. (ppb)	Max Conc.	No. Samples
Black Crappie	8	64	64	1
Channel Catfish	21	127	127	1
Common Carp	21	133	206	4
Largemouth Bass	10	98	98	1
Rock Bass	9	197	252	7
Smallmouth Bass	14	204	464	9
Yellow Bullhead	13	238	238	1

Table 4. PCB concentrations found in Kokosing River fish tissue samples listed by species, 2007.

Species	Ave. Length (inches)	Ave. Conc. (ppb)	Max Conc.	No. Samples
Black Crappie	8	ND	ND	1
Channel Catfish	21	121	121	1
Common Carp	21	203	358	4
Largemouth Bass	10	ND	ND	1
Rock Bass	9	ND	ND	7
Smallmouth Bass	14	72	226	9
Yellow Bullhead	13	ND	ND	1

Spills and Kills

In the Kokosing River watershed there have been thirteen reported spills and 16 fish kills dating from August 2, 1984 to September 21, 1999 (Table 5). One of the 16 fish kills listed below that occurred at Apple Valley Lake on June 10, 2005 killed 200 fish it was suspected to have resulted from natural causes. As shown in Table 2, spills in the Kokosing River watershed are not a common occurrence. Many of the pollutants found in the watershed are associated with non-point sources of pollution and poorly operated WWTP's. These pollution sources and non-point sources are discussed in further detail throughout the report.

Table 5. Historical spills and fish kills documented in the Kokosing River watershed, 1984 – 1999.

River	Date	RM	RM's Affected	# Fish Killed	Causative Pollutant	Source/Operation	Comments	Latitude	Longitude
Kokosing River	07-Aug-87			76	sewage				
Kokosing River	27-Jul-89			150	unknown				
Kokosing River	05-May-90			12	unknown				
Kokosing River	22-Mar-94	8.5		unknown	oil	Ross Brothers Salvage Yard			
Kokosing River	14-Aug-96	7.7	1	unknown	iron oxide, clays, suspended solids	Central Silica Co., Howard, Ohio	water was reddish tint, high in suspended solids	40.3869	-82.2666
Jelloway Creek	19-Jul-95	11.4	0.7	127	unknown	unknown	murky water, dead minnows; source unknown.	40.5317	-82.3028
Apple Valley Lake	10-Jun-05			200	temperature	natural	dead fish in several coves; possibly a natural fish kill		

Little Jelloway Creek	15-Apr-98	5	0.06	unknown	unknown	unknown	slug of whitish/gray substance entered Apple Valley Lake.	40.4639	-82.3378
E Br Jelloway Creek	21-Jul-86			2864					
Schenck Creek	01-Sep-85			117	dairy farm waste				
Schenck Creek	26-Aug-90	13.1		73	manure (cow)	Allen Ernest (farmer)	drainage from tile to ditch	40.4875	-82.3778
Schenck Creek	27-Jul-94	12.3	0.3	211	whey	Eric Diffs Farms		40.4758	-82.4622
Indianfield Run	21-Sep-99	4.4	0.75		unrefined oils	oil well leak, 23724 Newcastle Rd., Gambier		40.3435	-82.3261
Indianfield Run	10-Sep-01	5.4	1.75	2969	silo liquors	Indian Run Farm (dairy)	liquid waste entered tile and ran into stream.	40.3431	-82.3085
Trib. To Big Run (4.97)	23-Sep-97		2	unknown	manure (cattle)	Spring Flower Dairy	300,000 gal. manure spread on field; storm washed into creek	40.2936	-82.4091
Center Run	02-Aug-84			525	asphalt sealant				
Center Run	26-Aug-84			561	soybean products				
Center Run	26-Aug-84			4896	chlorinated water				
Center Run	08-Jul-93	2.1		10	chlorine	Mount Vernon Municipal Pool		40.4047	-82.4669
Armstrong Run	16-Nov-86			12					
N Br Kokosing River	25-Jul-97	15.1	0.25	300		Burgett Farm	stream was channelized w/o perrmit; fish dead in old channel	40.5412	-82.6379

Study Area Description

Location of Stream System *(TRIBS AND MAINSTEM)*

The Kokosing River system drains 482 square miles - predominantly in Knox and Morrow Counties but drains small portions of Ashland, Coshocton and Richland counties. Table 6 lists all of the streams in the watershed.

The Kokosing River and the North Branch Kokosing River originate in eastern Morrow County within Congress Township. The Kokosing River and the North Branch both rise approximately two miles from Williamsport, the North Branch starts to the east and the Kokosing River main stem to the west. Flowing southeast, the mainstem enters Knox County immediately south of the village of Lucern and near State Route 95. Coursing eastward toward Fredericktown, it bends to the Southeast joining with the North Branch approximately .5 mile north of Mt. Vernon, and visible from State Route 13. Continuing east into Coshochton Co. it joins the Mohican River to form the Walhonding near Newcastle Township Road 423. Approximately two miles south of Batemantown, the North Branch of the Kokosing River is dammed, forming Kokosing Lake, the centerpiece of the Kokosing Lake Wildlife Area.

Ecoregion

The Kokosing watershed drains the Low Lime Drift Plain of the Erie/Ontario Drift and Lake Plain. The topography is characterized as “rolling” with scattered end moraines and kettles. Typically, soil series found in this ecoregion are less fertile than the higher lime till plains of the Eastern Corn Belt ecoregion seen to the west. (Omernik 1987)

Table 6. Kokosing watershed streams and their respective gradients, drainage areas (sq./mi.), and main tributaries.

Stream Name	Average Fall Ft./Mi.	Drains Sq. Miles	Enters
Kokosing River	8.5	482	Walhonding River
Laurel Run	130.7	2.13	Kokosing River
Singer Run	20.5	1.16	Kokosing River
Brush Run	43	9.59	Kokosing River
Honey Run	103	2.05	Kokosing River
Jelloway Creek	17.6	74.2	Kokosing River
Little Jelloway Creek	32.2	19.5	Jelloway Creek
East Branch	23.5	10.46	Jelloway Creek
Sapps Run	55.4	3.93	Jelloway Creek
Dowd Creek	38.6	5.48	Jelloway Creek
Shadley Valley Creek	41.1	6.26	Jelloway Creek
Ireland Creek	45.3	3.41	Jelloway Creek
Barney Run	54.6	2.96	Kokosing River
Schenck Creek	21.8	41.8	Kokosing River
Coleman Branch	36.7	6	Schenck Creek
Little Schenck Creek	33.6	16.23	Schenck Creek
Mud Run	113.3	0.95	Little Schenck Creek
Indianfield Run	27.4	11.1	Kokosing River
Big Run	19	31.92	Kokosing River
Elliot Run	27.6	4.34	Big Run
Wolf Run	72.8	3.33	Kokosing River
Center Run	27.1	11.23	Kokosing River
Dry Creek	25.2	34.1	Kokosing River
Dry Run	51.4	6.16	Dry Creek
Armstrong Run	43.1	10.52	Kokosing River
North Branch	15.8	96.7	Kokosing River
Job Run	23.2	8.52	N. Br. Kokosing River
East Branch	13.8	30.6	N. Br. Kokosing River
Isaacs Run	24.9	4.59	E.Br. of N.Br. Kokosing
Markley Run	34.6	6.56	E.Br. of N.Br. Kokosing
Toby Run	39.2	4.49	E.Br. of N.Br. Kokosing
Lost Run	32.1	6.16	E.Br. of N.Br. Kokosing
Granny Creek	30.9	12.68	Kokosing River
Mile Creek	24.3	13.54	Kokosing River
South Branch	16.2	10.94	Kokosing River
Sylvester Run	46.4	2.07	Kokosing River

Climate

The Koppen climate classification system designates all of Ohio (and most of the United States east of the Mississippi) as a Mild Mid Latitude climate region (Cfa – humid subtropical) generally characterized by hot summers, no true dry season and mild to cold winters. (Strahler 1963) The Knox County Soil Survey describes this watershed as "cold in winter and fairly warm in summer. Winter precipitation, in the form of snow, results in good accumulation of soil moisture by spring and drought conditions during summer on most soils." Both localized convectional and frontal thunderstorms may contribute to stream flows from Spring through Fall. Normally short lived, their impacts on flow and surface runoff may be intensified with increased frequency over the short term. Slower moving systems, especially warm fronts, may bring longer lasting yet less intense periods of precipitation (United States Department of Agriculture, 1986).

Geology

Glacial phenomena (ablation, deposition, melt water flow etc.) and their interactions with bedrock and soils produced the present day topography seen on the majority of this watershed's landscapes.

The present day Kokosing watershed was covered by a series of glaciers during the Pleistocene epoch. The last glacier – the Wisconsin, melted between 15,000 and 16,000 years ago. It covered the approximate western half of this watershed. An earlier glacier the Illinoisan covered the eastern half. Of the two, the Wisconsin had more evident influence on topography than did the Illinoisan. The Soil Survey of Knox County, Ohio notes that much of the eastern part of the county was covered by an earlier Illinoisan glacier more than 100,000 years ago. The glaciation did not level the existing bedrock hills. Instead, the ice flowed around and between the hills and left thick glacial deposits in some areas and almost none in others. The result of this disparity between the two glaciations is evident in the contrasting relief between the western and the eastern portions of the Kokosing River watershed. The greatest topographic relief is found to the East (and western Coshocton Counties) where the Kokosing River flows towards its confluence with the Mohican River to form the Walhonding.

The bedrock seen in portions of the Kokosing River system is most commonly fine-grained sandstone and siltstone of the Mississippian age. Exposed bedrock can be seen near Tilden Avenue within the city of Mt. Vernon. The coarser Black Hand sandstone is seen exposed along the valley sides of the river system. The Kokosing

Scenic River Watershed Plan notes that both Illinoisan and Wisconsinan glacial deposits can be seen in a cut along Granny Creek in Wayne Township. (Ohio Department of Natural Resources. 2004)

Substrate Characteristics

The watershed's substrates originate in: bedrock immediate to the stream system, glacial tills of both distant (including igneous) and local origin and materials eroded, carried and deposited by stream flow.

Mineral Extraction

Gravel is mined throughout much of Ohio. Frequently the deposits are found within stream corridors, reflecting glacial processes. Gravel is extracted within the Kokosing watershed with regulatory oversight provided by the Ohio Department of Natural Resources – Division of Mineral Resources Management (Table 7).

Table 7. Kokosing watershed mineral extraction sites.

Permit	Resource Type	Permit Holder	Stream /County
IM-0269	Silica Sand	Oglebay Norton Industrial Sands	Kokosing Rv./Knox
IM-0300	Sand & Gravel	United Aggregates	Dry Creek/Knox
IM-0258	Sand & Gravel	Chesterville Sand and Gravel	Kokosing Rv./Morrow
IM-0870	Shale	Knox County Commissioners	Upstream of Apple Valley Lake/Knox
IM-0930	Sand & Gravel[1]	The Olen Corporation	N.Branch Kokosing Rv./Knox
IM-0967	Sand & Gravel	Small's Sand and Gravel	Kokosing Rv./Knox
IM-0968	Sand & Gravel	Small's Sand and Gravel	Kokosing Rv./Knox
IM-2000	Sand & Gravel	Small's Sand and Gravel	Kokosing Rv./Knox
IM-2078	Sand & Gravel	The Olen Corporation	N.Branch Kokosing Rv./Knox
IM-2159	Sand & Gravel	The Olen Corporation	Kokosing Rv./Knox

1 Inactive (5/4/09)

(Dave Crow, personal communication, 2009)

Soils

The effects of glaciation extend to the watershed soils. The Knox and Morrow Counties' Soil Surveys note that differences in the texture, thickness, and compositions of glacial deposits and the method of deposition resulted in many of the differences among the soils in the watershed. The very upper reaches of the mainstem, North Branch and South Branch of the Kokosing River drain soils formed in glacial till (Centerburg-Bennington, Amanda-Centerburg associations). Before entering Knox County, the

streams drain soils formed in loess, outwash and alluvium (Chili-Shoals-Lobdell association) (United States Department of Agriculture, 1993).

From the headwaters to Mt. Vernon, the watershed was extensively glaciated, with Mississippian sandstone exposed at some sites. Both glacial tills and melt water deposits are found in this portion of the watershed. The soils encountered strongly reflect this history. Those soils formed in glacial till deposits dominate the watershed from Mt. Vernon to the headwater reaches. They are most often found on uplands with steeper slopes and thus hold potential for erosion and sediment production.

Of these soils the Homewood, Titusville, Wooster, Canfield, Rittman and Wadsworth contain a dense subsoil layer - fragipan. This layer, believed caused by silica cementation, restricts water movement and to some extent, root development. It increases the potential for runoff by preventing water from moving into the lower part of the soil. When the pores above the fragipan are full of water, additional rainfall will run off. The fragipan also restricts root penetration in dry periods, reducing the volume of soil from which plants can extract water. The main management concern on the till derived soils is erosion control.

Melt water deposits characterize the major valleys and are source for the soils which are now present. With gentler slopes and higher infiltration rates, these areas are less prone to runoff-induced sedimentation. Ockley is the most common soil in the upper Kokosing valley with Chili, Fox and Bogart soils also seen.

Lakebed deposits are not extensive in the upper Kokosing valley, yet some are seen South of Mt. Vernon, along Blackjack Road. These areas are dominated by the Luray soil. Alluvial soils present on the flood plains of this upper valley are predominantly the Tioga fine sandy silt loam. Lobdell, Sloan and Medway soils are also seen.

From Mt. Vernon to Gambier many slopes are steep sided and show the Schaffenaker and Brownsville soils. These soils are deep to moderately deep and well drained. Both are droughty and tree growth is slow - a consideration for reforestation efforts or stream corridor restorations. Above, on the shoulder slopes, the Loudonville soils are found. Notable for its layer of glacial till over sandstone residuum, rooting depth here is limited, although trees may penetrate cracks.

Soils encountered from Gambier to Howard are notable for their diversity and reflect a complex geology, with most of this portion of the watershed exhibiting thin or no glacial deposits. Slopes range from nearly level to steep and drainage from well drained to poor.

A consideration relevant to erosion and sediment production in the Kokosing and other stream systems is the conversion of forage acreage to row crops. Increased erosion, sediment production and siltation may be the result – if occurring on highly erodible soils and appropriate conservation practices are not employed.

The Homewood, Titusville and Loudenville, soils are found on the watershed's glaciated uplands, downstream of Gambier. These soils too, show a frangipan layer and its limitations for water movement and root development. The highest elevations may totally lack or show thin glacial deposit layers. Soils encountered there are the moderately deep Gilpin and deep Westmoreland soils. Both are well drained and erosion prone. The five soils mentioned above are all suitable for conservation tillage and strip cropping.

The Kokosing Watershed Plan notes that the Fitchfille and Luray soils formed in glacial lakebeds and slackwater terraces downstream of Gambier are "very erosive but because of their gentle slopes, they are not a major source of sediment." For the floodplain soils seen in the same reaches - Tioga, Lobdell and Orville – the document states that "Stream bank erosion is a problem in localized areas."

The Kokosing downstream of Howard drains comparatively little watershed due to the valley's narrowness and the steeply inclined valley walls. The Brownsville and Westmoreland soils are dominant on the steep slopes. With forestry and the oil wells encountered here, erosion from trails and access roads is a potential threat to stream water quality. However, the tree cover present minimizes this potential.

Ridge top soils in this region of the watershed are Coshocton, Gilpin and Loudonville. These soil types are prone to erosion, thus storm water control is a key consideration for development projects and actions which include soil disturbance, vegetation removal and increase of impervious surfaces draining to tributary streams. The flood plain soils in this region are The Tioga and Landes. In total, roughly 94,739 acres of highly erodible soils were indicated in this watershed.

Ground Water

The watershed's population is predominantly rural, with many households relying on private wells for their water supply. Three principal aquifers underlie the watershed, including an unconsolidated coarse-grain aquifer, unconsolidated fine-grained aquifer, and sedimentary sandstone aquifer. These aquifers provide adequate water supplies for both individual wells and villages. Unconsolidated coarse-grain aquifers, seen in the western one-third of Knox County, consist of highly permeable sand and gravel deposited by glaciers into preexisting river valleys. These highly productive aquifers can produce well yields as high as 1,000 gallons per minute (gpm) at depths of 55 to 155 feet. A fine-grained unconsolidated aquifer, located in the southwestern corner and in other portions of Knox County, is similar to the unconsolidated coarse-grained aquifer but is less permeable because it consists of a higher proportion of mixed fine sands, silt and clay. Typical yields from this aquifer will fall in the range of 25 to 50 gpm. Average well depths found in this aquifer fall within a range of 66 to 165 feet. For Knox County, the primary ground-water source is a sandstone aquifer. This aquifer is characterized as massive to thin-bedded units of fine-grained sandstone, with yields usually ranging from 5 to 25 gpm. This aquifer may be confined or unconfined and well depths can range from 40 to 225 feet. (Barker, Boone, Brown. 1993)

WWTPs – Outstanding State Water

The "Outstanding State Water" classification for the Kokosing presents a major limitation on discharges from wastewater treatment facilities. Under this designation, the director of OEPA requires that new sources of pollution may not discharge directly to Outstanding State Water or points located upstream unless it can be demonstrated that the chemical and biological quality of the water will not be adversely affected. Additionally, the director of OEPA requires a reserved set-aside of 70 percent of the remaining available pollutant assimilative capacity, for which water quality criteria have been adopted or developed pursuant to chapter 3745-1 of the Administrative Code. The reserved portion cannot be allocated to any source unless the applicant requests and the director of OEPA approves a credit project per OAC 3745-1-05(C) (7) (Ohio Department of Natural Resources, 2004).

Corridor Vegetation

The Kokosing River's corridor was forested to a minimum depth of 300 feet from RM 0 to RM 41. In areas of less forest cover, the banks generally remain in a natural wooded condition of varying depths. The amount of corridor forested to at least 100 feet along the main stem of the Kokosing River is 56.1 percent. The most heavily wooded corridor occurs on the lower half of the river from RM 24 and below with at least 30 and up to 43 percent forested to a minimum of 300 feet. The section of river around Mount Vernon, from RM25 to RM29, contained the least amount of corridor with minimal to no corridor. The North Branch of the Kokosing River, for at least the first 3.4 miles, is 17.1 percent forested to a minimum depth of 300 feet. Sixty-three percent of the riparian corridor along the thirty-five Kokosing River tributaries were forested (Table 8).

Human activity is apparent within the riparian corridor to varying degrees along the length of the river. 35 bridges cross the Kokosing River from its headwaters to its mouth. While bridges disrupt the riparian corridor and detract from the river's visually scenic qualities, they do provide an opportunity to view the river and its wildlife inhabitants. In some cases, with the adjacent property owner's permission, access is possible for launching canoes or for passive recreation activities such as fishing or bird watching near the bridge. Roads paralleling the river also can detract from the scenic qualities of the river by subjecting river users to traffic noise and odors. Roads too close to the river disrupt the corridor and natural drainage reducing the natural buffering from nonpoint pollutants that the wooded corridor provides. They also increase the potential for hazardous materials entering the river because of accidents. Road miles paralleling the river within 300 feet total 12.8 along the Kokosing River. This is 22 percent of the river's total length.

Table 8. Linear extent of wooded riparian in Kokosing River tributaries.

Tributary	Total Length (miles)	Length Wooded (miles)	Percent Wooded %
Laurel Run	2.5	2.1	84.00
Singer Run	1.3	0.9	69.23
Brush Run	3.6	2.3	63.86
Honey Run	1.6	1.1	68.75
Jelloway Creek	13.2	7.9	59.85
Little Jelloway Crk.	6.2	4	64.52
East Branch	5.5	3.5	63.64
Sapps Run	3.3	2.1	63.64
Dowd Creek	3.4	1.4	41.18
Shadley Valley Crk.	4.7	2.6	55.32
Ireland Creek	2.0	1.4	70.00
Barney Run	2.1	1.8	85.71
Schenck Creek	12.2	9.5	77.87
Coleman Branch	4.2	2.1	50.00
Little Schenck Crk.	7.9	4.5	56.96
Mud Run	0.7	0.53	75.71
Indianfield Run	7.3	4.8	65.75
Big Run	4.6	3.0	65.22
Elliot Run	3.9	1.3	33.33
Wolf Run	1.7	1.2	70.59
Center Run	3.4	1.7	50.00
Dry Creek	18.9	14.3	75.66
Dry Run	4.7	3.9	82.98
Armstrong Run	5.9	3.7	62.71
North Branch	26.6	17.1	64.29
Job Run	3.8	1.1	28.95
East Branch	5.0	3.3	66.00
Isaacs Run	4.4	1.0	22.73
Markley Run	4.1	1.9	46.34
Toby Run	3.4	1.5	44.12
Lost Run	3.4	2.2	64.71
Granny Creek	9.0	7.2	89.00
Mile Creek	10.0	6.6	66.00
South Branch	9.7	5.6	57.73
Sylvester Run	3.0	1.3	43.33

The watershed's forest communities include those most commonly found in the Glaciated Appalachian Plateau region: Beech-Sugar Maple Forests, Maple-Cottonwood-Sycamore Flood Plain Forests, Mixed Mesophytic Forests, Oak-Hickory Forests and Hemlock-White Pine Hardwood Forests.

The beech-sugar maple forest type was predominantly in the western portion of the watershed. However, this community type grades into other community types such as oak-hickory, mixed mesophytic and maple-cottonwood-sycamore depending on the soils and topography and therefore throughout the watershed.

Species tolerant of seasonal flooding make up the maple-cottonwood-sycamore flood plain forest community that is most notable along North Branch and the other tributaries in the western portion of the watershed. Dominant species include soft maple, cottonwood and sycamore primarily.

Mixed mesophytic forests historically dominated the eastern portion of the watershed. This forest type grades into other types of wet-mesic to dry-mesic forest communities but generally the stands are dominated by combinations of beech (*Fagus grandifolia*), tuliptree (*Liriodendron tulipifera*), sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), white oak (*Quercus alba*), red oak (*Quercus rubra*) and white ash.

Prevalent in the gorge area between Mount Vernon and Gambier, the oak-hickory forest type is characterized by upland oaks and hickories. Specifically, this forest type is dominated by shagbark hickory (*Carya ovata*), pignut hickory (*Carya glabra*), bitternut hickory (*Carya cordiformis*), mockernut hickory (*Carya tomentosa*), white oak (*Quercus alba*), red oak (*Quercus rubra*) and black oak (*Quercus velutina*).

Hemlock-white pine-hardwood forests generally occur on valley slopes and bottoms. Examples of this type of community can be found around the Millwood area in the Kokosing watershed. Hemlock and/or white pine and hardwood species dominate this community over upland substrates.

The watershed's *Riverine* natural vegetation can be divided into two broad categories: a mixed emergent community and a water willow community. The mixed emergent community includes both herbaceous and immersed plant species. Found along stream channels, ponds and oxbows of annually flooded flood plains; they may include broad leaved cattail, bur-reed, water plantain, arrowheads, rice cutgrass, sedges, umbrella-

sedges, spike-rushes, bulrush, rushes, lizard's tail, smartweeds, docks, swamp mildewed, fog-fruit, monkey-flower, water-willow and beggar-ticks.

A water willow community is characterized by 50% plus water willow cover. Other plants that may be found in the water willow complex include: lizard's tail, sandbar willow, smartweeds, docks, dodder monkey flower, and beggar ticks.
(Ohio Department of Natural Resources. 2004)

Agriculture – Conservation Practices

The land use within the Kokosing River Watershed is dominantly cropland and pasture. Conservation practices BMPs (Best Management Practices) advanced by county Soil and Water Conservation Districts, NRCS staff; FSA and Ohio State University Extension can be protective of the water column if animal waste, agricultural chemicals and soil runoff are prevented from reaching the river system. These practices or BMPs (Best Management Practices) are also subject to the vagaries of the national, state and local economies as crop price and the costs of farming fluctuate yearly.

The trends observed (2008) in the Kokosing Watershed by county SWCD and NRCS staff are in part reflective of these economic forces as well as the continuous work of county, state, federal and university staff. They are:

- There is an observed shift from no-till cropping of corn to no-till soy beans. County staff notes that corn no-till practice is generally more effective at reducing erosion and run off than is soy bean no-till practice. However the proportion of cropland under no-till practice remains stable. Estimated no-till: corn = 60%, soy beans = 90%. (Denise Shafer, personal communication, 2008)

- Pasture management on livestock operations is improving with better managed grazing practices including the establishment of buffers along stream corridors.

- An increase in the development of contract feeding operations for swine and poultry has been observed. The swine CAFOs (Concentrated Animal Feedlot Operations) are under 2400 head, thus not subject to ODA rules.

- Recent discussion regarding possible expansion of existing dairy operations.

- Numerous instances of overgrazing and sediment runoff from recreational equine activities, often the result of inadequate pasture and grazing practices. (Robert Clendening, personal communication, 2009)

Land Use Change

Though agriculture is the dominant land use in the watershed, residential land use is an increasingly significant element of the landscape in unincorporated areas of the watershed's counties. Use of land for residences, rather than agriculture, increased substantially in recent years. The peripheral growth of Columbus combined with better highway access have contributed to increased demand for residential lots as Columbus workers commute from homes in the Kokosing watershed. Apple Valley, originally planned as resort housing has become home to full-time residents. The one to two acre lot splits for single-family homes along established roads have become common in rural areas of Knox County. While Knox County's growth rate is less than some adjacent counties closer to Columbus (Franklin County), it has still grown. Knox and Morrow counties are predicted to grow more than 20% during 2000 – 2030. During the same time, Ohio is only expected to grow 8.5%.

The watershed's four principal nodes of residential settlement are all found in Knox County. In descending order (estimated population) they are: Mt. Vernon 15,950 (2007), Union Township - including Danville village 2,455 (2000), Fredericktown village 2,428 (2007) and Gambier village 2,069 (2007) (Ohio Department of Development, 2007).

Each of the above four population centers is situated on, bisected by or in close proximity to the Kokosing River system. Mt. Vernon is bisected by the river's main stem, Danville drains to the East Branch of Jelloway Creek, and Fredericktown borders the North Branch of the Kokosing on its S.E. bank and Gambier sits upstream of the Kokosing - Big Run confluence.

The Knox County Comprehensive Plan (Update 2006) notes that four development related trends pose a challenge to maintaining the county's well regarded historic, cultural and rural atmosphere. These are:

- The county's high quality of life will continue to attract new residents.
- The demand for large rural lots in country settings will remain strong.

- The growth of employment opportunities in the Columbus metropolitan area (Easton, Polaris) will continue to stimulate commuting from and relocation to the watershed.
- The number of commuters expending over 40 minutes (one way) has and may continue to increase. (Knox County Regional Planning Commission 2006)

By extension, these same trends hold potential to impact both the high water quality and the multitude of biotic measures which cumulatively translate to the Kokosing River's designation as State Scenic River and classification as "Exceptional Warm Water Habitat" by the Ohio Environmental Protection Agency[1]. Riparian corridor deforestation, home sewage conveyance to the water column and silt laden run off are typical causes of water quality and habitat degradation that may arise from rapid land use change on rural landscapes.

Land Use Planning

Townships and municipalities within the Knox County portion of the watershed receive assistance in land use planning and related work from the Knox County Regional Planning Commission. The commission's intent and work are self described in the 2006 Update to the Knox County Comprehensive Plan. Relevant excerpts' from the document read:

- ". . .keeping proper focus on key planning principles aimed at maintaining and enhancing livable social and natural environments, while balancing growth and expanding economic opportunities. "

- "Addressing issues related to an increasing population in positive ways and with long-term vision requires sustained and coordinated planning. Patterns of slow growth and slow change that passed unnoticed have been replaced with

1 River mile 54.7 to confluence with the Walhonding River.

- increasing demand for residential and commercial development and with more rapid change in the community. “

- “Deliberate steps to maintain and enhance critical elements of the local quality of life will require public awareness, dedication and perseverance. Such steps should include periodic updating of the Comprehensive Plan to implement new efforts to enhance and preserve historic and cultural resources and the rural atmosphere needed to keep Knox County at the forefront of livability. “

Land use planning and zoning can be effective tools for the protection of surface water resources. All Knox County townships within the Kokosing River watershed are zoned with the exception of Ian and Butler townships. The former includes the village of Danville. The Kokosing River Watershed Plan provides detailed descriptions of all watershed township zoning ordinances. Morrow County township Zoning was adopted in 2008. However those townships which largely drain to the Kokosing headwater streams (Chester, Franklin, and South Bloomfield) are not under county zoning regulation.

Recreation

Forty-one miles of the main branch of the River and the lower 6.5 miles of the North Branch have been given “Scenic River” designation by the Director of the Department of Natural Resources. The designation means that the River “is representative of a waterway that still retains much of its natural character for the majority of its length. Shorelines are for the most part undeveloped, but the river may exhibit signs of disturbances by human activities. The adjacent river corridor must be forested to a minimum depth of 300 feet for 25% of the stream’s length.” This designation attracts fishermen, canoers, kayakers, birders, waders and others who experience primary and secondary contact with the water column and recreate in a high quality public resource setting.

The Department of Natural Resources has also designated a portion of the Kokosing River as a water trail for 27.9 miles of its length. The water trail has nine designated access points along the river. Many recreational opportunities are possible along this trail including: fishing, hunting, biking, hiking, paddling, and wildlife viewing. The water trail section begins in the city of Mount Vernon with access along Greenwood Avenue through Riverside Park. The final access point along the water trail is at the end of Township Road 423 near the confluence with the Mohican River. More information on

specific recreational opportunities at each area along with a printable map is available through the Department of Natural resources online at: http://www.ohiodnr.com/Portals/4/pdfs/access/kokosingrwt.pdf or by contacting the Division of Water Craft at : 1-877-4BOATER.

The preservation and protection of forested recreation and preserve acres within the watershed supports both the Scenic River designation and the Exceptional Warm Water Habitat status applied by the Ohio Environmental Protection Agency. The acquisition and protection - maintenance of forested and vegetated sites is carried out by multiple entities. The Knox County Park District notes recent (2007 – 2009) work which enhances the riparian corridor forest habitat and preserves forested watershed landscapes through purchase or conservation easement: (Kim Marshall, personal communication, 2009).

- Bird Nest Road – 130 acre conservation easement. In cooperation with ODNR Division of Natural Preserves, ODNR Wildlife Division and Ohio Environmental Protection Agency 319 funds.

- Indian Field Bluffs – 25.5 acres acquisition. Large main stem island and confluence area of Indianfield Run and the Kokosing River which includes canoe access. This area was funded by 319 program assistance.

- Hope Access Site – Acquisition of angler access site on main stem.

- North Branch Kokosing River – 50 acre acquisition, left ascending bank. With Fredericktown Recreation District, Mt. Vernon Community Association and Clean Ohio funding.

Recreational gold panning was observed on the Kokosing main stem in 5/2009. (Dirk Cochran, personal communication, 2009) This in stream activity is supported by The Buckeye Chapter of the Gold Prospectors Association of America (GPAA), a national organization based in California. The GPAA was founded in 1968 to “preserve and promote the great heritage of the North American prospector.” One of the organization’s programs is leasing gold claims from landowners across the U.S. The GPAA’s dues-paying members may then work those claims, keeping the gold they find. Three gold claims are located in Ohio. The newest of the three claims is the Frazee Claim, along the Kokosing River in eastern Knox County (Gross, 2008).

Tourism

Both the Kokosing Scenic River Watershed Plan and the Knox County Comprehensive Plan Update note the significance of tourism in the county and by extension the river system. Local and nearby attractions make tourism a significant part of the Knox County economy. Knox County is next to Holmes County, a tourist destination for approximately four million visitors in 2004. Knox County is considered part of "Mohican Country," a major tourist destination for camping, canoeing, and related activities.

Restoration & Protection

The Kokosing Scenic River Watershed Plan lists specific objectives or "action items" which address stream restoration, water quality protection and public resource stewardship. The plan is administered by the Ohio Department of Natural Resources and the Kokosing River Advisory Council. The council meets on a regular basis to help plan efforts to identify and protect the Kokosing River and tributaries. Fully endorsed by Ohio Department of Natural Resources and The Ohio Environmental Protection Agency - the endorsed plan qualifies NGOs, nonprofits and local government entities to apply for state administered grant funding toward stream restoration - protection. The plan's objectives derive from the priority threats or conditions which could limit full attainment of the Kokosing's use designations and degrade water quality. They include:

* Using geographic information system technology, map headwater streams in the watershed

* By September 2007, restore riparian vegetation in the North Branch Kokosing River headwaters to near State Route 13 sub watershed by approximately twenty percent (19,900 linear feet) and in the Jelloway Creek sub watershed by approximately twenty-six percent (19,100 linear feet);

* By September 2007, restore destabilized stream banks in the North Branch Kokosing River sub watershed from the headwaters to near State Route 13 by approximately thirty-six percent (10,000 linear feet) and in the Jelloway Creek sub watershed by approximately fifty-nine percent (19,100 linear feet);

* By September 2007, restore streams in the North Branch Kokosing River sub watershed from the headwaters to near State Route 13 by approximately twenty percent (19,900 linear feet) and in the Jelloway Creek sub watershed by approximately forty percent (19,100 linear feet) by September 2007;

* Manage storm water and development to protect water quality and floodplain function in the watershed; By September 2009, protect approximately 100 acres of wetlands in the Kokosing River below Dry Creek to above Big Run and restore approximately 100 acres of wetlands in the Kokosing River below South Branch to below Mile Run and Kokosing River Headwaters.

* By October 2009, protect approximately 500 acres of high value/high function riparian corridor habitat.[2]

Knox County Zoning Strategies in the Kokosing River Watershed

Berlin Township: Berlin Township currently has a Zoning Resolution adopted in 2001 but does not have a comprehensive plan. The Berlin Township Zoning Resolution contains some policies that indirectly protect the Kokosing State Scenic River. The plan also references Focus 2100. The plan does reference streams and watercourses but does not set specific standards for their protection. Cluster Residential Subdivisions are a very good example on how to conserve open space, natural features and farmland, all of which contribute to the protection of the Kokosing River. In cluster developments, 50% of the developable acreage is set aside as permanent open space or farmland. The township also has a restriction on the number of land subdivisions that can occur on a parcel of record after November 14, 2001 within the Agricultural District. This limits the amount of farmland that can be converted to residential development. The minimum lot sizes are two acres in the Agricultural District, one acre inR-1 and 14,000 square feet (sq. ft.) in R-2 (only when centralized sewer is available).

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[2] Ohio Department of Natural Resources. 2004 *Kokosing Scenic River Watershed Plan.* Division of Natural Areas and Preserves.

Brown Township: Brown Township currently has a Zoning Resolution, adopted 1961 and amended and revised in 1983, 1985, 1991, 1996 and 1999, but does not have a comprehensive plan. Natural resources are not referenced within the document and there is no reference to watercourses or streams. The minimum lot size within the township for residential development is three acres.

Butler Township: Butler Township is currently un-zoned.

ClintonTownship: Clinton Township currently has a Zoning resolution adopted in January 1998 but does not have a comprehensive plan. Natural resources are not referenced within the document and specifically there is no reference to watercourses or streams. Minimum lot size is two acres when sewers are unavailable and 10,000 sq. ft. when centralized sewer is available. Clinton Township does have a Planned Neighborhood District (PND) that could be used to protect natural resources but does not set out specific requirements. The zoning code also contains manufacturing districts, business districts and a Main Thoroughfare Corridor Overlay District (MTC) that provides guidelines for development of a commercial district along the major thoroughfares of the township. The Clinton Township Zoning Resolution allows for relatively high densities of development to occur.

College Township: College Township currently has a Zoning resolution adopted June 1973 and amended October 2000. The College Township Zoning Resolution contains significant protections to natural resources and the Kokosing State Scenic River and references Focus 2100. Many of the items in the resolution could be used as a model for other township within Knox County that wish to enhance their capacity to protect natural resources. The zoning resolution prohibits buildings or structures from being erected on slopes greater than 20 percent. The resolution establishes a 120-foot buffer zone along perennial streams and a minimum lot size of one acre per dwelling unit. The Planned Unit Development (PUD) and Conservation Development classifications require that 50 percent of the total acreage of the development is set aside as open space in R-1 and R-2 districts and 80 percent within agricultural districts.

Harrison Township: Harrison Township currently has a Zoning Resolution, adopted July 1973 and amended in 1984, 1990, 1996 and 2002 but does not have a comprehensive plan. They are in the process of drafting a plan currently. The Harrison Township Zoning Resolution does mention the Kokosing River, but there is no reference

to watercourses or streams in general. Harrison Township has a Conservation District (C-1) that protects the floodplain along the main stem of the Kokosing River. The minimum lot size per dwelling unit is five acres for lots created after November 22, 1996 and one acre for lots created before November 22, 1996.

Howard Township: Howard Township currently has a Zoning Resolution adopted November 4, 1980 but does not have a comprehensive plan. Natural resources are not mentioned within the document and specifically there is no mention of the words "watercourse" or "stream." Howard Township does have a Conservation District (C-1) classification to protect the public in regard to building in floodplains. The required lot area per dwelling unit is not less than one acre when water and sewer are unavailable and 12,000 square feet when sewer and water are available. In a PUD development 20 percent of the total acreage of the development is to be devoted to open space.

Liberty Township: Liberty Township currently has a Zoning Resolution adopted on December 18, 1996 but does not have a comprehensive plan. Natural resources are not mentioned within the document and there is no mention of the words "watercourse" or "stream." Liberty Township does have a Conservation District (C-1) classification to protect the public in regard to building in floodplains. The required lot area per dwelling unit is not less than two acres when water and sewer are unavailable and 12,000 square feet when sewer and water are available.

Monroe Township: Monroe Township currently has a Zoning Code Book issued in 1958 and revised in 1976, 1980, 1982, 1983, 1991, 1995 and 2002. The township does not have a comprehensive plan but references focus 2100. Natural resources are mentioned throughout the document with specific references to maintaining the natural beauty and natural flow of water through the township. Two zoning classifications, PUD and the Planned Unit Conservation Development (PUCD), contain significant protections for natural resources and streams. These classifications allow for flexibility in regard to lot size, lot setbacks and creative design to conserve the attributes that a property may contain. Within the PUCD, jurisdictional wetlands are protected with a 20-foot natural buffer and a building setback of 35 feet (measured from the edge of the designated wetland). Riparian buffers are provided for a width of not less than 120 feet, measured from the river or stream bank. Within the context of preserving natural resources the Monroe Township PUCD could be used as a model for all moderate to high-density development within Knox County.

Morgan Township: Morgan Township currently has a Zoning Resolution, adopted May 1971 and amended June 1989, but does not have a comprehensive plan. Natural resources are not referenced within the document and specifically there is no reference to watercourses or streams. Morgan Township does have a C-1 classification to protect the public in regard to building in floodplains. The required lot area per single-family dwelling unit is not less than two acres when water and sewer are unavailable and 12,000 sq. ft. when sewer and water are available. Morgan Township does not have a PUD zoning classification.

Morris Township: Morris Township currently has a Zoning Resolution adopted in January 1999. The importance of natural resources and farmland to the township is referenced in the preamble of the resolution but there are no specific standards outlining their protection. There is no reference to watercourses or streams in the document. Morris Township does have a Flood Plain Overlay District that affords enhanced protection to floodplains. The minimum lot size within the township is 1 acre without centralized sewer and 10,000 sq. ft. when centralized sewer is available. The township has a PUD district which requires a minimum of 20 percent of the land to be reserved as common open space. In addition, every property developed should be designed to abut the common open space.

Pike Township: Pike Township currently has a Zoning Resolution adopted in 1995, revised in 1998, but does not have a comprehensive plan. There is no reference to watercourses or streams within the document. There is a floodplain district, which prohibits development inconsistent with the requirements for the conveyance of flood flows in order to minimize the expense and inconvenience to the public. The minimum lot size within the township is one acre.

Union Township Union Township is currently unzoned.

Wayne Township: Wayne Township currently has a Zoning Resolution adopted in 1986 but does not have a comprehensive plan. Natural resources are not referenced within the document and specifically there is no reference to watercourses or streams. The minimum lot size within the township is one acre.

City of Mount Vernon The City of Mount Vernon currently has a zoning code and subdivision regulations but does not have a comprehensive plan. There are no

ordinances that contain specific standards for the protection of streams, riparian buffers, and/or natural resources. It is noted, however, that these are important community assets and due regard should be given to their protection within subdivisions. Within the subdivision regulations, there are some limited protections for watercourses and floodplains (but they relate more to the hazards of flooding rather than the health of the stream system). The City of Mount Vernon does have a Tree Preservation Ordinance that gives some protection to larger trees and woodlots within subdivision proposals. The City of Mount Vernon allows for high-density development with a minimum lot size of 8,000 sq. ft. in a traditional development. The Planned Neighborhood Development allows up to eight units per acre but has no minimum lot size to allow for creative design for the protection of open space or land for community facilities.

METHODS

All physical, chemical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 2006b) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989a, 1989b, 2008a, 2008b), The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995, 2006a) for aquatic habitat assessment, and the Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001). Sampling locations are listed in Table 9, pg.46.

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the Index of Biotic Integrity (IBI) and Modified Index of well being (MIwb), indices measuring the response of the fish community, and the ICI, which indicates the response of the macroinvertebrate community.

Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (Table 2, pg. 10) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by River Mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non-attainment), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

Habitat Assessment

Physical habitat was evaluated using the 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 the QHEI score which generally ranges 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 mean values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas mean segment scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Mean segment scores greater than 75 frequently reflect habitat conditions which have the ability to support exceptional warmwater faunas.

Sediment and Surface Water Assessment

Nitrile gloves were worn in handling decontaminated stainless steel scoops to collect fine grain sediment samples in the upper 4 inches of the bottom material at each location. Decontamination of sediment sampling equipment followed the procedures outlined in the Ohio EPA sediment sampling guidance manual (Ohio EPA 2001). Sediment grab samples were homogenized in stainless steel pans (material for VOC analysis was not homogenized), transferred into glass jars with Teflon® lined lids, placed on ice (to maintain 4^{o}C) in a cooler, and shipped to an Ohio EPA contract lab. Sediment data is reported on a dry weight basis. Surface water samples were collected, preserved and delivered in appropriate containers to either an Ohio EPA contract lab or the Ohio EPA Division of Environmental Services. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature. Sediment evaluations were conducted using guidelines established in MacDonald *et al.* (2000) and Ohio Specific Reference Values (2003).

Recreational Use Assessment

Recreation use attainment was determined using newly adopted criteria that became effective on March 15,2010. The newly adopted criteria (OAC 3745-1-07) resulted in several changes, which are noted below:
1) E. coli will be the only indicator organism used to evaluate recreation. The use of fecal coliform willbe discontinued.
2) The recreation season will be May 1 – October 31 instead of ending on October 15.
3) Geometric mean content will be computed on a seasonal basis instead of monthly.
4) Geometric mean content will be the sole basis of use attainment status when two or more samplesare taken.
5) Primary Contact Recreation (PCR) will be divided into three separate categories each with specific numerical criteria: Class A – high use paddling streams, Class B – most typical streams and Class C - historically channelized streams that drain less than 3.1 square miles.

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from natural habitats. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, margin). Stations with insufficient flow to place artificial substrates or where the artificial substrates were missing were only sampled qualitatively from the natural substrates. These stations were evaluated and assigned a narrative evaluation based on community attributes such as EPT (Ephemeroptera – mayfly, Plecoptera – stonefly, and Trichoptera – caddisfly) diversity and predominance, sensitive taxa diversity and predominance, and tolerant taxa predominance. Detailed discussion of macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life, Volume III (Ohio EPA 1989b).

Fish Community Assessment

Fish were sampled using pulsed DC electrofishing methods. Field processing of fish sampled included identifying each individual to species, counting, weighing, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life, Volume III, (Ohio EPA 1989b).

Fish Tissue Assessment

All field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 2006b), and State of Ohio Cooperative Fish Tissue Monitoring Program Fish Tissue Guidance Manual (Ohio EPA 2004). Fish tissue sampling locations are listed in Table 9, pg.46. Fish tissue sample specifications (species, average length, and pollutant concentrations in ppb) are provided in Table 3 (pg. 16) and Table 4 (pg. 17). Summarized results are presented in the fish tissue results section, pg. 16.

Fish were collected using a variety of pulsed DC electrofishing equipment, with collections occurring between June–October, 2007. Fish tissue samples were placed on either dry or wet ice in the field and transported back to the Ecological Assessment Section Laboratory at 4675 Homer Ohio Lane, Groveport, Ohio 43125 and placed in a chest freezer prior to being delivered to the Ohio EPA Division of Environmental Services Laboratory for analysis.

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward. The numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). Rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of

multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem "health" compared to human patient "health" (Suter 1993), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

Table 9. Study site list for the Kokosing River watershed, 2007.

River	River Mile	Location	Drainage Area (mi2)	USGS Quad	Latitude	Longitude	Sampling
Kokosing River	54.69	Pulaskiville Rd	8.3	Mount Gilead	40.5375	-82.7617	C,b,m,f
Kokosing River	49.73	Chipps Rd.	15.2	Shauck	40.5008	-82.7361	C,b,m,f
Kokosing River	45.44	SR 314, Chesterville	38.0	Chesterville	40.4747	-82.6839	C,O,D,B,M,F
Kokosing River	40.48	Lucerne Rd.	57.0	Chesterville	40.4610	-82.6284	T
Kokosing River	39.27	TR 411, Vail Rd.	55.5	Fredricktown	40.4643	-82.6097	C,b,M,F
Kokosing River	32.56	TR 401, Beckley Rd.	84.4	Fredricktown	40.4385	-82.5373	C,O,S,D,B,M,F
Kokosing River	29.70	From SR 13, Cassell Rd. Ust. N Br	100.0	Fredricktown	40.4187	-82.5045	T
Kokosing River	28.61	TR 386, Banning Rd.-Tilden Ave., USGS gage	202.0	Mt. Vernon	40.4056	-82.4997	C,O,S,D,B,M,F
Kokosing River	25.30	Mt. Vernon Ave., Ust. WWTP	251.0	Mt. Vernon	40.3833	-82.4692	C,B,M,F
Kokosing River	24.90	Mt. Vernon WWTP	262.0	Mt. Vernon	40.3788	-82.4665	Compliance
Kokosing River	24.3	TR 257, Glenn Rd., Dst. WWTP	272	Hunt	40.3717	-82.4625	C,S,D,B,M,F
Kokosing River	23	Adj. TR 262, Lower Gambier Rd	275	Mt. Vernon	40.3771	-82.4405	T
Kokosing River	20.90	TR 259, Laymon Rd.	280.0	Mt. Vernon	40.3761	-82.4036	C,S,D,B,M,F
Kokosing River	18.90	SR 229, Newcastle Rd.	313.0	Hunt	40.3619	-82.3931	C,D,B,M,F
Kokosing River	17.76	Gambier WWTP	314.0	Mt. Vernon	40.3658	-82.3844	Compliance
Kokosing River	16.14	CR 33, Zion Rd	315.0	Danville	40.3754	-82.3225	T
Kokosing River	11.60	CR 35, Pipesville Rd.	379.0	Danville	40.4050	-82.3225	C,D,B,M,F
Kokosing River	11.00	Adj. US 36, Dst. Jelloway Cr	453.0	Danville	40.4060	-82.3131	T
Kokosing River	6.2	US 36, Coshocton Ave.	463	Danville	40.3839	-82.2547	C,B,M,F
Kokosing River	2.70	TR 203, Riley Chapel Rd.	478.0	Walhonding	40.3722	-82.2008	C,O,S,D,B,M,F,T
Kokosing River	0.10	TR 423, MWCD Mohawk Area	485.0	Walhonding	40.3606	-82.1614	C,B,M,F
Delano Run	1.55	From Meadowbrook Dr	7.1	Hunt	40.3576	-82.4792	C,b,m,f
Brush Run	0.90	CR 36, Rutledge Rd	7.8	Walhonding	40.3683	-82.2425	c,b,m,f
Jelloway Creek	8.90	TR 325, Orange Hill Rd	16.5	Jelloway	40.5017	-82.2933	c,b,m,f

Jelloway Creek	4.30	CR 9, Danville-Howard Rd.	36.5	Danville	40.4472	-82.2956	c,b,M,f
Jelloway Creek	0.10	US 36, Coshocton Ave.	74.0	Danville	40.4066	-82.3208	C,O,S,D,B,M,F
Little Jelloway Creek	6.97	TR 318, Beaver Rd	10.5	Danville	40.4757	-82.3465	c,b,m,f
Little Jelloway Creek	1.63	Apple Valley Lake	18.5	Danville	40.4197	-82.3458	T
Little Jelloway Creek	0.88	CR 94, Magers Rd.	19.0	Danville	40.4156	-82.3347	C,B,D,M,f
Little Jelloway Creek	0.25	Little Jelloway WWTP	19.5	Danville	40.4136	-82.3263	Compliance
Little Jelloway Creek	0.10	Dst. Little Jelloway WWTP	20.1	Danville	40.4112	-82.3230	M,F
East Branch Jelloway Creek	3.33	US 62, Millersburg Rd., Ust. Danville	4.5	Brinkhaven	40.4511	-82.2486	c,b,m,f
East Branch Jelloway Creek	1.87	Danville WWTP	6.1	Danville	40.4436	-82.2696	Compliance
East Branch Jelloway Creek	1.03	TR 348, Carey Lane	9.1	Danville	40.4392	-82.2800	c,b,m,f
Schenck Creek	8.75	Driveway from TR 274, Proper Rd	8.9	Mt. Vernon	40.4442	-82.4319	c,b,m,f
Schenck Creek	2.64	US 36, Coshocton Ave.	37.3	Danville	40.4100	-82.3703	M,F
Schenck Creek	0.55	CR 34, Schenck Creek Rd.	41.2	Danville	40.3930	-82.3471	C,O,D,B,M,F
Little Schenck Creek	4.45	CR 66, Fredricktown-Amity Rd	8.2	Mt. Vernon	40.4942	-82.4181	c,b,m,f
Little Schenck Creek	0.20	CR 8, Gilchrist Rd	16.3	Mt. Vernon	40.4403	-82.3817	c,b,m,f
Indianfield Run	2.70	SR 229 Newcastle Rd	8.4	Martinsburg	40.3581	-82.3381	c,b,m,f
Big Run	4.40	SR 586, Martinsburg Rd	9.1	Hunt	40.3069	-82.3958	c,b,m,f
Big Run	0.66	CR 54, Big Run Rd.	29.2	Hunt	40.3481	-82.3833	C,O,D,B,M,F
Dudgeon Ditch/ Elliott Run	1.05	TR 415, Curtis Rd., Ust. RM 1.02 Trib.	8.0	Hunt	40.3094	-82.3756	c,b,m,f
Dudgeon Ditch/ Elliott Run	0.20	Sycamore Rd.	10.7	Hunt	40.3156	-82.3892	m,f
Center Run	1.70	Beech St	7.8	Mt. Vernon	40.4039	-82.4672	c,b,m,f

Dry Creek	10.72	CR 25 Simmons Church Rd	7.6	Centerburg	40.3453	-82.6292	C,b,m,f
Dry Creek	9.22	TR 121, Tucker Rd	16.0	Homer	40.3500	-82.6069	C,b,m,f
Dry Creek	4.50	TR 127, Thayer Rd., Dst landfill	25.1	Homer	40.3535	-82.5337	C,b,m,f
Dry Creek	1.00	CR 83, Parrott St.	33.7	Mt. Vernon	40.3784	-82.4966	C,O,D,B,M,F
Armstrong Run	1.10	TR 389, Lower Green Valley Rd	8.3	Fredericktown	40.4100	-82.5122	c,b,m,f
North Branch Kokosing River	17.77	Drive from CR 22, Mt. Vernon Tiffin Rd.	8.0	Shauck	40.5569	-82.6808	c,b,m,f
North Branch Kokosing River	14.00	TR 374, Levering Rd	17.4	Shauck	40.5447	-82.6197	c,b,m,f
North Branch Kokosing River	10.15	North Branch Kokosing Lake	43.0	Bellville	40.5095	-82.5829	T
North Branch Kokosing River	9.15	TR 377, Overly Rd	45.5	Bellville	40.5024	-82.5713	c,b,m,f
North Branch Kokosing River	6.20	Mill St. (CR 14, Fredericktown-Amity Rd.)	84.0	Fredericktown	40.4889	-82.5422	C,O,S,D,B,M,F
North Branch Kokosing River	5.55	Fredricktown WWTP	85	Fredericktown	40.4711	-82.5297	Compliance, m,f
North Branch Kokosing River	0.02	SR 13, Cassell Rd.	97.9	Fredericktown	40.4189	-82.5035	C,O,S,D,B,M,F,T
Trib. to N. Br. Kokosing R. (RM 9.99)	4.04	TR 178, Ruggles Rd	8.4	Shauck	40.5128	-82.6439	c,b,m,f
Job Run	0.08	CR 6, Upper Fredericktown Rd	8.5	Fredricktown	40.4331	-82.5061	c,b,m,f
East Branch Kokosing River	6.04	TR 288, Toms Rd	9.9	Butler	40.5389	-82.4919	c,b,m,f
East Branch Kokosing River	0.01	at mouth (access?)	31.8	Fredericktown	40.4881	-82.5394	c,b,M,F
Granny Creek	4.30	TR 402, Granny Creek Rd	9.1	Fredericktown	40.4272	-82.5919	c,b,m,f
Mile Run	4.75	Driveway from CR 11, Sparta Rd	9.0	Chesterville	40.4372	-82.6286	c,b,m,f
South Branch Kokosing River	2.96	CR 23, Cardington Chesterville Rd	8.4	Chesterville	40.4739	-82.7369	c,b,m,f

Sample type acronyms:

D - Datasonde	**M** - Macroinvertebrates, quantitative
C - Conventional water chemistry with metals	**m** - macroinvertebrates, qualitative
c - conventional water chemistry no metals	**F** - Fish, 2 pass
O - Organic water chemistry	**f** - fish, 1 pass
S - Sediment inorganic, organic and metal concentrations	**T** - Fish tissue, human consumption risk analysis
B - Bacteriological analysis	**b** - Bacteriological analysis
Compliance - Sampling will determine entity NPDES permit compliance	

Summary of Findings

Water Chemistry Summary and Trends

Summary

Surface water chemistry samples were collected from 49 sites in the Kokosing River Watershed (Table 9, pg. 46). All sites were sampled a minimum of five separate occasions, typically at two week intervals, from June 2007 to August 2007. Eight sentinel sites throughout the watershed were sampled more frequently (typically monthly) from December 2006 to October 2007. All samples were analyzed for a variety of parameters including nutrients and metals. Sites were sampled from free-flowing sections of streams and were primarily collected from bridge crossings. Surface water samples were collected in appropriate containers, preserved and delivered to Ohio EPA's Environmental Services laboratory. Sample collection followed the methods as outlined in Parts I and II of the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA, 2006).

Many graphs are provided with dotted lines representing water quality criteria or percentile concentrations from least impacted regional reference sites of similar size to assist in the analysis of chemical sampling results (Ohio EPA 1999). Data grouped by ecoregion and further stratified by three ranges of stream and river size for these analyses as follows: headwater streams (0-20 sq.mi.); wadeable streams (20-200 sq.mi.); and small rivers (200-1000 sq.mi.).

Generally, chemistry water quality sampling was conducted to capture a wide variety of stream flow conditions, however, a majority of samples collected during the summer of 2007 were collected at flows below the historical median. Data from the United States Geological Survey (USGS) gage station near Mount Vernon was examined to show flow trends in the Kokosing River during the 2007 survey (Figure 3). Dates when surface water chemistry samples were collected are noted on the graph.

