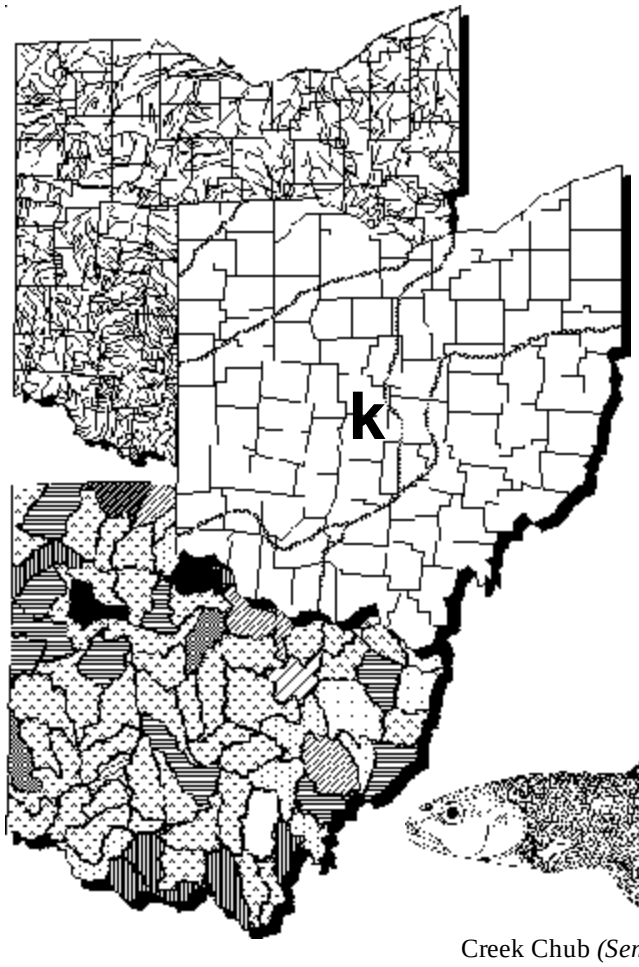
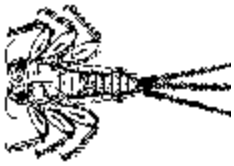
State of Ohio
Environmental Protection Agency

Ecological Assessment
Division of Surface Water

Biological and Water Quality Study of the Olentangy River and Selected Tributaries 1999

Delaware and Franklin Counties, Ohio





Mayfly *(Stenonema)*

Creek Chub *(Semolotus atromaculatus)*

Bob Taft
Governor, State of Ohio
Christopher Jones
Director, Ohio Environmental Protection Agency
P.O. Box 1049, Lazarus Government Center, 122 S. Front St., Columbus, OH 43216-1049

April 11, 2001

Biological and Water Quality Study of the Olentangy River and Selected Tributaries 1999

Delaware and Franklin Counties, Ohio

April 11, 2001

OEPA Technical Report MAS/2000-12-6

prepared by

State of Ohio Environmental Protection Agency
Division of Surface Water
Lazarus Government Center
122 South Front St., Columbus OH 43215
Mail to:
P.O. Box 1049, Columbus OH 43216-1049

Bob A Taft
Governor, State of Ohio
Christopher Jones
Director, Ohio Environmental Protection Agency

TABLE OF CONTENTS

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. 1989b. 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., Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989c. 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.

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
Monitoring and Assessment Section
4675 Homer Ohio Lane
Groveport, Ohio 43125
(614) 836-8777

ACKNOWLEDGMENTS

The following Ohio EPA staff are acknowledged for their contribution to this report:

Study Area - Vince Mazeika
Pollutant Loadings - Paul Vandermeer
Chemical Water Quality -Paul Vandermeer
Sediment Quality - Paul Vandermeer
Physical Habitat - Charles Boucher
Biological Assessment:
    Macroinvertebrate community - Chuck McKnight
    Fish community - Charles Boucher
Data Management - Dennis Mishne
TSD coordination - Chuck McKnight
Reviewers - Jeff DeShon, Jeff Bohne, Marc Smith, and Chris Yoder

This evaluation and report was possible only with the assistance of the study team, many full and part time field staff, and the chemistry analyses provided by the Ohio EPA Division of Environmental Services. Property owners who permitted access for sampling are also acknowledged for their cooperation.

Copies of this report are located on the Ohio EPA internet web page (www.epa.state.oh.us) or may be available from:

Division of Surface Water
Ecological Assessment Unit
4675 Homer Ohio Lane
Groveport, Ohio 43125
(614) 836-8777

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 10-15 different study areas with an aggregate total of 250-300 sampling sites.

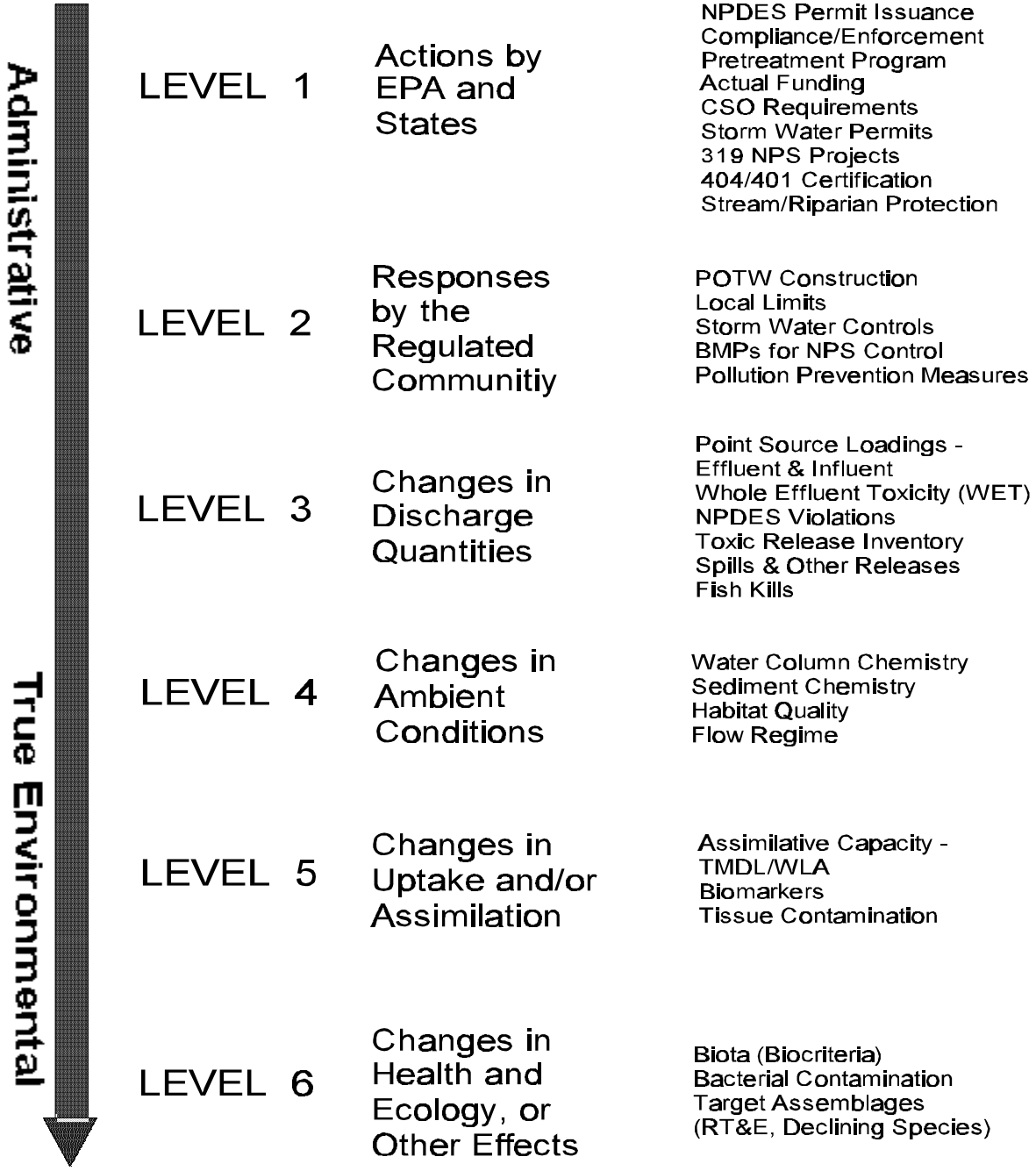
Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use 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 Ohio Water Resource Inventory (305[b]) report.

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators comprised 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 (Figure1). 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 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 recreational 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 Ohio Water Resource Inventory (305[b] report), 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) *Cold-water 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 is simply having a water depth of at least one meter over an area of at least 100 square feet or where canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.*, fecal coliform, *E. coli)* and the criteria for each are specified in the Ohio WQS.

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 Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, 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.

Biological and Water Quality Study of the Olentangy River 1999

Delaware and Franklin Counties, Ohio

State of Ohio Environmental Protection Agency
Division of Surface Water
Lazarus Government Center
122 South Front St., Columbus OH 43215

INTRODUCTION

As part of the five-year basin approach for monitoring, assessment, and the issuance of National Pollution Discharge Elimination System (NPDES) permits, ambient biological, water column chemical, sediment, and bioassay sampling was conducted in the Olentangy River basin from June to October, 1999. This study area included a 32 mile reach of the Olentangy River downstream from Delaware Reservoir to the mouth, and sites on nine tributaries in the watershed. Table 1 indicates sampling locations.

Specific objectives of this evaluation were to:

1) Monitor and assess the chemical, physical and biological integrity of the streams within the 1999 Olentangy River study area;

2) Characterize the consequences of various land uses on water quality within the Olentangy River watershed;

3) Evaluate the influence of the Delaware and Olentangy Environmental Control Center wastewater treatment plants (WWTPs);

4) Evaluate the potential impacts from spills, nonpoint source pollution (NPS), and habitat alterations on the receiving streams; and

5) Determine the attainment status of the current designated Warmwater Habitat (WWH), Exceptional Wamwater Habitat and Modified Warmwater Habitat aquatic life uses and other non-aquatic use designations and recommend changes where appropriate.

The findings of this evaluation factor into regulatory actions taken by the 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 incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Water Resource Inventory (305[b]) report.

SUMMARY

Aquatic Life Use Attainment Status

The 1999 Olentangy River study area included a mainstem reach beginning at RM 32.0, upstream from the City of Delaware and extending downstream to the mouth in Columbus and sites on nine tributaries. In all, 30 biological and chemical sample stations were visited. Effluent samples were also collected at the Delaware WWTP and the Olentangy Environmental Control Center. Based on the performance of biological communities with respect to ecoregional biocriteria, 23.8 miles of the mainstem of the Olentangy River were considered to be in FULL attainment of the applicable aquatic life use designation. PARTIAL attainment was documented for 7.9 miles of stream and only 0.3 miles of **NON** attainment was documented (Table 1). This represents more than twice as many miles of FULL attainment versus results similar studies yeilded in 1988 and 1989. The improvement can be largely attributed to improvements effluent quality at the Delaware WWTP.
The Olentangy River had generally good water quality, except for a few minor violations of bacterial water quality standards and pesticides. Low concentrations of pesticides were detected in every sample obtained from the Olentangy River mainstem. Mean dissolved oxygen concentrations were above 6 mg/l and nutrient concentrations, though often elevated , did not seem to be impacting the free-flowing portions of the stream. Upstream from the metropolitan Columbus area, both fish and macroinvertebrate communities were in good to exceptional condition. Among the fish species collected were two classified as endangered, threatened, or special status - river redhorse and bluebreast darter (Ohio DNR 1997).

The lower four miles of the Olentangy River demonstrated the combined effects of CSOs/SSOs, urban runoff and habitat modifications associated with an urbanized watershed. Use designations have been applied that account for the modified habitats resulting from the lowhead dams in the area. Nevertheless, the macroinvertebrates in both the MWH and WWH areas were significantly impacted in this reach. Sampling results decumented increasingly more tolerant communities in a downstream direction. In addition to the poorly performing macroinvertebrate communities, contaminated sediments were also documented in the dam pools. The fish assemblages in the dam pools met the MWH use and were apparently not affected by the accumulation of material in the pooled areas. As a result, much of this area was considered to be in partial attainment of the designated aquatic life uses.

Contaminated sediments in the mainstem and sampled tributaries were concentrated within the urban areas

of Delaware and Columbus. Mainstem sites in the Columbus urban area within the last

Table 1. Aquatic life use attainment status of the Olentangy River basin, June-October, 1999. The Index of Biotic Integrity (IBI), Modified Index of Well Being (MIwb), and Invertebrate Community Index (ICI) scores are based on the performance of fish (IBI, MIwb) and macroinvertebrate communities (ICI). The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support biological communities.

River Mile Invertebrate/Fish	IBI	MIwb	ICI[a]	QHEI	Attainment Status[b]	Comments
Olentangy River			*WWH Use Designation (Existing)*			
32.0/32.0	42	9.4	34[ns]	69.0	FULL	Main Rd
27.5/27.9	42	8.8	48	82.5	FULL	Hudson Rd.
25.4/25.4	43	9.8	MG[ns]	66.5	FULL	Ust. Delaware WWTP
25.26/25.26	39	9.6	-		n/a	Delaware WWTP mixing zone
24.5/24.5	42	8.6	40	68.5	FULL	Olentangy Ave
22.5/22.3	40	7.9[ns]	50	74.0	FULL	US 23
			EWH Use Designation (Existing)			
19.6/19.4	44*	9.0[ns]	52	75.0	PARTIAL	Hyatts Rd.
14.9/15.0	53	10.3	50	65.0	FULL	St Rt. 750
13.38/13.38	26	6.6	-		n/a	OECC WWTP mixing zone
12.8/12.4	50	9.6	44[ns]	63.5	FULL	
			WWH Use Designation (Existing)			
7.7/7.8	48	9.0	42	54.5	FULL	Kenny Park
6.9/6.8	50	9.7	44	60.0	FULL	Hendrson Rd.
			MWH Use Designation (Existing)			
5.5/5.5	40	8.4	22	44.0	FULL	E. North Broadway
			WWH Use Designation (Existing)			
4.0/3.9	49	10.1	26*	56.5	PARTIAL	Dodridge Rd.
			MWH Use Designation (Existing)			
2.0/2.0	39	8.7	12*	29.0	**NON**	Ust. 5th Ave. dam
1.9/1.8	42	9.7	20*	65.5	PARTIAL	Dst. 5th Ave. dam
			WWH Use Designation (Existing)			
0.6/0.7	35	8.9	28*	61.5	PARTIAL	Railroad bridge
			MWH Use Designation (Existing)			
0.2/0.3	38	9.3	12*	54.5	**NON**	near mouth
Adena Brook			*WWH Use Designation (Existing)*			
1.0/0.9	22*	n/a	P*	43.5	**NON**	Overbrook Dr.

-/0.1	32*	n/a	-	54.0	(**NON**)	Whetstone Park

Table 1 continued.

River Mile Invertebrate/Fish	IBI	MIwb	ICI[a]	QHEI	Attainment Status[b]	Comments
Turkey Run			*WWH Use Designation (Existing)*			
0.7/ -	20*	-	P*	-	**NON**	Shattuck Ave.
Rush Run			*WWH Use Designation (Existing)*			
0.4/0.3	28*	n/a	F*	48.5	**NON**	Walnut Grove Cemetary
Bartholomew Run			*WWH Use Designation (Existing)*			
1.0/ -	-	-	F*	-	(**NON**)	Bennett Rd.
Delaware Run			*WWH Use Designation (Existing)*			
1.2/1.2	34*	n/a	P*	61.0	**NON**	Limestone Park
0.2/0.2	30*	n/a	P*	40.0	**NON**	Henry St.
Horseshoe Run			*WWH Use Designation (Existing)*			
0.3/0.3	38ns	n/a	F*	63.5	PARTIAL	Panhandle Rd.
Lewis Center Tributary			*WWH Use Designation (Existing)*			
0.1/0.1	32*	n/a	G	65.5	PARTIAL	Taggert Rd.
Bill Moose Run			*WWH Use Designation (Recommended)*			
0.3/0.2	30*	n/a	F*	57.0	**NON**	Kenny Park
Linworth Run			*WWH Use Designation (Recommended)*			
0.9/0.9	26*	n/a	F*	53.5	**NON**	Linworth Rd.
Kempton Run			*WWH Use Designation (Recommended)*			
0.9/ -	22*	n/a	-	54.5	(**NON**)	Linworth Rd.

Ecoregion Biocriteria: E. Corn Belt Plains (ECBP)

INDEX - Site Type	WWH	EWH
IBI Headwater - Wading/ Boat	40/ 42	50
MIwb Wading/ Boat	8.3/ 8.5	9.4/ 9.6
ICI	36	46

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

two miles of the mouth were moderately to severely contaminated with metals and organic compounds. Of the nine tributary streams, Delaware Run, Rush Run and Adena Brook showed the highest degree of metals and/or organic contamination. Less severe levels of contamination were noted in the other urban tributaries sampled.

Both the Delaware WWTP and the Olentangy Environmental Control Center were found to be operating properly during the survey period. Flows were within design capacity and nutrient and metals loadings were within permit limits. Whole effluent toxicity testing conducted at the Delaware WWTP during April 1999 was found to be acutely toxic. The source of toxicity has not been determined. Whole effluent toxicity testing at the OECC WWTP indicated no acute toxicity for tests conducted in December 1998 and April 1999.

None of the sampled tributaries fully attained the WWH aquatic life use. Horseshoe Run partially met the use as the fish marginally met expectations but the macroinvertebrate community was in only fair condition. It appeared that drought conditions encountered during the summer of 1999 was a primary stressor on biological communities in the stream. The Lewis Center tributary supported a good macroinvertebrate assemblage but the fish community was only in fair condition. The reason for depressed fish results was not readily apparent. The remaining sampled tributaries were in developed or rapidly developing urbanized watersheds. The macroinvertebrate communities in these tributaries were predominated by tolerant taxa, and pioneering and tolerant fish made up a large proportion of the fish communities. Additionally, the most frequent exceedences of Ohio Water Quality Standards criteria were for fecal coliform and E. coli bacteria which are symptomatic of sewage releases, commonly from CSOs and SSOs. Delaware Run appeared to be the most severely impacted by sewage. The stream frequently was noted as having septic odors and supported only tolerant fish and macroinvertebrate communities. The presence of contaminated sediments in the urbanized streams is a clear indication that runoff carried with it a variety of chemical compounds that can be toxic to aquatic organisms. Changes in flow hydrology and habitat due to increasing development, urban runoff and CSO/SSO discharges all combined to varying degrees resulting in non-attainment of the WWH aquatic life use.

CONCLUSIONS

- The Olentangy River generally supported good macroinvertebrate and fish communities. Only 1%(0.3 miles) of the mainstem of the Olentangy River was considered to be in **NON** attainment of the applicable aquatic life use designations (Table 1). Partial attainment of the WWH criteria was documented for 7.9 miles (25%). Full attainment was documented for 23.8 miles (74%).

- The sampled tributaries, excepting Horseshoe Run and the Lewis Center tributary, were impaired by the effects of urban development. Only the Lewis Center tributary supported at least a marginally

good macroinvertebrate assemblage. The fish community of all the sampled tributaries excepting Horseshoe Run failed to meet the WWH biocriteria. As a result, the WWH use was partially attained in Horseshoe Run and the Lewis Center tributary with the remaining tributaries in non-attainment of the designated use. Evidence of degraded water quality in the urbanized streams included elevated nutrient and bacteria levels and contaminated sediments.

C The hydrology of urbanized tributaries in the Columbus metropolitan area have been altered resulting in flashy storm runoff events followed by often intermittent flows at other times. These changes in the hydrology included a high proportion of residential, commercial and transportation related impervious surfaces and past construction of buried sewer - septic lines in many urban tributary ravines adjacent to or under the streambed itself (Columbus Sewer and Drains Division, 1998).

C Habitat quality was very good in the Olentangy River mainstem with the exception of the impounded stream segments in the lower river. Habitat in the tributaries was somewhat variable but generally was of lesser quality than the mainstem. Loss of riparian vegetation, and channelization have contributed to the non-attainment in the urbanized tributaries.

C The overall good condition of the Olentangy River should be considered threatened because of the urban nature of the lower watershed and the ongoing development in Delaware County. Also, the influence of old landfills along the stream in and around Delaware (the old municipal landfills) and the old Gowdy landfill in Columbus may be chronically contributing pollutants, particularly the pesticides found in the Delaware area. Chemical water quality in the tributaries is already degraded and could impact the mainstem. Hardening of the watershed via further development will introduce further chemical contaminants due to increased runoff from roads, parking lots, manicured lawns and rooftops. Also, population growth in this area will strain the infrastructure in place for managing sewage. Both the OECC and Delaware City WWTPs have expanded their capacity in recent years. Further expansion of these plants may be warranted in the future with continued growth. Efforts to minimize additional nutrient loads above current levels are needed to insure maintenance of the EWH use downstream from these plants.

RECOMMENDATIONS

Status of Aquatic Life Uses

A number of the tributary streams evaluated in this study were originally designated for aquatic life use in the 1978 and 1985 Ohio WQS (Table 2); others were previously undesignated. The current biological assessment methods and numerical criteria did not exist then. This study, as an objective and robust use evaluation, is precedent setting in comparison to the 1978 and 1985 designations Several subbasin streams have been evaluated for the first time using a standardized biological approach as part of this study. Ohio EPA is obligated by a 1981 public notice to review and evaluate all aquatic life use designations outside

of the WWH use prior to basing any permitting actions on the existing, unverified use designations. Thus, some of the following aquatic life use recommendations constitute a fulfillment of that obligation.

The current suite of aquatic life use designations for the Olentangy River should be maintained. Use attainability analysis based on the 1999 biological and habitat results confirmed the appropriateness of the current aquatic life uses. Only two areas did not met the designated use. The first was in the EWH segment downstream from the city of Delawarewhich was due to a slight deviation of the IBI form the statewide biocriterion. The second non-attaining segment was in the lower 5.5 miles the river due to impairment in the macroinvertebrate community associated with the effects from the urban land use and impoundment of the river by lowhead dams (*i.e.* contaminated sediments and excessive algal productivity).

The current WWH aquatic life use designation for the sampled tributaries should also be maintained. It is further recommended that Linworth Run, Bill Moose Run and Kempton Run also be designated WWH. This designation is appropriate even though the use was not met. The streams are not candidates for a modified warmwater habitat use in that they have not been subjected to 401/404 permitted channel modifications. It is possible that some of the physical attributes that are currently lacking on many of these streams are restorable. It should be noted however that the urban landscapes which surround the majority of the tributaries have severely altered the flow requiem and contribute significant pollutant loads via nonpoint and/or CSO/SSO discharges.

Status of Non-aquatic Life Uses

The current Industrial and Agricultural Water Supply use designations on the Olentangy River and currently designated tributaries should remain in place. An Industrial Water Supply use is recommenced for the three undesignated tributaries, Linworth Run, Bill Moose Run), and Kempton Run. These three tributaries flow through urban areas negating the need for the Agricultural Water Supply use. The only tributary where pool depths exceeded one meter was Adena Brook. As such, the current Primary Contact Recreation use designation is appropriate. The Secondary Contact Recreation use sufficient to protect persons wading in the stream is recommended for the remaining sampled tributaries including the undesignated streams.

A rulemaking was initiated by the Ohio EPA in 2000 to designate public water supplies at four locations on the Olentangy River. The designations were adopted on 29 March, 2000 and became effective on 29 March, 2001. The use applies within 500 yds of drinking water intakes at RMs 31.23, 31.02, 18.19, and 0.2.

Table 2. Waterbody use designations for the Olentangy River basin. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). Designations based on Ohio EPA biological field assessments appear as a plus sign (+). Designations based on the 1978 and 1985 standards for which results of a biological field assessment are now available are displayed to the right of existing markers. Designated uses based on results other than Ohio EPA biological data are marked with an circle (o). A delta ( )) indicates a new recommendation based on the findings of this report.

Water Body Segment	Use Designations												
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Olentangy River													
Delaware Dam (RM 32.3) to Old Winter Rd. (RM 20.4)	*+	*+							*+	*+		*+	
at RM 31.23	*+	*+						o	*+	*+		*+	
at RM 31.02	*+	*+						o	*+	*+		*+	
Old Winter Rd. to I-270 (RM 11.6)	*+		*+						*+	*+		*+	
at RM 18.19	*+		*+					o	*+	*+		*+	
I-270 to St. Rte. 161 (RM 9.7)	*+	*+							*+	*+		*+	
St. Rt. 161 to Adena Brook (RM 5.9)	*+	*+							*+	*+		*+	
Adena Brook to the Dodridge St. dam (RM 4.0)				+					*+	*+		+	
Dodridge St. dam to adjacent Tuttle Park (RM 3.4)		+							*+	*+		+	
Adjacent Tuttle Park to Fifth Ave. dam (RM 1.9)				+					*+	*+		+	
Fifth Ave. dam to Conrail railroad crossing (RM 0.5)		+							*+	*+		+	
Conrail railroad crossing to mouth				+					*+	*+		+	
at RM 0.2		*+						o	*+	*+		*+	
all other segments		*+							*+	*+		*+	

Table 2 Continued.

Water Body Segment	Use Designations												
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Big Run (Adena Brook)		*+							*+	*+		*	
Turkey Run		*+							*+	*+		*	)
Rush Run		*+							*+	*+		*	)
Bartholomew Run		*+							*+	*+		*	)
Unnamed Tributary (RM 18.19, Lewis Center Tributary)		+							*+	*+			+
Delaware Run		*+							*+	*+		*+	
Horseshoe Run		*+							*+	*+		*	)
Linworth Run		)								)			)
Unnamed Tributary (RM 7.82, Bill Moose Run)		)								)			)
Kempton Run		)								)			)

Future Monitoring Needs

A complete reevaluation of the Olentangy River study area should be conducted in the year 2003. The reassessment is needed considering the rate of land use and population changes within the watershed and the TMDL report that is pending in 2005. Priority should be placed on revisiting segments which are identified as impaired or threatened in this report.

Additional bioassay testing at the Delaware WWTP is needed to further characterize the toxicity of the effluent and begin the process of identifying the source(s).

STUDY AREA DESCRIPTION

The Olentangy River originates in Crawford County and flows south across Marion, Delaware and Franklin counties to its confluence with the Scioto River near downtown Columbus. The 1999 study area included

the mainstem and selected tributaries between the United States Corps of Engineers dam at Delaware Reservoir and the confluence with the Scioto River. The elevation at the dam spillway is 884 feet. Elevation at the confluence is 702 feet. The average fall per mile for the study area is 5.6 feet per mile. The basin drains one hundred forty six square miles from the Delaware Dam south to the confluence.

The study area climate is one of cold winters and warm summers with ample precipitation throughout the year enabling forest growth and the raising of crops. Located at the Polar Front, contrasting air masses are primarily responsible for the area's weather and climate phenomena. Winter is characterized by dry continental polar (cP) air masses from Canadian source regions. Summer is characterized by maritime tropical (mT) air masses from the Gulf of Mexico. The Koppen-Geiger climate classification code for the study area is Cfa - "Warm temperate climate, mean temperature of coldest month 64.4°F down to 26.6°F; sufficient precipitation in all months, warmest month mean over 71.6°F" (Strahler 1963).

The Illinoisan and Wisconsin glacial periods influenced land forms, soil types and stream substrates in the Olentangy study area. Both ground and terminal moraines are seen in the watershed. Bedrock underlying the watershed is sedimentary. Lithologies consist of dolomitic limestone, shale and sandstone. The substrate reflects both glacial deposition and bedrock materials, with limestone, sandstone and shale being predominant constituents. Limestone bedrock is readily visible in some reaches of the streambed, particularly north of the Franklin - Delaware County line at High Banks Metro Park and the SR 315 and Home Road bridges.

The study area is within the Eastern Cornbelt Plains Ecoregion and divides into two subregions. Approximately north of the Franklin County line lie the Clayey High Lime Till Plains, a broad nearly level subregion containing end moraines and basins. South of this line begin the Loamy High Lime Till Plains, a subregion of level to rolling glacial till with end moraines and glacial outwash features. (Omernik, 1988)

Flood plain tree species included box elder, sycamore, green ash, willow, hackberry, buckeye, honey locust and silver maple. Beech, maples, cherry and redbud are more commonly seen in tributary ravines. Red oaks, other oaks, walnut, hickory and sugar maple appeared on the better drained uplands. On more limey soils chinkapin oak is seen. In urbanized areas, some reaches of wooded river corridor show extensive growth of bush honeysuckle, a nonindigenous species. Garlic mustard, also nonindigenous, was observed at numerous river corridor and tributary sites in the study area. (Personal communication: Harold Bower, Service Forester - Project 8. ODNR)

The soil associations outside the flood plain are products of glacial till. Associations within the flood plain showed influence of alluvium, glacial outwash and or loess deposition. North of the Franklin County line, the study area soils show a higher requirement for artificial drainage and, when eroded, contribute clayey sediments to surface water bodies.

The Franklin County portion of the flood plain is dominated by the Medway-Genesee-Sloan soil association formed in moderately coarse to moderately fine textured recent alluvium**.** East of the river corridor, the Cardington-Alexandria-Bennington soil association is found in a band between .25 and .5 miles wide, extending back from the flood plain proper. It also extended east into tributary ravines (Rush Run, Adena Brook, etc). This association is formed in medium textured and moderately fine textured glacial tills.