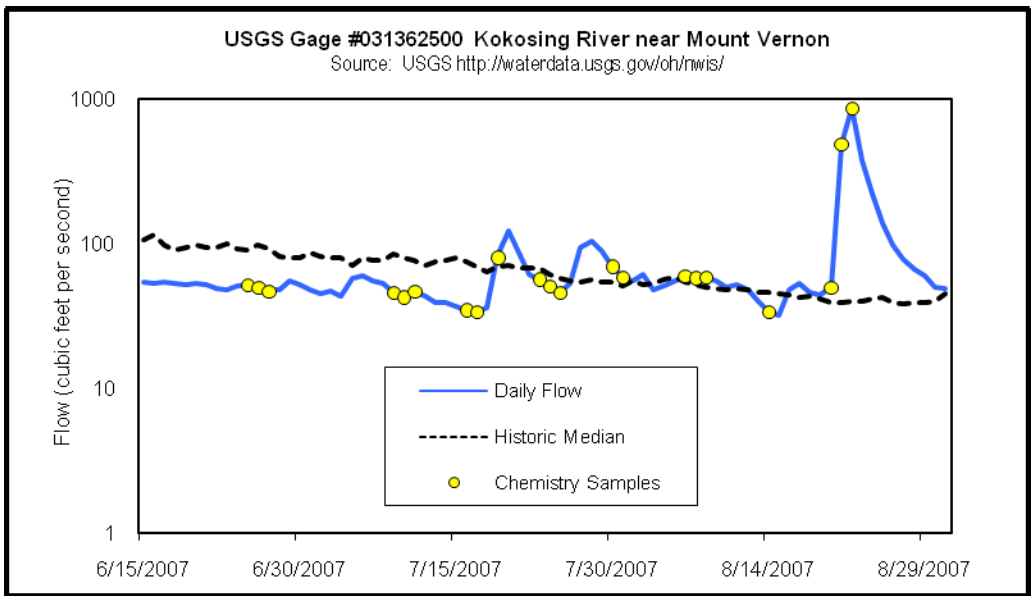

Figure 3. Water chemistry sampling dates plotted along daily stream flows (cubic feet per second) for the Kokosing River, 2007.

Overall, stream water quality conditions in the Kokosing River watershed were satisfactory. Few violations of Ohio Water Quality Standards were observed. The exception being dissolved oxygen where at a few impacted stream locations low dissolved oxygen levels were measured. At a vast majority of the sites, stream dissolved oxygen levels were high and easily met warmwater or exceptional warmwater criteria. Other physical/chemical parameters studied were mostly satisfactory and below ecoregion reference values for Ohio. Violations of Ohio Water Quality Standards for chemical/physical parameter are shown in Table 10, pg. 52.

Nutrient conditions, as measured by total phosphorus and nitrate + nitrite, did show some locations of elevated concentrations exceeding reference values. These locations included stream segments where agricultural land use dominates the reach and at locations below municipal wastewater treatment plants. In general, nutrient concentrations in the watershed appear to have decreased slightly compared to past survey results.

River/Stream	HUC	River Mile	Parameter/Result (mg/l)	Code
Kokosing River (WWH)	010	49.73	Dissolved Oxygen/2.90 mg/l	c
S.B. Kokosing River (WWH)	010	2.96	Dissolved Oxygen/2.85, 2.40, 1.89, 1.87	c
Mile Run (WWH)	010	4.75	Dissolved Oxygen/3.15, 2.71	c
N.B. Kokosing River (WWH)	020	14.00	Dissolved Oxygen/3.30	c
U.T. to N.B. Kokosing River (U)	020	4.04	Dissolved Oxygen/3.90, 2.10, 3.14	c
Delano Run (U)	030	1.55	Dissolved Oxygen/1.62, 2.47, 2.01	c
Big Run (WWH)	030	0.66	Dissolved Oxygen/3.80	c

WWH—Warm Water Habitat
U—Undesignated (treat as WWH, AWS, IWS, PCR or SCR)
c—violates the aquatic life protection criterion outside the mixing zone (minimum or maximum)

Table excludes violations of recreational use criteria (bacteria). Refer to Recreational Use Attainment Tables.

Table 10. Violations of chemical water quality standards in the Kokosing River study area, June through August, 2007.

At selected sites, stream sediment samples were collected to measure concentrations of metals, PCBs, pesticides, volatile organic compounds, polycyclic aromatic hydrocarbons and other compounds. Most of the parameters measured were below detection or at concentrations not expected to impact biological communities. Summarized sediment chemistry results for detected compounds are provided in Table 11, pg. 53.

KOKOSING RIVER BASIN (05040003)										
Analyte	Units	*Kokosing River*					*N. Br. Kokosing River*		*Dry Ck.*	*Jelloway Ck.*
	RM	**32.56**	**28.61**	**24.30**	**20.89**	**2.68**	**6.18**	**0.02**	**1.04**	**0.08**
	Region	EOLP	EOLP	EOLP	EOLP	WAP	EOLP	EOLP	EOLP	EOLP
Solids	%	40.1	61.1	43.3	62.7	49.6	72.1	63.1	43.3	61.9
Tot. Organic Carbon □	%	3.0_{LEL}	2.2_{LEL}	3.3_{LEL}	2.2_{LEL}	2.4_{LEL}	1.6_{LEL}	1.9_{LEL}	3.2_{LEL}	1.3_{LEL}
Ammonia	mg/kg		38			120				73
Phosphorus □	mg/kg		484			817_{LEL}				438
Aluminum	mg/kg	6940	4040	5560	4310	6260	3420	3720	7420	4900
Arsenic	mg/kg	15.8	10.7	10.3	7.78	10.2	7.88	10.9	14.8	7.30
Barium	mg/kg	126	56.7	87.2	45.1	83.9	39.8	53.9	71.1	51.2
Cadmium	mg/kg	0.595	0.248	0.466	0.242	0.336	0.178	0.254	0.513	0.109
Calcium	mg/kg	**38300**	**25600**	**35600**	**22100**	26500	9720	17200	**48700**	2730
Chromium	mg/kg	**34**	14	28	11	19	13	22	**30**	11
Copper	mg/kg	13.7	9.8	22.0	11.7	13.7	6.7	10.4	24.1	6.7
Iron	mg/kg	22200	15400	16500	13100	18100	11800	14600	26400	13800
$Lead_s$	mg/kg	17.7	12.1	36.6	26.3	20.2	12.1	13.7	23.4	8.67
Magnesium	mg/kg	5550	7030	**7130**	6250	6720	3540	5450	**12500**	1640
Manganese	mg/kg	979	585	451	336	548	264	476	453	496
Nickel	mg/kg	**45**	18	**37**	14	25	18	30	**40**	14
$Mercury_s$	mg/kg	0.057	0.045	0.065	0.032	0.035	0.037	0.032	0.049	0.033
Potassium	mg/kg	2270	922	1850	717	1260	881	1470	2010	702
Selenium	mg/kg	**2.27**	0.92	**1.85**	0.72	1.26	0.88	1.47	**2.01**	0.70
Sodium	mg/kg	5670	2300	4620	1790	3150	2200	3680	5020	1760
Strontium	mg/kg	**149**	34	**63**	34	43	13	22	58	11
Zinc	mg/kg	81.9	60.4	93.9	56.2	73.1	42.1	59.5	106	42.9
Fluoranthene	mg/kg			1.0	0.81					
Pyrene	mg/kg			0.83	0.64					

Table 11. Results of chemical/physical sediment quality sampling conducted in the Kokosing River study area during July-September, 2007. Underlined values indicate concentrations below the method-reporting limit. NA means not analyzed. Parameters noted with a □ are compared with the Ontario guidelines published by Persaud and Jaagumagi, 1993 (LEL = greater than the Lowest Effect Level but less than the Severe Effect Level, SEL = greater than the severe effect level). All metals parameters are compared with ecoregional (default) or statewide (noted by a subscript s) sediment reference values determined by Ohio EPA (Ohio EPA, 2003). Metals values in boldface are greater than the reference value. Boxes with no value were analyzed but not detected.

Recreational Use Assessment

Bacteria samples were collected during the survey to assess attainment with proposed Ohio Water Quality Standards for stream recreation use. Attainment is assessed based on E.coli bacteria sample results. For the Kokosing River mainstem where recreational use activities are most common, the highest E.coli concentrations were typically observed after significant rainfall. Under normal or low flow conditions most E.coli results appeared satisfactory. Evaluation of E.coli results revealed that approximately 65% of all sites (including tributaries) studied failed to meet the applicable recreation use standard. Sources of elevated bacteria concentrations were mostly likely due to a variety of sources including failing home sewage treatment systems (HSTS) and livestock access to streams. Summarized E.coli bacteria results are presented in Table 12.

Table 12. Recreation use attainment table for locations in the Kokosing River Watershed, May 1 through October 31, 2007.

Note: All values are expressed as ***E. coli*** colony forming units (cfu) per 100 ml of water. Gray shaded values exceed Primary Contact Recreation (PCR) criteria. Attainment decisions made based on cells outlined in bold.*

Location	River Mile	# Samples	Geometric Mean	Maximum Value	Attainment Status	Source(s) of Bacteria
Class A (lakes and popular paddling streams) – Geometric Mean < 126 Maximum Value ≤ 298						
Kokosing River	25.30	7	113	3000	**FULL**	
Kokosing River	24.30	7	183	2600	**NON**	Urban runoff, Municipal WWTP
Kokosing River	20.89	7	128	800	**NON**	Urban runoff
Kokosing River	18.05	6	72	620†	**FULL**	
Kokosing River	11.55	7	91	6100†	**FULL**	
Kokosing River	6.12	7	146	1900	**NON**	Agriculture, HSTS
Kokosing River	2.68	9	94	2400†	**FULL**	
Kokosing River	0.07	7	93	2100†	**FULL**	
Class B (most streams; those that are not Class A or C) – Geometric Mean < 161 Maximum Value ≤ 523						
Kokosing River	54.69	5	270	740	**NON**	Agriculture (livestock access), small WWTP
Kokosing River	49.73	5	219	620	**NON**	Agriculture, HSTS

Location	River Mile	# Samples	Geometric Mean	Maximum Value	Attainment Status	Source(s) of Bacteria
S. Branch Kokosing River	2.96	5	345	2900	**NON**	Agriculture (livestock access)
Kokosing River	45.44	10	143	1800†	**FULL**	
Kokosing River	39.27	5	804	1700	**NON**	Agriculture (livestock access)
Mile Run	4.75	2	92	120†	**FULL**	
Kokosing River	32.56	8	266	610	**NON**	Agriculture
Granny Creek	4.29	5	1005	2300	**NON**	Agriculture, HSTS
Kokosing River	28.61	12	330	5700	**NON**	Agriculture, HSTS
N. Branch Kokosing River	17.77	5	383	560	**NON**	Agriculture, HSTS
N. Branch Kokosing River	14.00	5	340	890	**NON**	Agriculture, HSTS
N. Branch Kokosing River	9.15	5	18	30	**FULL**	
N. Branch Kokosing River	6.18	7	32	110	**FULL**	
E. Branch Kokosing River	6.04	5	362	650	**NON**	Agriculture, HSTS
E. Branch Kokosing River	0.10	5	77	230	**FULL**	
Job Run	0.08	5	607	2900	**NON**	Agriculture, HSTS
N. Branch Kokosing River	0.02	10	123	1000†	**FULL**	
Armstrong Run	1.06	5	123	360	**FULL**	
Dry Creek	10.72	5	376	620	**NON**	HSTS
Dry Creek	9.22	5	451	6000	**NON**	HSTS
Dry Creek	4.52	5	131	620†	**FULL**	
Dry Creek	1.04	9	54	860†	**FULL**	
Center Run	1.72	5	575	8000	**NON**	Urban runoff
Delano Run	1.55	5	694	3300	**NON**	Urban runoff
Big Run	4.40	5	361	2300	**NON**	Agriculture (livestock access), HSTS
Big Run	0.66	9	335	2000	**NON**	Agriculture, HSTS
Elliot Run	1.05	5	90	740†	**FULL**	
Indianfield Run	2.62	5	267	600	**NON**	Agriculture, HSTS
Schenck Creek	8.75	5	2087	33000	**NON**	Agriculture, HSTS

Location	River Mile	# Samples	Geometric Mean	Maximum Value	Attainment Status	Source(s) of Bacteria
Schenck Creek	0.55	10	598	35000	**NON**	Agriculture, HSTS
L. Schenck Creek	4.45	3	1979	22000	**NON**	Agriculture, HSTS
L. Schenck Creek	0.15	5	730	23000	**NON**	Agriculture, HSTS
Jelloway Creek	8.85	5	473	2300	**NON**	Agriculture (livestock access)
Jelloway Creek	4.26	5	630	2400	**NON**	Agriculture (livestock access)
Jelloway Creek	0.08	10	446	80000	**NON**	Agriculture, Municipal WWTP
L. Jelloway Creek	6.97	5	1652	3800	**NON**	Agriculture (livestock access)
L. Jelloway Creek	0.88	7	28	60	**FULL**	
E.B. Jelloway Creek	3.33	5	2010	4500	**NON**	Agriculture
E.B. Jelloway Creek	1.03	5	677	3000	**NON**	Agriculture, Urban runoff
Brush Run	0.91	5	23	70	**FULL**	
Class C (streams that support infrequent recreation (e.g., wading)) – Geometric Mean < 206 Maximum Value ≤ 940						
Unnamed Trib. RM 9.99	4.04	5	6598	22000	**NON**	Agriculture (livestock access)

† Attainment status is determined based on geometric mean except at locations with only one sample. At such locations, attainment is determined based on the single sample maximum.

* Criteria based on Ohio EPA proposed recreation use rule (OAC 3745-1-41).

Trends

Upper Kokosing River

Kokosing River water quality sampling data from 1987 and 1998 were compared to the 2007 survey data to examine trends in water quality conditions over time.

In general, conditions in the upper Kokosing River hydrologic unit remained satisfactory and in some instances improved from previous sampling years. Dissolved oxygen conditions, especially downstream from the South Branch of the Kokosing River improved and remained well above the EWH minimum criteria of 5.0 mg/l (Figure 4). Despite sedimentation issues noted in this study, total suspended solids concentrations also remained comparable to 1987 and 1998 with 2007 results below the 75th percentile reference values for Ohio streams (Ohio EPA, 1999) (Figure 5, pg. 59).

Stream nutrient conditions over time also have appeared to have improved slightly. Both total phosphorus and nitrate+nitrite results were lower in 2007 than in previous sampling years at most sites. Notably, nutrient results downstream of the new Chesterville WWTP (operational in 2003) were lower than those observed in 1998 and 1987 (Figure 6, pg. 60 and Figure 7, pg. 61).

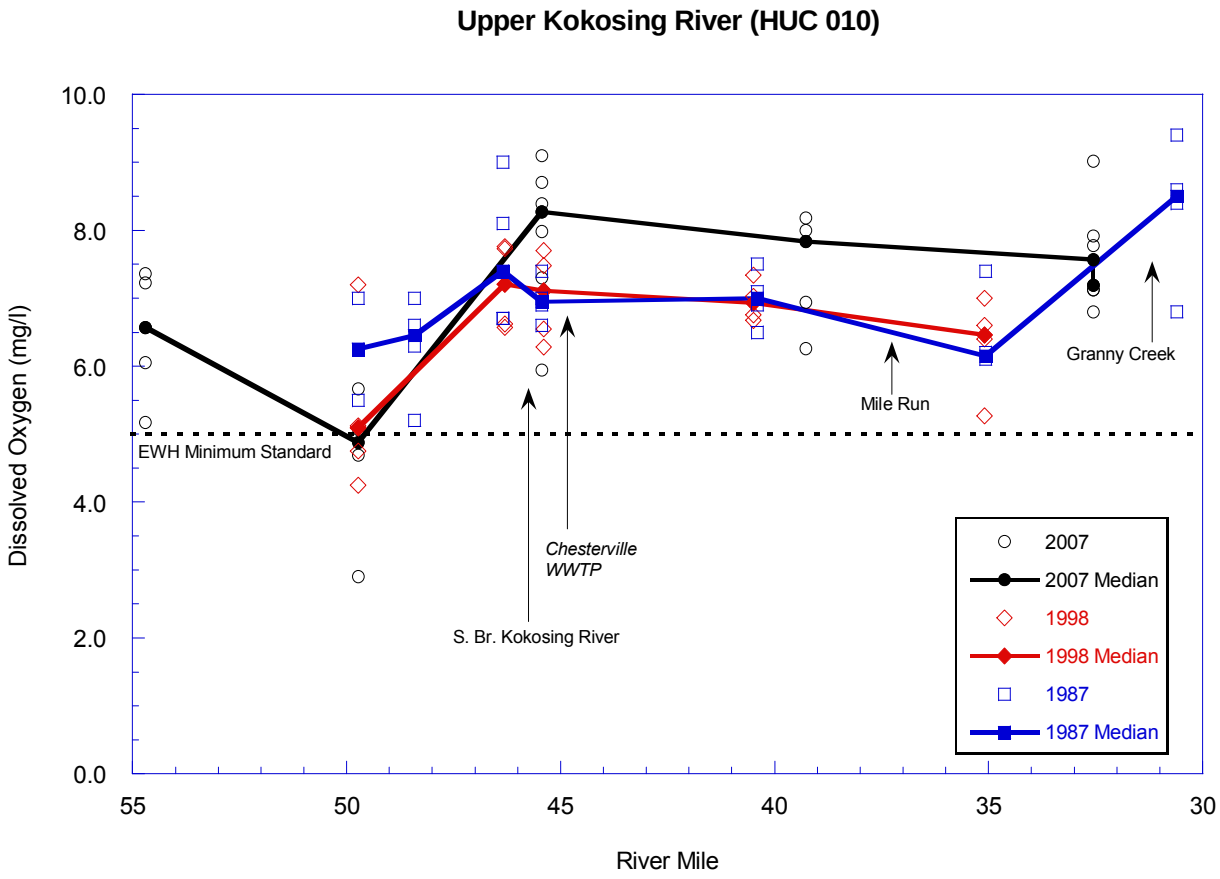

Figure 4. Historical trends for dissolved oxygen readings plotted by river mile in the upper Kokosing River.

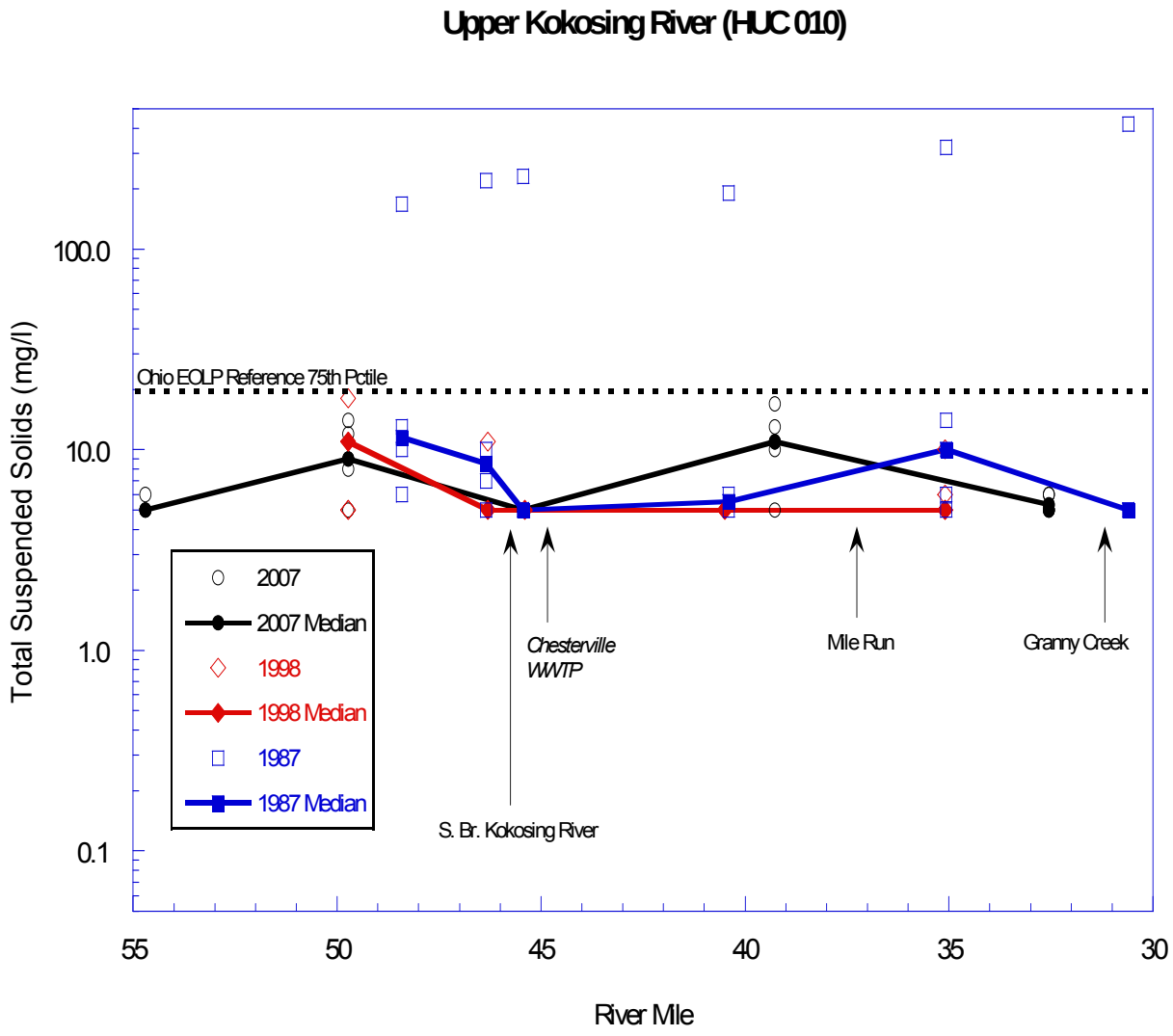

Figure 5. Historical trends for total suspended solids readings taken in the upper Kokosing River plotted by river mile.

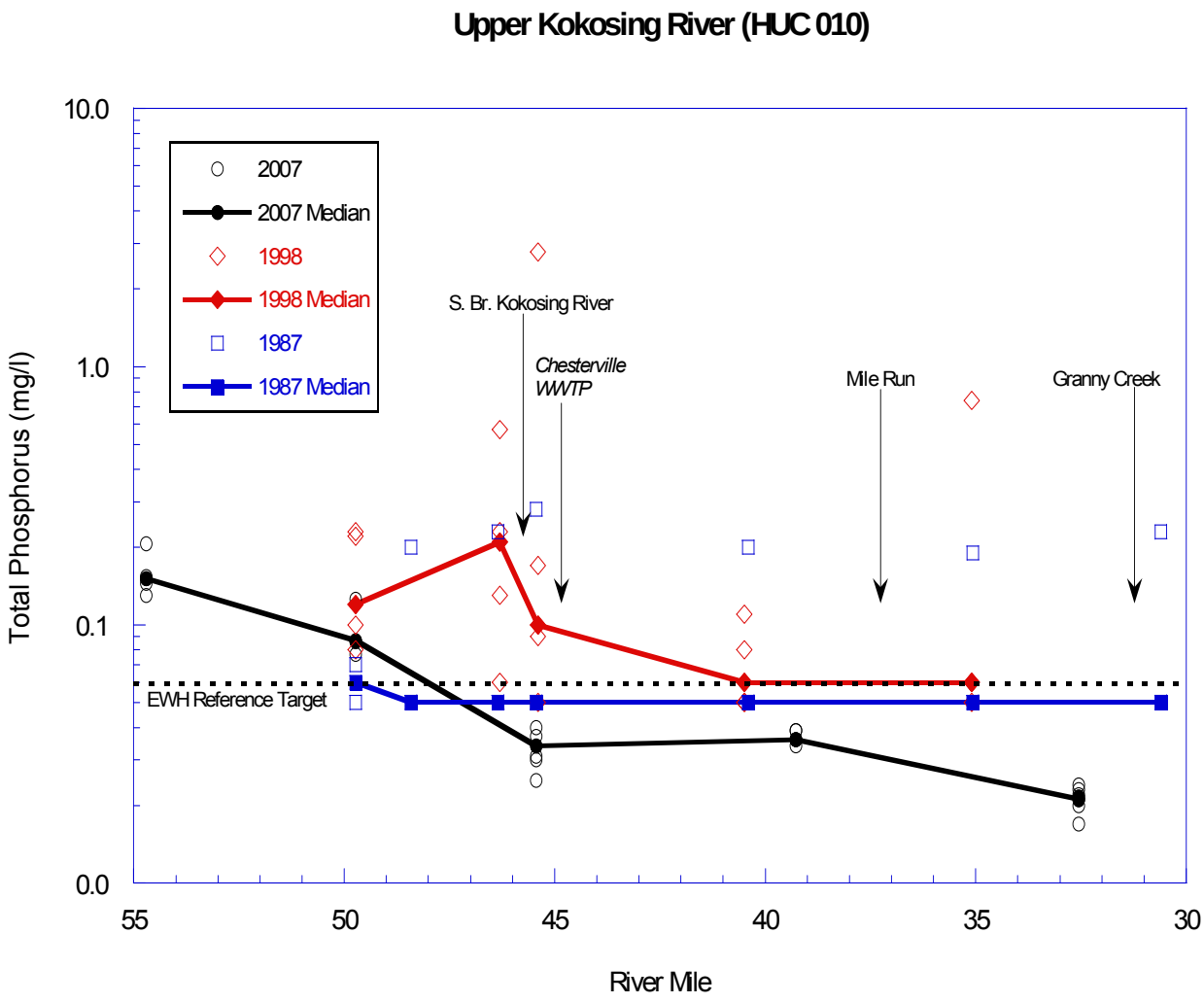

Figure 6. Historic trends for total phosphorus (mg/l) concentrations by river mile in the upper Kokosing River.

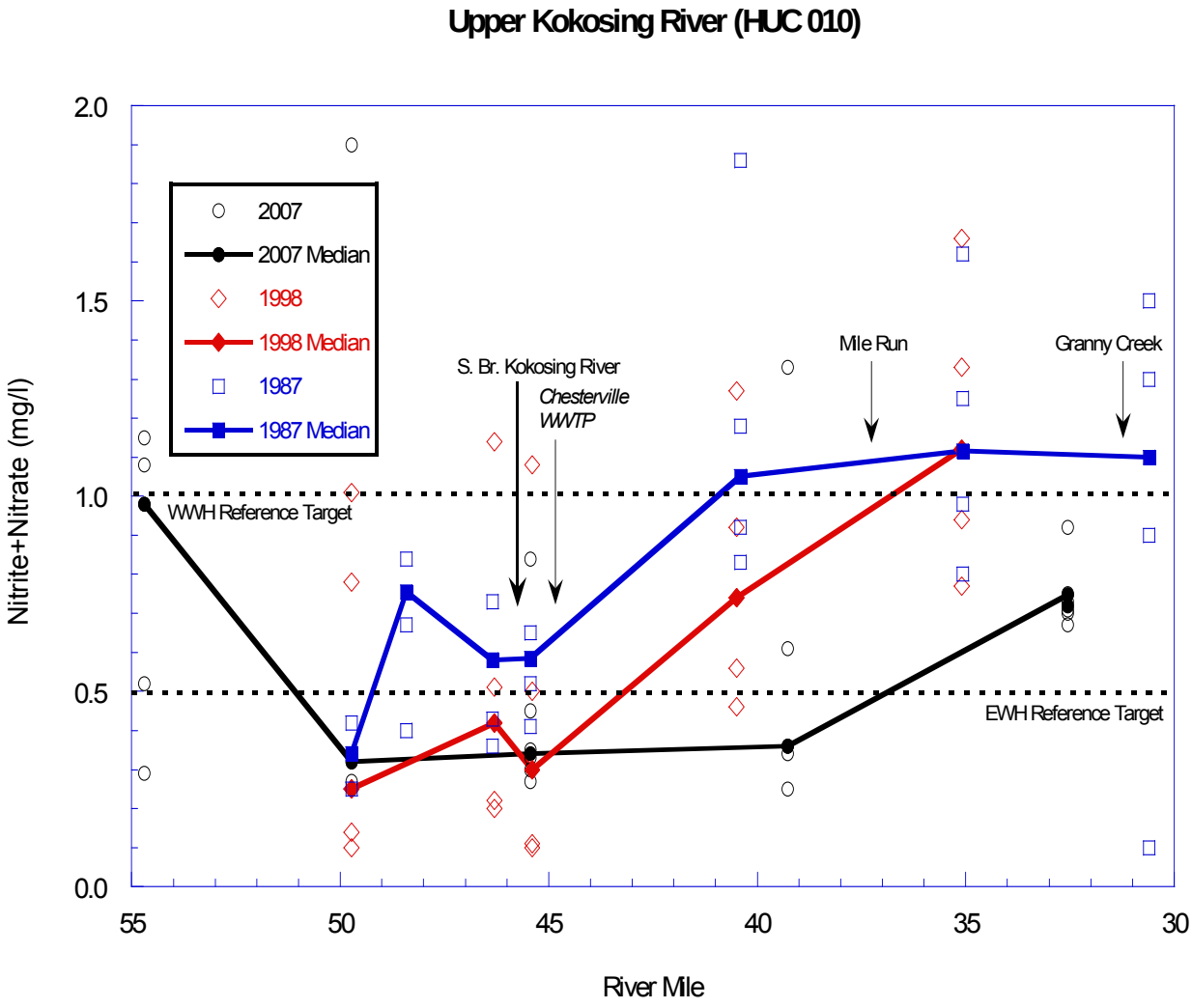

Figure 7. Historical trends in nitrite+nitrate (mg/l) levels detected by river mile in the upper Kokosing River.

North Branch Kokosing River

Historical trends in the North Branch demonstrated a high level of consistency for certain parameters. The longitudinal temperature comparison between 1998 and 2007 showed little difference (Figure 8). Dissolved and suspended solids concentrations for 1998-2007 were also very consistent (Figure 9 and Figure 10) as was nitrate+nitrite (Figure 11). Median total phosphorus concentrations were consistently lower in 2007 compared with 2002 and 1998 (Figure 12) possibly indicative of improved soil and water conservation measures in the watershed as well as dry summer weather.

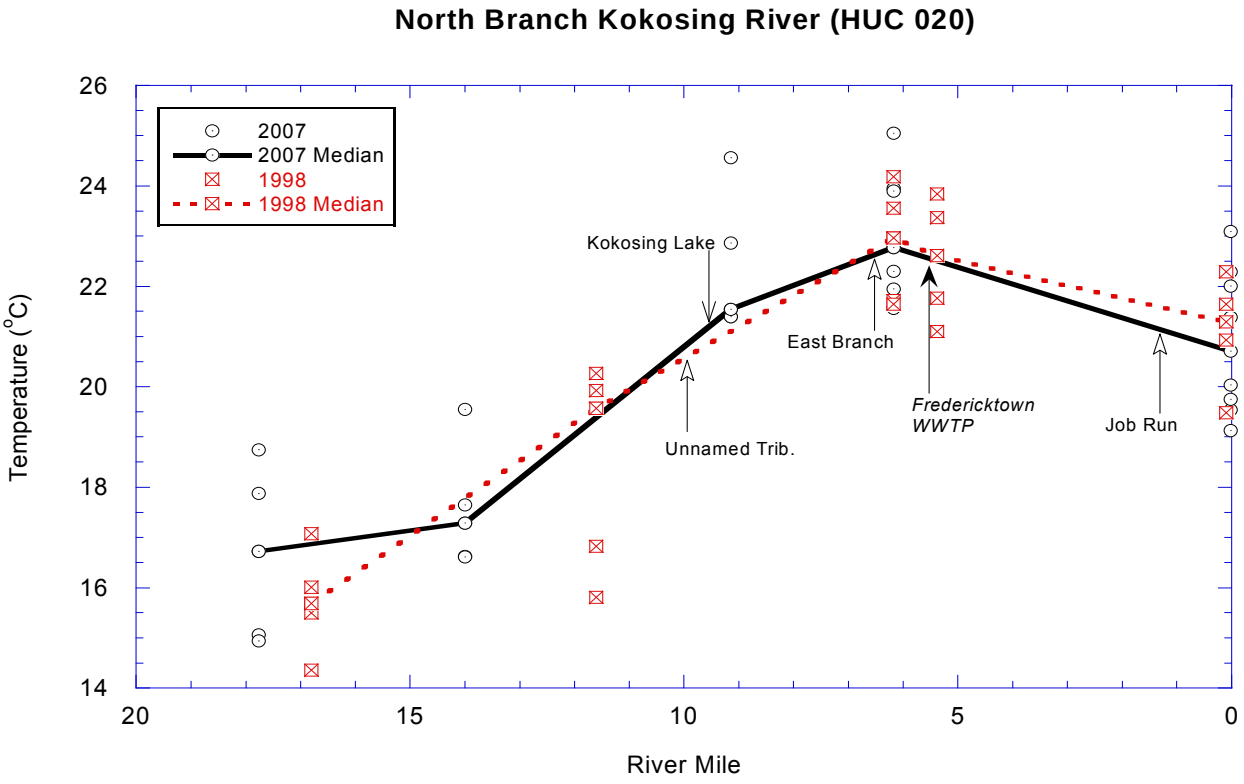

Figure 8. Historic trends in stream temperature by river mile for the North Branch Kokosing River.

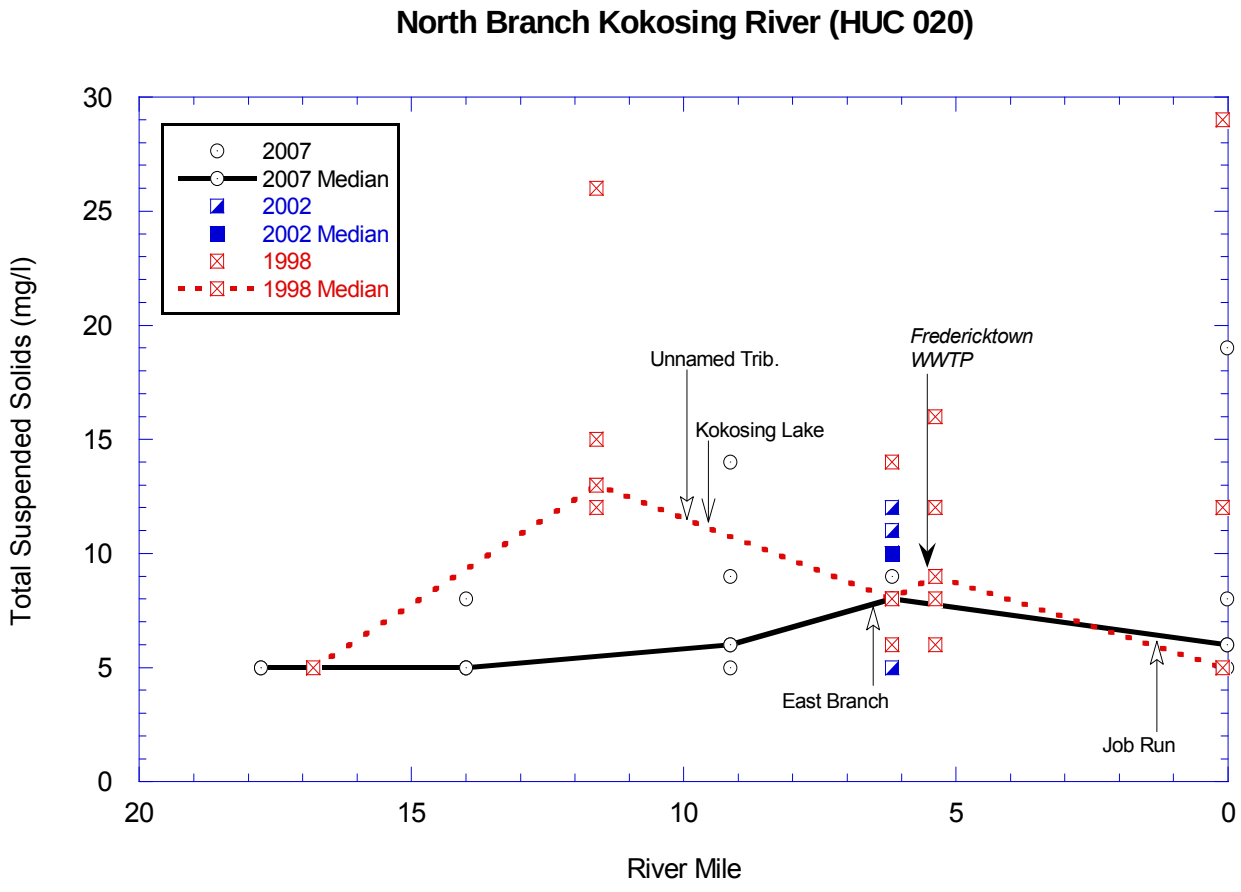

Figure 9. Historical trends for total suspended solids recorded by river mile in the North Branch Kokosing River.

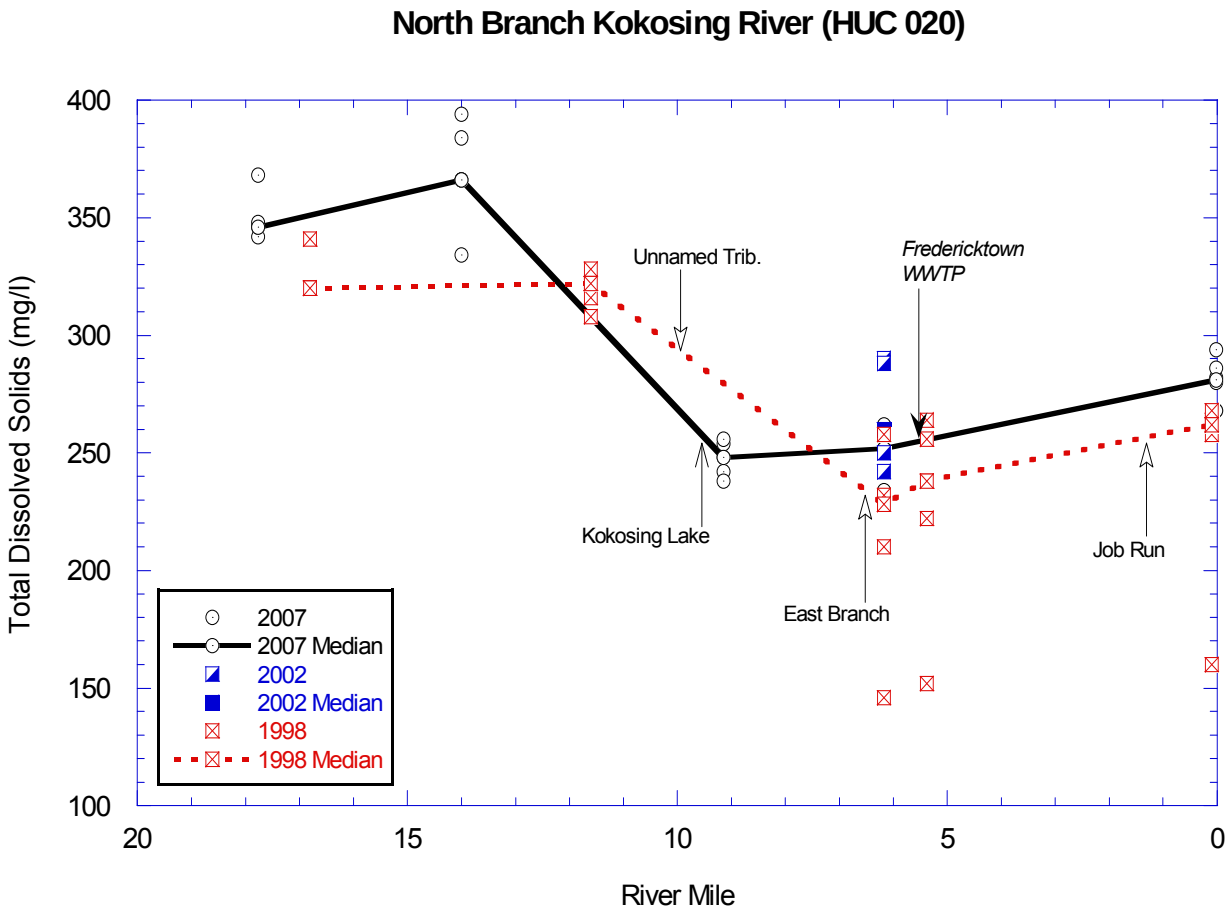

Figure 10. Historical trends for total dissolved solids (mg/l) listed by river mile for North Branch Kokosing River.

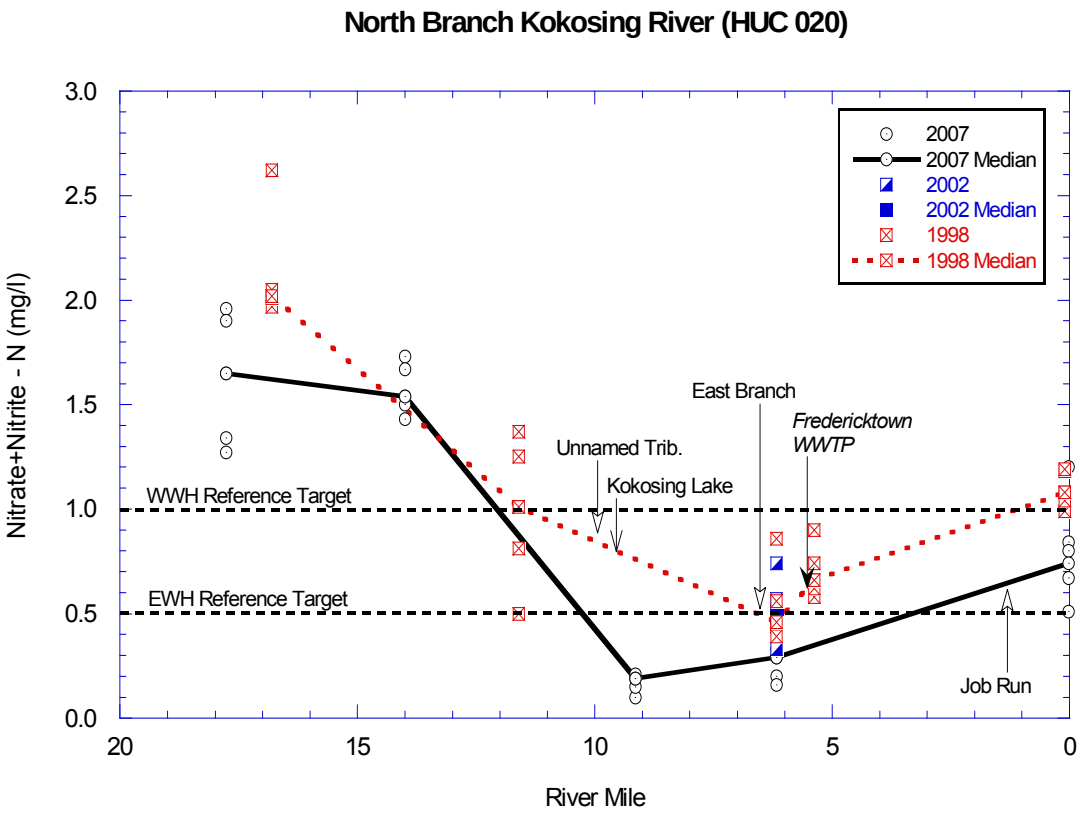

Figure 11. Historical trends for nitrite+nitrate by river mile in the North Branch Kokosing River.

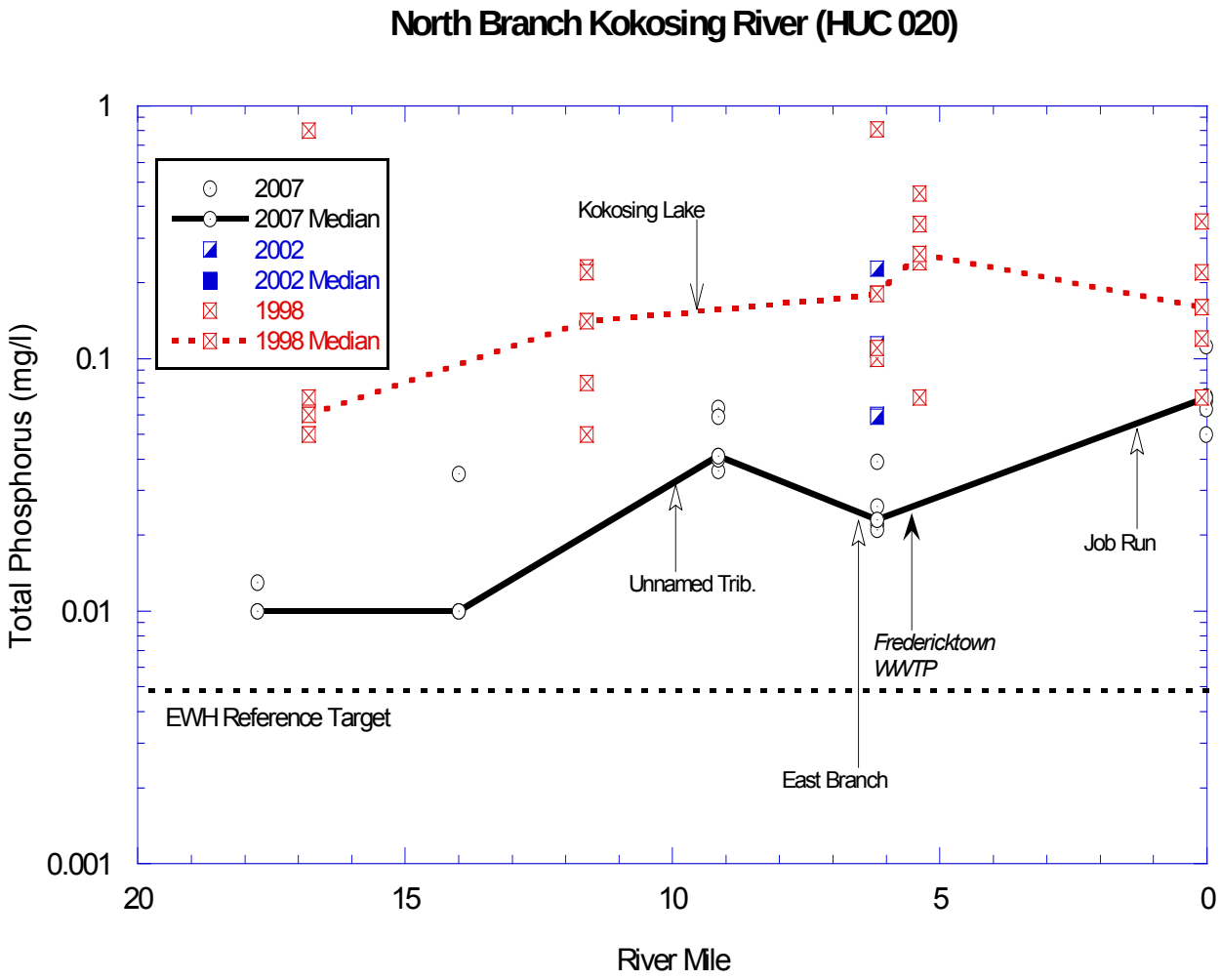

Figure 12. Historical trends for total phosphorus concentrations sampled by river mile in the North Branch Kokosing River.

Sediment

Two locations were evaluated for sediment composition on the North Branch Kokosing River, one at RM 6.18 and the other at the mouth (RM 0.02). Neither site revealed any contaminants of concern other than total organic carbon greater than the lowest effect level (Table 11, pg. 53). Index scores for both sites showed full attainment of water quality criteria for invertebrates indicating no adverse effects from organic carbon in sediments.

Middle Kokosing River

Summer trends comparisons for most parameters in the middle Kokosing River mainstem showed strikingly similar results indicating little change in the chemical composition of the river over time. Median values for 2007 ammonia-N and nitrate+nitrite were nearly identical to historical values (Figure 13 and Figure 14) as was the median for total phosphorus (Figure 15). Testing results for dissolved oxygen, temperature, TSS, TKN, and *E. coli* bacteria obtained in 2007 showed slight improvement over historical data, again generally mimicking historical readings (Figure 16, Figure 17, Figure 18, Figure 19, and Figure 20).

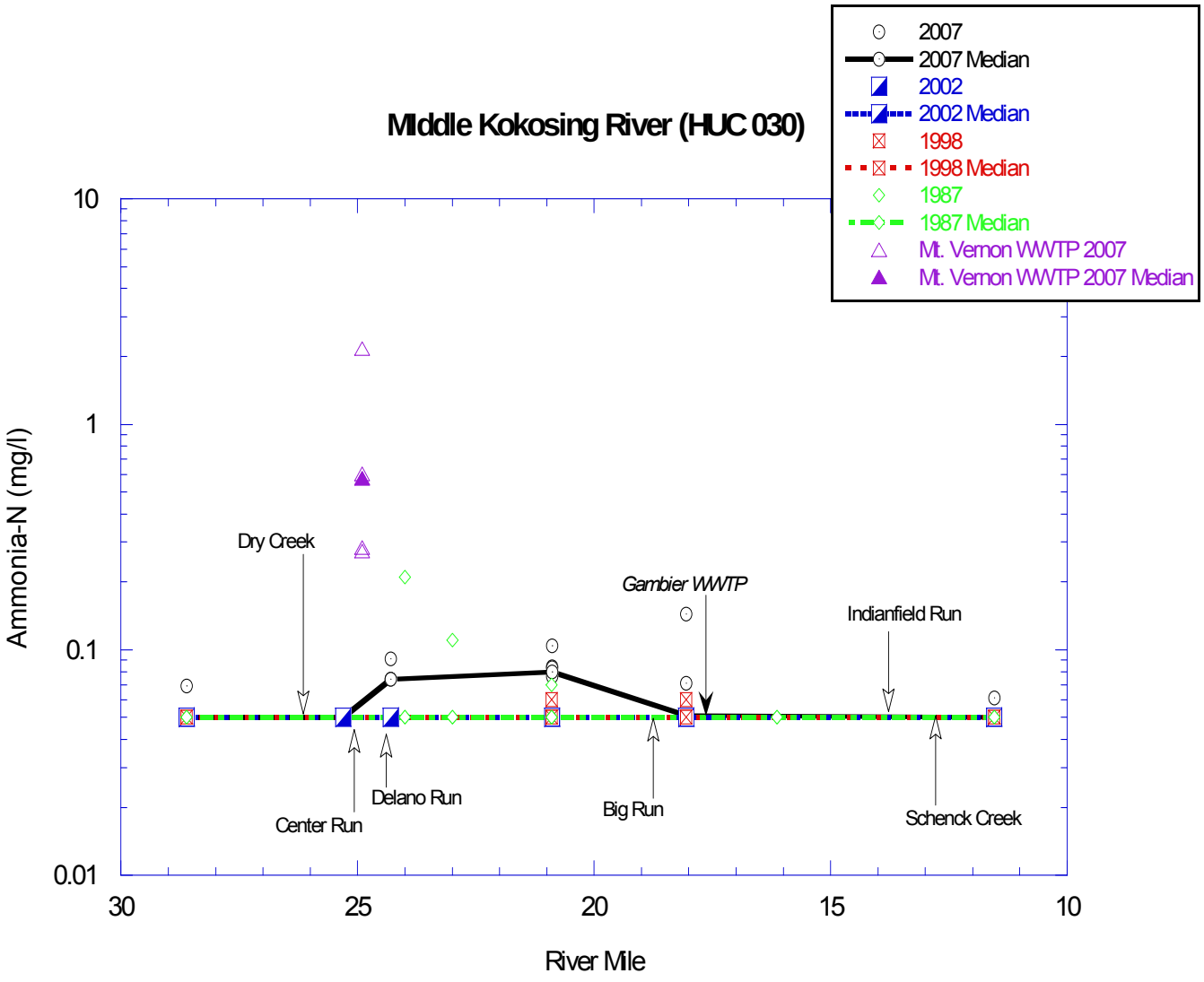

Figure 13. Historical trends in ammonia levels listed by river mile for the middle Kokosing River.

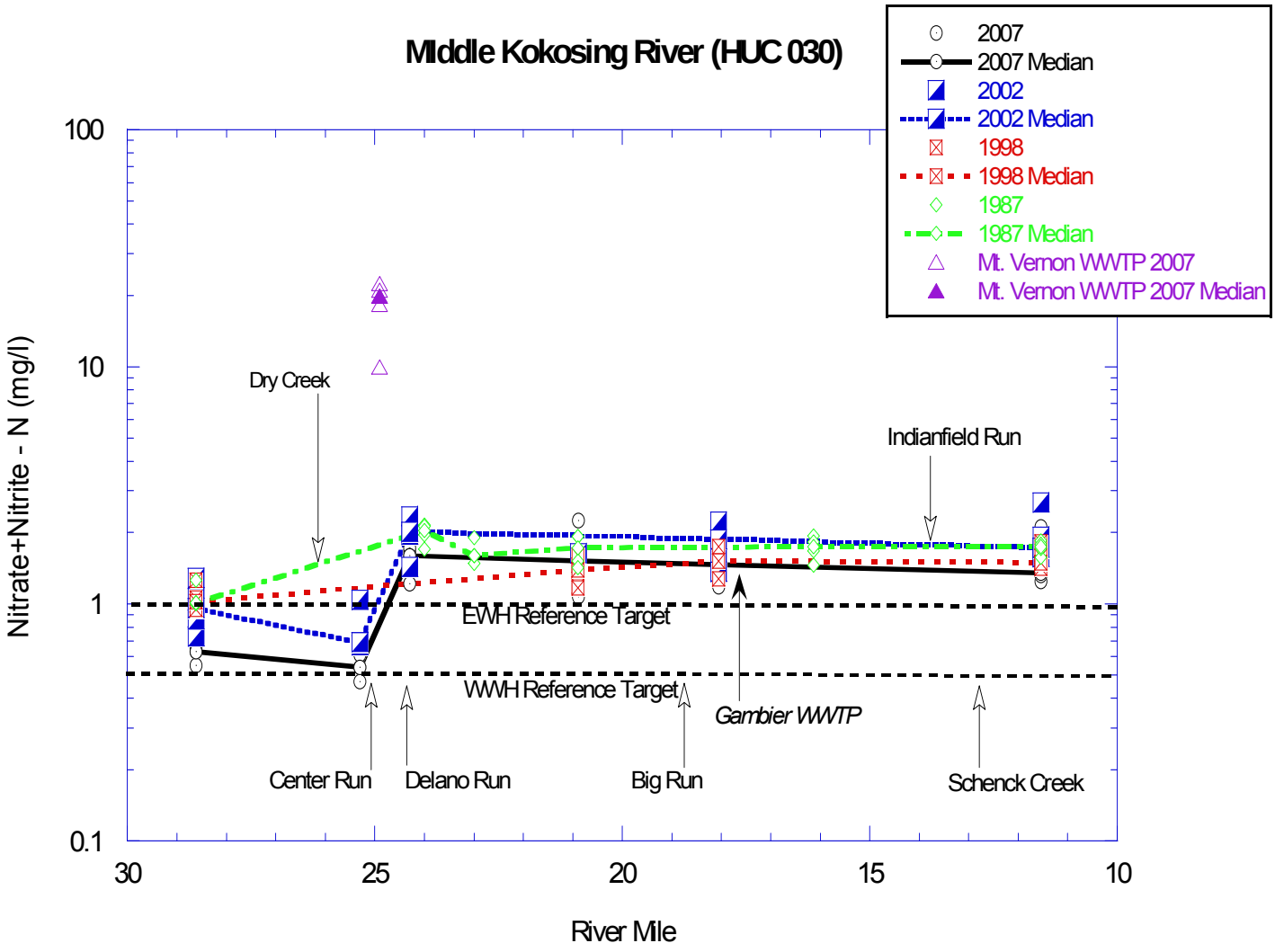

Figure 14. Historic trends in nitrate+nitrite levels listed by river mile for the middle Kokosing River.

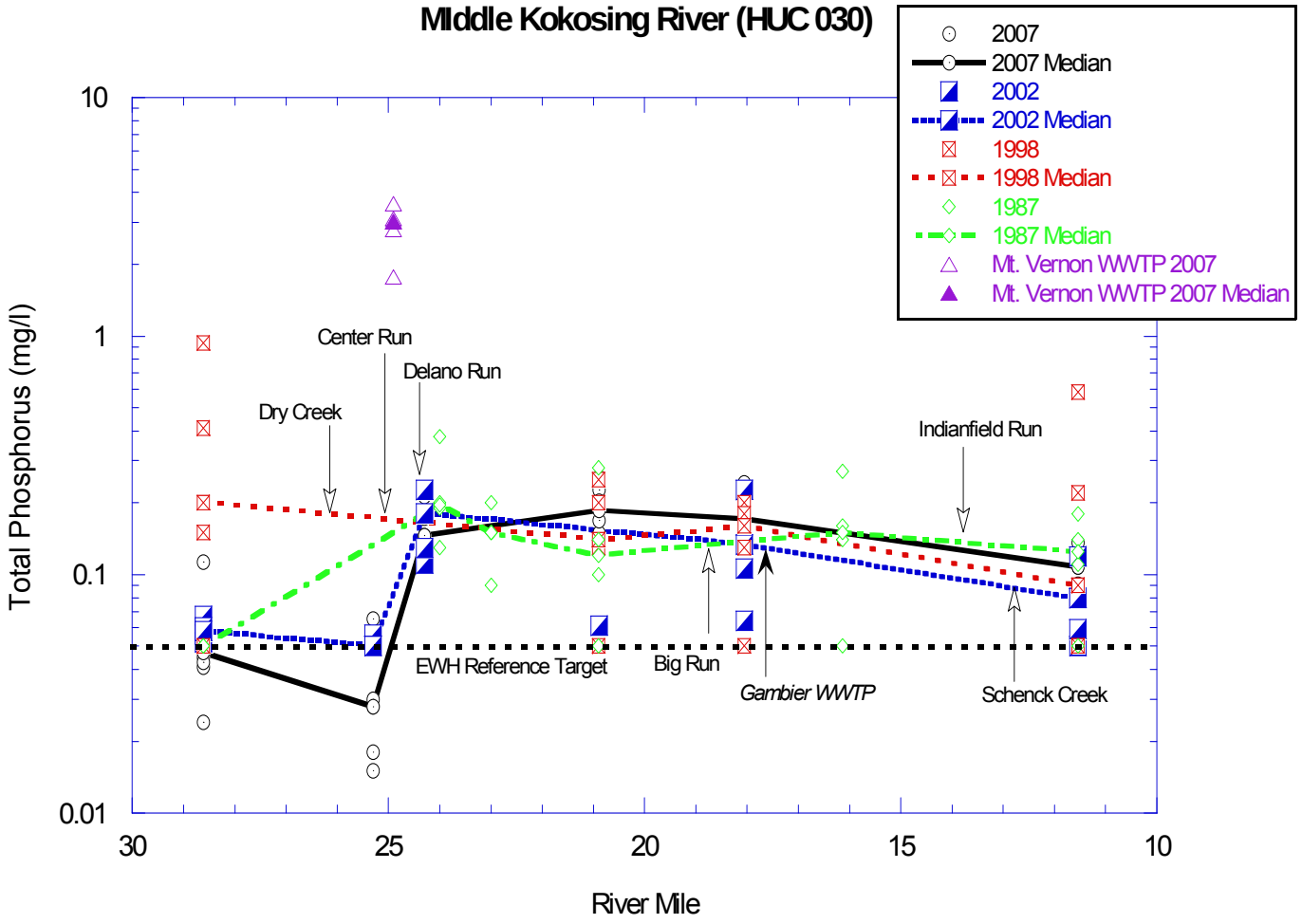

Figure 15. Historical trends in total phosphorus levels listed by river mile in the middle Kokosing River.

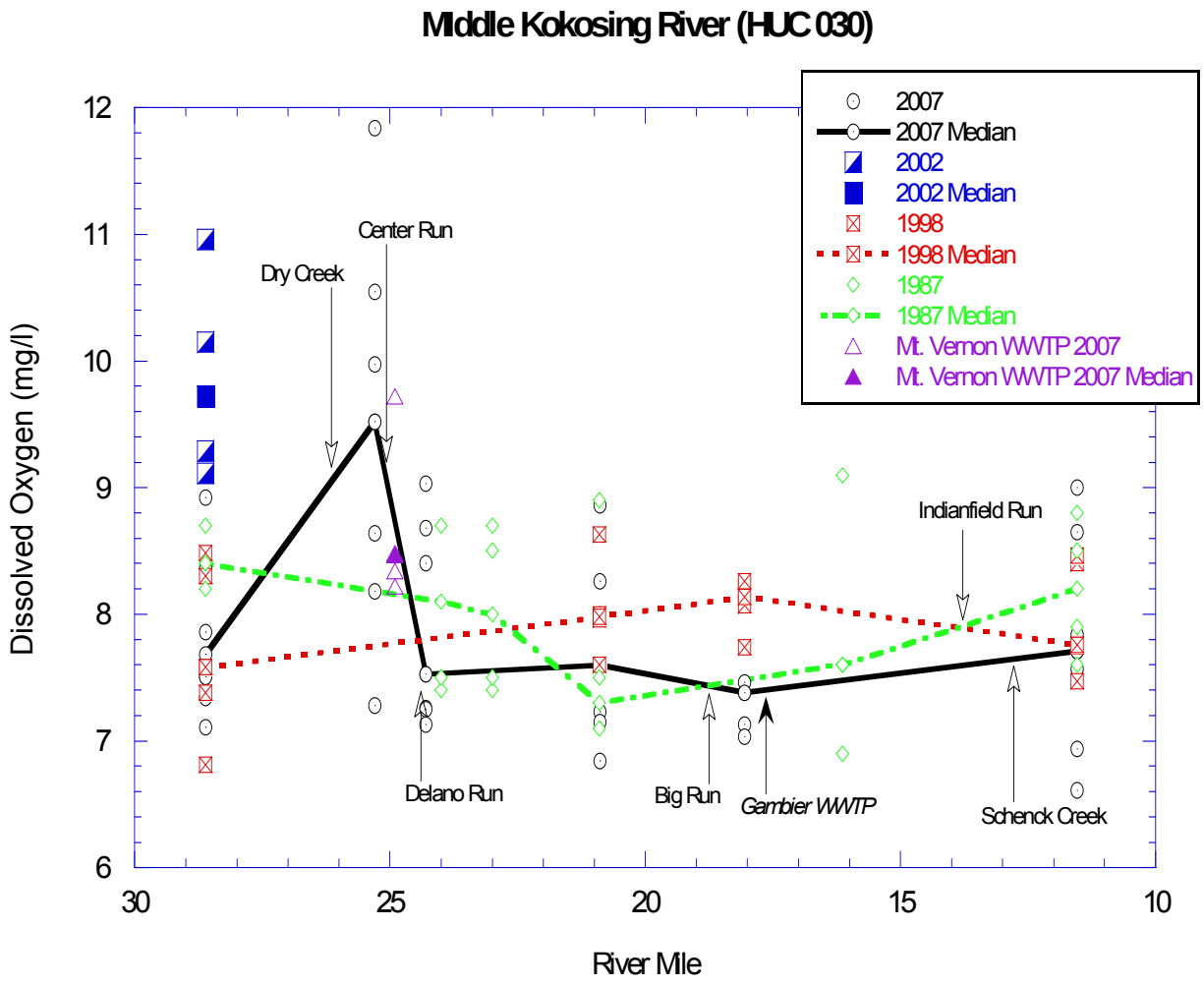

Figure 16. Historic trends in dissolved oxygen readings taken by river mile in the middle Kokosing River.

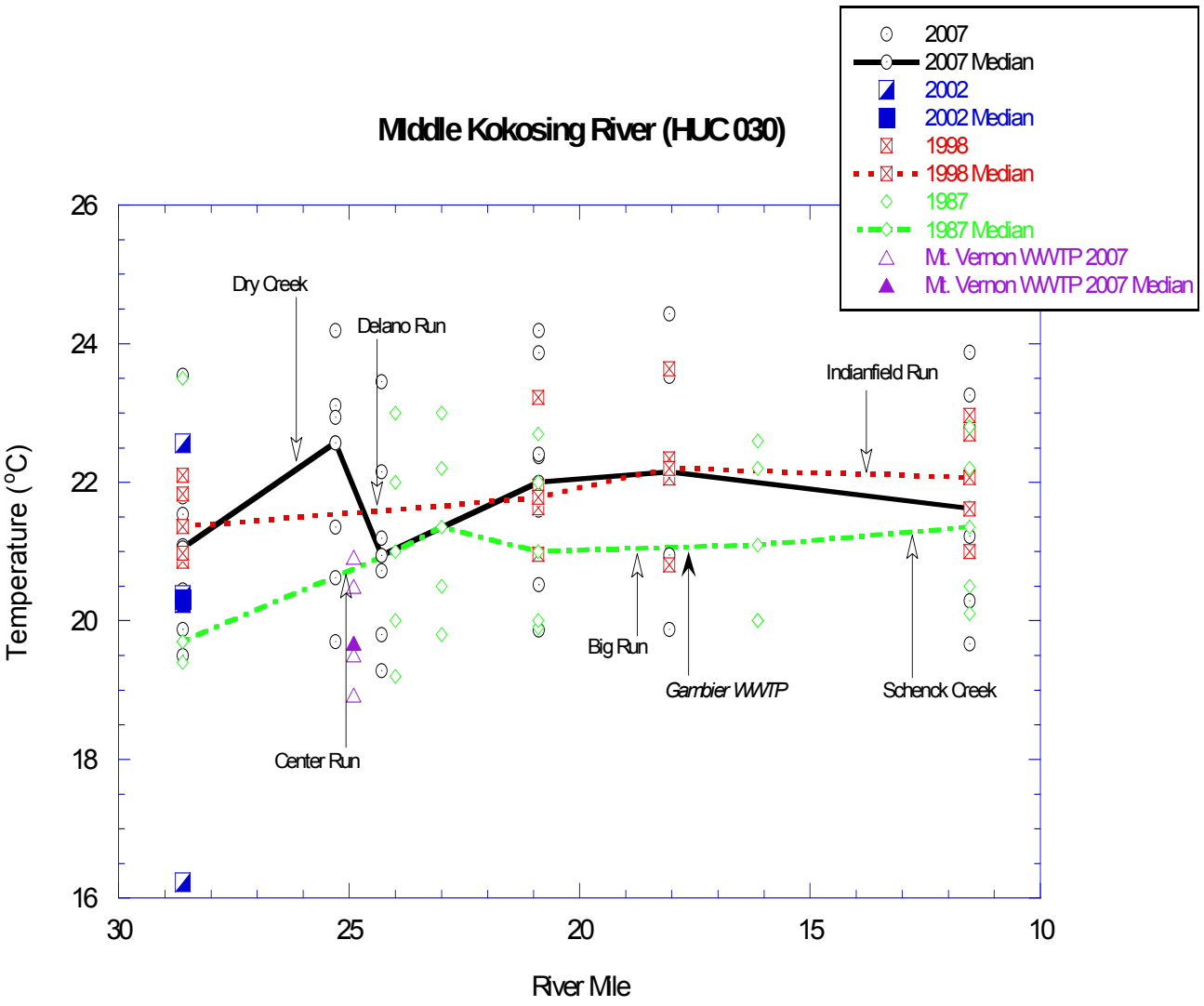

Figure 17. Historical trends in temperature by river mile in the middle Kokosing River.

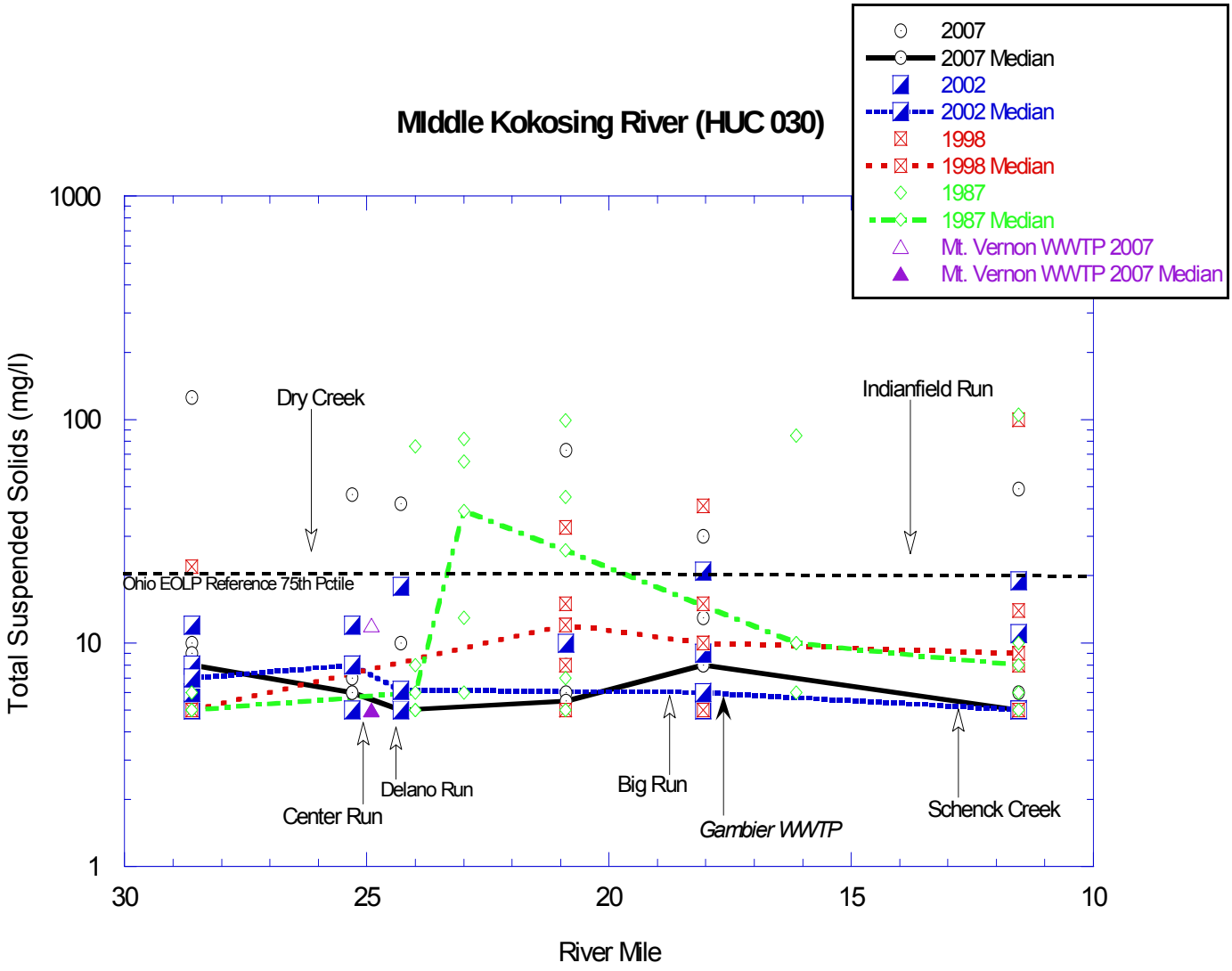

Figure 18. Historical trends in total suspended solids listed by river mile in the middle Kokosing River.

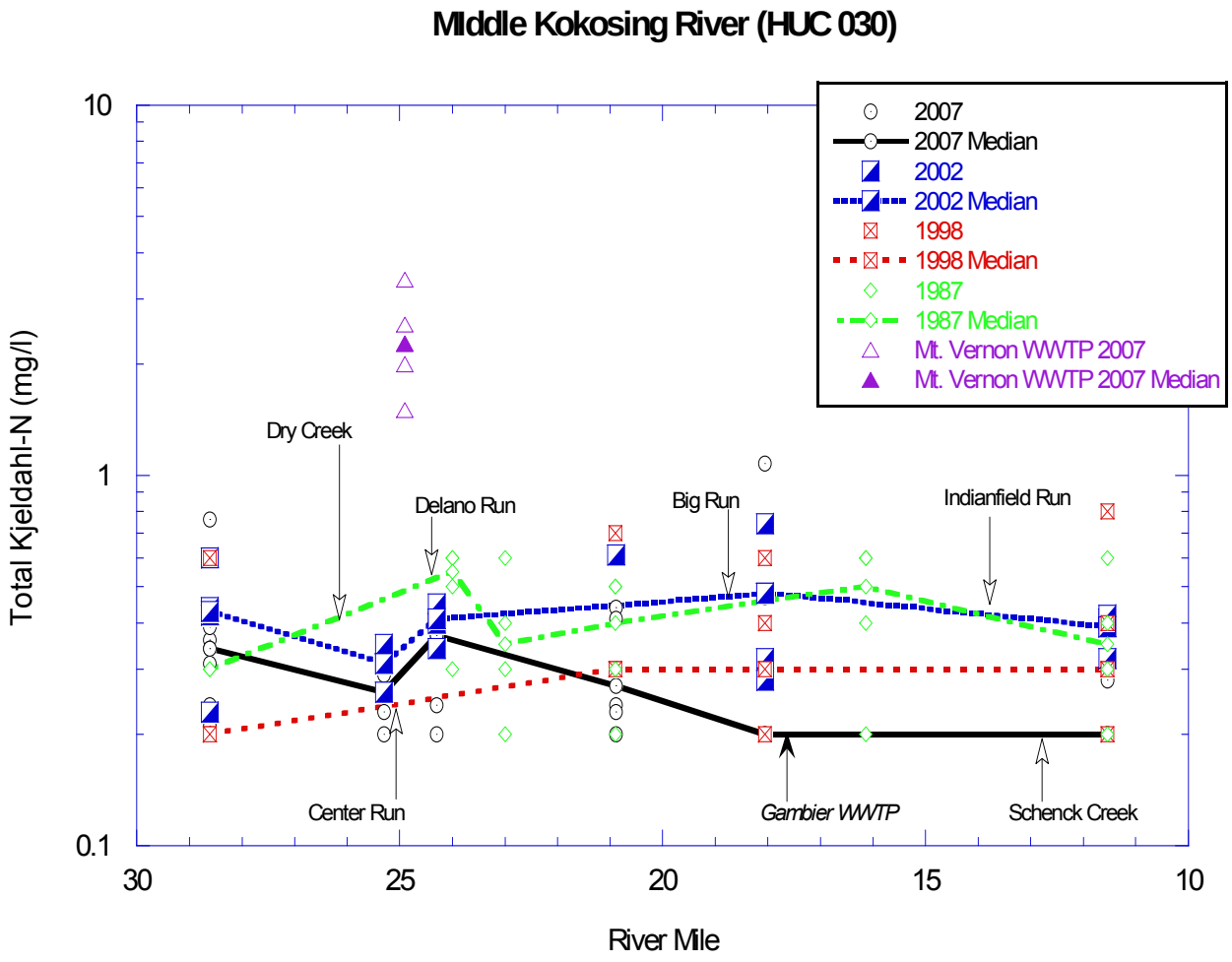

Figure 19. Historic trends for TKN listed by river mile for the middle Kokosing River.

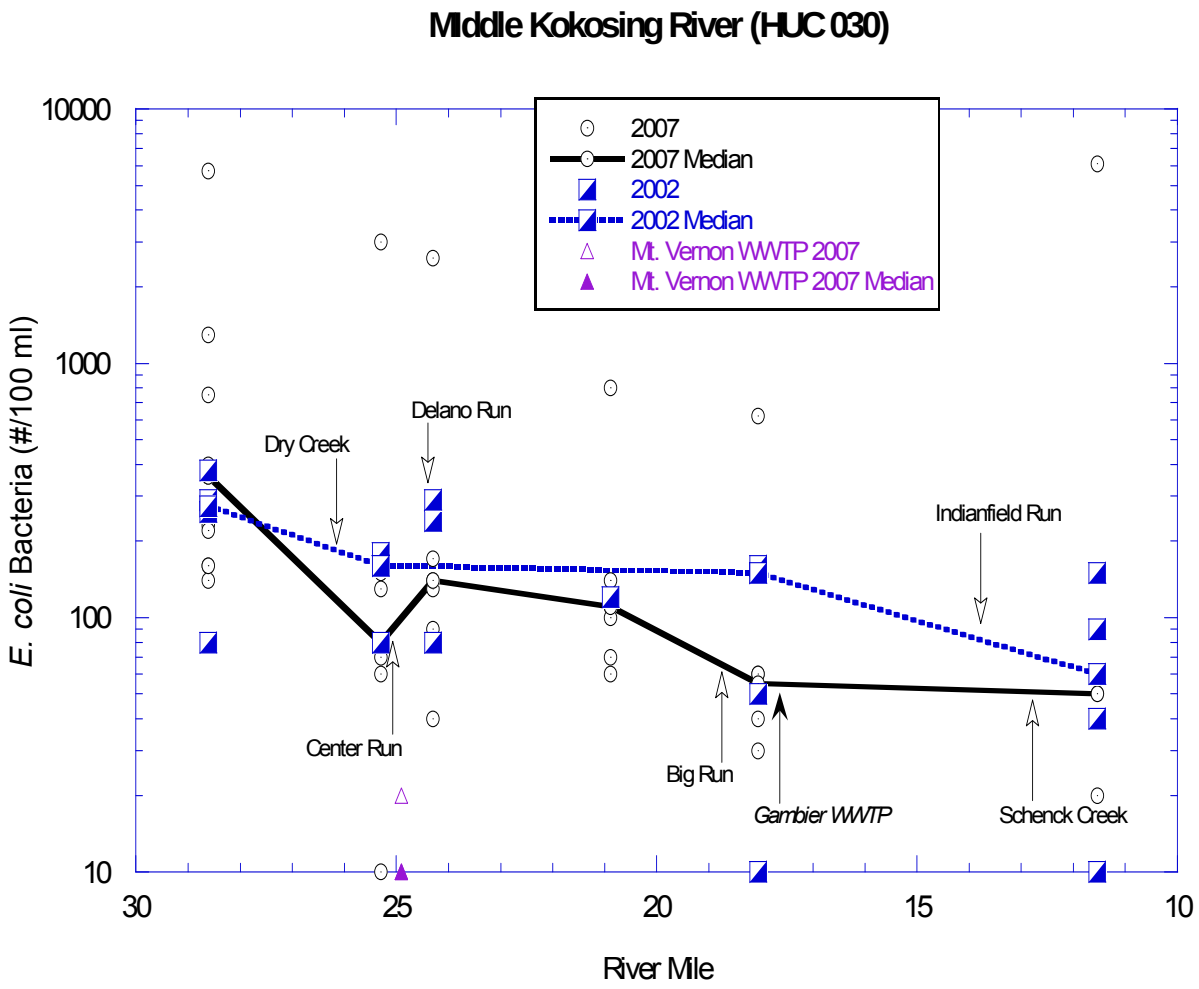

Figure 20. Historical trends in E.coli concentrations listed by river mile for the middle Kokosing River.

Lower Kokosing River

Trends in water quality sampling data were studied for the lower Kokosing River reach, Jelloway Creek, Little Jelloway Creek and East Branch Jelloway Creek. Historical sampling data examined included results from 1987, 1998 and 2002.

For the lower Kokosing River reach, water quality conditions were comparable to previous sample years. For example, total phosphorus concentrations in 2007 were nearly identical to historical results recorded for 1987, including RM 6.12 and the mouth, with medians ranging from 0.08 mg/l to 0.10 mg/l. Dissolved oxygen concentrations were also comparable with median concentrations during all sampling years above 7.0 mg/l. Nitrate+nitrite concentrations in 2007 were slightly lower than those recorded during previous sampling (Figure 21, pg. 77 and Figure 22, pg. 78).

For Jelloway Creek, historical sampling at the mouth showed similar concentrations of total phosphorus and dissolved oxygen over time. Median nitrate+nitrite concentrations in 2007 fell slightly at the mouth compared to those found in 1998 (Figure 23 (pg. 79), Figure 24 (pg. 80), and Figure 25 (pg. 81)).

Comparison of Little Jelloway Creek and East Branch Jelloway Creek historical water quality conditions was difficult due to a limited number of sites and comparable sample locations. Of note, were higher total ammonia nitrogen concentrations recorded downstream of Apple Valley Lake on Little Jelloway Creek compared to 2002 results. At this site, the 2007 median was 0.262 mg/l compared to the 2002 median of 0.05 mg/l. For East Branch Jelloway Creek, examination of historic water quality conditions at the upstream site at RM 3.33 (U.S. 62), showed slightly lower concentrations of nutrients in 2007 compared with 2002.

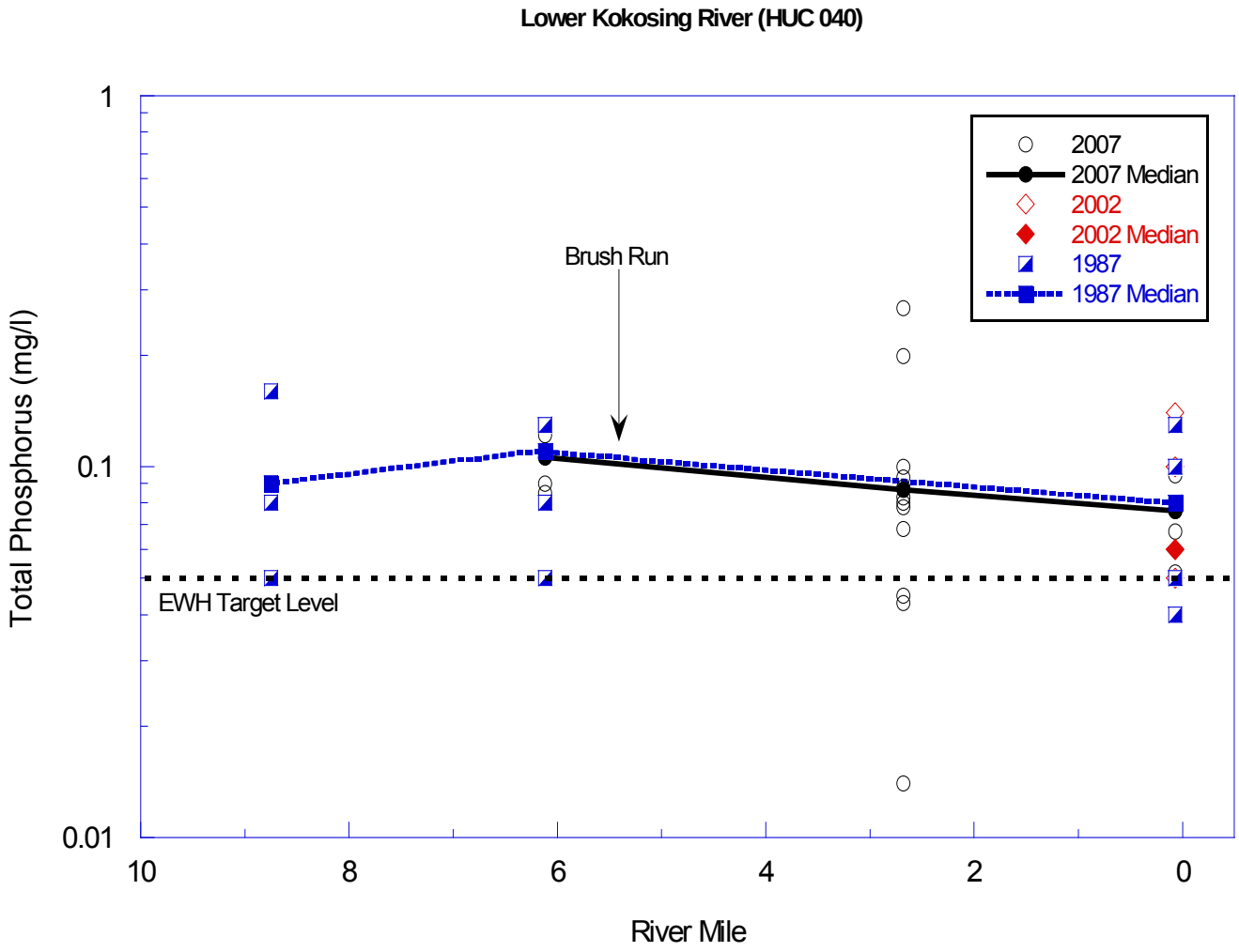

Figure 21. Historical trends in total phosphorus concentrations listed by river mile for the lower Kokosing River.

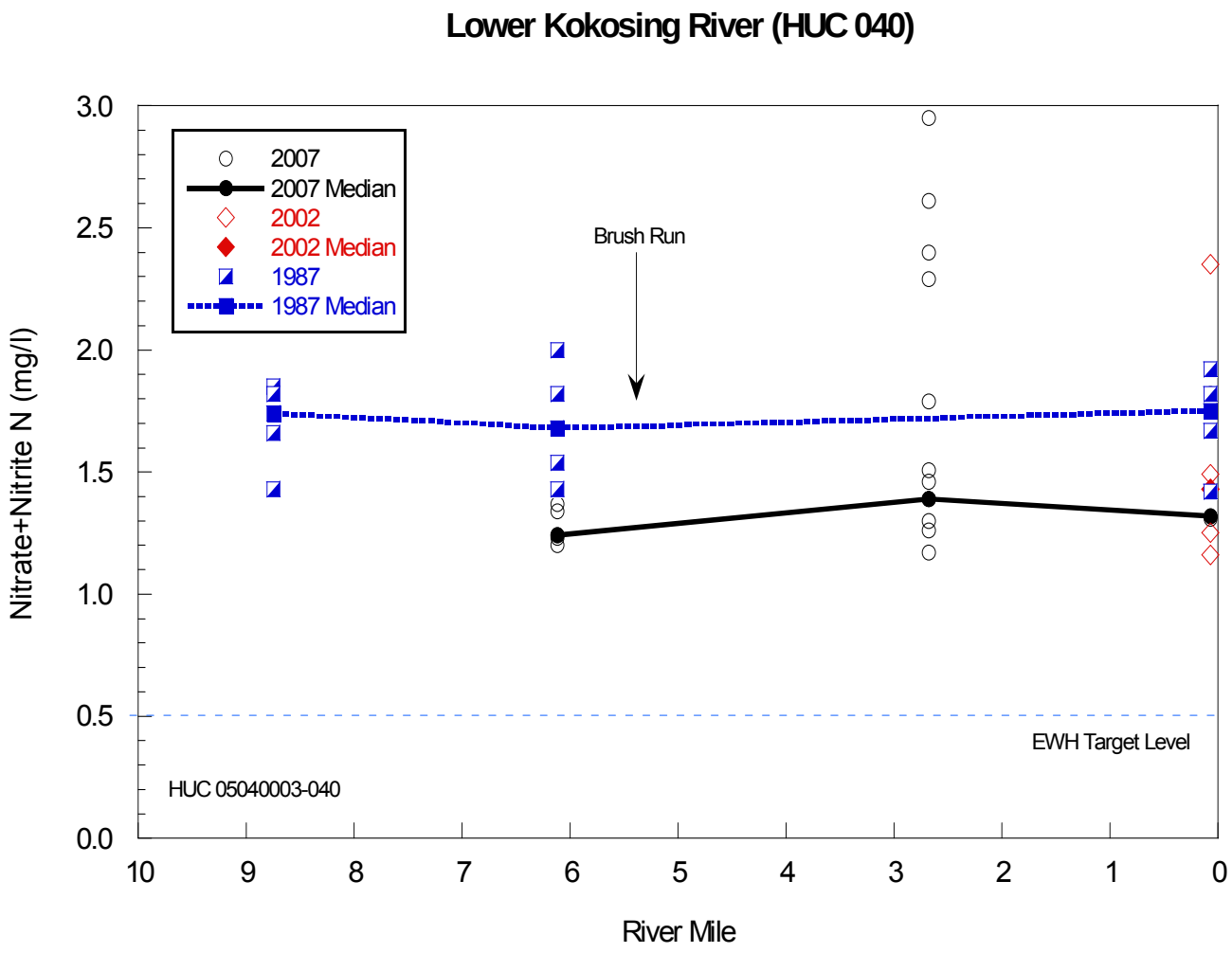

Figure 22. Historical trends in nitrate+nitrite levels listed by river mile in the lower Kokosing River.

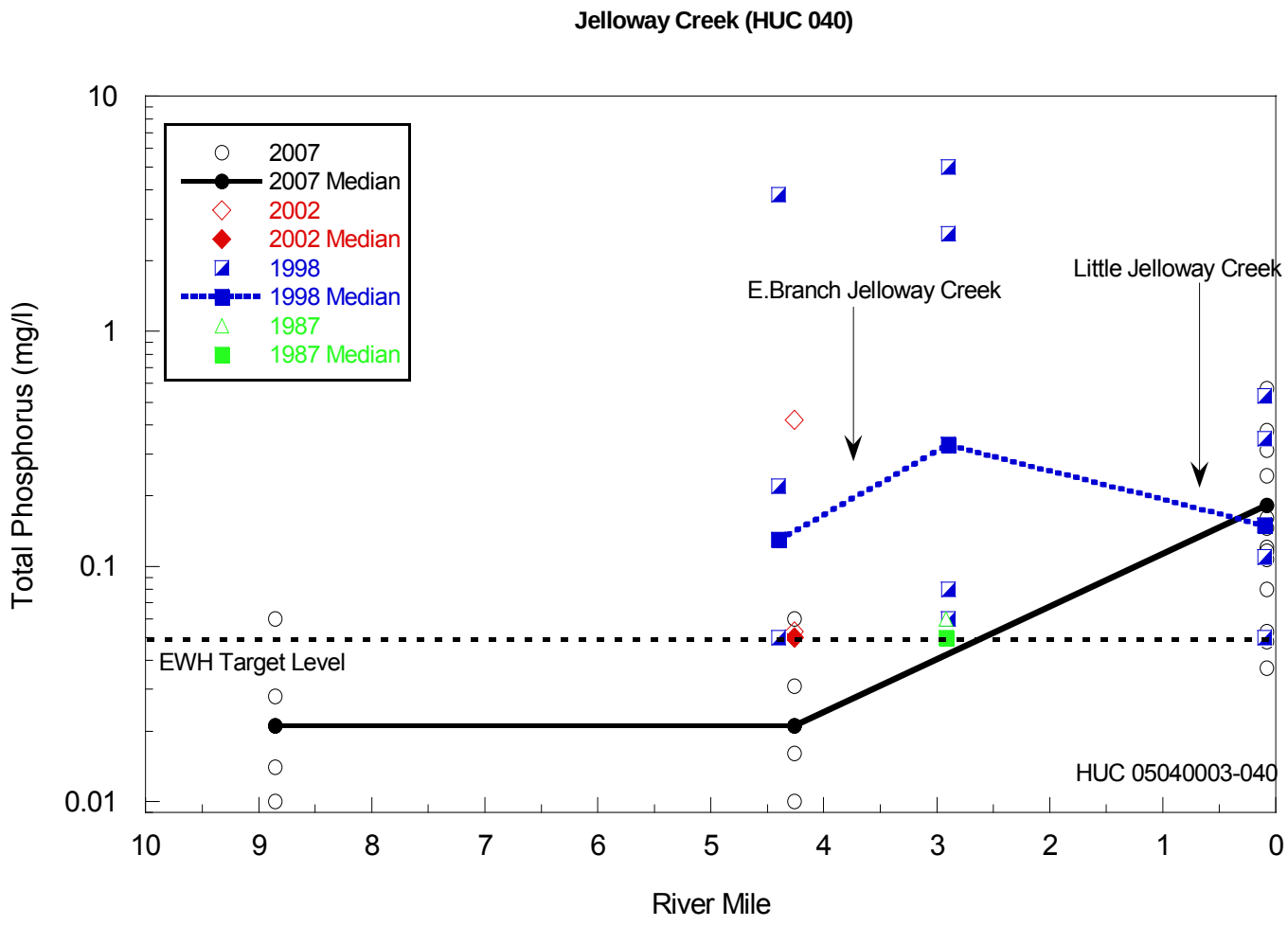

Figure 23. Historical trends in total phosphorus listed by river mile for Jelloway Creek.

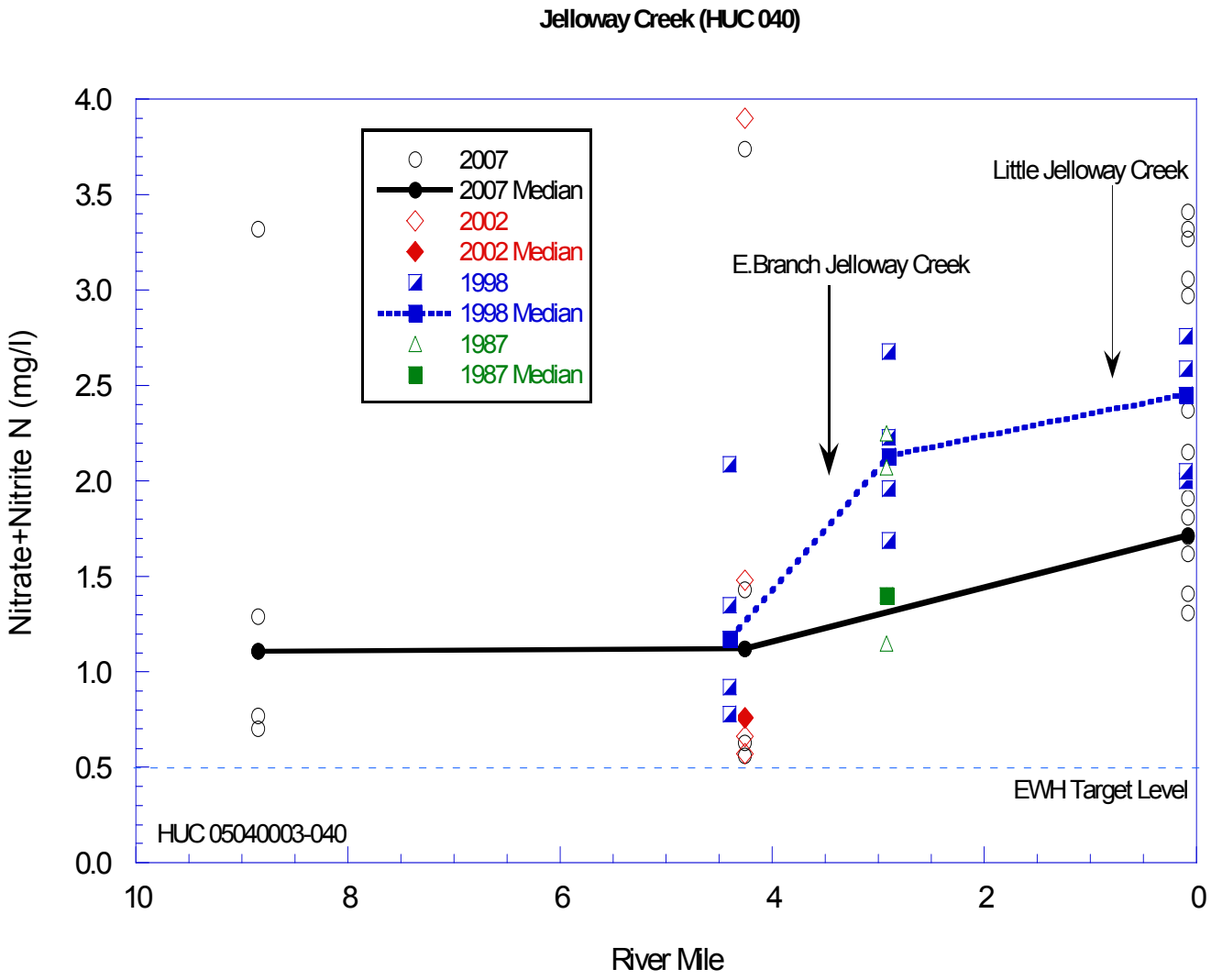

Figure 24. Historical trends in nitrate+nitrite levels listed by river mile for Jelloway Creek.

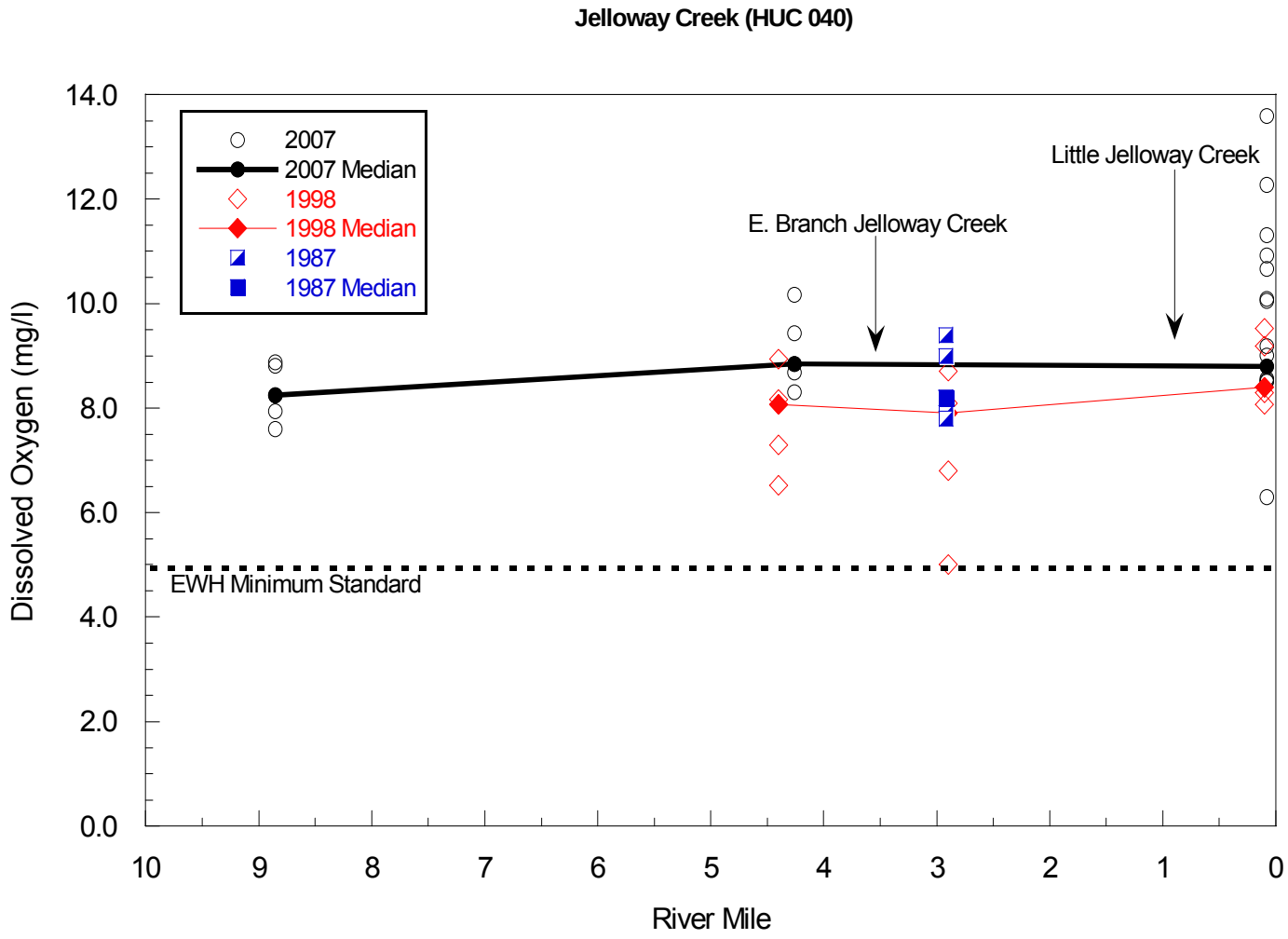

Figure 25. Historical trends in dissolved oxygen readings listed by river mile for Jelloway Creek.

Macroinvertebrate Community Summary and Trends

Summary

Fifty-four macroinvertebrate sites were sampled and assessed during June 15 – September 30, 2007. Twenty-one sites were quantitatively sampled, and 24 smaller stream sites of less than 20 mi.^{2} drainage area were qualitatively assessed. Nine larger drainage area stream sites (> 20 mi.^{2}) were also qualitatively assessed due to removed, missing, or dry quantitative macroinvertebrate colonizers.

The vast majority of assessed river/stream sites were of very high quality with 49 of 54 (91%) meeting or exceeding the narrative assessment or the specific ICI biocriterion (the minimum Invertebrate Community Index ICI) for their respective designated aquatic life use.

Diversity at high quality sites ranged to a high of 80-86 total taxa collected: 80 total taxa in the Upper Kokosing River mainstem (RM 45.4), 83 taxa at RM 4.5 in Dry Creek, 84 taxa in Big Run at RM 0.60, and 86 total taxa in the East Branch of the North Branch Kokosing River near the mouth, respectively (Table 13, pg. 102). There was a high of 70 qualitative taxa collected at the same East Branch site (RM 0.1) with the largest variety of mussels present. The North Branch Kokosing River downstream from Knox Lake (RM 8.7) also had the equally high number of mussel taxa present. The number of EPT taxa (Ephemeroptera / Plecoptera / Trichoptera) ranged to highs of 29-30 at Kokosing River at RM 28.7 and Dry Creek at RM 4.5, respectively and was indicative of diverse and exceptional water quality in those reaches (Figure 26, pg. 86).

Similarly, the number of sensitive taxa collected ranged to highs of 40 to 44 taxa. There were 40 sensitive taxa collected in the lower Kokosing River mainstem (RM 6.2) and in Jelloway Creek at RM 4.3 (Danville-Howard Rd.). Dry Creek macroinvertebrate collections at RM 4.5 (Thayer Rd.) totaled 41 sensitive taxa, and the highest number of sensitive taxa (44) collected occurred in Big Run at RM 0.6 (Figure 26, pg. 86).

Most of the highest Sensitive/Tolerant Taxa (S/T) ratios (i.e., > 10) found in the qualitative samples occurred in the highest quality, coldwater streams. Upper Jelloway Creek at RM 8.9 (Orange Hill Rd.) had the highest S/T ratio of > 26.0. Downstream at RM 4.3 the S/T ratio was at 12.0. Schenck Creek, a canopied, cold, ravine stream, had the second-highest S/T ratio of 23.0 at RM 8.8 - Proper Rd. with a ratio of 15.5 near the

mouth (RM 0.5). Little Schenck Creek in its upper watershed (RM 4.5) had a similar S/T ratio of 16.5 at Fredericktown-Amity Road. The upper North Branch Kokosing River site at Mt. Vernon–Tiffin Rd. (RM 17.77) had a S/T ratio of 11.33, and the S/T ratio of Armstrong Run, a small CW tributary adjacent Lower Green Valley Rd., was 10.5. One high quality site on the Kokosing River mainstem at Beckley Rd. (RM 32.5) had an equally high S/T ratio of 11.5 (Figure 26, pg. 86).

Trends

North Branch Kokosing River

The North Branch Kokosing River was previously sampled in 1987, 1998-99, and 2002. The more recent sampling occurred at RM 6.2, an ecoregional reference site, in 2002 and 1999. The 2007 survey at RM 6.2 indicated similar exceptional quality (ICI=50 in 2007 vs. 52 and 48). The 1987 survey of four reaches from RMs 11.6 (above Kokosing Lake) to 2.1 had ICI scores that ranged from 46 to 52. All scores in those lower reaches were similar to the exceptional scores during the 2007 survey. There was an improvement in quality in the upper watershed compared to the 1987 survey, as has been documented above at the upper North Branch 2007 sample sites.

Dry Creek

Dry Creek sites at RM 4.8 and 4.5 were sampled in the spring of 1988 and were narratively assessed as good macroinvertebrate community performance. The number of qualitative EPT taxa collected greatly increased 55 to 70 percent during the 2007 sampling to 25 with a total of 30 EPT taxa documented. The number sensitive taxa present in 2007 doubled from 14-15 in 1988 to 27 with a total of 41 sensitive taxa present. These subsequent improvements were confirmed with an exceptional ICI of 48 – a highly significant 12 to 14 point increase.

Schenck Creek

Sampling in Schenck Creek at RM 2.6 in 1987, 1998 and 2002 yielded exceptional ICI scores that ranged from 46 to 54. The 26 sensitive taxa and 18 EPT taxa collected in 2007 were similar to previous samples.

Little Schenck Creek begins north and east of Knox Lake and flows south to join Schenck Creek downstream near Gilchrist Road. Macroinvertebrate community quality

was exceptional at both sample sites with 19 EPT taxa and 24 sensitive taxa. The upstream site at Fredericktown-Amity Road (RM 4.5) contained seven CW taxa and had a very high S/T ratio of 16.5 confirming its exceptional warmwater habitat and coldwater habitat evaluations. All of Little Schenck Creek is recommended to be designated Exceptional Warmwater Habitat, and the upper reach downstream to RM 3.5 (Carson Rd.) is recommended to be designated CWH Aquatic Life Use.

Lower Kokosing River

Trends in the lower Kokosing River (HUC 040) indicate that no substantial variation in ICI scores has occurred. No large documented spills have occurred since 1994 and 1996 (RM 7.7 and 8.5) in this lower reach of the Kokosing River. Despite no large changes there was a 50 percent increase in the number of tolerant taxa collected in 2007 in concert with a commensurate decrease in the S/T ratio from over 7.2-7.25 in 2002 to 2.5-3.5 in 2007. These changes indicate a slight decrease in quality in the lower reach over time exacerbated by very low, dry conditions during the summer and fall and could be related to the ongoing Jelloway Creek basin issues (Little Jelloway Cr.) (Figure 26, pg. 86).

Jelloway Creek

Jelloway Creek samples at RM 1.6 in 1987 and at RM 4.4 in 1998 and 2002 all yielded exceptional scores with an ICI range of 48 to 50. The ICI score in 2007 was similar (48), and the numbers of sensitive and total EPT taxa were nearly identical. The number of tolerant taxa in 2007 had decreased with the S/T ratio almost doubling to 12.0 indicating very high quality conditions

East Branch Jelloway Creek

Macroinvertebrate ICI scores in the East Branch Jelloway Creek have not met the EWH biocriterion at any earlier sampling period. The ICI score was 32 (marginally good) in 1998 at RM 3.4, and a low fair ICI score of 14 was tabulated in 2002 at RM 3.1. The very good or marginally exceptional score of 44 did show a marked improvement despite the destabilized banks and flashy flows.

Little Jelloway Creek

The macroinvertebrate community evaluation in Little Jelloway Creek met the ecoregional EWH narrative biocriterion in 1987 at RM 6.3 (exceptional) confirming the EWH Aquatic Life Use designation. The ICI in 2002 was also exceptional (50), and the narrative evaluation of very good from 2007 at RM 6.9 suggested a slight decline due partly to issues mentioned above (Figure 26, pg. 86). The number of EPT taxa and sensitive taxa were all lower in 2007 than in the previous surveys in 1998 and 2002 in the upper reaches of Little Jelloway Creek (Figure 26, pg. 86).

Downstream from Apple Valley Lake the 2007 survey results indicated a sharp decline in ICI, EPT, and sensitive taxa from the previous results. However, note that there has been an incremental decrease over time in qualitative EPT and sensitive taxa. The highest qualitative EPT and sensitive taxa totals were documented in 1998 and then decreased substantially in the 2002 survey (Figure M4). Water quality downstream from Apple Valley Lake has degraded further, as the ICI score of 28 (fair) and number of qualitative EPT and sensitive taxa in 2007 were the lowest documented to date (Figure 26, pg. 86). This could be related to cumulative inputs into the lake.

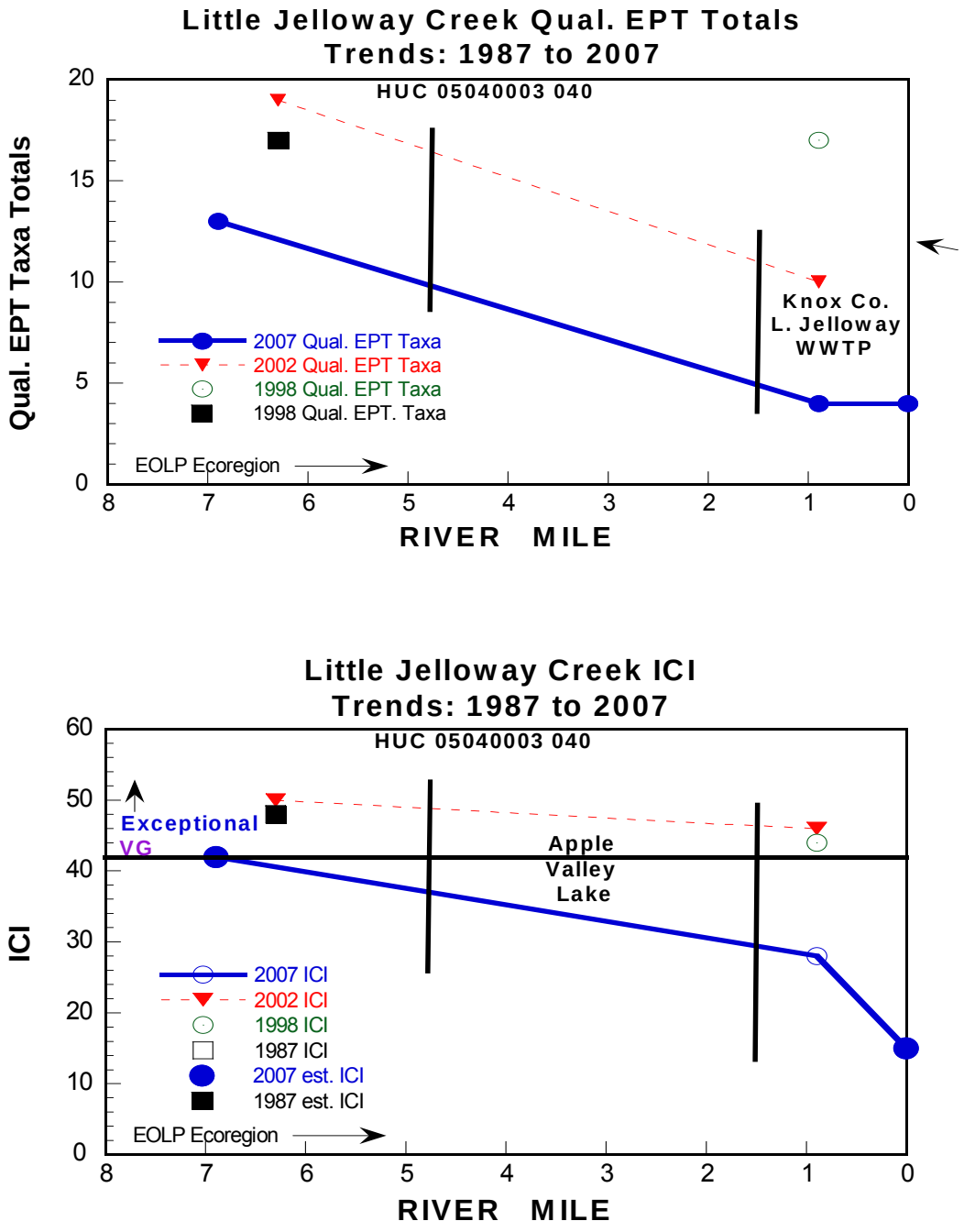

Figure 26. Trends for Invertebrate Community Index (ICI) and totals for qualitative EPT taxa and sensitive taxa for Little Jelloway Creek, 1987 to 2007.

Fish Community summary and Trends

Summary

Fish communities were assessed at 14 sites on Kokosing River (from River Mile 54.7 to River Mile 0.1) and at 39 sites on Kokosing River tributaries. Twelve (23%) sampling locations were impaired in the watershed (Table 9, pg. 46). The IBI scores ranged from 56 (RM 25.3) to 39 (RM 39.3) on the main stem and from 56 (Dry Creek RM 10.7) to 24 (East Branch Jelloway Creek RM 1.0) on the tributaries. As shown in Figure 27, IBI scores increased from upstream to downstream with the exception of RM 39.3, which had a physical habitat impairment from livestock (IBI= 39). Eleven sites on the main stem fully met (79%) and three Kokosing River sample sites partially met designated or recommended aquatic life use criteria (21%). Thirty Kokosing River tributaries fully met respective designated or recommended aquatic life use criteria (77% of tributaries). Five tributaries partially met (13% of tributaries) and four tributaries did not meet designated or recommended aquatic life uses (10% of tributaries) (Table 9, pg. 46).

Impairments to the aquatic community in the Kokosing River watershed were associated with livestock and agriculture, municipal discharges, hypolimnetic lake discharge, and urban runoff (Table 2, pg. 10). The three aquatic communities impaired by agricultural land uses are the following: Kokosing River (RM 50.5), East Branch Jelloway Creek (RM 3.3), and South Branch Kokosing River (RM 2.9). Livestock operations impaired aquatic communities at Kokosing River (RM 39.3), East Branch Jelloway Creek (RM 3.3), and North Branch Kokosing River (RM 4.0). Municipal dischargers impaired the following three aquatic communities: Kokosing River (RM 24.3), Jelloway Creek (RM 0.1), Little Jelloway Creek (RM 0.1), and East Branch Jelloway Creek (RM 0.1). Pollutants from the Apple Valley Lake discharge impaired Little Jelloway Creek from the dam's discharge to the mouth. Impairment by the hypolimnetic discharge also occurred in Jelloway Creek from the confluence of Little Jelloway to its mouth. Urban and storm water runoff in Delano Run at RM 1.5 impaired the fish community.

Trends

Kokosing River

The 2007 Kokosing River IBI scores compared well with historical values, generally deviating only a couple points (+ or -) and increasing in score from upstream to downstream. The site at RM 39.3 was only exception to this pattern and yielded the lowest IBI value of 39. This significant deviation from the linear average was due to excessive sediment runoff and elevated E.coli levels from cows freely accessing the river (Figure 27, pg. 89). Populations of bluebreast darters dramatically increased in the middle and lower portions of the Kokosing River and have populated further up the middle portion of the river, indicating a significant improvement in water quality (Figure 28). As mentioned in the water chemistry section, the water quality found in the lower Kokosing River was similar to the conditions recorded from the 1987 survey. Fish habitat conditions have remained at a steady state through those years as well (Figure 31, pg. 93). However, there have been no large documented spills in the Kokosing River since 1996 (RM 8.5) and in the watershed since 1999 (Indianfield Run, RM 4.4) (Table 5, pg. 18).