The Eldean-Ockley-Warsaw association extends along the southern third of the river corridor within the study area. These well drained soils, formed in moderately coarse to moderately fine textured glacial outwash, alluvium or loess, are found .5 to .75 mile west of the flood plain between Grant-Riverside Hospital thence south to the confluence.

From the hospital complex north to approximately 1 mile above Interstate 270 extends a band of Miamian-Celina association soils on west river valley side slopes. Formed in medium and moderately textured glacial till, these soils are subject to erosion. Regarding this soil association, the Franklin County Soil Survey noted that "Plant cover should be maintained as much as possible during construction" (United States Department of Agriculture, Soil Conservation Service. 1980).

Within Delaware county and north of Winter Road; the lower lime soils of the Cardigton-Alexandria association seen in the eastern tributary ravines and Bennington Pewamo associations of the east bank uplands are replaced by higher lime Glenwood-Blount and Blount-Pewamo associations. The Blount-Pewamo association is one of poorly to very poorly drained soils. In the flood plain and low outwash terraces of the Olentangy and the tributary, Horseshoe Run; Ross, Sloan and Scioto soils predominate. (Personal Communication: Delaware-Natural Resources Conservation Service).

The Gazetteer of Ohio Streams listed the length of the Olentangy as 88.5 miles from its source in Crawford Co. The elevation at source is recorded as 1189 feet. Twelve named tributaries are listed by the Gazetteer between the confluence with the Scioto and the Delaware Reservoir. They include Adena Brook, Turkey Run, Bartholomew Run, Deep Run, Weiser Run, Kingsbury Run, Mill Run, Delaware Run, Sugar Run, Clear Run and Horseshoe Run. Seven of these tributary streams have gradients greater than 60 feet per mile. The gradient for Deep Run in Delaware County (river mile 15.80) is steepest at 173.3 feet per mile. Upstream from the study area, three tributaries exceeded 30 feet per mile gradient.(Ohio Department of Natural Resources. 1960)

Numerous unnamed tributaries flow within the study area. Of note are those draining land east of the river. In urbanized Columbus and Worthington, these tributaries cut steep sided ravines through black shale bedrock. Runoff from residential, commercial and transportation related impervious surfaces constitute a significant portion of their flow (Table 3). Sewer - septic lines are buried in a number of the urban tributary ravines adjacent to or under the streambed itself. In 1999, a previously unnamed tributary entering the

Olentangy at river mile 7.82 was designated as Bill Moose Run by the United States Geological Survey.

NONPOINT SOURCE ISSUES

Traveling upstream in the study area from Franklin County into Delaware County, nonpoint sources transition from typically urban impervious surface runoffs and aged combined sewer systems to runoff from a rapidly developing, yet still predominantly rural - agricultural landscape.

Land use changes within the study area over the past decade partially reflect changes in population, economic activity, and agricultural practices. Between the census years of 1990 and 1999, the population of Franklin County increased from 961,438 to an estimated 1,027,821 residents - an increase of 7%. Delaware County increased from 66,929 in 1990 to an estimated 103,679 residents - an of increase of 55%.

The Delaware County portion of the study area lay within the boundaries of Delaware, Liberty, Orange and Troy townships. Their combined populations increased by an estimated 13,393 residents between 1990 and 1999. This increase was centered in Liberty and Orange townships which are served by sanitary sewers. Troy Township, north of the City of Delaware was not yet served by sanitary sewers (Personal Communication: Delaware County Regional Planning Commission).

In contrast to Delaware County, the Franklin County portion of the watershed is largely "built out". Agricultural practices or lands are not a significant potential or actual source of nonpoint source pollutants. Of greater weight are surface runoffs from an extensive road and highway network, overflows of combined sanitary-storm sewer systems, urban runoff (from driveways, parking lots, roofs, home and lawns) and the likely improper disposal and leakage into storm drains and tributaries of home, business and small industry byproducts including paints, lawn and garden chemicals, restaurant greases, soaps, cleaning products, vehicle lubricants and cleaning solvents.

The sanitary sewer system for the City of Columbus consists of both combined and separate sewers. There are nine permitted regulator discharges and relief structure overflows in the system known as combined storm and sanitary sewer overflows (CSOs) (Tables 3 and 4) that discharge to the Olentangy River. There are 51 documented sanitary sewer relief locations in the Olentangy River watershed. These "relief"sewers constitute separate sanitary sewer overflows (SSOs) and are designed to discharge directly to a storm sewer when the level in the "relief" sewer reaches a certain elevation (Table 5).

Table 3. List of combined storm and sanitary sewer overflows (CSOs) located in the City of Columbus sanitary collection system. These discharge points are at combined sewer regulators (Ohio EPA 1999).

Location	Outfall No.	Receiving Stream
First & Perry	4PF00000032	Olentangy River
Third & Perry	4PF00000027	Olentangy River
King Avenue	4PF00000007	Olentangy River
Regulator at OSU/Indianola Ave.	4PF00000006	Olentangy River
Tuttle Park at Frambes	4PF00000031	Olentangy River
Frambes and Neil Ave.	4PF00000005	Olentangy River
Hudson Street	4PF00000004	Olentangy River

Table 4. Combined sanitary sewer overflows (CSOs) without regulators located within the city of Columbus sanitary collection system (Ohio EPA 1999).

Location	Outfall No.	Receiving Stream
Third Ave. Relief Structure Discharge	4PF00000039	Olentangy R.
Main Interceptor Sewer, Discharge N of Hill Ave.	4PF00000040	Olentangy R.

Table 5. City of Columbus Sanitary Sewer overflow relief points discharging to storm sewers or open waterways. Reference number refers to the numbering system used by the city to track the SSOs in the collection system. MH = manhole (Ohio EPA 1999).

Relief Location	Type	Receiving Waters
MH s/s Third Ave., 490' w/o Olentangy R. Rd.	A	Olentangy R s/o Third
MH s/s Third Ave.,690' w/o Olentangy R. Rd.	A	Olentangy R. s/o Third
MH s/s Third Ave., 290' w/o Olentangy R. Rd.	A	Olentangy R. s/o Third
MH Northwest Blvd. & Hilo Lane	A	Olentangy R. s/o Third
MH f/o 814 W Third Ave.	A	Olentangy R. s/o Third
MH alley n/o King and w/o Star Ave.	A	Olentangy R. s/o King
MH Third & Morning	A	Olentangy R. s/o Fifth
MH King Ave & alley w/o Virginia	A	Olentangy R. s/o King
MH Meadow Rd & Third Ave.	A	Olentangy R. s/o Fifth
MH Third and Virginia	A	Olentangy R. s/o Fifth
MH Fifth Ave & North Star	A	Olentangy R. s/o Fifth
MH King and North Star	A	Olentangy R. s/o King
MH Fifth Ave & Eastview/Kenny	A	Olentangy R. s/o Fifth
MH alley n/o Hill Ave w/o Perry St.	A	Olentangy R. alley n/o Hill
MH Third Ave & Oxley (east)	A	Olentangy R. s/o Fifth
MH Third Ave & Oxley (west)	A	Olentangy R. s/o Fifth
MH Howey & Briarwood	A	Glen Echo Ravine e/o I-71
MH Akola and alley w/o Azelda	A	Glen Echo Ravine e/o I-71
MH Akola and alley w/o Hiawatha	A	Glen Echo Ravine e/o I-71
MH Azelda and alley n/o Hudson	B	Olentangy R . n/o Woody Hayes Dr.
MH Akola and alley w/o Atwood Terrace	A	Glen Echo Ravine e/o I-71
MH Velma and alley s/o Hudson	B	Olentangy R. n/o Woody Hayes Dr.
MH Maynard and Velma	A	Olentangy R. n/o Woody Hayes Dr.
MH Republic & Ontario	A	Glen Echo Ravine e/o I-71
MH Lexington & alley n/o Hudson	B	Olentangy R. n/o Woody Hayes Dr.
MH Criarwood and alley w/o McGuffy	A	Glen Echo Ravine e/o I-71
MH Hamilton & alley n/o Duxberry	B	Olentangy R. n/o Woody Hayes Dr.
MH n/o Pacemont at Olentangy River	A	Olentangy R. n/o Pacemont

Table 5 continued.

Relief Location	Type	Receiving Waters
MH e/o Olentangy st. & Indianola	A	Glen E. Ravine & Indianola
MH Midgard & alley e/o Indianola	A	Walhalla Ravine
MH Akola & alley w/o Osceola	A	Glen Echo Ravine e/o I-71
MH Akola & alley e/o Homecroft	A	Glen Echo Ravine e/o I-71
MH Osceola & alley s/o Weber	A	Glen Echo Ravine e/o I-71
MH Alamo and alley w/o Osceola	A	Glen Echo Ravine e/o I-71
MH Alamo and alley w/o Pontiac	A	Glen Echo Ravine e/o I-71
MH Akola & alley w/o Pontiac	A	Glen Echo Ravine e/o I-71
MH Minnesota & Hamilton	A	Glen Echo Ravine e/o I-71
MH n/o N.Broadway & e/o Olentangy R.	A	Olentangy R. n/o W.N.Broadway
MH Olentangy Blvd. & Montrose Way	A	Olentangy R w/o relief
MH Webster PK & Olentangy Blvd.	A	Ditch s/s Webster Park w/o Olentangy Blvd
MH e/s Indianola & alley E. N. Broadway	A	Walhalla Ravine & Walhalla/Diana
MH Pauline & Atwood Terrace	A	Ovrbrk. Ravine e/o Indianola
MH Richards & Granden	A	Olentangy R. n/o WN Brdway.
MH Northridge & Atwood Terrace	A	Overbrook R. e/o Indianola
MH w/o Rustic Pl and Olentangy Blvd.	A	Olentangy R. w/o relief
MH n/s Weisheimer and Starrett	A	Olentangy R. w/o relief
MH Alley e/o High & s/o Schreyer Pl.	B	Cr. w/o High & s/o Croswell Whetstone Park
MH w/o Olentangy Blvd & n/o Royal Frst.	A	Olentangy w/o relief
MH Wetmore and alley e/o High Street	B	Ditch e/o Rustic Bridge & s/o Beechwold Blvd.
MH s/o Rathbone & e/o Delawanda	A	Ditch s/o Rathbone & Delawanda
MH Alley e/o High & s/o Lincoln	A	Rush Run r/o 126 Sharon Springs

A-Discharge occurs when a manhole fills to a certain elevation.
B-Discharge occurs when sewage flows over a weir.

Dramatic increases in automobile and truck registration accompanies increased need for additional roads, lane expansions, driveways, parking and other impervious surfaces in the watershed. Between the years 1990 and 1999, motor vehicle registrations increased markedly in both Delaware and Franklin Counties (Table 6).

Table 6. Increase in registered cars and light trucks, Franklin and Delaware Counties, 1990 - 1999.

	DELAWARE			FRANKLIN		
Year	**Cars**	**Trucks**	**All**	**Cars**	**Trucks**	**All**
1990	43,144	8,655	51,799	624,922	62,433	687,355
1999	79,272	14,557	93,829	812,009	95,783	907,792
Increase	84%	68%	81%	30%	53%	32%

In Delaware County, State Route 315 and U.S. Route 23 parallel the river corridor and are the principle roads carrying traffic north and south through the study area portion of the watershed. In Franklin county, I-71 traverses the study area between Shrock Road and I-70, carrying traffic north and south as do routes US 23 and SR 315.

These north-south transportation corridors and the nodes at east-west road crossings are major impervious surfaces and foci of land use change-development and construction activity in the study area, particularly Delaware County where land use is changing from rural-agricultural to commercial and residential.

Within Franklin County and Columbus, there are fewer undeveloped tracts within the study area. Construction activity was more confined to the transportation corridors themselves with lane expansions, bridge reconstruction, interchange construction and resurfacing of State Route 315 and I-71. Commercial and other construction activity (most commonly redevelopment) are concentrated within or near these transportation corridors and intersection nodes.

METHODS

All chemical, physical, 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 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995) for aquatic habitat assessment. Chemical, physical and biological sampling locations are listed in Table 7.

Table 7. Sampling locations in the Olentangy River study area, 1999 (C - conventional water chemistry, S - sediment, D - Datasonde® continuous monitors, M - macroinvertebrates, F - fish).

RM	Sample Type	Location	Latitude/ Longitude
Olentangy River			
32.0	M,F,C,S,D	Main Rd	402115/830406
27.9	F,C	Hudson St. (opp. Law Rd)	401919/830413
27.5	M	Hudson Rd.	401855/830414
25.4	M,F,C	Ust. Delaware WWTP	401734/830336
25.3	M,F,C,S,E	Delaware WWTP mix zone	401734/830336
24.5	M,F,C,D	Olentangy Ave	401703/830356
22.5	M	Ust. US 23	401523/830345
22.3	F,C,S	US 23	401516/830347
19.6	M	Ust. Hyatts Rd.	401305/830341
19.4	F,C,S,D	Hyatts Rd.	401254/830338
15.0	F,C,D	St Rt. 750	400924/830243
14.9	M	Dst. St. Rt. 750	400921/830243
13.4	M,F,C,S,E	OECC mix zone	400815/830152
12.8	M	Dst. OECC	400745/830207
12.4	F,C,S,D	Dst. OECC	400720/830157
11.5	C	Ust. Wilson Bridge Rd.	400633/830204
7.8	F,C,S	Kenny Park	400352/830152
7.7	M	Kenny Park	400355/830153
6.9	M	Ust. Henderson Rd.	400311/830148
6.8	F,C,S	Henderson Rd.	400306/830151
5.5	M,F	Ust. N. Broadway	400203/830136
5.3	C	E. North Broadway	400153/830130
4.0	M,	Dst Dodridge Rd. dam	400102/830058
3.9	F,C,D	Dodridge Rd.	400057/830059
2.1	S	Adj. OSU Student Union	395953/830126
2.0	M,F	Ust. 5th Ave. dam	395624/830127
1.9	M	Dst. 5th Ave. dam	395917/830127

Table 7 continued.

RM	Sample Type	Location	Latitude/ Longitude
Olentangy River			
1.8	F,C,S	5th Ave.	395916/830128
0.7	F	Ust. railroad bridge	395819/830115
0.6	M,C,S,D	Railroad bridge	395818/830115
0.3	F	near mouth	395802/830114
0.2	M	near mouth	402015/ 830306
Horseshoe Run			
0.3	M,F,C,S	Panhandle Rd.	402015/830306
Delaware Run			
1.2	M,F,C	At Limestone Park	395847/830115
0.2	M,F,C,S	Henry St.	401750/830352
Lewis Center Tributary			
0.1	M,F,C	Taggert Rd.	401158/830303
Bartholomew Run			
1.0	M	Ust Bennett Rd.	395819/830115
0.7	C,S	Bennett Rd.	400904/830313
Linworth Run			
0.9	M,F,C	Linworth Rd.	400535/830259
0.1	S	Olentangy River Rd.	
Rush Run			
0.4	M,	Walnut Grove Cemetary	395802/830114
0.3	F,C,S	Walnut Grove Cemetery	400434/830144
Bill Moose Run			
0.3	M	At Kenny Park	400403/830140
0.2	F,C,S	At Kenny Park	400404/830144
Adena Brook			
1.0	M	Overbrook Dr.	400231/830141
0.9	F,C,S	Overbrook Dr.	400232/830140
0.2	F,C,S	at Whetstone Park	400246/830056

Table 7 continued.

RM	Sample Type	Location	Latitude/ Longitude
Turkey Run			
0.7	M,F,C,S	Shattuck Ave.	400205/830227
Kempton Run			
0.9	F,C	Linworth Rd.	400434/830247

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 7-14). 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 Invertebrate Community Index (ICI), which indicates the response of the macroinvertebrate community. Numerical endpoints are stratified by ecoregion, use designation, and stream or river size. 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 1) 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), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

The attainment status of aquatic life uses (*i.e.*, full, partial, and non-attainment) is determined by using the biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-14). The biological community performance measures used include the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al.* (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon *et al.* 1981).

Performance expectations for the principal aquatic life uses in the Ohio WQS (Warmwater Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes *et al.* 1986; Omernik 1987). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Attainment of the aquatic life use is FULL if all three indices (or those available) meet the applicable biocriteria, partial if at least one of the indices does not attain and performance is fair, and non-attainment if all indices fail to attain or any index indicates poor or very poor performance. Partial and non-attainment indicate that the receiving water is impaired and does not meet the designated use criteria specified by the Ohio WQS. Index scores and corresponding narrative evaluations for the Olentangy River are based on expectations in the Eastern Corn Belt Plain (Table 8)

Table 8 Biological metric scores and corresponding narrative evaluations for the Eastern Corn Belt Plains ecoregion. Minimum scores for attainment of the WWH criteria (bold), MWH (underlined) and EWH (italics) are also provided. The marginally good range represents nonsignificant departure of the WWH aquatic life use. The very good range corresponds with nonsignificant departure of the EWH aquatic life use.

Eastern Corn Belt Plains						
IBI			**MIwb**		**ICI**	**Narrative Evaluation**
Headwater	Wading	Boat	Wading	Boat	All	
50-60	*50*-60	*48*-60	$*9.4*	$*9.6*	*46*-60	Exceptional
46-49	46-49	44-47	8.9-9.3	9.1-9.5	42-44	Very Good
40-45	**40**-45	**42**-43	**8.3**-8.8	**8.5**-9.0	**36**-40	Good
36-39	36-39	38-41	7.8-8.2	8.0-8.4	32-34	Marginally Good
28-35	28-35	26-37	5.9-(6.2) 7.7	6.4-7.9	14-(22) 30	Fair
18-(24) 27	18-(24) 27	16-(24) 25	4.5-5.8	5.0-(5.8) 6.3	8-12	Poor
12-17	12-17	12-15	0-4.4	0-4.9	<8	Very Poor

Habitat Assessment

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine 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 values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

Macroinvertebrate Community Assessment

Macroinvertebrates were sampled quantitatively using multiple-plate, artificial substrate samplers (modified Hester/Dendy) in conjunction with a qualitative assessment of the available natural substrates. During the present study, macroinvertebrates collected from the natural substrates were also evaluated using an assessment tool currently in the field validation phase. This method relies on tolerance values derived for each taxon, based upon the abundance data for that taxon from artificial substrate (quantitative) samples collected throughout Ohio. To determine the tolerance value of a given taxon, ICI scores at all locations where the taxon has been collected are weighted by its abundance on the artificial substrates. The mean of the weighted ICI scores for the taxon results in a value which represents its relative level of tolerance on the 0 to 60 scale of the ICI. For the qualitative collections in the Olentangy River study area, the median tolerance value of all organisms from a site resulted in a score termed the Qualitative Community Tolerance Value (QCTV). The QCTV shows potential as a method to supplement existing assessment methods using the natural substrate collections. Use of the QCTV in evaluating sites in the Olentangy River study area was restricted to relative comparisons between sites and was not unilaterally used to interpret quality of the sites or aquatic life use attainment status.

Fish Community Assessment

Fish were sampled once or twice at each site using pulsed DC electrofishing methods. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b).

Area of Degradation Value (ADV)

An Area Of Degradation Value (ADV; Rankin and Yoder 1991; Yoder and Rankin 1995) was calculated for the study area based on the longitudinal performance of the biological community indices. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, or ICI) departs from the applicable biocriterion or the upstream level of performance (Figure 2). The “magnitude” of impact refers to the vertical departure of each index below the biocriterion or the upstream level of performance. The total ADV is represented by the area beneath

the biocriterion (or upstream level) when the results for each index are plotted against river mile. The results are expressed as ADV/mile to normalize comparisons between segments, sampling years, and other streams and rivers.

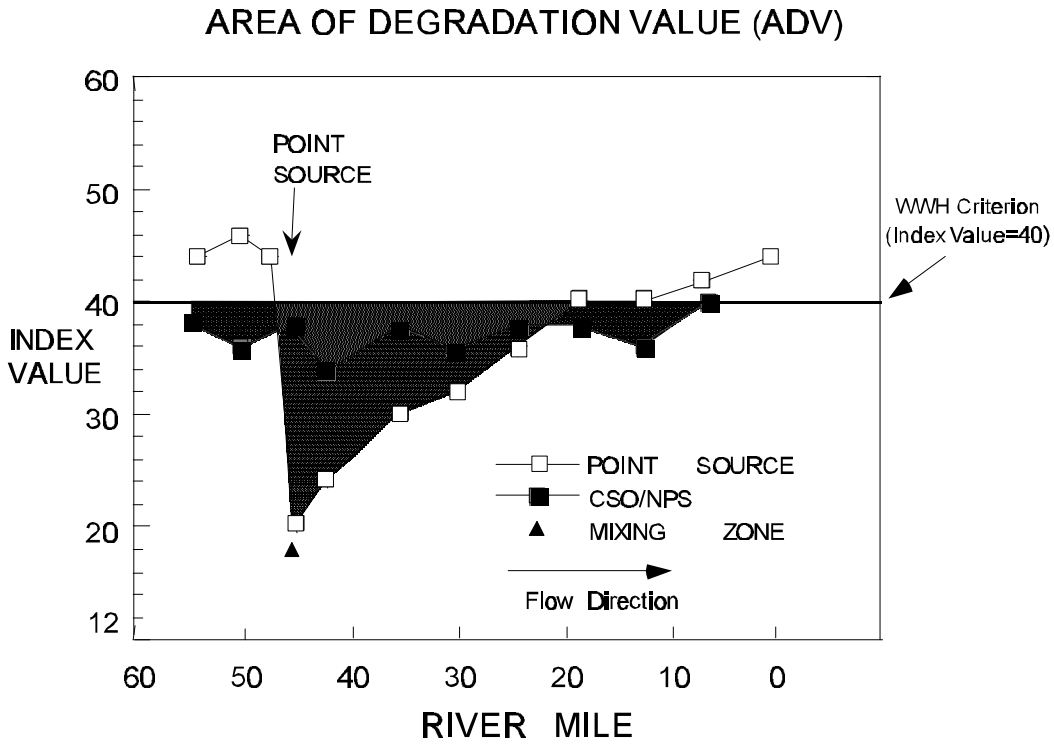


Figure 2 Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). The index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears as a solid triangle); the filled boxes and dashed shading (area of departure) represent a typical response to a nonpoint source or combined sewer overflow impact. The blended shading represents the overlapping impact of the point and nonpoint sources.

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). The 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.

RESULTS AND DISCUSSION

Pollutant Loadings: 1976-1999

Monthly effluent loadings are reported to Ohio EPA by all NPDES (National Pollutant Discharge Elimination System) permitted entities. About 30 permitted facilities discharge into the Olentangy River within the study area. Annual Monthly Operating Report (MOR) data was used to evaluate the quantity and character of pollutant loadings from 1976 through 1999 for the City of Delaware WWTP and the Olentangy Environmental Control Center (OECC).

Pollutant loading trends analysis included the 95th and 50th percentiles for Ammonia-nitrogen (NH_3-N),Nitrate (NO_3), Five-day Biochemical Oxygen Demand (BOD_5)/ Five-day Carbonaceous Biochemical Oxygen Demand ($cBOD_5$), Total Suspended Solids (TSS), Nickel and Annual discharge (MGD). Note that BOD_5 and $cBOD_5$ are combined on the same figure and reflect permit parameter changes emphasizing only carbonaceous BOD_5 not total BOD_5.

City of Delaware WWTP (Olentangy River RM 25.26)

Facility Description

The City of Delaware wastewater treatment plant (WWTP) discharges directly to the Olentangy River at RM 25.26. The WWTP was modified and upgraded to a two-stage activated sludge plant in 1986. The design capacity of the existing plant is 5.5 million gallons per day (MGD). Wastewater treatment processes include influent pumping, emergency off-line flow equalization, screening, grit removal, biochemical oxygen demand removal in first stage aeration, intermediate settling, ammonia-nitrogen removal in second stage aeration, final settling, tertiary filtration, chlorination, post-aeration and dechlorination. Solids handling

facilities include aerobic digesters for sludge stabilization, belt filter presses for sludge dewatering followed by land application or land filling. The facility is constructed on the edge of the old City of Delaware landfill.

Description of Existing Discharge

Delaware WWTP influent is comprised of 95.2% sewage and 4.8% industrial wastewater. Significant industrial contributors include Atofina North America (7000 gallons/day), Grady Hospital, and Willamette Industries (30,000 gallons/day).

Third quarter loadings data for 1999 indicated that Delaware WWTP was operating properly during the survey period. Median flow was nearly 3 MGD with 95th percentile flows of slightly over 5 MGD. These are well within the design capacity of the plant. Loadings of conventional pollutants and metals were all within permit limits for those parameters with a limit. Bacterial values were also well within permit limits. Plant upgrades that occurred in the late 1980s resulted in significant reductions of biochemical oxygen demand, ammonia and metals loading. Correspondingly, nitrate loadings increased as a consequence of the nitrification of ammonia. While the discharge volume has slowly increased due to local development pressures, loadings trend of most other parameters over the last 8 to 10 years have been decreasing or steady and is indicative of conscientious plant operation (Figure 3).

Whole effluent toxicity testing was most recently conducted during April 1999. Generally, the effluent was found to be acutely toxic to both fathead minnows (*Pimephales promelas*) and *Ceriodaphnia dubia* in the screening tests. Definitive testing showed a mortality of 20% for *P. promelas* or an acute toxic unit (TU_a) of 0.4. The *C. dubia* definitive test resulted in a 48-hour LC50 of 83.0% and an EC50 of 78.4% or TU_a of 1.2 and 1.3, respectively. Past bioassay screening test results from 1989, 1994, and 1998 indicated no effluent acute toxicity. The cause of the current toxicity is unknown but should be investigated further.

The Delaware WWTP violated the conditions of its NPDES permit only 3 times over the period January 1998 through December 1999. A violation for 30-day average mercury was observed during January 1998 with a value of 0.20 mg/l versus a permit limit of 0.02 mg/l. The other violations consisted of exceeding the minimum pH of 6.5 with a value of 6.2 (October 5, 1999) and the pH maximum of 9.0 with a value of 9.1 (October 16, 1999).

The Delaware WWTP did not appear to negatively impact the chemical water quality of the Olentangy River downstream from the discharge. There were no Ohio Water Quality Standards (WQS) violations found in the mix zone and only minor violations of the *E.coli* bacteria and lindane criteria downstream from the plant. The bacteria violations were not emanating from the WWTP, but may have resulted from general runoff. The lindane violation may have resulted from both lindane found in the effluent, and leachate

outbreaks or groundwater exchange from an old municipal landfill directly adjacent to the plant. In fact, the upgraded portions of the Delaware WWTP are built on a portion of the old landfill; this portion of the landfill was excavated and moved to accommodate the construction of the WWTP upgrade.

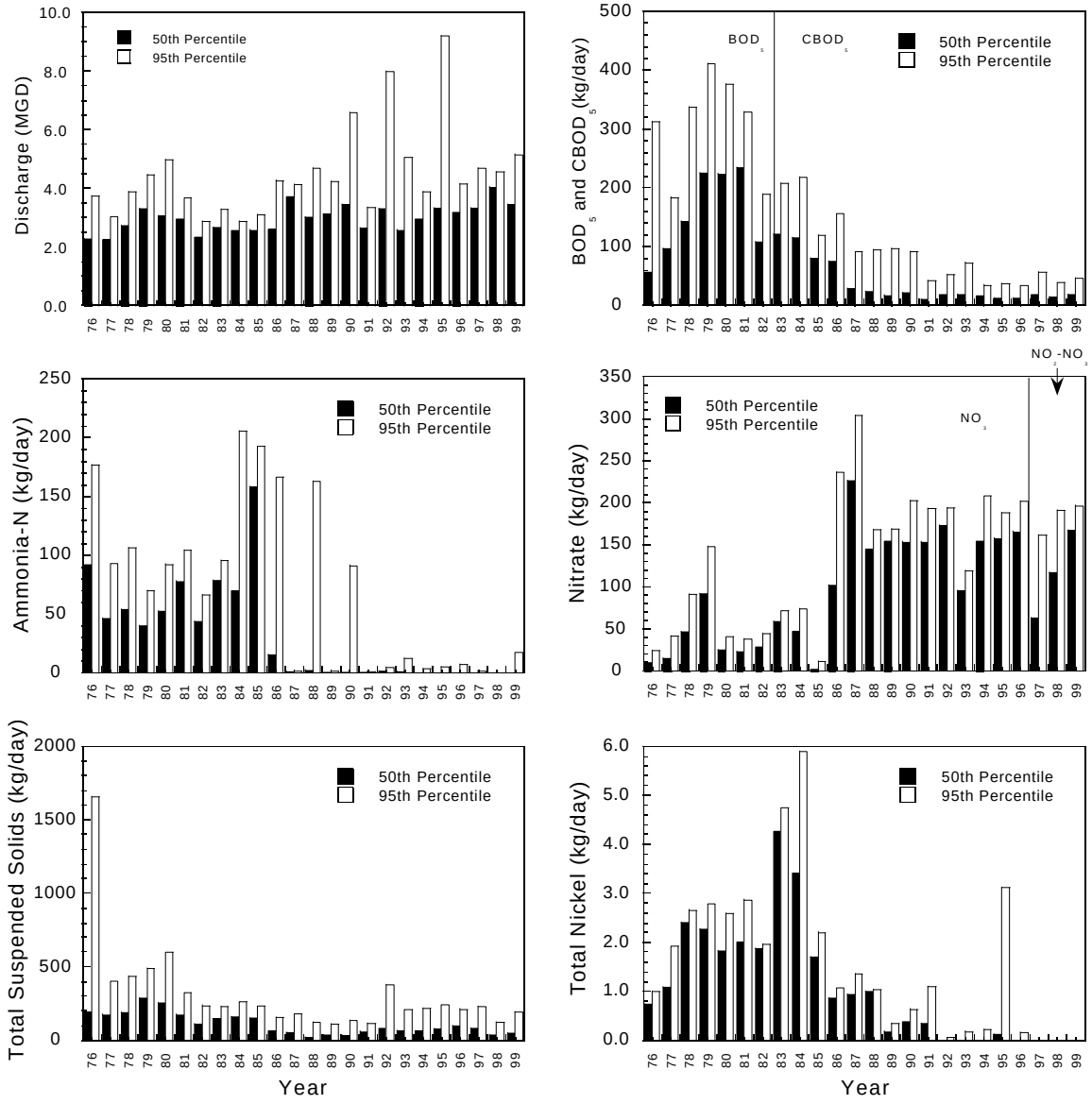


Figure 3 Median and 95th percentile third quarter discharge, BOD_5/$CBOD_5$, ammonia-N, nitrate, total suspended solids and nickel loadings to the Olentangy River from the Delaware WWTP, 1976-1999.