Kokosing River Tributaries

Eleven of the tributaries sampled during the 2007 survey season were not previously sampled for fish including Armstrong Run, Big Run, Brush Run, Center Run, Delano Run, Elliot Run, Granny Creek, Job Run, Mile Creek, S. Branch Kokosing River, and Tributary to North Branch Kokosing River. Of the streams that have been historically sampled IBI scores from the East Branch of Jelloway Creek and Little Jelloway Creek differed considerably from sampling events prior to 2007. Habitat alterations upstream of RM 3.3 East Branch of Jelloway Creek site, low stream flow, and impacts from the Danville WWTP upstream of the lower sample site (RM 1.0) revealed decreased water quality compared to historical data (Figure 29, pg. 90). Historical IBI scores in Little Jelloway Creek dropped as a result of the hypolimnetic discharge from Apple Valley Lake and the improperly treated waste water from the Knox County Little Jelloway WWTP (Figure 30, pg. 91).

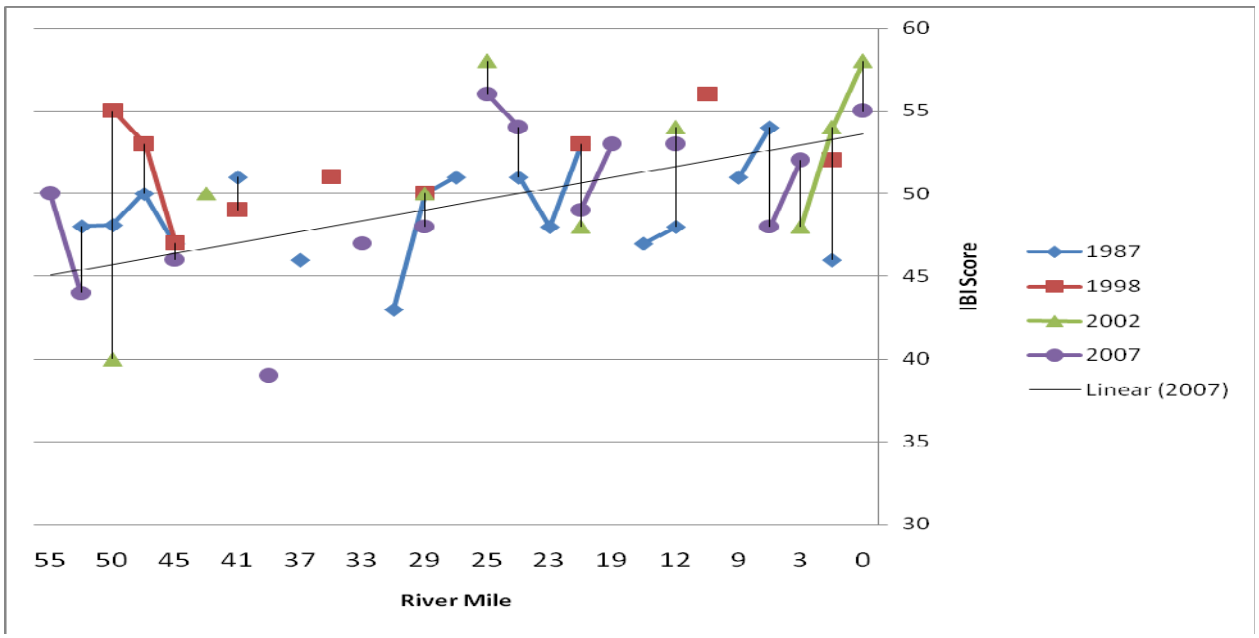

Figure 27. Historical trends for Kokosing River fish IBI scores, 1987 - 2007.

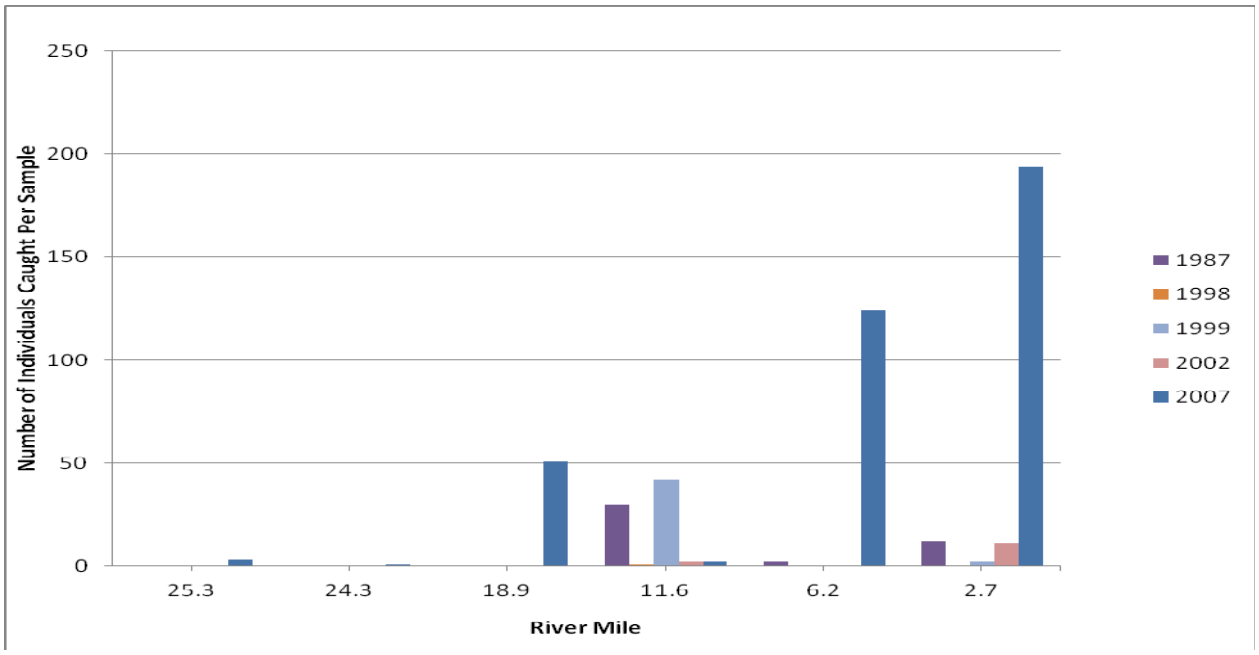

Figure 28. Historical trends of Bluebreast darter populations in the Kokosing River, 1987 - 2007 .

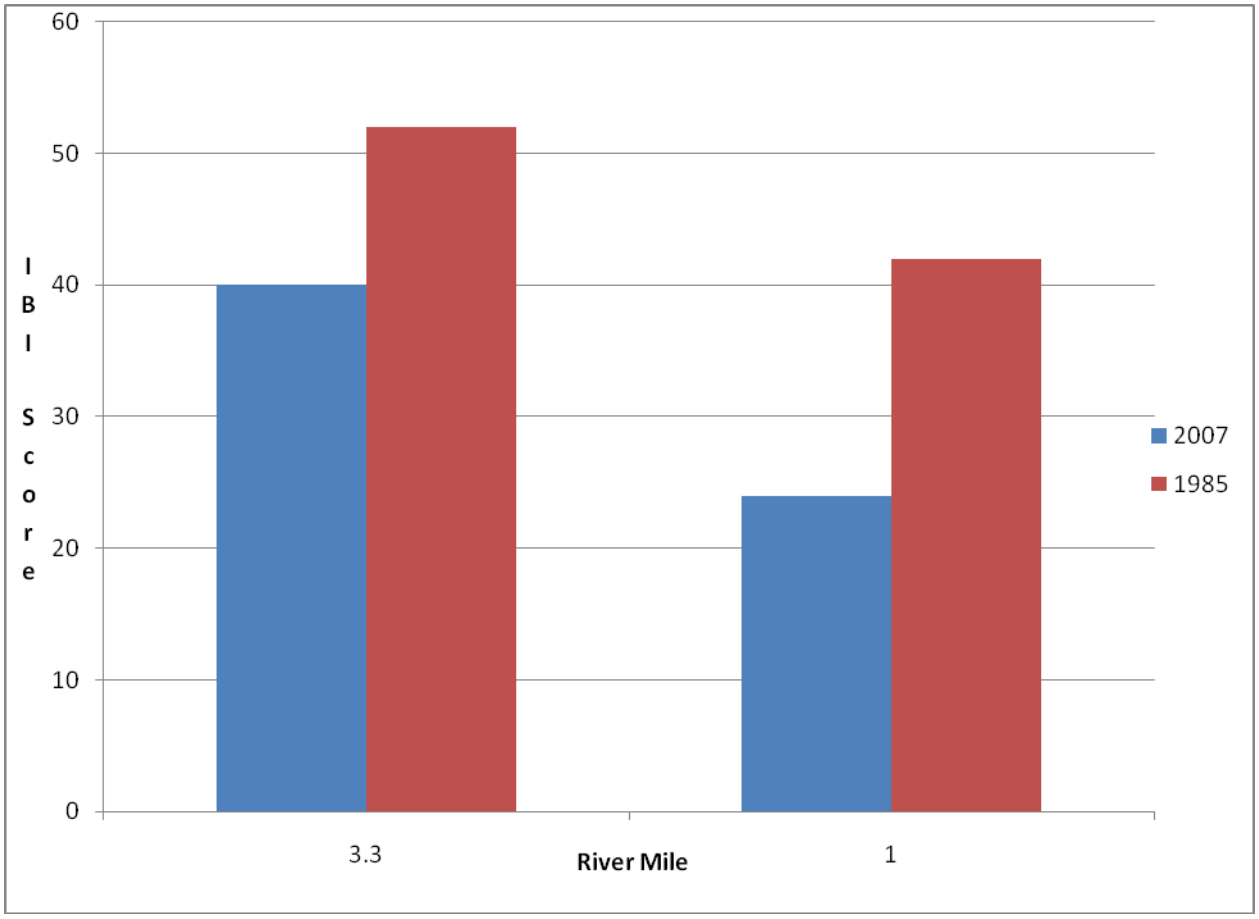

Figure 29. Historical IBI trends in East Branch Jelloway Creek, 1985 – 2007.

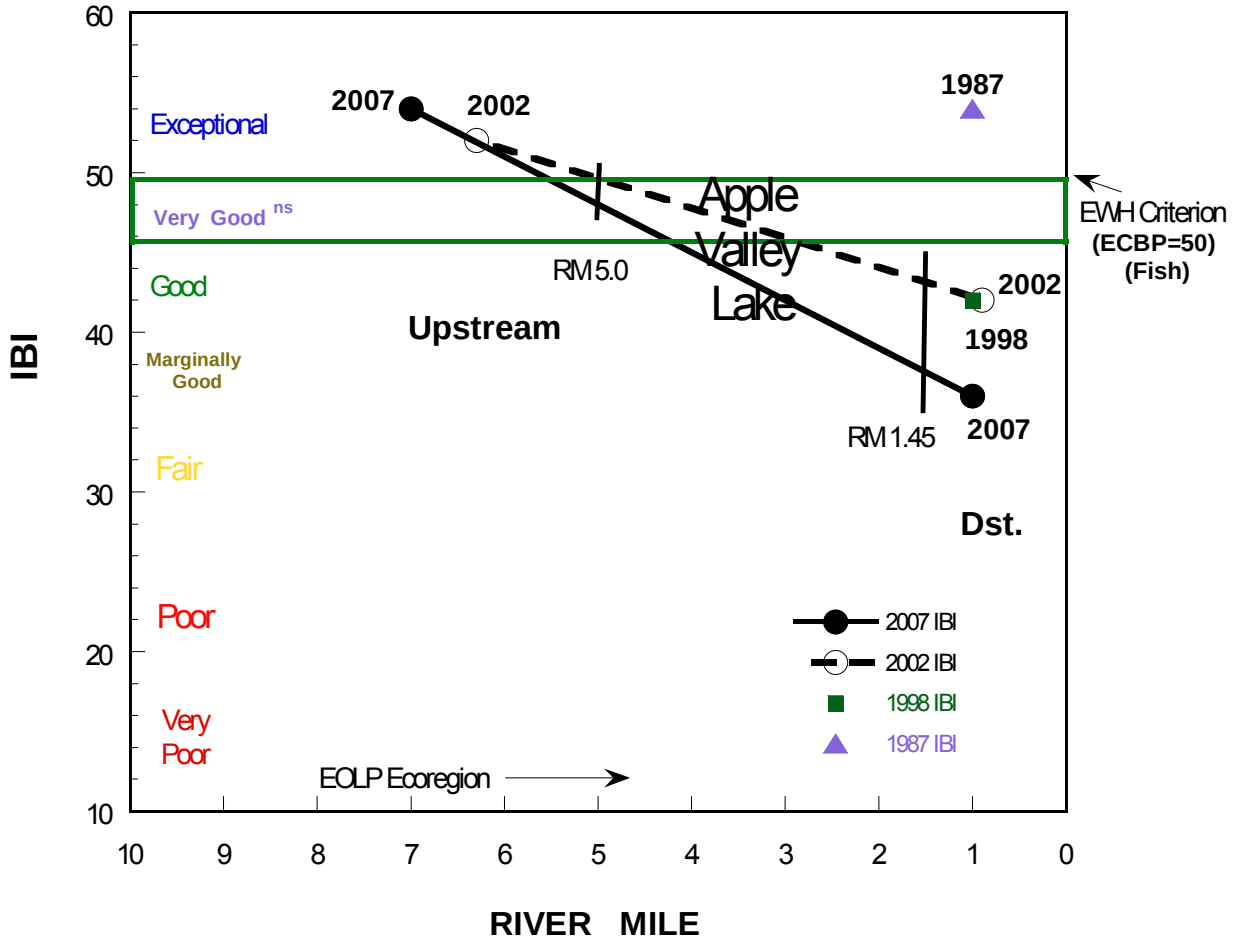

Figure 30. Fish community trends in Little Jelloway Creek, 1987 – 2007.

Physical Habitat Summary and Trends

Physical habitat assessments were completed at all of the fish sampling sites in the Kokosing River watershed (Table 9, pg. 46). The Kokosing River had good physical habitat on average in the main stem ($\bar{0}$ = 70) and the tributaries ($\bar{0}$ = 68). Drought conditions during the sampling season decreased the amount of good quality habitat features available to the biota in headwater streams. Most (n=10) of the main stem sites (sites from RM 28.6 to the mouth) had exceptional habitat, scoring QHEI's of 80 or more. The four most upstream sites (RM's 54.7, 50.5, 45.4, and 39.3) on the main stem scored 65.5 or lower on the QHEI which was attributed to livestock and agricultural land use practices. Fair/good habitat on the main stem of the Kokosing River began improving towards exceptional at the Beckley Road (RM 32.6) sample site. A total of seven (13%) sample sites in the watershed had physical habitat impairments so severe that they did not meet or only partially met their respective aquatic life use criteria (Kokosing River (RM 50.5 & 39.3), East Branch Jelloway Creek (RM 3.3), North Branch Kokosing River (RM 5.4), South Branch Kokosing River (RM 2.9), Delano Run (RM 1.5), and North Branch Kokosing River tributary (RM 4.0)) (Table 2, pg. 10). Specific reasons for the impairments can be found within the narrative habitat sections below.

Trends

Habitat on the main stem of the Kokosing River has changed very little in the past twenty years. Increases or decreases in QHEI scores for the Kokosing River between the 1987 and 2007 survey years were negligible (Figure 31). Habitat was exceptional in the river from approximately RM 32.0 downstream to its confluence with the Mohican River.

The 1985 QHEI score of 75 at State Route 62 on East Branch Jelloway Creek (RM 3.3) showed that there was much better habitat than what was found in 2007, (QHEI= 62). Upstream from State Route 62 riffles, runs, pools, sinuosity, and a 10-50 m wide treed riparian buffer created good habitat for aquatic life. However, silt and fine sediments were present in this stream reach as a result of nonpoint source runoff from upstream agriculture and livestock operations. This was the only historically sampled site among the Kokosing River tributaries to show a significant decrease in habitat quality.

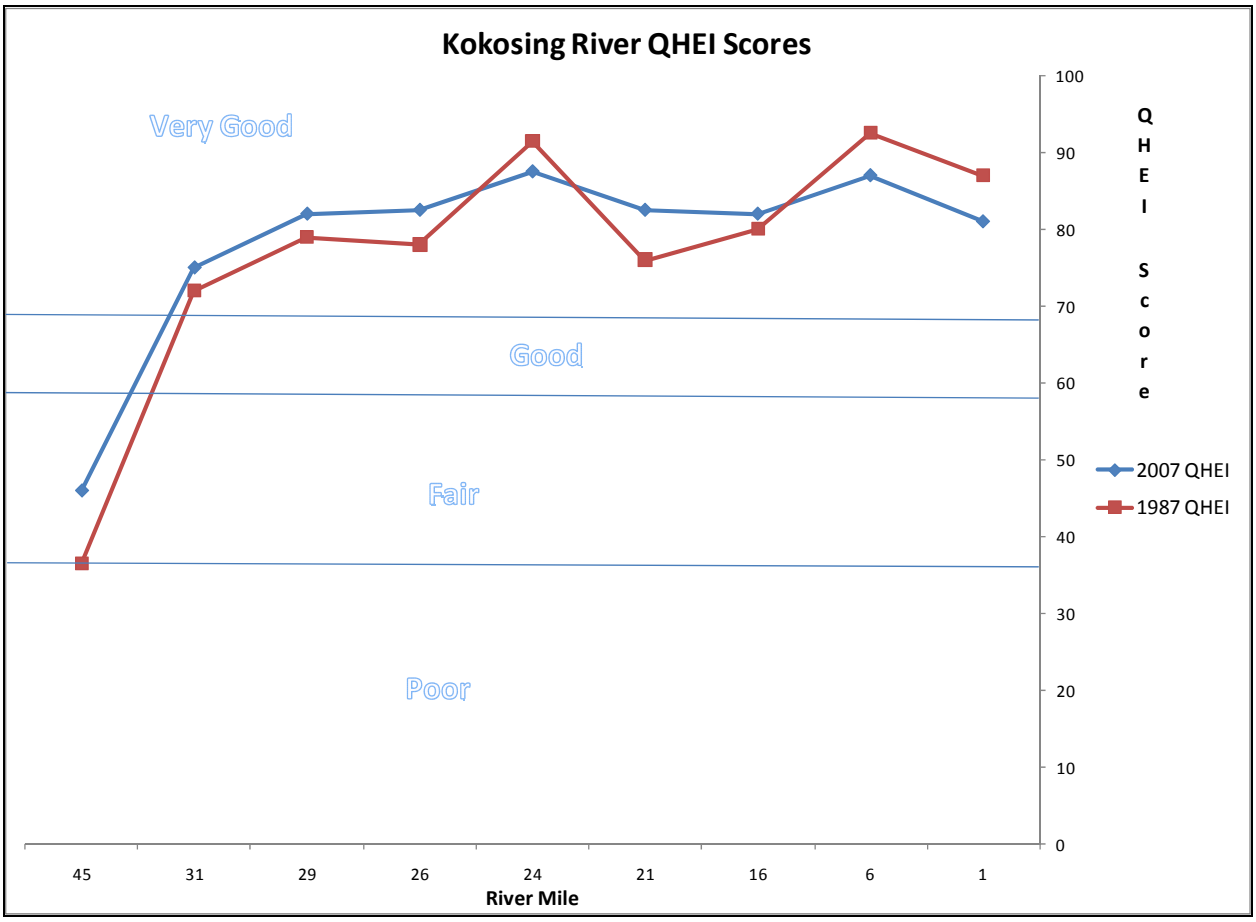

Figure 31. QHEI trends for the Kokosing River, 1987 – 2007.

Upper Kokosing River Assessment Unit (HUC 05040003 010)

The Upper Kokosing River assessment unit (Hydrologic Unit Code 05040003 010) encompasses 100.5 square miles of drainage area. This reach includes the headwaters of the Kokosing River in Morrow County to upstream of the confluence with North Branch Kokosing River in Knox County just north of Mount Vernon. In this portion of the watershed, the Kokosing River flows southerly through Morrow County before turning east toward Mount Vernon in Knox County. This assessment unit is located in the Erie Ontario Lake Plain (EOLP) ecoregion.

Chemical Water Quality

Narrative Water Chemistry Assessments for Individual Streams

Upper Kokosing River (WWH, AWS, IWS, PCR)

This stream segment included five sampling locations: RM 56.69 (Pulaskiville Road), RM 49.73 (Chipps Road), RM 45.44 (State Route 314), RM 39.27 (Vail Road) and RM 32.56 (Beckley Road) (Table 9, pg. 46). Water quality conditions in this segment were influenced by agricultural land use activities. In general, water quality conditions were favorable for supporting the existing warmwater habitat (WWH) use. With improvement in agricultural best management practices (BMP's) to control erosion and sedimentation, this segment has the potential to support the attainment of exceptional warmwater habitat (EWH).

Elevated concentrations of nutrients, reflective of an agricultural landscape, were observed for the upper site at RM 56.69 (Figure 6 (pg. 60) and Figure 7 (pg. 61). Here total phosphorus concentrations exceeded the 75th percentile reference value for Ohio streams (Ohio EPA, 1999). Overall, nutrients did not appear to be a significant problem in this segment. Median concentrations of total phosphorus and nitrate+nitrite at several of the sites were below the recommended statewide target levels for these pollutants in EWH streams (Ohio EPA, 1999).

A single dissolved oxygen violation was recorded at RM 49.73 on July 9, 2007. Here an instantaneous morning grab sample reading of 2.97 mg/l was recorded which is below the 4.0 mg/l dissolved oxygen minimum standard for the existing WWH designation. A lack of riffle habitat within this stream reach has eliminated the possibility for surface agitation and aeration. Otherwise dissolved oxygen measurements in this segment were mostly above the 5.0 mg/l standard for EWH streams (Figure 4, pg. 58). At RM 45.44 (State Route 314), 24-hour dissolved oxygen monitoring indicated normal conditions with dissolved oxygen readings remaining above the 5.0 mg/l criteria for EWH streams (Figure 32, pg. 95). In addition, favorable stream temperature conditions were noted along this reach with low to moderate temperatures (Figure 33, pg. 96). The contribution of groundwater is an important element in keeping good water quality in this stream segment.

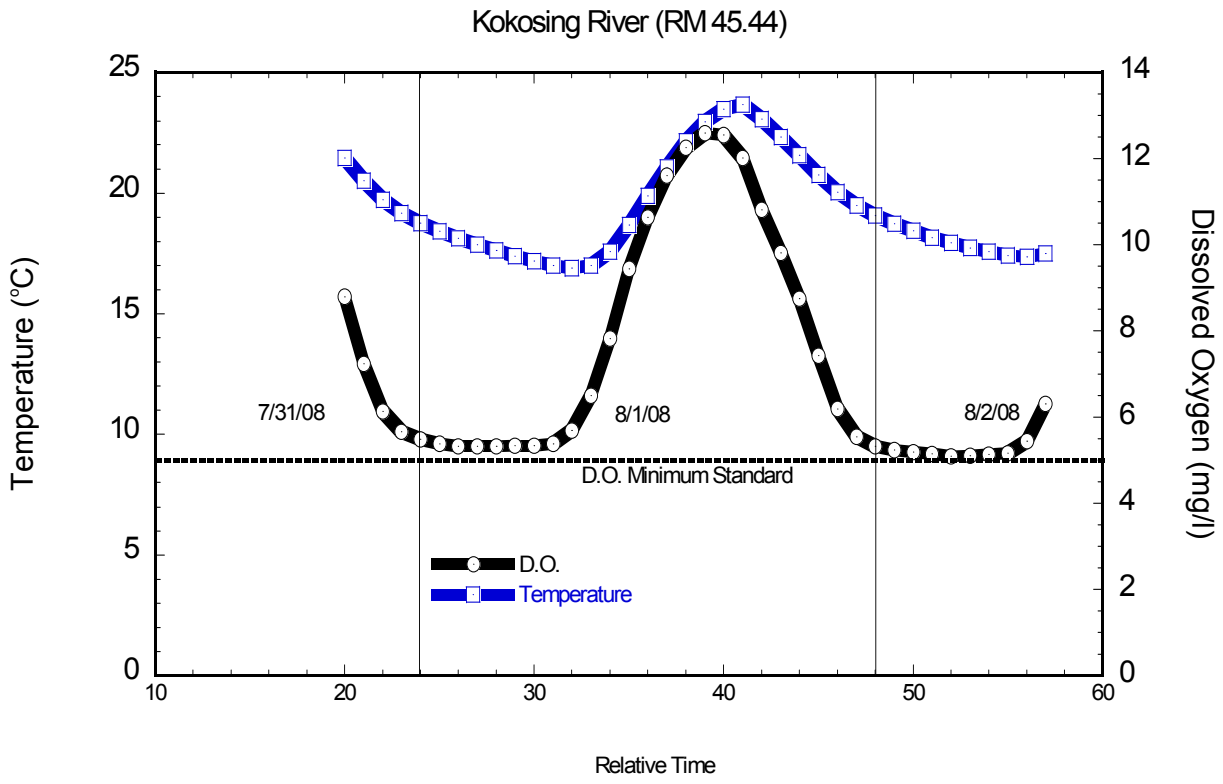

Figure 32. Temperature and dissolved oxygen concentrations plotted by date and river mile for the Kokosing River.

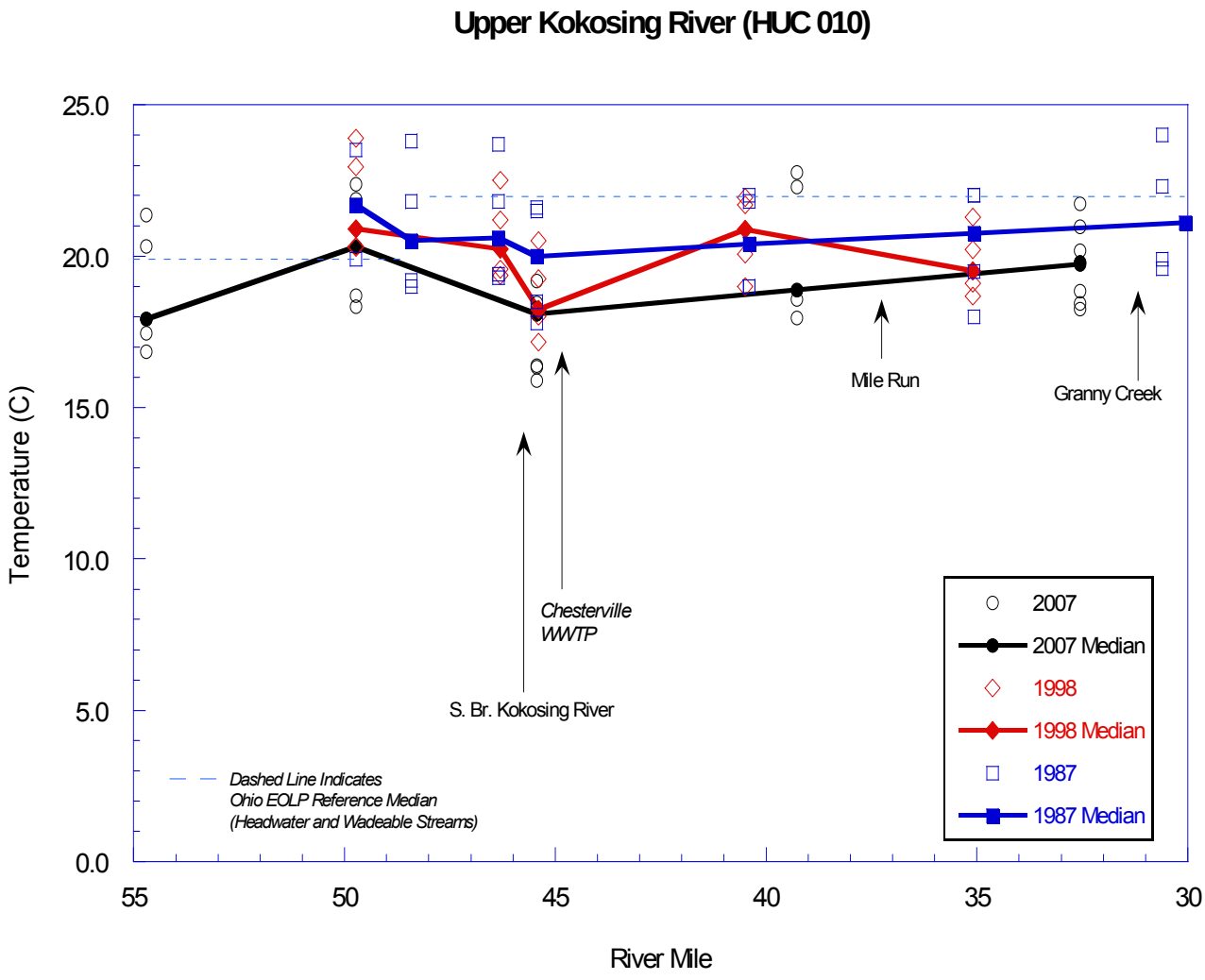

Figure 33. Median temperature trends listed by river mile for the upper Kokosing River.

Violations of the primary contact recreation bacteria standard were recorded at most sites in this reach (Table 12, pg. 54 and Table 10, pg. 52). The highest E.coli bacteria values were observed at RM 39.27 (Vail Road). Livestock (cows) were freely accessing the stream at several spots near this sample site.

Ohio EPA also conducted a single organics scan on July 16, 2007 for 43 pesticide/herbicide compounds, 53 semi-volatile compounds and 7 PCB cogeners at RM 45.44 and RM 39.27. All results were below-detection with the exception of bis(2-ethylhexyl)adipate and bis(2-ethylhexyl)phthalate. Results for these two common ingredients for plasticizers, were slightly above the detection limit but well below any established aquatic life or human health criteria. Similarly, mercury was tested for during five sample runs on each of the upper Kokosing sites. All results were below the detection limit of 0.2 ug/l.

Chesterville WWTP

The Chesterville WWTP was constructed in 2001-2002 and has a design flow of 0.095 MGD. Treatment consists of mechanical fine screens, extended aeration and clarification through the BIOLAC® system in two identical trains. Post aeration and ultraviolet disinfection treatment follow the system just prior to effluent discharge. A sludge holding tank is provided so that sludge can be hauled to another sewage treatment facility.

The facility has been in almost complete compliance with permit limits for the period March 2007 through March 2008 with just a single fecal coliform violation in July 2007. Average daily flow for the period January 2007 through March 2008 was 0.02 MGD.

Upper Kokosing River Tributaries

Three tributaries to the upper Kokosing River were sampled for chemical water quality. Tributary streams studied included South Branch (RM 2.96), Mile Run (RM 4.75) and Granny Creek (RM 4.29), and are listed in Table 9, pg. 46.

South Branch Kokosing River (WWH. AWS, IWS, PCR)

South Branch Kokosing River located in Morrow County joins the Kokosing River at RM 45.93. South Branch is 9.0 miles long with a drainage area of 11.8 square miles. One site was evaluated at RM 2.96 (off CR 11, Sparta Road).

Low flow conditions, attributed to natural causes, were documented here (see QHEI section). This can impact water chemistry results. For example, water chemistry sampling at this site indicated significantly elevated TKN and ammonia-N results (Appendix F1). The median value for TKN exceeded the 90th percentile while the ammonia-N median exceeded the 95th percentile reference values for Ohio streams (Ohio EPA, 1999).

Normal nutrient cycling conditions appear disrupted here by the low flow conditions. This may be a partial explanation for the higher than expected TKN and ammonia-N readings when compared to other similar sized streams in the Kokosing watershed (Figure 34).

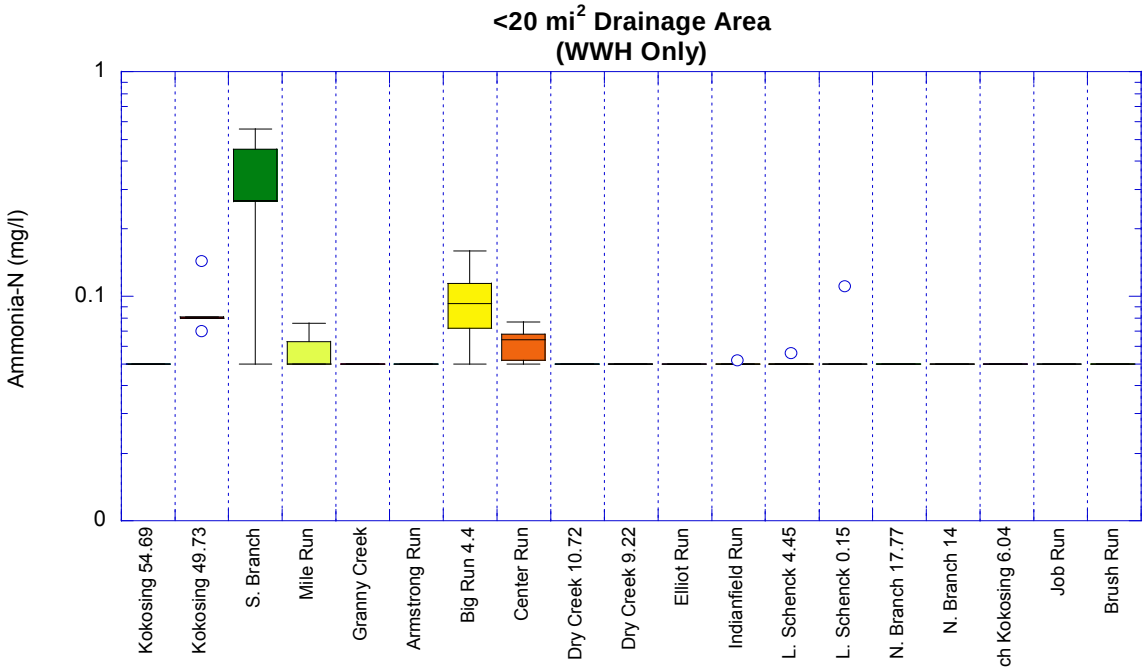

Figure 34. Ammonia readings taken for headwater streams in the Kokosing River watershed, 2007.

In addition, all readings taken here violated the 4.0 mg/l minimum dissolved oxygen standard (Table 10, pg. 52). Again, low flow conditions at the sample site here (stagnant pool, lack of functioning riffles) adversely impacted stream dissolved oxygen. These water quality conditions contributed to macroinvertebrate communities only partially meeting the WWH criteria.

Violations of the primary contact recreation bacteria standard were also recorded from this site. Agricultural land use dominates this portion of the watershed making associated activities (e.g. livestock production) likely sources for bacteria.

Mile Run (WWH, AWS, IWS, PCR)

Mile Run is 9.6 miles in length and flows easterly across this subwatershed entering the Kokosing River at RM 37.22. It has a drainage area of 12.0 square miles. One site on Mile Run was sampled for water chemistry at RM 4.75 (off CR 11, Sparta Road).

Low flow conditions were noted here with interstitial stream flow characteristics. Not surprisingly, low dissolved oxygen readings were recorded due to these conditions (Table HUC 010 Violations). Qualitative macroinvertebrate results were slightly lower than expected for WWH streams possibly due to these conditions. Otherwise, water chemistry conditions appeared satisfactory, with no significant nutrient concerns.

Granny Creek (WWH, AWS, IWS, PCR)

Running just south and somewhat parallel to Mile Run, Granny Creek has drainage area 14.7 square miles and a length of 8.0 miles. The site sampled on Granny Creek was located at RM 4.29 (CR 402, Granny Creek Road). Like Mile Run, low stream flow conditions were noted on at least one occasion.

While the total phosphorus median recorded here met the recommended statewide target for EWH streams, the nitrate+nitrite median result of 1.08 mg/l did not meet the EWH target level and was slightly above the WWH target level of 1.0 mg/l (Ohio EPA, 1999).

Each of the five samples taken here showed elevated ***E.coli*** bacteria levels resulting in a violation of the primary contact recreation standard (Table 12, pg. 54). Sampling site

observations recorded a significant mat of sewage fungus in the stream, possibly indicating a failed home sewage treatment system (HSTS) discharge.

Despite these water quality conditions, Granny Creek fully met both EWH and CWH attainment for biological communities. Cool stream temperatures (18.29ºC median) and high dissolved oxygen concentrations (8.53 mg/l median) were contributing factors in this attainment.

Sediment

For this assessment unit, one location at Kokosing River RM 32.56 (Beckley Road) was evaluated for sediment composition. At this site, sediment chemical concentrations did not appear to be problematic. Calcium, chromium, nickel, selenium and strontium were above the Ohio Sediment Reference Values (SRV) (Ohio EPA, 2003). Chromium, nickel and selenium concentrations, however, were below the method-reporting limit (Sediment Table). Total organic carbon (TOC) concentration was greater than the Lowest Effect Level (LEL) (Persuad *et. al.* 1993). These concentrations did not impair macroinvertebrate communities with this site meeting full attainment of EWH criteria.

Macroinvertebrates

Narrative Macroinvertebrate Community Assessments for Individual Streams

Upper Kokosing River (WWH, AWS, IWS, PCR)

Of the over 56 miles of mainstem Kokosing River assessed, 13 of 14 (93%) sampled reaches met or exceeded the existing or recommended EOLP ecoregion biocriterion for Exceptional Warm water Habitat (EWH) or met the minimum qualitative narrative assessment for EWH.

There was very good to exceptional macroinvertebrate community quality performance in the upper Kokosing River mainstem (HUC 010) with Invertebrate Community Index (ICI) scores or estimated narrative ICI scores from 44 (Very Good) to 48 (Exceptional) (Figure 26, pg. 86). EPT taxa collected ranged from 18 at the most upstream site (RM 54.6 – Pulaskiville Rd.) to a high of 25 EPT at the Beckley Rd. site (RM 32.5). Two of the highest Sensitive/Tolerant Taxa Ratios were in the upper mainstem: a ratio of 9.0 at RM 54.6 and the highest S/T ratio of any mainstem site (of 11.5) again at Beckley Rd. (RM 32.5). All sampled reaches met or marginally met the Exceptional Warmwater Habitat (EWH) biocriterion. This upper reach is recommended to be elevated from the existing WWH aquatic life use to EWH aquatic life use (Table 13, pg. 102).

Upper Kokosing River Tributaries

South Branch Kokosing River (WWH, AWS, IWS, PCR)

The South Branch Kokosing River flows north in rural Morrow County before turning east and joining the mainstem of the Kokosing River along Chesterville Road at RM 45.93. Due to dry conditions there was only interstitial flow between pools. Only one mayfly was collected with no baetid or heptageneid mayflies found. Only five EPT taxa were collected. The caddisfly and dipteran communities present were sparse (no tanytarsini midges collected) with an increased number of tolerant taxa comparatively (S/T Ratio = 0.75). This fair macroinvertebrate community performance did not meet WWH expectations. Increased nutrient eutrophication from NPS agriculture along with sporadic higher ammonia and lower D.O. concentrations combined with dry conditions exacerbate the stress in the macroinvertebrate community.

Mile Run (WWH, AWS, IWS, PCR)

Mile Run, which joins the Kokosing River southwest of Fredericktown, had been reduced to mostly shallow bedrock pools with some interstitial flow through the pool bottom due to dry conditions. The shallow pools had increased temperatures to 23^{o} C., but deeper pools with a strong groundwater connection were a cold 13o C. that even yielded a cold water midge. Open canopy reaches resulting from NPS agriculture and open pastures has resulted in accumulations of algae in the warm exposed pools. There were enough deeper, cooler, shaded pools to yield a marginal good macroinvertebrate community quality, and Mile Run met the WWH biocriteria expectations. Increased canopy maturation along Mile Run would improve shading and capture some NPS nutrients thereby decreasing water temperatures and algal production.

Granny Creek (WWH, AWS, IWS, PCR)

Granny Creek, an agricultural stream with a good riparian corridor, flows east along Green Valley Rd. to join the Kokosing R. two miles northwest of Mt. Vernon. This coldwater stream (17 ^{o} C.) yielded an exceptional community with 20 sensitive taxa and five CW taxa, including the *Leuctra* stonefly. Granny Creek, despite the decreased flows from drought conditions, met and is recommended for CWH and EWH aquatic life use designations.

Table 13. *Summary of Macroinvertebrate Data Collected from Artificial Substrates (Quantitative Sampling) and Natural Substrates (Qualitative* **sampling) in the Kokosing River Study Area, June through October, 2007.**

Stream RM	Drain. Area (mi. ^{2})	Data Code	Ql. / Total Taxa	EPT Ql. / Total	No. CW Taxa	Sens. Taxa Qual. / Total	Qual. Tol. Taxa	Qual. Sens./ Tol. Ratio	Rel. Density Ql. /Qt.	QCTV	Predominant Organisms on Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
Hydrologic Unit 05040003 010 **(Upper Kokosing River Assessment Unit)**													
Kokosing River (17-650) (EOLP) - **WWH** (existing) **EWH** (recommended)													
54.6	8.3	X19	42 / 42	18 / 18	2	18 / 18	2	9.00	M / --	42.6	*Rheotanytarsus* and *Neophylax* sp. (MI)	VGns	**Very Good**
49.8 **R**	15.2	X4, X12	52 / 65	15 / 15	1	26 / 32	3	8.67	M-L / 518	42.1	*Chimarra* & *Neophylax* spp. Caddisflies (MI), baetid mayflies (MI,F), water penny (MI), *Rheotanytarsus* sp. midges (MI)	44ns	**Very Good**
45.4	38.0	--	62 / 80	18 / 24	1	24 / 35	7	3.43	M-H / 1904	41.0	*Rheotanytarsus* spp. (MI), *Optioservus* beetles (MI), baetid mayflies (MI,F), *Atherix* sp. (MI), *Neophylax* sp. (MI)	48	**Exceptional**
39.2	60.0	--	56 / 75	19 / 22	0	25 / 33	5	5.00	M-L / 660	42.3	*Chimarra*, *Neophylax*, & hydropsychid caddisflies (MI), Tanytarsini midges (MI)	46	**Exceptional**
32.5	79.9	--	47 / 67	20 / 25	1	23 / 34	2	11.50	M / 761	42.6	*Rheotanytarsus* spp. (MI), *Atherix* sp., *Neophylax* sp. (MI), *Elimia* sp. (MI)	48	**Exceptional**
Hydrologic Unit 05040003 030 **(Middle Kokosing River Assessment Unit)**													
Kokosing River (17-650) (EOLP) - **EWH** and **SRW** (existing)													
28.7 **R**	202	--	58 / 74	24 / 29	0	30 / 39	3	10.00	M-L / 1422	42.5	Caddisflies (*Chimarra* sp., *Ceratopsyche morosa*, *Psychomyia* & *Leucotrichia* spp.) (MI), Baetis spp. (MI)	52	**Exceptional**
25.1 **R**	251	--	48 / 68	16 / 22	0	20 / 31	9	2.22	M-H / 1798	42.1	*Chimarra* sp & hydropsychid caddsiflies (MI,F), *Elimia* sp. (MI), sponge (F)	52	**Exceptional**
24.5	272	--	51 / 59	12 / 15	0	23 / 27	4	5.75	High / 4380	41.0	*Rheotanytarsus* spp. (MI), hydropsychid caddsiflies (MI,F), *Polypedilum flavum* midge (F), oligochaete worms (T)	38*	**Good***

Stream RM	Drain. Area (mi. ^{2})	Data Code	Ql. / Total Taxa	EPT Ql. / Total	No. CW Taxa	Sens. Taxa Qual. / Total	Qual. Tol. Taxa	Qual. Sens./ Tol. Ratio	Rel. Density Ql. /Qt.	QCTV	Predominant Organisms on Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
Hydrologic Unit 05040003 030 **(Middle Kokosing River Assessment Unit)** (cont.)													
Kokosing River (17-650) (EOLP) - **EWH** and **SRW** (existing)													
22.1	275	--	47 / 61	15 / 18	0	22 / 29	4	5.50	Mod. / 1453	41.6	*Elimia* sp. (MI), *Rheotanytarsus* sp. (MI), stenonemid mayflies (MI), hydropsychid caddisflies (MI,F), oligochaete worms (T)	42ns	**Very Good**
18.9	281	--	61 / 74	19 / 24	0	31 / 37	6	5.17	Mod. / 1050	42.3	*Elimia* sp. (MI), *Corbicula fluminea* (MI), *Rheotanytarsus* sp. (MI), *Caenis* sp. (MI)	52	**Exceptional**
11.6	379	X12	51 / 51	22 / 22	0	24 / 24	8	3.00	M-H / --	42.3	*Isonychia* mayflies (MI), *Rheotanytarsus* sp. (MI), Stenonemid mayflies (MI), hydropsychid caddisflies (MI,F)	E	**Exceptional**
Hydrologic Unit 05040003 040 **(Lower Kokosing River Assessment Unit)**													
Kokosing River (17-650-000) (EOLP) - **EWH** and **SRW** (existing)													
6.2	463	--	53 / 71	17 / 26	0	28 / 40	7	4.00	M-H / 1046	43.2	*Rheotanytarsus* sp. (MI), *Isonychia* mayflies (MI), hydropsychid caddisflies (MI,F)	52	**Exceptional**
2.7 **R**	478	--	57 / 75	20 / 24	1	28 / 39	8	3.50	Mod. / 1414	42.7	*Rheotanytarsus* sp. (MI), *Isonychia* mayflies (MI), baetid mayflies (MI,I), hydropsychid caddisflies (MI,F)	50	**Exceptional**
0.1	485	--	54 / 54	19 / 19	0	25 / 25	10	2.50	M-H / --	41.9	*Isonychia* mayflies (MI), *Rheotanytarsus* sp. (MI), Stenonemid mayflies (MI), hydropsychid caddisflies (MI,F)	E	**Exceptional**
Kokosing River Tributaries													
Hydrologic Unit 05040003 010 **(Upper Kokosing River Assessment Unit)**													
South Branch Kokosing River (17-683-000) (EOLP) - **WWH** (existing)													
2.9	8.4	X19	31 / 31	5 / 5	0	6 / 6	8	0.75	L / --	34.4	Hydroptilids & *Stictochironomus* sp.(F)	HF*	**High Fair***
Hydrologic Unit 05040003 010 **(Upper Kokosing River Assessment Unit) (cont.)**													
Mile Run (17-682-000) (EOLP) – **WWH** (existing)													
4.6	9.0	X9,19	34 / 34	6 / 6	1	6 / 6	6	1.00	Mod./ --	35.5	*Stictochironomus* sp. & *S. femoratum* (F)	MGns	**Marg. Good**
Granny Creek (17-681-000) (EOLP) – **WWH** (existing) **EWH** and **CWH** (recommended)													

Stream RM	Drain. Area (mi. ^{2})	Data Code	Ql. / Total Taxa	EPT Ql. / Total	No. CW Taxa	Sens. Taxa Qual. / Total	Qual. Tol. Taxa	Qual. Sens./ Tol. Ratio	Rel. Density Ql. /Qt.	QCTV	Predominant Organisms on Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
4.3	9.1	X19	40 / 40	13 / 13	5	20 / 20	3	6.67	M-L / --	42.1	*Rheotanytarsus* sp. (MI), *Helicopsyche borealis* (MI), Leptocerids (MI), *Leuctra* sp. (I), *Macaff. vicarium* (MI)	VGns	**Very Good**
Hydrologic Unit 05040003 020 **(North Branch Kokosing River Assessment Unit)**													
North Branch Kokosing River (17-674-000) (EOLP) - **WWH** (existing) **EWH** and **CWH** (recommended)													
17.77	8.0	X19	63 / 63	28 / 28	8	34 / 34	3	11.33	Mod./ --	42.7	Hydropychids (MI,F), *Chimarra* sp. (MI), baetid mayflies (MI,F,I), *Glossosoma* sp. (I), *Helicopsyche borealis* (MI)	E	**Exceptional**
14.0	17.4	--	66 / 66	25 / 25	3	30 / 30	5	6.00	M-H / --	41.0	Tanytarsini midges (MI,F), *C. slossonae* & *C. morosa gr.* (MI) & *Cheumatopsyche* sp. (F), *Helicopsyche borealis* (MI)	E	**Exceptional**
North Branch Kokosing River (17-674-000) (EOLP) - **WWH** (existing) **EWH** (recommended)													
8.7	45.8	--	51 / 58	12 / 17	0	21 / 25	4	5.25	M-H / 770	41.0	*Chimarra* sp. (MI), *Cheumatopsyche* sp. (F), *Neophylax* sp. (MI), baetid & stenonemid mayflies (MI)	42ns	**Very Good**
6.2 **R**	84.0	--	60 / 73	19 / 21	0	28 / 34	7	4.00	L-M / 1033	41.6	Caddisflies (*Chimarra*, hydropsychids, *Psychomyia*) (MI,F), *B. intercalaris* (MI), *Polypedilum flavum* (F), *Tricoythodes* sp.	50	**Exceptional**
5.5	85.0	X16	46 / 46	16 / 16	0	14 / 14	8	1.75	M-L / --	39.2	Riffle beetles (F), steno. mayflies (MI,F), *Elimia* sp.(MI), *Petrophila* sp.(MI)	G*	**Good***
0.1	97.9	--	55 / 69	20 / 23	0	24 / 32	3	8.00	L-H / 6892	42.6	Baetid & stenonemid mayflies (MI,F), Rheo. midges (MI), hydropsychids (MI,F)	52	**Exceptional**
Hydrologic Unit 05040003 020 **(North Branch Kokosing River Assessment Unit) (cont.)**													
Trib. to North Branch Kokosing River @ RM 9.99 (17-674-001) (EOLP) - **WWH** (existing)													
3.9	8.4	X19	52 / 52	11 / 11	0	16 / 16	9	1.78	M-H / --	38.0	*Helicopsyche borealis* (MI), tanypode & *Rheotanytarsus* sp. midges (F,MI), water mites (F), hydroptilids (F)	MGns	**Marg. Good**
East Branch North Branch Kokosing River (17-676-000) (EOLP) - **WWH** (existing) **CWH** (recommended)													
6.0	9.9	X19	60 / 60	9 / 9	3	24 / 24	5	4.80	H-L / --	42.1	*C. morosa* & *slossonae* (MI), tanypode, *Rheotanytarsus* & *Cricotopus* sp. (MI,F,T)	G	**Good**
East Branch North Branch Kokosing River (17-676-000) (EOLP) - **WWH** (existing) **EWH** (recommended)													

Stream RM	Drain. Area (mi. ^{2})	Data Code	Ql. / Total Taxa	EPT Ql. / Total	No. CW Taxa	Sens. Taxa Qual. / Total	Qual. Tol. Taxa	Qual. Sens./ Tol. Ratio	Rel. Density Ql. /Qt.	QCTV	Predominant Organisms on Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
0.1	31.8	X8	70 / 86	17 / 20	1	25 / 34	12	2.08	M-L / 623	39.1	*Chimarra* sp. (MI), midges (MI,F, MT), *Caenis* sp., flatworms, hydropsychids(F,MI)	VGns	**Very Good**
Job Run (17-675-000) (EOLP) - **WWH** (existing) **EWH** & **CWH** (recommended)													
0.1	8.5	X19	55 / 55	23 / 23	3	28 / 28	5	5.60	Mod./ --	43.2	*Ceratopsyche slossonae* (MI),*Glossosoma* sp., *Rheotanytarsus* sp., & *Elimia* sp. (MI)	E	**Exceptional**
Hydrologic Unit 05040003 030 **(Middle Kokosing River Assessment Unit)**													
Armstrong Run (17-673-000) (EOLP) - **WWH** (existing) **EWH** & **CWH** (recommended)													
1.6	8.1	X19	37 / 37	18 / 18	4	21 / 21	2	10.50	M-L / --	43.5	Ceratopsyche morosa gr. and C. slossonae (MI), *Rheotanytarsus* sp. midges	E	**Exceptional**
Dry Creek (17-671-000) (EOLP) - **WWH** (existing) **EWH** & **CWH** (recommended)													
10.8	7.6	X19	50 / 50	15 / 15	5	24 / 24	5	4.80	M-L / --	41.0	*Leuctra* sp. (MI), *Rheotanytarsus* sp. (MI), *Neophylax* sp. & *Helicopsyche borealis* (MI)	E	**Exceptional**
9.2	16.0	--	55 / 55	13 / 13	7	24 / 24	5	4.80	L-H / --	41.0	*Rheotanytarsus* (MI) & tanypode midges, *C. slossonae* (MI), *Atherix lantha* (MI)	VGns	**Very Good**
4.5	25.1	X15	58 / 83	25 / 30	3	27 / 41	5	5.40	Mod./ --	42.1	*Isonychia* sp. (MI), *Elimia* sp. (MI), *Caenis* sp. (F), *Helicopsyche borealis* (MI)	48	**Exceptional**
Hydrologic Unit 05040003 030 **(Middle Kokosing River Assessment Unit) (cont.)**													
Dry Creek (17-671-000) (EOLP) - **WWH** (existing) **EWH** (recommended)													
1.0	33.7	--	52 / 69	17 / 20	1	20 / 31	4	5.00	M-L / 319	41.0	Hydropsychids (MI,F), tanytarsini midges (MI,F), stenonemid mayflies (MI,F)	44ns	**Very Good**
Center Run (17-670-000) (EOLP) - **WWH** (existing) **CWH** (recommended)													
1.7	7.8	X19	62 / 62	19 / 19	6	26 / 26	8	3.25	M-H / --	42.3	Hydropsychids (MI,F), *Chimarra* sp. (MI), water pennies (MI), baetids (MI,F)	E	**Exceptional**
Delano Run (17-650-005) (EOLP) - **WWH** (existing)													
1.6	7.1	X19	37 / 37	12 / 12	0	13 / 13	4	3.25	Mod./ --	39.2	*Chimarra* sp. (MI), *Cheumatopsyche* sp. (F), *Helicopsyche borealis* (MI)	G	**Good**
Big Run (17-667-000) (EOLP) - **WWH** (existing) CWH (recommended)													

Stream RM	Drain. Area (mi. ^{2})	Data Code	Ql. / Total Taxa	EPT Ql. / Total	No. CW Taxa	Sens. Taxa Qual. / Total	Qual. Tol. Taxa	Qual. Sens./ Tol. Ratio	Rel. Density Ql. /Qt.	QCTV	Predominant Organisms on Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
4.5	9.1	X19	56 / 56	10 / 10	0	9 / 9	13	0.69	M-H / --	34.3	Hydropsychids (F), *Chimarra* sp. (MI), flatworms (F), *B. intercalaris* (MI), fingernail clams (F)	MGns	**Marg. Good**
0.6	29.2	--	67 / 84	22 / 24	2	34 / 44	4	8.50	M-L / 1246	41.6	Hydropsychids (MI,F), tipulids (F), *Rheo*. midges (MI), *Atherix lantha* (MI)	50	**Exceptional**
Elliott Run (17-668-000) (EOLP) - **WWH** (existing)													
1.0	8.0	X19	36 / 36	9 / 9	0	7 / 7	7	1.00	L-H / --	37.6	Baetid mayflies (MI,F), Caenis sp. (F), hydroptilids (F), midges (MI,F,T)	MGns	**Marg. Good**
0.2	10.7	--	66 / 66	19 / 19	0	19 / 19	12	1.58	M-H/ --	39.6	Hydropsychids (MI,F), *Rheo.* & *P. flavum* midges (MI), *Helicopsyche borealis* (MI)	VG	**Very Good**
Indianfield Run (17-666-000) (EOLP) - **WWH** (existing) **EWH** & **CWH**(recommended)													
2.8	8.4	X19	45 / 45	12 / 12	3	20 / 20	3	6.67	M-H / --	39.6	Cased caddisflies (*Neophylax*, *Oecetis, Glossosoma* & *Helicopsyche*) (MI,F), Petrophila moth larvae (MI)	VGns	**Very Good**
Hydrologic Unit 05040003 030 **(Middle Kokosing River Assessment Unit) (cont.)**													
Schenck Creek (17-662-000) (EOLP) - **WWH** (existing) **EWH** & **CWH** (recommended)													
8.8	8.9	X19	46 / 46	17 / 17	4	23 / 23	1	23.00	Mod./ --	42.5	Hydropsychids (MI,F), *Rheotanytarsus* midges (MI), *Neophylax* & *Glossosoma* sp. caddisflies (MI)	E	**Exceptional**
2.6	37.3	--	55 / 55	18 / 18	2	26 / 26	6	4.33	Mod./ --	41.6	*Leucotrichia pictipes* & *Rheo*. midges (MI)	E	**Exceptional**
0.5	41.2	--	52 / 52	23 / 23	2	31 / 31	2	15.5	Mod./ --	42.6	Hydropsychids (MI,F), *Isonychia* sp.(MI), *Rheotanytarsus* sp. (MI), stenonemid mayflies (MI,F), crayfish (F)	E	**Exceptional**
Little Schenck Creek (17-664-000) (EOLP) - **WWH** (existing) **EWH** & **CWH** (recommended)													
4.5	8.2	X19	53 / 53	19 / 19	7	24 / 24	2	16.50	M-H / --	43.2	*Ceratopsyche slossonae* (MI), *Psychomyia flavida* (MI), *Rheotanytarsus* sp. (MI)	E	**Exceptional**
0.2	16.3	--	63 / 63	19 / 19	0	24 / 24	7	3.43	M-H / --	40.0	*Helicopsyche borealis*, *Psychomyia flavida* & *Neophylax* (MI), *Ceratopsyche morosa* gr. (MI), *Rheotanytarsus* sp. (MI)	E	**Exceptional**
Hydrologic Unit 05040003 040 **(Lower Kokosing River Assessment Unit)**													
Jelloway Creek (17-654-000) (EOLP) - **EWH** (existing) **EWH** & **CWH** (recommended)													

Stream RM	Drain. Area (mi. ^{2})	Data Code	Ql. / Total Taxa	EPT Ql. / Total	No. CW Taxa	Sens. Taxa Qual. / Total	Qual. Tol. Taxa	Qual. Sens./ Tol. Ratio	Rel. Density Ql. /Qt.	QCTV	Predominant Organisms on Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
8.9	16.5	--	47 / 47	20 / 20	3	26 / 26	0	26.0+	M-H / --	43.0	*Ceratopsyche slossonae* & *morosa gr.*(MI), riffle beetles (F/MI), *Rheotanytarsus* (MI)	E	**Exceptional**
4.3 R	36.5	--	48 / 76	15 / 24	2	24 / 40	2	12.00	M-L / 559	42.3	*Isonychia* sp. (MI), hydropsychids (MI,F), hydroptilids (F)	48	**Exceptional**
0.1	74.0	--	47 / 47	13 / 13	0	18 / 18	3	6.00	M-L / --	39.9	*Rheotanytarsus* sp. (MI), hydropsychids	G*	**Good***
East Branch Jelloway Creek (17-656-000) (EOLP) - **EWH** (existing)													
3.3 **R**	4.5	X19, X15	51 / 69	12 / 14	2	15 / 25	9	1.67	M-L / 612	39.6	Baetids (F,MI,I), hydropsychids (F), tanytarsini midges (MI,F)	44ns	**Very Good**
Hydrologic Unit 05040003 040 **(Lower Kokosing River Assessment Unit) (cont.)**													
East Branch Jelloway Creek (17-656-000) (EOLP) - **EWH** (existing)													
1.1	9.2	X19	46 / 65	11 / 14	2	15 / 28	6	2.50	M-H / 484	39.4	Baetids (MI,F), hydropsychids (F,MI)	52	**Exceptional**
Little Jelloway Creek (17-655-000) (EOLP) - **EWH** (existing) **EWH** & **CWH** (recommended)													
6.9	10.5	--	43 / 43	13 / 13	3	24 / 24	3	8.00	H-L / --	42.4	*Atherix lantha* (MI), *Optioservus* (MI), *Ceratopsyche slossonae* (MI), *Neophylax* sp. (MI), *Rheotanytarsus* sp. (MI)	VGns	**Very Good**
0.9 **R**	19.0	--	27 / 45	4 / 5	3	7 / 15	4	1.75	M-H / 4885	38.9	*Cheumatopsyche* sp. (F), *Paratanytarsus* n. sp. 1 (MI), *Parametriocnemus* sp. (MI), *Micropsectra* & *Paratrichocladius* sp. (MI)	28*	**Fair***
0.01	19.5	--	22 / 22	4 / 4	1	6 / 6	6	1.00	M-L / --	34.7	Flatworms (F), limpet snails (F), tanypode midges (F)	LF*	**Low Fair***
Brush Run (17-667-000) (EOLP) - **WWH** (existing) **CWH** (recommended)													
0.9	7.8	X19	43 / 43	12 / 12	6	21 / 21	4	5.25	Mod./ --	42.5	Hydroptilids (F), C. slossonae (MI), tany- tarsini maidges (MI)	G	**Good**

Table acronym descriptions:

RM: River Mile.
Ql.: Qualitative sample collected from the natural substrates.
Data Codes: X: 8=Non-Detectable Current, 11=Lake Erie Influence (Lacustuary), 12=Suspected High Water Influence/Disturbance, 13=Suspected Disturbance By Vandalism, 15=Current >0.0 fps but <0.3 fps, 19=Drainage Area<10 mi2 , 21=Acute Mixing Zone, 26=Replicate with shared Ql.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant
ns : nonsignificant departure from attainment criteria of designated aquatic life use (four units)
R ecoregional reference site
* nonattainment of aquatic life us

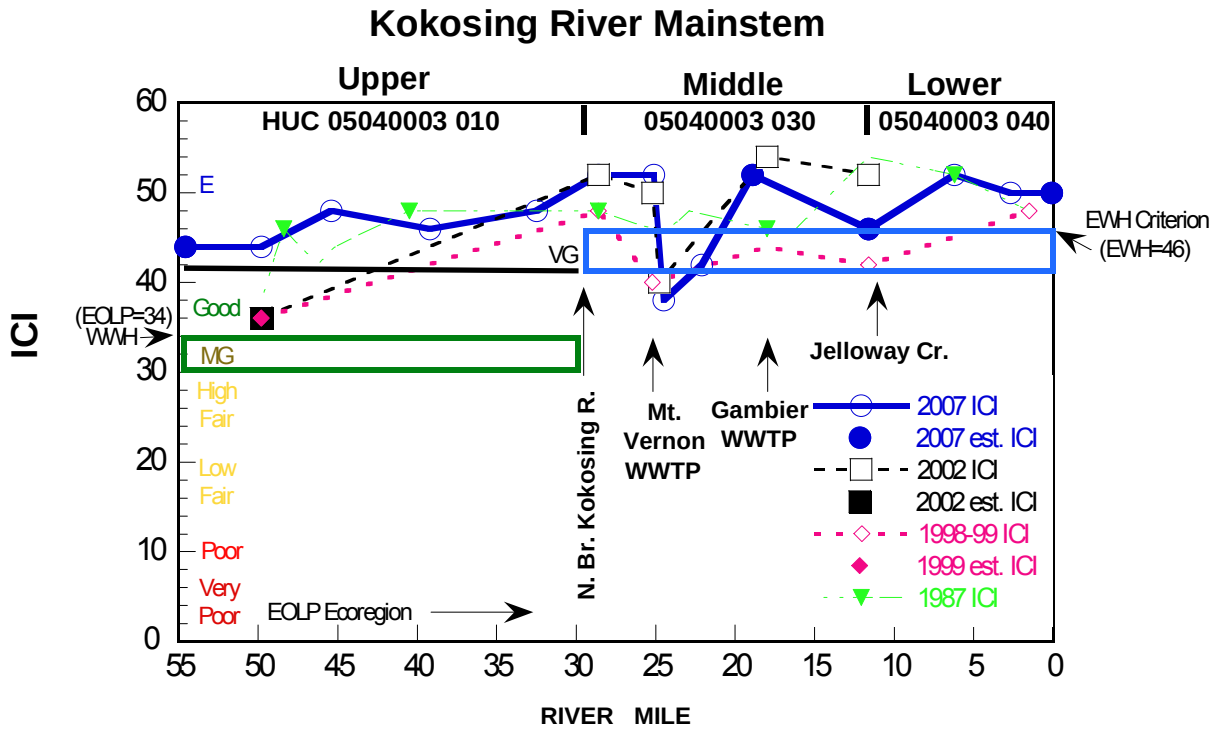

Figure 35. Historical Invertebrate Community Index (ICI) scores for sampled Kokosing River mainstem sites from 1987 to 2007.

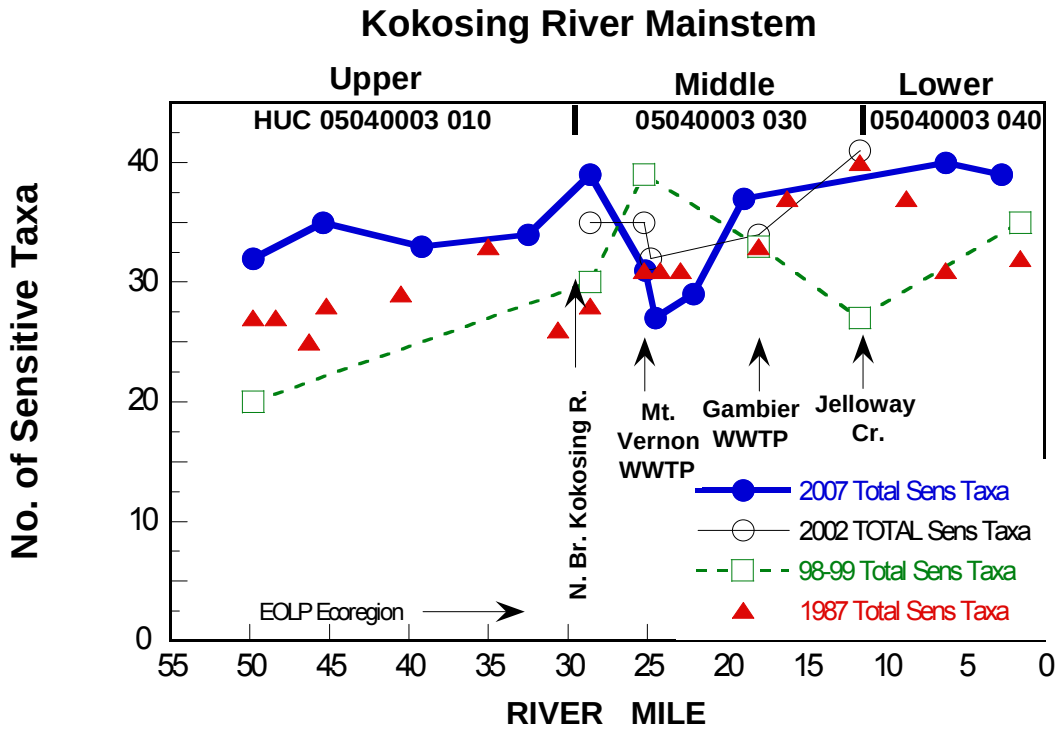

Figure 36. Trends for Total Number of Sensitive Taxa collected historically for sampled Kokosing River mainstem sites from 1987 to 2007.

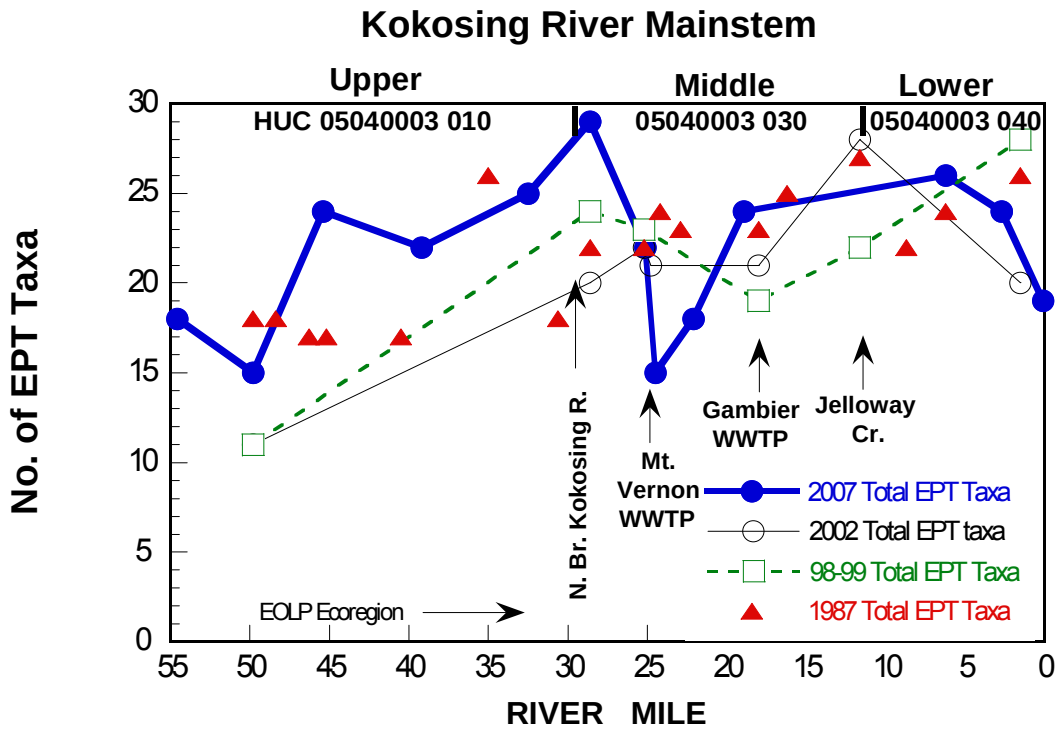

Figure 37. Trends for Total EPT Taxa collected historically for sampled Kokosing River mainstem sites from 1987 to 2007.

Fish

Narrative Fish Community Assessments for Individual Streams

Upper Kokosing River (WWH, AWS, IWS, PCR)

Biological fish sampling for this stream segment was conducted at four (4) locations on the Kokosing River: RM 54.69 (Pulaskiville Road), RM 50.5 (Chipps Road), RM 45.44 (State Route 314), RM 39.27 (Vail Road) and RM 32.56 (Beckley Road). Three (3) tributary streams sampled included South Branch (RM 2.96), Mile Run (RM 4.75), and Granny Creek (RM 4.29). The average IBI score for the Upper Kokosing River tributaries was 47, meeting EWH criteria. These sites are listed in Table 46.

The average IBI score for the main stem sites was 45, which is one point away from meeting EWH criteria (Table 2, pg. 10). Sediment run off due to agriculture and livestock influences were noted at two of the sites (RM 50.5 and RM 39.3) as sources of impairment. The most upstream site (RM 54.7) met EWH criteria with an IBI score of 50. Seventeen species of fish were found there at 8.3 sq/mi. drainage area. Cows freely accessing the river at RM 39.3 elevated the sediment and the E.coli bacteria levels (see chemistry section) in the river which had a strong influence on the fish community. This was the lowest scoring fish site on the main stem with an IBI value of 39 (Table 2, pg. 10 and Figure 27, pg. 89). The entire mainstem of the Upper Kokosing River has the potential to meet EWH criteria pending the remediation of agricultural and livestock pollution at RM 50.5 and RM 39.3.

Upper Kokosing River Tributaries

South Branch Kokosing River (WWH. AWS, IWS, PCR)

The South Branch of the Kokosing River located in Morrow County joins the Kokosing River at RM 45.93. The South Branch is 9.0 miles long with a drainage area of 11.8 square miles. One site was evaluated at RM 2.96 (off CR 11, Sparta Road). The IBI score (38) for the South Branch did not significantly depart from the applicable WWH criteria assigned to this stretch of river. However, the macroinvertebrate community did not meet WWH criteria due to agricultural runoff. Water chemistry problems associated with eutrophication such as elevated ammonia levels and low dissolved oxygen in the stream impacted the Macroinvertebrate community.

Mile Run (WWH, AWS, IWS, PCR)
Mile Run is 9.6 miles in length and flows easterly across this subwatershed entering the Kokosing River at RM 37.22. It has a drainage area of 12.0 square miles. Fish were sampled at RM 4.75 (off CR 11, Sparta Road).

Drought conditions at the sampling location limited Mile Run to isolated pools and interstitial flows. An IBI score of 50 fully secured the fish community into EWH attainment (Table 2, pg. 10). However, the historical and current use designation for this stream reach is WWH. As a result of the extreme dessication the Qualitative Macroinvertebrate results were lower than expected for this site, but still met the WWH criteria.

Granny Creek (WWH, AWS, IWS, PCR)
Running just south and somewhat parallel to Mile Run, Granny Creek drains 14.7 square miles and is 8.0 miles long. The site sampled on Granny Creek was located at RM 4.29 (CR 402, Granny Creek Road).

Granny Creek scored above (IBI = 52) its historical WWH use designation and now is in full attainment of the EWH criterion. The exceptional fish community at Granny Creek Road was diverse (18 species) for a sample location with only 9.1 square miles in drainage area. Immediately downstream from the sample location cows were unrestricted in their access to Granny Creek. It is recommended that livestock be fenced out of Granny Creek and provided an alternate watering method.

Habitat

Narrative Habitat Assessments for Individual Streams
Upper Kokosing River (WWH, AWS, IWS, PCR)
The upper Kokosing River assessment unit scored the lowest average QHEI score ($\bar{x}$ = 60)/narrative range = Good) for main stem sites (Table 2 (pg. 10) and Figure 31 (pg. 93)). In the headwaters of the Kokosing River at RM 54.69, Pulaskiville Road, physical habitat was good (QHEI = 65.5). However, the adjacent landowners did express concerns about upstream bacteria runoff from campgrounds. Fair quality habitat in the Kokosing River was found at the next three downstream sample locations (RM 50.5, 45.4, and 39.3) (Figure 31 (pg. 93)). The fair habitat found at RM 50.5, Chipps Road, was partially attributed to the low flow conditions. Riffles were very shallow with very little flow running across the rocky substrates. Developmental characteristics of the stream channel were lacking because of the near stagnant flow (Appendix A).

Upstream (RM 45.4) from SR 314 at Fredericktown the Kokosing River is recovering from being straightened (Figure 38). Row crops were planted right up to the incised stream banks. Unconnected from its the flood plain at this location, a moderate amount of silts and fines confined to the stream channel had embedded the otherwise coarser substrates. Despite this being the lowest scoring site for habitat on the main stem, the biology was in full EWH attainment. This can be attributed to the cold ground water keeping potential pollution problems at bay and a more intact treed riparian buffer and natural stream channel ~100 meters upstream. In the absence of cold water this stream segment would most likely show signs of eutrophication and the biology would not have met the recommended EWH aquatic life use. The Kokosing River showed signs of recovery (beginnings of a sinuous channel and enough vegetation inside the incised channel to limit erosion) from being straightened and could continue to improve over time if left alone.

Figure 38. Kokosing River RM 45.4, Upstream from SR 314 at Fredericktown.

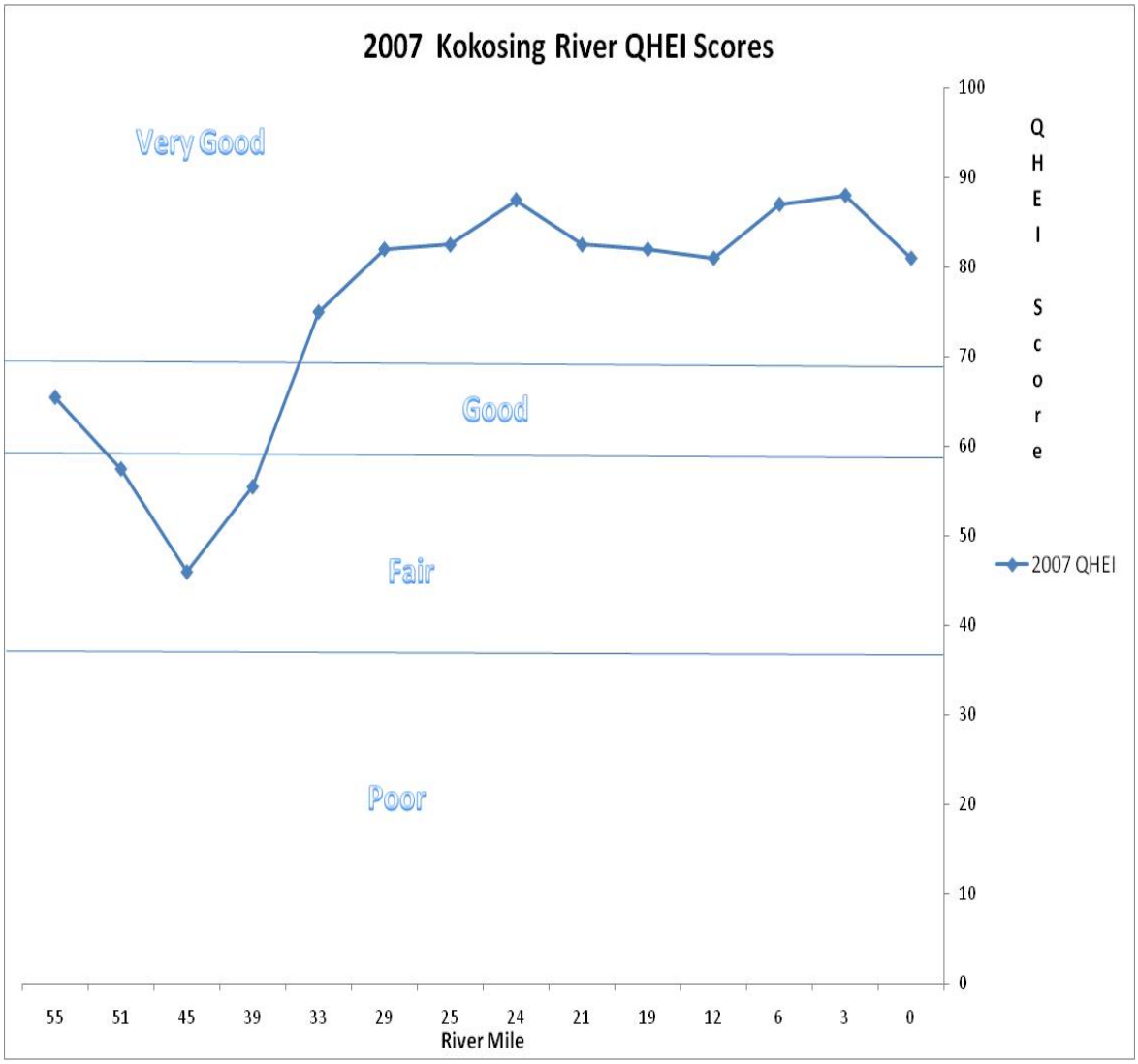

Figure 39. Kokosing River 2007 QHEI scores with narrative ratings.

Downstream at Vail Road, RM 39.3, livestock freely accessed the Kokosing River immediately upstream of the sample site (Figure 40). The soil runoff from the trampled banks covered the coarser substrates and other instream habitat downstream with silts and fines. Excluding livestock from this stream section would permit its recovery towards its natural condition. Vegetation would grow back and restabilize the upstream banks and as the river would wash the silts/fines downstream and eventually deposit them along the flood plain. At Beckley Road, RM 32.6, the habitat was very good scoring 75 on the QHEI (Table 2, pg. 10). Cobble and gravel were the predominant substrate types. The riparian buffer was 5-10m wide which seemed to be a sufficient

buffer for the Kokosing River from the adjacent row crops in the upstream half of the sample site (Appendix A).

Figure 40. Kokosing River Upstream of Vail Road, RM 39.3.

Upper Kokosing River Tributaries

Granny Creek (WWH, AWS, IWS, PCR)

Granny Creek, Mile Run, and S. Branch Kokosing River were evaluated for habitat quality. The best quality habitat among the upper Kokosing River tributaries was found at Granny Creek (RM 4.3), scoring a QHEI of 79, narrative = very good (Table 2, pg. 10). Just upstream from the sample location cows had open access to Granny Creek. It is recommended that livestock be excluded from the creek and provide an out of stream watering area to insure good water quality conditions continue in Granny Creek and the Kokosing River watershed.

Mile Run (WWH, AWS, IWS, PCR)

Fair physical habitat quality (QHEI = 57.5) characterized Mile Run (RM 4.8) with most of the decline attributed to the drought conditions experienced during the 2007 summer sampling period (June 15th – October 15th). Stream flow in Mile Run was reduced to

only isolated pools. These pools were well connected to ground water and cold despite appearing stagnant and for the most part in full sun light (one deep pool at the end of the sample zone had an ambient temperature of 13 degrees C). These attributes were sufficient in sustaining a EWH level fish community (Table 2, pg. 10). This aquatic community is protected by WWH criteria because the macroinvertebrates were less diverse than the fish community, resulting from the loss of riffle habitat and flow.

South Branch Kokosing River (WWH. AWS, IWS, PCR)

The S. Branch of the Kokosing River (RM 2.9) scored just below the narrative range for good quality physical stream habitat (QHEI = 57.5) (Table 2). The high quality coarse substrates (cobble and gravel) that dominated this stream reach would have provided better instream habitat if there were more flow. However, the S. Branch did not appear to be flowing at all in this reach and water was limited to isolated pools. Stream channel morphological characteristics and riffles were lacking due to the drought conditions. Achieving a good or excellent QHEI score during normal flow conditions would not be out of the question. The moderate to narrow vegetative riparian corridor effectively kept algae growth down, stream banks stabilized, and provided instream biotic habitat.

North Branch Kokosing River Assessment Unit (05040003-020)

The North Branch Kokosing River assessment unit (Hydrologic Unit Code 05040003-020) encompasses the entire drainage area of the North Branch Kokosing River and its tributaries. This area falls within the Erie Ontario Lake Plain (EOLP) ecoregion.

Chemical Water Quality

There were 9 stream monitoring sites in this unit that were evaluated for chemical water quality, 5 sites on the North Branch Kokosing River, 2 sites on the East Branch, 1 site each on Job Run and an unnamed tributary which flows into the North Branch at RM 9.99. (Table 9).

North Branch Kokosing River (WWH, AWS, IWS, PCR)

The North Branch Kokosing River drains approximately 98 square miles of mostly rural farm land and woodlots flowing into the Kokosing River on the north side of Mt. Vernon at RM 29.66. The only semi-urbanized portion of the watershed is found in the vicinity of the Village of Fredericktown. Kokosing Lake influences a portion of the North Branch downstream of the dam located at RM 10.15. Five sampling sites were monitored on North Branch beginning at RM 17.77 and extending down to the mouth (RM 0.02).

Generally, chemical water quality was good in the North Branch Kokosing River and biological communities were in attainment of water quality standards (Table 2). Groundwater influences were apparent in the upper watershed with daytime summer temperatures in the mid to upper teens for all measurements (Appendix F2), among the lowest temperatures found in headwater streams during the survey (Figure 41). Moving downstream, Kokosing Lake reservoir served as a heat source, raising downstream temperatures in North Branch (Figure 8). Groundwater influences were noted again at the mouth, thus decreasing mean summer temperatures. Elevated total dissolved solids concentrations also indicated the presence of substantial groundwater augmentation in North Branch upstream of the reservoir (Figure 42).

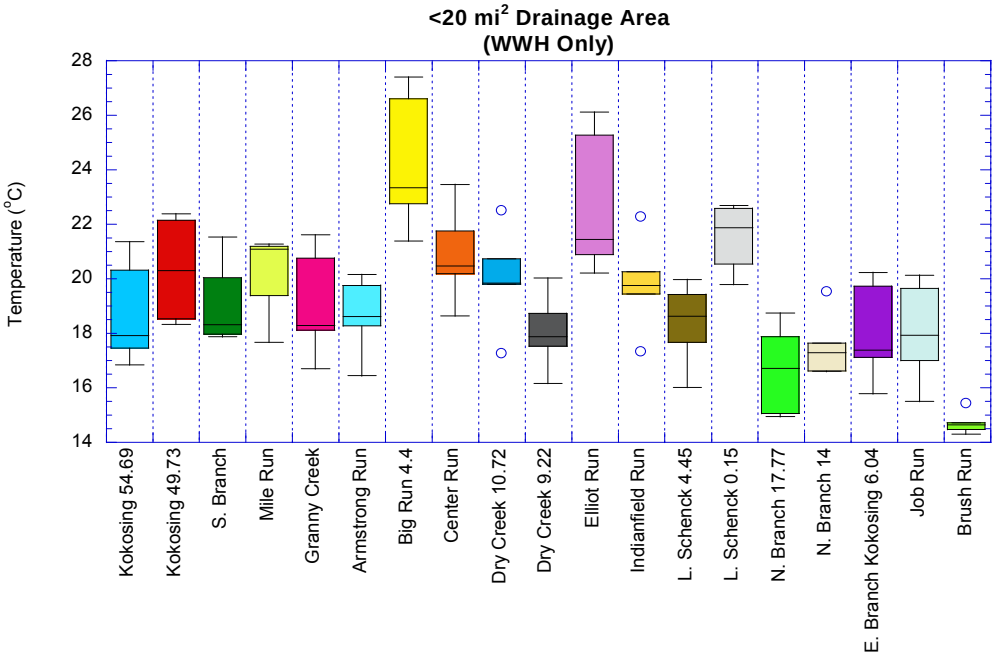

Figure 41. Ambient water temperatures for Kokosing River watershed headwater streams, 2007.

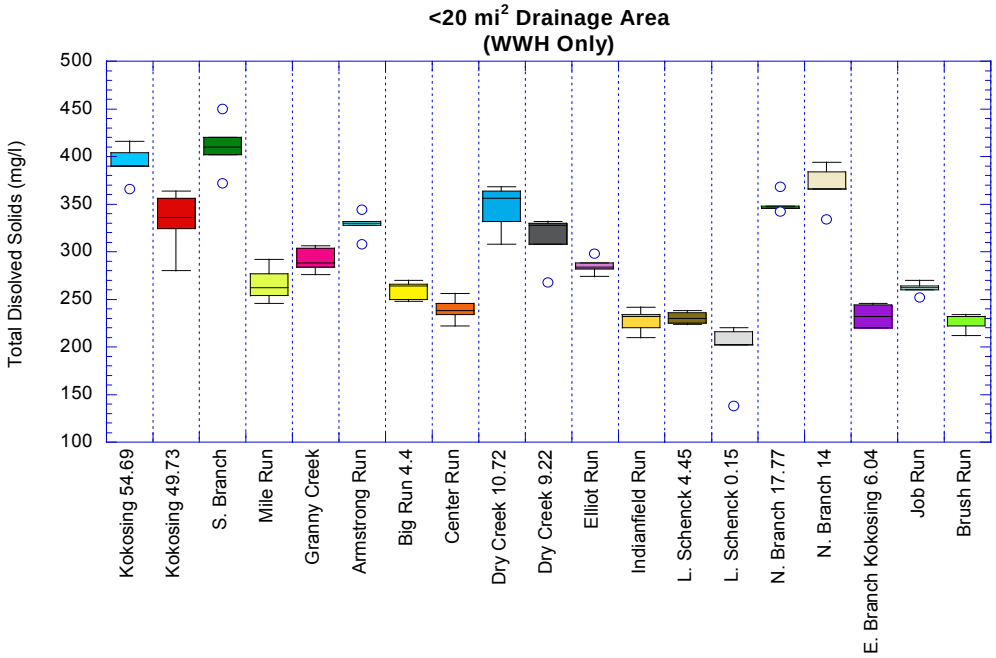

Figure 42. Readings for TDS in Kokosing River watershed headwater streams.

There were numerous violations of water quality standards, primarily for E. coli bacteria in this segment (Table 10, pg. 52). Elevated E. coli concentrations dropped precipitously immediately downstream of Kokosing Lake, with the reservoir acting as a bacteria sink, but increasing again further downstream (Figure 43). Bacteria sources basin-wide include failing home sewage treatment systems, especially in the upstream reaches, the Fredericktown WWTP (see discussion below for additional information), and livestock operations.

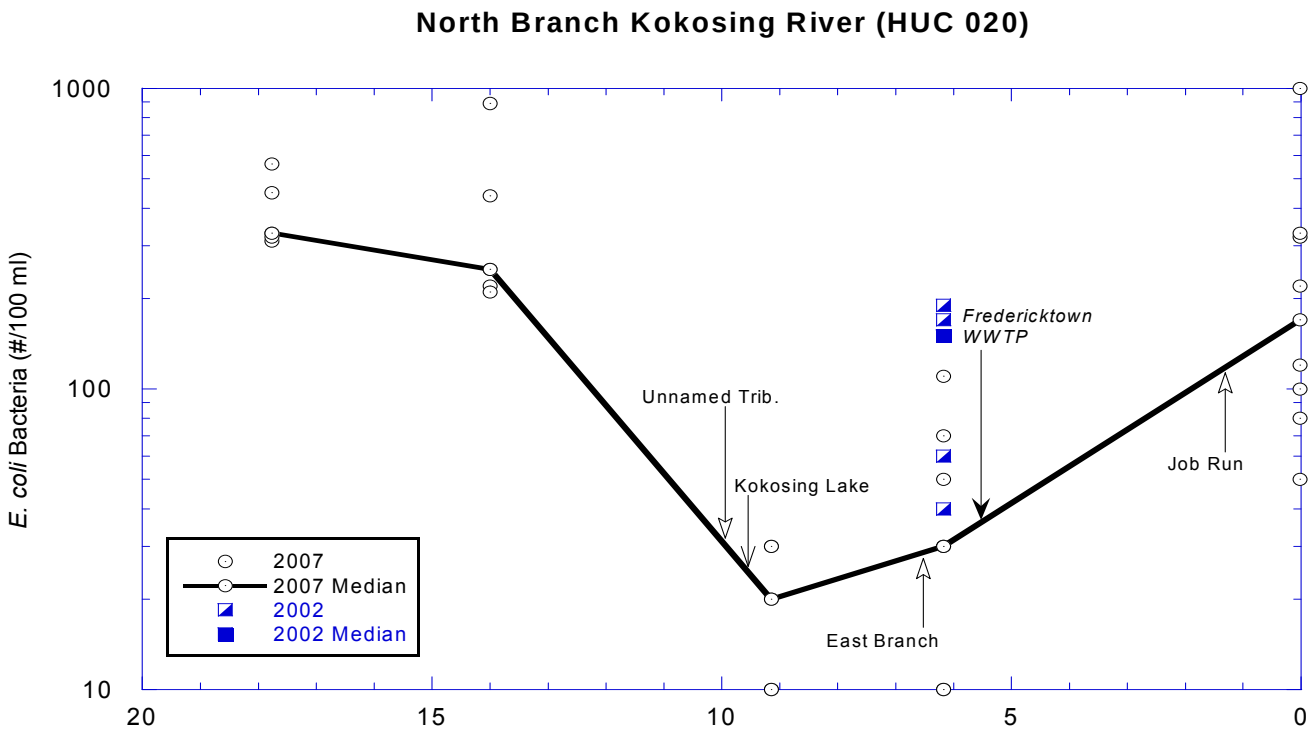

Figure 43. Longitudinal trends in historic values for E.coli samples taken by river mile in the North Branch Kokosing River.

One violation of the minimum dissolved oxygen criterion was detected at RM 14.00 (Table 10, pg. 52). The cause and source of this one excursion was not determined and the other 4 dissolved oxygen readings from this site were all well above WWH water quality criteria (Appendix F2). Generally speaking, dissolved oxygen concentrations showed a similar pattern to that of bacteria (Figure 44, pg. 121 and Figure 45, pg. 122). Lower dissolved oxygen concentrations and saturation levels downstream of Kokosing Lake were artifacts of the reservoir, including the effects from reduced reaeration (lotic to lentic changes) and (possibly) lake stratification. Downstream dissolved oxygen values had fully rebounded from that found immediately downstream from the dam at RM 9.15, by RM 6.18.

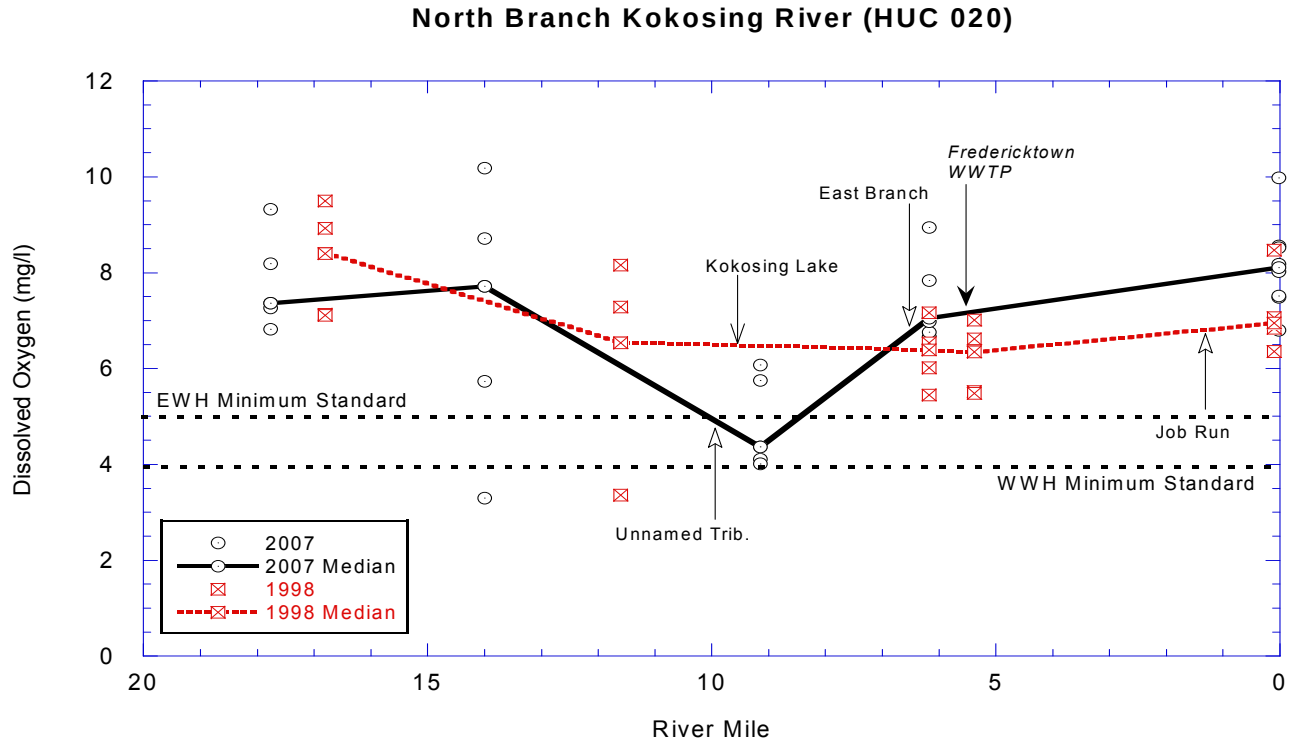

Figure 44. Dissolved oxygen concentration (mg/l) trends listed by river mile for the North Branch Kokosing River.

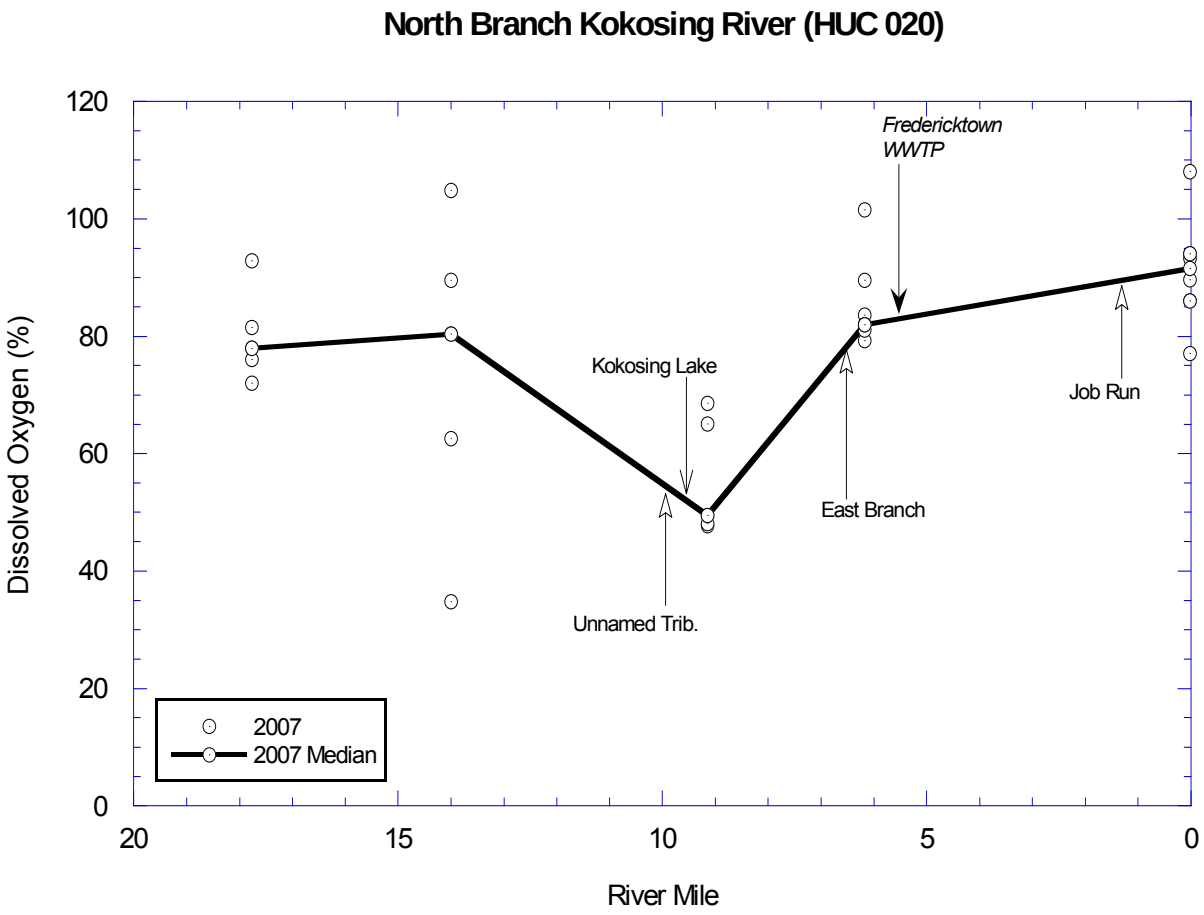

Figure 45. Percent dissolved oxygen saturation longitudinally plotted by river mile for the North Branch Kokosing River.

Nitrogen cycling in the North Branch was also heavily influenced by the presence of Kokosing Lake. Concentrations of nitrate+nitrite at the upper 2 locations upstream from the reservoir were among the highest and most consistent in the survey area (Appendix F2 , Figure 45), well above the background 75th percentile in every sample. Sources of this material are undoubtedly agricultural and possibly influenced by discharges from home sewage treatment systems. Immediately downstream of the Kokosing Lake dam, ammonia-N values were elevated in most samples (Appendix F2, Figure 47). This is typical downstream of a reservoir where reducing conditions in the hypolimnion often promote the conversion of some of the available nitrates back into ammonia. Both winter and springtime sampling at the mouth (RM 0.02) also revealed elevated concentrations of nitrate+nitrite in the water column (Appendix F2).

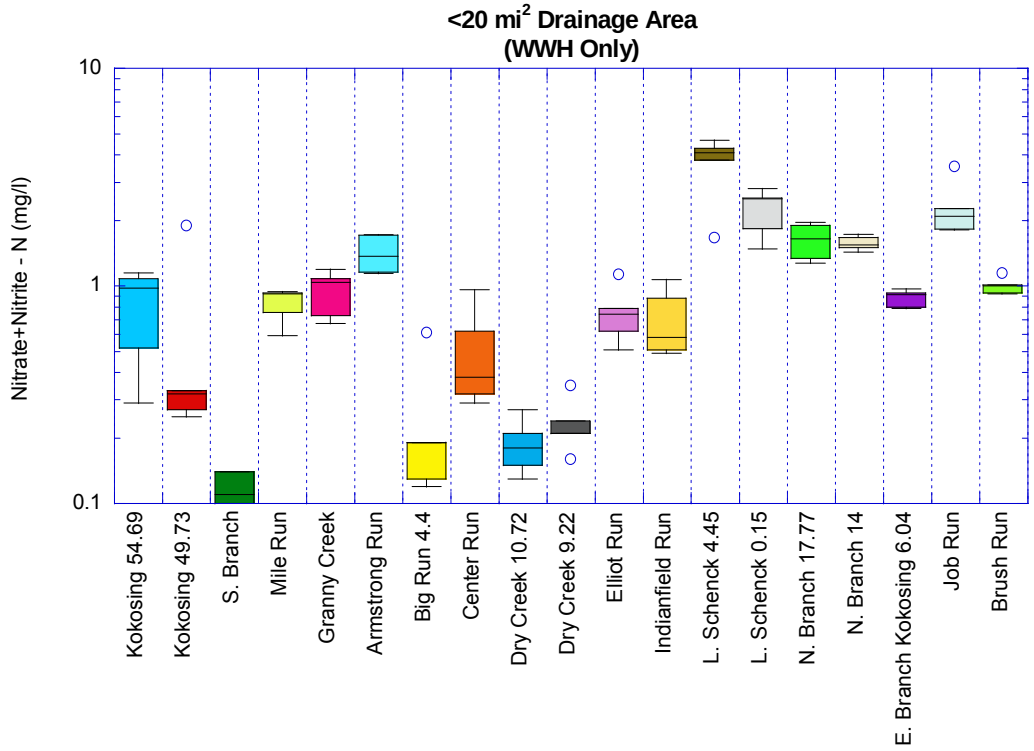

Figure 46. Nitrate+nitrite levels recorded for Kokosing River watershed headwater streams, 2007.

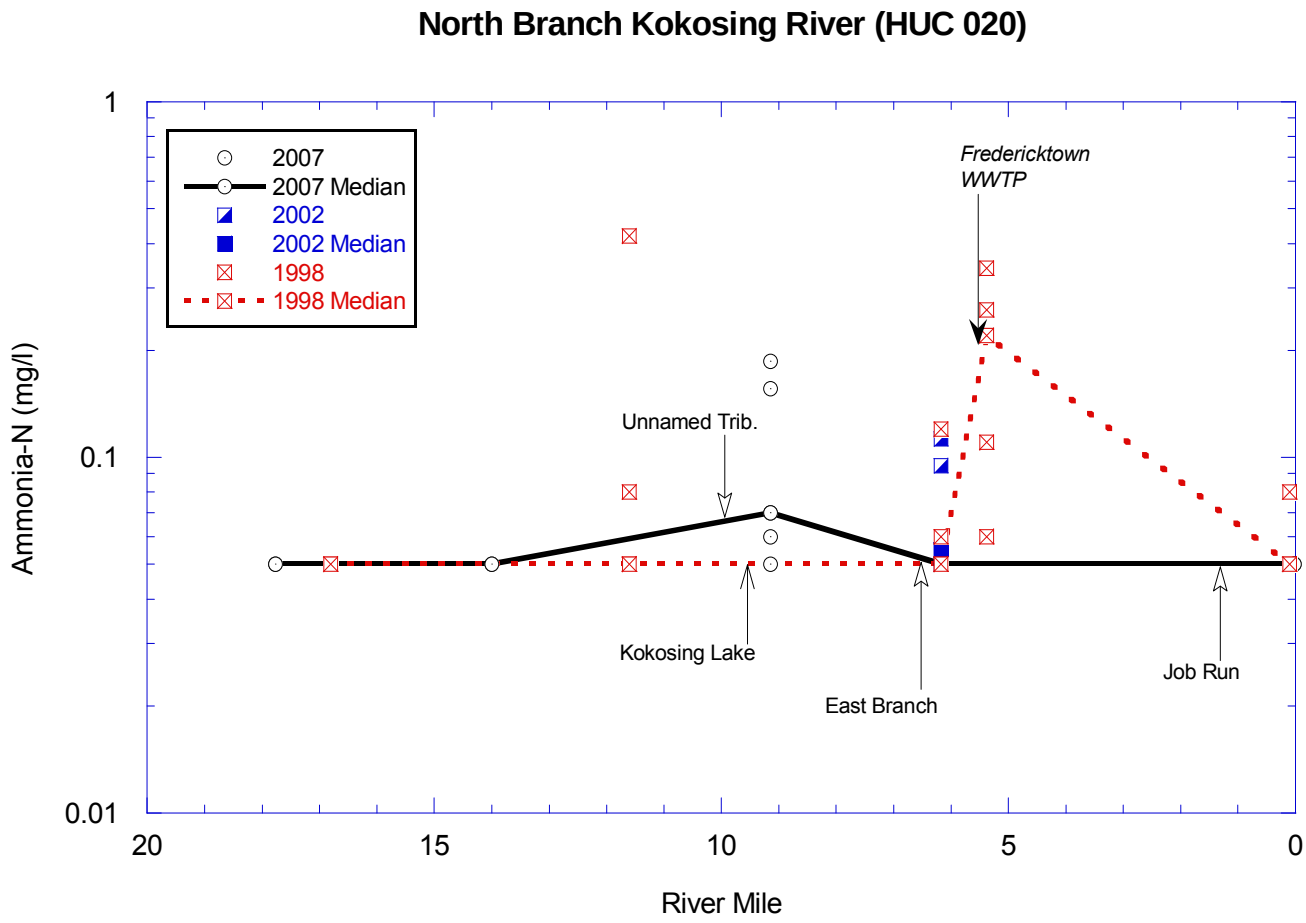

Figure 47. Historical trends in ammonia-N (mg/l) concentrations for the North Branch Kokosing River longitudinally plotted by river mile.

Again, this is expected in rural, agricultural areas around Ohio outside of the growing season, where increased runoff and drainage from feedlots and tiled fields accelerate the movement of soluble nitrates into streams (Appendix F2) particularly early season nitrate+nitrite values for Big Run RM 0.66, Kokosing River RM 28.61, Dry Creek RM 1.04, Schenck Creek RM 0.55).

Other nutrients such as total phosphorus and organic nitrogen (measured by TKN) were not typically excessive in the North Branch, although there were a few elevated values noted during the survey, mostly related to rain events (Appendix F2).

Water quality values measured in most of the North Branch support the recommendation of an upgrade to EWH from WWH with the only exception at RM 9.2 (just downstream of Kokosing Lake). In situ dissolved oxygen concentrations showed evidence to support such an upgrade. Dissolved oxygen concentrations at all sites (besides RM 9.2) revealed mean and median values well above the 6 mg/l mean standard and only 1 value at RM 14.0 fell under the EWH minimum value of 5 mg/l (Appendix F2). Additionally, data datasonde data taken from 2-day deployments at RM 6.18 and RM 0.02, revealed dissolved oxygen concentrations exceeding 6 mg/l for all measurements (

Figure 48 and Figure 49).

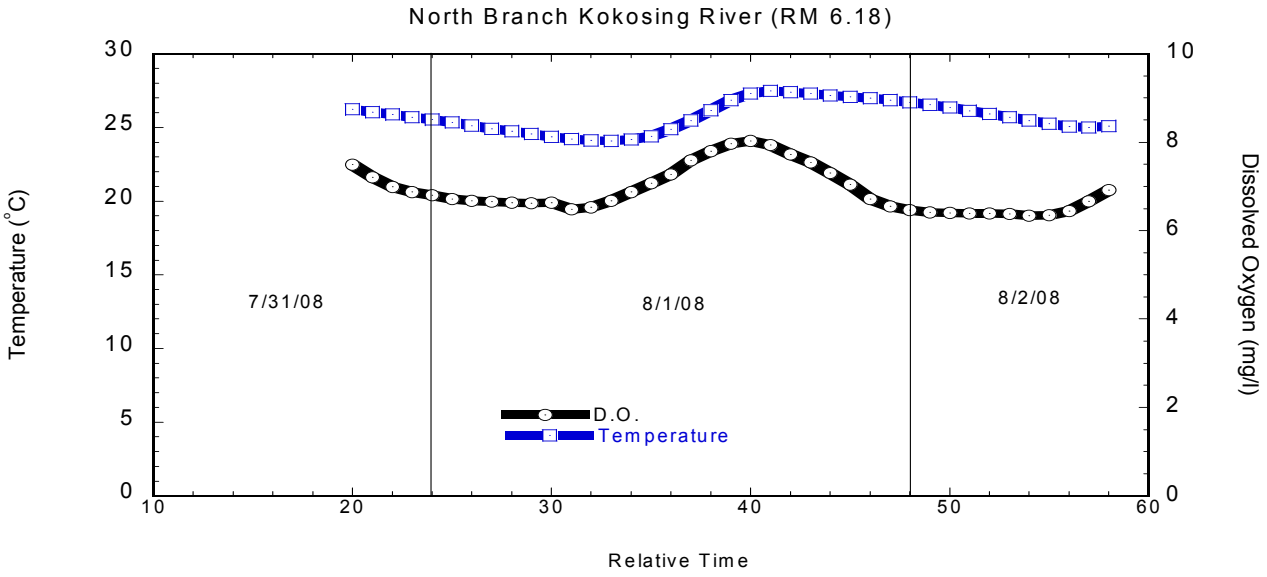

Figure 48. Temperature and dissolved oxygen concentrations in the North Branch Kokosing River (RM 6.18) longitudinally plotted by date and river mile.

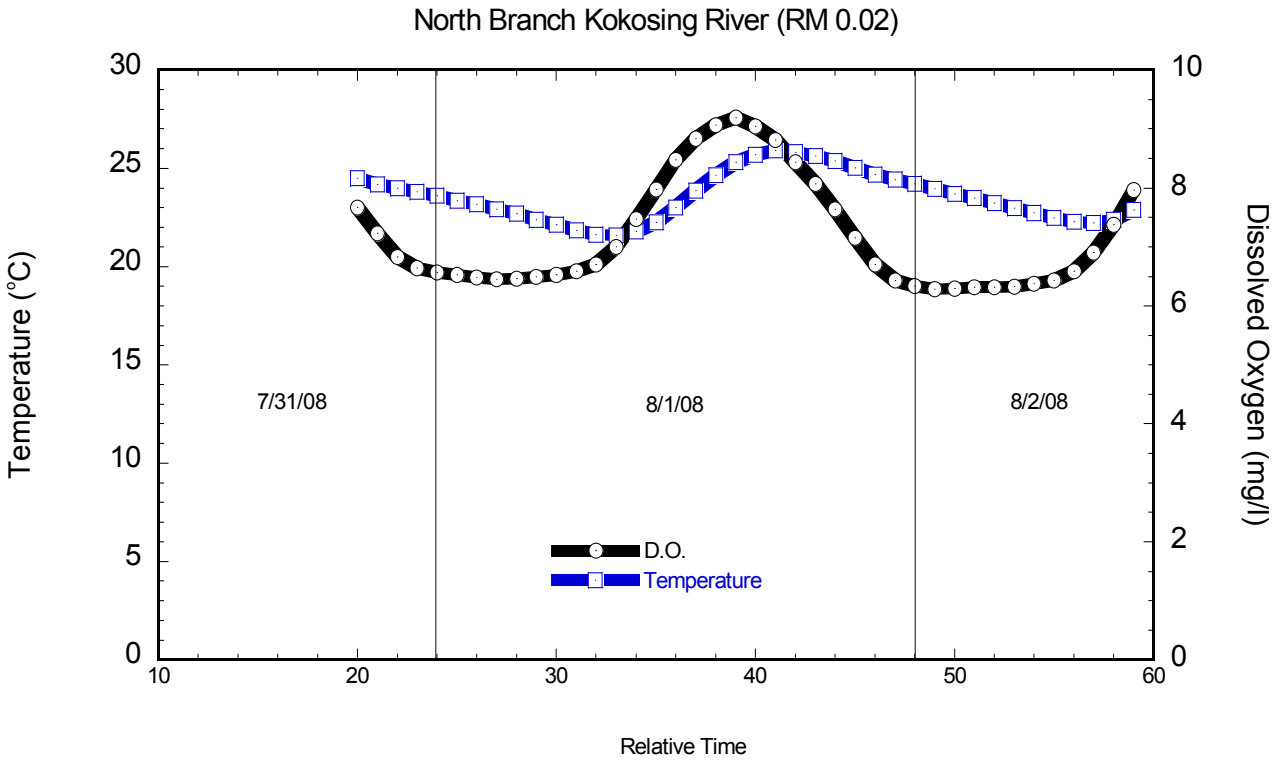

Figure 49. Temperature and dissolved oxygen concentrations in the North Branch Kokosing River (RM 0.02) longitudinally plotted by date and river mile.

Village of Fredericktown

The Village of Fredericktown has a combined sewer system coupled with an older WWTP with a current design capacity of 0.3 MGD. Treatment consists of manual bar screens, two flow equalization basins, grit removal, primary clarification, trickling filters, secondary clarifiers, chlorination and dechlorination. The average daily flow for the period January 2007 through March 2008 was 0.37 MGD.