The comparison of upstream chemical water quality to that downstream from the discharge showed decreases in suspended solids concentrations and biochemical oxygen demand. Increased concentrations instream were noted for dissolved oxygen, nitrate-nitrite (typical for a nitrifying system), organic nitrogen (as measured by TKN), sulfate, chloride, and bacteria. Effluent concentrations of lindane are also a concern (Table 16). Dissolved oxygen was enhanced instream due to the aeration the wastewater receives during treatment. Ionic content of water (e.g., chloride, sulfate, sodium and potassium) will almost always be increased downstream from a WWTP as a product of properly treated sewage. Although nitrate-nitrite concentrations increased above the median reference concentration for the Eastern Corn Belt Plains ecoregion, this was expected as the Delaware WWTP accomplishes nitrification of ammonia as part of the treatment of the waste. However, general contributions of phosphorus and nitrate-nitrite by the Delaware WWTP are a concern and should be monitored as nutrient enrichment may become more of a problem in the future with continued heavy development in the City of Delaware and the surrounding county.

Delaware County-Olentangy Environmental Control Center WWTP (Olentangy River RM 13.39)

Facility Description

The Olentangy Environmental Control Center (OECC) WWTP, owned and operated by Delaware County, discharges directly to the Olentangy River at RM 13.39. The OECC completed a two phase plant expansion to increase the average design flow from 1.5 to 4.5 MGD in 1998. Phase one involved the construction of a new 4.5 MGD plant and phase two consisted of the rehabilitation of the original 1.5 MGD plant. OECC has submitted a permit modification request and accompanying antidegradation addendum in order to increase the permitted loadings and corresponding flows from 4.5 to 6.0 MGD. Wastewater treatment processes at the current facility include influent pumping, single stage aeration, clarification, tertiary sand filtration, ultraviolet disinfection and post aeration. Solids handling consists of aerobic digestion and a gravity belt thickener followed by land application.

Description of Existing Discharge and Instream Chemical Water Quality

The OECC WWTP influent is comprised of nearly 100% conventional sewage with an industrial input of less than 1%. The two categorical industries within the system (Abrasive Tech and Tracewell) together contribute only 4000 gallons/day (0.004 MGD) of pretreated wastewater.

Third quarter loadings data 1999 suggested that the OECC WWTP was operating properly during the survey. Median and 95th percentile effluent flows were within design criteria for the newly modified WWTP (Figure 4). Loadings of conventional pollutants and metals were all within permit limits for those parameters with a limit. Bacterial numbers were also well within the permit limits. With the increase in residential and commercial development in the area served by the OECC WWTP, increases in certain

parameters, especially discharge volume were observed. Loadings of ammonia, nitrate-nitrite, phosphorus, suspended solids, and zinc also showed increases (Figure 4). $CBOD_5$ loadings, fecal coliform bacteria concentrations and oil and grease loadings declined, but have shown irregularities in the past, probably due to treatment capacity issues now solved by the plant upgrade (Figure 5). The low level presence of some

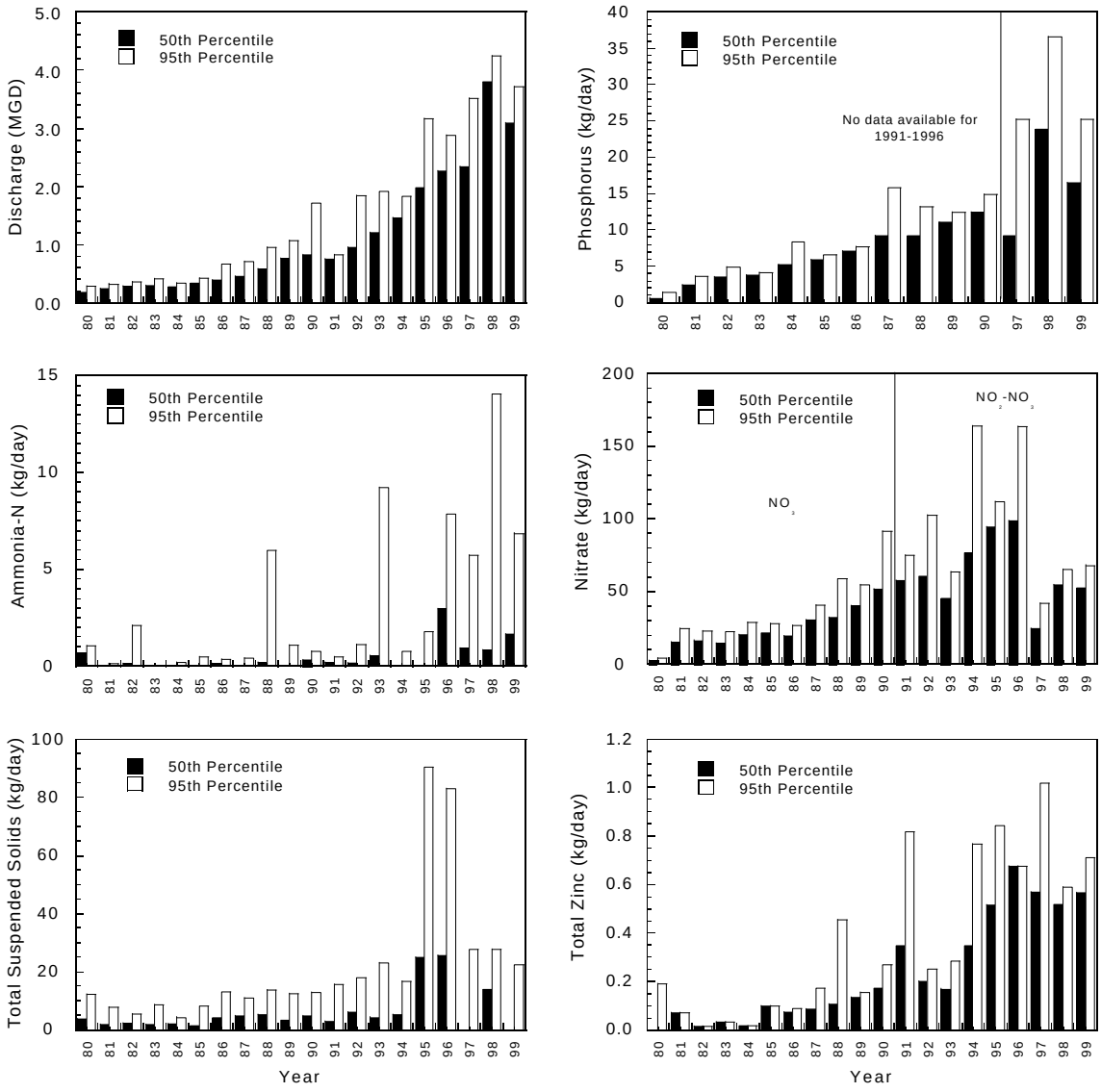


Figure 4 Median and 95th percentile third quarter discharge, phosphorus, ammonia-N, nitrate, total suspended solids and zinc loadings to the Olentangy River from the Olentangy Environmental Control Center, 1980-1999.

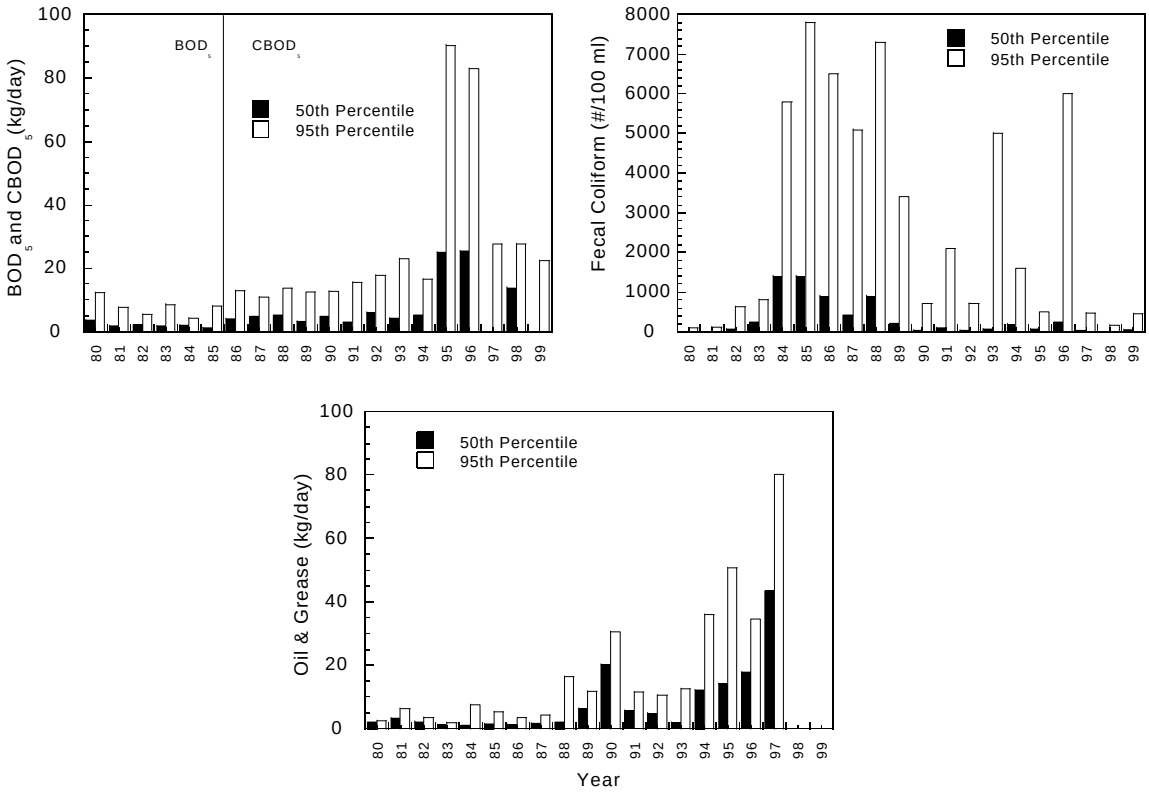


Figure 5 Median and 95th percentile third quarter biochemical oxygen demand/ carbonaceous biochemical oxygen demand, fecal coliform, and oil and grease loadings to the Olentangy River from the Olentangy Environmental Control Center, 1980-1999.

pesticides in the effluent was noticeable, but unknown in origin, possibly due to commercial or household usage or disposal (Table 16).

Whole effluent toxicity testing at the OECC WWTP indicated no acute toxicity for the most recent tests conducted in December 1998 and April 1999. This is an improvement compared with testing done in July 1994 which revealed acute toxicity to Ceriodaphnia (TU_a 4.2). Tests performed in 1989 did not show toxicity.

Several violations of the NPDES permit limitations were reported to Ohio EPA for outfall 001, although these violations were not numerous or particularly extreme over the 22 month period. See Table 9 for the specific violations.

The OECC does not appear to negatively impact the chemical water quality of the Olentangy River downstream from the discharge. The comparison of upstream chemical water quality to that downstream from the discharge shows slightly increased concentrations of nitrate-nitrite, phosphorus, and organic nitrogen (as measured by TKN). More substantial increases in chloride and sodium were also noted downstream from the plant. However, no violations of chemical or bacteriological Ohio WQS criteria were measured in the mixing zone (RM 13.38) or immediately downstream (RM 12.40) of the OECC.

Table 9. NPDES permit violations for the Olentangy Environmental Control Center WWTP from January 1998 through October 1999.

Date	Parameter	Period	Value
1/98	Ammonia	30 day average	0.92 mg/l
	Ammonia	7 day average	1.17 mg/l
			1.70 mg/l
7/98	Ammonia	7 day average	1.86 mg/l
11/98	Nitrate-Nitrite	30 day average	6.30 mg/l
1/99	Oil & Grease	any time	11.0 mg/l
7/99	pH	minimum	6.4 S.U.
			6.4 S.U.

Pollutant Spills and Unauthorized Releases

In addition to NPDES permit violations and Ohio WQS criteria exceedences, a review of the Ohio EPA Division of Emergency and Remedial Response (DERR) Release Reporting System (RRS) database indicated eleven unpermitted releases of toxic or oxygen-demanding substances occurred in 1999 in the Olentangy River study area. Accidental spills and unauthorized discharges of pollutants represent a potential impact on aquatic life which may or may not be traceable to a specific source. Spills occur at random and may significantly impact aquatic and terrestrial organisms without leaving obvious signs. It is likely that the reported spills represent a fraction of the actual spill occurrences within the Olentangy River study area.

Fish Kills

A review of Water Pollution, Fish Kill and Stream Litter Investigation Reports from the Ohio Department of Natural Resources Division of Wildlife indicated that only six fish kills were reported in the Olentangy

River basin between 1990-1999 (Table 10). It should be noted that the majority of tributaries were predominated by pioneering and tolerant species which suggests that degraded habitat and water quality of the streams was limiting the establishment of typical warmwater fish assemblages.

Chemical Water Quality

Sampling stations in the Olentangy River watershed were chosen to provide information concerning ambient water quality. Sample results were evaluated to determine impacts from land use practices around the area and to determine instantaneous exceedences of criteria listed in the Ohio Water Quality Standards (OAC 3745-1). Exceedences were based on Exceptional Warmwater Habitat (EWH) or Warmwater Habitat (WWH) aquatic life use, Primary or Secondary Contact Recreation (PCR or SCR), and Agricultural and Industrial Water Supply (AWS or IWS). These are summarized in Table 11. Numerical chemical criteria exist for the prevention of acute and chronic toxicity for most pollutants. The appropriate acute aquatic criterion (AAC) and chronic aquatic criterion (CAC) apply to samples outside of mixing zones. Minimum and average criteria exist for dissolved oxygen. Primary and Secondary Contact Recreation (PCR and SCR) criteria apply to fecal coliform bacteria counts. Primary contact waters are suitable for full body contact recreational activities and will pose minimal threat to public health as a result of the water quality. Secondary contact waters are suitable for limited activities, such as wading, with minimal threat to public health. Except for Adena Brook, SCR is the recommended recreational use standard for the sampled tributaries. Adena Brook had the requisite pool depths to continue with the PCR use. Evaluation of bacterial levels in the remaining streams was conducted using the SCR standard.

Table 10. Recent documented fish kills in the Olentangy River and tributaries.

River	RM	# Fish Killed	Date	Comments
Olentangy River	2.6	10	12/23/92	unknown, originating from Ohio State U.
Turkey Run	1.2	142	5/14/93	fertilizer runoff from unknown source
Adena Brook	0.9	59	7/15/93	unknown product and source
Turkey Run	1.2	30	7/20/94	runoff from extinguishing a fire
Olentangy River	26.3	26	9/19/94	chlorinated swimming pool water pumped from the Mingo Park pool into the river
Adena Brook	0.4	60	7/5/96	sewer line break in Whetstone Park

Olentangy River flows are monitored at the USGS station located at Worthington, Ohio. During the period of July through September of 1999, flows ranged from a high of 716 cfs on June 2nd to a low of 12 cfs on September 2nd. The historical mean flow for this period is 63 cfs (USGS 1981). Water chemistry

sampling conducted during this period took place under low to moderate flow conditions ranging from 20 to 70 cfs.

Water chemistry sampling protocols were used based on the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 1989) and samples were collected, preserved, and analyzed for a variety of parameters including demand parameters, nutrients, and metals. A more limited set of grab samples was collected for organic compounds. Mean concentrations of dissolved oxygen, fecal coliform bacteria, nutrient and metals parameters were determined and plotted longitudinally to display trends in these physical and chemical properties. In calculating mean concentrations, a value equal to the analytical method detection limit (MDL) was used for results reported less than the MDL. Geometric means were used to calculate the fecal coliform values. See Appendix A for a complete listing of the analytical results for all waterbodies studied.

Olentangy River Mainstem

The Olentangy River mainstem exhibited a very limited number of violations of Ohio Water Quality Standards (WQS) criteria. Most violations were bacterial in nature ranging in frequency from a few in the Delaware city area to almost none in the Scenic Rivers section (Table 11). The lower reaches in the Columbus city area had the greatest number of bacterial violations. *E. coli* bacteria was the dominant bacterial contaminant in addition to a few fecal coliform violations. Based on evaluations of many larger rivers performed even 10 years ago, these results demonstrate how point source pollution abatement efforts

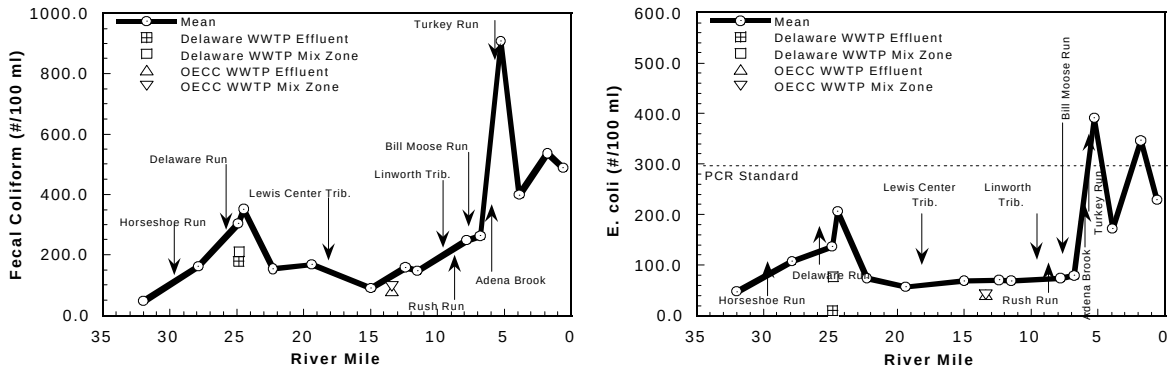


Figure 6 Longitudinal mean concentrations of fecal coliform and e-coli from the Olentangy River, 1999.

have matured and produced tangible results. Even so, the violations of the bacteria standards arose from stormwater inputs and combined sewer overflows concentrated in urban areas (Figure 6). Additional

violations of aquatic life criteria were noted for two pesticides, gamma-BHC (a.k.a. Lindane) and dieldrin, both of which were banned from current usage in the United States. These violations occurred in the upper part of the river at RM 22.30 and further upstream (Table 11).

Table 11. Exceedences of Ohio EPA Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) water quality criteria (OAC 3745-1) for chemical/physical parameters in the Olentangy River study area, 1999. All RMs are assumed to be WWH, AWS, IWS, PCR unless noted. **Boldface** river miles are designated Exceptional Warmwater Habitat, effluent discharges are *italic* print, areas designated Modified Warmwater Habitat are <u>underlined</u>, and undesignated streams are highlighted (Units are #/100 ml for bacteria, µg/l for metals, cyanide and pesticides, and mg/l for all other parameters)

.

River/Stream	River Mile	Parameter	Value (code)
Olentangy River	32.00	E. coli	(165)"
		Lindane	0.011a
		Dieldrin	0.008a
	27.90	E. coli	(175, 190)"
	25.40	E. coli	(130, 160, 210, 288)"
	25.26 (effluent)		
	25.26 (mix zone)		
	24.50	E. coli	(150, 170)", (420)""
	22.30	E. coli	(210)"
		Lindane	0.012a
		Dieldrin	0.007a
	19.40	None	
	15.00	E. coli	(197)"
	13.39 (effluent)		
	13.38 (mix zone)		
	12.40	None	
	11.50	None	
	7.80	E. coli	(207, 213)"
	6.80	E. coli	(130, 265)"
	<u>5.28</u>	E. coli	(200, 250)", (510, 591, 610, 712)""
		F. coliform	(1236, 1364)"
	3.90	E. coli	(150, 160, 178, 290)", (386)""
		F. coliform	(1036)"
	1.80	E. coli	(185, 254, 290)", (350)"", (630)""

	0.60	E. coli	(130, 190, 200, 247, 290)", (310)""

Table 11 continued.

River/Stream	River Mile	Parameter	Value (code)
Horseshoe Run (SCR)	0.30	E. coli	(685)"""
		D.O.	(3.93)‡‡
Delaware Run (SCR)	1.20	E. coli	(697)"""
Kempton Run (SCR)	0.90	E. coli	(775, 3100)"""
		F. coliform	(17000)"""
Bartholomew Run (SCR)	0.70	E. coli	(650, 800, 809)"""
		F. coliform	(11818)"""
Linworth Run (SCR)	0.90	E. coli	(570, 1298)"""
Rush Run (SCR)	0.30	E. coli	(1150)"""
Bill Moose Run (SCR)	0.20	E. coli	(624)"""
		F. coliform	(10636)"""
Turkey Run (SCR)	0.70	E. coli	(6800)"""
		F. coliform	(59000)"""
		Dieldrin	0.011**a**
Adena Brook	0.90	E. coli	(945)"""
		F. coliform	(5300)"""
	0.20	E. coli	(230, 240)", (350, 364)""
		F. coliform	(12500)"""
		D.O.	(2.97, 3.56)‡‡

‡ exceedence of the average warmwater habitat dissolved oxygen criterion (5.0 mg/l).

‡‡ exceedence of the minimum warmwater habitat dissolved oxygen criterion (4.0 mg/l).

• exceedence of the average Primary Contact Recreation criterion (E. coli 126/100 ml, Fecal coliform 1000/100 ml).

•• exceedence of the maximum Primary Contact Recreation criterion (E. coli 298/100 ml, Fecal coliform 2000/100mL).

••• exceedence of the maximum Secondary Contact Recreation criterion (E. coli 576/100 ml, Fecal coliform 5000/100 ml).

a exceedence of the Ohio River drainage basin water quality criteria for the protection of aquatic life.

Demand parameters exhibited some variability in the mainstem. Oxygen demanding substances (as measured by BOD_5 and COD) were noticeable in the upper and lower sections of the survey area (Figure 8). All BOD values at RM 32.00 were found to exceed the 50th percentile background for rivers in the Eastern Corn Belt Plains (ECBP) ecoregion (Table 12). Continuing downstream, there was a BOD spike again at RM 25.40 within the Delaware city limits. Downstream from the Delaware WWTP both BOD and COD decreased and leveled off to near detection limits increasing again within Columbus city limits.

Suspended solids concentrations were irregular down the length of the river (Figure 8). All measurements taken at RM 32.00 exceeded the 50th percentile background for rivers in the ECBP ecoregion (Table 12). This may have been an artifact of a bridge construction project at this site and/or due to the reservoir just upstream. Mean concentrations dropped until reaching the Delaware WWTP when they began to rise again. Mean suspended solids concentrations then rose and fell again several times before reaching the mouth. The steady rise between RM 24.50 and RM 15.00 may be attributable to the steady level of development occurring in this area of Delaware County. The suspended solids spike at RM 5.28 is due in part to the impounded nature of the river at this point. The decrease noted at RM 3.90 (downstream

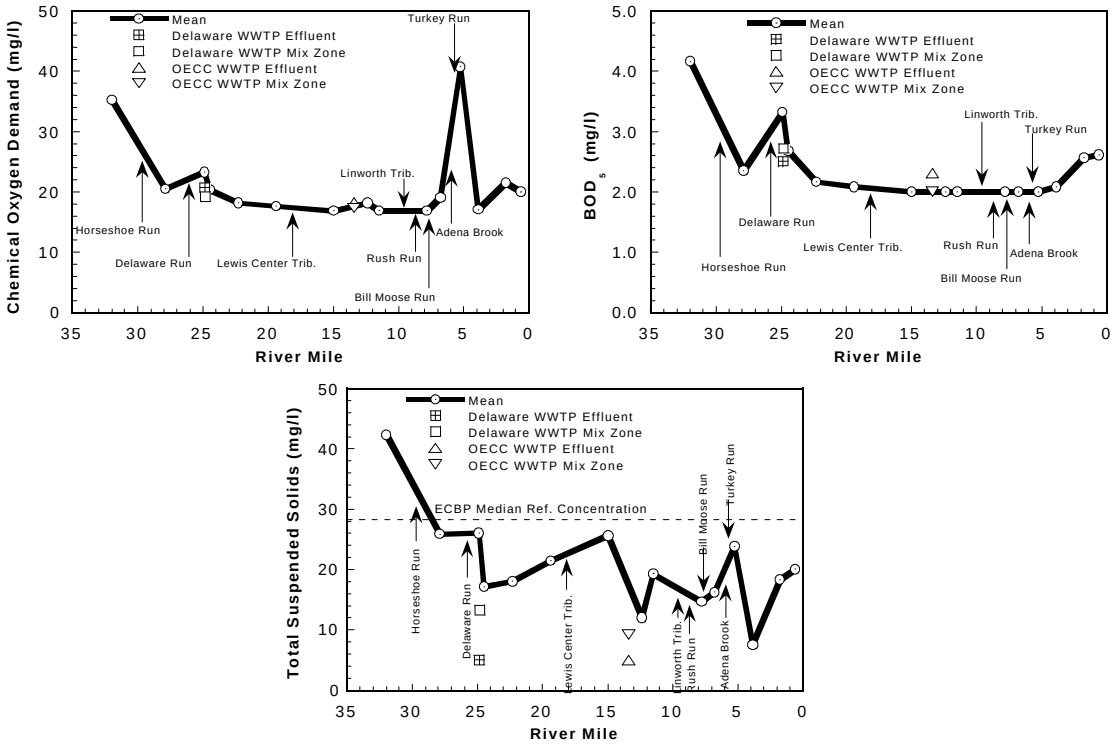


Figure 8 Longitudinal mean concentrations of chemical oxygen demand, biochemical oxygen demand and total suspended solids from the Olentangy River, 1999.

from the Olentangy Wetlands and the Dodridge dam) may be influence from the wetland. Solids increased again downstream from 5th Avenue and at RM 0.60 indicating the influence of an urbanized environment including, but not limited to, road construction projects as well as construction of a river walking/biking trail.

Table 12. Comparison of background nutrient and demand parameter concentrations with those found in the Olentangy River study area, 1999. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background median (50th percentile), 75th, 90th, and 95th percentile values for small river sites. Units are mg/l for all parameters. Sample size, n = 6 unless otherwise stated

River/Stream	River Mile	Parameter(s)	Value(s)
Olentangy River	32.00	BOD_5	(6.0, 5.9, *4.0*, 3.8, 2.8, 2.5)
		Total Suspended Solids	(*60.0*, *46.5*, *44.0*, 37.5, 37.0, 29.0)
		Ammonia	(**0.98**, **0.46**, **0.42**, **0.34**, 0.12)
		Nitrite	(**0.15**, **0.13**, **0.07**, 0.06, *0.03*)
		Tot. Kjeldahl Nitrogen	(**1.43**, *0.97*, *0.92*, *0.82*, 0.64)
		Phosphorus	(0.22)
	27.90	BOD_5	(3.6, 2.4)
		Total Suspended Solids	(*36.0*, *33.0*)
		Ammonia	(0.10, 0.08, *0.07*)
		Nitrate+Nitrite	(1.74)
		Nitrite	(0.05, *0.03*)
		Tot. Kjeldahl Nitrogen	(0.68, 0.62)
	25.40	BOD_5	(**7.2**, 3.3, 2.9, 2.5)
		Total Suspended Solids	(37.0)
		Ammonia	(*0.06*)
		Nitrate+Nitrite	(2.96, 2.46)
		Nitrite	(0.04, *0.03*)
		Tot. Kjeldahl Nitrogen	(*0.81*, 0.73, 0.61)
		Phosphorus	(0.48, 0.22)
	24.50	BOD_5	(*5.5*, 2.6)
		Ammonia	(0.08, *0.07*, *0.06*)
		Nitrate+Nitrite	(2.35, 2.09, 2.06, 1.62, 1.52)
		Nitrite	(*0.03*, *0.03*)
		Tot. Kjeldahl Nitrogen	(*0.94*, 0.72, 0.69, 0.66, 0.65)
		Phosphorus	(0.21, 0.19, 0.17)

Table 12 continued.