A new sewage treatment plant is currently under construction for the village and should be completed and operating sometime during October 2008. The new plant will be designed to treat 0.7 MGD and will consist of two flow equalization basins of 410,000 gallons each, a new pump station, mechanical screening, grit removal, a modified oxidation ditch with 3 channels, two final clarifiers, ultraviolet disinfection, and post-aeration. Sludge will be gravity thickened, passed through a belt filter press and conveyed through a microwave unit for pathogen destruction. The final product will be in the range of 85-90 % solids and approval is being sought from USEPA to make this an alternative Class A sludge process. The old plant has had numerous permit violations over the past year; however, part of this is due to ammonia limits in the permit which were not supposed to take effect until the new plant was operating.

Tributaries to the North Branch Kokosing River

Unnamed Tributary to North Branch Kokosing River at RM 9.99 (Undesignated)

This headwater stream drains less than 20 square miles of rural farmland in northeastern Knox County and east-central Morrow County. Water chemistry was evaluated near the center of the basin at RM 4.04 on Ruggles Road. Temperature data obtained from this stream indicates substantial influence from ground-water. Cooler water temperatures were maintained throughout the hot summer months.

There were several water quality problems noted in this stream. Dissolved oxygen concentrations were significantly below the WWH standard of 4 mg/l for 3 of 5 samples and bacteria concentrations were highly elevated in all 5 samples. Organic forms of nitrogen (as measured by TKN) were elevated instream as was nitrite-N. Total suspended solids were also mildly elevated when compared with other similarly-sized streams (Figure 50).

These water quality problems were caused in large part by an adjacent cattle farm. Cattle were allowed free access to the stream throughout the pasturage area and were found eliminating into the stream itself on each sampling occasion. Animal wastes are sources of nutrients and bacteria as well as oxygen demanding substances. Additionally, the constant movement of cattle in and out of the stream denudes the banks of protective vegetation and allows for significant erosion, smothering rocky substrates and adding suspended solids to the water column.

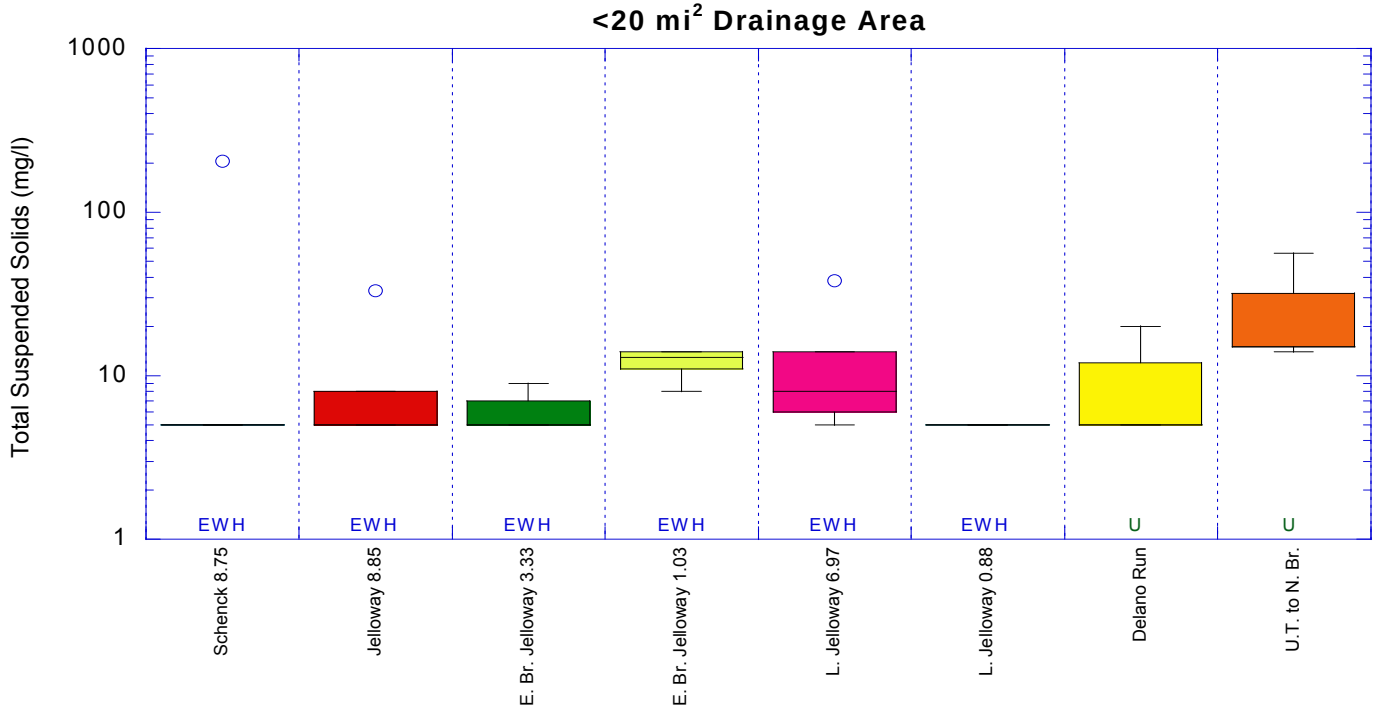

Figure 50. TSS values in mg/l for headwater streams in the Kokosing River watershed listed by stream and river mile.

Job Run (WWH, AWS, IWS, PCR)

Job Run is a headwater stream encompassing approximately 8.5 square miles drainage. It discharges directly to the North Branch at RM 1.34 and is located roughly midway between Fredericktown and Mt. Vernon.

Job Run exhibited cool summertime temperatures indicative of substantial groundwater influence. Instream, midday dissolved oxygen concentrations were excellent and among the best of any headwater stream found in the survey (Figure 51 and Figure 52, pg. 131). Significant concentrations of bacteria were also found in most samples, violating recreation use criteria but were typical of most of the headwater streams evaluated in this survey (Figure 53, pg. 131).

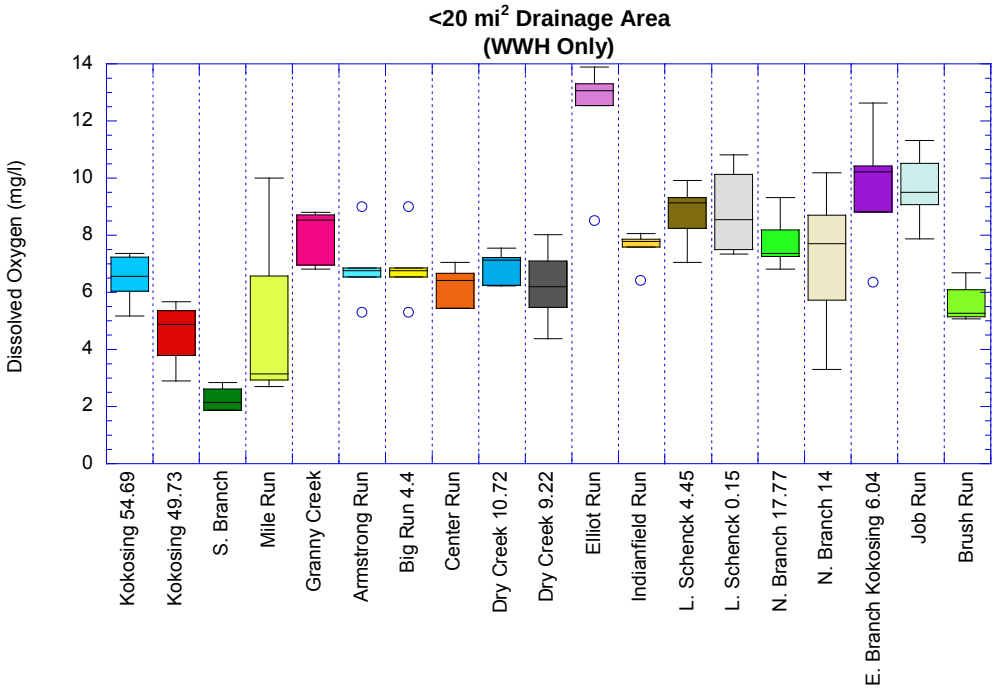

Figure 51. Dissolved oxygen concentrations (mg/l) in Kokosing River watershed headwater streams listed by stream name and river mile for the 2007 sampling season.

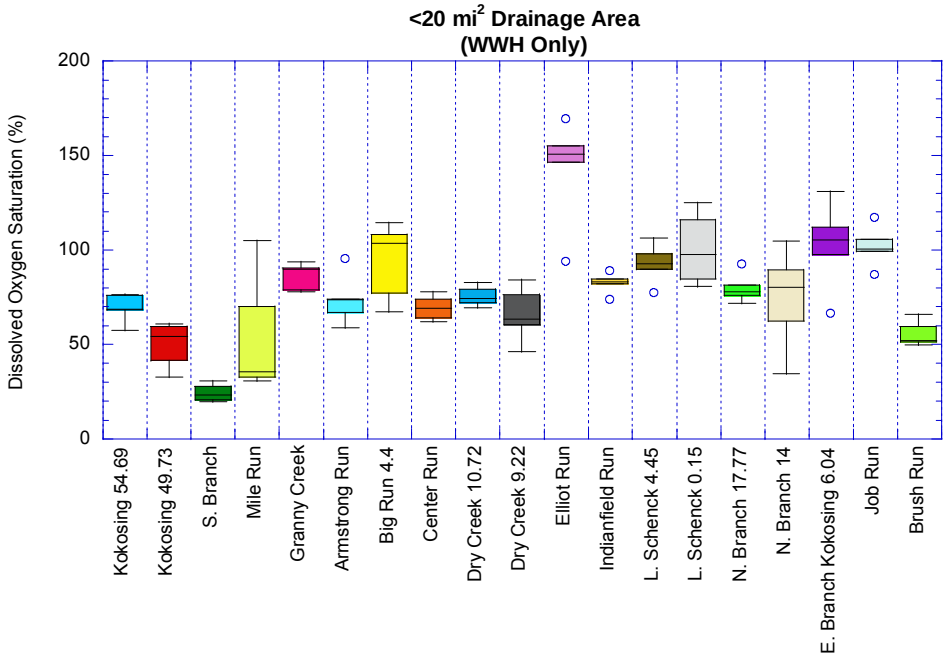

Figure 52. Percent saturation for dissolved oxygen concentrations for headwater streams in the Kokosing River watershed, 2007.

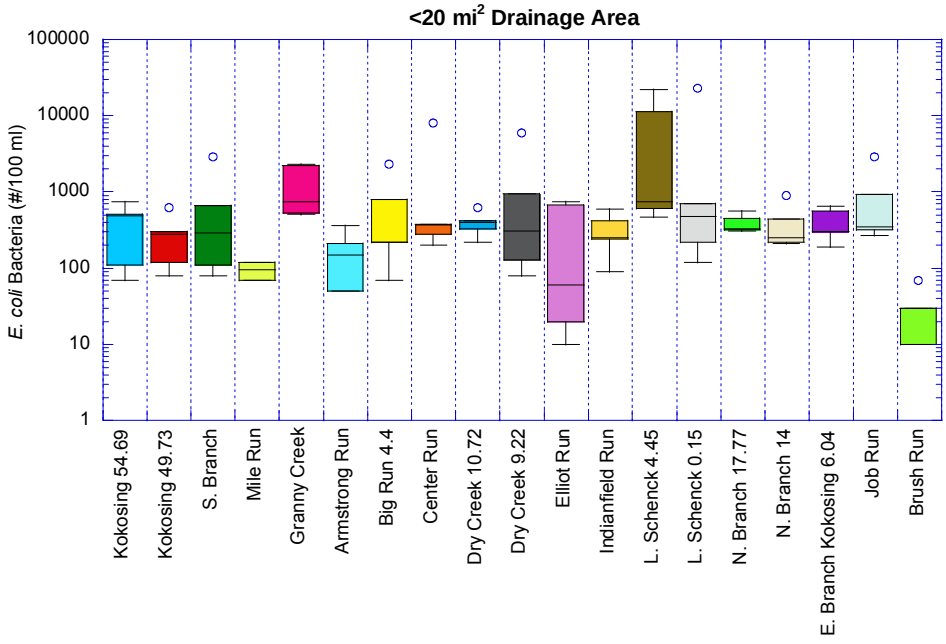

Figure 53. E.coli concentrations in Kokosing River watershed headwater streams listed by stream name and river mile, 2007.

East Branch Kokosing River (WWH, AWS, IWS, PCR)

The East Branch Kokosing River is actually a tributary to the North Branch. The East Branch is dominated by Knox Lake. Chemical water quality was evaluated at 2 sites, one upstream of the reservoir at RM 6.04 and one downstream at RM 0.10.

The upstream site revealed an open, straightened channel which facilitates agricultural drainage. In spite of the lack of riparian shade, upper East Branch exhibited cool water temperatures indicative of a significant groundwater flow component (Appendix F2) Excellent concentrations of dissolved oxygen were also present (Appendix F2). Moderate dissolved oxygen supersaturation was noted and E. Branch values were on the high side for headwater streams (Figure 52, pg. 131).

Nutrient concentrations were well within normal ranges for nitrates, TKN, and total phosphorus. Supersaturated dissolved oxygen coupled with low nutrient concentrations are often artifacts of high primary productivity. Additionally, significant numbers of *E. coli* bacteria were noted instream revealing violations of recreation use criteria in the majority of samples (Appendix F2, Table 10, pg. 52). In spite of some water quality disturbances, biological communities easily met WWH water quality standards (Table 2, pg. 10).

The downstream site was influenced by the reservoir. Water temperatures were more than 5 ^{o}C higher than the upstream site averaging 23.18 ^{o}C (Appendix F2). Most nutrients and *E. coli* bacteria were not found in any appreciable concentrations. The only parameter with mildly elevated concentrations was ammonia-N, likely due to the influence of the reservoir upstream (Appendix F2). Again, biological communities at this site met WWH water quality standards.

Macroinvertebrates

North Branch Kokosing River

The North Branch Kokosing River, with abundant groundwater and excellent habitat, contained an exceptional macroinvertebrate community virtually throughout its length with only two exceptions. There was very good or marginally exceptional macroinvertebrate performance adjacent to Pinkney Rd (RM 8.7) with decreased EPT and sensitive taxa due to increased sand embeddedness and influences from Kokosing Lake as well. There was, though, the largest variety of mussel taxa collected during the survey at this site. Downstream from the Fredericktown WWTP there was an increased NPS silt deposition of up to 0.5 inch on the substrates which increased embeddedness and decreased diversity, especially among cased caddisflies and hellgrammites which attach to or utilize rocky substrates. These conditions temporarily caused by WWTP improvement/expansion construction were resolved soon after sampling. The North Branch Kokosing River overall is performing at an exceptional level and is recommended for the EWH aquatic life use designation throughout its length to its confluence with the Kokosing R. mainstem at SR 13 except for immediately downstream from the Kokosing Lake Dam.

The upper two sites sampled on the North Branch Kokosing River also demonstrated a coldwater component, as eight CW taxa and three CW taxa were collected at Mt. Vernon-Tiffin Rd. (RM 17.77) and Levering Rd. (RM 14.0), respectively. Coldwater taxa, such as the sensitive caddisflies *Ceratopsyche slossonae* and *Glossosoma* sp. and CW stonefly *Leuctra* sp., were predominant or common in this upper reach of the North Branch. Also with the supporting evidence of the presence of CW fish, these upper two sites were recommended for CWH aquatic life use designation.

North Branch Kokosing River Tributaries

Tributary to North Branch Kokosing River @ RM 9.99 (undesignated)

This unnamed tributary flows east from Morrow County into the North Branch Kokosing in Kokosing Lake. The reach sampled flowed through an open pasture area and therefore it is nutrient enriched with algal mats in open canopy areas of the stream. Where rocky substrates were available above the softer bottom cased caddisflies, including *Neophylax*, *Helicopsyche borealis*, and *Pycnopsyche* sp., were present in good numbers. The mayfly population was somewhat limited, but the caddisfly taxa present were representative. The midge population collected was mostly MI and facultative taxa with six tanytarsini taxa. Overall the macroinvertebrate community performance of marginally good met the WWH biocriteria expectations, but fencing the stream within the pasture with only a couple of accesses for crossings would decrease the silt and nutrients immediately available to enrich the stream. Also, partitioning the stream from livestock would decrease somewhat the fecal bacteria delivery to this stream and thus to Kokosing Lake which would decrease public exposure.

East Branch Kokosing River (WWH, AWS, IWS, PCR)

The upper East Branch of the North Branch Kokosing River was sampled at RM 6.0 upstream from Knox Lake. Upstream from Toms Rd. along SR 93 just in Knox County the stream had been recently channelized. Downstream from Toms Rd. it was stable within a wooded tract. There was some sand bedload that had transported downstream from the channelized portion, but in stable stick riffles and coarse gravel in riffles and runs there an abundance of hydropsychids, tanytarsini midges and baetids. There were nine EPT taxa sampled, and 24 sensitive taxa collected with a high S/T ratio of 4.80. One of the predominant hydropsychid caddisflies collected was the CW *C. slossonae*. There was good macroinvertebrate community performance meeting the WWH ecoregional expectations. Three CW taxa were collected (matching with the documented CW fish present), and the upper reach is recommended for CWH aquatic life use designation to the confluence into Knox Lake.

The lower reach downstream from Knox Lake before the confluence with the North Branch Kokosing River was sampled near the mouth (RM 0.1) in a Fredericktown park. There was an excellent riffle habitat with coarse substrates, and developed pools with woody debris and mixed rocky substrates. The largest number of qualitative taxa (70) and total taxa (86) collected at any one site occurred here. Also the most variety of mussel taxa collected at one site in this survey occurred here and similarly upstream on the North Branch Kokosing River downstream from Kokosing Lake. There were 20 total

EPT and 34 total taxa collected. Very good or marginally exceptional community quality was observed despite some enrichment from Knox Lake inputs upstream. Sensitive (Moderately Intolerant) *Chimarra*, *Psychomyia*, *Neophylax*, and hydropsychid caddisflies with tanytarsini midges were predominant or common with facultative flatworms and Moderately Tolerant *Glyptotendipes* midges.

Job Run (WWH, AWS, IWS, PCR)

This small coldwater tributary flows south into the North Branch Kokosing River north of Mt. Vernon near Upper Fredericktown Rd.. The exceptional macroinvertebrate community quality was demonstrated by CW caddisflies, MI *Rheotanytarsus* midges, and *Elimia* snails being predominant in the riffle and runs. There were high numbers of qualitative EPT taxa (23) and sensitive taxa (28) along with a high S/T Ratio of 5.60 which indicated recovery from earlier channelization utilizing available rocky substrates amidst areas of sand bedload. The Aquatic Life Use Designation of Job Run is recommended to be upgraded to EWH and CWH from the current Warmwater Habitat use. The additional recommendation of the CWH Aquatic Life Use is based on the collection of three coldwater taxa, two of which were predominant caddisflies, and the presence of two coldwater fish taxa.

Fish Community

North Branch Kokosing River (WWH, AWS, IWS, PCR)

Fish sampling was conducted at 10 stream monitoring sites in this unit, 6 sites on the North Branch Kokosing River, 2 sites on the East Branch, and 1 site each on Job Run and an unnamed tributary of the North Branch coming in at RM 9.99. (Table 9, pg. 46). The average IBI score for the North Branch of the Kokosing River was 50.5, fully meeting EWH criteria. The upper two fish sampling locations (RM 17.8 and RM 14.0) yielded IBI scores of 50 and 54 respectively. Two cold water fish species, redside dace and the mottled (Cottus bairdii) sculpin, were recorded at both sites (Appendix C and Figure 54). The collection of cold water Macroinvertebrate taxa were also recorded at these locations further support the recommendation to protect the North Branch with the CWH use designation (Table 2, pg. 10).

Figure 54. Two cold water fish species collected in the North Branch Kokosing River at RMs 17.8 and 14.0, redside dace (left) and mottled sculpin (right).

As the North Branch flows from Kokosing Lake stream temperatures downstream of the dam making it uninhabitable to stenothermic fish species at RM 9.2, which was dominated by yellow bullhead, *Ameriurus natalis*, catfish (Appendix C). The historic WWH use designation assigned to the North Branch will remain at this lake influenced sample site downstream to RM 6.3. Downstream, cold ground water and good habitat restored the biological integrity of the fish community in the North Branch from RM 6.2 to its confluence with the Kokosing main stem (with the exception of a resolved sediment issue downstream of the Fredericktown WWTP). This section from RM 6.2 to its mouth is designation Exceptional Warm Water habitat (Table 2, pg. 10).

Sediment runoff from poor construction practices at the Fredricktown WWTP contributed to this segment only partially attaining its recommended EWH designated use. A low narrative score for the Macroinvertebrate community (G*) at RM 5.5 showed the immediate effects of the sediment runoff. This issue has since been resolved (Table 2, pg. 10).

North Branch Kokosing River Tributaries

Unnamed Tributary to North Branch Kokosing River at RM 9.99 (Undesignated)
This headwater stream drains less than 20 square miles of rural farmland in northeastern Knox County and east-central Morrow County. The fish community was evaluated down stream of Ruggles Road RM 4.0, just down stream of an open cow pasture (Table 9, pg. 46).

Results from the fish sampling at this location were poor, IBI = 32* (Table 2, pg. 10). Pollution tolerant fish such as creek chubs and central stoneroller minnows dominated the fish community. The riparian buffer adjacent to the sample site, downstream of the open pasture, was intact. However, the substrates were smothered in organic sediments most likely washed down from the open pasture. Water chemistry results showed low dissolved oxygen and organic enrichment to be problematic. Some of the physical effects of organic enrichment such as algae blooms were alleviated by the cold ground water keeping surface water temperatures low.

Job Run (WWH, AWS, IWS, PCR)
Job Run is a headwater stream encompassing approximately 8.5 square miles drainage. It discharges directly to the North Branch at RM 1.34 and is located roughly

midway between Fredericktown and Mt. Vernon. Fish sampling was conducted upstream of County Road 6, Upper Fredricktown Road, RM 0.08 (Table 9, pg. 46).

This stream segment was channelized and appeared to be regularly mowed along the banks. Cold ground water helped to keep the fish community in balance ameliorating any possible runoff problems from adjacent row crops or increased surface water temperatures from the lack of shade. Pollution sensitive taxa such as: least brook lamprey and hornyhead chubs were part of the fish community at this location which met EWH criteria (IBI = 48^{ns}) (Table 2, pg. 10). Two cold water fish species, brook stickleback and mottled sculpin, supported the recommendation to designate and protect Job Run as a cold water habitat (Appendix C).

East Branch Kokosing River (WWH, AWS, IWS, PCR)

The East Branch Kokosing River is actually a tributary to the North Branch. The East Branch is dominated by Knox Lake. Fish communities were evaluated at 2 sites on the East Branch Kokosing River, one upstream of the reservoir at RM 6.1 and one downstream at RM 0.10 (Table 9, pg. 46).

Both sample sites on the East Branch met the criteria for the existing WWH designated uses. Cold ground water at this location has held in check many of the problems usually associated with open cow pastures (please see habitat section for more specifics on this location). Despite very poor habitat, the upstream site was home to a cold water fish community with redside dace, mottled sculpin, and brook stickleback recorded among other species at the site. The CWH use designation is being recommended to protect the headwaters of the East Branch. The lower site, downstream of Knox Lake, scored 51 on the IBI and fully met recommended EWH use. The fish community at the mouth was home to twenty-seven species, many of which were pollution sensitive simple lithophilic spawners (Appendix C).

Habitat

North Branch Kokosing River (WWH, AWS, IWS, PCR)

Physical habitat quality was assessed at all of the fish sampling sites in the North Branch Kokosing River assessment unit (Table 9, pg. 46). The QHEI scores were very good on (0 = 75) the North Branch Kokosing River (Table 2, pg. 10). The North Branch was found to be a very clear water stream with moderate to fast flow throughout its drainages. Heterogeneous habitat supporting exceptional biological communities was found at five of the six sampling locations (Appendix A). The exception was the sample site downstream of the North Branch Kokosing River Lake outlet (RM 9.15). Stream flow in this section was primarily controlled by the discharge from the lake outlet. Water was directed to a straight glide (lined with riprap and exposed to full sun which was ~400m long) and then to a large man-made pool habitat under and around the bridge on Overly Road.

Fish, macroinvertebrate, and habitat sampling was conducted beyond the Overly Road bridge, downstream of the first riffle. Habitat features at this location were less developed than other sections of the North Branch. The riffles had less depth and consisted more of large gravel rather than cobble and boulder substrates. Pools were less developed as well, having less depth than upstream sections which were smaller in drainage area. Overall, the river had less energy to create and maintain complex habitats capable of supporting diverse biological communities. Given the relative permanence of the reservoir and the expectation that the local conditions downstream from the dam will not be changing the decision was made to designate the short reach immediately downstream from the dam as WWH to reflect the biological communities that are attainable given prevailing water resource conditions. The exceptional water quality of the North Branch rebounded at the next downstream site and persisted to its confluence with the Kokosing River.

North Branch Kokosing River Tributaries

Three tributaries to the North Branch Kokosing River were evaluated for physical habitat quality (Job Run, East Branch Kokosing River, and a tributary that comes into the North Branch of the Kokosing River at RM 9.9).

Job Run (WWH, AWS, IWS, PCR)

The physical habitat at Job Run (RM 0.1) was fair, QHEI = 46.5. The stream had been straightened and mowed right up to the edge of both banks. Seasonally sparse shading was provided by some instream grass lining the stream channel. The channel

morphology was poor, but it did show some signs of recovery. However, there may not be enough flow in this headwater stream for it to fully recover on its own without engineering a new channel. A very shallow and unstable riffle comprised of fine gravel and sand was the best habitat feature present. Despite such degraded habitat, Job Run was in full attainment of the recommended EWH and CWH aquatic life uses (Table 2, pg. 10). Direct ground water connections dominated the flow in Job Run and alleviated the potentially harmful effects of habitat degradation. It is recommended to allow the vegetative riparian buffer grow back along Job Run.

East Branch Kokosing River (WWH, AWS, IWS, PCR)

The headwaters of East Branch Kokosing River (RM 6.1) had the most impaired physical habitat scored in the entire watershed study, (i.e., QHEI=23). This section of stream was recovering from channel straightening. The predominant substrate was silt, completely embedding the instream substrates. The adjacent land use was an active open cow pasture with freshly trampled stream banks and sparse mature vegetation along the East Branch (Figure 55). Some of the silt at this site came from upstream sources as well. A couple miles upstream from the sample site at State Route 95, the East Branch had been straightened, leveed, and stripped of vegetation (Figure 56). This appeared to be a significant source of sediment runoff. Cold ground water in the East Branch helped to ameliorate the harmful effects of poor habitat, helping this site reach full attainment of its recommended CWH aquatic life use (Table 2, pg. 10). It is recommended the cattle be fenced out of the stream and an alternative watering method be developed at Tom's Road. Water resource quality can be improved at State Route 95 by allowing the riparian buffer and natural stream channel to reestablish and halting the ditch maintenance.

Figure 55. Trampled stream banks on East Branch Kokosing River (RM 6.1).

Figure 56. East Branch Kokosing River at State Route 95 had been straightened, leveed, and stripped of vegetation.

Excellent habitat characterized the East Branch near the confluence with the North Branch (RM 0.1) with a QHEI score of 87.5. The biology reflected this by meeting the recommended EWH aquatic life use criteria. However, the cold water habitat found upstream was lost as a result of the warming effects from Knox Lake.

Unnamed Tributary to North Branch Kokosing River at RM 9.99 (Undesignated)
An unnamed tributary to the North Branch was assessed for physical habitat downstream of an open cow pasture at Ruggles Road (RM 4.04). Organic sediments smothered the otherwise coarse substrates in the upper half of the sample site, closest to the open pasture. Approximately one hundred meters downstream of the open pasture, the North Branch tributary already showed signs of recovery compared to the decimated stretch that flowed through the open pasture. A good vegetated riparian corridor, coarser substrates (gravel and cobble), cold water, and sinuosity helped aid the tributary's start to recovery. Were it not for the cold ground water in this reach, limiting algae growth, the effects of the excess nutrients (via cow manure) could have been much more harmful to the aquatic community. It is recommended to fence the cows out of the stream and provide an out of stream watering area.

Middle Kokosing River Assessment Unit (05040003-030)

The Middle Kokosing River assessment unit (Hydrologic Unit Code 05040003-030) encompasses the drainage area of the Kokosing River from just downstream of the North Branch (RM 29.66) to just upstream of the confluence with Jelloway Creek (RM 11.38). The Middle Kokosing flows in an easterly direction and absorbs several significant tributaries including Armstrong Run, Dry Creek, Center Run, Delano Run, Big Run (including Elliot Run), Indianfield Run, and Schenck Creek (including Little Schenck Creek). This assessment unit is located within the Erie Ontario Lake Plain (EOLP) ecoregion.

Chemical Water Quality

There were 21 stream monitoring sites in this unit that were evaluated for chemical water quality, 6 sites on the Kokosing River mainstem, 4 sites on Dry Creek, 2 sites each on Big Run, Schenck Creek, and Little Schenck Creek, and 1 site each on Armstrong Run, Center Run, Delano Run, Elliot Run, and Indianfield Run. Two effluent discharges were evaluated, one each at the City of Mt. Vernon WWTP and the Village of Gambier WWTP (Table 9, pg. 46).

Middle Kokosing River (EWH, AWS, IWS, PCR)

The Middle Kokosing River was evaluated for chemical water quality at 6 sites extending from RM 28.61, downstream of the confluence with North Branch, to RM 11.55, downstream of Gambier. Generally speaking, water chemistry parameters were within normal ranges for smaller rivers with a few exceptions. Nutrient enrichment in the form of elevated concentrations of nitrate+nitrite and total phosphorus, was evident downstream of the Mt. Vernon WWTP. Nearly all measurements for both of these parameters exceeded the background 75th percentile (Appendix F3). This is the typical chemical composition of water downstream of a major WWTP that does not have tertiary treatment for nutrient removal and one reason that biological communities were impaired downstream of the WWTP (Table 2, pg. 10).

Datasonde deployments revealed no problems with low dissolved oxygen concentrations within this reach of the middle Kokosing River although evidence suggested some problems with supersaturated conditions at locales with more open channels (Figure 57, Figure 58, Figure 59, Figure 60, Figure 61, and

Figure 62).

Recreation use attainment was also impaired at 3 of the 6 sites evaluated due to elevated *E. coli* concentrations (Appendix F3, Table 12, pg. 54). A large storm event on August 22, 2007 influenced recreational use attainment. Diffuse urban and agricultural storm runoff are likely contributing sources. Given that the Kokosing River is a state scenic river downstream of Mt. Vernon and exhibits heavy recreational use during the summer, elevated bacteria concentrations are cause for concern. However, sampling during normal flow conditions (non-storm event) did not indicate a serious bacteria threat for recreational use activities in this reach.

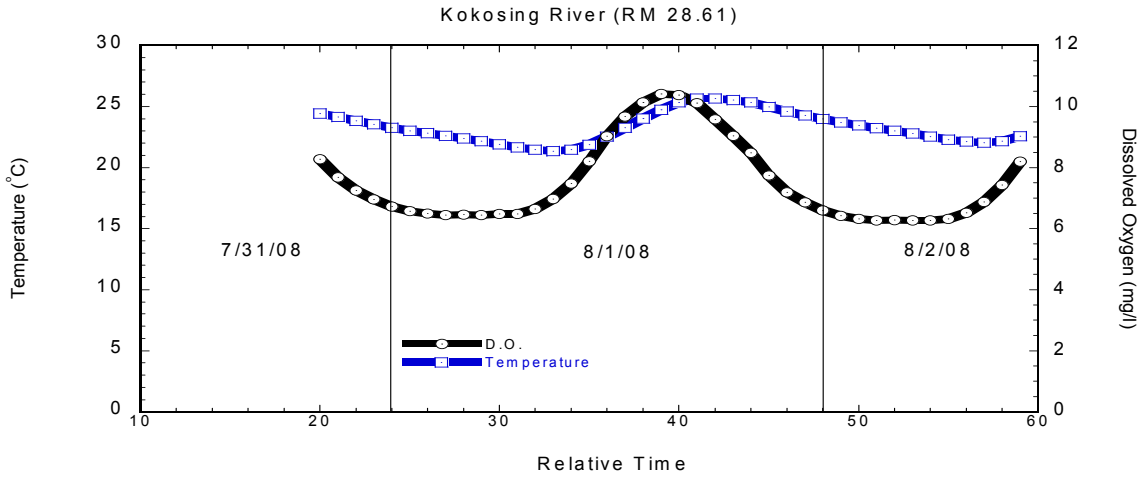

Figure 57. Temperature and dissolved oxygen readings longitudinally plotted by time (hours) and date for the Kokosing River (RM 28.61).

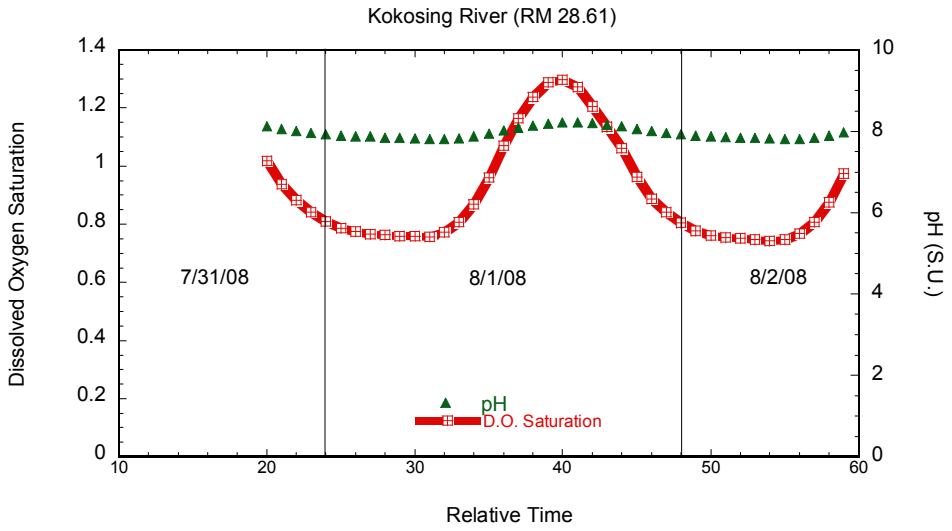

Figure 58. Dissolved oxygen saturation and pH concentrations longitudinally plotted by time (hours) and date for the Kokosing River (RM 28.61).

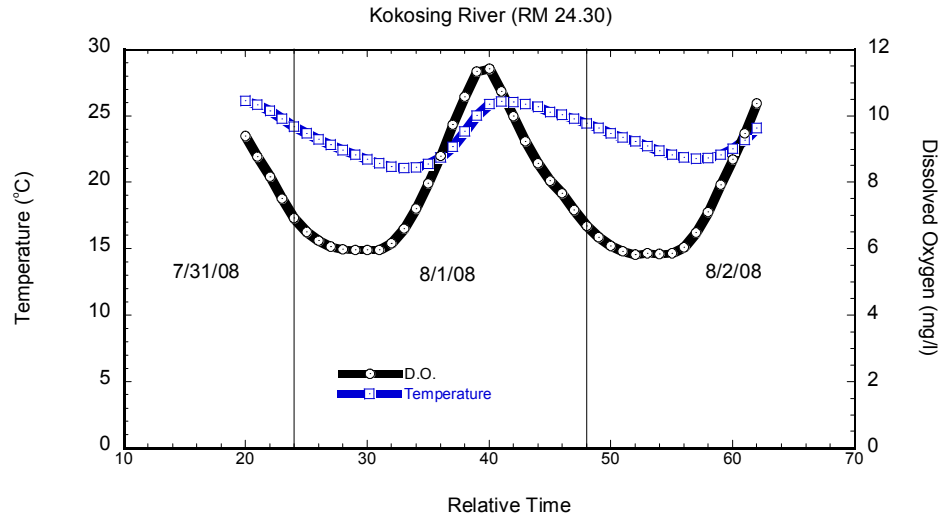

Figure 59. Temperature and dissolved oxygen readings longitudinally plotted by time (hours) and date for the Kokosing River (RM 24.30).

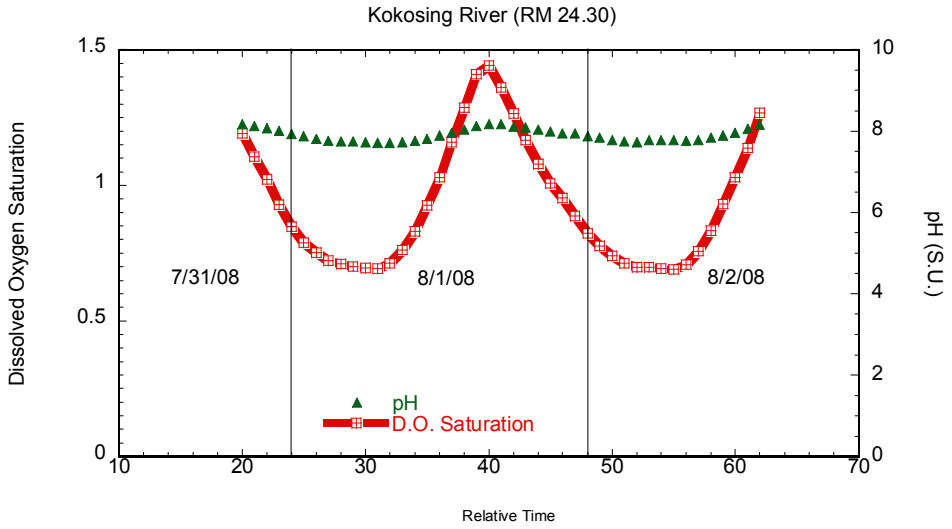

Figure 60. Dissolved oxygen saturation and pH concentrations longitudinally plotted by time (hours) and date for the Kokosing River (RM 24.30).

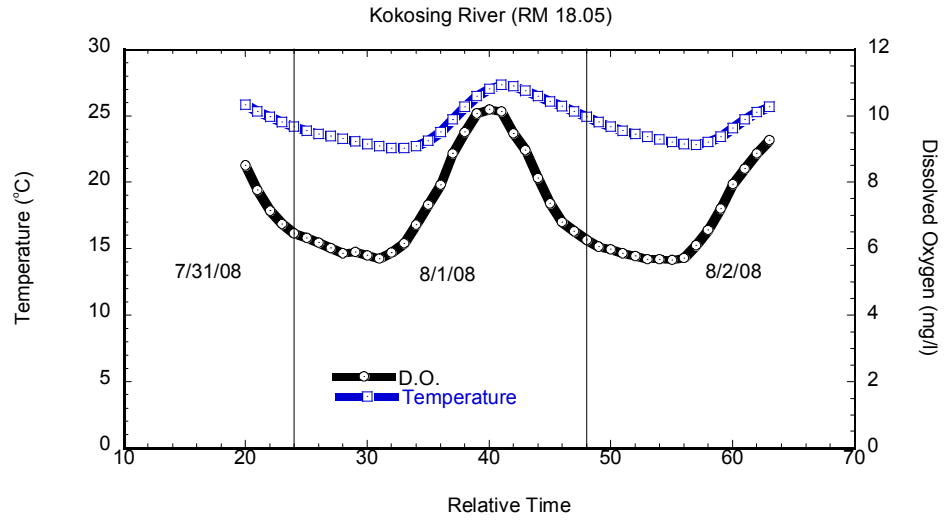

Figure 61. Temperature and dissolved oxygen readings longitudinally plotted by time (hours) and date for the Kokosing River (RM 18.05).

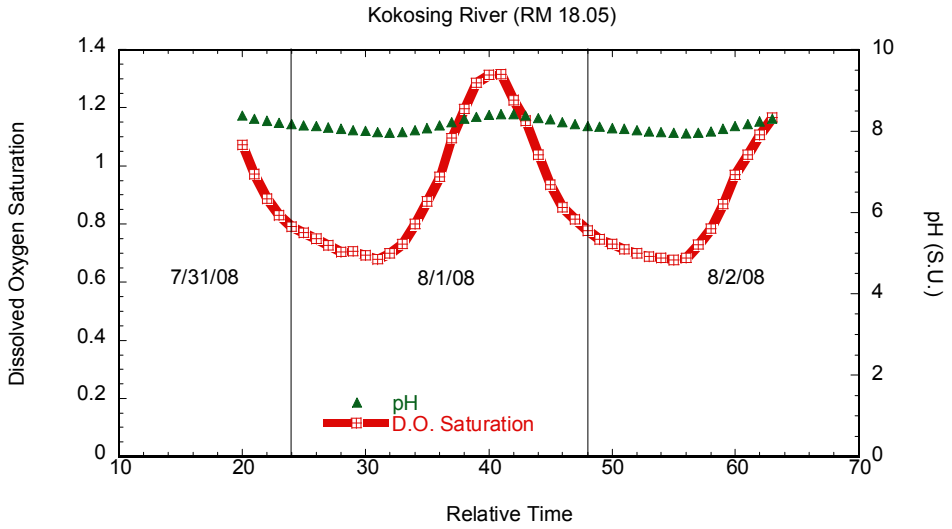

Figure 62. Dissolved oxygen saturation and pH concentrations longitudinally plotted by time (hours) and date for the Kokosing River (RM 18.05).

City of Mount Vernon

The City of Mount Vernon WWTP is designed to treat up to 5.0 MGD and was constructed in 1952 with major upgrades occurring in 1992 and 2007. Additional upgrades are planned over the next few years.

Treatment consists of new (2007) mechanical screening, grit removal, primary clarification, contact stabilization (with new aerators and diffusers installed in 2007), secondary clarification, chlorination and dechlorination. Sludge handling processes include thickening and anaerobic digestion, with eventual land application. The average daily flow for January 2007 through March 2008 was 3.44 MGD. There is significant inflow/infiltration (I/I) in the collection system evidenced by a daily flow of 12.93 MGD recorded on 3/4/08.

Mount Vernon is currently implementing a ■No Feasible Alternatives Analysis 2006 Report• which includes several projects to reduce I/I in the collection system and to eliminate bypasses of the secondary treatment portion of the WWTP (bypasses can occur during power outages and/or heavy precipitation). Implementation of this report will also help to maintain operational efficiency. Ongoing projects include the I/I investigation along with preliminary design for electrical upgrades which include a new generator which will run the entire WWTP and eliminate bypasses due to power outages. Additionally they are instituting upgrades to import all in-plant monitoring to the SCADA system.

The City of Mt. Vernon has been in almost complete compliance with permit limitations for the period March 2007 through March 2008.

Village of Gambier

The Village of Gambier WWTP is a relatively new facility constructed in 1995-1996 with a design capacity of 0.45 MGD. Treatment consists of influent pumping, flow equalization, anoxic treatment basin, dual oxidation ditches, final clarification, chlorination/dechlorination, and post aeration. Sludge is aerobically digested and can either be placed in a sludge drying building with wedge-wire screening, or hauled as a liquid directly to farm fields and incorporated as a soil amendment. The average daily flow for the period January 2007 through March 2008 was 0.16 MGD. There were no permit violations for the period March 2007 through March 2008.

Middle Kokosing River Tributaries

Armstrong Run (WWH, AWS, IWS, PCR)

As with many streams in this survey area, Armstrong Run was influenced by a moderate amount of groundwater which cooled water temperatures and maintained adequate stream-flow throughout the hot and dry summer. Median water temperature was 18.62 ^{o}C, rising only to a maximum of 20.17 ^{o}C at the single sampling location. This compared well with other streams of similar size within the Kokosing River watershed (Figure 41, pg. 118). Cooler water temperatures also served to maintain dissolved oxygen concentrations above WWH water quality criteria, also comparing well with other local headwater streams (Appendix F3 and Figure 51, pg. 130). Daytime supersaturated dissolved oxygen concentrations were not evident during any sampling event.

Nutrient enrichment in Armstrong Run did not appear to be problematic. Nitrate+nitrite concentrations were found between 1.1 and 1.8 mg/l over the entire summer. All results exceeded the EOLP background 75th percentile (Appendix F3) which is not typical of Ohio streams unless they are influenced by a WWTP which treats for ammonia. Of course, nitrate+nitrite was elevated compared to most Kokosing basin headwater streams (Figure 46, pg. 123) and the cause or source of this situation is unknown. Conversely, total phosphorus, ammonia-N, and TKN concentrations were amongst the lowest found in the survey. Nutrient enrichment was not apparent instream in the form of large algal blooms or excessive aquatic plant biomass.

Bacteria populations in Armstrong Run were generally lower than other headwater streams evaluated during the survey (Figure 53, pg. 131). Exceptional biota and very good chemical water quality in Armstrong Run certainly support the proposed upgrade in status from WWH to EWH.

Dry Creek (WWH, AWS, IWS, PCR)

Dry Creek was evaluated at 4 different sites along its length, beginning at RM 10.72 and ending near the mouth at RM 1.04. Monitoring effort was also directed to the area just downstream of the old Knox County landfill at RM 4.52 (Thayer Road).

The upstream station on Dry Creek (RM 10.72) showed evidence, through elevated strontium concentrations, that groundwater provided a significant percentage of flow to the stream (Figure 63, pg. 149). Water temperatures also confirmed the likelihood of some groundwater contribution to surface flows as temperatures were comparable to other headwater streams with these attributes (Figure 41, pg. 118). Water temperatures were cool along the length of Dry Creek with the median stream temperature hovering between 17.7 and 20.5 ^{o}C (Figure 64, pg. 149). Riparian shading enhanced cool water temperatures at all sites but the one at the mouth.

Cool temperatures helped promote therapeutic concentrations of dissolved oxygen in Dry Creek. Even during dry summer conditions where flows were reduced to low volumes, median dissolved oxygen concentrations never fell below 6 mg/l (Appendix F3 and Figure 65, pg. 150). Datasonde deployments at the end of July confirmed very good concentrations of dissolved oxygen present throughout the day at RM 1.04 (Figure 66, pg. 150).

Nutrient enrichment was not problematic in Dry Creek during the summer low-flow period. Elevated concentrations of nitrate+nitrite and occasional high concentrations of phosphorus were the only nutrients of concern noted at RM 1.04 during the winter and early spring months similar to other sentinel sites monitored in the basin (e.g., Big Run, Schenck Creek, See Appendix F3).

E. coli bacteria concentrations were often elevated in Dry Creek, especially in the upper portion of the basin. Recreation use attainment was not met at the two upper sites (Table 12, pg. 54). Here, the village of Mount Liberty is unsewered. One source of this contamination was observed directly at RM 9.22 in the form of black sewage solids resting on the creek bottom. These solids were present during all low-flow sampling events and were indicative of contamination from poorly operating home sewage treatment systems discharging to the stream. These conditions will improve as the Knox County Board of Commissioners move forward with plans to install a community sewage treatment system for this area.

Good chemical water quality found in Dry Creek contributed to the high quality macroinvertebrate and fish communities found in the stream at RM 10.72 and RM 9.22.

Water quality conditions are capable of supporting the recommended Exceptional Warmwater Habitat aquatic life use in upper Dry Creek. At RM 4.52, downstream of the old Knox County landfill, water quality conditions were satisfactory. Biological communities at this site were in full attainment of WWH criteria.

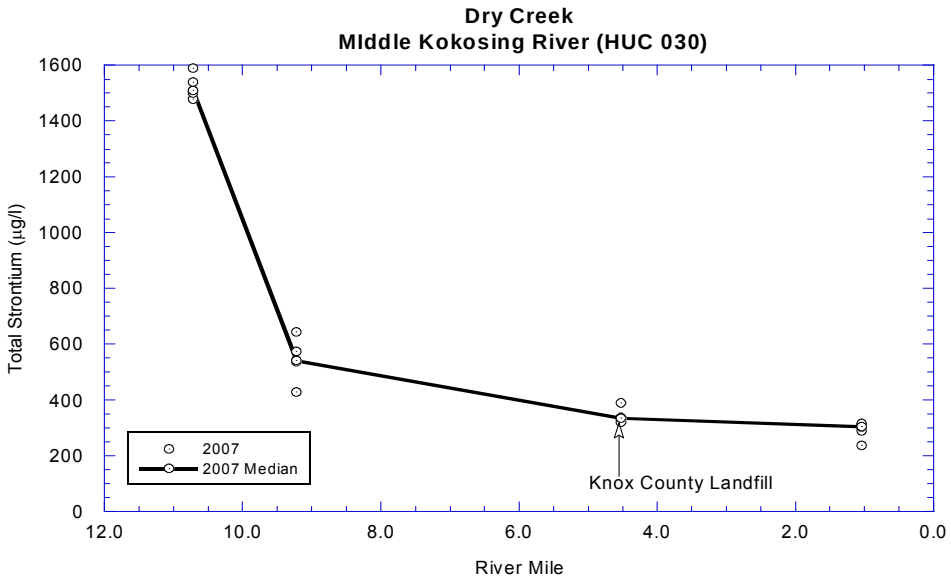

Figure 63. Strontium concentrations (µg/l) longitudinally plotted by river mile for Dry Creek, 2007.

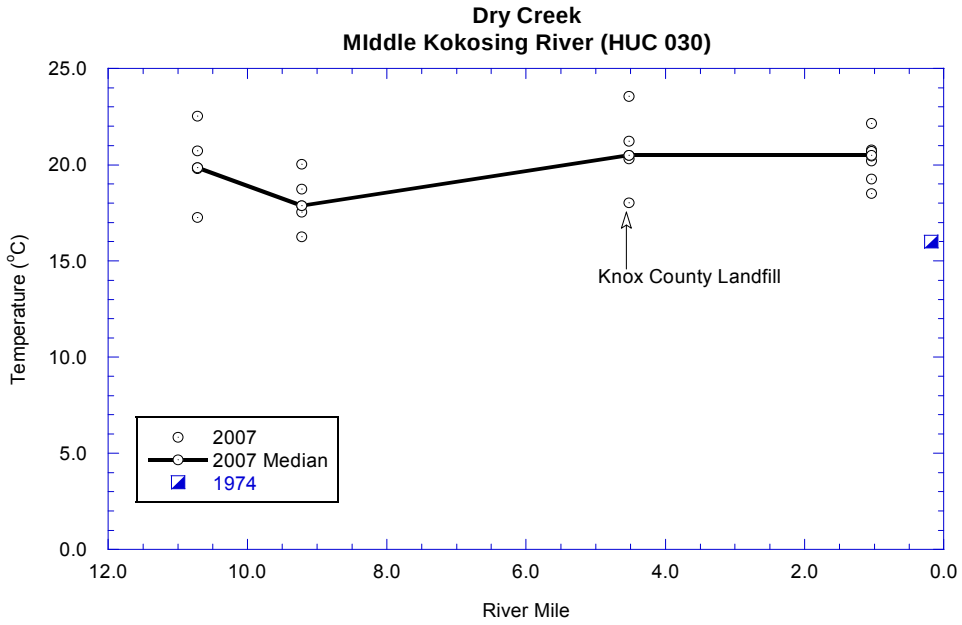

Figure 64. Ambient temperature readings longitudinally plotted by river mile for Dry Creek, 2007.

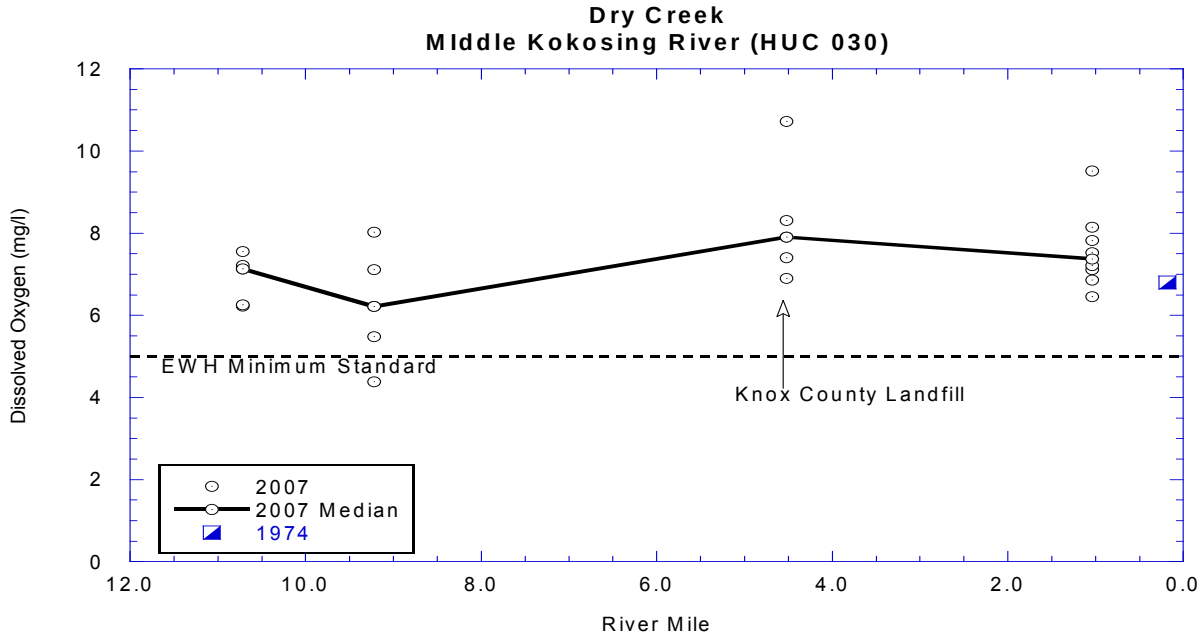

Figure 65. Dissolved oxygen (mg/l) reading longitudinally plotted by river mile for Dry Creek, 2007.

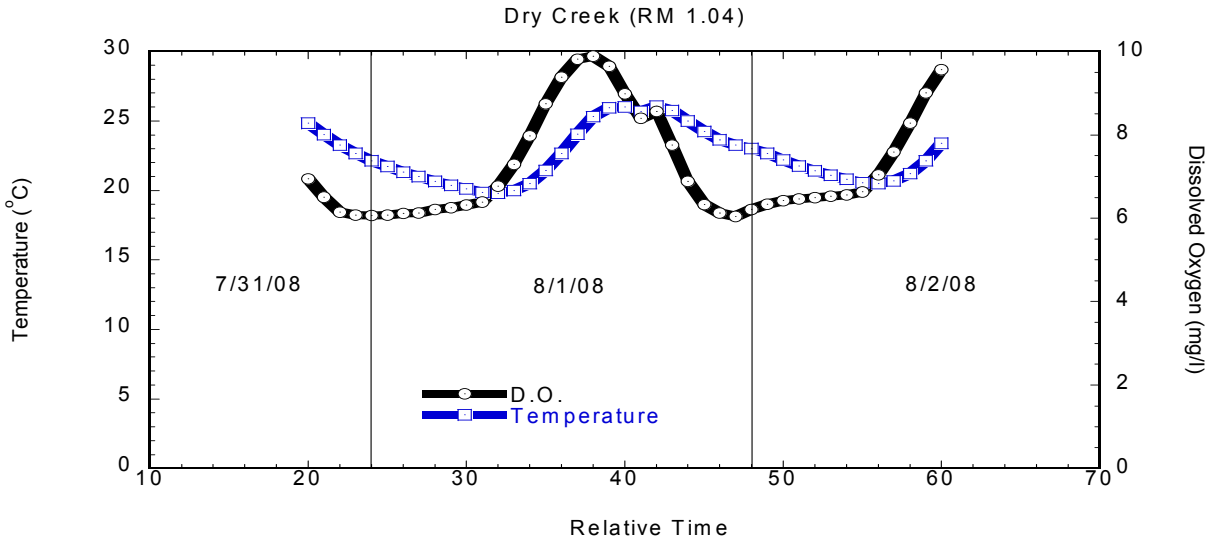

Figure 66. Temperature and Dissolved oxygen concentrations longitudinally plotted by date and time (hours) for Dry Creek (RM 1.04).

Center Run (WWH, AWS, IWS, PCR)

Center Run is a small headwater stream flowing through the northern portion of Mount Vernon. One site was evaluated for chemical water quality. In some ways, this stream was an enigma. While the stream had evidenced of historical channel modification and the effects from urban runoff (e.g., litter noted instream), the only impairments noted were from bacteria (Appendix F3, Table 12, pg. 54).

Water temperatures were moderately low, with a median around 20.48 ^{o}C. Dissolved oxygen concentrations were more than adequate for a WWH stream. Nutrient and organic enrichment were not evident. Additionally, biological communities exhibited exceptional performance. Typically, urban streams do not have these attributes. Current chemical water quality conditions support of the upgrade in biological use from WWH to EWH.

Delano Run (Undesignated)

Delano Run is a small, urban headwater stream that flows into the Kokosing River on the far south side of Mount Vernon. The stream drains into an impoundment prior to discharge to the Kokosing River. Water quality sampling was performed at one site upstream of the impoundment. Dry summer weather reduced Delano Run to a series of disconnected pools during July and early August with accompanying water quality problems including chronic, elevated concentrations of ammonia-N (median=0.125 mg/l), and excessive concentrations of *E. coli* bacteria and low dissolved oxygen concentrations (median = 2.47 mg/l) due to a lack of reaeration from consistent flow (Appendix F3).

Big Run (WWH, AWS, IWS, PCR)

Big Run was evaluated at 2 sites during the survey. The upstream site at RM 4.4 consisted of a historically modified stream channel in open pastureland with little riparian cover. The lower site at RM 0.66 was more wooded and less modified.

Water temperatures averaged 24.3 ^{o}C and ranged from 21.38 to 27.4 ^{o}C. In fact, the upper site on Big Run had the highest median and maximum temperatures noted for any headwater stream evaluated during the survey (Appendix F3 and Figure 41, pg. 118). The open channel coupled with the lack of groundwater augmentation served to keep summertime temperatures elevated. Despite higher stream temperatures, dissolved oxygen concentrations were well within WWH criteria, averaging 7.84 mg/l and had only minor problems with supersaturation (Appendix F3). Both of these results compared favorably with other headwater streams (Figure 51, pg. 130 and Figure 52, pg. 131.

Nutrient enrichment at this upstream locale was not problematic for nitrate+nitrite or total phosphorus. Ammonia-N exceeded the background 75th percentile in 4 of 5 samples. Additionally, this site exhibited violations of the maximum primary contact recreation standard for *E. coli* on 2 occasions likely due to runoff from nearby pastures during wet weather. In spite of the elevated levels of ammonia, bacteria, and the modified habitat conditions, biological communities were in full attainment of the existing WWH aquatic life use.

The Big Run site near the mouth revealed cooler water temperatures than the upstream site. Riparian shading was likely the major factor influencing these cooler temperatures although comparison results amongst other 20-200 square mile (i.e., wadeable) streams seemed to indicate a groundwater component as Big Run had one of the lowest median temperatures of wadeable streams in the Kokosing watershed
(

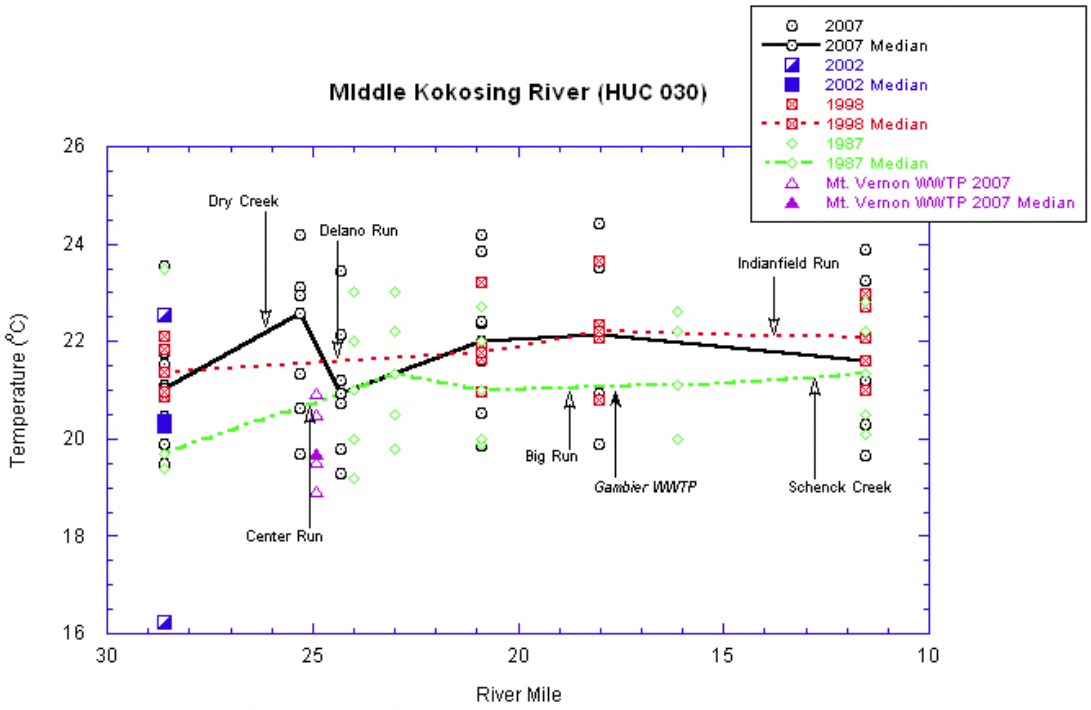

Figure 67, pg. 154). Dissolved oxygen concentrations met WWH criteria in the majority of samples with one exception found on August 7, 2007 of 3.8 mg/l. This violation of water quality standards seemed spurious although measurement equipment was

functioning properly. It is unknown what caused this violation. Comparisons of dissolved oxygen data from Big Run with other wadeable streams in the Kokosing watershed revealed similar circumstances (Figure 68, pg. 155). Datasonde results from late July/early August revealed typical diurnal dissolved oxygen cycling at this location with no indications of low dissolved oxygen instream (Figure 69, pg. 155).

Enrichment from nutrients or organic sources did not seem problematic at this site, although instream nitrate+nitrite concentrations were elevated in the winter and early spring (Appendix F3) as they were at other sites within the watershed (e.g., North Branch mentioned in a previous section). *E. coli* bacteria concentrations were found in non attainment of recreation use criteria for primary contact recreation (Table 12, pg. 54).

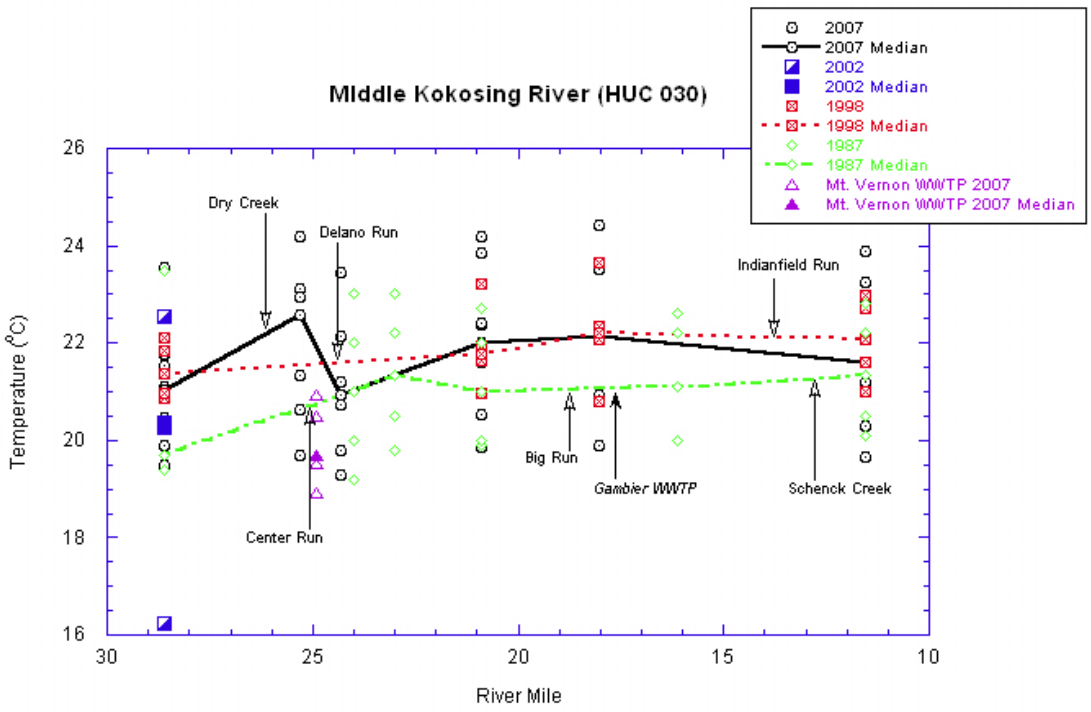

Figure 67. Ambient temperature ranges for Kokosing River watershed wading sites listed by stream name and river mile, 2007.

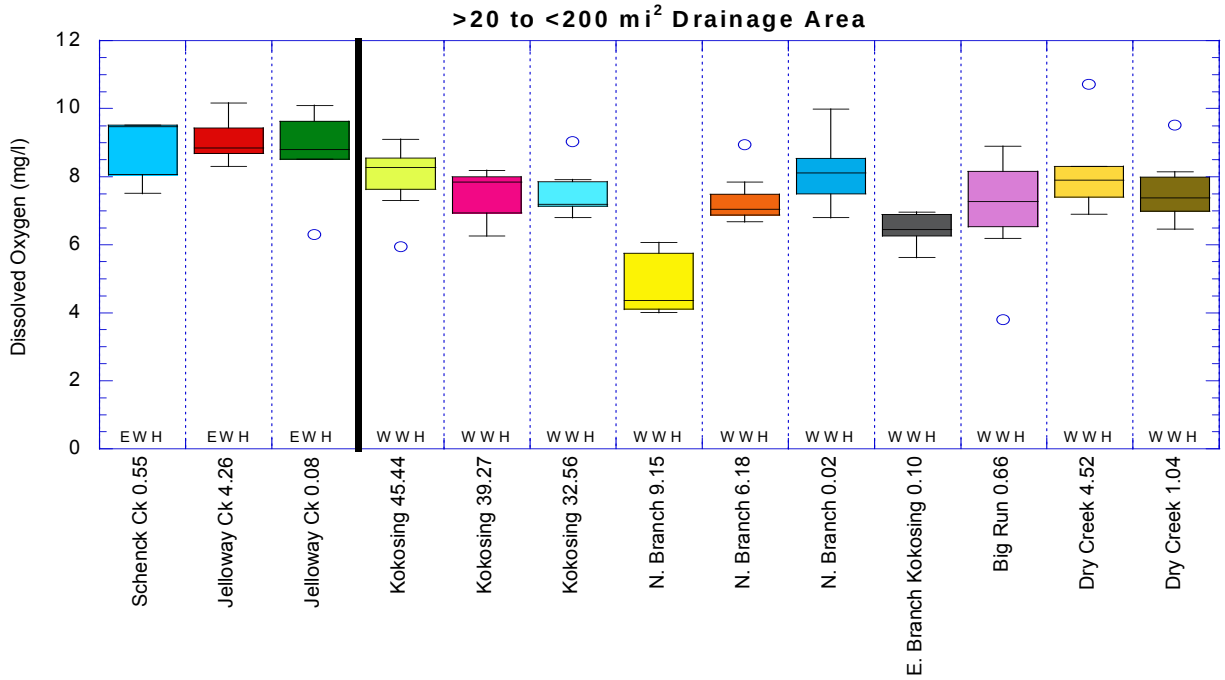

Figure 68. Dissolve oxygen concentrations (mg/l) for Kokosing River watershed wading sites listed by stream name and river mile, 2007.

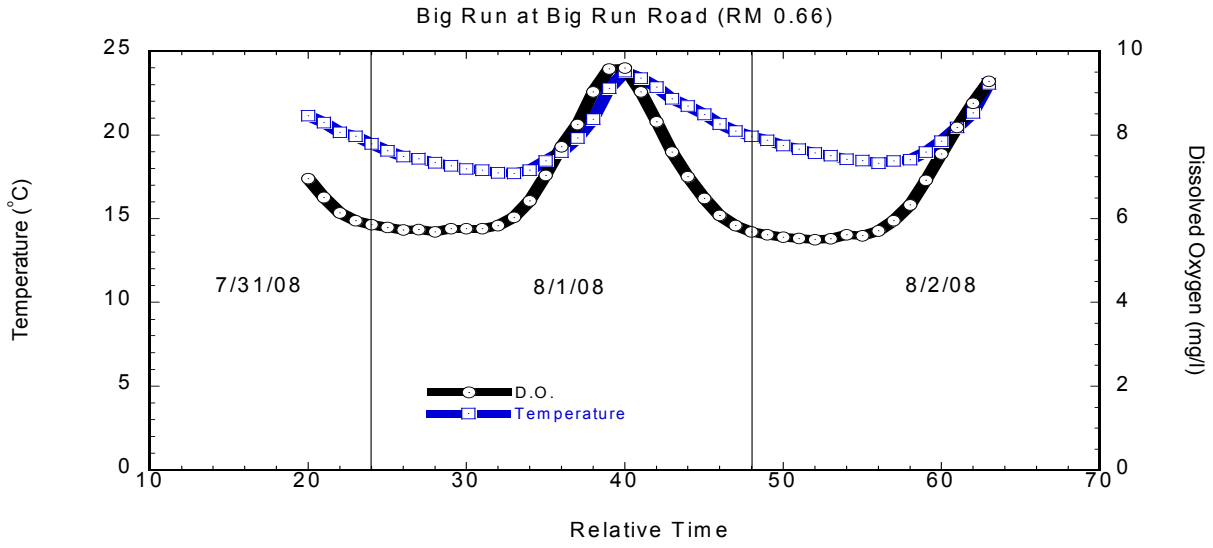

Figure 69. Temperature and dissolved oxygen readings longitudinally plotted by time (hour) and date for Big Run (RM 0.66), 2007.

Elliot Run (WWH, AWS, IWS, PCR)

Elliot Run (Dudgeon Ditch) is a small headwater stream encompassing 8 square miles of drainage and forming a confluence with Big Run at RM 1.56. Elliot Run was evaluated at a single site (RM 1.05) for water chemistry.

Water temperatures in Elliot Run were typical of a stream modified for agricultural drainage. This stream had one of the highest median temperatures as well as some of the highest peak temperatures noted amongst headwater streams in the Kokosing River basin (Figure 51, pg. 130). This was caused by a complete lack of riparian shading in the active pastures surrounding the evaluation area. The lack of shade yielded moderately sized filamentous algal blooms with resulting supersaturated conditions for dissolved oxygen (Appendix F3). Nutrient enrichment was noted early in the summer and certainly contributed to the algal blooms. Bacteria samples also revealed violations of primary contact recreation maximum standards (Appendix F3).

In spite of these water quality issues, the biota in Elliot Run met the WWH standards even though the macroinvertebrate community score was noticeably reduced by impaired water chemistry. Additions of riparian shading and measures to restrict access of cattle to the stream would serve to alleviate water quality issues and probably improve the moderately-good macroinvertebrate community scores.

Indianfield Run (WWH, AWS, IWS, PCR)

This headwater stream meets the Kokosing River at RM 13.78. Chemical water quality was evaluated at one location (RM 2.62) on Indianfield Run.

Indianfield Run did not appear to be augmented by groundwater to the same extent as other headwater streams in the Kokosing basin (Figure 41, pg. 118). The median stream temperature was 19.77 ^{o}C with a range between 17.34 ^{o}C and 22.29 ^{o}C (Appendix F3). Dissolved oxygen concentrations were well above minimum water quality standards and saturation values revealed no supersaturation (Appendix F3). Nutrient concentrations showed little or no nutrient enrichment except for the typical spike during the June sampling, particularly for nitrate+nitrite and TKN (Appendix F3).

Bacteria sampling in Indianfield Run revealed non attainment with recreation use criteria indicating possible periodic contamination from the livestock agribusiness upstream.

Current chemical water quality conditions are supportive of the upgrade in biological use from WWH to EWH.

Schenck Creek (EWH, AWS, IWS, PCR)

Schenck Creek is a medium sized tributary of the Kokosing River discharging to the Kokosing at RM 12.94. Two locations were evaluated for chemical water quality during the 2007 survey work, one at RM 8.75 and one at RM 0.55.

Water temperatures were very consistent over the summer with a median value of nearly 20 ^{o}C at each site (Figure 70, pg. 158). Groundwater did not seem to be a significant portion of surface flow in Schenck Creek although abundant riparian vegetation perpetuated relatively cool water temperatures. This data supports the proposed new CWH designation.

Like temperature, dissolved oxygen concentrations were very similar along the length of Schenck Creek during the summer. All measurements exceeded the EWH minimum standard of 5 mg/l with most greater than 8 mg/l (Appendix F3 and Figure 71, pg. 159). Significant supersaturated conditions were not observed during summer sampling. Forty-eight hour datasonde deployments at RM 0.55 confirmed high dissolved oxygen values within acceptable ranges (Figure 72, pg. 159 and Figure 73, pg. 160).

Nutrient enrichment did not appear problematic at the upper sampling site, although there were a few instances of elevated nitrate+nitrite concentrations, particularly on August 21, 2007, a day of substantial runoff from a rain event (Appendix F3). The site near the mouth revealed significant concentrations of nitrate+nitrite throughout the year, with especially high concentrations during the winter and spring (Appendix F3). A large portion of the elevated nitrate+nitrite in Schenck Creek seems to come from Little Schenck Creek (discussed below). There were no other nutrients of concern for the monitoring site at the mouth.

Monitoring for *E. coli* bacteria in Schenck Creek revealed non attainment with recreation use criteria (Appendix F3 and Table 12, pg. 54). Elevated bacteria concentrations are likely the result of a combination of agricultural runoff and discharges of poorly treated sewage from home sewage treatment systems.

Despite developing issues with nutrient enrichment and elevated bacteria concentrations, biological communities in Schenck Creek were in full attainment of the EWH aquatic life use (Table 9, pg. 46) although the fish community did show signs of environmental stress with several instances of IBI or MIwb scores in non-significant departure from the standard. Additional monitoring may be warranted to document any additional declines.

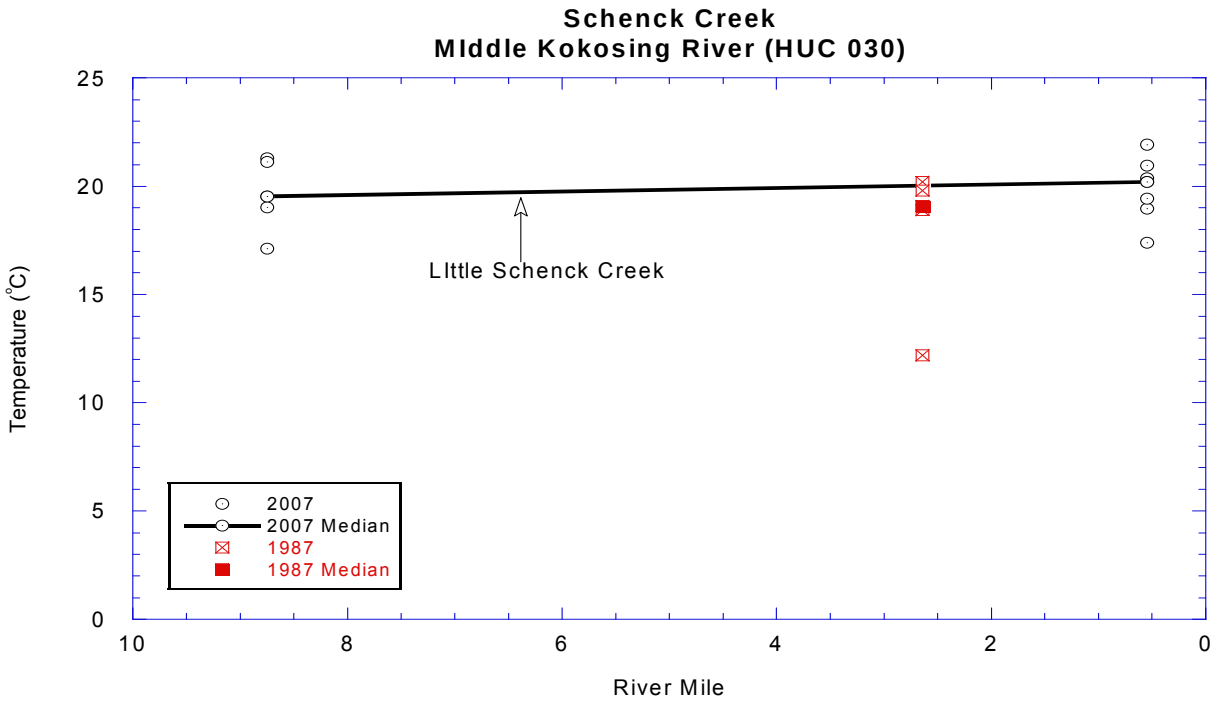

Figure 70. Temperature readings longitudinally plotted by river mile from the 2007 sampling season with comparative historic temperatures from 1987 plotted at RM 2.5.

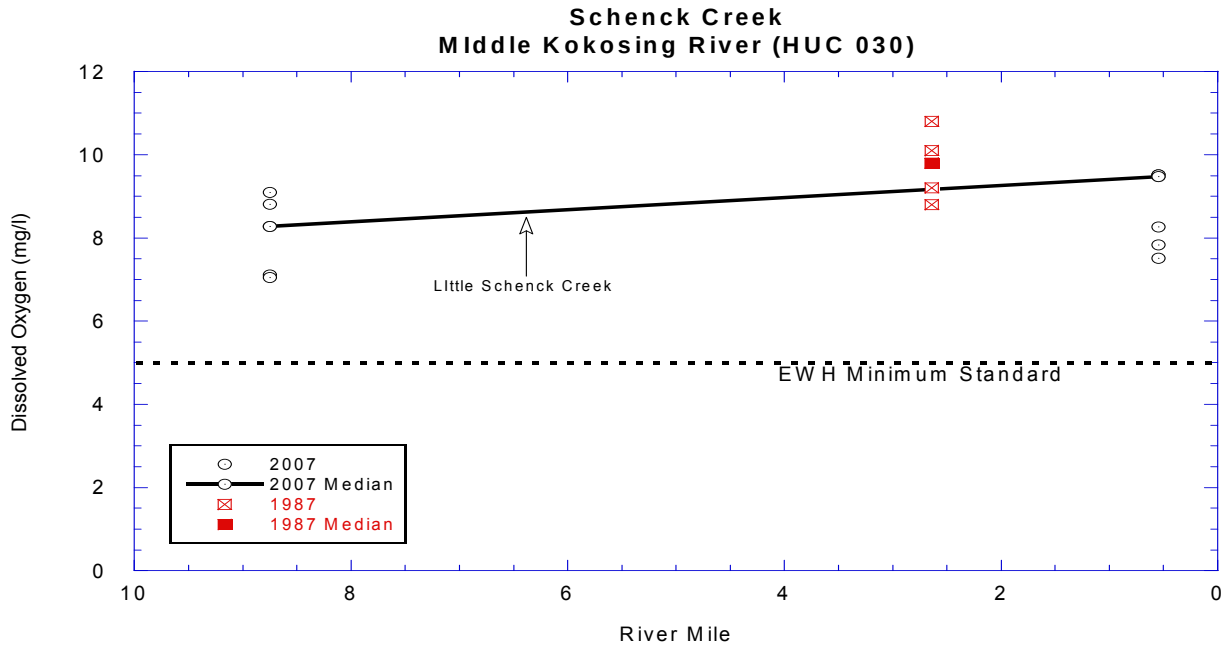

Figure 71. Dissolved oxygen (mg/l) readings longitudinally plotted by river mile from the 2007 sampling season with comparative historic dissolved oxygen readings from 1987 plotted at RM 2.5.

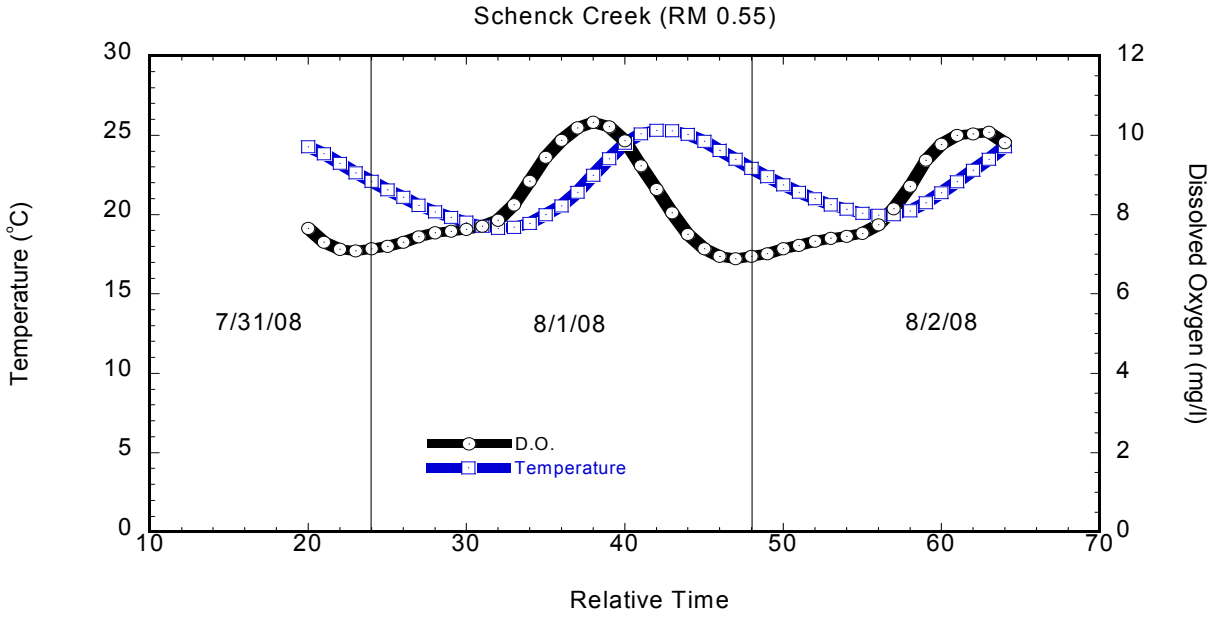

Figure 72. Temperature and dissolved oxygen readings longitudinally plotted by time (hour) and date for Schenck Creek (RM 0.55), 2007.

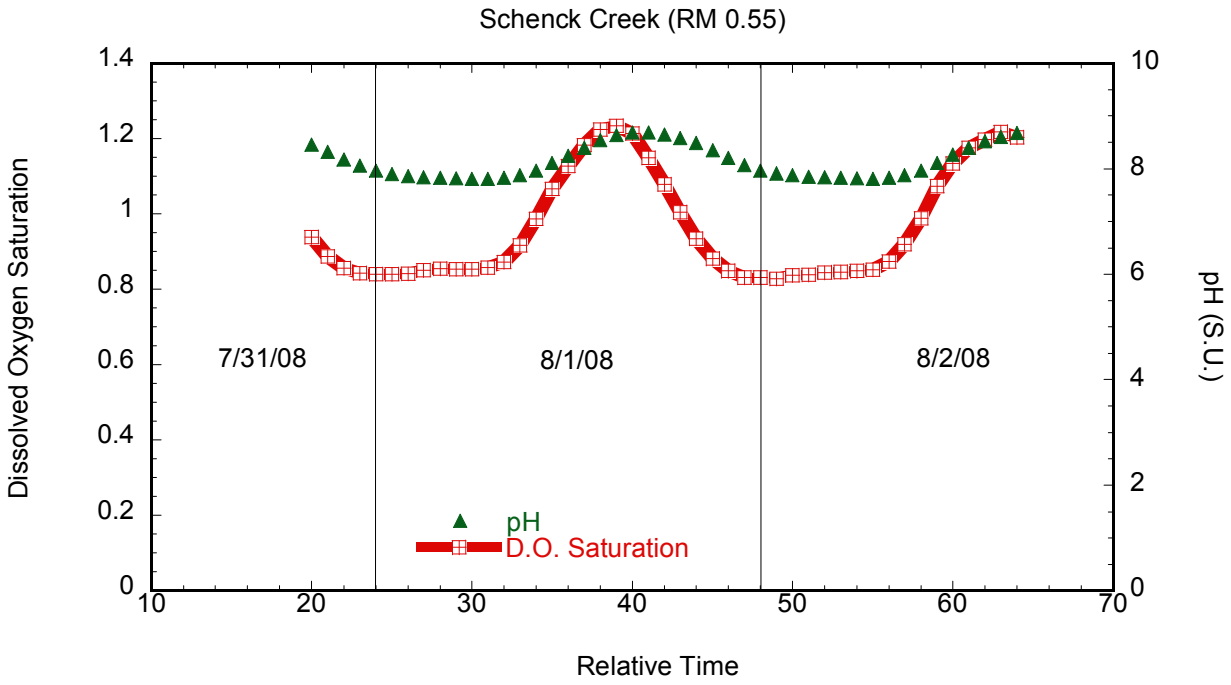

Figure 73. Dissolved oxygen saturation and pH concentrations longitudinally plotted by time (hours) and date for Schenck Creek (RM 0.55).

Little Schenck Creek (WWH, AWS, IWS, PCR)

Little Schenck Creek is a headwater stream draining approximately 17 square miles, flowing into Schenck Creek at RM 6.40. Two locations were evaluated for water chemistry and bacteria at RM 4.45 and RM 0.15.

Water temperature varied significantly between the headwaters of Little Schenck Creek and the mouth averaging 18.35 ^{o}C and 21.56 ^{o}C respectively (Appendix F3). Apparently, the upper reaches of the stream were positively influenced by cool water temperatures while in the lower reaches the cooling effect was much less pronounced. This was due copious shading in the upper basin and reduced shading in the lower basin due to riparian removal. The water chemistry in the upper basin is certainly capable of supporting the proposed EWH/CWH designation.

Dissolved oxygen concentrations did not fall below the WWH standard of 4 mg/l at any time, averaging over 8 mg/l (Appendix F3). There were instances of significantly supersaturated conditions in Little Schenck Creek during some sampling events (Appendix F3).

Nutrient enrichment in the form of nitrate+nitrite was commonplace over the length of Little Schenck Creek. All samples taken at both sites exceeded the 75th percentile of background with 5 of the 10 exceeding the 90th percentile (Appendix F3). Median concentrations of nitrate+nitrite exceeded 4.0 mg/l at RM 4.45 and 2.5 mg/l at RM 0.15. No other headwater stream exhibited higher median concentrations of nitrate+nitrite than Little Schenck Creek (Figure 46, pg. 123). Early summer mobilization of nitrates is well documented in watersheds dominated by agricultural uses such as that found in the Little Schenck Creek basin. The presence of excessive nitrates later in the summer was inexplicable although an agricultural source is suspected since the basin is dominated by that land use.

Elevated concentrations of *E. coli* bacteria were also noted in the Little Schenck Creek watershed. Recreation use criteria were not met for the two sites studied (Appendix F3). Sources of this bacterial contamination were from nearby cattle farms and home sewage treatment systems.

Nutrient enrichment was contributing to the fish community exhibiting a non-significant departure from EWH biological criteria (Table 9, pg. 46). Little Schenk Creek is certainly capable of fully supporting exceptional biological communities as noted by habitat scores (Table 9, pg. 46). Reducing nutrient loadings to this stream should improve fish community scores by improving oxygen cycling, reducing supersaturation problems, and reducing excessive primary productivity.

Sediment

Sediment samples were obtained from 4 locations in the middle Kokosing watershed, 3 sites on the Kokosing River and 1 site on Dry Creek. Total organic carbon concentrations in sediment were found above the LEL at all sites. Calcium and magnesium concentrations were also elevated (Table 11, pg. 53). At 3 of the 4 sites, biological impairment was not found indicating no effect from elevated concentrations of organic carbon or metals. The Kokosing River at RM 24.30 was the only site where organic carbon in sediments might have impaired the invertebrate community.

Macroinvertebrate Community

Middle Kokosing River (EWH, AWS, IWS, PCR)

Historically in the middle reaches of the Kokosing River (HUC **030**) the impaired reach downstream from the Mt. Vernon WWTP had a similarly low ICI score (38 to 40) during the 2002 survey and did not meet the EWH aquatic life use biocriterion . The total number of EPT taxa decreased 30 percent, and the number of sensitive taxa decreased 16 percent from the 2002 survey results (Figure 35, pg. 109 and Table 13, pg. 102). Recovery downstream from Mt. Vernon was similar compared to 2002 (**Figure 35** (pg. 109), Figure 36 (pg. 109), and Figure 37 (pg. 110)). Upstream from the Jelloway Creek confluence macroinvertebrate performance was lower in 2007 compared to the previous survey. The 2002 ICI was significantly higher (50 to VG – an estimated 44), and there was a 20 percent reduction in the number of EPT taxa collected in 2007 likely due to the observed increased sediment (sand) bedload from periodic higher flashy flows.

Middle Kokosing River Tributaries

Armstrong Run (WWH, AWS, IWS, PCR)

Armstrong Run drains agricultural areas west of Mt. Vernon. Its confluence with the Kokosing River mainstem is on the west side of Mt. Vernon. With a good intact riparian corridor there was 18 qualitative EPT taxa and 21 sensitive taxa collected. The S/T Ratio was very high (10.50) and indicated exceptional community quality. There were four CW taxa with CW *C. slossonae* among the predominant organisms along with *Glossosoma* caddisflies commonly collected. Armstrong Run met and is recommended to be designated to EWH and CWH Aquatic Life Uses.

Dry Creek (WWH, AWS, IWS, PCR)

Dry Creek is a larger tributary draining the southwest portion of the watershed along SR 3/US 36 and joins the Kokosing River mainstem south of downtown Mt. Vernon and just east of SR 13. There was very good to exceptional community performance at all four sampling sites from RM 10.8 to RM 1.0 and should be designated EWH Aquatic Life Use. Twenty to 41 sensitive taxa were collected per site with the high in EPT taxa (25/30) and sensitive taxa collected at RM 4.5. Downstream to below RM 4.5 it is recommended to be designated CWH, as there were 5, 7 and 3 CW taxa collected at the three upland sites with the supporting CW fish communities present. Temperatures were less than 20^{o}C. at all sites. Good, intact riparian corridors adjacent to Dry Creek ameliorated some NPS nutrient inputs. Decreasing inputs from small unsewered

housing areas or small communities adjacent Dry Creek will reduce nutrient inputs and thus some algal production in sunlit areas of the stream.

Center Run (WWH, AWS, IWS, PCR)

A small coldwater stream with good groundwater recharge flows south through Mt. Vernon near a hospital, a golf course, a city park with a pool, and through a residential area into the Kokosing River mainstem past the east end of town at RM 25.05. Center Run has had a history of spills (asphalt sealant and agricultural waste products in 1984 and chlorinated pool water in1984 and 1993). Fish kill totals in 1984 ranged from 525 to almost 5000 fish from the pool discharges. Now with a mature riparian corridor and no new documented spills, there was an exceptional coldwater macroinvertebrate community present during the 2007 sampling. There were 62 total taxa collected including 19 EPT taxa and 26 sensitive taxa during the qualitative sampling. Six coldwater taxa were collected including a CW stonefly and caddisfly. Center Run has been recommended for an Aquatic Life Use designation of CWH.

Delano Run (Undesignated)

Delano Run drains the area south of Mt. Vernon and joins the Kokosing River southeast of Mt. Vernon. The WWH stream flows through an agricultural area along with light industrial properties before it flows past a single home residential development and then higher density residential complexes at the edge of Mt. Vernon. Due to low flows from very dry conditions Delano Run consisted of primarily interstitial pools, though a consistent riparian corridor kept the stream shaded and relatively cool (18^{o}C.). Predominant organisms in small riffles between pools were moderately intolerant (MI) *Chimarra* and spiral-cased caddisflies and common facultative hydropsychid caddisflies. For mostly a pooled habitat, there were good numbers of EPT taxa and total taxa, and Delano Run met the WWH ecoregional biocriteria expectations.

Big Run (WWH, AWS, IWS, PCR)

Big Run drains the southwest portion of the watershed and joins the Kokosing River just south of Gambier. Big Run near SR 586 flows through open pastures, therefore the stream temperature was elevated at 26.5^{o}C.. There had been manure spills from dairy operations upstream in 1997. The upstream site, despite some silt and embeddedness, still contained 10 EPT and was populated by a mixture of MI caddisflies and baetid mayflies and facultative hydropsychids, flatworms, and fingernail clams. There were still two species of mussels present – the Creeper mussel (*Strophitus undulatus*), a MI headwater species, and the facultative pool species, the Giant Floater (*Pyganodon*

grandis). The marginally good macroinvertebrate community performance minimally met the WWH ecoregional criteria.

Big Run was sampled near the mouth, and scored an exceptional ICI score of 50. The high S/T Ratio of 8.50 parallels the higher number of sensitive taxa (44), EPT taxa (24), and total taxa (84). The improved riparian corridor shaded the stream, captured nutrients, and allowed for lower stream temperatures. The lower water temperature, 16.5^{o}C., allowed two CW taxa to be present with a good population of coldwater fish. The relative density was still moderate to high with approximately 1250 organisms/ ft.^{2} due to inputs from Elliott Run - an agricultural stream with some channelized reaches with open canopy and open pastures.

Elliot Run (WWH, AWS, IWS, PCR)

Despite sampling a channelized reach surrounded by row crop agriculture occurring close to the banks with unstable riffles and small substrates the macroinvertebrate community in Elliott Run at RM 1.0 still met the minimum WWH ecoregional narrative criteria (Marginally Good) due to groundwater quality. Downstream Elliott Run was sampled near the mouth (RM 0.2) after the stream had flowed through some sporadic shading (incomplete riparian corridor) which allowed some natural assimilative instream treatment. Cobble substrates predominated the good riffle/run habitats with some larger substrates present in the pools. Despite flowing across an open pasture (low numbers of cattle) the macroinvertebrate community quality was very good and met the narrative WWH biocriterion. Any improvement in riparian quality like fencing the stream off through the open pasture with only a couple of crossing areas would improve the quality of the stream by: 1) decreasing nutrient, sediment, and bacteria inputs, 2) shading the stream (lower temperatures), and 3) allowing for better natural instream nutrient assimilation.

Indianfield Run (WWH, AWS, IWS, PCR)

Indianfield Run, a coldwater tributary to the Kokosing River southwest of Howard at RM 13.88, had recovered from spills from oil wells and agriculture production waste in 1999 and 2001, respectively. Sensitive cased caddisflies and moth larvae were predominant with 21 sensitive taxa and confirmed marginally exceptional performance. Exceptional Warmwater Aquatic Life Use is recommended as well as CWH use, since three CW taxa, including a predominant sensitive caddisfly and stonefly, combined with the large population of CW fish were collected.

Schenck Creek (EWH, AWS, IWS, PCR)

Schenck Creek, whose source is just south of Knox Lake, flows south and west to join the Kokosing River southwest of Howard and is a high quality groundwater-fed stream. Its abundant larger rocky substrates and consistent flows allowed for high diversity. The upstream site at RM 8.8, flowing in a ravine valley, had the second-highest S/T ratio of 23.0. That same quality was evident to the mouth, as the S/T ratio was still 15.5 near the mouth (RM 0.5). The predominant organisms ranged from sensitive CW caddisflies and minnow mayflies to a rare caddisfly, *Leucotrichia*, which prefers boulder habitat with good flows. A Hellbender salamander was observed at the US 36 site (Monroe Mills) at RM 2.6. The macroinvertebrate community performance was evaluated as exceptional and met the existing EWH narrative biocriterion. Coldwater taxa (4 - 2) and two to three CW fish populations present at each site supported the recommendation of Schenck Creek to also be designated CWH Aquatic Life Use.

Fish Community

Middle Kokosing River

Fish sampling was conducted at 6 sites in the Middle Kokosing River extending from RM 28.61, downstream of the confluence with North Branch, to RM 11.55, downstream of Gambier with an average IBI score of 52 and an average MIwb score of 9.4. The only main stem site in this section not in full attainment of its designated use was downstream of the Mt. Vernon WWTP at RM 24.3 (Table 2, pg. 10). This impairment was not habitat related (QHEI = 87.5), but rather a water chemistry issue. The chemistry results showed exceedances of nitrates and phosphorus levels. This is not uncommon downstream of WWTP's that are not tertiary treatment facilities. Physical evidence of eutrophication such as large algae blooms covering the Kokosing River was not apparent in this reach; however, small amounts of algae along the stream banks were present. The exceptional water quality up and downstream of this location, good flow, and ground water regulated water temperatures and helped to reduce the severity of the pollution impacts associated with the elevated nutrients. Unable to escape the localized impacts of this pollution, the macroinvertebrate community sampling showed the greatest impairments. Data collected from this location yielded an ICI score of only 38 at this site (Table 2, pg. 10).

Middle Kokosing River Tributaries

Armstrong Run (WWH, AWS, IWS, PCR)

Armstrong Run attained its CWH and EWH recommended aquatic life uses. Among other pollution sensitive fish species found at this site two cold water fish, redside dace and mottled sculpin were a significant part of the community at 33 and 217 individuals sampled respectively (Appendix C). Signs of non-point source nutrient runoff were apparent in the algae blooms along the stream banks.

Dry Creek (WWH, AWS, IWS, PCR)

Dry Creek was evaluated at 4 different sites along its length, beginning at RM 10.72 and ending near the mouth at RM 1.04. Monitoring effort was also directed to the area just downstream of the old Knox County landfill at RM 4.52 (Thayer Road). Coincidentally the Thayer Road sample location scored the lowest (IBI = 42) out of all the Dry Creek sites, although it completely met its WWH use designation (Table 2, pg. 10). Redside dace and mottled sculpin were collected at the upper three sample sites qualifying that section of Dry Creek to become designated CWH (Appendix C). An EWH use

designation is recommended for the upper two sites (RM 10.7 & 9.2). These exceptional fish communities scored IBI's of 56 and 54 respectively (Table 2, pg. 10).

Center Run (WWH, AWS, IWS, PCR)

Center Run is a small headwater stream flowing through the northern portion of Mount Vernon. One site was evaluated for biology. The first half of the fish sampling zone appeared to be recovering from historical channelization, while the second half resembled a natural stream channel again (See habitat section for more). Cold ground water coming into Center Run helped to ameliorate any urban runoff issues or habitat issues. Two cold water fish species, redside dace and mottled sculpin, were collected in this stream. The fish community as a whole scored exceptionally (IBI = 48^{ns}) (Table 2, pg. 10). Based upon the findings of this report CWH and EWH use designations are recommended for Center Run (Table 1, pg. 6).

Delano Run (WWH Recommended)

Delano Run is a small, urban headwater stream that flows into the Kokosing River on the far south side of Mount Vernon. The stream drains into an impoundment prior to discharge to the Kokosing River. One fish site was sampled on Delano Run at RM 1.5 (Table 9, pg. 46). The fish community in Delano Run scored poorly on the IBI = 30. Creek chubs, a pollution tolerant fish species, heavily dominated the decimated fish community (Appendix C). A combination of urban storm water runoff and restricted stream flows from an impounded lake that Delano Run forms on the east side of State Route 13 are some of the reasons for the non attainment of its recommended WWH aquatic life use. As noted for other small streams studied in the watershed, cold ground water can sometimes ameliorate problems associated with habitat and storm water runoff (please see habitat section for more). However, Delano Run was without a good ground water connection and therefore displayed the full effects of poor habitat and storm water pollution. Delano Run was surrounded by impervious surfaces, including urban housing, industry, and a state route. The substrates were covered in silt from stormwater runoff and litter was found within the stream channel. Delano Run is dammed, forming a small reservoir on the east side of State Route 13.

Big Run (WWH, AWS, IWS, PCR)

Big Run was evaluated at 2 sites during the survey. The upstream site at RM 4.4 consisted of a historically modified stream channel accompanied by open pasture land and little riparian cover. The lower site at RM 0.66 was more wooded and less modified. Both sample sites met WWH criteria (Table 2, pg. 10).

The fish community scored exceptionally (IBI = 50) at the upstream Big Run site at State Route 586, Martinsburg Road, despite the instream access of cows and the heavily grazed riparian area (Please see habitat section for more) (Table 2, pg. 10). This is another scenario where cold ground water has ameliorated many of the problems associated with excess nutrients and degraded habitat. Despite the cold groundwater, the upper site on Big Run was designated WWH having only one cold water fish species, redside dace, recorded among the list sampled (Appendix C). The downstream site at Big Run Road (RM 0.66) scored lower on the IBI (IBI = 44), but still met WWH criteria (Table 2, pg. 10). The CWH aquatic life use criteria is recommended for Big Run at RM 0.66. Two cold water species sampled at this location, redside dace and mottled sculpin, fulfill the cold water criteria (Appendix C).

Elliot Run (WWH, AWS, IWS, PCR)

Elliot Run (Dudgeon Ditch) is a small headwater stream encompassing 8 square miles of drainage confluencing with Big Run at RM 1.56. Elliot Run was sampled for fish at two locations, Curtis Road (RM 1.1) and Sycamore Road (RM 0.2). Fish communities in both sample locations benefited from cold ground water relief reducing potential nutrient problems. Stressors to Elliot Run included loss of riparian cover and instream livestock access. Despite these threats to the stream the WWH criteria were still met (Table 2, pg. 10). One cold water fish species was recorded present in both sample locations, the redside dace; however, this single species was not enough to assign the CWH aquatic life use designation to this stream (Appendix C).

Indianfield Run (WWH, AWS, IWS, PCR)

This headwater stream meets the Kokosing River at RM 13.78. Fish sampling was conducted at New Castle Road, State Route 229 (RM 2.62) on Indianfield Run. The fish community scored exceptionally (IBI = 54) at this location which flowed through a heavily shaded and wooded riparian corridor (Table 2, pg. 10). Two cold water species were collected in the sample, redside dace and mottled sculpin (Appendix C). The new aquatic life uses of EWH and CWH were recommended for Indianfield Run.

Schenck Creek (EWH, AWS, IWS, PCR)

Schenck Creek is a medium sized tributary of the Kokosing River discharging to the Kokosing at RM 12.94. Three sites were evaluated on Schenck Creek at Township Road 274 (RM 8.75), US 36 (RM 2.64), and County Road 34 (0.6). An exceptional cold water fish community was found at all three sample locations on Schenck Creek and therefore the EWH and CWH aquatic life use designations are recommended to protect Schenck Creek (Table 2, pg. 10). Three native cold water fish species, mottled sculpin,

brook stickle back, redside dace, made up between 8 and 17% of the fish population at these three sites. Further demonstrating the streams ability to support cold water fish, a 1000g brown trout, *Salmo trutta,* was caught among the other fish sampled at the lower sample site (RM 0.6) and a 150g brown trout was recorded from the RM 2.64 sample location (Appendix C and Figure 74).

Figure 74. A 1,000 gram brown trout caught from Schenck Creek, RM 0.6.

Little Schenck Creek (WWH, AWS, IWS, PCR)

Little Schenck Creek is a headwater stream draining approximately 17 square miles, flowing into Schenck Creek at RM 6.40. The fish community was evaluated at County Road 66 (RM 4.50) and Gilchrist Road (RM 0.2). The upper site had an IBI score of 50 and is recommended CWH and EWH (Table 2, pg. 10). Mottled sculpin dominated the fish community at this site, accounting for 50% of the total sample with 310 individuals caught (Appendix C). The CWH use designation is only recommended downstream to RM 3.5 based upon field observations of degraded habitat around and downstream of Carson Road due unrestricted cattle access to the stream. The downstream sample site at RM 0.2 scored an IBI of 46, which met the lower limit of the EWH recommendation. Insufficient cold water fish and Macroinvertebrate taxa at this site eliminated the possibility of extending the CWH use to the mouth. Numerous live stock operations with unrestricted cattle access to Little Schenck Creek were documented along the mainstem and tributaries. Despite full attainment scores (by virtue of cold ground water relief) at the sample locations, water quality improvements could be made by fencing the livestock out of the streams and allowing the natural riparian vegetation to grow back along the stream banks to help shade the stream and prevent bank erosion in Little Schenck Creek (Figure 75).

Figure 75. (Top) Eroded and broken down stream banks from livestock in Little Schenck Creek at the intersection of Arnold and Earnest Roads. **(Bottom)** Livestock with access to a tributary to Little Schenck Creek at the intersection of North Liberty and Keller Roads.

Habitat

Middle Kokosing River (EWH, AWS, IWS, PCR)

Excellent physical habitat characterized the middle (RM 28.6 – RM 11.6) section of the Kokosing River (QHEI $\overline{x}$ = 83) (Figure 31, pg. 93 & Table 2, pg. 10) where six stream sites were evaluated for habitat quality. Tremendous flow in the Kokosing River upstream of Banning Road (RM 28.6) helped to provide exceptional fish and macroinvertebrate habitat with fast riffles, long swift runs, and deep pools. Boulders and cobbles were the dominant substrates with some bedrock surrounding a deep pool in the upper end of the 200m sampling reach. Altogether, six high quality substrates helped to diversify habitat niches for stream biota (Appendix A). Both sides of the river had possible localized and downstream impacts on the river. On the East bank (river left) there was a junk yard in operation approximately 100m up the steep bank. The west bank (river right) was heavily eroded and the home owner routinely mowed along the bank. Stabilizing this stream bank by planting native trees and allowing the vegetation to establish will help slow down future sediment runoff and loss of property.

Just upstream of the Mount Vernon WWTP (RM 25.3) the Kokosing River flows swiftly over stable cobble and gravel substrates into well developed riffle, run, and pool sequences (Appendix A). This sampling location had the highest quality fish and macroinvertebrate community on the main stem of the river (IBI = 56, ICI = 52; Table 2, pg. 10). The next two sample sites downstream (RM 24.3 & RM 20.9) had excellent physical habitat, but showed some signs of nutrient enrichment. Pools and slower flowing run habitats of these two stream reaches had nuisance algae growth along the stream banks. The species composition and richness of the macroinvertebrate community at RM 24.3 reflected the degraded water quality (Table 2, pg. 10). Water chemistry results for RM 24.3 also confirmed excess nutrients in the river due to elevated phosphorus and nitrate levels from insufficient treated sewage effluent that came out of the Mount Vernon WWTP.

Drainage area increases to over 300 mi^2 on the Kokosing River at Big Run Road (RM 18.9) sample location (Table 9, pg. 46). Downstream of Big Run Road (RM 18.9) the Kokosing River habitat was exceptional. The river flowed through two large riffles and swiftly flowed into one of the largest pools on the main stem as the channel carved out a bedrock shelf and flowed down another spectacular riffle. As a result of the strong flows in this segment the substrates were free from silt and other nuisance debris. The exceptional quality of the stream in this segment provided habitat for a healthy population of state threatened bluebreast darters.

Downstream of Howard (RM 11.55) at County Road 35 the Kokosing River flows over a long and swift riffle into a long and deep pool as it receives on one of its high quality tributaries, Jelloway Creek, just downstream of County Road 35. Habitat in this reach was excellent (QHEI = 81) and supported an exceptional biological community. The wooded riparian corridor was narrow on both sides of the river with State Route 36 (river left) on one side and agricultural use (river right) along the other side.

Middle Kokosing River Tributaries

Armstrong Run (WWH, AWS, IWS, PCR)

One site was assessed for physical habitat on Armstrong Run at Lower Green Valley Road (RM 1.1) (Table 9, pg. 46). The habitat was good (QHEI = 71.5), but showed signs of nutrient enrichment. Algae blooms covered the instream substrates of Armstrong Run despite the very cold water and treed riparian corridor which would usually limit algae growth. Moderately stable to slightly unstable substrates of gravel and sand comprised the streambed. Overhanging vegetation, rootwads, logs and other woody debris provided a considerable amount of cover for fish in this reach.

Dry Creek (WWH, AWS, IWS, PCR)

Starting at Simmons Church Road (RM 10.72) and going downstream to Parrott Street (County Road 83, RM 1.04) four sites were assessed for physical habitat on Dry Creek (Table 9, pg. 46). Dry creek was a very cold and clear stream with good flows most of the year. During our second sampling pass near the end of July, Dry Creek was going through a period of dessication, even more than the other tributaries in the watershed. Despite the low water conditions, the upper three sites are recommended to be designated CWH having better stream substrates (cobble/gravel) than the lower WWH sampling site (sand/gravel) (Appendix A). Downstream of County Road 83 (RM 1.0), Dry Creek is leveed along the left bank and the stream channel is less developed than the upstream sample locations.

Center Run (WWH, AWS, IWS, PCR)

Center Run was sampled for physical habitat at Beech Street (RM 1.72) (Table 9, pg. 46). A marginally good QHEI score of 60.5 was surprising for a location that the aquatic life use recommendations were EWH and CWH. The biology performed well in these circumstances because of the cold water and its proximity of better stream habitat. The first part of the 150 meter sampling zone was recovering from channelization (from the bridge upstream ~35m). The last ~115 meters of the zone had natural stream channel characteristics including good sinuosity, riffles, runs, and pools (Appendix A). Heavy

amounts of silt embedded the instream substrates throughout. What appeared to be runoff from an algaecide was visible on the surface of Center Run. Either the golf course (river left) or public swimming pool (river right) would have possibly used an algae treatment agent in the operations. Within the 150 meter sample zone a pipe was found draining water into Center Run (river right) the same side as that of the swimming pool, although the origin of the pipe is not known. It is recommended that operations using an algicides do not allow them to be discharged into receiving waters. Algaecides can have harmful effects on aquatic communities and sometimes result in fish kills.

Delano Run (Undesignated)

Along Meadowbrook Drive, upstream of State Route 13 (RM 1.5), Delano Run was assessed for physical habitat (QHEI=53.5) (Table 9, pg. 46). Due to poor stormwater management, habitat in Delano Run was not good for aquatic life. Stormwater runoff from urban and industrial areas had delivered trash to the stream. The headwaters of Delano Run flowed through an industrial parkway before flowing through a residential area and eventually draining into an impoundment downstream of State Route 13. Habitat in Delano Run seemed to improve downstream of the impoundment again became free flowing with riffles, runs, and pools. The channel had been straightened and the flow was restricted considerably from the impoundment on the downstream side of State Route 13. Most of the sample site had cobbles and gravel as predominant substrates; however, these high quality substrates were filled in by silts and fines further downstream.

Big Run (WWH, AWS, IWS, PCR)

Two sites were assessed on Big Run (RM 4.40 & RM 0.7) for physical habitat (Table 9, pg. 46). Both sample locations scored well on the QHEI, 65 and 70.5 respectively (Table 2, pg. 10). The habitat at State Route 586 (upstream and downstream) was threatened by livestock (cows) that had open access to the stream throughout this reach (Figure 76). The stream banks were broken down from cows crossing and entering Big Run which lead to erosion problems from fine silts and sediments that smothered the natural instream substrates (Figure 77). Loss of vegetation along the banks from overgrazing caused further erosion of the stream banks during storm events. A cold groundwater connection to Big Run helped to prevent major damage to the aquatic communities at this location. It is recommended that livestock be fenced out of the stream and an out of stream watering area be established. If this is done, Big Run has the potential to be an exceptional aquatic community.

Figure 76. Livestock freely access Big Run (RM 4.40) upstream of State Route 586.

Figure 77. Broken down banks and erosion from instream livestock activity downstream of State Route 586 on Big Run (RM 4.40).

Elliot Run (WWH, AWS, IWS, PCR)

Dudgeon Ditch/Elliot Run was assessed for physical habitat at Curtis Road (RM 1.1) and Sycamore Road (RM 0.2) (Table 9, pg. 46). The habitat was poor at the upstream site (QHEI = 32) and fair at the downstream sample location (QHEI = 47.5) (Table 2, pg. 10). These sites were examples of cold groundwater flow helping to reduce physical habitat impairments associated with land use practices. At RM 1.1 Elliot Run was channelized with no riparian buffer and choked out with filamentous algae throughout the 150m sample zone. The channel morphology was uniform as one long glide habitat, no riffle, run, or pool (Appendix A). Row crops were planted up to the leveed stream banks on both sides. Field drain pipes protruded through the leveed stream banks into Elliot Run. Despite all the adverse habitat characteristics, the biology in Elliot Run met WWH criteria. If habitat improvements were made the biological community in the stream has the potential to be exceptional.

An exceptional aquatic community of fish and macroinvertebrates was found at the lower site upstream from Sycamore Road, despite habitat impairments from livestock in Elliot Run that provided only fair quality stream niche's for aquatic life (Figure 78). Heavy grazing limited the vegetation along the stream banks and shade was limited to only a couple of large trees too big for the cows to tear down. The stream appeared unmodified, channel sinuosity was good and a fair amount of morphological development existed (Appendix A). However, heavy amounts of silt filled in the interstitial spaces between the coarser stream substrates otherwise available for aquatic life. Indicators of nutrient enrichment such as algae blooms and cow manure were present throughout the sample zone. It is recommended to fence the cows out of the stream and establish an alternative watering regime.

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Figure 78. The banks of Elliot Run upstream of Sycamore Road show the effects of grazing and instream livestock access.

Indianfield Run (WWH, AWS, IWS, PCR)

One sample site was assessed for habitat quality on Indianfield Run at State Route 229 (RM 2.7) (Table 9, pg. 46). Habitat at Indianfield Run was exceptional upstream of State Route 229. Boulders and cobbles consisting of sandstone and glacial tills were the predominant stream substrates within the sampling reach (Appendix A). The wide treed riparian buffer provided good amounts of shade, instream rootwads, and rootmat cover. Riffle habitats consisted of stable substrates (cobble & boulder) suitable for diverse macroinvertebrate and fish communities. However, a moderate amount of silt had washed down from upstream and partially filled in the interstitial spaces between high quality substrates.