River/Stream	River Mile	Parameter(s)	Value(s)
Olentangy River	22.30	BOD_5	(3.0)
		Ammonia	(*0.06*, *0.06*, *0.06*)
		Nitrate+Nitrite	(2.82, 2.45, 2.26, 1.84, 1.69, 1.54)
		Nitrite	(*0.03*)
		Tot. Kjeldahl Nitrogen	(1.29, 0.79, 0.79, 0.71, 0.62)
		Phosphorus	(*0.32*, 0.23, 0.18, 0.16)
	19.40	BOD_5	(2.5)
		Ammonia	(*0.06*, *0.06*, *0.06*)
		Nitrate+Nitrite	(2.65, 2.30, 1.71, 1.56, 1.52)
		Tot. Kjeldahl Nitrogen	(*0.90*, 0.67, 0.62)
		Phosphorus	(0.40, 0.23, 0.22, 0.21)
	15.00	Total Suspended Solids	(29.5)
		Nitrate+Nitrite	(2.01, 1.70, 1.60, 1.38)
		Tot. Kjeldahl Nitrogen	(0.62, 0.61)
		Phosphorus	(0.25, 0.22, 0.20, 0.18, 0.17)
	12.40	Ammonia	(0.10, 0.08, *0.07*)
		Nitrate+Nitrite	(2.75, 2.10, 1.75, 1.47, 1.32)
		Tot. Kjeldahl Nitrogen	(0.74, 0.70, 0.69, 0.67, 0.64)
		Phosphorus	(*0.36*, *0.31*, *0.28*, *0.27*, *0.25*, 0.15)
	11.50	Total Suspended Solids	(38.5)
		Ammonia	(0.11, *0.07*)
		Nitrate+Nitrite	(2.42, 2.06, 1.78, 1.51)
		Tot. Kjeldahl Nitrogen	(0.75, 0.64, 0.62)
		Phosphorus	(0.46, *0.36*, *0.31*, *0.26*, 0.21)
	7.80	Ammonia	(*0.07*, *0.06*)
		Nitrate+Nitrite	(2.55)
		Tot. Kjeldahl Nitrogen	(*0.97*, 0.66, 0.63)
		Phosphorus	(*0.31*, *0.28*, 0.23, 0.19, 0.18)
	6.80	Ammonia	(*0.06*)
		Nitrate+Nitrite	(2.68)
		Tot. Kjeldahl Nitrogen	(*0.92*, 0.67)
		Phosphorus	(0.40, *0.27*, *0.24*, 0.22, 0.19, 0.18)
	5.28	Ammonia	(0.12, 0.10, 0.10, 0.09, *0.06*)
		Nitrate+Nitrite	(*3.20*)
		Tot. Kjeldahl Nitrogen	(**2.18**, *1.09*, 0.63, 0.63)
		Phosphorus	(0.47, *0.26*, 0.22, 0.18, 0.17, 0.16)

Table 12 continued.

River/Stream	River Mile	Parameter(s)	Value(s)
Olentangy River	3.90	BOD_5	(2.5)
		Ammonia	(**0.16**, **0.15**, **0.13**, 0.12, 0.11, 0.09)
		Nitrate+Nitrite	(*4.65*)
		Nitrite	(0.04)
		Tot. Kjeldahl Nitrogen	(*1.07*, 0.74, 0.67, 0.64, 0.64)
		Phosphorus	(*0.30*, 0.18, 0.17, 0.17)
	1.80	BOD_5	(3.2, 3.0, 2.6, 2.6)
		Ammonia	(**0.25**, **0.16**, **0.14**, 0.06)
		Nitrate+Nitrite	(4.98)
		Nitrite	(**0.08**, 0.04, *0.03*)
		Tot. Kjeldahl Nitrogen	(*0.89*, 0.77, 0.73, 0.69)
		Phosphorus	(*0.30*)
	0.60	BOD_5	(*4.9*, 2.7)
		Ammonia	(**0.28**, 0.11, 0.10, 0.10, 0.10, *0.07*)
		Nitrate+Nitrite	(*4.78*)
		Nitrite	(**0.08**, *0.03*, *0.03*)
		Tot. Kjeldahl Nitrogen	(*0.83*, *0.81*, 0.68, 0.63)
		Phosphorus	(**0.80**)

Normal print values exceed the 50th percentile background
Italic print values exceed the 75th percentile background
Underlined values exceed the 90th percentile background
Boldfaced values exceed the 95th percentile background

Nutrient concentrations (ammonia, nitrates, nitrites, organic nitrogen, phosphorus) within the Olentangy River mainstem exhibited some similar distribution patterns as demand parameters. Ammonia concentrations at RM 32.00 were all greater than the 90th percentile background for the ECBP ecoregion, most were even above the 95th percentile value (Table 12). These high values fell to more normal ranges and remained steady, rising again in the urban environment of Columbus. Neither the Delaware WWTP or the OECC WWTP seemed to contribute to increased ammonia concentrations instream. Mean nitrate+nitrite concentrations exhibited the opposite pattern of ammonia. Concentrations rose steadily from a low at RM 32.00 to a high just downstream from the Delaware WWTP (Figure 9). Nitrate+nitrite values then stabilized and remained stable down to the mouth with another small increase just downstream from the OECC WWTP. Nitrite concentrations were highest at RM 32.00 with 3 of the 6 values exceeding the 95th percentile for background (Table 12). Mean organic nitrogen concentrations (as measured by total kjeldahl nitrogen, TKN) fluctuated between 0.5 and 1.0 mg/l. Increases were noted downstream from each major WWTP and at RM 5.28 (an impounded section). Mean phosphorus concentrations showed a very similar pattern to that of TKN fluctuating between 0.08 and 0.30 mg/l.

Mean concentrations of dissolved oxygen remained above 6 mg/l along the entire length of the Olentangy River peaking at RM 22.30 (Figure 9). Dissolved oxygen values were especially satisfactory downstream from the two major wastewater treatment plants.

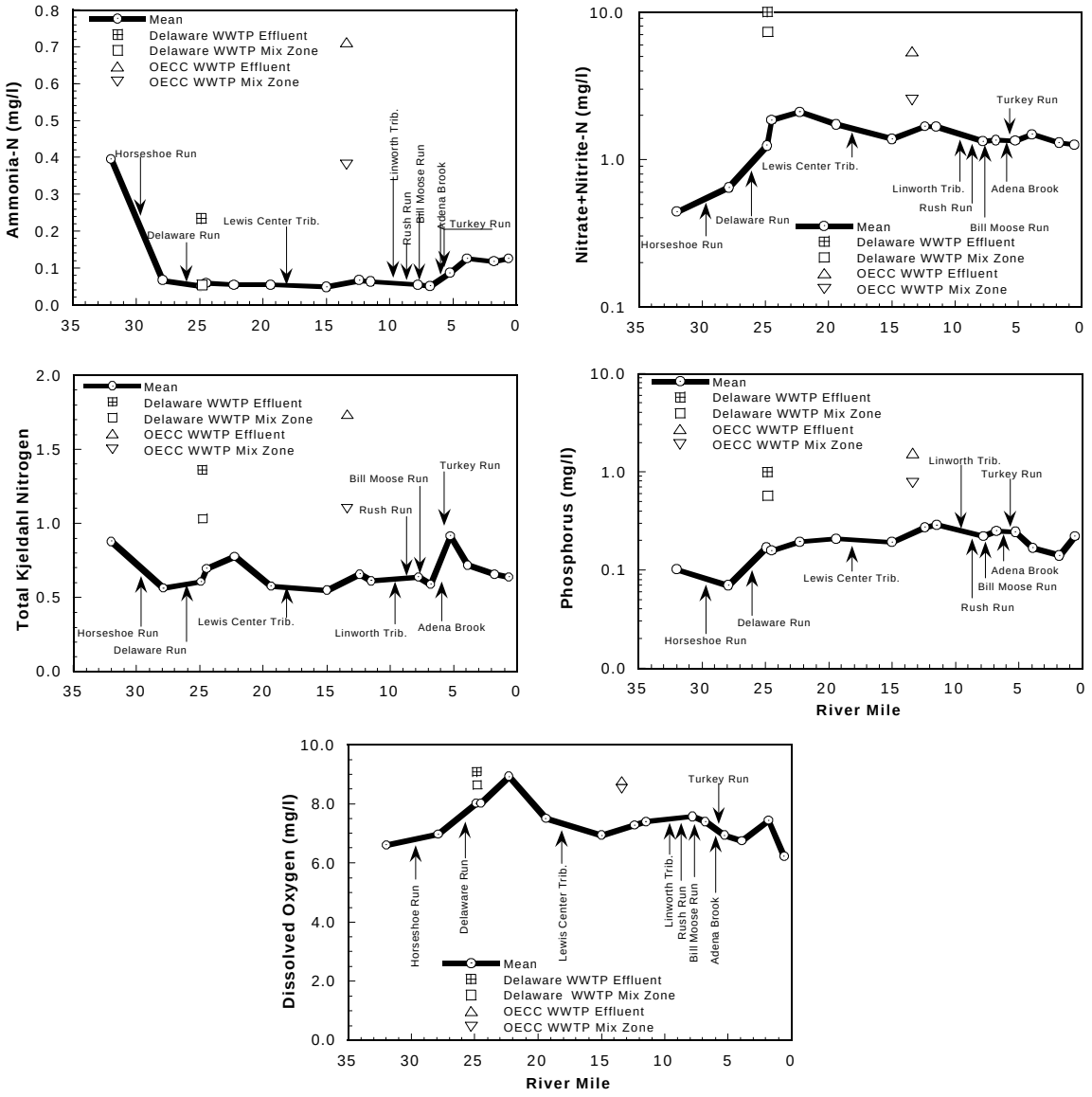


Figure 9 Longitudinal trend of mean concentrations of ammonia, nitrate-nitrite, total Kjeldahl nitrogen, phosphorus, and dissolved oxygen.

Median phosphorus and nitrate-nitrite concentrations frequently exceeded the proposed statewide criteria for WWH and EWH aquatic life uses (Figure 10). Nevertheless, only one location between RM 32.0 and the modified stream segments in the lower river failed to fully attain the designated aquatic life use. Similar situations have been described in *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams (*Ohio EPA, 1999) where exceptional aquatic communities and high nutrient concentrations co-occur as long as beneficial habitat and landuse features are present. This result points out the important role habitat plays in the assimilation of excessive nutrient concentrations in the Olentangy River. The full attainment in the Exceptional Warmwater Habitat portions of the Olentangy should be considered threatened, however, due to continued development in the watershed.

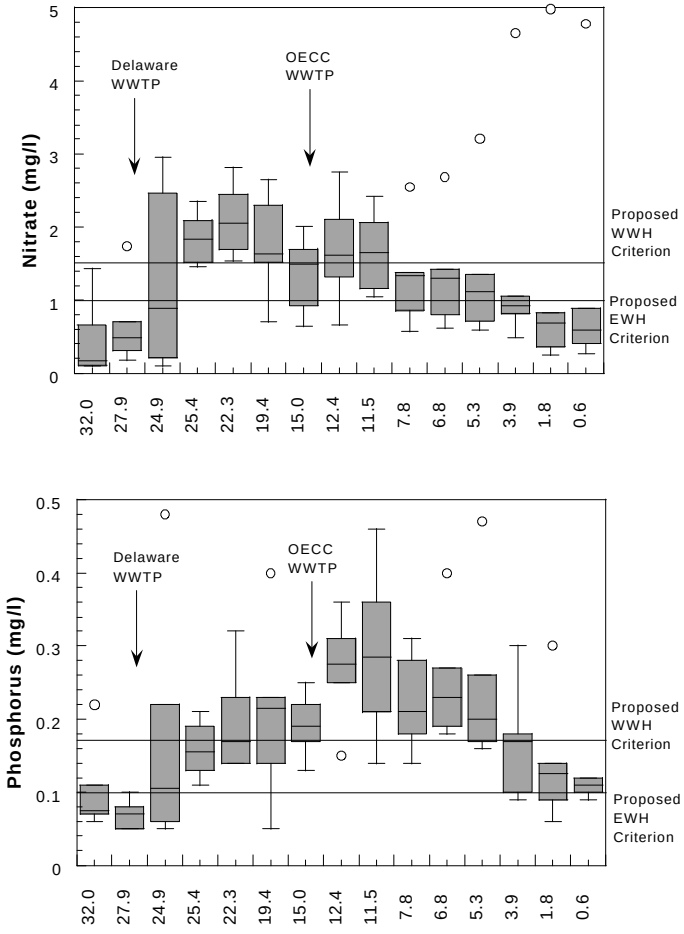


Figure 10 Nitrate and phosporus concentraions versus river mile for the Olentangy River, June to October, 1999. Boxes enclose the 25th and the 75th percentiles, outliers deviate more then two times the interquartile range from the median. Proposed criteria values are included for reference purposes and do not reflect violation of current water quality standards.

In general, chemical water quality in the Olentangy River from RM 32.00 to the mouth was good to excellent. Except for a few minor violations of bacterial water quality standards and pesticides, the river appeared to have good water quality. This may be threatened however because of the urban nature of the lower watershed and the ongoing development in the upper watershed in Delaware County. Also, the influence of old landfills along the stream in and around Delaware (the old municipal landfills) and the old Gowdy landfill in Columbus may be chronically contributing pollutants, particularly the pesticides found in the Delaware area. Chemical water quality in the tributaries is already degraded (see below) and could further threaten the mainstem itself. Hardening of the watershed via further development will introduce further chemical contaminants due to increased runoff from roads, parking lots, manicured lawns and rooftops. Also, population growth in this area will strain the infrastructure in place for managing sewage. As noted in the sections above, both the OECC and Delaware City WWTPs have expanded their capacity in recent years due to growth. Further expansion of these plants may be warranted in the future with continued growth.

Olentangy River Tributaries

Horseshoe Run

Horseshoe Run is designated WWH, AWS, and IWS in the Ohio Water Quality Standards. Horseshoe Run drains approximately 13 square miles in Delaware County and flows into the Olentangy River at RM 29.74. Water quality measurements were made near the mouth at RM 0.30. A total of 6 samples were obtained over the summer of 1999. At times, flow was extremely limited in the stream due to the drought, resulting in minimal flow between pools.

There were single exceedences of the 4.0 mg/l WWH minimum criterion for dissolved oxygen and E. coli bacteria (Table 11). Nutrient concentrations in Horseshoe Run were moderately elevated for a headwater stream. All phosphorus measurements exceeded the 75th percentile background for the ECBP ecoregion with two readings exceeding the 90th percentile background (Table 13). Five of six measurements for organic nitrogen (TKN) surpassed the 50th percentile background with two of these exceeding the 75th percentile value (Table 13).

Chemical water quality in Horseshoe Run appeared to be somewhat impaired by low dissolved oxygen, elevated bacterial concentrations, and nutrient enrichment. Drought conditions may have exacerbated some of these conditions (e.g., dissolved oxygen).

Table 13. Comparison of background nutrient and demand parameter concentrations with those found in the Olentangy River study area, 1999. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background median (50th percentile), 75th, 90th, and 95th percentile values for headwater sites. Units are mg/l for all parameters. Sample size, n = 6 unless otherwise stated.

River/Stream	River Mile	Parameter(s)	Value(s)
Horseshoe Run	0.30	Total Suspended Solids	(8.5)
		Ammonia	(0.09, *0.06*, *0.06*)
		Nitrate+Nitrite	(2.15)
		Tot. Kjeldahl Nitrogen	(*0.75*, *0.60*, 0.50, 0.42, 0.41)
		Phosphorus	(0.37, 0.21, *0.18*, *0.15*, *0.13*, *0.11*)
Delaware Run	1.20	Ammonia	(*0.06*)
		Nitrate+Nitrite	(0.98)
		Tot. Kjeldahl Nitrogen	(*0.87*, 0.50)
		Phosphorus	(*0.14*, *0.09*, 0.07, 0.07, 0.06, 0.05)
	0.20	Total Suspended Solids	(9.0)
		Ammonia	(*0.06*)
		Nitrate+Nitrite	(1.16)
		Tot. Kjeldahl Nitrogen	(*0.78*, 0.50, 0.50)
		Phosphorus	(**0.64**, *0.11*, *0.10*, *0.08*, 0.06)
Lewis Center Tributary	0.10	Ammonia	(0.06)
		Nitrate+Nitrite	(*2.44*)
		Tot. Kjeldahl Nitrogen	(0.40, 0.40, 0.40)
		Phosphorus	(**1.35**, *0.17*, *0.08*, *0.08*, 0.05)
Kempton Run	0.90	Total Suspended Solids	(*23.5*)
	n=5	Ammonia	(*0.06*)
		Nitrate+Nitrite	(2.01)
		Tot. Kjeldahl Nitrogen	(*0.84*, *0.60*, 0.49)
		Phosphorus	(*0.19*, *0.17*, *0.15*, *0.15*, *0.08*)
Bartholomew Run	0.70	Total Suspended Solids	(*23.5*, 13.5, 8.0)
		Nitrate+Nitrite	(0.98)
		Tot. Kjeldahl Nitrogen	(0.50, 0.40)
		Phosphorus	(*0.15*)
Linworth Run	0.90	Total Suspended Solids	(7.0)
	n=3	Ammonia	(*0.09*)
		Tot. Kjeldahl Nitrogen	(0.40)
		Phosphorus	(0.26, *0.15*)

Rush Run	0.30	Total Suspended Solids	(7.5)
		Tot. Kjeldahl Nitrogen	(0.40)
		Phosphorus	(*0.13*, 0.06)

Table 13 continued.

River/Stream	River Mile	Parameter(s)	Value(s)
Bill Moose Run	0.20	Tot. Kjeldahl Nitrogen	(0.40, 0.40)
		Phosphorus	(*0.16*, 0.06)
Turkey Run	0.70	Ammonia	(0.10)
	n=4	Nitrite	(0.05)
		Tot. Kjeldahl Nitrogen	(*0.70*, 0.40)
		Phosphorus	(0.25, *0.10*)
Adena Brook	0.90	Nitrate+Nitrite	(*2.32*)
	n=1	Tot. Kjeldahl Nitrogen	(*0.60*)
		Phosphorus	(0.07)
	0.20	Ammonia	(0.13, *0.09*, *0.06*)
	n=4	Nitrate+Nitrite	(2.09)
		Tot. Kjeldahl Nitrogen	(*0.70*, 0.40)
		Phosphorus	(*0.16*, *0.13*, *0.09*, *0.08*)

Normal print values exceed the 50th percentile background
Italic print values exceed the 75th percentile background
Underlined values exceed the 90th percentile background
Boldfaced values exceed the 95th percentile background

Delaware Run

Delaware Run is designated as WWH, AWS, and IWS in the Ohio Water Quality Standards. Delaware Run is approximately 6 miles in length draining nearly 11 square miles in Delaware County and within the Delaware city limits. Water quality data was collected 6 times at 2 sites in the drainage (RM 0.20 and RM 1.20). In spite of the drought, Delaware Run exhibited continuous flow at both sites. At some locations along the creek sulfurous groundwater seeps occurred leaving a whitish precipitate combined with a rotten egg odor. These did not seem to impact the creek negatively.

A single WWH criterion exceedence for E. coli bacteria (Table 11) was recorded at RM 1.2. Nutrients did not appear to be excessive other than phosphorus. Phosphorus concentrations exceeded the 50th percentile background in the ECBP ecoregion in every sample at RM 1.20 and in 5 of 6 samples at RM 0.20 (Table13). In one instance at RM 0.20, phosphorus concentrations surpassed the 95th percentile for background. Chemical water quality impairment in Delaware Run was limited to bacteria and phosphorus.

Lewis Center Tributary (a.k.a. Unnamed Tributary to the Olentangy River at RM 18.19)

Lewis Center Tributary is designated as WWH, AWS, IWS, and SCR in the Ohio Water Quality

Standards. This tributary is less than 10 square miles of drainage area. Water quality measurements were made near the mouth at RM 0.10. A total of 6 samples were obtained over the summer. The drought impacted flow in the stream at times limiting it to just a trickle, however, the creek never became completely dry.

There were no violations of Ohio WQS criteria discovered in the Lewis Center Tributary. Nutrient concentrations did not appear to be a concern except for phosphorus. Phosphorus concentrations exceeded the 75th percentile for background in the ECBP ecoregion on three occasions and the 95th percentile once (Table 13). Chemical water quality was not significantly impaired in the Lewis Center Tributary although nutrient input may be a cause for concern, especially phosphorus.

Kempton Run

Kempton Run flows into the Olentangy River at RM 7.74. Chemical sampling results reflected the urban nature of the watershed. A total of 5 water samples were obtained during the summer from RM 0.90; a sixth run was attemptedbut the stream was dry. Based on the Ohio Water Quality Standards for SCR, bacterial concentrations were frequently elevated. Additonally, phosphorus levels exceeded the 75th percentile for background in the ECBP ecoregion for all 5 sampling events (Table 13). Organic nitrogen (as measured by TKN) was present in 3 of the 5 samples at concentrations greater than the median for the ECBP ecoregion background, two of these exceeded the 75th percentile background.

Bartholomew Run

Bartholomew Run is designated as WWH, AWS, and IWS in the Ohio Water Quality Standards. This stream is 1.3 miles in length with approximately 4 square miles of drainage area. Water quality samples were collected at RM 0.70 a total of 6 times during the summer. Ohio WQS criteria exceedences were recorded for *E. coli* or fecal coliform bacteria at least once during each pass (Table 11). Nutrient contamination was not a concern in this creek. However, suspended solids concentrations did surpass the median for this ecoregion in 3 of 6 cases (Table 13). Bacteria and suspended solids are indicative of impacts from soil disturbing activities due to development.

Linworth Run

Linworth Run is an undesignated, small headwater stream which flows into the Olentangy River at RM 9.90. Water quality samples were obtained at RM 0.90. Only 3 of 6 attempts were successful due to lack of surface flow in the stream; there were disconnected pools present. Bacteria concentrations were elevated, as was phosphorus, where 1 of the 3 samples exceeded the 75th percentile background for headwater streams in the ECBP ecoregion and another exceeded the 90th percentile for background (Table 13).

Water quality in Linworth Run appears threatened.

Rush Run

Rush Run is designated WWH, AWS, and IWS in the Ohio Water Quality Standards. This stream is 1.5 miles in length with approximately 2 square miles of drainage area and flows into the Olentangy River at RM 8.75. Water quality samples were collected at RM 0.30 (adjacent to Walnut Grove Cemetery) a total of 6 times during the summer. Flow was substantial in Rush Run even during the height of the drought. Ohio WQS criteria violations in Rush Run were limited to a single SCR exceedence for *E. coli*. bacteria (Table 11). Nutrients were not found at elevated concentrations in Rush Run (Table 13) although the stream exhibited large blooms of algae and supersaturated dissolved oxygen conditions (Table 14) which are both indicative of nutrient enrichment (algae and other organisms were using dissolved nutrients immediately).

Table 14. Temperature and dissolved oxygen data taken from Rush Run during the summer of 1999. Percent saturation values are calculated using an average barometric pressure of 760 mm of mercury. Temperature and dissolved oxygen concentration were readings obtained instantaneously from a YSI probe.

Date	Temperature (°C)	Dissolved Oxygen	
		Concentration (mg/l)	% Saturation
7/8/99	18.92	9.02	97.2
7/20/99	22.01	9.93	113.6
8/4/99	20.38	10.43	115.5
8/18/99	20.50	9.70	107.8
9/1/99	19.07	11.70	126.2
9/14/99	17.30	10.97	114.2
Mean	19.70	10.29	112.4

Bill Moose Run

Bill Moose Run is a small headwater tributary of the Olentangy River at RM 7.82. This stream had perennial flow over the entire summer and was sampled 6 times. The stream was similar to other urban streams in that exceedences of the SCR criteria for bacteria were recorded (Table 11). Nutrient concentrations were not found to be elevated (Table 13).

Turkey Run

Turkey Run is undesignated in the Ohio Water Quality Standards but has been recommendd for WWH, AWS, and IWS uses. This stream is 1.5 miles in length with approximately 2.4 square miles of drainage area. Turkey Run is tributary to the Olentangy River at RM 5.82. Water chemistry sample collections were attempted 6 times with 4 successful collections. Zero stream flow accounted for the 2 missed samples. Ohio WQS criteria violations were infrequent. Bacterial criteria were exceeded twice (Table 11) during the survey and aquatic life criterion was exceeded once for dieldrin (Table 15). Nutrient concentrations instream were noticeable, but not exceptional (Table 13).

Table 15. Results of organic chemical water quality sampling conducted in the Olentangy River study area during August, 1999.

Olentangy River Tributaries Water Column Organics

		Stream					
Compound	*Units*	**DR**	**LR**	**RR**	**BMT**	**AB**	**TR**
Alpha-BHC	µg/l		0.004	0.007	0.005	0.004	0.009
Delta-BHC	µg/l		0.004				
Gamma-BHC	µg/l			0.002		0.003	0.002
Dieldrin	µg/l			0.004	0.004		0.011
Chloroform	µg/l	1.38					

DR=Delaware Run, LR=Linworth Run, RR=Rush Run, BMT=Bill Moose Run, AB= Adena Brook, TR=Turkey Run

Underlined values exceed the criteria established for the protection of aquatic life for streams in the Ohio River basin (OAC 3745-1-14)

Adena Brook

Adena Brook (a.k.a. Big Run) is designated WWH, AWS, IWS, and PCR in the Ohio Water Quality Standards. This stream is 2.0 miles in length with approximately 3.5 square miles of drainage area. Adena

Brook is tributary to the Olentangy River at RM 6.00. Samples were attempted on Adena Brook six times at two different sites (RM 0.90 and RM 0.20). The site at RM 0.90 was not flowing with widely disconnected pools during 5 of the 6 sampling attempts and the site at RM 0.20 was not flowing with disconnected pools during 2 of the 6 sampling attempts. Both sites on Adena Brook exhibited multiple violations of Ohio WQS criteria. All samples from both sites exhibited violations of bacterial standards (Table 11). The dissolved oxygen minimum criterion was violated twice at the RM 0.20 site likely due to a lack of adequate flow; this site was a bare trickle during the drought. Nutrient concentrations in Adena Brook were also conspicuous and a concern (Table 13). Known sanitary sewer overflows combined with food grade oil spills, and an urbanized watershed have severely affected chemical water quality in Adena Brook.

Diurnal Dissolved Oxygen Study-Olentangy River

Diurnal dissolved oxygen patterns in the Olentangy River were examined as part of the survey work completed in this study. Eight locations were evaluated.

Daily dissolved oxygen concentrations found at RM 32.00 exhibited a flattened pattern (Figure 11). No violations of dissolved oxygen Ohio WQS criteria were noted here and supersaturated conditions were not apparent.

Datasonde results obtained immediately downstream from the Delaware WWTP discharge at RM 24.50 from July 27-29, 1999 show a normal diurnal fluctuation in dissolved oxygen and dissolved oxygen saturation (Figure 11). A “normal” diurnal fluctuation in instream dissolved oxygen shows lower concentrations and saturation in the early morning hours after plants have been respiring overnight followed by gradual increases as it gets light and photosynthesis begins to increase with a peak in the late afternoon or early evening followed by a decrease at dusk. Little supersaturation was observed. No violations of the minimum warmwater habitat criteria for dissolved oxygen within the river were noted and the WWTP does not appear to negatively impact dissolved oxygen levels even up to 5 miles further downstream at RM 19.40 (Figure 11).

Diurnal dissolved oxygen readings at RM 19.40 exhibited a normal pattern with some readings dipping slightly below the minimum 5.0 mg/l EWH criterion. Normal supersaturation was apparent in the later part of the day, but posed no significant problem. The diurnal pattern was similar at RM 15.00, however, the lowest readings dipped significantly lower than the EWH minimum criterion of 5 mg/l (Figure 11).

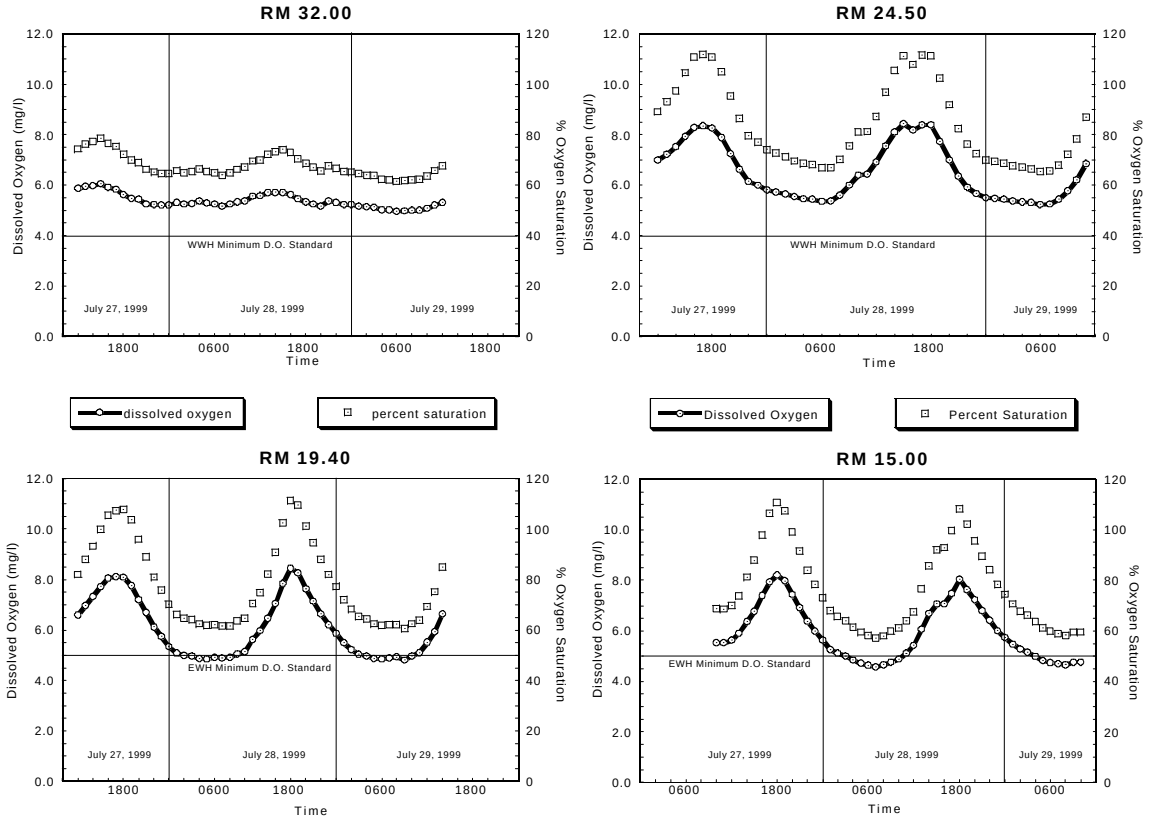


Figure 11 Diurnal dissolved oxygen measurements from RMs 32.0, 24.5, 19.4 and 15.0, August 27-29, 1999.

Datasonde results obtained downstream from the OECC WWTP discharge at RM 12.40 show typical diurnal variation for dissolved oxygen and dissolved oxygen saturation. No violations of the EWH minimum criterion of 5 mg/l were noted although some significant supersaturation (nearly 120%) did occur (Figure 12). This was indicative of elevated levels of photosynthesis and indirectly suggested nutrient enrichment. Undoubtedly, the OECC WWTP contributes somewhat to nutrient enrichment due to the discharge of nitrates and phosphorus in the effluent, however this is not the only source of nutrients.

Diurnal dissolved oxygen measurements were also obtained at RM 7.80. The normal, daily fluctuations in dissolved oxygen were present if somewhat irregular. Concentrations were well above the minimum WWH criteria of 4 mg/l and supersaturated conditions were not apparent (Figure 12). An even more irregular pattern was exhibited at RM 3.90, but with similar results (no values below minimum and no supersaturation). Discharges from the Olentangy wetland research area (RM 3.90 only) and influences from impounded areas (both RM 7.80 and RM 3.90) may be causing these irregularities.

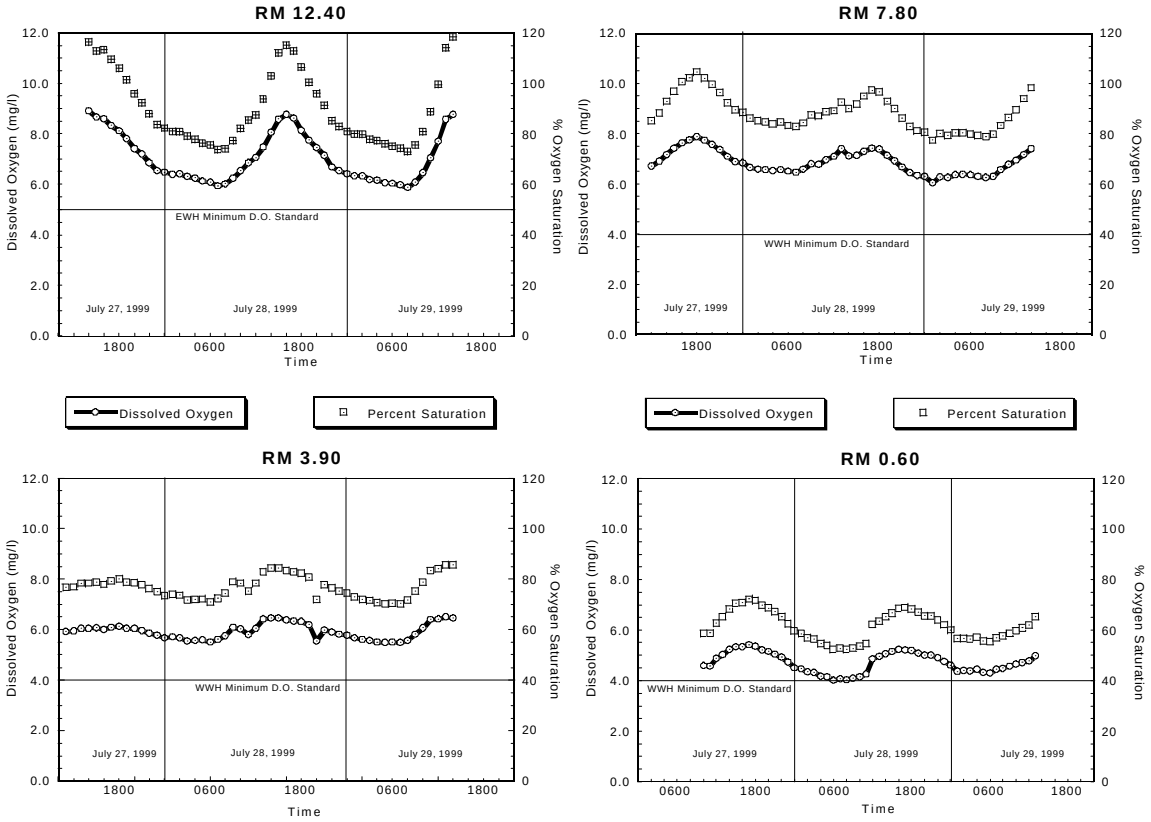


Figure 12 Diurnal dissolved oxygen measurements from RMs 32.0, 24.5, 19.0 and 15.0, August 27-29,1999.

The station at RM 0.60 showed a typical, but flattened, diurnal fluctuation which hovered just above the minimum WWH criterion of 4 mg/l (Figure 12). Supersaturated conditions were not apparent at this locale. In fact, saturation was somewhat lacking which is indicative of the lack of riffle reaeration at this site; reoxygenation of water occurs in part via the mixing of water and air as the water tumbles over the rocky areas of shallow riffles.

Water Column Organics

Olentangy River Mainstem

Low concentrations of pesticides were detected in every sample obtained from the Olentangy River mainstem. Lindane was detected in all samples in concentrations ranging from 0.002 mg/l to 0.023 mg/l (Table 16). Other detections worth noting were dieldrin, heptachlor epoxide, and alpha-BHC. All BHC

compounds (including lindane) and dieldrin have been banned from usage in the United States. Heptachlor (the parent chemical to heptachlor epoxide) is currently under restricted use. Atrazine was listed as tentatively identified in all but one sample. Halogenated volatile compounds were also detected at low levels in the effluent from the Delaware WWTP (Table 16). Since there was no trip blank associated with this particular sample, these results were treated with skepticism, although it is not uncommon for small amounts of halogenated organic compounds to emanate from WWTPs that chlorinate their effluent.

Table 16. Results of organic chemical water quality sampling conducted in the Olentangy River study area during August, 1999.

Compound (mg/l)	**River Mile**										
	32.00	***25.26***	*25.26*	*22.30*	*15.00*	***13.39***	*13.38*	*12.40*	*6.80*	*1.80*	*0.60*
Alpha-BHC					0.008			0.010	0.008	0.008	0.007
Gamma-BHC (a.k.a. Lindane)	0.011	0.023	0.018	0.012	0.003	0.008	0.004	0.002	0.002	0.003	0.003
4-4' DDT						0.008					
Dieldrin	0.008			0.007	0.004	0.004	0.008	0.004	0.003		
Endosulfan I										0.003	
Heptachlor Eploxide	0.006	0.008	0.006			0.011					
Endrin aldehyde		0.012									
Hexachloro benzene										0.003	0.003
Atrazine (TIC)	1.0	0.6	0.8	1.0	0.7		0.7	0.7	0.6	0.5	0.5
Bromomethane		2.0*									
Bromodichloromethane		1.04*	0.85*								
Chloroform		2.71*	2.24*								

Boldface italic type and highlighting indicates WWTP discharge, 25.26=Delaware WWTP, 13.39=OECC WWTP
* no trip blank submitted with sample
TIC=Tentatively Identified Compound
Underlined values exceed the criteria established for the protection of aquatic life for streams in the Ohio River basin (OAC 3745-1-14)

The discovery of low level organic pollution in the Olentangy River mainstem was not surprising. However, the degree of contamination in upstream areas from lindane and dieldrin was unexpected since these chemicals have been banned for many years. Concentrations of lindane in upstream areas were in violation of the criteria for the protection of aquatic life outside of the mixing zone (OAC 3745-1-34) as were concentrations of dieldrin. This contamination of the water column may be arising from many sources including, but not limited to, movement of residuals left from previous applications, release from sediments instream or old disposal areas situated alongside the river, specifically the old Delaware municipal landfills, or air deposition from areas where application of these pesticides is still legal. The Delaware and OECC WWTPs may also be "sources" for lindane as this was detected in both effluents (Table 16). Release from sediments seems improbable because neither lindane or dieldrin were found in Olentangy River mainstem sediments or tributary stream sediments from tributaries discharging in the upper watershed. Old landfills or disposal areas in Delaware with documented leachate outbreaks and possible groundwater connections to the river may be the major culprits as these facilities were virtually unregulated even 30 years ago and disposal of hazardous chemicals including pesticides into these types of landfills was common practice.

Olentangy River Tributaries

Low concentrations of organic contaminants were discovered in several Olentangy River tributaries (Table 15). A single, insignificant detection of chloroform was recorded on Delaware Run with no other organic contaminants detected. Pesticides including lindane (Gamma BHC), other BHC compounds, and dieldrin were detected in several other tributaries including Linworth Run, Rush Run, Bill Moose Run, Adena Brook, and Turkey Run. Dieldrin detected in Turkey Run exceeded the criterion for protection of aquatic life outside the mixing zone. The source of this contamination in Turkey Run can be speculated, but not proved. It was not found in sediments. Since dieldrin has been banned for some time and has a lengthy half life, sources for this contamination are likely residuals left over from previous applications. These could include, but are not limited to, the Ohio State University golf course which is upstream from the sampling site and local use in the suburban neighborhoods draining into the creek.

Sediment Chemistry

Sediment sampling protocols were used based on the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 1989) and samples were collected, preserved, and analyzed for a variety of parameters including metals, base neutral and acid extractable compounds, volatile organic compounds, pesticides, polychlorinated biphenyls, and nutrients. See Appendix A for a complete listing of the analytical results for all waterbodies studied.

Sediment contamination was characterized with respect to appropriate literature (Kelly and Hite, 1984; Persaud, *et al.*, 1994) and metal concentrations were compared with statewide Ohio EPA data (Appendix Table A-6). The Kelly and Hite stream sediment classification system (Illinois EPA) ranks relative pollutant concentrations, from non-elevated to extremely elevated, based on mean values. It does not directly assess

toxicity. *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (Persaud, *et al*). define two levels of ecotoxic effects, and are based on the chronic, long-term effects of contaminants on benthic organisms. A "Lowest Effect Level (LEL)" is a level of sediment contamination that can be tolerated by the majority of benthic organisms. A "Severe Effect Level (SEL)" indicates a level at which pronounced disturbance of the sediment-dwelling community can be expected. When any parameters are at or above the SEL Guideline, the material tested is considered highly contaminated and will likely have significant effects on a majority of the benthic species.

Olentangy River Mainstem

Contaminated sediments in the Olentangy River were concentrated within the urban areas of Delaware and Columbus. Sites in the Columbus urban area within the last couple of miles of the mouth were moderately to severely contaminated with metals and organic compounds. The stream was being inudated with contaminates flowing off of the surrounding landscape which contributed to the impairment seen in the biological communities.

Metals

Sediment samples follow a general pattern of increasing concentrations of metals with movement downstream. The single exception was found at RM 22.30 where concentrations of many parameters spiked upward with some metals exhibiting the highest concentrations found within the mainstem. These sediments showed a variety of elevated parameters including slightly elevated concentrations of nickel; elevated concentrations of arsenic, copper, manganese, zinc, and iron; highly elevated concentrations of barium and chromium; and extremely elevated concentrations of aluminum (Table 17). These elevated concentrations may be an artifact of drainage from a foundry sand disposal site at the General Castings Corp. which drains into the river upstream from this site and of the old municipal landfills nearby. .Moving downstream from RM 22.30 concentrations generally drop and then begin rising, culminating with many elevated metals near the mouth. The old Gowdy landfill near Goodale Avenue on the west side of the river could be a possible source as well as urban influences via storm runoff, CSOs, and air deposition.

Table 17. Results of chemical/physical sediment quality sampling conducted in the Olentangy River study area during July-September, 1999. Values in parentheses indicate concentrations below the method detection limit. NA means not analyzed. Parameters noted with a * are compared with the Illinois guidelines published by Kelly and Hite, 1984. All other parameters are compared with Ohio EPA sediment guidelines. Descriptive guidelines are as follows: Not elevated, **slightly elevated**, elevated, highly elevated*, extremely elevated**. Parameters in *italic* have no established guideline for comparison.

Olentangy River Sediments											
		River Mile									
Analyte	Units	32.00	25.26	22.30	19.40	13.40	12.40	6.80	2.10	1.80	0.60
Solids	%	*61.4*	*76.7*	*42.2*	*55.5*	*44.1*	*53.5*	*45.7*	*42.0*	*32.3*	*31.3*
pH	S.U.	*7.55*	*7.69*	*7.36*	*7.52*	*7.35*	*7.47*	*7.32*	*7.29*	*7.26*	*7.42*
Ammonia	mg/kg	*20.6*	*(9.13)*	*(16.6)*	*23.1*	*(15.9)*	*(13.1)*	*37.8*	NA	NA	NA
Phosphoru	mg/kg	**619**	**527**	**827**	**701**	**1060**	**888**	**1020**	NA	NA	NA
COD*	mg/kg	49300	53000	41500	33700	**99700**	27900	70100	NA	NA	NA
METALS											
Aluminum	mg/kg	18300	10300	46700**	18500	25100*	**14200**	20900	21800	23500*	32800*
Arsenic	mg/kg	**9.94**	6.47	19.8	9.01	**13.4**	**10.6**	14.2	**12.1**	**9.95**	13.7
Barium	mg/kg	84.8	75.5	257*	**126**	156	**115**	164	**133**	186	235*
Cadmium	mg/kg	0.28	0.27	0.38	0.24	0.39	0.22	**0.73**	**0.67**	0.86	1.31*
Calcium	mg/kg	*7860*	*12100*	*15200*	*23600*	*16400*	*12700*	*28600*	*23800*	*31000*	*38100*
Chromium	mg/kg	17.4	(13.5)	46.5*	**22.4**	28.9	20	28.6	28.2	33.2	46*
Copper	mg/kg	11.8	12.6	29.6	16.8	**25.8**	15.4	35	30.9	**44.2**	58.3*
Iron	mg/kg	16300	13500	34800	18200	**26300**	19600	**25200**	21600	**22400**	**27500**
Lead	mg/kg	(22.5)	19.8	(33.8)	(24.8)	(31.3)	(26.7)	44.6	37	**58.6**	83
Magnesium	mg/kg	*4490*	*4500*	*10200*	*6210*	*7040*	*4670*	*11900*	*10600*	*9950*	*14600*
Manganese	mg/kg	**338**	174	570	**328**	279	291	**363**	**306**	237	**327**
Nickel	mg/kg	(22.5)	(18.0)	**39.8**	(24.8)	**31.3**	(26.7)	31.8	35.3	44.2	44.8
Mercury*	mg/kg	(0.030)	0.037	(0.042)	(0.040)	(0.046)	(0.033)	0.048	**0.078**	**0.090**	0.128
Potassium	mg/kg	*3370*	*2700*	*13500*	*4970*	*6260*	*4000*	*4770*	*5290*	*6630*	*10100*
Selenium	mg/kg	*(1.12)*	*(0.90)*	*1.95*	*(1.24)*	*(1.56)*	*(1.34)*	*(1.59)*	*(1.76)*	*(2.21)*	*(2.24)*
Sodium	mg/kg	*(2810)*	*(2250)*	*(4230)*	*(3110)*	*(3910)*	*(3340)*	*(3980)*	*(4410)*	*(5530)*	*(5600)*
Strontium	mg/kg	*52.8*	*41.4*	*64.3*	*169*	*75.8*	*107*	*111*	*113*	*181*	*132*
Zinc	mg/kg	68.5	65.6	149	84.5	**112**	69.4	187	177	293*	292*

Organics

Organic sediment contamination from pesticides and PCBs was generally slight upstream from central Columbus. The areas downstream from the Delaware WWTP outfall showed contamination from PAHs (polycyclic aromatic hydrocarbons) above the lowest effect level (LEL) as stated by Persaud and Jaagumagi (1993). Concentrations increased significantly beginning with RM 6.80 and continuing to the mouth. Total chlordane, DDT breakdown products, and PCBs were all above the lowest effect level (LEL) as defined in Persaud and Jaagumagi (1993) (Table 18). Some individual PAH compounds were found to exceed the severe effect level (Persaud and Jaagumagi, 1993). See Table 18 for details. Sources for PAH contamination include tributary sediments and runoff from city streets and highways. Pesticide and PCB contamination in the lower river resulted from a combination of factors including contaminated runoff, Gowdy landfill, and CSO/SSO contributions.

Table 18. Results of chemical/physical sediment quality sampling conducted in the Olentangy River study area during July-September, 1999. **Boldface** type indicates values greater than the severe effect level and *italic* type indicates values greater than the lowest effect level (Persaud and Jaagumagi, 1993). An * means a compound was not evaluated by Persaud and Jaagumagi, 1993. A blank space indicated that the substance was not detected in the sample.

		River Mile									
Compound	Units	32.00	25.26	22.30	19.40	13.40	12.40	6.80	2.10	1.80	0.60
Solids	%	67	63.2	49.6	72	59.7	65.4	58.3	45.2	59	46.6
Total Organic Carbon	%	*2.6*	*2.1*	*2.4*	*4.8*	*4.4*	*3.9*	*4.0*	*5.7*	*9.0*	*6.8*
VOLATILE ORGANIC COMPOUNDS											
Acetone	mg/k		0.109								
PESTICIDES											
4-4' DDD	mg/k									*8.16*	
4-4' DDE	mg/k									*8.88*	
Alpha-chlordane*	mg/k							9.98	11.1	12.8	17.9
Gamma-chlordane*	mg/k							8.05	17.9	13.3	20.9
Total Chlordane	mg/k	0	0	0	0	0	0	*18.0*	*29*	*26.1*	*38.8*
POLYCHLORINATED BIPHENYLS (PCBs)											
PCB-1254	mg/k								*165*	*86.2*	*140*
PCB-1260	mg/k										*175*

Table 18 Continued.

Compound	Units	River Mile									
		32.00	25.26	22.30	19.40	13.40	12.40	6.80	2.10	1.80	0.60
BASE NEUTRAL AND ACID EXTRACTABLE COMPOUNDS (BNAs)											
Anthracene	mg/k				*0.94*					*20*	
Benz[a]anthracene	mg/k		*0.73*		*2.8*			*1.9*	*2.5*	*47*	*2.7*
Benzo[a]pyrene	mg/k		*0.7*		*2.2*			*2*	*2.8*	*41*	*3.2*
Chrysene	mg/k		*0.69*		*3*			*2.8*	*3.6*	**52**	*3.9*
Dibenz[a,h]anthracen	mg/k				*0.55*					*8.7*	
Dibenzofuran*	mg/k									8.5	
Fluoranthene	mg/k		*1.6*		*5.8*			*5.9*	*7.2*	**120**	*7.3*
Fluorene	mg/k									*13*	
Indeno (1,2,3,cd)	mg/k				*1.5*			*1.9*	*2.4*	*27*	*3.1*
2-Methyl	mg/k									2.8	
3&4 Methyl phenol*	mg/k									1.3	
Naphthalene*	mg/k									2.9	
Phenanthrene	mg/k		*0.76*		*4.4*			*3.3*	*2.5*	**110**	*3.4*
Pyrene	mg/k		*1.3*		*4.5*			*4.5*	*5.6*	**95**	*5.7*
Total PAHs	mg/k	0	5.78	0	25.7	0	0	22.3	26.6	*549*	*29.3*
Bis (2-ehtyl.hexyl)	mg/k							0.76	2	1	1.4

Olentangy River Tributaries

Of the nine tributary streams where sediment samples were obtained, Rush Run and Adena Brook were the most contaminated with metals, followed by Delaware Run and Turkey Run . Linworth Run and Bill Moose Run were the least contaminated by metals. Organic sediment contamination was not existent in Horseshoe Run and Linworth Run, but noticeable in Rush Run, Bill Moose Run, and Turkey Run. Delaware Run and Adena Brook contained significant organic contamination. The contaminated sediments can be attributed to runoff from the surrounding urban areas and contributed to the degraded aquatic biological commnities found in these tributaries.

Metals

Adena Brook generally had the most contaminated sediment of the tributaries surveyed. Slightly elevated to elevated concentrations of mercury, arsenic, and lead were detected, along with highly to extremely elevated concentrations of cadmium (Table 19). Elevated to highly elevated concentrations of copper, elevated concentrations of chromium, barium, and aluminum, and highly elevated concentrations of zinc were also detected.

Rush Run sediments were also contaminated with metals including slightly elevated concentrations of mercury, lead, and nickel; elevated concentrations of chromium and zinc; and highly elevated concentrations of aluminum, arsenic, barium, cadmium, and copper.

In the other tributaries surveyed, metals contamination was much less apparent although present. The only other significant results showed highly elevated concentrations of copper and elevated concentrations of cadmium in Turkey Run. Highly elevated concentrations of aluminum were present in Horseshoe Run sediments. Delaware Run sediments contained highly elevated aluminum as well as elevated chromium, copper, and zinc.

Concentrations of these metals result from polluted runoff from city streets, sidewalks, and roof areas which include sources such as metallic particles from automobile brakes, leached materials from concrete, aluminum and copper gutters, and galvanized metal products.

Organics

Horseshoe Run and Linworth Run did not show any organic contaminants in sediments other than an insignificant, low-level detection of acetone in Horseshoe Run (Table 19). All of the other tributaries assessed showed significant concentrations of organic materials in sediments. Delaware Run sediments were severely contaminated with the pesticide chlordane (above the severe effect level or SEL) and contained PAHs above the LEL as defined in the study by Persaud and Jaagumagi (1993). Methoxychlor was also detected. Rush Run, Adena Brook and Turkey Run sediments also contained significant concentrations of chlordane as well as PAHs, all above the LEL. Additionally, Adena Brook sediments contained the pesticide dieldrin at concentrations above the LEL. Sediments obtained from Bill Moose Run contained PCB 1254 above the LEL in addition to chlordane and PAHs. Bartholomew Run showed sediment contamination only from PAHs (Table 19).

Table 19. Results of chemical/physical sediment quality sampling conducted in the Olentangy River study area during July-September, 1999. Values in parentheses indicate concentrations below the method detection limit. **HR**=Horseshoe Run, **DR**=Delaware Run, **BR**=Bartholomew Run, **LR**=Linworth Run, **RR**=Rush Run, **BMR**=Bill Moose Run, **AB-1**=Adena Brook at Overbrook Drive, **AB-2**=Adena Brook at Whetstone Park, **TR**= Turkey Run. Parameters are compared with Ohio EPA sediment guidelines. Descriptive guidelines are as follows: Not elevated, **slightly elevated**, elevated, highly elevated*, extremely elevated**. Parameters in *italic* have no established guideline for comparison.

Analyte	Unit	HR	DR	BR	LR	RR	BMR	AB-1	AB-2	TR
Solids	%	*65.2*	*54.0*	*59.8*	*75.7*	*42.4*	*78.5*	*59.0*	*41.6*	*42.6*
pH	S.U.	*7.45*	*7.79*	*7.46*	*7.42*	*7.50*	*7.74*	*7.54*	*7.30*	*7.10*
Ammonia	mg/k	*(10.7)*	*(46.9)*	*(11.7)*	*9.25*	*32.0*	*(8.92)*	*(11.9)*	*41.7*	*NA*
Tot.	mg/k	**518**	**895**	**596**	**684**	**910**	**372**	**861**	**1060**	NA
COD*	mg/k	66800	84600	47300	17200	154000	37700	105000	176000	NA
METALS										
Aluminum	mg/k	24800*	29700*	17600	5670	22600*	4110	17100	17600	15800
Arsenic	mg/k	**10.2**	**10.9**	**13.1**	4.5	27.8*	6.23	12.2	15.9	**12.5**
Barium	mg/k	166	185	**105**	38.2	267*	24.6	174	170	155
Cadmium	mg/k	0.29	0.56	0.25	0.14	1.32*	0.16	1.90**	1.53*	0.87
Calcium	mg/k	*9660*	*41500*	*31600*	*25400*	*58700*	*31400*	*51100*	*48100*	*59300*
Chromium	mg/k	**22.7**	34.5	**22.3**	(14.7)	29.4	(13.6)	29.9	34.9	**26.4**
Copper	mg/k	14.8	33.8	**20.4**	11.7	39.2*	8.19	34.5	55.8*	44.5*
Iron	mg/k	16500	**22400**	19700	7980	34900	8700	19700	**23000**	18900
Lead	mg/k	(22.7)	**68.3**	(24.8)	19.6	**56.1**	(18.2)	**51.7**	88.4	**45.3**
Magnesium	mg/k	*3410*	*12800*	*11100*	*9780*	*19600*	*8190*	*13200*	*13200*	*21400*
Manganese	mg/k	708	**333**	**409**	156	**399**	117	266	**415**	259
Mercury*	mg/k	(0.03)	(0.04)	(0.038)	(0.031)	**0.076**	(0.026)	**0.073**	0.129	NA
Nickel	mg/k	(22.7)	(25.5)	(24.8)	(19.6)	**38.3**	(18.2)	(23.0)	(**31.0**)	(**32.9**)
Potassium	mg/k	*6250*	*7660*	*5570*	*1470*	*7120*	*1360*	*5170*	*5430*	*4940*
Selenium	mg/k	*1.53*	*(1.28)*	*(1.24)*	*(0.98)*	*(1.78)*	*(0.91)*	*1.67*	*1.55*	*(1.65)*
Sodium	mg/k	*2840*	*3190*	*3100*	*2450*	*4450*	*2270*	*2870*	*3880*	*4120*
Strontium	mg/k	*57.9*	*103*	*86.1*	*70*	*150*	*37.8*	*98.2*	*93*	*453*
Zinc	mg/k	79	167	83.6	37.2	224	40	238*	353*	208

Since many organic contaminants are hydrophobic, they tend to be found attached to sediment particles rather than dissolved in the water. Pesticide contaminants are likely the result of years of application prior to the banning of the specific compound (e.g., chlordane). Many of the pesticides detected are resistant to degradation and take many years to decay into other, less toxic forms. Polychlorinated biphenyls (PCBs) were used for many years as dielectric fluids in electrical transformers and spills of these materials were common before they were phased out years ago. PCBs are also very persistent in the environment due to their chemically stable structure, so they will remain sequestered in sediments for decades undergoing little change. Polycyclic aromatic hydrocarbons (PAHs) are common materials found in the heavy fractions of petroleum tars. They are used for road construction, roofing and the like; hence, their presence is common in the sediments around urban and suburban areas with road networks.

Table 20. Results of organic chemical sediment quality sampling conducted in the Olentangy River study area during August, 1999. Blank spaces indicate concentrations below the method detection limit. *Italic* type indicates values greater than the lowest effect level and **bold** type values greater than the severe effect level (Persaud and Jaagumagi, 1993). Compounds designated by an * are not evaluated in Persaud and Jaagumagi, 1993. **HR=** Horseshoe Run**, DR**=Delaware Run at Henry Street, **BR=** Bartholomew Run**, LR**=Linworth Run, **RR**=Rush Run, **BMR**=Bill Moose Run, **AB-1=**Adena Brook at Overbrook Rd., **AB-2**=Adena Brook at Whetstone Park, **TR**= Turkey Run.

Olentangy River Tributaries Sediments

Compound	Units	HR	DR	BR	LR	RR	BMR	AB-1	AB-2	TR
Solids	%	61.6	51.7	68.3	68.7	59.5	64.3	63.6	47.5	48.7
Total Organic Carbon	%	*5.0*	*5.1*	*2.8*	*1.7*	*9.4*	*1.5*	*5.0*	*8.3*	*5.8*
VOLATILE ORGANIC COMPOUNDS										
Acetone	mg/kg	0.144								
PESTICIDES AND PCBS										
Dieldrin	mg/kg							*6.43*	*11.2*	
Alpha-chlordane*	mg/kg		146			13.1		22.1	35.9	22.5
Gamma-chlordane*	mg/kg		150			10.1	7.94	18.3	33.9	18.7
Cis-nonachlor*	mg/kg		49.1						10.6	
Trans-nonachlor*	mg/kg		117					8.84	21.6	15.2
Total Chlordane	mg/kg		**462.1**			*23.2*	*7.94*	*49.24*	*102*	*56.4*
Methoxychlor*	mg/kg		57.2							
PCB 1254	mg/kg						*131*			

Table 20 Continued.