Schenck Creek (EWH, AWS, IWS, PCR)

Physical habitat was assessed at three locations on Schenck Creek. From upstream to downstream, the sampling locations were located at Proper Road (RM 8.7), US 36 (RM 2.6), and Schenck Creek Road (RM 0.6) (Table 9, pg. 46). Exceptional physical habitat quality characterized the entire length of the creek. Schenck Creek had cold, clear flowing water over clean substrates of boulder, cobble, gravel, bedrock, and some sand within the pools. The treed riparian corridor was 10 to over 50 meters wide. Fast flowing riffles and deep pools over 1 meter deep, even at the most upstream site, were among the key heterogeneous habitat features that yielded a diverse biological community in Schenck Creek.

Little Schenck Creek (EWH, AWS, IWS, PCR)

Two sampling stations (County Road 66 (RM 4.45) and County Road 8 (RM 0.15)) on Little Schenck Creek were sampled for physical habitat (Table 9, pg. 46). The upper site at RM 4.45 scored the highest QHEI in the Kokosing River watershed study, QHEI = 91.5. A wide (>50 meters) treed riparian corridor buffered the highly sinuous, cold, and clear flowing Little Schenck Creek in its headwaters. Extensive amounts of instream cover types were present which provided a diversity of habitat niches for multiple species to occupy (Appendix A). The lower site at RM 0.2 was adversely affected by the upstream cow pasture. Many of the silts and other fine sediments washing downstream from the cows had heavily settled out in the first pool downstream of the bridge. Brown foam had accumulated on the creeks surface at the upper end of the sample zone, ~ 130 meters downstream from the bridge. A good treed riparian zone, good flow, good sinuosity, and cold groundwater helped to keep the effects of the upstream nutrient loading (cow manure) at a minimum. This lower section of Little Schenck Creek currently meets EWH water quality standards and is threatened by the upstream land use. It is recommended that cattle be fenced out of the creek and they be provided an out of stream watering area.

Lower Kokosing River Assessment Unit (HUC 05040003 040)

The Lower Kokosing River assessment unit (Hydrologic Unit Code 05040003 040) encompasses 106.3 square miles of drainage area. This reach includes the Kokosing River upstream of Jelloway Creek in Knox County to the mouth located in Coshocton County. In this portion of the watershed, the Kokosing River flows east to west through Knox County and the villages of Howard and Millwood along State Route 36 and then adjacent to State Route 715 before joining with the Mohican River near the Knox/Coshocton County line to form the Walhonding River. This assessment unit is predominantly located in the Erie Ontario Lake Plain (EOLP) ecoregion with the extreme western edge located in the Western Allegheny Plateau (WAP).

Chemical Water Quality

There were a total of eleven (11) stream sites studied for chemical water quality, including three (3) sites on the Kokosing River from RM 6.12 to RM 0.07. Tributary streams studied included Jelloway Creek (RM 8.85, 4.26 and 0.08), Little Jelloway Creek (RM 6.97 and 0.88), East Branch Jelloway Creek (RM 3.33 and RM 1.03) and Brush Run (RM 0.91). Effluent samples from the Knox County Little Jelloway WWTP and Danville WWTP were also collected and analyzed during the study. These sites are all listed in Table 9, pg. 46.

Lower Kokosing River (SRW, EWH, AWS, IWS, PCR)

This lower Kokosing River reach is characterized by excellent habitat and water quality conditions. This stream reach included sampling locations at RM 6.12 (U.S. Route 36), RM 2.68 (Riley-Chapel Road) and RM 0.07 (near TR 423 at mouth).

Sampling for nutrients in this reach showed moderate levels of total phosphorus and nitrate+nitrite. Median concentrations exceeded the recommended statewide target levels of 0.05 mg/l for total phosphorus and 0.5 mg/l for nitrate+nitrite (Figure 21 (pg. 77) and Figure 22 (pg. 78). For the sentinel site location at RM 2.68, median nutrient concentrations were higher than other Kokosing River sentinel sites (RM 45.44 and RM 28.61) (Figure 79 (pg. 179) and Figure 80 (pg. 180) . Diel dissolved oxygen monitoring at RM 2.68 did indicate several hours of moderate supersaturated conditions (nearly 150%) on August 1, 2007 (Figure 81, pg. 180).

Overall, dissolved oxygen readings in this reach showed exceptional stream conditions with median results over 7.50 mg/l (Figure 82, pg. 181). In addition, median

concentrations of total suspended solids (TSS) were below 10 mg/l (Figure 83, pg. 181). Excellent habitat conditions were also noted at the chemistry sampling locations. Not surprisingly, this reach was in full attainment of EWH criteria for biological communities.

Violation of the primary contact recreation bacteria standard was recorded at RM 6.12 (Table 12, pg. 54). This was primarily due to a large storm event during sampling on August 22, 2007 resulting in high bacteria concentrations. Otherwise, sampling did not indicate a pervasive bacteria threat for recreational use activities under normal flow conditions in this reach.

Ohio EPA also conducted a single organics scan on July 16, 2007 for 43 pesticide/herbicide compounds, 53 semi-volatile compounds and 7 PCB cogeners at RM 2.68. All results came back below-detection with the exception of bis(2-ethylhexyl)phthalate. Results for this common plasticizer, was slightly above the detection limit but well below any established aquatic life or human health criteria. Analysis for mercury revealed no detections during any of the 5 sampling events.

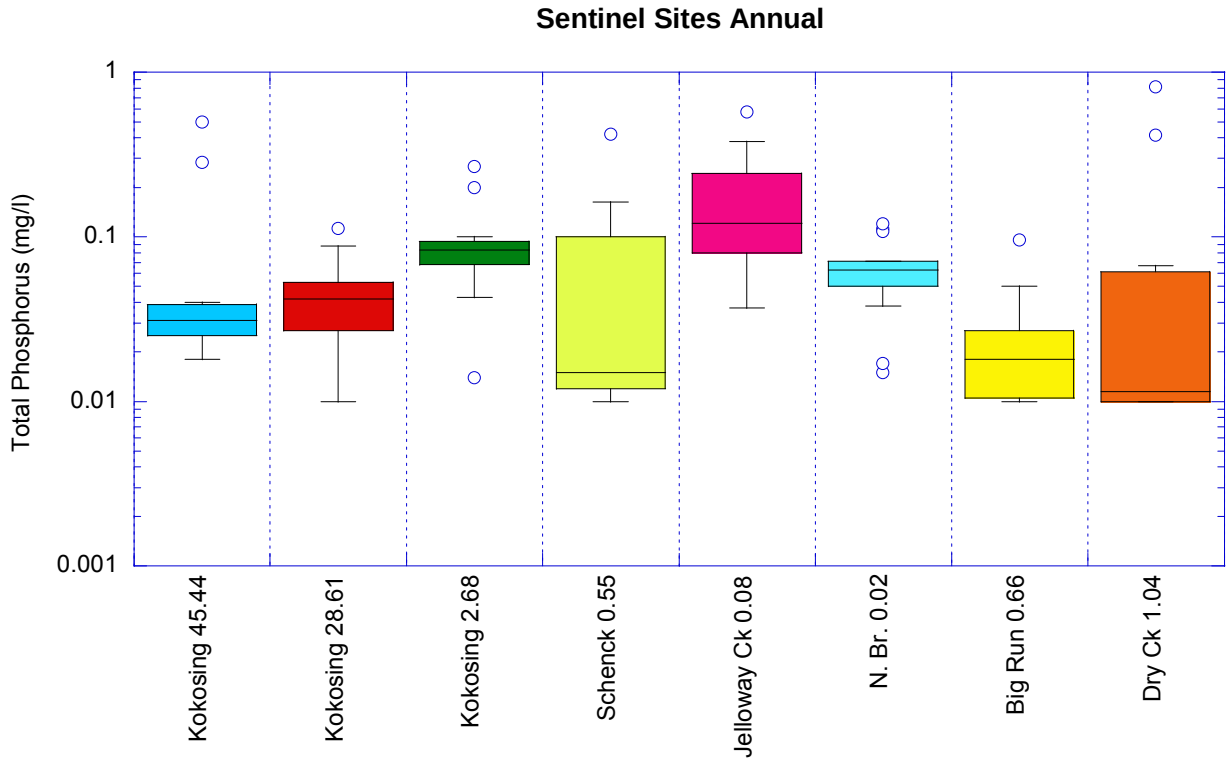

Figure 79. Total phosphorus (mg/l) levels for sentinel sites in the Kokosing River watershed, 2007.

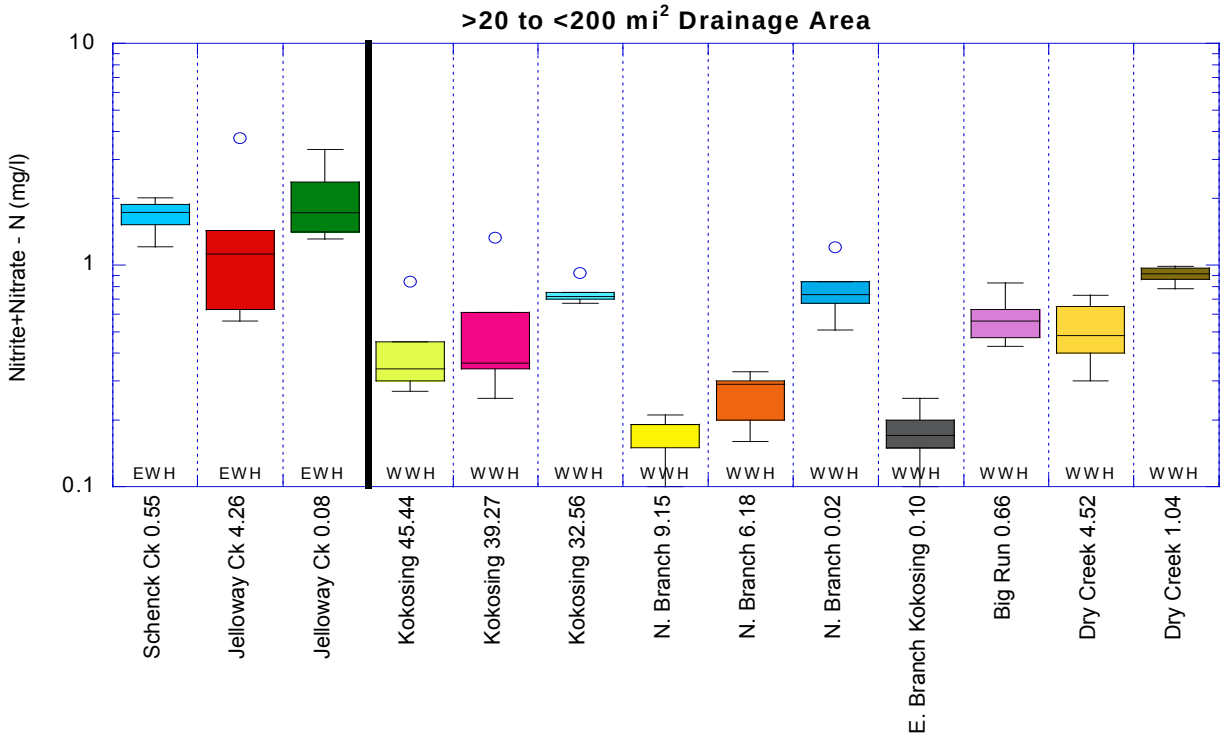

Figure 80. Nitrite+nitrate levels (mg/l) recorded for wading sites in the Kokoisng River watershed.

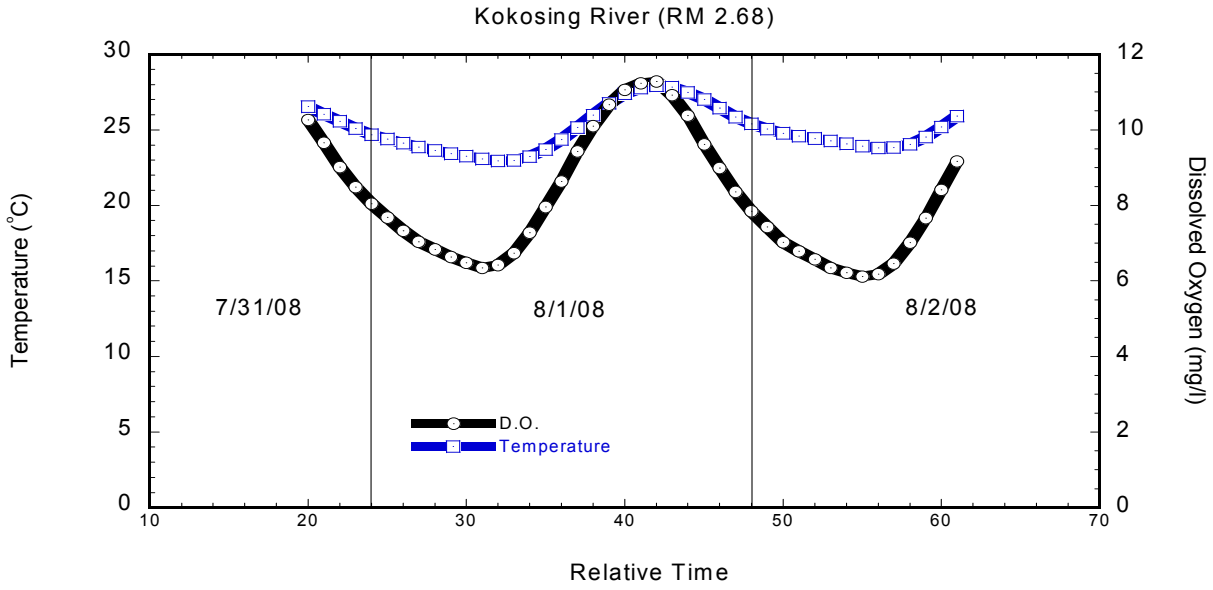

Figure 81. Temperature and dissolved oxygen readings longitudinally plotted by time (hour) and date for Kokosing River (2.68), 2007.

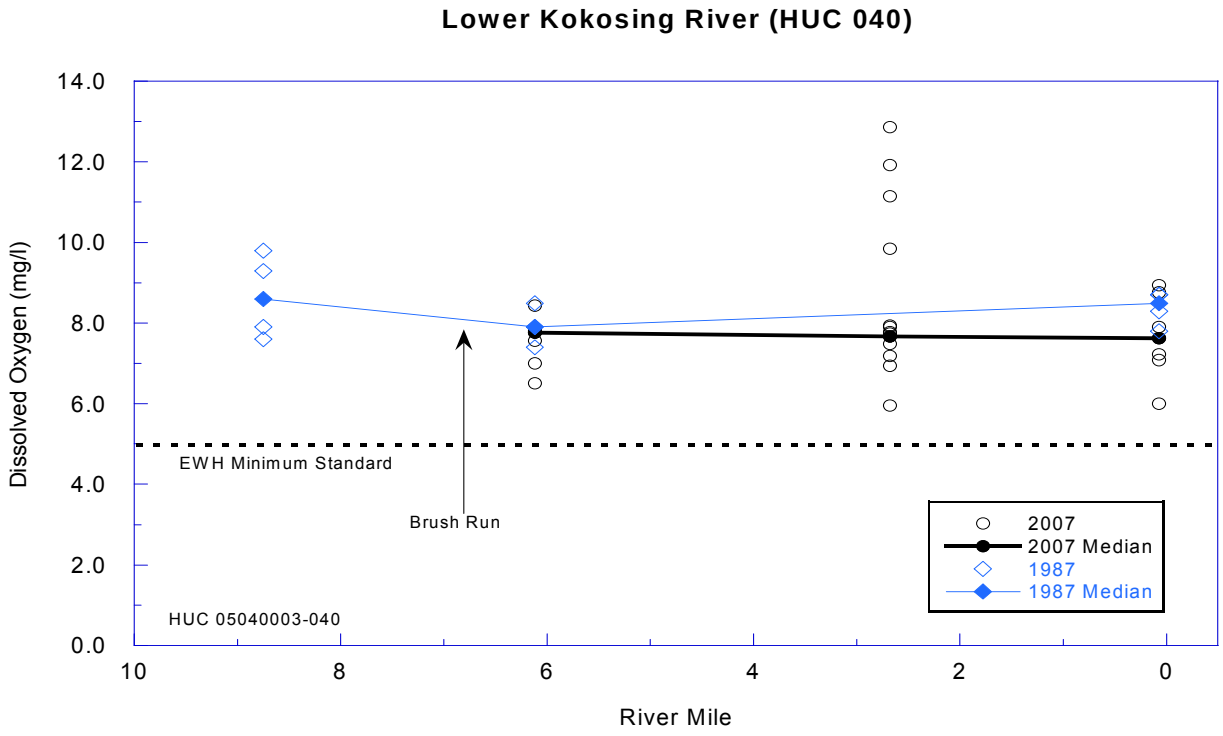

Figure 82. Trends in dissolved oxygen concentrations (mg/l) longitudinally plotted by river mile for the lower Kokosing River were found to be similar 20 years apart.

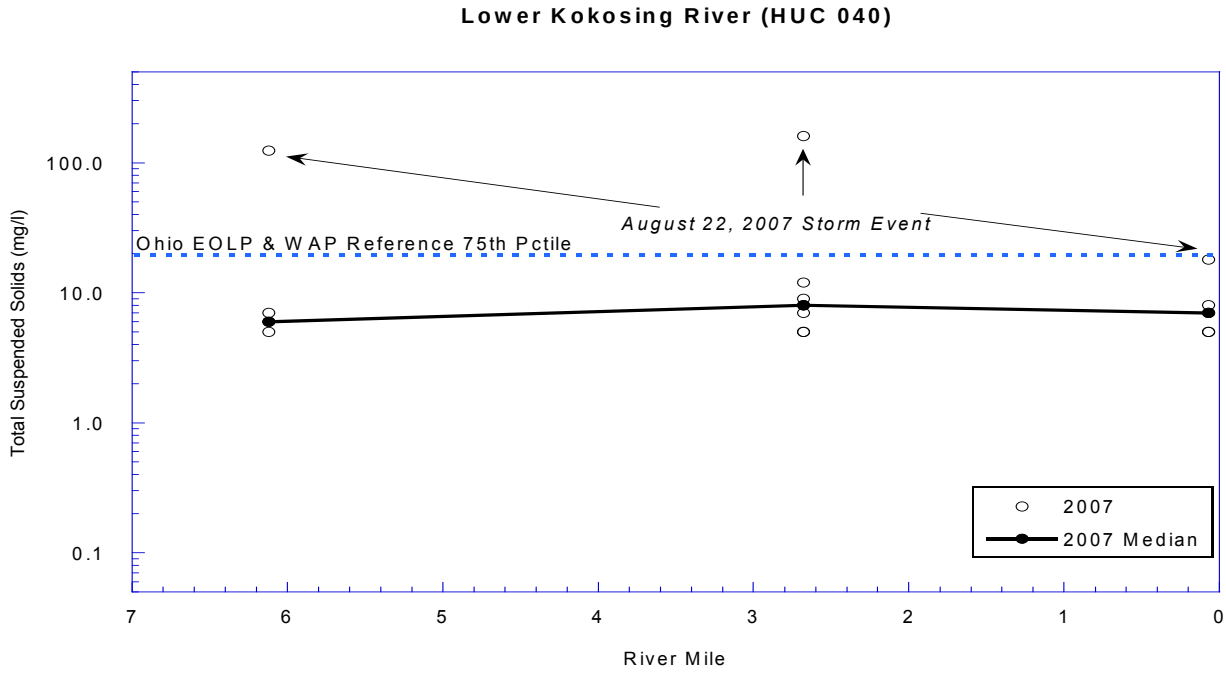

Figure 83. Concentrations of total suspended solids (mg/l) longitudinally plotted by river mile for the lower Kokosing River, 2007.

Lower Kokosing River Tributaries

Jelloway Creek (EWH, AWS, IWS, PCR)

Jelloway Creek flows mostly north to south in this subwatershed and discharges into the Kokosing River at RM 11.38. Jelloway Creek is 13.3 miles in length and drains 74 square miles. Three (3) sites were sampled including RM 8.85 (Orange-Hill Road), RM 4.26 (CR 9) and RM 0.1 (U.S. Route 36).

Dissolved oxygen conditions in Jelloway Creek were excellent. Median results were all above 8.2 mg/l (Figure 25, pg. 81). No instances of dissolved oxygen falling below 6.30 mg/l were recorded (Appendix F4).

Nitrate+nitrite concentrations in Jelloway Creek were well above 0.5 mg/l on all sampling events with the median values at each site over 1.0 mg/l. These results are above the recommended statewide target level for nitrate+nitrite in EWH streams (Figure 24, pg. 80).

Near the mouth (U.S. 36), upstream agricultural activities, the Knox County Little Jelloway WWTP effluent discharge and the release from Apple Valley Lake combine to adversely impact water quality at this sentinel site location. Total phosphorus, nitrate+nitrite, and ammonia nitrogen concentrations were among the highest in the entire watershed when compared to sites of similar drainage area (Figure 80, pg. 180 and Figure 84, pg. 183). The medians for these pollutants were recorded at 0.121 mg/l, 2.15 mg/l and 0.111 mg/l respectively. This nutrient enrichment was also reflected in supersaturated dissolved oxygen conditions recorded during diel monitoring (Figure 85, pg. 183). As a result, macroinvertebrate communities sampled at the mouth were only in partial attainment of EWH criteria.

High bacteria levels were routinely observed in the Jelloway Creek subwatershed. Each site in this reach recorded a violation on the primary contact recreation water quality standard (Table 12, pg. 54). Unrestricted livestock activities were common particularly in the open pastures of the upper watershed. In addition, high *E. coli* bacteria concentrations (22,000 #/100 ml) discharged from the Little Jelloway Creek WWTP were documented on June 27, 2007 (Appendix F4).

Ohio EPA also conducted a single organics scan on July 16, 2007 for 43 pesticide/herbicide compounds, 53 semi-volatile compounds and 7 PCB cogeners at the mouth. All results came back below-detection with the exception of bis(2-ethylhexyl)phthalate. Results for this common plasticizer, was slightly above the

detection limit but well below any established aquatic life or human health criteria. Analysis for mercury revealed no detections during any of the 5 sampling events above the detection limit of 0.2 ug/l.

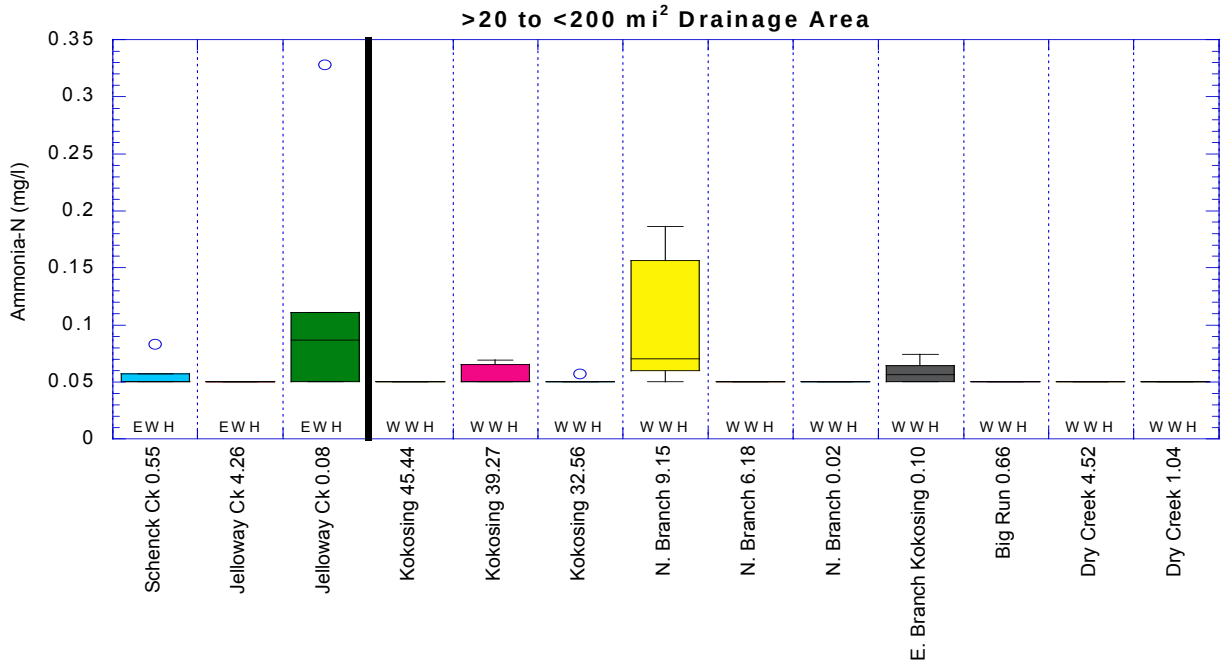

Figure 84. Ammonia-N (mg/l) reading taken for wading sites in the Kokosing River watershed, 2007.

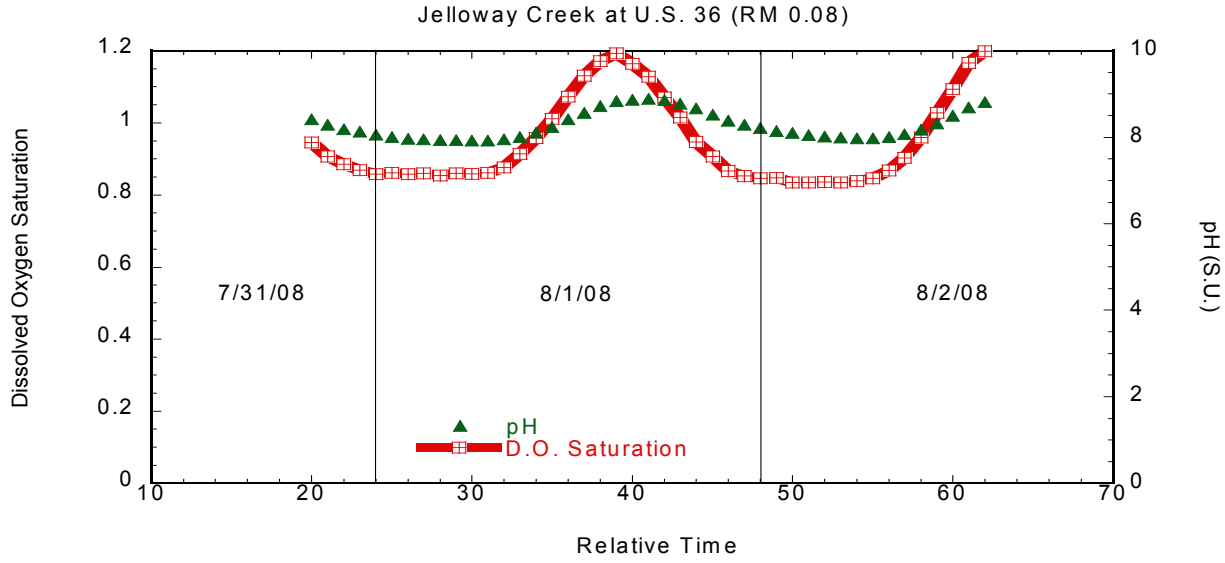

Figure 85. Dissolved oxygen saturation and pH concentrations longitudinally plotted by time (hours) and date for Jelloway Creek (RM 0.08)

Little Jelloway Creek (EWH, AWS, IWS, PCR)

Little Jelloway Creek drains 19.5 square miles with a length of 10.5 miles. Two sites on Little Jelloway Creek at RM 6.97 (Beaver Road) and RM 0.88 (Magers Road) below Apple Valley Lake were sampled for water chemistry. Little Jelloway discharges into Jelloway Creek at RM 0.65 at Howard. Effluent samples from the Little Jelloway WWTP were also collected and analyzed as part of this study.

Nitrate+nitrite concentrations recorded at the upper site on Beaver Road were the highest results for small streams in the Lower Kokosing subwatershed. Here the median concentration of 2.62 mg/l approached the 90th percentile for reference streams in this ecoregion. Other nutrients, such as total phosphorus and TKN were not a concern during sampling at this upper site. Positive water quality readings at this site did include cool stream temperatures (18.87ºc) and excellent dissolved oxygen levels (8.81 mg/). However, these positive results were not enough to overcome the sediment/siltation in this reach which adversely impacted macroinvertebrate communities.

Violations of the primary contact recreation standard were recorded at the upper site (Table 12, pg. 54). Elevated E.coli results were recorded during each sampling event. In this portion of the watershed livestock activities are a primary contributing source.

At the lower sample site on Little Jelloway Creek (RM 0.88) at Magers Road, water quality conditions were adversely impacted from the hypolimnetic dam release from Apple Valley Lake. Here the median stream temperature of 10.52ºC was unnaturally low compared to the upstream site and the ecoregion median reference value of 18.0ºC. In addition, ammonia-nitrogen values were extremely elevated with mid-summer sampling results of .262 mg/l, .394 mg/l and .665 mg/l recorded (Appendix F4).

An Ohio EPA stream investigation and sampling conducted in October 2007 near the discharge from the Apple Valley Lake dam to Little Jelloway Creek further confirmed the poor quality of this release. Hydrogen sulfide odors were strong and a blackish blue discharge was noted. At a location just upstream from the Magers Road study site, an extremely low stream dissolved oxygen reading (less than 1.0 mg/l) was documented along with extremely elevated lead, zinc and manganese concentrations. Predictably, these adverse water quality conditions resulted in poor biological communities and non-attainment of EWH criteria for both fish and macroinvertebrates.

Little Jelloway Creek WWTP (Knox County Commissioners)

The Little Jelloway Creek WWTP is operated by the Knox County Commissioners through the Knox County Water and Wastewater Department. The plant was constructed in 1974 with the last major upgrade in 1992. Treatment consists of a bar screen, grit removal, comminution, aerated lagoons, final clarification, secondary microstrainers, chlorination and dechlorination. The Little Jelloway Creek WWTP design flow is 0.900 MGD. Average daily flow for the period January 2007 through March 2008 was 0.51 MGD.

Violations have been quite frequent for the months of January 2007 through March 2008. Included were permit violations involving CBOD5, ammonia-N and total suspended solids. During the survey, water chemistry results were obtained from five (5) grab samples collected from the Little Jelloway Creek WWTP effluent (Appendix F4). Dissolved oxygen and p.H. field measurements were satisfactory on all sample events.

Median concentrations for total phosphorus, nitrate+nitrite and ammonia-nitrigen were 3.54 mg/l, 3.91 mg/l and 1.23 mg/l respectively. A single grab sample on August 22, 2008 indicated significant levels of ammonia-nitrogen (10.8 mg/l) and TKN (12.5 mg/l). These concentrations are a source of nutrient enrichment noted instream.

Extremely elevated bacteria results for E.coli were recorded on two sample days. On June 27, 2008 and August 27, 2008 E.coli sample results were 22,000 #/100 ml and 4,408 #/100ml respectively. These concentrations would contribute to violations of the instream primary contact recreation standard (Table 12, pg. 54).

East Branch Jelloway Creek (EWH, AHS, IWS, PCR)

East Branch Jelloway Creek originates northeast of Danville in Knox County and flows southwesterly through Danville before discharging into Jelloway Creek at RM 3.43. East Branch is 8.3 miles long and drains 31.8 square miles. Two sample sites were sampled on East Branch at RM 3.3 (U.S. 62) and RM 1.0 (Carey Lane).

The upper site at RM 3.43 on U.S. 62 was impacted by agricultural activities including livestock operations and row crop production. Nitrate+nitrite values routinely exceeded the 75th percentile reference values for Ohio streams (Ohio EPA, 1999). These conditions along with observations of stream sedimentation contributed to fish assessment results below EWH expectations.

Elevated bacteria results were recorded on each sample event resulting in a violation of the primary contact recreation standard. These results were among the highest when compared to similar sized streams in the Kokosing watershed (Figure 53, pg. 131).

East Branch of Jelloway Creek at RM 1.0 (Carey Lane) showed nutrient impacts from the Danville WWTP discharge. Several sampling day observations noted greenish colored discharge from the Danville WWTP extending downstream past the sample site. Median total phosphorus and nitrate+nitrite results at RM 1.0 exceeded the recommended statewide target levels in EWH streams for these pollutants (Appendix F4). In addition, low stream flow conditions exacerbated these already poor stream quality conditions. These results adversely affected fish communities that were very poor and did not meet either EHW or WWH criteria.

Danville WWTP

The Danville WWTP was constructed in 1993 with a design capacity of 0.2 MGD. Treatment consists of mechanical bar screens, influent lift station, continuous release treatment lagoons, chlorination/dechlorination, and post aeration. There are six lagoons with lagoon #1 acting as a complete mix activated sludge basin. Lagoon #2 is the ammonia nitrification cell and acts as a complete mix activated sludge basin. Lagoons #3 and #4 are for sludge settling and stabilization. Lagoons #5 and #6 act as facultative polishing cells. The sewage collection system has a large inflow/infiltration problem.

The average daily flow for the period January 2007 through March 2008 was 0.21 MGD, which exceeds the design flow. The Danville WWTP has been in almost complete compliance with permit limits for the period January 2007 through March 2008 except for a few dissolved oxygen violations in May and June 2007.

During the survey, water chemistry results were obtained from five (5) grab samples collected from the Danville WWTP effluent (Appendix F4). Readings for dissolved oxygen and p.H. field were satisfactory on all sample events.

Median concentrations for total phosphorus, nitrate+nitrite and ammonia-nitrogen were 0.552 mg/l, 5.31 mg/l and 0.193 mg/l respectively. Observations of green effluent were noted on several occasions. Downstream of the Danville WWTP, these same green conditions were noted with additional sampling results indicating concerns with nutrient enrichment. Bacteria results for E.coli were satisfactory during the sample events.

Brush Run (WWH, AWS, IWS, PCR)

Brush Run is 3.0 miles in length and drains 9.59 square miles. One site on Brush Run was sampled at RM 0.91 (off CR 36). Brush Run empties into Kokosing River at RM 5.27.

Brush Run had very favorable groundwater conditions with stream temperatures averaging 14.72ºC and no instances of low dissolved oxygen conditions. Some minor algae growth was observed here but nutrient concentrations did not appear to be a significant concern. Similarly, E.coli sample results did not indicate any problems with bacteria pollution.

Due to favorable habitat characteristics, cool stream temperatures and the presence of coldwater biology, this site meets expectations for a CWH stream.

Sediment

For this assessment unit, one location at Kokosing River RM 2.68 (Riley-Chapel Road) was evaluated for sediment composition. At this site, only total organic carbon appeared greater than reference guidelines (Table Sediment). Macroinvertebrate scores at this site indicated full attainment with EWH criteria.

Macroinvertebrates

Lower Kokosing River (SRW, EWH, AWS, IWS, PCR)

Lower quality water inputs (lower D.O. and elevated bacteria) sourced from Little Jelloway Creek (via Jelloway Creek at RM 0.65) flowed into the lower Kokosing River at RM 11.38 (HUC 040). The seasonal lower water quality inputs due to environmental conditions in Little Jelloway Creek (hypolimnetic impoundment discharges and WWTP discharges near the mouth) were exacerbated by drought conditions during the summer/early fall sampling period. (The lowest number of taxa collected throughout the survey area was only 22 taxa with only four to five EPT taxa in lower Little Jelloway Creek).

The macroinvertebrate community on the Kokosing River improved quickly downstream below the Jelloway Creek confluence to consistently superior exceptional performance similar to earlier exceptional community quality (ICI = 52) downstream to the mouth (confluence with the Mohican River to form the Walhonding River). The highest number of sensitive taxa collected (40) at all mainstem Kokosing River sites occurred at RM 6.2 (US 36).

Lower Kokosing River Tributaries

Jelloway Creek (EWH, AWS, IWS, PCR)

Beginning in forested hills of southern Ashland County Jelloway Creek flows south into Knox County joining the Kokosing River at Howard (RM 11.38). Macroinvertebrate community quality at the upstream site (Orange Hill / Snively Rd. RM 8.9) was exceptional with 20 EPT taxa and 26 sensitive taxa with the highest S/T ratio in the survey (i.e., 26.0+). Three coldwater taxa were present, and the coldwater taxa *Ceratopsyche slossonae* was among the predominant organisms. The upper stream reach of Jelloway Creek is recommended to be designated CWH. Stream temperatures should have been cooler; hillside tributaries upstream contained open pastures and resulted in flashy flows with some silt transported. Mainstem riparian cover and groundwater recharge buffered these sporadic inputs.

Downstream there was still evidence of sporadic flashy flows, but community performance was still exceptional, as the ICI at RM 4.3 (Danville-Howard Rd.) was 48, which met the ecoregion biocriterion. Forty sensitive taxa and 24 total EPT taxa were

collected from areas of stable substrates, despite some bank destabilization and sand bedload.

Downstream from the confluence with Little Jelloway Creek, Jelloway Creek (RM 0.1) did not meet the EWH narrative biocriterion. The number of qualitative EPT taxa and sensitive taxa diminished substantially compared to upstream sites. The good community performance was lowered by effects from Little Jelloway Creek. Flashy conditions in Jelloway Creek had resulted in increased embeddedness associated with the sand bedload. The poor quality water discharge from Apple Valley Lake's hypolimnion and from the regional WWTP near the mouth of Little Jelloway Creek adversely affected the macroinvertebrate community in lower Jelloway Creek. Macroinvertebrate habitat, such as the interstitial spaces between the stream substrates were filled in by organic matter coming from the hypolimnetic discharge.

East Branch Jelloway Creek *(EWH, AHS, IWS, PCR)*

East Branch Jelloway Creek flows southwest through Danville and joins Jelloway Creek downstream of Humbert Rd. at RM 3.43 The upstream reach near US 62 marginally met the EWH ecoregional biocriterion despite the unstable substrates from a large sand bedload. This destabilization was likely related to open pastures in steeper terrain and possibly some urban runoff from Danville.

The sample downstream from the Danville WWTP and downstream from Carey Lane showed improved quality with an ICI of 52. There was some enrichment from the municipal inputs with moderate to high relative organism density observed during qualitative sampling, but there was still 28 total sensitive taxa collected at RM 1.1, which indicated higher quality performance. Upstream from Carey Lane the habitat is mostly pooled which would allow for more primary productivity. Consequently the macroinvertebrate colonizers were placed downstream below the first riffle.

Little Jelloway Creek (EWH, AWS, IWS, PCR)

Little Jelloway Creek, which begins just west of Berger in Knox County, flows south and then southeast filling Apple Valley Lake before flowing into Jelloway Creek at Howard near the mouth at RM 0.65. The free flowing upstream reach, sampled at Beaver Rd. at RM 6.9, has coldwater attributes associated with good groundwater recharge (19.0^{o}C.). The three CW taxa collected (*C. slossonae*, the predominant caddisfly collected, a cased caddisfly, and a coldwater baetid mayfly) along with the predominant CW fish population present (59%) supported the recommendation of this upstream reach to be designated CWH.

The lack of diversity of heptageneid, ephemerellid, or burrowing mayflies at RM 6.9 was likely due to sediment NPS inputs or from cattle with complete access to the stream in the woodlot directly upstream from the sample site. There was some enrichment with more algal growth on rocks, which was utilized by the increased population of the dipteran *Atherix lantha*. This decrease in mayfly diversity and lower EPT totals (13) yielded a very good macroinvertebrate evaluation barely meeting the EWH narrative biocriterion, despite possessing 24 sensitive taxa and a high S/T Ratio of 8.0. Free livestock access upstream and the subsequent NPS inputs (silt and chemicals) could contribute to lower biological performance and future nonattainment. Partitioning off the stream with only a couple of crossing areas would benefit Little Jelloway Creek water quality.

Little Jelloway Creek downstream from Apple Valley Lake did not meet EWH expectations. The ICI at Magers Rd. (RM 0.9) only scored a 28 (fair). There was scum on the rocks from the milky-grey water discharged from the bottom of Apple Valley Lake (Figure 86). Large amounts of black solids filled the interstitial spaces among the rocky substrates, thus limiting habitability for macroinvertebrates. Some fungus or bacterial growth was present on rock surfaces. There were some extremely low D.O. readings (< 1.0 mg/l) and elevated manganese, zinc, and lead concentrations recorded. Despite the cold water temperatures (13^{o}C.) which ameliorated the impacts somewhat, the number of EPT taxa and sensitive taxa decreased dramatically. No mayflies were collected in the qualitative sample and just one taxa from the quantitative sample. There were parasites on many of caddisflies collected, a deformed *Polypedilum* midge was also found. Oligochaete worms and a coldwater midge comprised approximately 80 percent of the population indicating nutrient enrichment and lower quality conditions for the macroinvertebrate community.

Figure 86. Striking differences pictured above between the polluted water in Little Jelloway Creek flowing into the exceptionally clear water of Jelloway Creek at the confluence, just east of the town of Howard.

Little Jelloway Creek was sampled downstream from the Knox County / Little Jelloway Creek WWTP near its mouth at RM 0.01. The macroinvertebrate community performance was low-fair, which did not meet the EWH narrative biocriterion. Low to moderate numbers of facultative organisms, such as flatworms, limpet snails, and tanypode midges, were the predominant taxa present. Only four EPT and six sensitive taxa were collected. High ammonia concentrations up to10.8 mg/l were documented along with elevated phosphorus and high bacteria concentrations. Hypolimnetic lake discharges upstream also continued affecting the macroinvertebrate community in this segment.

The CWH use designation should be continued downstream from Apple Valley Lake as three CW taxa were still present with a high percentage of the population, and two CW fish were still present further downstream despite the poor water quality conditions (and historically present at RM 1.0).

Brush Run (WWH, AWS, IWS, PCR)

Brush Run flows northwest along SR 36 southwest of Zuck at RM 5.27. Six CW taxa were collected at this coldwater stream that benefited from a fairly nice riparian corridor. Upstream there were some farms, hay pastures, and oil wells. There were large amounts of algae that likely limited diversity. Still, the 2007 survey found 12 EPT taxa, 21 sensitive taxa and an S/T ratio of 5.25. This good macroinvertebrate quality met the current WWH narrative biocriterion. Decreasing NPS inputs upstream would further improve the quality of Brush Run.

Fish Community

Lower Kokosing River (SRW, EWH, AWS, IWS, PCR)

Fish sampling locations for the lower Kokosing River were at RM 6.2 (U.S. Route 36), RM 2.7 (Riley Chapel Road) and RM 0.1 (near TR 423 at mouth). Each of the three zones had exceptional physical habitat and biological communities with an average IBI score of 52 and an average MIwb score of 9.3 (Table 2, pg. 10). The habitat within the 200m sampling reach upstream of U.S. Route 36 was dominated by a spectacular 100m long riffle cutting through a sandstone gorge. This riffle was home to hundreds of sensitive darters [bluebreast darter (*Etheostoma camurum),* banded darter (*Etheostoma zonale*), variegate darter (*Etheostoma variatum*), and rainbow darter (*Etheostoma careuleum*)] (Appendix C). The site downstream at Riley Chapel Road had the greatest biodiversity among the lower three sampling locations with 26 species. This was also the only location the state endangered spotted darter (*Etheostoma maculatum*) was found in the watershed, with only two individuals recorded (Appendix C). The fast riffle from which the spotted darters were collected had cobble, boulder, and gravel substrates that were free from any silts or fines. Riffle habitats such as this typify historical spotted darter collection sites described by Dr. Trautman (Fishes of Ohio 1981). The record number of bluebreast darters caught in the Kokosing River at RM 2.7 of 194 individuals sampled more than doubled the old record of 82 bluebreast darters caught in 2001 at RM 13.4 in Big Darby Creek.

Northern pike (*Esox lucius*) were part of the fish community in the Kokosing River (RM 0.1) just upstream of its confluence with the Mohican River (Appendix C, Figure 87). This was the only site within the study area that northern pike were found. Four northern pike were caught during the first sampling pass and three northern pike were

recorded from the second pass. Out of the three lower Kokosing River sites, this site scored the highest IBI = 55 (Table 2, pg. 10). This additional predator captured near the mouth of the Kokosing River yielded the maximum top carnivore metric score (5) (Appendix B).

Figure 87. Northern pike from the lower Kokosing River, RM 0.2.

The main reason this site scored a couple of points more than the two upstream locations was due to a greater number of sucker (catostomidae) species in the catch. Deep runs in this section of the Kokosing River created exceptional habitat for pollution sensitive sucker species. A total of seven different sucker species were recorded from the site that included smallmouth redhorse, black redhorse, golden redhorse, northern hog sucker, silver redhorse, quillback, and white sucker (Appendix C & Figure 88).

Figure 88. Two pollution intolerant species caught in the lower Kokosing River, RM 0.2, (Left) smallmouth redhorse and (Right) black redhorse.

Lower Kokosing River Tributaries

Jelloway Creek (EWH, AWS, IWS, PCR)

Jelloway Creek flows mostly north to south in this subwatershed and discharges into the Kokosing River at RM 11.38. Jelloway Creek is 13.3 miles in length and drains 74 square miles. The three sites sampled included RM 8.9 (Orange-Hill Road), RM 4.3 (CR 9) and RM 0.1 (U.S. Route 36). All of Jelloway Creek yielded exceptional index scores (Table 2, pg. 10). The upstream site (RM 8.9) on Jelloway Creek also supported an exceptional coldwater habitat fish community with significant numbers of mottled sculpin and redside dace collected along with supporting CW macroinvertebrate taxa.

Little Jelloway Creek (EWH, AWS, IWS, PCR)

Little Jelloway Creek drains 19.5 square miles with a length of 10.5 miles. Three sites on Little Jelloway Creek at RM 7.0 (Beaver Road), RM 0.8 (Magers Road) below Apple Valley Lake and RM 0.1 (Howard Danville Road) were sampled for fish. The upstream site at Beaver Road (RM 7.0) had an exceptional fish community (IBI =54) that displayed CW properties (Table 2, pg. 10). Two CW fish, redside dace and mottled sculpin were caught at the site along with one very pollution sensitive least brook lamprey (*Lampetra aepyptera*). A total of 716 fish were caught at this site (Appendix C). There is concern that the unrestricted cattle access upstream of Beaver Road and the adjacent row crops downstream of the bridge are threatening the EWH and CWH water quality. To prevent future impairments to Little Jelloway Creek livestock should be provided limited access to the stream and a vegetative riparian buffer should be allowed to re-establish along the stream banks downstream

The two downstream sites (RM 0.8 & RM 0.1) were both heavily impacted by the Apple Valley Lake dam bottom discharge and had steadily declined in water quality since it was impounded (Figure 30, pg. 91). The lake had been discharging anoxic hypolimnetic water (Table 2, pg. 10). The fish community was poor (36) at RM 0.8 (Magers Road) (Table 2, pg. 10). The fish sampling crew caught only 49 fish within the 150m zone. The substrates were smothered in a gray flocculent that had settled out from the lake's discharge (Figure 86, pg. 191).

The downstream site at RM 0.1 scored poorly as well, IBI=44 (Table 2, pg. 10). Impairments from the Apple Valley Lake discharge persisted to this location along with those from the polluted effluent from improperly treated waste water coming from the Knox County WWTP. A pollution tolerant species commonly found in organically enriched streams are central stoneroller minnows (*Campostoma anomalum*). Stonerollers accounted for more than half of the fish community, far outnumbering all the other species combined with 1,926 individuals recorded at the site (Appendix C).

The IBI at this site was eight points higher than the upstream site partly because of the high numbers of fish and in part due to the proximity of Jelloway Creek. Many of the species recorded in small numbers at the site would not have been able to successfully reproduce in such poor conditions and presumably came from the main stem of Jelloway Creek (Appendix C). Little Jelloway Creek downstream of Apple Valley Lake has the potential to support a similar fish and macroinvertebrate community to that documented upstream of the impoundment and is recommended to be designated EWH and CWH (Table 2, pg. 10).

East Branch Jelloway Creek (EWH, AHS, IWS, PCR)

Two sites were sampled on the East Branch at RM 3.3 (U.S. 62) and RM 1.0 (Carey Lane). The upper site (RM 3.3) scored lower with an IBI of 40, but still yielded two coldwater fish species (4-redside dace, and 1-brook stickleback) and is partially attaining its designated aquatic life use (Table 2, pg. 10). Fine silts and sediments covered the stream substrates despite a vegetated and treed riparian zone and a natural stream channel. Upstream of Black Road the E. Br. of Jelloway Creek has been straightened (channelized) having no treed riparian buffer to trap sediment runoff from the adjacent agricultural and livestock operations (Figure 89). It is recommended that this section upstream of Black Road be restored to a more natural condition by restructuring the channel to a more sinuous form and permitting the riparian buffer to revegetate. Those changes would help trap sediment and slow storm water velocity, lessening erosion downstream.

Figure 89. East Branch of Jelloway Creek upstream of Black Road (Left) exports sediments downstream (right) of Black Road after rain events, covering stream substrates and perpetuating downstream erosion.

Downstream at RM 1.0 (Carey Lane) the East Branch of Jelloway Creek scored very poorly on the IBI with a score of 24 (Table 2, pg. 10). Only 78 fish were caught within the 150m sampling zone. The dominant (>70%) species in the fish community were tolerant of pollution (creek chub, bluntnose minnow, and white sucker) (Appendix C). The water at the site was green, indicative of excess nutrients in the stream. Water chemistry results later confirmed nutrient enrichment resulting from improperly treated effluent coming from the Danville WWTP (Table 2, pg. 10).

Brush Run (WWH, AWS, IWS, PCR)

One site on Brush Run was sampled at RM 0.9 (off CR 36). Full biological attainment was documented from the sampling at Brush Run (Table 2, pg. 10). The fish score (IBI=48) well exceeded WWH criteria and met the EWH criteria, while the macroinvertebrate community did not perform as well. This could be attributed to the drought conditions experienced during the 2007 sampling period that made riffle habitats very shallow and slow moving. Two cold water fish species were found among the community, redside dace and mottled sculpin, therefore Brush Run is recommended as CWH (Table 2, pg. 10).

Habitat

Lower Kokosing River

Physical habitat was evaluated for three sites on the lower Kokosing River at US 36 (RM 6.2), Riley Chapel Road (RM 2.7), and one site at the mouth off of Township Road 423 (RM 0.1). The habitat was exceptional at all three locations, supporting EWH aquatic communities. Long fast flowing riffles with large cobbles, and boulders for substrates typified the exceptional darter habitat found at the upper two sample sites (RM 6.2 and 2.7) (Appendix A). Just as the river flowed from the sandstone gorge, upstream of US 36, it carved out a long (~100 meter) fast flowing riffle that plunged into a large pool downstream of the bridge. A wide treed riparian corridor and fast flow in this reach kept the new parent substrate material of glacial tills free from silt and fine sediments.

Upstream of the Riley Chapel Road bridge (RM 2.7) the Kokosing River cascades down a bedrock shelf and splits into two very fast riffles downstream of the bridge. This is the location where the only state endangered spotted darters in the watershed survey were found (Appendix C). A narrow treed riparian strip buffered the Kokosing River from sediment runoff along this stream reach.

The Kokosing River widens towards the mouth (RM 0.1) with the habitat shifting from very well developed riffles at the two upstream sites to moderately stable, less developed riffles at its confluence. Large gravel and some sand made up the weaker riffles at this site; however, the run habitats in this section were better developed and created more diverse habitat for sucker species. Pool sections through this sampling reach contained more large woody debris than faster flowing upstream locations, providing habitat for multiple adult size northern pike throughout the 500 meter sampling zone (Appendicies A & C). A wide wooded riparian buffer on the right and a narrow one river left, buffered the river through this location.

Lower Kokosing River Tributaries

Four tributaries were evaluated for habitat quality in the Lower Kokosing River assessment unit: Jelloway Creek, Little Jelloway Creek, East Branch Jelloway Creek, and Brush Run (Table 9, pg. 46). Physical habitat was good for the entire length of Jelloway Creek and exceptional at the mouth of Jelloway Creek; however, there were some pollution threats at the upper two sites (Table 2, pg. 10). Brush Run, Little Jelloway Creek, and the headwaters of Jelloway Creek were all recommended for the

CWH aquatic life use. This portion of the watershed had the good groundwater connection in this part of the watershed that has provided sustainable conditions for CW biota. The East Branch of Jelloway Creek and Little Jelloway Creek had some physical habitat alterations and disturbances.

Jelloway Creek (WWH, AWS, IWS, PCR)

Jelloway Creek is threatened in its headwaters (RM 8.9, upstream of Shively Road) from runoff, river right, coming from a cow pasture. Livestock should be fenced from the tributary draining into Jelloway Creek. Evidence of torrent flows from improperly managed storm water was apparent by the eroded banks and multiple trees swept down at RM 4.26 on Jelloway Creek, despite a vegetative and treed riparian buffer on both sides of the creek (Figure 90). Erosion and sediment export downstream will continue to occur if this problem is not addressed. It is recommended that the Knox County Soil and Water Conservation District become involved in remediating this issue.

Figure 90. Jelloway Creek (RM 4.26) adjacent Chapel Road was threatened from poorly managed upstream storm water, apparent from the eroded banks and silted substrates, despite a good vegetated riparian buffer.

East Branch Jelloway Creek (WWH, AHS, IWS, PCR)

Upstream from State Route 62 on the East Branch Jelloway Creek (RM 3.3) riffles, runs, pools, sinuosity, and a 10-50m treed riparian buffer created good habitat for aquatic life. However, a moderate amount of silt and fine sediments were in this stream

reach as a result of nonpoint source runoff from upstream agriculture and livestock operations (Figure 89, pg. 195). Upstream from Black Road the East Branch of Jelloway Creek was straightened and devoid of the healthy physical habitat attributes found immediately downstream from Black Road. Storm water in this reach severely eroding the stream banks and is smothering the otherwise clean substrates with silt. It is recommended to restoring this section of the East Branch upstream of Black Road to its natural state will avoid future siltation and erosion of the downstream segments.

The East Branch of Jelloway Creek (RM 1.0) scored poorly on the QHEI at Township Road 348, downstream of the Danville WWTP (Table 2, pg. 10). A moderate to heavy amount of silt covered the natural stream substrates. Very few fish were caught in this stream reach as a result of sparse habitat. The water chemistry results showed nutrient enrichment from improperly treated waste water from the Danville WWTP plant. Algal blooms provided physical evidence of eutrophic conditions in the stream. Drought conditions in the summer of 2007 exacerbated water quality impairments. Ohio EPA scientists will be working with the Danville WWTP to improve its sewage treatment process.

Little Jelloway Creek (WWH, AWS, IWS, PCR)

Little Jelloway Creek was sampled downstream of Beaver Road (RM 7.0). Physical habitat was good at this location. Fast flows and good sinuosity helped to keep clean substrates despite the upstream and adjacent landuse practices. On the upstream side of Beaver Road, instream access of cattle has destroyed physical habitat. Row crops were planted all the way up to the eroded stream banks river right on the downstream side of the bridge (within the sample zone). These landuse practices are a threat to the water quality and biota in this EWH and CWH recommended stream. Livestock should be fenced out of the creek upstream of the bridge. Downstream of the bridge it is advised to stop farming up to the eroded stream bank. This is not only harmful from a water quality perspective, but also from an agricultural perspective. Over time, valuable farm land will be lost due to erosion. It is more beneficial to leave a green space between the crops and the stream to establish a permanent buffer from erosion and future soil loss along the banks.

Downstream of the Apple Valley Lake hypolimnetic lake discharge the water in Little Jelloway Creek (RM 0.8) was grey and the substrates were covered in a grey floculent. Physical habitat in this reach was good; however, the chemical water quality was poor and unable to sustain the existing EWH community (Table 2, pg. 10). The Apple Valley Lake committee is concerned about the water quality and is currently taking measures to remedy the problem.

One site at the mouth of Little Jelloway Creek (RM 0.1) was sampled. Physical habitat was good at this location, QHEI = 71. However, water chemistry impairments at this location from multiple sources were polluting Little Jelloway Creek. The Apple Valley Lake discharge was still impacting the creek down at the mouth and the Knox County WWTP was discharging improperly treated waste water. Ohio EPA scientists will be working with the WWTP operators to improve that plant's treatment process.

Brush Run (WWH, AWS, IWS, PCR)

Habitat in Brush Run at RM 0.9 was good overall, displaying very few anthropogenic disturbances. The substrates were normal with very little silt. However, the coarser substrates were still moderately embedded (Appendix A). Sand and gravel were the dominant stream substrates through this reach and the sand had left very few interstitial spaces among the gravel and what little cobble present. Sandstone, glacial tills, logs and woody debris were the main instream habitats available for aquatic life in this reach.

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