Olentangy River Tributaries Sediments

Compound	Units	HR	DR	BR	LR	RR	BMR	AB-1	AB-2	TR
BASE NEUTRAL AND ACID EXTRACTABLE COMPOUNDS										
Anthracene	mg/kg		*1.1*			*1.2*		*0.98*	*1.4*	*1.1*
Benz[a]anthracene	mg/kg		*4*	*0.63*		*5.8*	*2*	*5*	*8.9*	*6.2*
Benzo[a]pyrene	mg/kg		*4*	*0.68*		*6.6*	*2.2*	*6.2*	*11*	*6.9*
Benzo[b]fluoranthene*	mg/kg		4.7	0.94		8.2	2.9	7.6	12	7.8
Benzo[g,h,i]perylene	mg/kg		*2.7*	*0.6*		*4.9*	*1.7*	*5.2*	*9.1*	*5*
Benzo[k]fluoranthene	mg/kg		*3.5*	*0.65*		*6.3*	*1.7*	*9.4*	*12*	*7*
Chrysene	mg/kg		*4.9*	*1.1*		*8.8*	*3*	*7.4*	*15*	*9.7*
Dibenz[a,h]anthracene	mg/kg		*0.78*			*1.6*		*1.6*	*3.2*	*1.7*
Fluoranthene	mg/kg		*12*	*2.1*		*16*	*6.4*	*14*	*27*	*19*
Indeno[1,2,3-cd]pyrene	mg/kg		*3.2*	*0.66*		*5.4*	*1.9*	*5.7*	*10*	*5.6*
Phenanthrene	mg/kg		*6.9*	*0.83*		*8.8*	*3.2*	*7.6*	*12*	*10*
Pyrene	mg/kg		*8.9*	*1.6*		*12*	*4.8*	*11*	*20*	*16*
Total PAHs	mg/kg	0	*56.68*	*9.79*	0	*85.6*	*29.8*	*81.68*	*141.6*	*96*
bis (2-ethylhexyl)	mg/kg		3.8			1.1		1.2	4.1	1.9

Physical Habitat for Aquatic Life

Olentangy River (mainstem)

The quality of near and instream macrohabitat of the Olentangy River was evaluated at 16 ambient fish sampling stations. QHEI values ranged between 82.5 (RM 27.9, Hudson Rd.) and 29.0 (RM 2.0, 5th Ave. dam pool), with a reach mean of 61.8 (± 12.7 SD). Mean reach QHEI values $ 60.0 generally indicate a level of macrohabitat quality sufficient to support an assemblage of aquatic organisms fully consistent with the WWH biological criteria. Average reach values $ 75.0 are generally considered adequate to support exceptional (EWH) aquatic communities (Rankin 1989 and Rankin 1995). A matrix of the habitat features and accompanying QHEI score, by sampling station, are presented in Table 22.

Most stations were found to contain a complement of positive habitat features and appeared capable of supporting, at a minimum, WWH assemblages. However, habitat quality was not uniform throughout the Olentangy River study area. Macrohabitat conditions characterized as very good to exceptional were

consistently observed within the upper and middle segments, between RM 32.0 (downstream from the Delaware Reservoir) and RM 15.0 (SR 750). The sites contained within this reach typically possessed a predominance of positive features that included alternating series of riffle-run-pool complexes, abundant coarse substrates, a diversity of instream cover types, a channel morphology in a natural or recovered state, and a well established wooded riparian corridor.

In comparison with the upper segment, macrohabitat quality was diminished as the Olentangy River entered the greater Columbus metropolitan area. This decline began at approximately RM 12.4 (downstream. Mt. Air), and marginal conditions largely persisted through the remaining downstream river segment. Both high and moderate influence negative habitat features were predominant within this reach (Table 22). The shift in macrohabitat quality was reflective of landuse pressures and demands common to developing and established urban and suburban areas. These stressors included, but were not limited to, direct stream channelization (or relocation), riparian encroachment (or removal), sedimentation, and impoundments formed by several lowhead dams. These activities tended to simplify near and instream habitat, resulting in increased channel monotony, increased embedding of substrates, extensive pooled reaches (where impounded), limited vegetative buffer, and a paucity of instream cover types. Every station within the lower 12 miles was affected to some degree by one or more of these detrimental activities. The deleterious effects to aquatic biota of diminished habitat quality are often exacerbated in metropolitan setting by the impervious and well-drained nature of the landscape and the attendant diffuse pollution sources.

Despite the habitat deficits listed above, the free flowing (unimpounded) stations within the urbanized portion of the Olentangy River displayed varying degrees of physical recovery, with QHEI values at or near 60.0 commonly observed. Macrohabitat quality of the lower 12 miles of the was not optimal. However, sufficient recovery or in some instances the conservation of positive features was evident at many sites. Baring other environmental factors, significant habitat derived impairment did not appear likely within the lower segment of the mainstem. In contrast, habitat evaluations at three impounded fish stations on the lower Olentangy (RMs 5.5, 2.0, and 0.3) consistently yielded the poorest QHEI scores, with values as low as 29.0 observed. As such, these impoundments exerted a strong suppressive influence on ambient biological performance.

An important aspect of physical habitat not directly measured by the QHEI, but which appeared as a prominent influence during the sampling efforts was the very low discharge of the Olentangy River over the course of the summer of 1999. As classified by the Palmer Drought Severity Index, severe to extreme drought conditions were indicated for the period between July and October 1999 (Ohio DNR 1999). The effect of nearly every stressor within the basin was likely made more acute by significantly diminished stream flow within the entire catchment.

Olentangy River Tributaries

Nine streams comprise the principal drainage network of the lower Olentangy River: Adena Brook, Turkey Run, Rush Run, Delaware Run, Kempton Creek, Linworth Run, Horseshoe Run, Lewis Center tributary, and Bill Moose Run. Macrohabitat quality of these mainstem tributaries was evaluated at 11 fish sampling stations. Adena Brook and Delaware Run were each evaluated at two sampling sites. The remaining tributaries were evaluated at one location, typically less than a mile upstream from the point at which the stream(s) joins the Olentangy River. A matrix of the habitat features and accompanying QHEI score, by sampling station, are presented in Table 22.

Five of these sampling sites were found to contain habitat quality very near or greater than the minimum WWH threshold. These stations and/or stream segments included Turkey Run, upper Delaware Run (RM 1.2), Horseshoe Run, Lewis Center tributary, and Bill Moose Run. QHEI values at these sites ranged between 65.5 and 57.0, averaging 62.6. Positive habitat features common to these sites included unmodified or recovered channel morphology, pool depth > 40 cm, low to normal substrate embeddedness, and abundant coarse substrates. Despite severe to extreme drought conditions (Ohio DNR 1999), perennial flow was indicated at all these sites, except Horseshoe Run. The reach of Horseshoe Run evaluated in 1999 consisted of a series of pools connected by subsurface (interstitial) flow. These pools, kept from stagnation by subsurface augmentation, provided refugia for headwater adapted taxa during the drought of 1999. This is a common feature of headwater streams with a minimally disturbed catchment. Barring other environmental factors and/or stressors, aquatic life use impairment derived solely from deficient habitat did not appear likely at these sites.

Macrohabitat quality of Kempton Run, Linworth Run, and lower Adena Brook (RM 0.1) was characterized as marginal, with each stream achieving QHEI scores of 54.5, 53.5, and 54.0 respectively. Both Linworth Run and Adena Brook were found intermittent. The reach sampled in these two streams consisted of a series of widely separated, disjunct pools. Based upon field observations, augmentation by subsurface (interstitial) flow appeared minimal or entirely lacking. The absence of perennial, or significant interstitial flow, appeared the most prominent limiting aspect of physical habitat for these streams. The magnitude of intermittence was undoubtedly a result of the severe to extreme drought conditions experienced during 1999. However, the impervious and well-drained nature of the urban landscape that constitutes the catchments of Linworth Run and lower Adena Brook was also significant contributing factor. Urban watersheds typically lack the ability to attenuate and gradually release surface runoff. In urban areas, the pervasive nature of drainage modifications, by design, rapidly deliver rainwater from the landscape to the local drainage network. Alterations to runoff patterns in intensely developed environments are often the antecedences of stream intermittence.

The habitat deficits observed in Kempton Run appeared more natural in character. Despite its position within an urban/suburban landscape, many positive habitat features were present (e.g., perennial flow–albeit

very minimal, unmodified channel, abundant course substrates, low level substrate embeddedness, and a well-established riparian corridor). However, several important attributes were lacking. These included well-developed channel features (pools, riffles etc.) and a diversity of instream cover. As Kempton Run possess a drainage area of only 1.5 miles^2 the lack of the diverse physical features was likely related to its very small size. Additionally, the surrounding urban area likely hampered the ability of this stream to create and maintain positive habitat features by disrupting the flow regime through modification of runoff patterns.

Ultimately, Kempton Run, Linworth Run, and lower Adena Brook (RM 0.1) were found lacking the typical habitat features associated with WWH assemblages. As stated above, near and instream macrohabitat quality within these streams or stream segments was not severely degraded, but many negative habitat features were observed. The conditions documented during the 1999 sampling effort suggested the *sub par* habitat conditions would likely have deleterious effects on ambient biological performance. However, significant impairment of the aquatic life use derived solely from marginal macrohabitat did not appear certain.

The remaining three stations or stream segments were found habitat deficient and included lower Delaware Run (RM 0.2), upper Adena Brook (RM 0.9), and Rush Run. These sites achieved QHEI scores of 40.0, 43.5, and 48.5, respectively. Detrimental features common to these sites were all associated with previous modification (and its attendant effects on channel morphology and substrate composition), and the impervious and well-drained nature of the surrounding urban landscape. The predominance of negative habitat features appeared to exert a strong suppressive influence on ambient biological performance.

Table 21 Qualitative Habitat Evaluation Index (QHEI) matrix showing warmwater and modified habitat attributes for the Olentangy River study area, 1999.

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes: No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	MWH Attributes: *High Influence*: Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total HI MWH Attributes	*Moderate Influence*: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total MI MWH Attributes	(MWH HI+1)/(WWH+1) Ratio	(MWH MI+1)/(WWH+1) Ratio
(02-400) Olentangy River																																	
Year: 1999																																	
32.0	**69.0**	3.82	■			■	■	■		■			6						0	■	■			■	■				■	■		6	0.14	1.00
27.9	**82.5**	5.68	■	■		■	■	■	■	■	■		9						0											■		1	0.10	0.20
25.4	**66.5**	6.58		■				■	■		■		4	◆					1		■			■	■				■	■		5	0.40	1.40
24.5	**68.5**	6.58	■			■		■	■	■	■	■	7				◆		1						■				■			2	0.25	0.50
22.3	**74.0**	9.43	■	■		■	■	■		■	■	■	8						0						■				■			2	0.11	0.33
19.4	**75.0**	7.58	■	■		■	■	■		■	■	■	8						0										■			1	0.11	0.22
15.0	**65.0**	3.97	■	■				■			■		4						0		■			■	■				■	■	■	6	0.20	1.40
12.4	**63.5**	2.98		■							■		2				◆		1	■	■			■	■				■	■	■	7	0.67	3.00
7.8	**54.5**	2.59		■							■		2				◆		1	■	■			■	■				■	■	■	7	0.67	3.00
6.8	**60.0**	2.59		■				■			■		3				◆		1	■	■			■	■				■	■	■	7	0.50	2.25
5.5	**44.0**	0.10						■			■		2	◆	◆		◆		3		■			■	■				■	■		6	1.33	3.33
3.9	**56.5**	0.10		■				■			■		3	◆			◆		2	■	■			■	■				■	■	■	7	0.75	2.50
2.0	**29.0**	0.10									■		1	◆	◆		◆		3		■			■	■				■	■		6	2.00	5.00
1.8	**65.5**	3.30		■		■	■	■			■		5						0	■	■			■	■				■	■	■	7	0.17	1.33
0.7	**61.5**	0.10		■				■			■		3						0	■	■			■	■				■	■		7	0.25	2.00
0.3	**54.5**	0.10		■				■			■		3		◆				1	■	■			■	■				■	■	■	7	0.50	2.25
(02-401) Adena Brook																																	
Year: 1999																																	
0.9	**43.5**	83.33	■							■		■	3			◆	◆	◆	3					■	■	■	■	■				5	1.00	2.25
0.1	**54.0**	31.25	■	■			■			■	■		5			◆	◆		2					■	■			■			■	4	0.50	1.17
(02-402) Turkey Run																																	
Year: 1999																																	
0.7	**66.0**	55.56	■	■		■	■	■		■	■	■	8						0					■				■				2	0.11	0.33
(02-403) Rush Run																																	
Year: 1999																																	
0.3	**48.5**	55.56		■						■		■	3			◆	◆	◆	3	■				■	■	■		■				5	1.00	2.25
(02-409) Delaware Run																																	
Year: 1999																																	
1.2	**61.0**	13.33	■	■				■			■		4				◆	◆	2					■	■				■	■	■	5	0.60	1.60
0.2	**40.0**	3.70		■									1	◆		◆	◆	◆	4					■	■	■		■	■	■		6	2.50	5.50

Table 21 continued.

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes: No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	MWH Attributes: *High Influence*: Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	**Total H.I. MWH Attributes**	*Moderate Influence*: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total M.I. MWH Attributes**	**(MWH H.I.+1)/(WWH+1) Ratio**	**(MWH M.I.+1)/(WWH+1) Ratio**
(02-412) Horseshoe Run																																	
Year: 1999																																	
0.3	**63.5**	23.68	■	■			■	■		■	■		6						0			■					■		■		3	0.14	0.57
(02-437) Trib. to Olentangy R. (RM 18.19)																																	
Year: 1999																																	
0.1	**65.5**	25.00	■	■			■	■		■	■	■	7				◆		1			■					■				2	0.25	0.50
(02-440) Trib. to Olentangy R. (RM 7.82)																																	
Year: 1999																																	
0.2	**57.0**	34.48	■	■			■			■	■	■	6				◆		1			■					■				2	0.29	0.57
(02-441) Kempton Run																																	
Year: 1999																																	
0.9	**54.5**	76.92	■	■			■			■	■	■	6				◆		1			■					■				2	0.29	0.57
(02-442) Linworth Run																																	
Year: 1999																																	
0.9	**53.5**	58.82	■	■						■	■		4				◆	◆	2			■	■				■		■		4	0.60	1.40

Biological Assessment: Macroinvertebrate Community

Olentangy River

Macroinvertebrate samplings was conducted at eighteen locations on the Olentangy River from downstream from Delaware Dam (RM 32.0) to the confluence with the Scioto River. Fifteen of 16 artificial substrate sets were collected on the mainstem. Qualitative sampling was conducted at all mainstem locations. Sampling of the Delaware WWTP and Olentangy Environmental Control Center mix zones were sampled twice using the qualitative method. A summary of the sampling results are provided in Table 22.

Two of the three sampling sites upstream from the Delaware WWTP (RMs 32.0 and 25.4) were immediately downstream from lowhead dams. These sites had lower quality habitat and supported markedly different communities compared with more natural habitat at RM 27.5. The less diverse habitat corresponded with reduced total taxa diversity and most notably lower diversity of EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera). Qualitative sampling at RMs 32.0 and 25.4 yielded 9 and 7 EPT taxa, respectively compared to 23 EPT taxa from the high quality habitat available at RM 27.5. The Invertebrate Community Index (ICI) score marginally attained the WWH criterion at RM 32.0 but was in the exceptional range at RM 27.5 (Figure 13). The artificial substrates at RM 32.0 were predominated by filter feeding caddisfly and midge taxa, likely in response to suspended organic material in the water released from Delaware Reservoir.

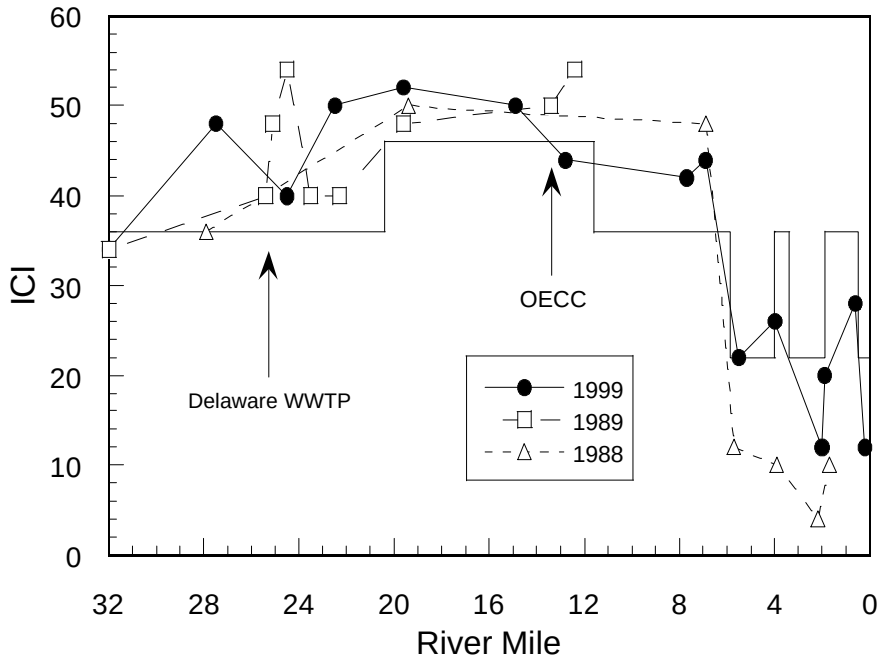


Figure 13 Longitudinal trend of the Invertebrate Community Index (ICI) in the Olentangy River, 1988, 1989 and 1999.

Habitat was limited to a pooled area at the Delaware WWTP mixing zone. Qualitative sampling was not reflective of acute toxicity. An increase in the number of the mayfly species *Baetis intercalaris* at RMs 24.5 and 22.5 may have been in response to enrichment from the WWTP and/or urban runoff from the city of Delaware. Any impact was

not severe, however, as ICI scores exceeded expectations for WWH at RM 24.5 and EWH at RM 22.5.

Table 22. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Olentangy River basin, July - October, 1999.

Stream River Mile	Rel. Density (#/ft.^{2})	No. Quant. Taxa	No. Qual. Taxa	Qual. EPT[a]	Predominant Organisms	QCTV[c]	ICI	Narrative Evaluation[b]
Olentangy River								
32.0	1767	22	32	9	Hydropsychid caddisflies, midges	39.1	34[ns]	Mar. Good
27.5	1443	44	49	23	Hydropsychid caddisflies, mayflies	42.3	48	Exceptional
25.4	-	-	40	7	Midges	33.2	MG[ns]	Mar. Good
25.26	-	-	26	6	Midges	24.9	-	Fair
25.26	-	-	19	1	Midges	25.8	-	Fair
24.5	1676	33	47	19	Baetid mayflies, caddisflies, midges	42.2	40	Good
22.5	2160	35	61	20	Hydropsychid caddis, baetid mayflies	39.8	50	Exceptional
19.6	879	33	56	23	Hydropsychid caddisflies, mayflies	42.5	52	Exceptional
14.9	298	46	55	21	Hydropsychid caddisflies, mayflies	42.5	50	Exceptional
13.38	-	-	41	17	Hydropsychid caddisflies	42.0	-	Good
13.38	-	-	32	11	Hydropsychid caddisflies	39.1	-	Good
12.8	447	29	37	19	Hydropsychid caddisflies, mayflies	42.2	44[ns]	Very Good
7.7	362	31	53	18	Hydropsychid caddisflies, mayflies	40.8	42	Very Good
6.9	576	35	50	20	Hydropsychid caddisflies, midges	42.1	44	Very Good
5.5	991	33	27	2	Midges, aquatic worms	32.9	22	Fair
4.0	2177	19	34	11	Midges	37.3	26*	Fair
2.0	1521	23	28	0	Midges, aquatic worms	24.9	12*	Poor
1.9	2488	36	46	11	Midges, aquatic worms	36.0	20*	Fair
0.6	211	35	18	2	Mayflies, river snails	34.5	28*	Fair
0.2	1194	24	17	2	Midges, aquatic worms	32.0	12	Poor
Horseshoe Run								
0.3	-	-	24	3	Alder flies, midges	36.9	F*	Fair

Table 22 Continued.

Stream River Mile	Rel. Density (#/ft.^{2})	No. Quant. Taxa	No. Qual. Taxa	Qual. EPT[a]	Predominant Organisms	QCTV[c]	ICI	Narrative Evaluation[b]
					Delaware Run			
1.2	-	-	30	3	River snails	27.6	P*	Poor
0.2	-	-	20	1	River snails	27.6	P*	Poor
					Lewis Center Tributary			
0.1	-	-	36	9	Isopods, flatworms	35.3	G	Good
					Bartholomew Run			
1.0	-	-	16	4	Hydropsychid caddisflies, isopods	35.3	F*	Fair
					Linworth Run			
0.9	-	-	24	2	Stenonema mayflies, isopods	32.9	F*	Fair
					Rush Run			
0.4	-	-	21	3	Blackflies, aquatic worms	33.4	F*	Fair
					Bill Moose Run			
0.3	-	-	16	4	Midges, hydropsychid caddisflies	37.3	F*	Fair
					Adena Brook			
1.0	-	-	10	1	Flatsworms, blackflies, aquatic worms	32.0	P*	Poor
					Turkey Run			
0.7	-	-	15	2	Flatworms, aquatic worms, midges	25.8	P*	Poor

Ecoregion Biocriteria: Eastern Corn Belt Plain

INDEX	WWH	EWH
ICI	36	46

[a]-EPT=total Ephemeroptera (mayflies), Plecoptera (stoneflies), & Trichoptera (caddisflies) taxa richness.
[b]-Qualitative narrative evaluation is based on best professional judgment utilizing sample attributes such as taxa richness, EPT richness, and QCTV score and is used when quantitative data are not available to calculate an Invertebrate Community Index (ICI) score.
[c]-Qualitative Community Tolerance Value (QCTV) is derived as the median of the tolerance values calculated for each qualitative taxon present (see discussion in Methods Section).
[d]-Qualitative assessment used in lieu of quantitative score due to lack of flow and/or vandalism of artificial substrates.
*-Significant departure from ecoregion biocriterion (>4 ICI units); poor and very poor results are underlined.
[ns]-Nonsignificant departure from ecoregion biocriterion (≤4 ICI units).

Exceptional macroinvertebrate communities were present at the three sampling sites from RM 22.5 to RM 14.9, upstream from the Olentangy Environmental Control Center (OECC). ICI scores of 50 to 52 were

recorded and 20 to 23 EPT taxa were collected. There appeared to be a reduction in enrichment with increased distance downstream from the city of Delaware.

There was no impact apparent on the macroinvertebrate assemblage present in the OECC mixing zone. The sampled area was relatively small but qualitative sampling produced numerous sensitive taxa. Downstream from the OECC (RM 12.8), the ICI score declined somewhat but the score of 44 was considered to be in the range of nonsignificant departure from the EWH criterion. Qualitative sampling continued to produce numerous sensitive taxa and the resultant QCTV scores were on par with those collected upstream from the OECC.

The aquatic life use changes from Exceptional Warmwater Habitat to Warmwater Habitat at RM 11.6 (I-270). The WWH use extends downstream to Adena Brook (RM 5.9). The two sites located within this reach (RMs 7.7 and 6.9, adjacent to Kenny Park and upstream from Henderson Rd.) exceeded ecoregional expectations and were in the range of nonsignificant departure for an EWH use. The very good communities were also reflected in qualitative sampling which continued to produce numerous EPT and other pollution sensitive taxa.

The Olentangy River at RM 5.5 was impounded by the Dodridge St dam and has been designated a Modified Warmwater Habitat (MWH) stream segment. There was no discernable flow and the stream bottom was comprised of silt and detritus. The ICI marginally attained the MWH use with a score of 22. Predictably, the diversity of taxa collected from natural substrates was much lower than was present at upstream free flowing sites.

A combination of impacts were likely influencing the macroinvertebrate community at RM 4.0. Eleven EPT taxa were collected downstream from the Dodridge St. dam, significantly less than were recorded at free flowing sites upstream from the dam, but still within the expected range of diversity for a WWH stream. Nevertheless, the decline in EPT taxa reflected a lowering in water and habitat quality likely due to the increasingly urbanized character of the watershed. The ICI score of 26 was also largely influenced by the altered habitat in this area. The only place that afforded sufficient flow velocity over the artificial substrates was among the riprap boulders at the base of the lowhead dam. Consequently, the quantitative sample yielded only nineteen predominantly facultative taxa.

Upstream from the Fifth Ave. dam at RM 2.0 the macroinvertebrate community was greatly impaired. Pollution tolerant organisms predominated and suggested toxicity as at least partially responsible for the poor condition of the community. Impoundment, silty/mucky substrate, CSO/SSO discharges and contaminated sediment are all factors that could negatively affect the stream in this area.

Sampling sites at RMs 1.9 and 0.6 were in a WWH segment of the Olentangy River. The former was

immediately downstream from the 5th Ave. lowhead dam. The community was relatively diverse with eleven EPT taxa collected from the natural substrates; however, the artificial substrates were predominated by tolerant aquatic worms and moderately tolerant midges of the genus *Glyptotendipes*. Consequently, the ICI score was only in the fair range. Sampling at RM 0.6 produced results that were reflective of the slow current, limited habitat and urban impacts. The ICI was again in the fair range and qualitative sampling yielded only 18 total taxa; two were EPT taxa.

The lower half mile of the Olentangy River is a MWH use segment because the stream is impounded by a dam downstream on the Scioto River. The artificial substrates were predominated by pollution tolerant aquatic worms and moderately tolerant midges of the genus *Glyptotendipes;* and the ICI was in the poor range. The macroinvertebrate community was impaired by conditions similar to those encountered upstream from the 5th Ave. dam.

Delaware County tributaries

Horseshoe Run

Qualitative taxa at RM 0.3 produced 24 taxa in relatively low density. An absence of hydropsychid caddisflies in riffle habitats indicated that the stream may have become intermittent over the previous summer months. A total of 3 EPT taxa were recorded. The macroinvertebrate community was in fair condition.

Delaware Run

Delaware Run is a largely urbanized watershed. Both sampling locations supported poor quality macroinvertebrate communities. Moderately intolerant snails of the genus *Elimia* were present in moderate density. Most telling was the QCTV score of 27.6 at both sites which is well below the range of values expected for streams that attain a WWH use. It appeared that toxicity and/or excessive organinc enrichment were impacting the stream. The odor of sewage and chlorine was evident at RM 0.2. Potential sources of impact include breaks in the buried sewer lines that lie adjacent to the stream and urban runoff.

Lewis Center tributary

The Lewis Center tributary may have gone intermittent earlier in the summer. Qualitative sampling yielded a good diversity of macroinvertebrate taxa including 9 EPT taxa. The number of pollution intolerant and moderately intolerant taxa identified exceeded the number of moderately tolerant and pollution tolerant taxa. A predominance of bedrock substrate may have limited the available habitat , but good water quality was indicated.

Bartholomew Run

Bartholomew Run offered relatively good habitat; however, extensive bank erosion was evident at RM 1.0. Existing and future development within the basin will continue to alter the flow regime resulting in more bank erosion during runoff events. The stream did not appear to be overly enriched. Qualitative sampling produced a limited fauna (16 taxa) in which facultative organisms predominated and moderate numbers of EPT taxa were present. The low diversity of taxa and a marginal QCTV score demonstrated that the flashy nature of the stream was having a significant impact. Consequently, the community was considered in only fair condition.

Linworth Run

Linworth Run provided pooled habitat connected by interstitial flow at RM 0.9. The site may not have had sustained flow earlier in the summer. The streambed was dry downstream, nearer to the confluence with the Olentangy River. A relatively natural channel was present, however, a largely urbanized watershed has resulted in alteration of the flow regime. This leads to more frequent extremes in high and low flow conditions. The macroinvertebrate community was in fair condition. The overall density and diversity of macroinvertebrate organisms was low. The facultative mayfly species *Stenonema femoratum* predominated, indicating that the stream was not excessively enriched. Nevertheless, the collection of eleven moderately tolerant and very tolerant taxa among the 24 total taxa was atypical for a WWH stream.

Franklin County tributaries

The sampled tributaries to the Olentangy River in Franklin County were highly urbanized watersheds. Over the course of the summer, the streams were susceptible to periods of little, if any, sustained flow excepting storm runoff events. As a result, the macroinvertebrate communities of all four tributaries were relatively low in diversity and density of organisms.

Rush Run

Rush Run has been subjected to extensive channel alteration at RM 0.4. Blackflies and aquatic worms were predominant and eight of the twenty one taxa collected were considered moderately pollution tolerant to tolerant. The macroinvertebrate community was symptomatic of a chronically degraded stream. Potential sources of degradation include excessive nutrients and toxicity associated with urban runoff and CSO/SSO discharges.

Bill Moose Run

Qualitative sampling of Bill Moose Run at RM 0.3 included 4 EPT taxa among the sixteen taxa collected. The number of EPT taxa and the QCTV score minimally met expectations for a WWH use. The stream appeared to be the least impacted by degraded runoff or CSO/SSO discharges of the four sampled tributaries in Franklin County. However, the low diversity of taxa demonstrated that the altered flow regime caused by hardening of the watershed had a significant impact. Consequently, the community was

in only fair condition.

Adena Brook
Adena Brook at RM 1.0 was in a wooded ravine; however, the surrounding area was extensively urbanized. The streambed contained a series of disconnected pools. The macroinvertebrate community was in poor condition. Ten taxa, primarily facultative to pollution tolerant, were collected. It was evident that the stream had lost most WWH use attributes resulting from alteration of the flow hydrology. The remaining primary function was as a conveyance for stormwater flows and periodic CSO/ SSO discharges.

Turkey Run
Turkey Run had interstitial flow at RM 0.7. Qualitative sampling yielded 15 primarily facultative and pollution tolerant taxa. The QCTV score of 25.8 was the lowest value of all the Olentangy tributaries sampled and it reflected the poor condition of the Turkey Run macroinvertebrate community. Likely sources of degradation included excessive nutrients and toxicity associated with urban runoff and SSO discharges in addition to the altered flow pattern.

Biological Assessment: Fish Community

Olentangy River
A total of 10,789 fish comprising 48 species and four hybrids was collected from the Olentangy River between July and August 1998. The fish sampling effort included 16 free flowing and two mixing zone stations, evaluating mainstem from RM 32.0 (Main Rd.-downstream from the Delaware Reservoir) to RM 0.3 (near mouth).

Multiple aquatic life use designations are in effect for the lower Olentangy River (OAC 3745-1). The following river segments, demarcated by River Mile and landmark, are designated WWH: 1) RM 32.3 (Delaware Reservoir spillway) to RM 20.4 (Old Winter Rd.), 2) RM 11.6 (I-270) to RM 5.9 (Adena Brook confluence), 3) RM 4.0 (Dodridge Dam spillway) to RM 3.4 (Tuttle Park), and 4) RM 1.9 (5th Ave Dam spillway) to RM 0.5 (Conrail Railroad crossing). The MWH use is applied to the following Dam pools: 1) RM 5.9 (Adena Brook) to RM 4.0 (Dodridge Dam), 2) RM 3.4 (Tuttle Park) to RM 1.9 (5th Ave. Dam), 3) and RM 0.5 (Conrail crossing) to RM 0.0 (at mouth). The remaining segment, from RM 20.4 (Old Winter Rd.) to RM 11.6 (I-270) is designated EWH.

Based on the aggregated results of the 1999 fish sampling effort, numerically predominant species included spotfin shiner (13.9%), golden redhorse (9.5%), smallmouth bass (8.6%), bluntnose minnow (7.6%), and bluegill sunfish (7.5%). In terms of biomass, dominant species were, common carp (30.3%), golden

redhorse (23.0%), silver redhorse (10.3%), black redhorse (6.4%), and quillback carpsucker (4.5%). Species classified as endangered, threatened, or special status included river redhorse and bluebreast darter (Ohio DNR 1997). Collections of river redhorse were made at RMs 0.7, 3.9, and 25.4. The bluebreast darter was observed at two locations, RMs 7.8 and 15.0.

Community indices and accompanying narrative evaluations ranged between exceptional (IBI=53.0, MIwb=10.3), and good/fair (IBI=35, MIwb=8.0). Overall, the fish assemblage of the Olentangy River below Delaware Lake was characterized as good. Longitudinal performance of the IBI, MIwb, and QHEI are presented in Figure 14. Summarized index scores and community statistics by station are presented in Table 23.

As measured by the IBI and MIwb, departures from the applicable biological criteria were indicated at only two fish sampling stations. The first was located within the upper limits of the EWH designated segment at RM 19.4 (Hyatts Rd.). The remaining site, RM 0.7 (Conrail Railroad crossing), was located within the lower limits of the last WWH segment on the Olentangy River. Departure from the ambient biological criteria at both stations was very modest. Of the two community indices employed to evaluate the condition of the fish assemblage, only the IBI failed to meet the prescribed biocriterion. The MIwb was found consistent with the applicable biocriterion at every mainstem sampling site.

Community performance at RM 19.4 was characterized as good-very good, achieving IBI and MIwb scores of 44 and 9.1, respectively. The IBI missed the area of nonsignificant departure of the EWH biocriterion by only two units. In comparison with other (unimpaired) EWH stations on the Olentangy River, three IBI metrics appeared responsible for the *subpar* performance: species richness, number of sucker species, and the proportion of simple lithophiles. The performance of these metrics was consistently better at all other EWH stations (i.e., greater number of native taxa, additional sucker species, and greater proportion of environmentally sensitive lithophilic species). However, it is important to reiterate that the results from sampling at RM 19.4 did not yield a severely degraded or depauperate assemblage. On the contrary, the community was in good to very good condition; it simply did not meet the more stringent biological benchmarks prescribed by the EWH designation.

The associated causes and sources of the modest impairment are likely diverse and cumulative in nature. Multiple stressors are operative upstream from RM 19.4 and included both point and diffuse pollution sources. This reach of the Olentangy River receives treated effluent from the Delaware WWTP and other (minor) permitted discharges. Diffuse pollution sources include, cityof Delaware (e.g., SSOs, CSOs, and stormwater), suburban, and agricultural areas. Additionally, the affected segment is under considerable development pressure. The conversion from a rural landscape to a more intensive suburban landuse has many attendant consequences that cascade through a watershed, affecting drainage patterns, sediment loads, nutrient inputs, and riverine habitat quality. The cumulative effects of these various stressors were

undoubtedly heightened by the drought conditions that typified the summer of 1999. Very low stream flow likely protracted or delayed the natural assimilation of the various pollutant inputs (diffuse and point source), resulting in the modest impairment observed within the upper reach of the EWH segment.

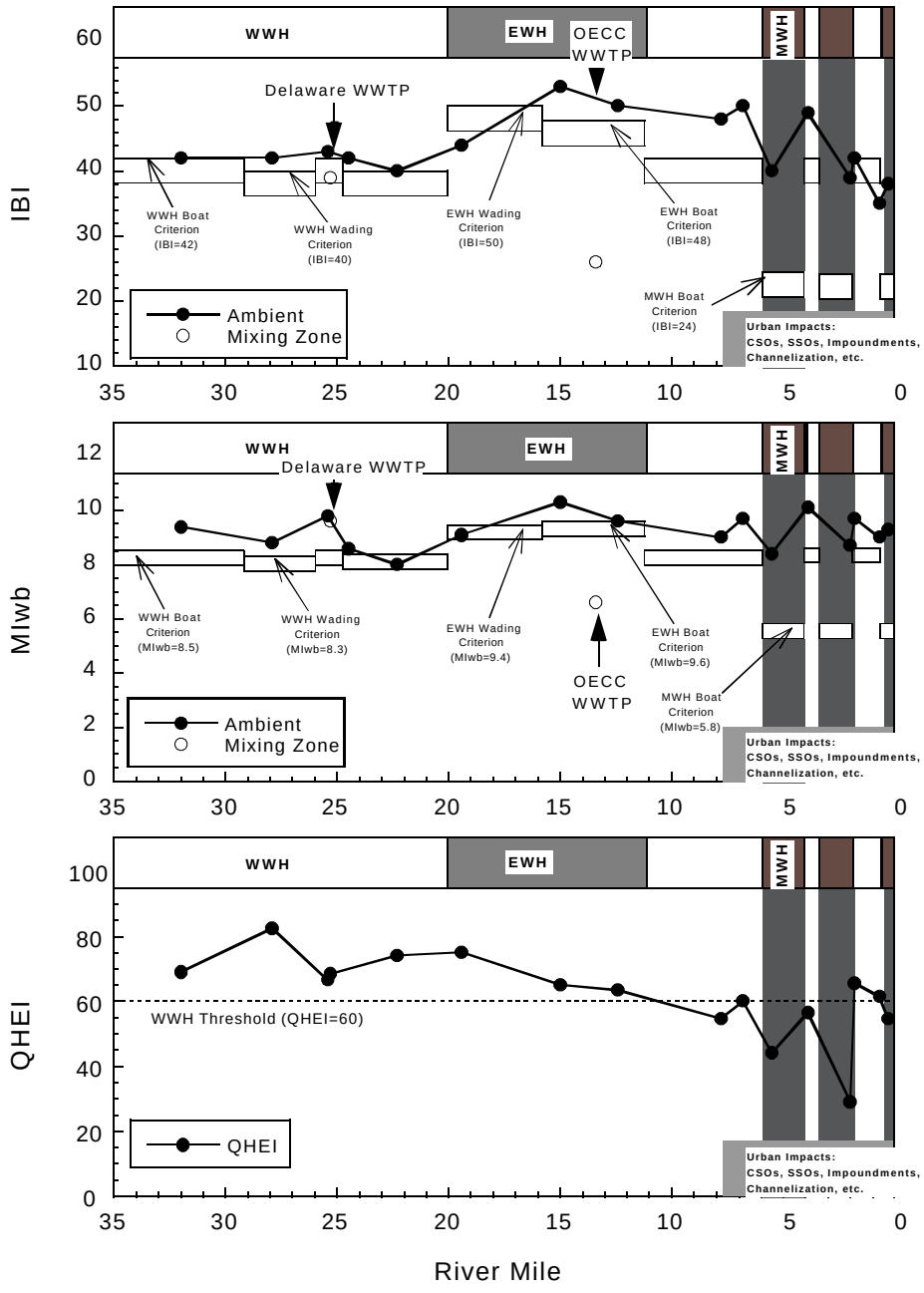


Figure 14 Longitudinal performance of the Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb), and Qualitative Habitat Evaluation Index (QHEI) for the lower Olentangy River, 1999. Solid lines represent the prescribed biocriteria and area of nonsignificant departure supporting the various aquatic life use designations.

Table23. Fish community indices and descriptive statistics based on samples collected by Ohio EPA from the lower Olentangy River and selected tributaries, 1988-1999.

Stream River Mile	Mean Number Species	Cumulative Species	Mean Rel .No (No./km)[a]	Mean Rel Wt. (Wt./km)[a]	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Olentangy River (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
32.0(B)	23.0	28	659.0	99.2	69.0	42	9.4	Good-Very Good
27.9(W)	22.0	22	735.0	34.4	82.5	42	8.8	Good
25.4(B)	22.0	27	697.4	201.7	66.5	43	9.8	Good-Exceptional
25.3(B)MZ	*19.0*	*21*	*850.0*	*344.2*	*NA*	*39*	*9.6*	*M. Good-Exceptional*
24.5(W)	14.5	23	1284.8	49.3	68.5	42	8.6	Good
22.3(W)	18.0	18	644.3	32.9	74.0	40	8.0ns	Good-M. Good
Eastern Corn Belt Plains - EWH Use Designation (Existing)								
19.4(W)R	21.5	26	441.8	36.6	75.0	44*	9.1ns	Good-Very Good
15.0(B)	25.5	31	828.8	195.5	65.0	53	10.3	Exceptional
13.4(W)MZ	*9.0*	*9*	*798.0*	*2.1*	*NA*	*26*	*6.6*	*Poor-Fair*
12.4(B)	20.5	25	601.0	164.2	63.5	50	9.6	Exceptional
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
7.8(W)	25.0	29	317.3	33.3	54.5	48	9.0	Very Good
6.8(B)	22.0	26	579.0	194.0	60.0	50	9.7	Exceptional
Eastern Corn Belt Plains - MWH Use Designation (Existing)								
5.5(B)M	16.0	20	363.0	105.0	44.0	40	8.4	Marginally Good
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
3.9(B)	26.0	28	728.0	118.9	56.5	49	10.0	V. Good-Exceptional
Eastern Corn Belt Plains - MWH Use Designation (Existing)								
2.0(B)	18.5	23	671.3	129.5	29.0	39	8.7	M. Good-Good
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
1.8(B)	22.5	26	964.1	195.3	65.5	42	9.7	Good-Exceptional
0.7(B)	18.0	22	477.0	92.4	61.5	35*	9.0	Fair-Good
Eastern Corn Belt Plains - MWH Use Designation (Existing)								
0.3(B)	21.5	25	658.0	110.8	54.5	38	9.3	M.Good-V.Good

Table 23 Continued.

Stream River Mile	Mean Number Species	Cumulative Species	Mean Rel .No (No./km)[a]	Mean Rel Wt. (Wt./km)[a]	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Olentangy River (1996)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
0.7(B)	24.0	28	1033.0	193.0	66.0	43	9.5	Good-V. Good
Olentangy River (1991)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
7.6(B)	22.3	29	733.0	165.7	84.0	48	9.4	Exceptional-V.Good
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
3.9(B)	21.0	26	743.3	125.8	63.0	43	9.2	Good
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
1.4(B)	17.0	23	573.7	42.6	73.0	28*	6.1*	Fair-Poor
Olentangy River (1991)								
Eastern Corn Belt Plains - MWH Use Designation (Existing)								
0.4 (B)	17.5	22	215.0	29.2	54.0	33	8.1	Fair-M. Good
Olentangy River (1989)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
31.2(B)	20.5	28	383.7	90.8	80.0	33*	8.0ns	Fair-M.Good
25.4(B)	16.0	21	713.6	189.7	67.0	36*	8.2ns	Fair-M.Good
25.3(B)MZ	15.0	*15*	*780.0*	*89.1*	*NA*	*44*	*9.4*	*Good-V.Good*
25.1(B)	23.0	23	442.5	179.6	–	44	9.5	Good-V.Good
25.0(B)	22.5	23	457.0	161.8	76.0	41	9.6	Good-Exceptional
24.5(W)	19.0	26	216.1	28.7	76.0	34*	6.6*	Fair
23.5(B)	13.0	13	211.5	36.6	75.0	34*	5.2*	Fair-Poor
22.0(B)	20.0	24	415.2	101.5	72.0	29*	7.7*	Fair
Eastern Corn Belt Plains - EWH Use Designation (Existing)								
19.8(B)	25.0	30	565.0	208.8	86.0	48	10.0	Exceptional
13.6(B)	26.5	29	394.0	110.8	88.0	48	9.8	Exceptional
12.8(B)	20.5	23	365.0	93.9	82.0	43*	9.2	Good-V.Good

Table 23 Continued.

Stream River Mile	Mean Number Species	Cumulative Species	Mean Rel .No (No./km)[a]	Mean Rel Wt. (Wt./km)[a]	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Olentangy River (1988)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
28.1$^{(B)\mathbf{M}}$	21.0	26	630.0	98.4	52.0	36*	7.9*	Fair
26.5$^{(B)}$	14.0	14	268.0	71.4	58.0	30*	7.2*	Fair
Eastern Corn Belt Plains - MWH Use Designation (Existing)								
5.5$^{(B)\mathbf{M}}$	21.0	25	560.0	93.0	58.0	39	9.2	M.Good-V.Good
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
5.0$^{(B)}$	15.0	19	444.0	58.6	57.0	32*	7.3*	Fair
4.3$^{(B)}$	14.5	24	482.0	70.4	62.0	31*	7.6*	Fair
3.9$^{(B)}$	16.0	21	654.7	85.7	59.0	37*	8.0^{ns}	Fair-M.Good
Eastern Corn Belt Plains - MWH Use Designation (Existing)								
2.1$^{(B)}$	14.0	20	417.4	119.6	53.0	31*	7.0*	Fair
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
1.7$^{(B)}$	24.5	34	668.0	125.3	79.0	38^{ns}	9.6	M.Good-Exceptional
Eastern Corn Belt Plains - MWH Use Designation (Existing)								
0.3$^{(B)}$	15.3	21	350.7	88.3	58.0	32	7.9	Fair
Delaware Run (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
1.2$^{(H)}$	10.0	10	169.5	0.9	61.0	34*	NA	Fair
0.1$^{(H)}$	8.0	8	69.0	0.3	40.0	30*	NA	Fair
Horseshoe Run (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
0.3$^{(H)}$	13.0	13	2,014.5	5.1	63.5	38^{ns}	NA	Marginally Good
Lewis Center Trib. (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
0.1$^{(H)}$	11.0	11	2,070.0	5.2	65.5	32*	NA	Fair
Linworth Run (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								

0.9(H)	5.0	5	838.2	1.5	53.5	26*	NA	Poor

Table 23 Continued.

Stream River Mile	Mean Number Species	Cumulative Species	Mean Rel .No (No./km)[a]	Mean Rel Wt. (Wt./km)[a]	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Kempton Run (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
0.9(H)	4.0	4	137.7	1.0	54.5	22*	NA	Poor
Bill Moose Trib. (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
0.2(H)	10.0	10	1,411.7	4.4	57.0	30*	NA	Fair
Rush Run (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
0.3(H)	6.0	6	2,056.5	4.8	48.5	28*	NA	Fair
Rush Run (1994)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
0.2(H)	8.0	8	436.0	–	69.0	26*	NA	Poor
Adena Brook (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
0.9(H)	3.0	3	453.0	0.4	43.5	22*	NA	Poor
0.1(H)	10.0	10	729.0	2.2	54.0	32*	NA	Fair
Turkey Run (1999)								
Eastern Corn Belt Plains - WWH Use Designation (Existing)								
0.7(H)	3.0	3	1,299.0	7.5	66.0	20*	NA	Poor

*- Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
ns- Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 Iwb units).
Site type: H - headwater, W - wading, and B - boat.
MZ- Mixing zone sample.
a-Relative abundance and weight estimates per 0.3km (headwater and wading) or per 1.0 km (boat).

Ecoregion Biocriteria: E. Corn Belt Plains (ECBP)

INDEX - Site Type	WWH	EWH	MWH[a]
IBI - Headwater/Wading	40	50	24
MIwb - Wading	8.3	9.4	6.2
IBI - Boat	42	48	24
MIwb - Boat	8.5	9.6	5.8

ICI	36	46	22

[a] - Modified Warmwater Habitat for channelized habitats/impounded habitats.

It is also possible that departure from the biocriterion observed at RM 19.4 indicated an erosion of the ability of the Olentangy River to consistently support exceptional aquatic communities within the EWH designated segment, brought about by changing landuse within the catchment. Significant negative relationships have been found between increasing land use intensity and instream biological integrity (Yoder 1996 and Steedman 1988). Future monitoring of the transitional area between WWH and EWH segments will be required to determine if the impairment documented at RM 19.4 was either a temporal phenomenon (drought related) or represented the first indications of a more systemic decline in the environmental conditions of the Olentangy River.

Community performance at the remaining impaired site (RM 0.7) was characterized as fair to good, achieving IBI and MIwb scores of 35 and 9.0, respectively. Departure from the WWH biocriterion was modest, as the IBI missed the minimum threshold by only three units. Most measures of community structure and functional organization remained comparable between similarly situated WWH sampling locations. The modest departure from the WWH benchmark was a result of deficiencies in two IBI metrics: native species richness and the incidence of Deformities, Eroded fins and/or barbels, Lesions, and Tumors (DELT) anomalies.

The comparative loss of several fish species at RM 0.7 appeared a result of construction activities associated with the Spring Sandusky interchange. Specifically, the installation of large construction fords across the Olentangy River approximately 0.4 miles downstream, effectively impounded the once free flowing segment. The loss of species was limited to those adapted to free flowing riverine habitats (e.g., selected darter species and river chub). These taxa were present at this location in the past (Ohio EPA 1999), and were also persistent at other free flowing sites in 1999. The inundation and subsequent loss of these selected species are likely temporary. Following the completion of the interchange project, the fords will be removed, returning this segment to a free flowing state. Baring other significant environmental stresses, recovery of this segment should proceed rapidly after restoration of the natural flow regime.

The rise in the incidence of DELT anomalies, however, was more indicative of degraded water quality. Elevated occurrence of gross external anomalies has been found to be a reliable indicator of chronic sublethal stress in wild fish populations (Steedman 1988 and Sanders et al. 1998). A general pattern of a longitudinal increase in the proportion of gross external anomalies was evident, with highest values occurring within the lower most stations. This segment of the Olentangy River drains an intensely urbanized portion of the city of Columbus. The deleterious effects of general urban runoff, SSOs, and CSOs, were likely made more acute by the summer drought. These factors, coupled with widespread habitat modifications, appeared the most prominent stressors within the urbanized portion of the lower Olentangy River.

The remaining 14 ambient sampling stations were found to support fish assemblages having a species

composition, structure and functional organization fully consistent with the prescribed biological criteria (EWH, WWH, or MWH). As measured by the IBI and MIwb, no obvious or otherwise apparent impact was indicated downstream from the Delaware WWTP or the OECC WWTP. Given the extremely low river discharge over the course of the summer sampling effort, pollutant loads from the Delaware WWTP may have been a contributing factor to the impairment documented approximately five miles downstream from the facility's point of discharge (RM 19.4). However, the two ambient stations within the intervening stream reach (between the 001 discharge and RM 19.4) were found to support fish communities fully consistent with the applicable biocriteria. Furthermore, toxicity or avoidance was not indicated in the Delaware mixing zone. The condition of the fish community within this area of high effluent concentration was characterized as marginally good. Considering the positive performance of these environmental indicators a clear and compelling casual link between use impairment at RM 19.4 and the Delaware WWTP was not evident.

Olentangy River Tributaries

Nine streams comprise the principal drainage network of the lower Olentangy River: Adena Brook, Turkey Run, Rush Run, Delaware Run, Kempton Creek, Linworth Run, Horseshoe Run, Lewis Center tributary, and Bill Moose Run. Samples of the resident fish community from these mainstem tributaries were collected at 11 stations. Adena Brook and Delaware Run were each evaluated at two sampling sites. The remaining tributaries were evaluated at one location, typically less than a mile upstream from the point at which the stream(s) joins the Olentangy River. As all of the sampling sites distributed among these tributaries possessed a drainage area < 20 mile^2, the IBI was the only applicable measure of fish community performance (Ohio EPA 1989). Summarized index scores and community statistics, by station, are presented in Table 23 and Figure 15.

Despite the lack of continuous surface flow, sampling efforts on Horseshoe Run at RM 0.3 (Panhandle Rd.) yielded a community; possessing species richness, structure and functional organization consistent with the WWH biological criteria. All remaining Olentangy River tributaries evaluated in 1999 failed to support WWH fish communities. The magnitude of impairment at the remaining ten sites was split evenly between *fair* and *poor* levels of community performance. The specific conditions of these two grouping are further detailed below.

Fair Communities

Community performance characterized as fair (IBI range 34 to 30) was observed at five streams or stream segments and included Delaware Run (upper and lower), Lewis Center tributary, Bill Moose Run, and lower Adena Brook (RM 0.1). Collectively, these sampling sites were found to contain a predominance of highly tolerant and pioneering fish species, averaging 62.2% and 62.8%, respectively. Few, if any, headwater adapted taxa were observed. Environmentally sensitive species were either lacking or collected infrequently. The dominance of pioneering species at these sites suggested that these streams

or segments were regularly subjected to significant episodic stress. As a group, pioneering taxa have been found highly adaptable and are often the first fish species to reinvade an impacted stream or stream reach once the stress (e.g., chemical spill, CSO/SSO release, desiccation) has subsided (Bayley and Osborne 1993). As these streams are all contained within urbanized catchments, potential water quality and habitat

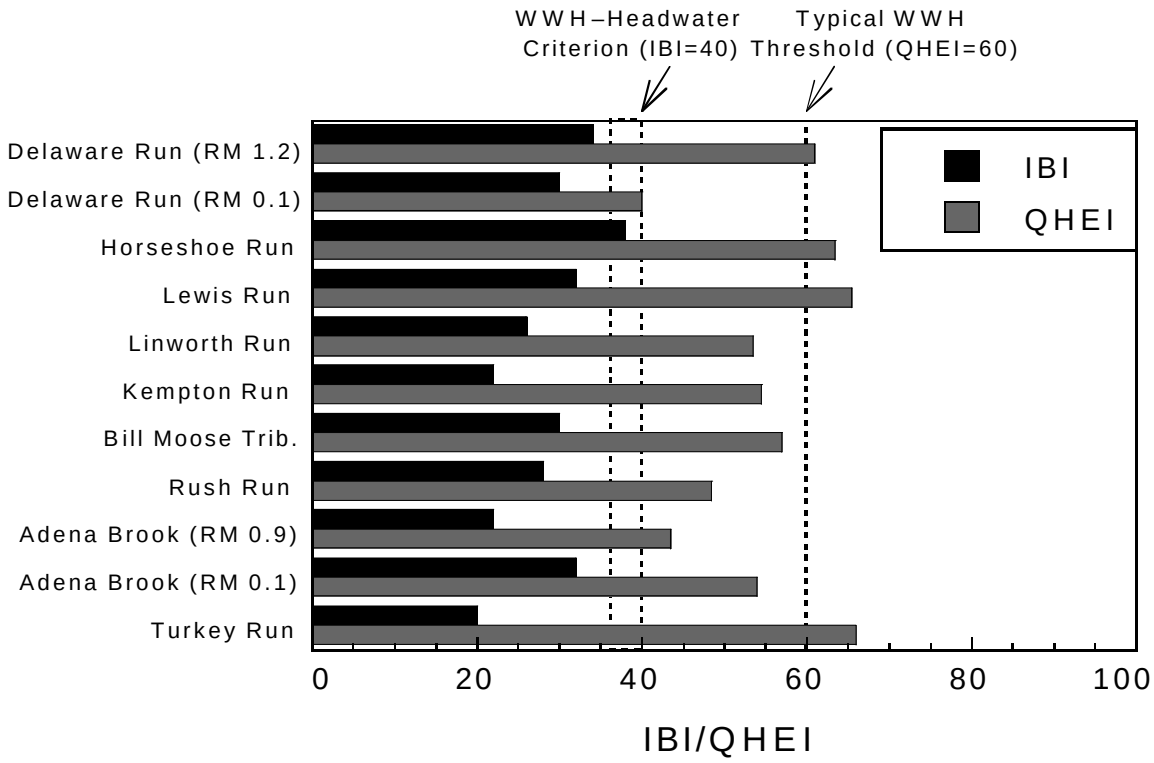


Figure 15 Summarized Index of Biotic Integrity (IBI) and Qualitative Habitat Evaluation Index (QHEI) scores from the principal Olentangy River tributaries evaluated in 1999. Dashed lines represent the prescribed headwater IBI biocrterion for the existing WWH aquatic life use and the typical WWH threshold for QHEI. Asterisk indicates discontinous surface flow (interstitial or intermittent)

stressors are numerous.

Both sites on Delaware Run, the Lewis Center Tributary, and Bill Moose Run were found to possess perennial surface flow. Given that perennial flow was maintained during severe to extreme drought conditions, episodic stress derived soley from stream desiccation did appear a likely explanation for the depauperate communities collected from these streams. Rather, the depressed fish communities was more

likely related to the urban nature of these catchments (e.g., CSOs, SSOs, storm runoff, habitat modification).

The conditions of the lower reach of Delaware Run (RM 0.2) were reflective of significant urban related stress. Channel conditions were highly artificial, with nearly half of the sampling site contained within stone retaining walls. Evidence of impacted water quality was abundant. The water column was gray with a slight petroleum sheen on the surface of the pools. The entire segment evaluated had a mild septic odor and water born trash and debris were abundant. These types of observations have been found to be reliable field indicators of episodic releases of combined sanitary and stormwater runoff.

Stream intermittence appeared a contributing factor to aquatic life use impairment for lower Adena Brook only. The deleterious effects of diffuse urban pollution sources coupled with discontinuous surface flow appeared the principal environmental stresses. These problems were undoubtedly made worse by the summer drought.

Poor Communities

The remaining five stations supported poor assemblages (IBI range 26 to 20) and included Linworth Run, Kempton Run, Rush Run, Turkey Run, and upper Adena Brook (RM 0.9). As observed within the preceding group of streams (i.e., sites classified as *fair*), these sampling sites were found to contain simple and poorly organized fish communities. However, as reflected in worsening IBI scores, the degree of simplification within the assemblage was more acute. Specifically, the mean proportion of tolerant and pioneering species was significantly increased, reaching 98% and 72.4%, respectively. The average number of native species was reduced by over 50% from 11.0 (*fair* streams) to 4.2 (*poor* streams). The paucity of environmentally sensitive species and headwater taxa was comparable between the *fair* and *poor* sites.

As observed elsewhere within the study area, stream intermittency appeared a poor predictor of community performance. Only two of the five *poor* sites were found lacking perennial surface flow. Furthermore, indicators of macrohabitat quality also failed to yield consistent predictions of community performance. These data strongly suggested water quality as the most influential determinant of ambient biological performance. Diffuse urban nonpoint source pollution appeared the most prominent source of environmental stressors.

Trends Assessment

Fish Community Trend Assessment

Olentangy River: 1988-1999

Multiple data sets were available to assess environmental condition of the lower Olentangy River through

time. These data included fish survey results for the years: 1988, 1989, and 1991. Unfortunately none of the previous efforts evaluated the entire lower Olentangy River during a single field year; rather, sampling was typically limited to discrete portions of the mainstem. As such, the analysis of trends employed these various historical segments, comparing the results with similar river reaches or stations evaluated in 1999.

The 1988 sampling effort evaluated two disparate segments of the Olentangy River. The first reach included two stations upstream from the city of Delaware at RMs 28.1 and 26.5. The second reach was limited to the lower 5.5 miles of the mainstem and included seven sites. Sampling efforts in 1989 provided more robust coverage, with ten contiguous stations dispersed between RM 31.2 (downstream Delaware Reservoir) and RM 12.8 (lower limits of the EWH designated segment). In 1991 the sampling effort again focused on the lower portion of the mainstem from RM 7.6 to RM 0.4.

In comparison with these previous efforts, significant improvements in the overall environmental conditions of the Olentangy River were indicated in 1999. At comparable sites or within comparable stream segments community performance as measured by the IBI and MIwb was considerably advanced in nearly every instance. Longitudinal performance of the IBI and MIwb, through time, are presented in Figure 16.

Clear and marked impacts to the fish assemblage were documented downstream from the Delaware WWTP in 1989. This impact was portrayed by both the IBI and MIwb as these indices precipitously declined immediately downstream from the facility. Recovery was indicated approximately six miles downstream, within the upper limits of the EWH segment, where full use attainment was observed. Progressing downstream, an additional use impairment was associated with the OECC. The impact was not nearly as pronounced or severe as that documented downstream from the Delaware WWTP, as only the IBI failed to meet the prescribed biocriterion. A near complete recovery from the aquatic life use impairment was indicated in 1999. The impacted segment downstream from the Delaware WWTP appeared fully recovered in 1999. Similarly, the modest impairment associated with the OECC was fully recovered.

Additional positive performance of environmental indicators within the upper and middle portions of the study area included measures of community structure, organization, and the health of individual fish. Sampling efforts in 1989 and 1999 yielded comparable species richness estimates, with many sensitive forms persistent through time. However, the functional and structural organization of the fish community was significantly different between the sampling years. These differences were largely responsible for the improved index scores observed in 1999, and appeared well-correlated with pollution abatement efforts at the major point source discharges.

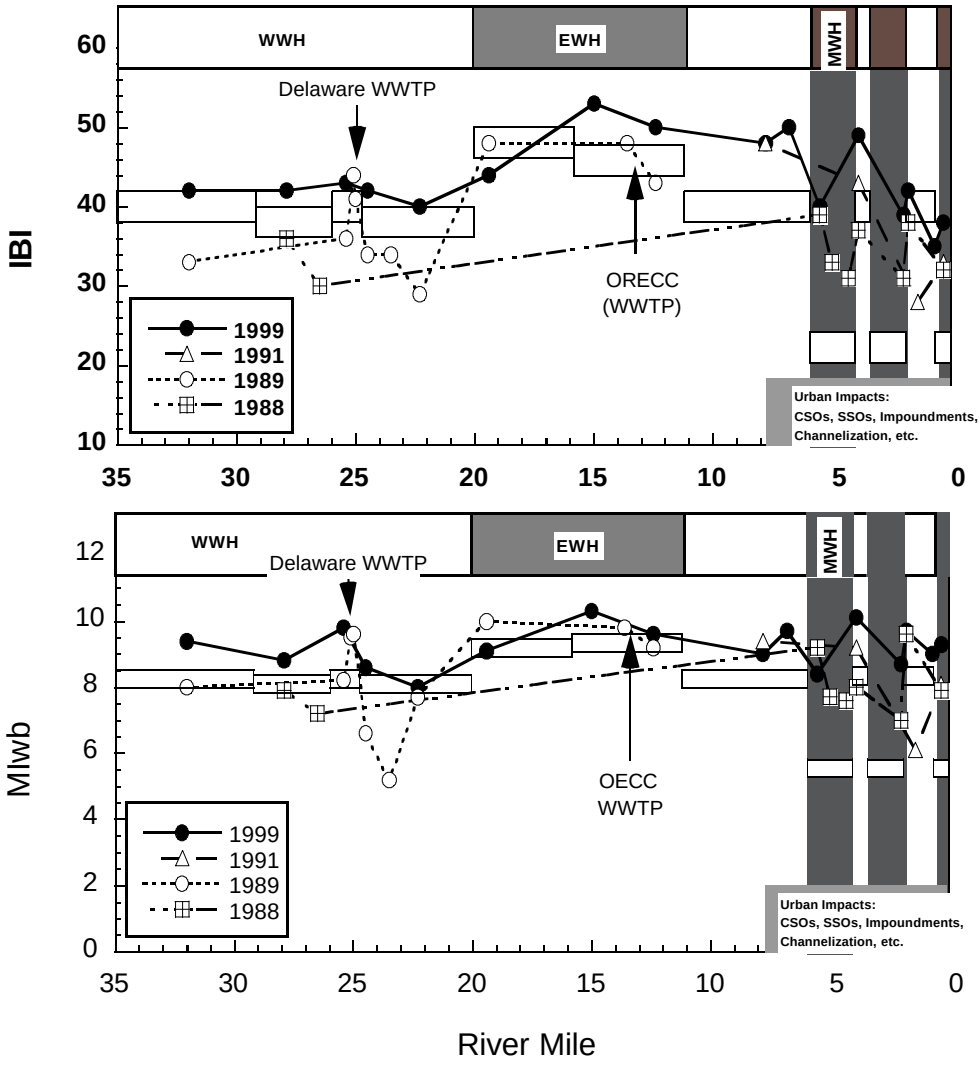


Figure 16 Longitudinal performance of the Index of Biotic Integrity (IBI) and Modified Index of well-being (MIwb) for the lower Olentangy River, 1988-99. Solid lines represent the prescribed biocriteria and area of nonsignificant departure supporting the various aquatic life use designations.

Specifically, the shifts in relative abundance and proportion of environmentally sensitive species between 1989 and 1999 were the most pronounced (Figure 17). The principal components of fish biomass also was indicative of improved environmental conditions. Analysis of these data revealed a concentration of fish biomass, through time, in round-bodied sucker species. As of 1999, these environmentally sensitive taxa comprised the majority (62%) of total fish biomass, compared with 34.7% in 1989.

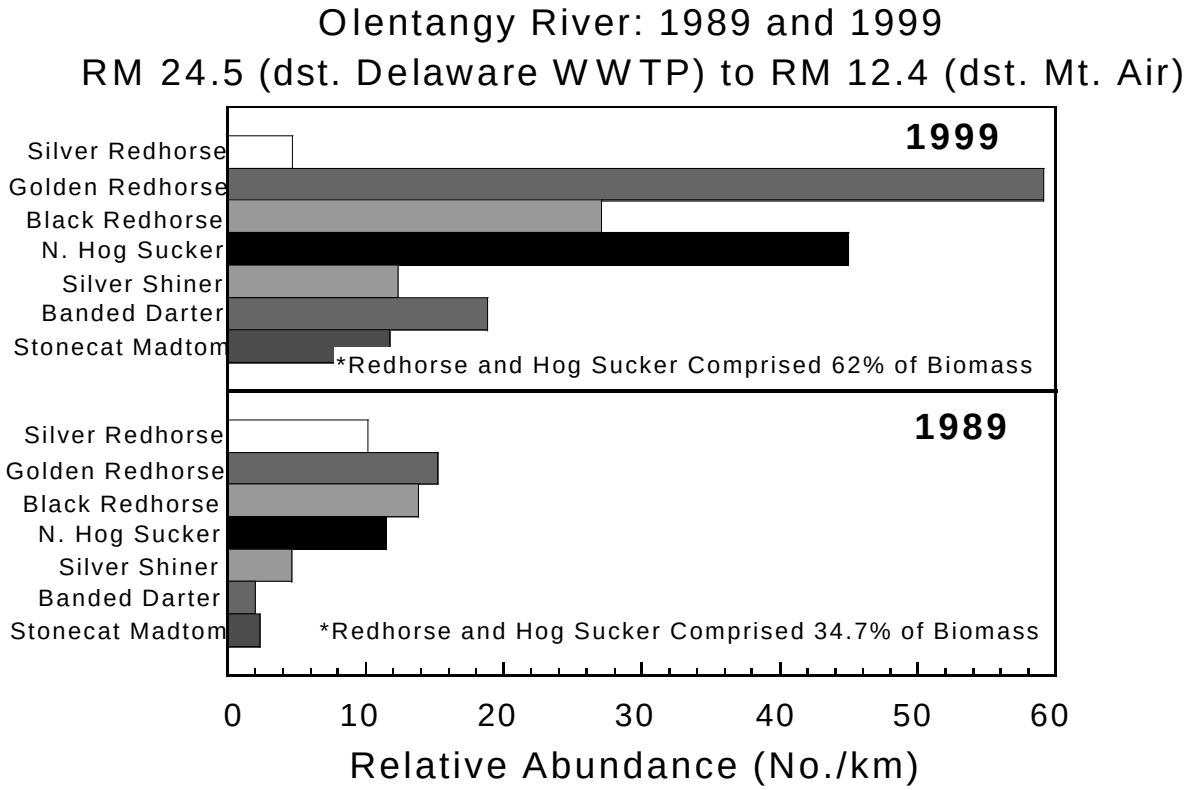


Figure 17 A comparison between mean relative abundance (no./km) of selected environmentally sensitive species from the Olentangy River, 1989 and 1999. These data were exclusive to the stream segment between RM 24.5 and RM 12.4.

The incidence of DELT anomalies, through time, provided additional evidence of improving environmental conditions within this segment of the Olentangy River (Figure 18). In 1989, the average proportion of gross external anomalies, was classified as elevated or highly elevated, with the greatest proportion occurring within the impacted river reach downstream from the Delaware WWTP. The results from the 1999 survey found improved fish health, as the incidence of DELT anomalies was reduced to background levels (nonelevated), and remained longitudinally stable.

In summary, environmental conditions of the upper and middle segments of lower Olentangy River study area were significantly improved in 1999. However, modest and localized impairment was indicated at RM 19.4, within the upper limits of the EWH segment. As this station was in full attainment of the EWH biocriterion in 1989, the departure is noteworthy. The cause for the decline is not clear at this time, but may have been related to the drought experienced during the summer of 1999. Future monitoring of this transitional area will be required to determine if the modest impact observed in 1999 was temporal in

nature or indicative of a recently derived, ongoing stress.

Comparisons with the 1999 survey results and previous efforts within the lower eight miles of the Olentangy River also showed improved conditions. At common stations among these surveys, community performance as measured by the IBI and MIwb was either advanced or remained comparable.

The results from the 1999 survey found that as the Olentangy River entered the greater Columbus area, the incidence of DELT anomalies increased in a longitudinal, stepwise manner. Diverging from

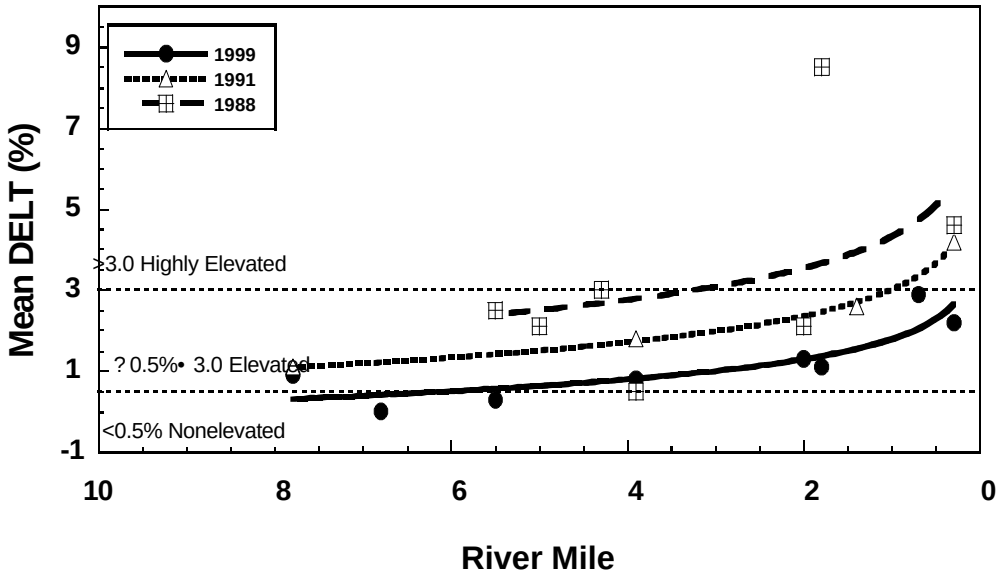


Figure 18 Longitudinal distribution of Deformities, Eroded fins and/or barbels, Lesions, and Tumors (DELT anomalies) throughout the entire length of the lower Olentangy River, 1988-99. Solid lines represent the magnitude of the occurrence based on ecoregional expectations, and calibrated by sample type (Ohio EPA 1989).

background levels at approximately RM 7.6, the proportion of DELT anomalies continued to rise, reaching the highest values near the confluence with the Scioto River. This phenomenon appeared reflective of increasing urbanization and the effects of associated diffuse pollution sources (CSOs, SSOs, contaminated stormwater, etc.). Both the 1988 and 1991 surveys also found increasing DELTs associated with increasing urbanization, similar to the pattern observed in 1999. However, the magnitude and frequency of gross external anomalies were greater before 1999 (Figure 19).

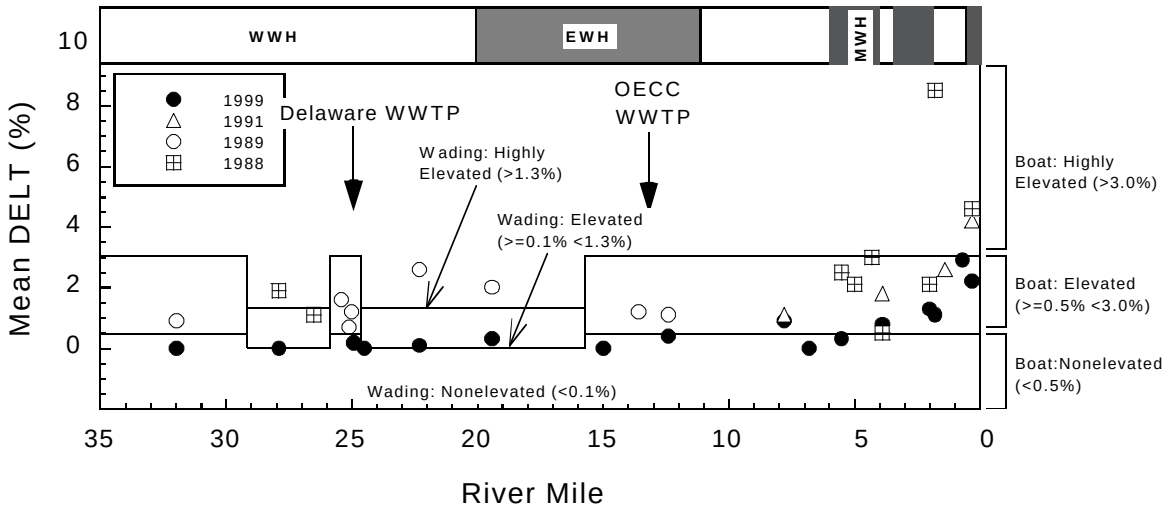


Figure 19 Longitudinal distribution of Deformities, Eroded fin and/or barbels, Lesions and Tumors (DELT anomalies) through the lower ten miles of the Olentangy River for the sampling years: 1998, 1991, and 1999. Dashed lines represent the magnitude of the occurance based on ecoregional expectations (Ohio EPA, 1989). Note the similar longitudinal pattern displayed between years, but overall decreasing trend through time.

Despite persistent evidence of chronic sublethal stress within the lower eight miles of the Olentangy River (i.e., elevated DELT anomalies), community performance has improved considerably since the initial investigation in 1988. Only one sampling station failed to support a fish assemblage consistent with the prescribed biological criteria in 1999. This site was located within the lower limits of the last WWH segment at RM 0.7. A survey of the Scioto River basin in 1996 included this station within the sampling effort, and found it to support a WWH community (Ohio EPA 1999). The departure observed in 1999 appeared related to construction activities in support of the Spring Sandusky interchange project, more specifically the result of an impoundment created by the installation of a temporary ford. As the ford will be removed following the completion of the project, the impairment at RM 0.7 is very likely temporary.

Olentangy River Tributaries: 1994-99

Historical fish community data were available from Rush Run only. In comparison with the 1994 sampling effort, modest improvements were indicated. Community performance was advanced from poor (IBI=26) to low fair (IBI=28). Also, relative abundance was substantially increased from 436/0.3km in 1994 to 2,056.5/0.3km in 1999. Overall, the organization of the assemblages between sampling years was similar.

Macroinvertebrate Community Trend Assessment

Trends assessment of macroinvertebrate community health in the Olentangy River is possible by comparing results of previous surveys conducted in 1988 and 1989 with the 1999 results and analyzing multiple years of ICI results from RMs 19.6 and 19.4 dating back to 1983.

Conditions in the Olentangy River have shown little change in the intervening years since 1988 with one notable exception. A suspected dissolved oxygen sag was identified in 1989 downstream from the Delaware WWTP (RMs 23.5 and 22.3). Here the ICI score declined from the exceptional range into the good range. No such decline was noted in the macroinvertebrate community in 1999, indicating that suspected excessive nutrient loads from the Delaware WWTP have been largely curtailed or assimilated. Within the Columbus metropolitan area there continue to be disernable impacts associated with the dam pools though slightly higher ICI scores were attained in 1999 versus 1989 (Figure 13).

In addition to the 1988 survey, data from multiple years has been collected at RMs 12.4-12.6 (upstream from Hyatt Rd.) since 1983. Comparison of ICI scores and EPT taxa both demostrate consistently exceptional macroinvertebrate community condition (Figure 20).

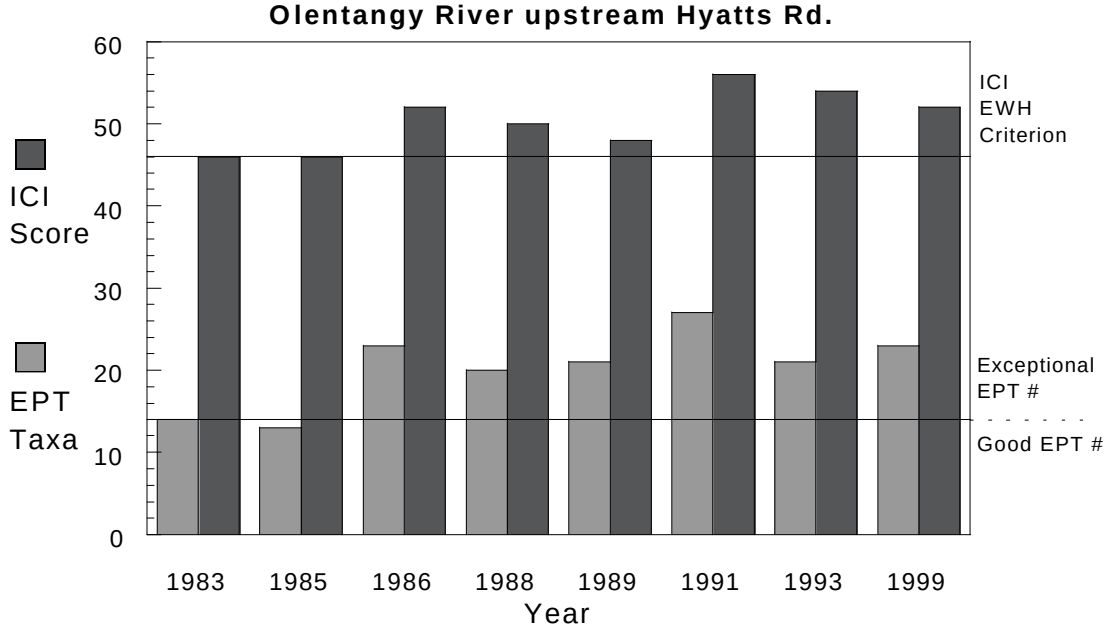


Figure 20 Invertebrate Community Index (ICI) scores and number of Ephemeroptera, Plecoptera and Trichoptera taxa (EPT) collected from the Olentangy River upstream from Hyatts Rd. (RMs 19.4-19.6) from 1983 to 1999.

Area of Degradation Value Trend Assessment: 1988-1999

The Area of Degradation Value (ADV) portrays the length and amount of departure from a biocriterion by an aquatic community. It reflects the distance that the biological index (IBI, MIWB, or ICI) moves longitudinally from the applicable biocriterion or from an upstream measurement of performance. A positive ADV is represented by the area above the biocriterion (or upstream level) when the results for each index are plotted against river mile. Conversely, a negative ADV represents the more typical degradation (Figure 2). The results are also expressed as ADV/mile to normalize comparisons between segments and other streams and rivers. ADV statistics reported in Table 24 reflect positive and negative influences on the aquatic communities because a given reach can have segments which exceed and which do not attain biocriteria. ADV statistics for 1999 of comparable stream reaches demonstrated moderate improvement for indices which had negative statistics in 1988 or 1989.

The attainment statistics indicated that 23.8 miles of the Olentangy River fully met the applicable WWH/EWH biocriteria in 1999. Partial attainment was recorded at 7.9 miles and 0.3 miles failed to attain the biocriteria.

Table 24. Area of Degradation Values (ADV) statistics for the Olentangy River, 1999. Values were calculated using applicable Eastern Cornbelt Plain ecoregion biocriteria as the baseline for community performance.

Stream (Year)			Biological Index Values		ADV Statistics				Attainment Status		
	Reach				Positive		Negative		(miles)		
Index	Upper RM	Lower RM	Mini-mum	Maxi-mum	ADV	**ADV/ Mile**	ADV	**ADV/ Mile**	FULL	PARTIAL	**NON**
Olentangy River (1999)											
IBI	32.0	0.0	35	53	1781	**55.6**	53	**1.6**	23.8	7.9	**0.3**
MIwb			7.9	10.3	1559	**49.9**	5	**0.1**			
ICI			12	52	2597	**81.1**	610	**19.0**			
Olentangy River (1999)											
IBI	32.0	12.0	39	53	893	**44.6**	39	**1.9**	17.9	2.1	**0.0**
MIwb			7.9	10.3	885	**42.7**	5	**0.2**			
ICI			34	52	2044	**102.1**	0	**0.0**			
Olentangy River (1999)											
IBI	28.5	0.0	35	53	1653	**57.9**	53	**1.8**	20.3	7.9	**0.3**
MIwb			7.9	10.3	1422	**49.9**	5	**0.1**			
ICI			12	52	2358	**82.7**	610	**21.4**			
Olentangy River (1989)											
IBI	32.0	12.0	29	48	281	**14**	424	**21.1**	7.8	11.3	**0.9**
MIwb			5.3	9.9	391	**19.5**	239	**11.9**			
ICI			34	54	1544	**77.2**	0	**0.0**			
Olentangy River (1988)											
IBI	28.5	0.0	29	39	12	**0.4**	1614	**56.6**	1.5	21.3	**5.7**
MIwb			7.0	9.6	328	**11.5**	749	**26.2**			
ICI			4	50	2233	**78.3**	1336	**46.8**			

REFERENCES

Bayley, P.B., and L.L. Osborne. 1993. Natural rehabilitation of stream fish populations in an Illinois catchment. Freshwater Biology 29, pg 295-399.

Columbus Sewers and Drains Division. 1998. Columbus Sanitary and Storm Sewer Atlas.

DeShon, J.D. 1995. Development and application of Ohio EPA's invertebrate community index (ICI), *in* W.S. Davis and T. Simon (eds.). Biological assessment and criteria: tools for risk-based planning and decision making. CRC Press/Lewis Publishers, Ann Arbor.

Fausch, D.O., Karr, J.R. and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Amer. Fish. Soc. 113:39-55.

Gammon, J.R., A. Spacie, J.L. Hamelink, and R.L. Kaesler. 1981. Role of electrofishing in assessing environmental quality of the Wabash River. pp. 307-324. In: Ecological assessments of effluent impacts on communities of indigenous aquatic organisms. ASTM STP 703, J.M. Bates and C.I. Weber (eds.). Philadelphia, PA.

Gammon, J.R. 1976. The fish populations of the middle 340 km of the Wabash River. Tech. Report No. 86. Purdue University. Water Resources Research Center, West Lafayette, Indiana. 73 pp.

Hughes, R. M., D. P. Larsen, and J. M. Omernik. 1986. Regional reference sites: a method for assessing stream pollution. Env. Mgmt. 10(5): 629-635.

Karr, J. R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications 1(1): 66-84.

Karr, J.R., K.D. Fausch, P.L. Angermier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Ill. Nat. Hist. Sur. Spec. Publ. 5. 28 pp.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6 (6): 21-27.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Env. Mgmt. 5(1): 55-68.

Kelly, M. H. and R. L. Hite. 1984. Evaluation of Illinois stream sediment data: 1974-1980. Illinois Environmental Protection Agency, Division of Water Pollution Control. Springfield, Illinois.

Miner R. and D. Borton. 1991. Considerations in the development and implementation of biocriteria, Water Quality Standards for the 21st Century, U.S. EPA, Offc. Science and Technology, Washington, D.C., 115.

Novotny, V. and G. Chesters. 1981. Handbook of nonpoint source pollution, sources and management. Van Nostrand Reinhold Environmental Engineering Series. Van Nostrand Reinhold Company, 555 pp.

Ohio Department of Natural Resources 1999. Monthly water inventory report for Ohio: June through October. Division of Water, Water Inventory Unit, Columbus, Ohio.

___ 1997. Special endangered wild animal regulations. Division of Wildlife, Columbus, Ohio. 7pp.

___ 1985. Principal streams and their drainage area. Division of Water. Ohio Department of Natural

Resources. Columbus, Ohio.

___ 1960. Gazetteer of Ohio streams. Ohio Dept. Natural Resources, Division of Water, Ohio Water Plan Inventory Report No. 12.

Ohio Environmental Protection Agency. 1999. Biological and Water Quality Study of the Middle Scioto River and Alum Creek: Franklin, Delaware, Morrow, and Pickaway Counties, Ohio. Division of Surface Water, Ecological Assessment Unit, Columbus.

___ 1991. Calculation and uses of the Area of Degradation Value (ADV). Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___ 1990. The cost of biological field monitoring. Division of Water Quality Planning and Assessment, Columbus, Ohio.

___ 1990a. State of Ohio nonpoint source assessment: Volume 5. Region. Division of Water Quality Planning and Assessment, Nonpoint Source Program Management Section, Columbus, Ohio.

___ 1990b. Ohio water resource inventory - 1990 305b report. Volume II. Edward T. Rankin, editor. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___ 1989a. Addendum to biological criteria for the protection of aquatic life: Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___ 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning and Assessment, Columbus, Ohio.

___ 1989c. Ohio EPA policy for implementing chemical specific water quality based effluent limits and whole effluent toxicity controls in NPDES permits. Divisions of Water Pollution Control and Water Quality Planning and Assessment, Columbus, Ohio.

___ 1989d. Assessment of the 1988 drought: chemical, biological, and physical impacts at selected Ohio stream sites. Division of Water Quality Planning and Assessment, Columbus, Ohio.

___ 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___ 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

Omernik, J.M. 1988. Ecoregions of the conterminous United States. Ann. Assoc. Amer. Geogr. 77(1): 118-125.

Omernik, J.M. and A.L. Gallant. 1988. Ecoregions of the upper midwest states. EPA/600/3-88/037. U. S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon. 56 pp.

Rankin, E.T. 1995. The qualitative habitat evaluation index (QHEI), *in* W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC

Press/Lewis Publishers, Ann Arbor. (in press).

Rankin, E.T. and C.O. Yoder. 1991 Calculation and use of the area of degradation value (ADV). Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus, Ohio.

Sanders, R.E., R.J. Miltner, C.O. Yoder, and E.T. Rankin. 1999. The use of External Deformities, Erosion, Lesions, and Tumors (DELT anomalies) in Fish Assemblages for characterizing Aquatic Resources: a case study of seven Ohio streams, in T.P. Simon (ed.) Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press Publisher.

Steedman, R.J. 1988. Modification and assessment of an index of biotic integrity to quantify stream quality in southern Ontario. Can. J. Fish. Aquat. Sci. Vol. 45.

Strahler, A.N. 1963. Physical Geography. John Wiley and Sons, Inc. New York 534 pp.

Suter, G.W., II. 1993. A critique of ecosystem health concepts and indexes. Environmental Toxicology and Chemistry, 12: 1533-1539.

Trautman, M. B. 1981. The fishes of Ohio with illustrated keys. Ohio State Univ. Press, Columbus. 782 p

United States Department of Agriculture, Soil Conservation Service. In cooperation with Ohio Department of Natural Resources , Division of Lands and Soil, and Ohio Agricultural Research and Development Center. 1980 Soil Survey of Franklin County.

United States Geological Survey, 1981. Low Flow Characteristics of Ohio Streams. Open-file Report 81-1195. 285pp.

Whittier, T.R., D.P. Larsen, R.M. Hughes, C.M. Rohm, A.L. Gallant, and J.M. Omernik. 1987. The Ohio stream regionalization project: a compendium of results. EPA/600/3-87/025. 66 pp.

Yoder, C.O., J. DeShon, R. Thoma, E. Rankin, and R. Beaumier. 1986. Evaluation of effluent toxicity screening of two selected discharges. Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

Yoder, C.O. 1995. Policy issues and management applications of biological criteria, *in* W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor.

___ 1991**.** Answering some concerns about biological criteria based on experiences in Ohio, *in* G. H. Flock (ed.) Water quality standards for the 21st century. Proceedings of a National Conference, U. S. EPA, Office of Water, Washington, D.C.

___ 1989. The development and use of biological criteria for Ohio surface waters. U.S. EPA, Criteria and Standards Div., Water Quality Stds. 21st Century, 1989: 139-146.

Yoder, C.O. and E.T. Rankin. 1996. Assessing the condition and status of aquatic life designated uses in urban and suburban watersheds. *in* Effects of Watershed Development and Management on Aquatic Ecosystems, Engineering Foundation Conference Proceedings, August 5-7, 1996, Salt Lake City, UT. (in press)

___. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multi-metric data, *in* W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor.