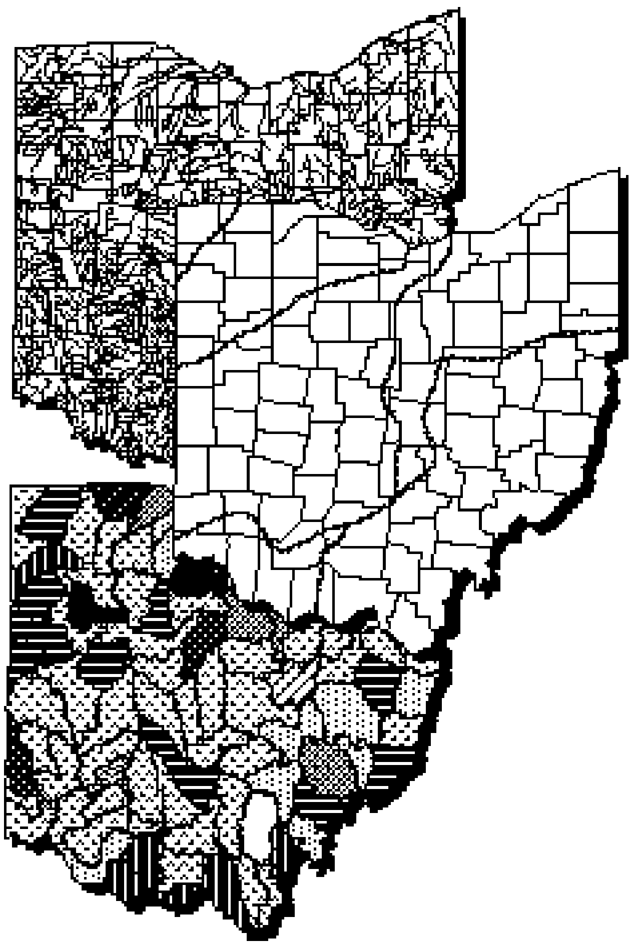
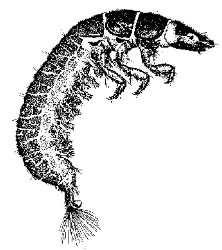
State of Ohio
Environmental Protection Agency

Biological and Water Quality Study of The Black River Basin

Lorain and Medina Counties





HydropsychidCaddisfly
(*Hydropsyche* sp.)

Greenside Darter (*Etheostoma blenniodes*)

March 31, 1999

Bob Taft, Governor
Christopher Jones, Director
State of Ohio EPA
P.O. Box 1049, Lazarus Government Center., 122 S. Front Street, Columbus, Ohio 43216-1049

Biological and Water Quality Study of the Black River Basin, 1997

Lorain and Media Counties

March 31, 1999

OEPA Technical Report
Number MAS/1998-11-4

Bob Taft, Govenor
Chris Jones, Director
State of Ohio Environmental Protection Agency
P.O. Box 1049, Lazarus Government Center
122 S. Front Street, Columbus, Ohio 43216-1049

TABLE OF CONTENTS

Appendix tables containing results from chemical grab samples and biological sampling are available electronically on the Internet at http://chagrin.epa.ohio.gov/.

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 new publications by Ohio EPA have become available. The following publications should also be consulted as they represent the latest information and analyses used by 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 can be obtained by writing to:

Ohio EPA, Division of Surface Water
Monitoring and Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228-3809
(614) 728-3377

Acknowledgments

Paul Anderson - Pollutant loadings, water chemistry and sediment chemistry evaluation.
Martin Knapp - macroinvertebrate community assessments.
Robert Miltner - Fish community and habitat quality assessments, and TSD editor.
Jeff DeShon, Marc Smith and Chris Yoder - Reviewers.

Water chemistry analysis was provided by the Ohio EPA Division of Environmental Services. Numerous college interns and district office staff assisted in the collection of field samples. Pete Ward and Mike Harvan helped with the arduous task of collecting fish. Landowners who granted permission for site access are duly appreciated.

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]), and are eventually incorporated into Water Quality Permit Support Documents (WQPSDs), 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 is outlined in Figure 1 and includes a hierarchical continuum from administrative to true environmental indicators. 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,

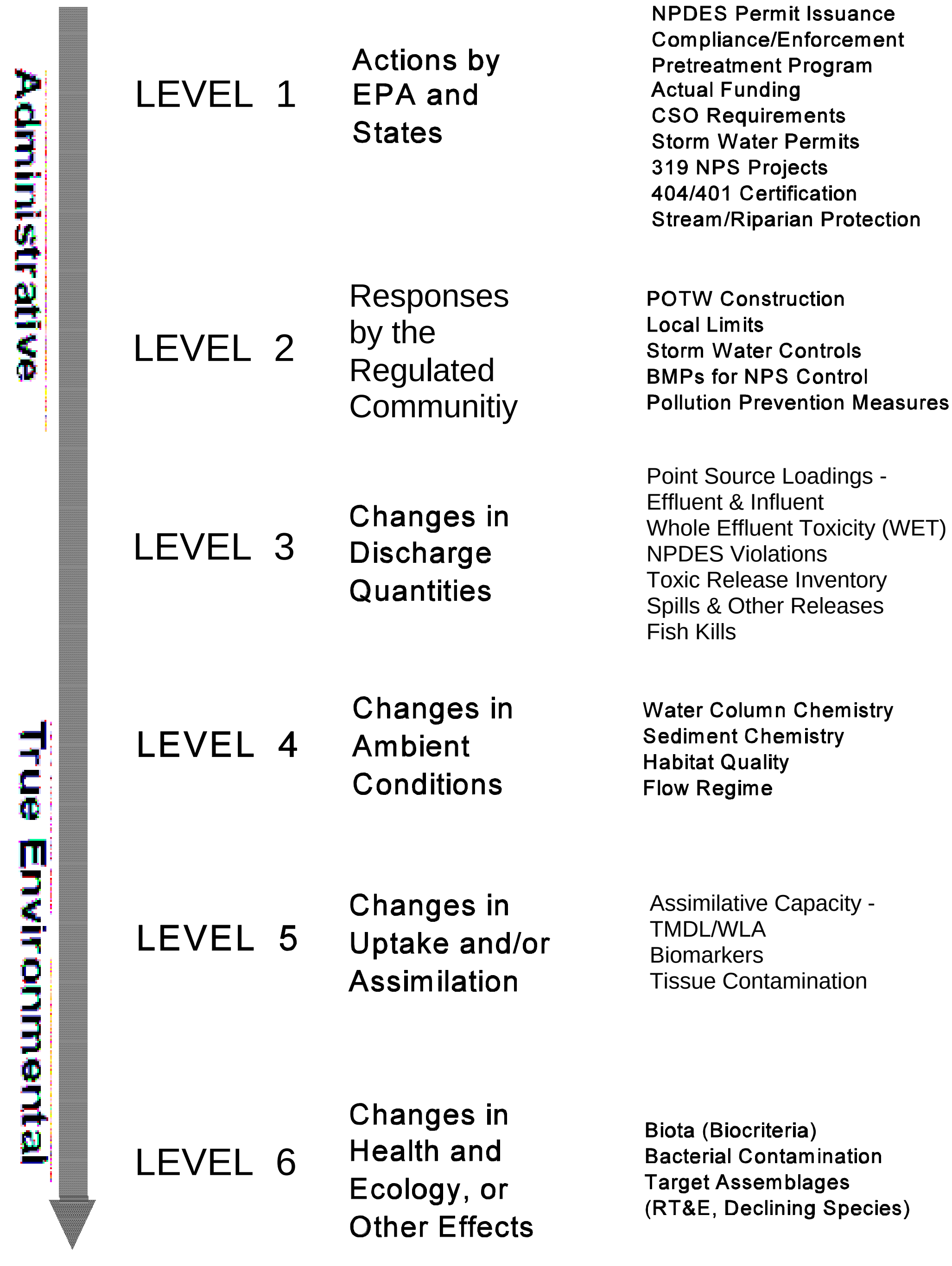


Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA (1995).

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 Uses

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

The five different aquatic life uses currently defined in the Ohio WQS are described as follows:

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

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

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

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned and permitted 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, NH_3-N, 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 coliforms, *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 are detailed in other documents.

INTRODUCTION

Biological, physical, surface water and sediment samples were collected from the Black River basin in 1997. The information gathered from this survey evaluates ambient conditions, existing environmental impacts from both point source discharges and nonpoint sources of pollution, attainment of designated stream uses, and is used to develop Water Quality Based Effluent Limits. The areas sampled included the Black River mainstem, the East Branch and East Fork of the East Branch, the West Branch near the mouth, French Creek, Willow Creek, Plum Creek, and Beaver Creek.

Specific objectives of this study were:

1) evaluation of impacts to water quality and aquatic life from the following point source dischargers:

   - USS/Kobe Steel
   - Elyria WWTP
   - North Ridgeville WWTP
   - Lorain Eastside WWTP
   - Grafton WWTP
   - Lodi WWTP
   - Oberlin WWTP
   - Amherst WWTP
   - Eaton Estates WWTP

2) evaluate the nonpoint pollution impacts from the following sources: Elyria compbined sewer overflows (CSOs), USS/Kobe's D2 landfill, and the fly ash disposal site adjacent to French Creek,

3) determination of attainment status of aquatic life and non-aquatic life use designations, and recommend changes where appropriate, and

4) comparison of results from this survey with previous surveys in 1982 and 1992 to assess changes in water quality and biological integrity, especially for the lower Black River mainstem following removal of contaminated sediments.

Additional information the Black River basin, and on portions not covered by this study can be found in the "Interim Report on the Black River Total Maximum Daily Load Project" and on the Internet at http://chagrin.epa.ohio.gov/programs/rap/rap.html.

SUMMARY

The Black River and six tributaries were surveyed by the Ohio EPA in 1997 to determine their attainment with chemical and biological water quality criteria. The Ohio EPA assessed a total of thirty six sites which included the Black River mainstem and the East Branch watersheds. The

West Branch watershed was not assessed in the 1997 study. The assessments included sampling for water and sediment chemistry and evaluation of fish and benthic macroinvertebrate communities during the summer low-flow period. This assessments are conducted on a five to ten year cycle by the Ohio EPA as a regular mechanism to assess the condition of the river as well as the impacts of point and non-point sources of pollution on the health of the river. In addition, sediment sampling was conducted throughout the lower Black River to assess long term trends in sediment quality following the closing of coking operations at the USS/Kobe Steel facility in Lorain and the remedial dredging conducted in the late 1980's to remove sediments that were heavily contaminated with polycyclic aromatic hydrocarbons (PAH's), a pollutant generated by the coking process.

Overall biological community performance within the portions of the Black River watershed sampled during 1997 showed few differences compared to the 1992 survey owing to continued and pervasive nonpoint pollution, and a few localized impacts from wastewater treatment plants (WWTP's). Detectable point source impacts included the Lorain WWTP, and to a lesser extent the Grafton and Elyria WWTPs. Compared to the 1992 survey, however, both the Grafton and Elyria WWTPs showed some improvement. Another segment showing improvement was the lake-influenced reach from river mile 6.8 to the mouth. Though a localized impact to the fish community remains downstream from the USS Kobe 001 discharge, IBI scores in 1997 were generally higher than those recorded in 1992 or 1982. The higher IBI scores in 1997 are likely the combined result of lower pollutant loadings from upstream, and dredging of sediments in the shipping channel to remove PAH's.

Dissolved oxygen concentrations in the shipping channel remain low during summer due to combined pollutant loadings from the Elyria WWTP, French Creek WWTP, Lorain WWTP, and USS/Kobe, and nonpoint sediment loadings. The low dissolved oxygen concentrations resulted in poor macroinvertebrate communities, and as a consequence the lake influenced portion of the river was assessed as being in non-attainment of the biological water quality criteria. The continuing poor D.O. regime in the Black River estuary even under conditions where significant improvement in upstream water quality has been achieved indicates that the assimilative capacity of the estuary continues to be exceeded and that a comprehensive evaluation of the dynamics of this system must be investigated to determine if the Black River estuary is capable of meeting the applicable water quality criteria, and if so, what steps are necessary to achieve this goal.

Sediment sampling in the lower Black River found that concentrations of PAH’s have been dramatically reduced in the sediments of the Black River since the cessation of coking operations at the USS/Kobe Steel facility in Lorain and the 1989-1990 remedial dredging of the Black River conducted by the USS Steel Co. under a consent agreement with the U.S.EPA. Concentrations of PAH’s have remained relatively constant during the five years since the previous Ohio EPA water quality survey in 1992. Total PAH concentrations in grab samples from the Black River estuary ranged from 6.85 mg/kg to 114.8 mg/kg in 1992, and from 6.0 mg/kg to 37.0 mg/kg in 1997. Concentrations of PAH’s in core samples of the sediment collected in 1997 ranged from 0.8 mg/kg to 46.6 mg/kg. Concentrations of PAH’s in sediments collected from the Black River upstream from the estuary ranged from 2.4 mg/kg to 3.0 mg/kg in 1997. The presence of persistent contamination of the Black River sediments with PAH's continues to provide an exposure pathway for aquatic life in the estuary of the river. In addition, the sediements from the lower Black River were found to have very high concentrations of heavy metals which has not been significantly reduced over time.

Studies conducted by the US Geological survey in 1997 found that fish tumor frequencies have declined significantly in the Black River estuary, indicating that the remedial dredging has been effective in reducing the long term impacts of the coking operations on the river. However, studies of the toxicity of the Black River sediments conducted at the same time by Wright State University found that the sediments have the potential to be toxic to aquatic organisms. Toxicity was found to be greater in laboratory studies than it was in field experiments. The conclusion of the Wright State study was that even the low concentrations of PAH's found in the Black River estuary may result in photo-induced toxicity to aquatic organisms, especially when in-stream turbidity decreases under low flow conditions. In addition, toxic effects of elevated concentrations of heavy metals may also be important in determining the overall toxicity of sediments from the lower Black River.

RECOMMENDATIONS

Black River

Status of Aquatic Life Uses

The Black River mainstem is designated Warmwater Habitat (WWH) from the confluence of the East and West Branches to Lake Erie. Of the 14.1 miles assessed, 2.9 miles of this reach fully attained, 5.7 miles partially attained, and 5.5 miles did not attain the biological criteria for WWH. The overall performance of the biological community demonstrates that the WWH aquatic life use designation is appropriate. Low dissolved oxygen concentration derived from pollutant loadings is the primary cause of biological impairment in the lake influenced reach, with sediment contamination by heavy metals and PAHs a secondary cause. The Lorain Eastside WWTP had a local impact due to high loadings of NH_3-N (NH3-N). Combined sewer overflows (CSOs) were the primary cause of biological impairment in the reach flowing through and downstream from Elyria, with a secondary impact associated with the Elyria WWTP. Legacy sediment contamination in the vicinity of USS/Kobe is a secondary source of biological impairment.

Status of Non-aquatic Life Uses

The Black River mainstem is designated for agricultural and industrial water supply, and has a Primary Contact Recreational designation. Those uses are all appropriate.

Other Recommendations and Future Monitoring Concerns

- Additional controls or operation and maintenance improvements capable of controlling the amounts of oil and grease discharged from USS/Kobe outfall 001 should be evaluated and implemented to eliminate frequent violations of discharge limitations for this pollutant.

- The results of bioassay testing at the USS/Kobe indicate that a plant performance evaluation specified in OAC 3745-07 (B)(3) should be conducted to determine and eliminate sources of toxicity in the outfall 001 and that permit limits for whole effluent toxicity may be necessary for this discharge.

- Although net thermal loadings from USS/Kobe utfall 002 were well within the permitted limit of 120 BTU/hr, this limit does not appear to be protective of water quality. In-stream temperature violations were noted on more than one occasion downstream of this outfall. Analysis of thermal loadings in relation to in-stream conditions is needed so that permit limits can be developed which will ensure that the water quality criteria for temperature are met.

- Results of chronic bioaassy testing of the USS/Kobe outfall 002 effluent indicate that further biomonitoring of the outfall 002 discharge may be warranted to determine if plant performance evaluation or permit limits relating to whole effluent toxicity are warranted.

- In order to facilitate modeling of the water quality of the Black River lacustuary, the collection of accurate water intake flow values should be included in future permits for the USS/Kobe facility.

- The need for effluent limits for NH_3-N for the Lorain Eastside WWTP should be evaluated because of flow regimes at the mouth of the Black River which can cause flow reversals in the lower Black river. There exists a potential for adverse impacts on the biota of the lower river from this discharge under conditions of rising lake levels and high temperatures when the effluent water mass either is pushed upstream or if it becomes stagnated in the vicinity of the discharge.

- The continuing poor D.O. regime in the Black River estuary even under conditions where significant improvement in upstream water quality has been achieved indicates that the assimilative capacity of the estuary continues to be exceeded and that a comprehensive evaluation of the dynamics of this system must be investigated to determine if the Black River estuary is capable of meeting the applicable water quality criteria, and if so, what steps are necessary to achieve this goal. It is recommended that an integrated water quality model be developed for the entire Black River mainstem which can be utilized to predict the impacts of the various stressors on the Black River estuary (non-point pollution from the watershed, CSO/SSO contributions, point source impacts and lake water intrusion). This model could also be used to evaluate the feasibility of attainment of the water quality criteria in the estuary under various pollutant abatement scenarios to assess alternative strategies for meeting this goal. All of the stakeholders potentially effected by this effort should be included in the model development process from the outset in order to ensure that the final product is realistic for implementation. Until a model of this type is constructed, the Ohio EPA should not allow any increases in pollutant loads for point source dischargers that discharge to, or influence water quality in, the mainstem of the Black River. In addition, final approval of a long term control plans for combined sewer discharges from within Elyria should not be granted until their overall contribution to the existing water quality problems in the Black River estuary are quantified.

- Continued assessment of the river over time is necessary to determine if fish tissue contaminant levels will decline to the point where fish advisories currently in place for the Black River can be lifted. In addition, it is important to thoroughly understand the long term impacts to aquatic life from the continued presence of elevated concentrations of heavy metals and residual PAH contaminants in the sediments to restore the estuary to its full potential.

French Creek

Status of Aquatic Life Uses

French Creek is designated Warmwater Habitat (WWH). Of the reach sampled, 1.4 miles partially attained, and 3.7 miles did not attain the biological criteria for WWH. The full and partial attainment of the biological communities demonstrates that the WWH aquatic life use designation is appropriate. An unknown source of toxicity is responsible for the impaired biological communities.

Status of Non-aquatic Life Uses

French Creek is designated for agricultural and industrial water supply. It also has a Primary Contact Recreational designation downstream from East River Road (Gulf Road), and a Secondary Contact Recreational use designation upstream from Gulf Road. The secondary use designation is not appropriate given that French Creek upstream from East River Road has pools deeper and wider than 1 m, and it flows through a county metropolitan park. Otherwise, the use designations are all appropriate.

Other Recommendations and Future Monitoring Concerns

Effects of expansion of the French Creek WWTP on the shipping channel will need to be addressed and monitored. As noted in the 1994 Biological and Water Quality Study of the Black River, toxicity was evident upstream from the French Creek WWTP. No source was identified, but a fly ash disposal area was suspected. The toxicity was still evident in the fish and macroinvertebrate communities in 1997; however, the community upstream from the fly ash disposal area also reflected toxicity. The source of the toxicity needs to be identified.

East Branch Black River

Status of Aquatic Life Uses

The East Branch Black River is designated Warmwater Habitat (WWH). Nineteen and two tenths miles fully attained, and 18.3 miles partially attained the biological criteria for WWH. The overall performance of the biological community demonstrates that the WWH aquatic life use designation is appropriate. Nonpoint agricultural pollution was a source of impairment in the upper reach, and pollutant loadings by the Grafton WWTP, particularly phosphorus, impaired the biological communities downstream from the WWTP discharge.

Status of Non-aquatic Life Uses
The East Branch Black River is designated for agricultural and industrial water supply, and has a Primary Contact Recreational designation. Those uses are all appropriate.

Other Recommendations and Future Monitoring Concerns
The channel in the reach upstream from Grafton is particularly susceptible to destabilization from loss of riparian vegetation; therefore, riparian buffers should be restored or protected.
Given that the fish community only partially attained the WWH biological criteria, the reach downstream from the Grafton WWTP will need to be monitored following expansion of the WWTP. To effect an improvement in the biological community, instream total phosphorus (TP) concentrations of 0.32 mg/l or less are needed downstream from the Grafton WWTP plant. To achieve this downstream concentration, an effluent limit of 0.5 mg/l (30 day average) is needed based upon a mass balance approach, and is strongly recommended as a summertime limit in any permit issued for the expansion of the plant. In the winter, a limit of 1.0 mg/l would be protective of the aquatic life use because of higher upstream flows. Suburban development in the Spencer Lake area may also be contributing pollutant loads and should be monitored more closely in the next basin survey.

East Fork East Branch
Status of Aquatic Life Uses
The East Fork of the East Branch Black River is designated Warmwater Habitat (WWH). The 2.7 miles sampled fully attained the biological criteria for WWH. The overall performance of the biological community demonstrates that the WWH aquatic life use designation is appropriate. The Lodi WWTP had a minor but detectable impact to the biological communities.

Status of Non-aquatic Life Uses
The East Fork of the East Branch is designated for agricultural and industrial water supply, and has a Primary Contact Recreational designation. Those uses are all appropriate.

Other Recommendations and Future Monitoring Concerns
The fish community at RM 2.1 and the macroinvertebrate community at RM 2.7 met expectations for Exceptional Warmwater Habitat (EWH), suggesting that the potential exists for the East Fork to fully achieve EWH standards. Habitat restoration and protection efforts should be directed toward this part of the watershed to protect the few high quality segments and tributaries remaining in the watershed. Given the elevated concentrations of nutrients and the marginal performance of the macroinvertebrate community in the East Fork downstream from the WWTP, it is possible that dissolved oxygen (D.O.) depletion is occurring in the stream during the nighttime hours as the result of microbial respiration. Diurnal monitoring of the D.O. concentrations downstream from the Lodi

WWTP should be conducted to determine if this is the case. The addition of phosphorus control equipment at the Lodi WWTP should be required to improve downstream water quality and biological integrity. Future monitoring of the biological communities downstream of the discharge should be conducted to evaluate whether nutrient enrichment remains a problem following the completion of the facility upgrades currently contemplated.

Willow Creek

Status of Aquatic Life Uses

Willow Creek is not designated under Chapter 3745-1 of the Ohio Water Quality Standards. The biological communities evaluated over a 3.2 mile reach in 1997 did not meet expectations for a WWH aquatic life use designation due to extensive channel modifications. However, Willow Creek is not under an active maintenance program at the county level, and given that the existing channel modifications were either unpermitted or the result of road construction, the habitat and biological communities should recover; therefore, a WWH use designation is appropriate.

Status of Non-aquatic Life Uses

Willow Creek should be designated for agricultural and industrial water supply, and have a Primary Contact Recreational use designation.

Other Recommendations and Future Monitoring Concerns

Channel modified portions of Willow Creek should be allowed to recover free flowing characteristics, and riparian buffers need to be restored.

West Branch Black River

Status of Aquatic Life Uses

The West Branch Black River is designated Warmwater Habitat (WWH). The one site evaluated partially attained the biological criteria for WWH indicating that the WWH aquatic life use designation is appropriate. Discharges of poorly or untreated sewage from onsite septic systems was the primary source of the aquatic life use impairment.

Status of Non-aquatic Life Uses

The West Branch is designated for agricultural and industrial water supply, and has a Primary Contact Recreational designation. Those uses are all appropriate.

Other Recommendations and Future Monitoring Concerns

Effects of rehabilitation efforts from the Remedial Action Plan should be assessed during the next 5-year basin survey. The failing onsite sewage systems need to be identified and remediated.

Plum Creek

Status of Aquatic Life Uses

Plum Creek is designated Warmwater Habitat (WWH). For the 3.3 mile reach sampled, 0.5 miles partially attained, and 2.8 miles did not attain the biological criteria for WWH. The partial attainment of the biological community at the downstream most site demonstrates that the WWH aquatic life use designation is achievable and appropriate.

Status of Non-aquatic Life Uses
Plum Creek is designated for agricultural and industrial water supply, and has a Primary Contact Recreational designation. Those uses are all appropriate.

Other Recommendations and Future Monitoring Concerns
The reach of Plum Creek upstream from the Oberlin WWTP is impacted by stormwater runoff from the City of Oberlin; therefore, a stormwater retention program should be implemented.

Beaver Creek
Status of Aquatic Life Uses
Beaver Creek is designated Warmwater Habitat (WWH). Of the 7.1 miles sampled, 2.3 miles fully attained, 1.0 miles partially attained, and 3.8 miles did not attain the biological criteria for WWH. The overall performance of the biological community demonstrates that the WWH aquatic life use designation is appropriate. The Amherst WWTP was solely responsible for at least 1.1 miles in non-attainment, and a faulty lift station at RM 2.7 contributed to the impairment of the other 2.7 miles. The results of chemical sampling indicate that chronic toxicity to aquatic organisms within the stream exists during summer low flow conditions as the result of elevated concentrations of NH_3-N in the Amherst WWTP effluent. Discharges of NH_3-N, oxygen demanding compounds, and other nutrients resulted in a dissolved oxygen sag downstream from the Amherst WWTP.

Status of Non-aquatic Life Uses
Beaver Creek is designated for agricultural and industrial water supply, and has a Primary Contact Recreational designation. Those uses are all appropriate.

Other Recommendations and Future Monitoring Concerns
Dissolved oxygen modeling should be conducted before the reissuance of any NPDES permit for the treatment plant to ensure that impacts from the WWTP do not result in violations of Ohio Water Quality Standards. Due to the low flow characteristics of Beaver Creek, abandonment of the Amherst WWTP with a tie in to a regional wastewater treatment facility should be considered as an alternative to expansion or upgrade of the plant. Continuing water quality problems in Beaver Creek can be expected unless significant improvement in effluent quality is achieved from this facility.

Monitoring of chemical and biological water quality in Beaver Creek following the implementation of a plan to alleviate the current pollution problem is necessary. This monitoring should be capable of determining the effectiveness of the remedy and whether additional pollution controls are necessary to achieve full attainment of the designated stream uses.

Table 1. Aquatic life use attainment status for stations sampled in the Black River basin July-September, 1997. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Comment
Black River (20-001)			*Erie-Ontario Lake Plain WWH (existing)*			
15.0/15.1	36[ns]	8.5	44	79.5	Full	Dst E. and W. Branch, Dst CSOs
11.9/12.3	33[*]	7.8[ns]	52	75.0	Partial	Ust Elyria WWTP, Dst CSOs
10.6/10.6	*35[ns]*	*7.1[*]*	*MG/G*	--		Elyria WWTP mix zone
10.3/9.8	36[ns]	6.8[*]	44	79.5	Partial	Impact
8.5/8.7	37[ns]	7.7[ns]	44	78.0	Full	Impact/Recovery
			Lake Erie Lacustuarine Criteria (interim)			
5.8	36[*]	7.6	--	58.0	(Partial)	Ust. D 2 landfill
5.5	32[*]	6.5[*]	10[*]	42.5	NON	Ust. D 2 landfill
5.2	36[*]	6.8[*]	10[*]	48.5	NON	Dst. D2 landfill, Ust 006, 001
4.8/4.9	25[*]	6.1[*]	24[*]	55.0	NON	USS Kobe Dst 006, 001
3.7	*32[*]*	*7.4[ns]*	--	--		USS Kobe 005 mix zone
3.6			12[*]		(NON)	Dst USS Kobe 005
3.1	37[*]	7.3[ns]		53.5	(Partial)	USS Kobe Ust 003/004
2.3	34[*]	7.2[ns]	20[*]	45.0	NON	USS Kobe Dst 003/004
0.9	45	8.5	18[*]	34.5	NON	Dst. Kobe/Ust Lorain WWTP
0.1	24[*]	6.2[*]	12[*]	27.0	NON	Dst Lorain WWTP
French Creek (20-002)			*Erie-Ontario Lake Plain WWH (existing)*			
6.1/5.5	20[*]	4.7[*]	F[*]	73.5	NON	Ust fly ash
3.2/3.2	22[*]	5.8[*]	40	71.0	NON	Ust N. Ridgeville WWTP, dst fly ash
1.0/0.4	41	7.7[ns]	F[*]	66.5	Partial	Dst North Ridgeville WWTP
East Branch Black River (20-010)			*Erie-Ontario Lake Plain WWH (existing)*			
40.5/40.4	44	7.8[ns]	48	63.5	Full	Trends//Dst. Lodi
32.5/32.4	30[*]	6.8[*]	44	58.5	Partial	NPS impacts
18.9/18.9	42	7.7[ns]	44	63.5	Full	Ust. Grafton
11.3/11.3	38	8.0	48	74.0	Full	Ust. Grafton WWTP
10.9/10.8	33[*]	7.5[ns]	44	71.5	Partial	Dst. Grafton WWTP
6.0/6.0	34[ns]	7.6[ns]	46	56.0	Full	Ust. Brentwood Trib.
5.5/5.2	42	8.3	48	75.5	Full	Dst. Brentwood/Willow Creek
3.0/3.0	41	8.2	44	62.0	Full	Ust. Elyria/DMT reference
--/0.1	--	--	46	--	(Full)	Dst. SSOs, CSOs, high gradient

Table 1 Continued.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Comment
East Fork East Branch (20-014)			*Erie-Ontario Lake Plain WWH (existing)*			
2.7/2.7	38	NA	E	52.0	Full	Ust Lodi WWTP
2.1/--	48	NA	--	76.5	(Full)	Ust Lodi WWTP
0.1/0.1	39	NA	MG	44.5	Full	Dst Lodi WWTP
Willow Creek (20-018)			*Erie-Ontario Lake Plain WWH (existing)*			
6.0/6.1	--	--	P*	24.0	(NON)	Ust Eaton Estates WWTP
4.9/4.9	19*	NA	P*	55.0	NON	Dst Eaton Estates WWTP
2.9/2.9	20*	NA	MG[ns]	39.0	NON	Dst Ross Incinerator, EE WWTP
West Branch Black River (20-020)			*Erie-Ontario Lake Plain WWH (existing)*			
1.2/0.1	30*	6.7*	38	47.5	Partial	Unsewered, Dst CSO
Plum Creek (20-021)			*Erie-Ontario Lake Plain WWH (existing)*			
3.3/3.3	27*	NA	MG	73.0	NON	Ust Oberlin WWTP
2.9/2.9	27*	NA	*34*	63.0	NON	Oberlin WWTP/mix zone
1.6/0.8	31*	NA	44	80.5	Partial	Impact/Recovery
Beaver Creek (20-003)			*Erie-Ontario Lake Plain WWH (existing)*			
6.8/7.1	35[ns]	6.4*	48	60.5	Partial	Ust. Amherst
4.6/4.8	37[ns]	7.3[ns]	44	58.0	Full	Ust. Amherst WWTP
2.8/2.8	21*	4.2*	14*	49.5	NON	Dst. Amherst WWTP

Ecoregion Biocriteria: Erie-Ontario Lake Plain

Site Type	IBI WWH	IBI EWH	IBI MWH[d]	MIwb[a] WWH	MIwb[a] EWH	MIwb[a] MWH[d]	ICI WWH	ICI EWH	ICI MWH[d]
Headwaters	40	50	24	NA	NA	NA	34	46	22
Wading	38	50	24	7.9	9.4	6.2	34	46	22
Lacustuarine	32	48	--	7.5	9.6	--	42	52	--

a - MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.
b - A qualitative narrative evaluation used when quantitative data were not available or unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates (P = Poor, F = Fair, MG = Marginally Good, G = Good, VG = Very Good, E = Exceptional).
c - Use attainment status based on one organism group is parenthetically expressed.
d - Modified Warmwater Habitat criteria for channel modified habitats.
ns - Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

Table 2 Use designations for streams in the Black River basin. Recommended changes within a specific segment or to a listed tributary appear as ***bold italics***. Designations changed or confirmed as the result of biological field assessments appear as triangles within a specific use category. A (+) sign means the use designation has been verivied by a survey.

SEGMENT	SRW	WWH	EWH	MWH	SSH	CWH	LRW	AWS	IWS	PWS	BW	PCR	SCR
Brownhelm Creek		*						*	*			*	
Quarry Creek		*						*	*			*	
Beaver Creek		*▲						*	*			*	
Martin Run		*						*	*			*	
Black River - Elyria STP to confluence with Lake Erie		+			+			+	+			+	
- Park boundaries in Elyria		+			+			+	+			+	
- all other segments		+			+			+	+			+	
French Creek - Gulf Road to mouth		+			+			+	+			+	
- all other segments		+						+	+			▲	+
East Branch		+						+	+			+	
Salt Creek		*▲						*	*			*	
Willow Creek (Easton Estates Trib)		▲						▲	▲			▲	
Crow Creek		*▲						*	*			*	
Coon Creek		*▲						*	*			*	
East Fork		*▲						*	*			*	
West Fork		*▲						*	*			*	
Clear Creek		*▲						*	*			*	
West Branch - U.S. Route 20 to the Black River		+						+	+			+	
- Parsons Road to U.S. Route 20	*	+						+	+			+	
- all other segments		*						*	*			*	
Plum Creek		▲						*	*			*	
Elk Creek		*						*	*			*	

Table 2 Continued: Use designations for streams in the Black River basin. Recommended changes within a specific segment or to a listed tributary appear as ***bold italics***. Designations changed or confirmed as the result of biological field assessments appear as triangles within a specific use category.

SEGMENT	SRW	WWH	EWH	MWH	SSH	CWH	LRW	AWS	IWS	PWS	BW	PCR	SCR
Wellington Creek - Findley State Forest boundaries	*	*						*	*			*	
- all other segments		*						*	*			*	
Charlemont Creek		*						*	*			*	
Buck Creek		*						*	*			*	

Study Area Description

Black River

The Black River Watershed covers 467 square miles (298,880 Ac.) and drains 887 stream miles in Lorain County as well as portions of Ashland, Medina, Cuyahoga and Huron Counties (Figure 1). The Black River has two main branches: the East Branch, which drains 222 square miles of land in Medina and southeast Lorain Counties, and the West Branch, which drains 174 square miles of land primarily in southwest Lorain County. The East and West Branches meet to form the mainstem in Elyria, and then flow north for 15.6 miles to Lorain Harbor in Lake Erie. French Creek, tributary to the mainstem at RM 5.1, drains 31.6 square miles of land in northeastern Lorain County. The entire Black River basin lies within the Erie/Ontario Lake Plain ecoregion. Like most of north central and northwest Ohio, geographic relief is flat to gently rolling due to past glacial activity. The gradient of the Black River ranges from about 0.8 ft. per mile at the French Creek confluence to 29.8 ft. per mile at Charlemont Creek. The geology and ground water resources of the basin also have been affected by glaciation. Generally, unconsolidated glacial deposits overlie consolidated sandstone and shale bedrock. Ground water resources are limited in the basin, yielding only five to 25 gallons per minute from sandstone and shale bedrock and glacial end moraines. The exceptions to this are in the extreme southeast where 100 to 500 gallons per minute are available from a buried valley aquifer and in the area near the Black River's mouth where clay and silt deposits yield less than five gallons per minute. The northeast Ohio climate where the Black River is located is characterized by moderate precipitation which is fairly evenly spread throughout the year. The total yearly precipitation averages about 34.5 inches. The average temperature is 50^{o} F with values rarely exceeding 90^{o} F or falling below 0^{o} F. Most streams in the Black River basin are designated Warmwater Habitat (WWH). Two streams, a portion of the West Branch of the Black River running from Parsons Road to US Route 20 and Wellington Creek in the boundaries of Findley State Forest, are designated as State Resource Waters. The entire Black River and French Creek from Gulf Road to the creek's mouth are, also designated Seasonal Salmonid Habitat. The International Joint Commission has designated the Black River and its harbor as one of four Areas of Concern (AOC) on Ohio's Lake Erie shoreline. A Remedial Action Plan (RAP) is being prepared to resolve the pollution problems in the lower mainstem as well as additional watershed concerns.

Soils

The soil associations of Mahoning, Trumbull and Ellsworth silt loams comprise 90% of the soils in the watershed. These glacial till soils are classified as somewhat poorly drained to moderately well drained. Wetness is the main limitation to crop production. The surface soil is a medium to fine textured silt loam or silty clay loam. These soils are typically found on nearly level to gently rolling landscapes with long slopes. The combination of soil texture and slope allow these soils to erode easily. However, soil erosion is not uniform across the watershed. It varies as a function of local soil type, land slope, and land use. The soils in the watershed have an average soil loss tolerance of 3 tons/acre/year. Studies conducted by the Northeast Ohio Area Wide Coordinating Agency (NOACA) indicate that the area of greatest soil loss is the rolling till plain of western Medina County and Southern Lorain County. This area comprises much of the upper portion of the

Black River basin along both the East and West Branches. The sub-basins within this area have greater than 20 % of their land area eroding at a rate of more than 5 tons/acre/year. The most erosive of these highly eroding sub-basins are: East Branch (West Fork to Crow Creek), Coon Creek, Charlemont Creek, West Branch (Headwaters to Charlemont Creek) and Buck Creek. NOACA grouped the Highly Erodible Land (HEL) within the upper portion of the Black River basin along both the East and West Branches according to land use type. Over 17,000 acres were eroding at "excessive" levels in these basins. Cropland accounted for 82% of this total, followed by open space categories (e.g. grasslands, forestlands, and pastures) at 14 % and developed lands at 4 %. The open space categories are areas least disturbed by human activities and are representative of background erosion problems. Therefore, naturally occurring erosion and sedimentation rates are high in much of the upper basin along both the East and West Branches. Steep slopes and deep soil depth combine to create erosive conditions. Background erosion rates are considered to be one of the major sources of sediment in the Area of Concern. Erosion on cropland can be substantial given that some commonly used agricultural practices result in the ground laying bare for extended periods of the year. In its Erosion and Sedimentation Study, Lorain, Ohio, August, 1982, the U.S. Army Corps of Engineers reported that cropland in the Black River watershed is eroding at an average rate of 4.7 tons/acre/year. According to the U.S. Army Corps study, 107,000 acres of cropland in the Black River watershed is eroding at approximately twice the tolerable soil loss rate. The Corps further determined 835,000 tons of sediment is produced annually within the watershed with 80% coming from cropland.

Soil erosion in the Black River basin is detrimental in many ways. Soil loss from fertile cropland not only harms productivity, but does considerable damage to the drainage network throughout the watershed. Furthermore, sediment deposited on stream bottoms interferes with the reproductive cycle of many fish species, thus reducing the diversity and numbers of species in the aquatic environment. Suspended sediments irritate and clog the gills of many fish species, and reduce the amount of light available to aquatic plants (see Fish Community section for further details).

Beaver Creek

Beaver Creek is a tributary of Lake Erie located entirely in Lorain County. The mainstem of the stream is 12.2 miles long and the watershed drains an area of 43.92 square miles, with an average gradient of 19.1 feet/mile. The watershed is located in the northern most reach of the Eastern Corn Belt Plains (ECBP) ecoregion. The topography of the watershed is characterized by low rolling hills, except for areas adjacent to the main channel, which is characterized by occasional shale and sandstone bedrock outcroppings and rough, wooded terrain. Soils composition in the watershed is mostly of lacustrine sandstone and shale origin, predominantly of the Caneadea series. These soils are low in organic matter, acidic, and difficult to drain (McDonnel, Proudfoot, and Associates, 1991).

Land use in the headwaters of the Beaver Creek watershed (above RM 10.0) is mostly low density residential and rural agriculture. The greatest threats to water quality within this reach of stream are discharges from on-site sewage systems and non-point runoff from agricultural and residential land. Beaver Creek also receives urban runoff from the unsewered South Amherst area (RM 9.0-10.0), plus agricultural and on-site sewage system drainage from Schramm Ditch (confluence RM 9.41). The single major point source of pollutants to Beaver creek is the City of Amherst WWTP, which discharges to the stream at RM 3.85. The flow in Beaver Creek downstream from the Amherst WWTP is heavily effluent dominated during summer low flow conditions. Wastewater effluent may comprise up to 94 percent of the stream flow during these periods of the year.

Willow Creek empties into Beaver Creek at RM 2.01. This tributary receives urban runoff from the City of Amherst, discharge from a wastewater treatment unit at the Amherst mobile home park, and discharges from several small commercial properties with individual wastewater treatment plants as well as agricultural runoff.

Biological monitoring was conducted at four sites and water samples were collected for chemical analyses at three sites along the mainstem of Beaver Creek in 1997 (Table 3). Sampling locations were selected for comparison to data collected by the Ohio EPA in 1992 (Ohio EPA, 1994), with the primary emphasis to determine the water quality trends associated with the Amherst WWTP discharge to the stream.

The quality of surface waters in Ohio have generally improved over the past 25 years owing to improved point source discharges and upgraded sewage treatment facilities. Now the leading cause of water quaity impairment is water pollutantion and habitat destruction caused by nonpoint sources: urban stormwater run-off, agricultural runoff, construction, and drainage alterations. Specific nonpoint source pollution concerns in the Black River basin include:

Construction Sites

Construction activities such as individual houses, residential developments, commercial properties and industrial sites occurr sporadically throughout these watersheds. Uncontrolled stormwater runoff can carry tons of soil into local streams, which can devastate an aquatic community. If the excavated are is to exceed 5 acres, then an NPDES permit must be filed with Ohio EPA and a stormwater plan developed. Each of the local Soil and Water Conservation Districts are to work with the Ohio EPA and developer to minimize soil loss from these properties.

Farm/Orchards/Nurseries

The East Branch and West Branch of the Black River are primarily agricultural. Plowing fields to the edge of waterways can cause significant soil loss into local streams by direct erosion of destabilized banks and loss of filtration of surface runoff. Sudden sediment loads can totally change a stream bottom habitat directly impacting the entire aquatic community, and sediments carry adsorbed nutrients. Allowing livestock to enter streams accelerates bank erosion and increases nutrient levels in the water. Run off from feed lots, animal waste piles or improper manure applications contributes nutrients to local streams. Over application or untimely application of herbicides/pesticides stresses or eliminates aquatic organisms.

In 1998, the Lorain and Medina Soil and Water Conservation Districts began participation in the Upper Black River Watershed 319 Grant administered by Seventh Generation. The initiatives they will undertake are: 1) Cost sharing with farmers in target areas of the watershed to implement precision farming practices (increases crop yields, yet minimizes over application of chemicals that degrade water quality); 2) Installation of landowner stream conservation practices (i.e. sod waterways, WASCOB's, erosion structures).

The Conservation Reserve Program (CRP) implemented by the Natural Resource and Conservation Service is very active in the Black River Watershed because it is within the Great Lakes National Priority area. This program pays landowners, (for 10 years) to plant crop land to grass or tree cover. Lorain and Medina counties have between 2,000 and 2,500 acres in the Black River Watershed currently enrolled in the CRP.

The 1995 Black River Watershed Nonpoint Source Management Plan states there were 85 dairy farms, 42 Amish farms and 57 other mixed livestock farms within the watershed. Less than 50% of the dairy operations lacked adequate manure storage facilities and consequently had to rely on daily hauling and land application.

Lorain County has an estimated 141,000 acres of agricultural land operated by 890 farm operations for an average farm size of 158 acres. No-till acreage within this watershed continues to increase due to cost share programs and continuing education. Many of these operators have discovered that new techniques may not only improve the environment, they often save time and money.

Failing Septic Systems

The larger cities in the Black river watershed have sanitary sewers servicing most of the residences and businesses developed heavily in the 1930's, 40's and 50's and are not within the city limits. However, the adjacent townships tied into sanitary sewers. A high percentage of the septic systems in this watershed are well beyond 20 years in age, (The expected life of a system). Additionally, high percentages of clay content in the local soils further contribute to high failure rates of septic systems. Inadequately treated sewage impacts the water quality of roadside ditches, wetlands, streams and lakes. This can cause health hazards in drinking and recreational waters, decreased oxygen levels, excessive aquatic plant growth and offensive odors. Areas identified with large concentrations of failing septic systems:

<u>Lorain County</u>

Huntington Township Center	Sheffield Township	Carlisle Township
Elyria Township	North section of Rochester	Portions of Eaton Township

<u>Medina County</u>

Note: The western portion of Medina County in the Black River watershed is sparsely populated, except for the Village of Lodi and Spencer that have sanitary sewer systems.

Data indicating how many failing systems are within this watershed is currently not available. The Lorain County Health Department allowed 12 experimental constructed wetland home sewage disposal systems (HSDS) to be installed in 1993 & 1994. The Health Department Officials continue to monitor and test these systems to determine if constructed wetlands may adequately serve as an alternative treatment system.

In 1998, the Lorain County Health Department and Medina County Health Department began participation in the Upper Black River Watershed 319 Grant administered by Seventh Generation. The initiatives they will undertake are: 1) Investigating the locations of known and suspected failed HSDS's in the Black River watershed through an inventory and tracking process, records search, and on-site inspections; 2) Performing bacteriological sampling to verify HSDS failure rates needed for ranking existing and emerging problems; 3) Using the monitoring and analytical data to support the implementation of HSDS maintenance and inspection programs in both Lorain and Medina portions of the Black River watershed; and 4) Establishing homeowner educational/outreach efforts regarding (NPS) effects. These initiatives are supported by the goals of Black River Remedial Action Plan (RAP) Long Range Plan and the 208 Water Quality Management Plan.

Urban Runoff

Large and small communities have storm sewer systems that discharge to all of the watershed basins. Urbanized pollutants such as road salts, vehicle fluids, litter, lawn chemicals and yard waste, and pet wastes are detrimental to local water quality. City ordinances and programs that help control these concerns are important. Community outreach and education is very important in minimizing these sources of pollution.

Sanitary Landfill/Industrial Sites

Up to the mid 1970's it was common for every community and township to have at least one garbage dump. Many of these dumps closed when state regulations required licensing and daily cover. Some of these abandoned garbage dumps certainly continue to degrade surface water and groundwater. The garbage dumps surviving the mid 1970's evolved into sanitary landfills. More stringent state regulations continue to upgrade all existing sanitary landfills. Leachate from closed and operating landfills can negatively impact local surface water quality. Sanitary landfills in this watershed are listed by county:

<u>Lorain County</u>

BFI-Oberlin Landfill (Plum Creek) 1976-Present
Cromwell Park Site (172 acres in city of Lorain) 1948-1976
Ford Road Landfill (15 acres in Elyria along west bank of Black River) 1900-1975

<u>Lorain County- continued.</u>

Garden Street Landfill (90 acres in Elyria) 1952-1978
Huntington Township Landfill (Clark Road) 1960's-1988
Carlisle Township Landfill (2 acres Nickle Plate Diagonal Road) pre 1965-1976

Eaton Township Landfill (5 acres on Island Road) pre 1967-1976
North Ridgeville Landfill (Cooke Road) 1967-1977
Rochester Township Dump (Anderson Road) 1965-1972
Wellington Village Township Dump (north of city WWTP) 1965-1970
Grafton Village Dump (Crook Street) pre 1965-1972

Medina County

Chatham~Litchfield Township Dump pre 1966-1970
Homer Township Dump pre 1966-1970
Spencer Township Dump pre 1966-1970

For more than 150 years industries have filled many areas with industrial wastes. The water quality impact from most of these nonpoint sources is currently unknown, however, one active slag pile on the east shoreline of the mainstem (at RM 5.8) appears to have caused non attainment for warm water habitat in 1992. Another area of concern is the Sandstone Quarry formerly owned by Republic Steel. It is located on the West Branch of the Black River at RM 1.8. Between 1950 and 1972, thousands of gallons of used pickle liquor were disposed at this site. Chromium, cadmium, zinc and arsenic are primary concerns with this site. Larson Consolidated Industries disposed of foundry sand between 1959 and 1984 in LaGrange Township and at Indian Hollow Road prior to 1979 in Carlisle Township. General Motors had an industrial sludge and landfill on Murray Ridge Road in Elyria between 1946 and 1979. Harshaw Chemical had a 1 acre chemical waste landfill in Elyria between 1950 to 1967.

Ross Industrial Disposal Landfill operated an 80 acre site on Giles road in Eaton Township between 1950 and 1979. They disposed of incinerator wastes and had industrial lagoons. U.S. Steel Corporation operated a 48 acre industrial landfill and lagoons between 1918 and 1980 off of East 28th Street in Lorain adjacent to the Black River Mainstem.

Riparian Corridor Protection

Vegetation along the embankments of streams and lakes offers many benefits to both aquatic and terrestrial biota including lower sedimentation rates through stream bank stabilization, filtration of run-off waters, food source, cooler water temperatures and more stable flows, and habitat enhancement. Protection of existing riparian corridors is as important as the need to reestablish vegetation. Conservation easements, land trusts, education, zoning ordinances and other responsible legislation are valuable tools for riparian corridor protection.

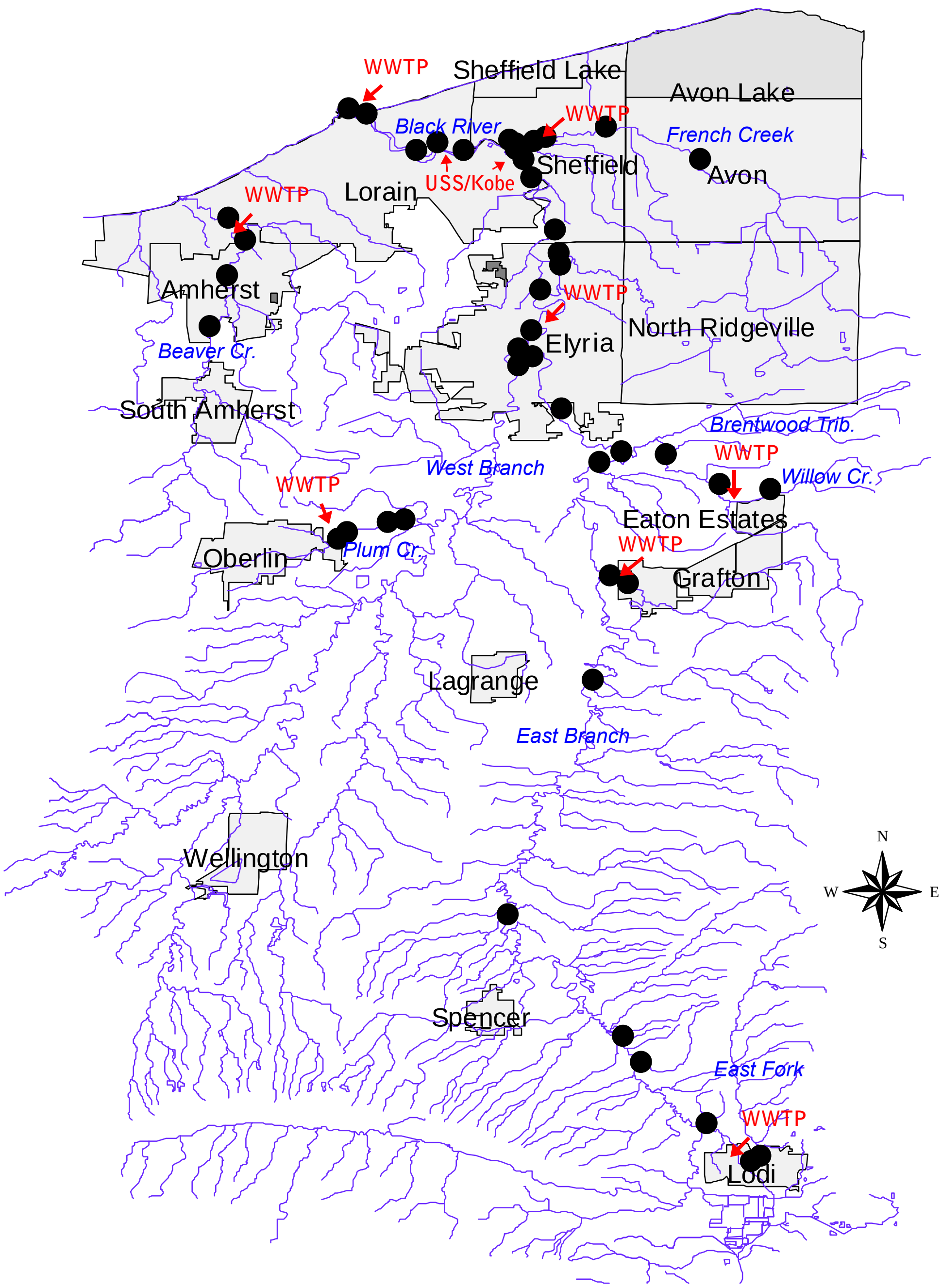


Figure 2. Water quality and biological sampling locations for the Black River basin survey, 1997 in relation to the evaluated point source dischargers.

Table 3. Sampling locations in the Black River study area, 1997 (C-conventional water chemistry, C_o-conventional water chemistry+organics, S-sediment chemistry, F-fish, B- quantitative artificial substrate macroinvertebrate sample, B_q-qualitative macroinvertebrate sample).

Stream/ RM	Location	Latitude/Longitude		Type of Sampling	USGS Topo
Black River					
15.00/14.95	Cascade Park	412237	820643	B, C_o, F, S	Avon
11.90	Spring Valley Country Club	412346	820612	B, C_o, F	Avon
10.60	Elyria WWTP Mix Zone	412439	820525	B_q-2x	Avon
9.80/10.10	Ford Rd.	412442	820545	B, C_o, F, S	Avon
8.80	Detroit Rd.	412532	820613	B, M, F	Avon
6.20	E. 31st St.	412635	820624	C_o	Avon
5.80	adj. Slag Pile,	412653	820630	F	Avon
5.50	ust. D-2 Landfill	412716	820648	B, F	Avon
5.20/5.30	ust French Creek, USS/Kobe outfall 006	412717	820658	B, C_o, F, S	Avon
4.80	dst French Cr., USS Kobe outfalls 006/001	412733	820742	B, C_o, F	Avon
3.60/3.80	dst. USS/Kobe outfall 005	412715	820806	B, F, S	Lorain
3.00	ust Turning Basin, USS/Kobe outfalls 003/004	412720	820850	F, C_o	Lorain
2.30/2.58	dst Turning Basin, USS/Kobe outfalls 003/004	412712	820915	B, C_o, F, S	Lorain
0.42	ust. U.S. Route 6 (Erie St.)	412754	821014	B, C_o, F, S	Lorain
0.10	At mouth dst. Lorain WWTP	412818	821057	B, C_o, F	Lorain
French Creek					
6.10	Detroit Rd. (S.R. 254)	412702	820211	C_o , F	
5.50	adj. Colorado Ave	412754	820227	B	Avon
3.20	Abbe Road	412750	830434	B, C_o, S, F	Avon
1.00	dst. N. Ridgeville WWTP	412737	820606	F	Avon
0.40	East River Rd.	412730	820621	B, C_o	Avon
West Branch Black River					
1.20	3rd Street	412118	820641	F	Grafton
0.20	Lake Ave.	412218	820645	C, B	Grafton
East Branch Black River					
41.50	Shaw Rd.	410511	820408	C, D	Lodi
40.40	Old Mill Road	410512	820410	F, B	Lodi
32.50	Smith Rd.	410812	820700	B, C, S, F	Lagrange
18.90	Vermont St.	411404	820455	B, D, S, F	Grafton
11.30	Parsons Rd.	411628	820401	B, C, S, F	Grafton
10.10	dst Grafton WWTP	411724	820454	B, C, D, F	Grafton
6.00	ust. Brentwood Trib.	411930	820438	B, C, F	Grafton
5.20	dst. Willow Creek	411958	820411	B, C, D, F	Grafton
3.00	Fuller Street	412049	820541	B, M, F	Grafton
0.30	Washington Ave	412207	820624	B, C	Grafton

Table 3. Continued.

Stream/ RM	Location	Latitude/Longitude		Type of Sampling	USGS Topo
East Fork East Branch					
2.70	Lodi Park	410224	820047	B, C, D, F	Lodi
2.10	Ust. Lodi WWTP	410204	820058	F	Lodi
0.06	Richman Rd.	410300	820203	B, C, D, F	Lodi
Willow Creek					
6.00	SR 82, Ust Eaton Estates	411850	820028	B_q, C, D	Grafton
4.83	Dst Eaton Estates, adj. Giles Rd.	411852	820144	B_q, C, F	Grafton
2.90	Durkee Rd.	411936	820304	B_q, C_o, F	Grafton
Beaver Creek					
7.0	Middle Ridge Rd	412251	821428	B, F	Grafton
4.60	W. Martin St.	412408	821359		Lorain
2.80	Cooper Foster Rd	412501	821332	B,F,C_o, D	Lorain
1.75	Longbrook Rd	412534	821359	C_o	Lorain
Plum Creek					
3.30	E. Lorain Street	411735	821114	B, F	Oberlin
2.90	Oberlin WWTP	411743	821101	B, F	Oberlin
1.60	Lorain County Landfill	411758	820956	F	Oberlin
0.80	Old US 20	411804	820936	B	Oberlin

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). Chemical, physical and biological sampling locations are listed in Table 3.

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 (see 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 comments and observations for each sampling location.

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 7-17). 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.

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 representing its relative level of tolerance on the 0 to 60 scale of the ICI. For the qualitative collections made for this study, the median tolerance value of all organisms from a site resulted in a score termed the Qualitative Community Tolerance Value (QCTV). The QCTV is a potential method to supplement existing methods using the natural substrate collections. Use of the QCTV in evaluating sites was restricted to relative comparisons between sites and was not unilaterally used to interpret quality of the sites or aquatic life use attainment status.

Macroinvertebrates were sampled at thirty-five locations (Table 3) in the Black River basin, French Creek, the East Branch, East Fork of the East Branch, Willow Creek, the West Branch, Plum Creek, and Beaver Creek (a direct tributary to Lake Erie). Both artificial (quantitative) and natural substrate (qualitative) samples were collected at most sites except mixing zones and in Willow Creek and the East Fork of the East Branch where only qualitative samples were collected. Lists of macroinvertebrate taxa and ICI metric scores from each site in the study area are available electronically on the Ohio EPA Division of Surface Water home page at http://chagrin.epa.ohio.gov/.

Fish Community Assessment

Fish communities were sampled twice at 4 to 5 week intervals at the same location for all locations except RM 32.5 of the East Branch, which was only sampled once. All samples were collected using either the longline or wading electrofishing methodology. Lists of fish species and their relative abundance and IBI metric scores from each site in the study area are available electronically on the Ohio EPA Division of Surface Water home page at http://chagrin.epa.ohio.gov/.

Area of Degradation Value (ADV)

An Area Of Degradation Value (ADV; Rankin and Yoder 1991; Yoder and Rankin 1995) 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 3). 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. The ADV in this study was simplified to an average percent deviation from respective criterion for the IBI, ICI and MIwb (Figure 2).

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.

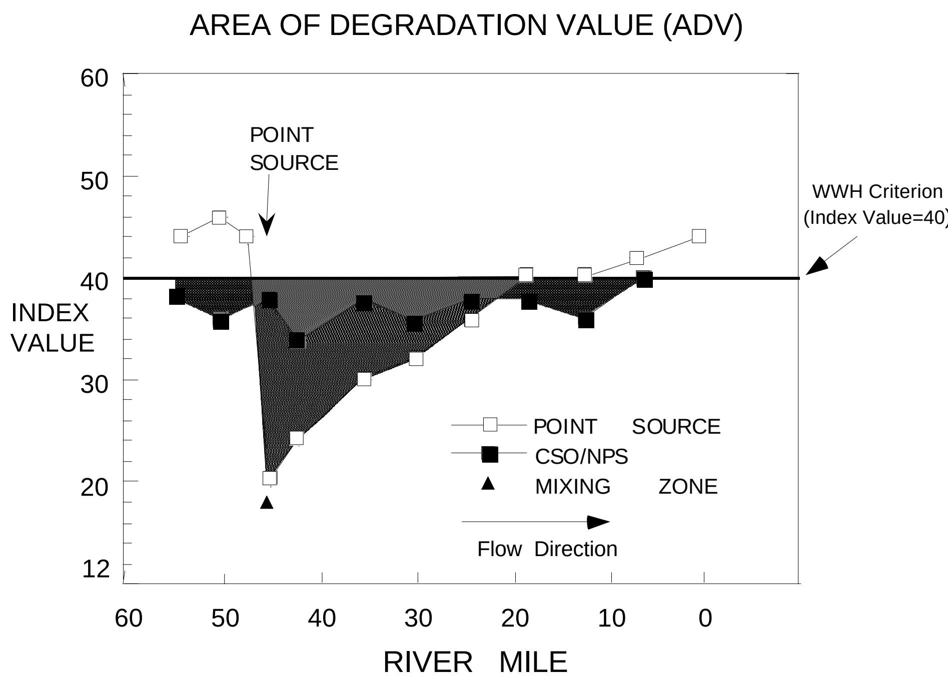


Figure 3. Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). the index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears 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.

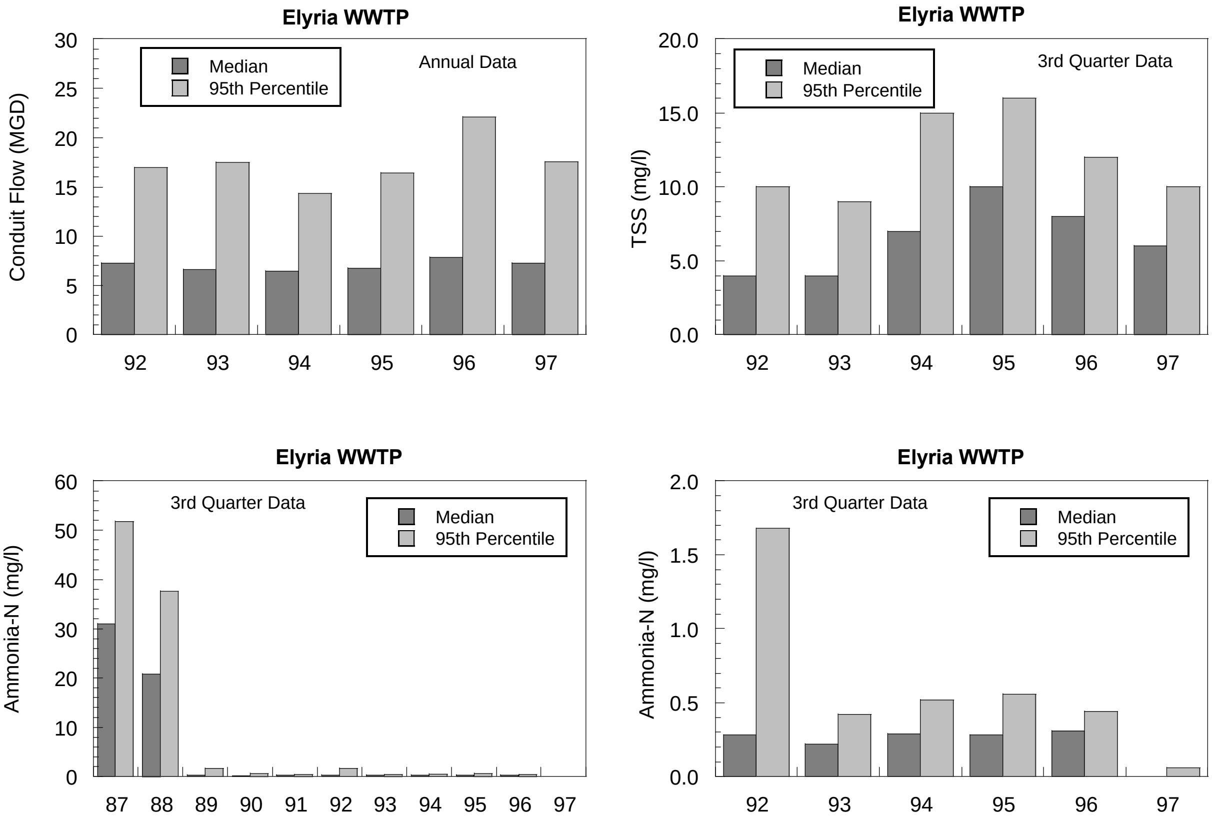
Pollutant Loadings: 1992-1997

Black River
City of Elyria WWTP(3PD00034):
The Elyria WWTP is a secondary treatment facility that receives sewage from a collection system consisting of approximately 180 miles of sewers. The plant receives domestic and industrial wastewaters and discharges the effluent into the Black River via a single outfall located at RM 10.6. Following a $38 million upgrade of the facility in 1987-89, the plant's average flow was expanded to 13 MGD. The plant is designed to fully treat peak flows up to 30 MGD and can provide primary treatment for peak flows up to 60 MGD. Treatment at the plant consists of screening, chlorination for odor control, grit removal, addition of ferrous chloride for phosphate removal, primary settling, biological treatment with trickling filters, polymer addition of sodium hydroxide for pH adjustment, aeration, further addition of polymer to aid settling of solids, final settling, disinfection through chlorination, and dechlorination using sulfur dioxide. All sludges are combined and are reduced in volume via anaerobic digestion. Dewatered sludge cake is transported to a local solid waste landfill for disposal.

A 1.6 MG wet weather storage tank is available at the Elyria WWTP to store inflows greater than 30 MGD for subsequent treatment. According to a study of wet weather events conducted by the City of Elyria between 1993 and 1995, the average daily inflow at the plant was 7.65 MGD. During this two year period, bypasses of the secondary treatment system occurred ten times during storm events (average inflow = 32.32 MGD). The operating practice at the Elyria WWTP includes automatic diversion of any flow greater than 30 MGD to the wet weather storage tank, with bypass to the stream occurring if the tank becomes full. Data submitted by the City of Elyria as part of the monthly operating reports to the Ohio EPA indicates that median flows through the Elyria WWTP have remained constant since 1992 (Figure 4), although peak flows exceeding the average plant design continue to occur.

Compliance sampling was conducted at the Elyria WWTP by the Ohio EPA on April 21-22 and August 11-12, 1997. Analyses of treated effluent from the plant found no exceedances of permitted effluent limits and no toxic organic compounds were detected. Bioassay testing of the treated effluent and from samples collected from the Black River found no acute toxicity associated with the discharge.

Monthly operating report data for the Elyria WWTP indicates that the facility upgrade completed in 1989 has resulted in consistently good effluent quality. Concentrations of suspended solids, cBOD and especially NH_3-N have been well below the permitted limits (Figure 4), and have been significantly reduced compared to those observed prior to the plant improvements. Figure 4 shows the pre- and postupgrade loadings for NH_3-N as an example of the pattern observed for other parameters.



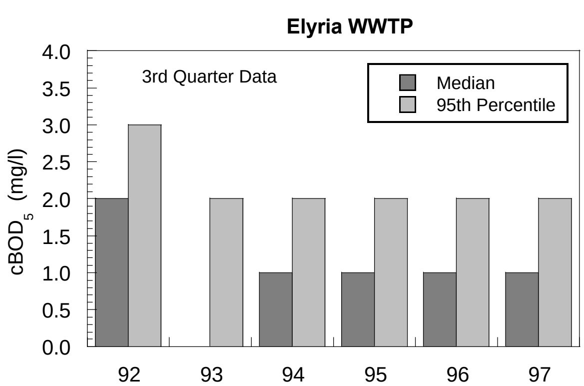


Figure 4. Annual effluent flow and third quarter effluent concentrations of total suspended solids, ammonia-nitrogen (1987 - 1997), ammonia-nitrogen (1992 - 1997), and 5-day carbonaceous biological oxygen demand for the Elyria WWTP.

The City of Elyria is currently in process of developing a long term control plan for combined sewers found in their collection system. The purpose of the long term control plan is threefold: 1) to characterize the collection system and overflows utilizing data collected from monitoring and modeling the sewer system and the Black River; 2) to identify areas served by combined and separate sewers; 3) to minimize the impacts of separate sanitary sewer flows on CSO discharges; and 4) to propose an implementation schedule for necessary sewer system improvements which will increase the treatment of wet weather flows at the WWTP. The plan, which was originally due on November 1, 1997, was submitted to the Ohio EPA on June 29, 1998 (Montgomery Watson, 1998). The plan is currently undergoing review by the Ohio EPA. An updated listing of CSO and SSO locations as well as recently completed improvement projects is provided in Appendix Table 1 of this report.

USS/Kobe Steel (3ID00028):
The USS/Kobe Steel Company owns and operates an integrated steel manufacturing facility in Lorain, Ohio. The facility consists of iron and steel making operations using the basic oxygen process (BOP) and various finishing and semi-finishing operations. The facility does not conduct steel processing operations that include sintering, pickling or metal coating. Water from the Black River is used in the plant as cooling water and for various processes within the plant. Of the water used in the facility, approximately 98 percent is used as non-contact cooling water and approximately 2 percent is used as process water. Non-contact cooling water and process wastewaters are discharged through five separate outfalls from the facility. A sixth outfall (Outfall 006) discharges treated leachate and accumulated stormwater from a closed hazardous waste landfill site designated as the D-2 landfill. A summary of each outfall and the associated processes generating wastewater associated with each is given in Table 4.

Several changes resulting from the modernization of the USS/Kobe facility have occurred since the last intensive survey of the Black River conducted in 1992. These changes include the installation of a second continuous caster (#2 Continuous Bloom Caster), a vacuum degasser, the Bloom Reheat Furnace, and a second ladle metallurgy facility (No. 2 LMF).

The installation of the #2 Continuous Bloom Caster was approved by the Ohio EPA in 1993 and was completed in 1995. This system utilizes both contact and non-contact cooling water. Contact cooling water from this process is re-used in the BOP scrubber system. Blowdown from this system is treated and discharged via internal outfall 603 which contributes to the wastewater stream discharged via outfall 003 to the Black River. Non-contact cooling waters from the second continuous caster are discharged to the Black River via outfall 002.

The Bloom Reheat Furnace is used in conjunction with the Continuous Bloom Caster at the facility to reheat steel produced by the process prior to rolling the steel in the No. 4 Blooming Mill. This process also generates non-contact cooling water which is discharged via outfall 002. Process wastewater from the Bloom Reheat Furnace (flume flush water) is discharged to the outfall 001 water recycle/treatment system.

Table 4. Summary of Wastewater Treatment at the USS/Kobe Steel Company in Lorain, Ohio based upon NPDES Permit Effective November 1, 1994.

Outfall Number	Discharge Point (RM)	Flow (MGD)	Process Generating Wastewater	Treatment Process[1]
001	5.05	1.2	Process wastewater (hot and cold forming operations, flume flush, and bloom reheat furnace), non-contact cooling water, storm water	Scale pits (process WW only), polymer addition, settling, oil removal and recycle.
002	3.50	0.14	Emergency overflow (caster spray system), non-contact cooling water (BOP), storm water.	None
003	2.65	57.9	Non-contact cooling water (power house, blast furnace), blowdown from treatment system for the BOP scrubber system.	None (cooling water). Treatment systems for caster spray water treatment system, vacuum degasser treatment system and BOP scrubber system associated with this outfall via discharge point 603. Blowdown from the BOP scrubber system treated using polymer addition and gravity settling.
004	2.60	44.9	Non-contact cooling water (power house), blowdown from blast furnace treatment system.	Blast furnace treatment system includes clarification, thickening, filtration and recycle with blowdown to outfall 004 via discharge point 602.
005	3.95	11.3	Non-contact cooling water (bar mill), storm water	None
006	5.60	0.04	Runoff and leachate from the D-2 hazardous waste landfill.	Settling, coagulation, filtration and carbon absorption (operated by USX Corp.).

[1]Note: as of 9/29/95 each outfall has been equipped with dechlorination equipment.

Also associated with the installation of the #2 Continuous Bloom Caster was the installation of a vacuum degasser that is used to remove gaseous impurities from the molten steel. Condensate wastewater generated from this process is treated and recycled, with blowdown being used as makeup in the caster recycle water system. Some of this water is blown down to the BOP scrubber system as make up water. In 1994, the Ohio EPA approved the installation of the No. 2 LMF at the USS/Kobe facility. The additional process was installed in 1995 and generates non-contact cooling water which is blown down to the vacuum degasser system described above.

Other significant activities associated with the operations at the USS/Kobe facility included the installation of dechlorination equipment added to outfalls 001, 002, 003, 004, and 005 in 1995. In addition, the pipe mill lagoon associated with the outfall 001 treatment system was dredged during 1996 and was completed during the period of February through April of 1998. The removal of accumulated solids in the pipe mill lagoon was conducted in order to re-establish proper retention times in the impoundment for the treatment process. A total of 38,268 wet tons of sediment was removed from the lagoon and disposed of in a solid waste landfill.

Compliance sampling was conducted by the Ohio EPA at outfalls 001 and 006 in 1997. Sampling occurred on November 4-5, 1996 and July 28-29, 1997. Sampling of the outfall 006 effluent was limited during the November 4-5, 1996 sampling event because the discharge was shut off. A noticeable oil sheen was observed on the wastewater effluent discharged via outfall 006 and on the Black River in the vicinity of the discharge during both sampling events. Oil and grease concentrations were measured at 3.66 mg/l on November 5, 1996 and at 33.7 mg/l on July 29, 1997. The sampling documented a violation of the facility's NPDES permit, which limits oil and grease concentrations to 10 mg/l. All other permit limits were met for both outfalls, and bioassay testing found that neither outfall had any associated acute toxicity. No toxic organic compounds were detected in any of the effluent samples collected from the facility. Violations of permitted effluent limits for the USS/Kobe discharges are summarized in Appendix Table 2 of this report.

The following summarizes trends in self-monitoring data for outfalls 001 - 006, 1992 through 1997:

Outfall 001:
Flows from the 001 outfall have remained fairly stable since 1992 (Figure 5), with median daily flows ranging from 0.71-2.21 MGD based upon annual data. Periodic exceedances of the average design flow of 1.2 MGD for this outfall are common, likely due to runoff entering the pipe mill lagoon treatment system during storm events. Despite the periodic high flows, the treatment system has been efficient in controlling concentrations of total suspended solids (Figure 5). Median concentrations for total suspended solids from outfall 001 have ranged from 8-11 mg/l during the 1992-1997 period. One consequence of fluctuating flow in the outfall 001 treatment system may be impacts on the removal efficiency for oil and grease. Five exceedances of the permitted concentration of 10 mg/l have been reported from the 001 outfall since 1992. In addition, visual observations by Ohio EPA staff during the 1997 intensive survey of the Black River have confirmed the presence of an oil sheen and oil stained banks and vegetation in the vicinity of the discharge on

occasion. Additional controls or operation and maintenance improvements capable of controlling the amounts of oil and grease discharged from this location should be evaluated and implemented to eliminate this problem. By way of comparison, discharge flow, and loadings of total suspended solids, and oil and grease have all decreased by an order of magnitude since 1985.

Outfall 001 has been monitored for whole effluent acute and chronic toxicity by the company on a quarterly basis since January of 1995. Of the fifteen quarters of data compiled at the time of this writing, none of the bioassay tests have found acute toxicity associated with the discharge. However, six of the fifteen (40%) tests have found the effluent to possess chronic toxicity for fathead minnows (*Pimephales promelas*), and ten of the 15 tests (67%) found chronic toxicity for *Ceriodaphnia dubia* (water flea). The geometric mean for the calculated chronic toxicity units (TU_c) is 2.35 TU_c for *P. promelas* and 2.45 TU_c for *C. dubia*. In-stream toxic effects (decreased *C. dubia* reproduction, decreased *P. promelas* growth rates, or both) was identified in the Black River downstream from outfall 001 during six (40%) of the sampling events. In-stream toxicity was detected in only one (7%) of the samples collected from the Black River upstream of the facility. The bioassay data collected by the company correlates well with results from biological sampling conducted by the Ohio EPA in the vicinity of the discharge, where a significant decline in the Index of Biotic Integrity (IBI) scores for the fish community downstream of the 001 outfall was observed. These results indicate that a plant performance evaluation specified in OAC 3745-07 (B)(3) should be conducted to determine and eliminate sources of toxicity in the outfall 001 and that permit limits for whole effluent toxicity may be necessary for this discharge. The results of the biomonitoring program for this outfall are summarized in Appendix Table 3 of this report.

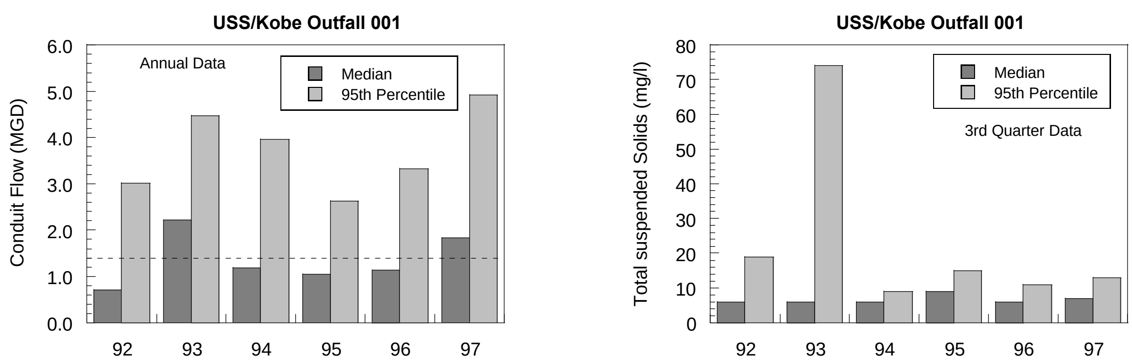


Figure 5. Median and 95th percentile conduit flows and effluent concentration of total suspended solids, 1992 - 1997, for the USS/Kobe Outfall 001.

Outfall 002:
Effluent flow rates from outfall 002 increased dramatically following the installation of the second continuous caster, bloom reheat furnace, vacuum degasser, and the second LMF in 1994 and 1995 (Figure 6), such that flows now equal those of the early 1980s. However, loadings of total suspended solids and NH_3-N remained stabled at rates an order of magnitude lower than the early 1980s. Median flows from outfall 002 increased from a range of 0.63-1.08 MGD during the period of 1992-1994 to 22.00-43.70 MGD during 1995-1997 (using annual data). A concomitant increase in outfall 002 effluent temperature also occurred during this period, with median third quarter temperatures of the 002 effluent increased from 20.1-25.4°C during the period of 1992-1994 to 26.8-26.9°C following the changes at the facility (Figure 6). Although net thermal loadings from outfall 002 were well within the permitted limit of 120 BTU/hr (Figure 6), the permitted loading may not be protective of water quality, since in-stream temperature violations were noted during the ambient water quality sampling conducted for this study (see chemical water quality section).

Changes within the USS/Kobe facility affecting outfall 002 seem to have had little impact in the concentration of total suspended solids in the effluent (Figure 6). However, concentrations of NH_3-N and fecal coliform bacteria counts have decreased significantly (Figure 6). The outfall 002 collection system receives discharges from sanitary sewer overflows from the City of Lorain sewer system impacting effluent quality. The observed reductions in NH_3-N and fecal coliform bacteria are likely the result of dilution effects caused by increased flows of non-contact cooling water through the outfall 002 system rather than improvement in the sanitary sewer overflow or process changes within the USS/Kobe facility.

Outfall 002 has been monitored for whole effluent acute and chronic toxicity by the company on two occasions in 1995. No acute toxicity was found associated with the effluent on either occasion. Chronic toxicity to *C. dubia* (3.3 TU_c) was identified during one of the sampling events. No chronic toxicity was identified for *P. promelas*. Further biomonitoring of this discharge may be warranted to determine if plant performance evaluation or permit limits relating to whole effluent toxicity are warranted.

Outfall 003:
Median effluent flows from outfall 003 have declined by over 50 percent from 1994 to 1997 (Figure 7) as a result of process changes within the USS/Kobe facility. Peak flows, as represented by 95^{th} percentile flow data have also declined somewhat, but not as dramatically as median flows. Peak flows may be up to 20 MGD higher than median flows, indicating that storm events may have a significant effect on flow within the outfall 003 collection system. Chemical effluent quality from the 003 outfall has remained consistent since 1992. Ammonia-nitrogen concentrations have been well within permitted limits (Figure 7), with median concentrations below 0.5 mg/l for the entire period). Median total suspended solids concentrations have also remained consistent, ranging from 27-42 mg/l. The impact of high flow events in the Black River, which is the source water for all of the process and non-contact cooling waters within the USS/Kobe facility, and stormwater runoff events is evident through observation of the 95^{th} percentile total suspended solids data for outfall 003

which ranged from 85 to 213 mg/l during the study period. Though flows or loadings of NH_3-N have decreased or remained stable since 1994, loaing rates reported in 1997 were within the range of those reported since 1982.

Median third quarter effluent temperatures have remained consistent throughout the 1992-1997 period (Figure 7), ranging from 26.1-33.8°C. However, thermal loading from outfalls 003 and 004 (reported as pooled data in monthly operating reports) has decreased markedly (Figure 7). This decrease occurred in 1996 and 1997 following a period of steadily increasing thermal loadings which occurred from 1992 to 1995. Median third quarter thermal loading increased from 141 BTU/hr in 1992 to 472 BTU/hr in 1995. Median third quarter thermal loadings during the 1996-1997 period decreased to 208 BTU/hr following the process changes which occurred at the facility in 1995.

Outfall 004:
Trends in effluent flow for outfall 004 followed the same general pattern as that observed for outfall 003 during the study period (Figure 8), however flows and loadings from 004 for the 1992-1997 period were higher by a factor of 2-3 than those in the previous decade. From 1992 through 1995, median flows increased from 24.0 to 40.5 MGD, but then were reduced to 31.7-30.8 MGD during 1996-1997. Median third quarter effluent temperatures also increased steadily from 1992 (29 °C) to 1995 (34.8°C), and then declined in 1996 and 1997 (median = 28.1°C in 1997) (Figure 8). Also similarly to the outfall 003 data, chemical effluent quality at outfall 004 was consistent during the study period (Figure 8). Fluctuations during this time period were again probably more reflective of changes in Black River intake water than to processes within the USS/Kobe facility.

Outfall 005:
Flows from the 005 outfall doubled between 1982-1992, but since 1992, flows have declined slightly (Figure 9). Median conduit flow values have decreased from 11.10 MGD in 1992 to 9.76 MGD in 1997. Effluent temperatures and net thermal loadings (Figure 9) have been more variable than those observed at other outfalls at the facility, probably due to fluctuations in the contribution of stormwater in the effluent flow. As with other outfalls at the facility which are affected by stormwater flows, wide differences in the median and 95th percentile concentrations of total suspended solids in the effluent are observed over time, indicating changes in the source water and runoff impacts caused by storm events (Figure 9).

Outfall 006:
Flows from the USS/Kobe 006 outfall are extremely small compared to the remainder of the wastewater outfalls from the facility (Figure 10). Median flow rates from outfall 006 ranged from 0.020-0.026 MGD for the 1992-1996 period, and fell to 0.014 MGD in 1997. The company has indicated that the design flow for this outfall should be reduced from 0.032 MGD to 0.015 MGD in the permit renewal application submitted for the facility.

Chemical effluent quality from the outfall 006 treatment system has shown an improving trend since 1992. Although concentrations of NH_3-N and COD in the outfall 006 effluent have remained relatively constant over time, other parameters such as heavy metals including copper as an example (Figure 10), have steadily decreased in concentration. This trend could be indicative of the cumulative leaching of mobile metals from the D-2 landfill waste over time resulting in a more dilute leachate.

Overall Trends:
The trends for effluent flows for the five major wastewater outfalls from the USS/Kobe facility are pooled in Figure 11. Total flows from the facility steadily increased from 1992 to 1995, and then decreased by approximately 20 percent between 1995 and 1996, when the total flows equaled 96.9 and 91.6 MGD, respectively. These overall changes in water effluent flow are reflected in the NPDES permit renewal application which reflects a 21.3 percent decrease in average daily flows, from 130.93 to 102.92 MGD. Distribution of the total flow between outfalls has also changed during the 1992-1997 period, mainly because of the process changes at the facility which have resulted in increased effluent flows at outfall 002. Effluent flow at outfall 002 has increased from approximately one percent of the total effluent flow during the period of 1992-1994 to 12.9-24.0 percent of the total flow during the 1995-1997 period. At the same time, flows from outfall 003 have decreased from 59.2 percent of the total flow in 1993 to 29.7 percent of the flow in 1997. Another factor which will impact flows over the long term is the reduction to only one active blast furnace at the USS/Kobe facility which occurred in mid-1998. Changes in proposed average daily flow rates for outfalls 001-006 from the USS/Kobe described in the NPDES permit renewal application are listed in Table 5.

Trends in net thermal loadings to the Black River from USS/Kobe are also summarized in Figure 11. The trends are largely flow dependant, and follow closely the trends for effluent flow. The primary issue this raises, with respect to ambient water quality in the Black River, is that impacts from thermal loads have essentially been transferred one mile upstream from outfalls 003 and 004 (RM 2.60-2.65) to outfall 002 (RM 3.5). The impacts of this change are discussed in the water quality section of this report.

It is difficult to assess the overall impact of the wastewater discharges from the USS/Kobe facility using chemical parameters alone because of confounding factors associated with interactions with the Black River. These include the high ambient concentrations of suspended solids in the Black River, which is used as the water supply for the USS/Kobe complex, and the relative location of water intakes for the facility with respect to the discharge point. Intake 902 is located downstream of outfalls 006, 001, and 005, and intake 901 is located downstream of these outfalls and outfall 002. Therefore, water taken into the facility contains not only pollutants transferred by the river downstream from the watershed, but also some of those previously discharged by the facility. In addition, USS/Kobe does not directly measure the flow of water taken into the facility, so that any mass balance approach for chemical-physical analyses of the impacts of the facility must use estimated inflow values.

Table 5. Proposed Changes in Permitted Average Daily Flows from Outfalls at the USS/Kobe Steel Facility in Lorain, Ohio[1].

Outfall	1994 Permitted Flow (MGD)	Proposed Flow (MGD)
001	1.20	2.58
002	15.00	20.06
003	58.00	42.81
004	45.00	28.08
005	11.70	9.37
006	0.032	0.015
Total	130.93	102.92

With these cautions taken in mind, estimates of the net effects of the USS/Kobe facility on NH_3-N and total suspended solids loadings are presented in Figure 11. Intake flow values were estimated by adding evaporative losses from the facility water flow diagram included with the USS/Kobe NPDES permit renewal application dated November 11, 1993 to the reported effluent flow values for the outfalls at the facility. Based upon this limited analysis, it appears that the USS/Kobe facility has been either neutral or a net sink for both pollutants over the 1992-1996 time period, with up to 17.37 kg/day of NH_3-N and 3,392 kg/day of suspended solids removed from water passing through the facility. It is interesting to note that the facility was a net source for both pollutants in 1997, in contrast to all of the preceding years. In 1997, median (third quarter) net loadings of NH_3-N equaled 17.37 kg/day and median (annualized) loadings of total suspended solids equaled 1,460 kg/day.

The data in Figure 11 are provided for illustrative purposes and cannot be considered accurate for modeling impacts on ambient water quality in the Black River. In order to fine tune understanding of the impacts of the facility on the river, the collection of accurate water intake flow values should be included in future permits for the USS/Kobe facility so that the net impacts of the facility can be accurately assessed. If the trends observed in Figures 54 and 55 are found to be accurate, a re-assessment of the permitted limits for the USS/Kobe effluent streams may be justified in order to protect ambient water quality.

[1]Source: USS/Kobe NPDES Permit Renewal Application, September, 1998.

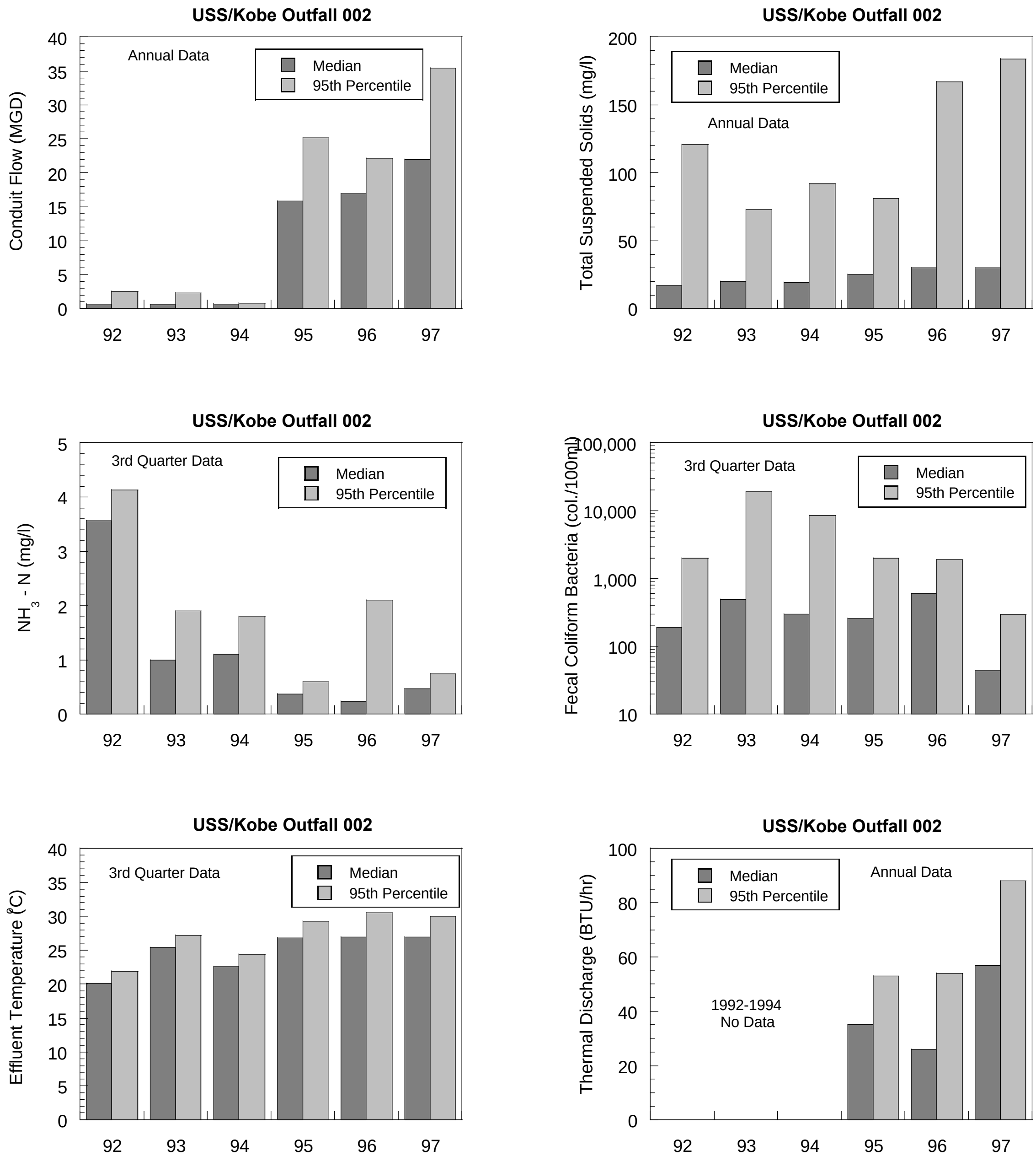


Figure 6. Median and 95th percentiles of annual conduit flows and effluent concentrations of total suspended solids, 3rd quarter ammonia-nitrogen and fecal coliform concentrations, 3rd quarter effluent temperature, and annual thermal discharge for the USS/Kobe Outfall 002.

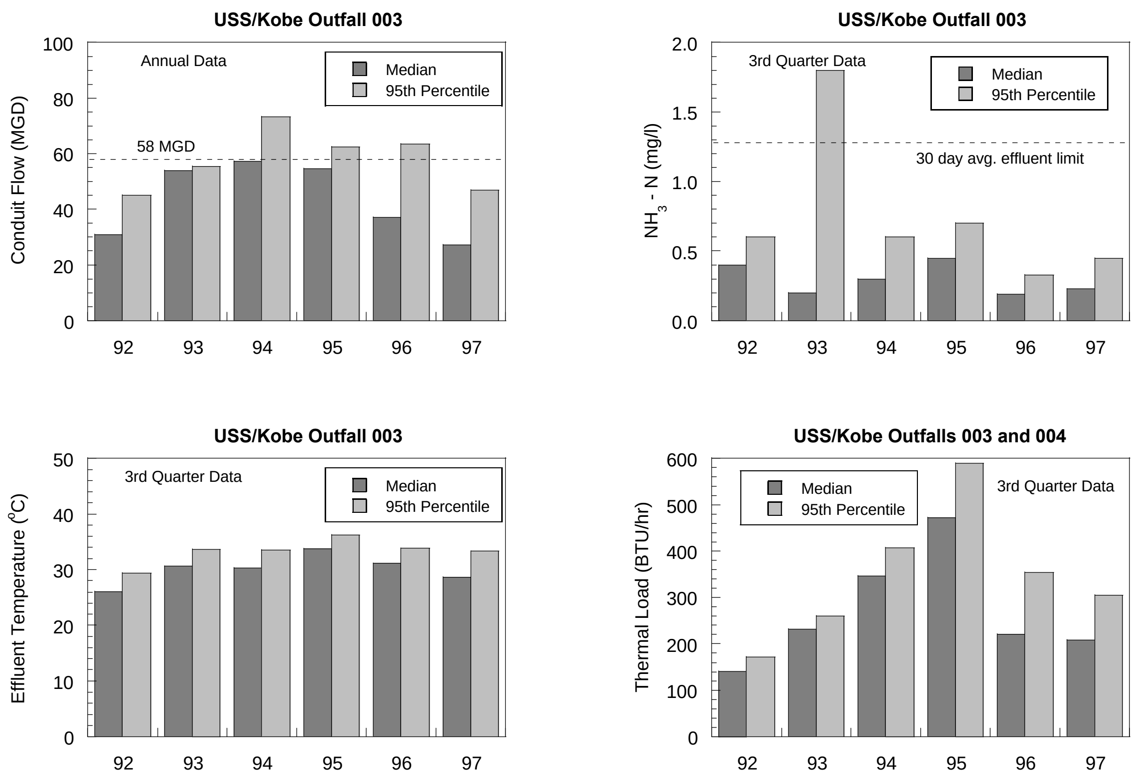


Figure 7. Median and 95th percentiles of annual conduit flows, 3rd quarter effluent concentrations of ammonia-nitrogen, temperature, and thermal loadings, 1992 - 1997, for the USS/Kobe Outfall 003.

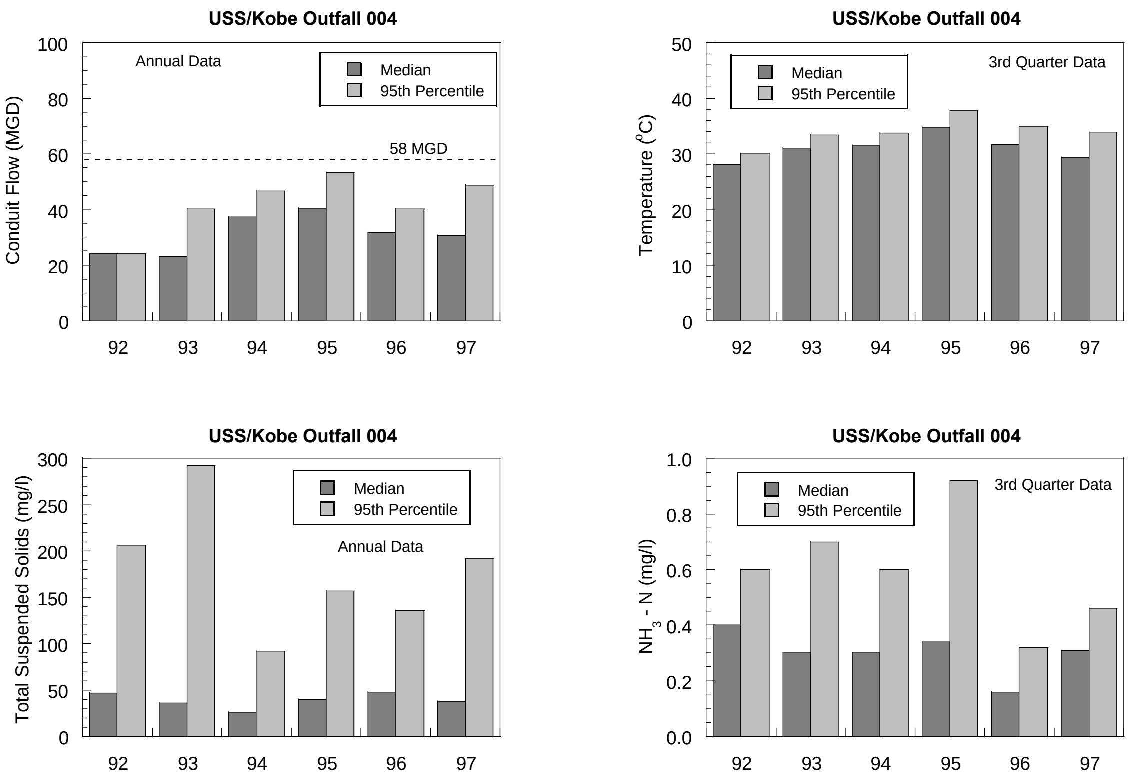


Figure 8. Median and 95th percentiles of annual conduit flows, 3rd quarter effluent temperature and concentrations of total suspended solids and ammonia-nitrogen, 1992 - 1997, for the USS/Kobe Outfall 004.

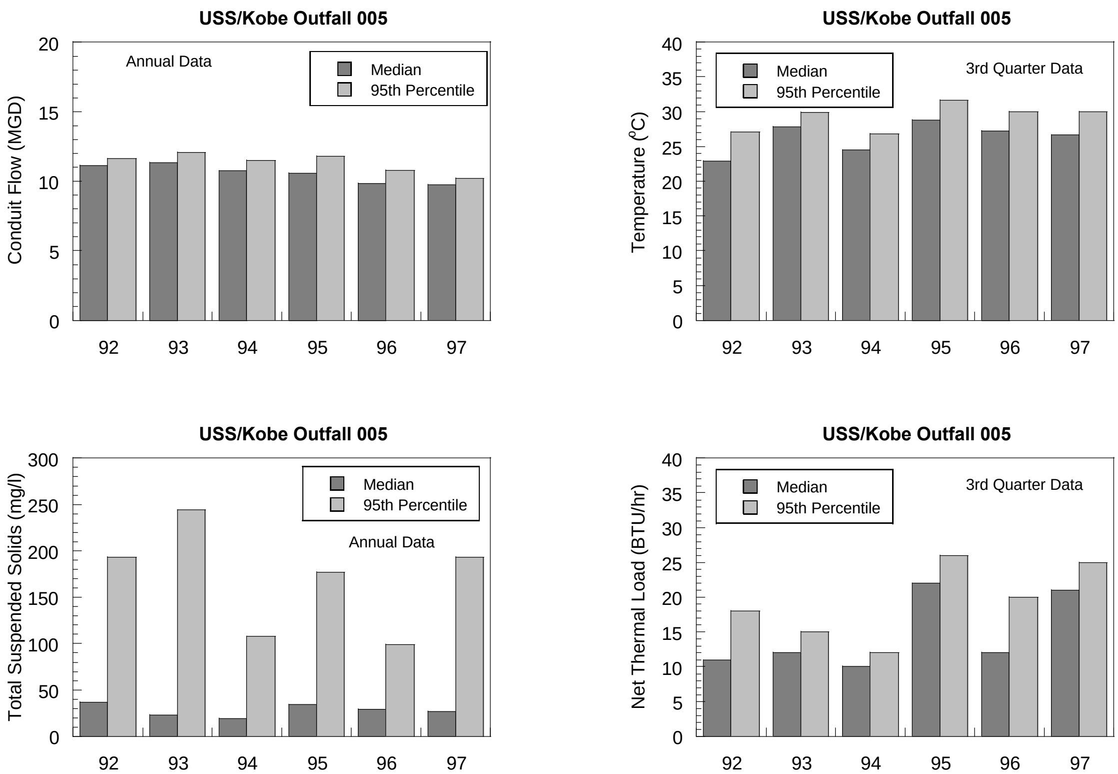


Figure 9. Median and 95th percentiles of annual conduit flows, 3rd quarter effluent temperature and concentrations of total suspended solids and thermal loadings, 1992 - 1997, for the USS/Kobe Outfall 005.

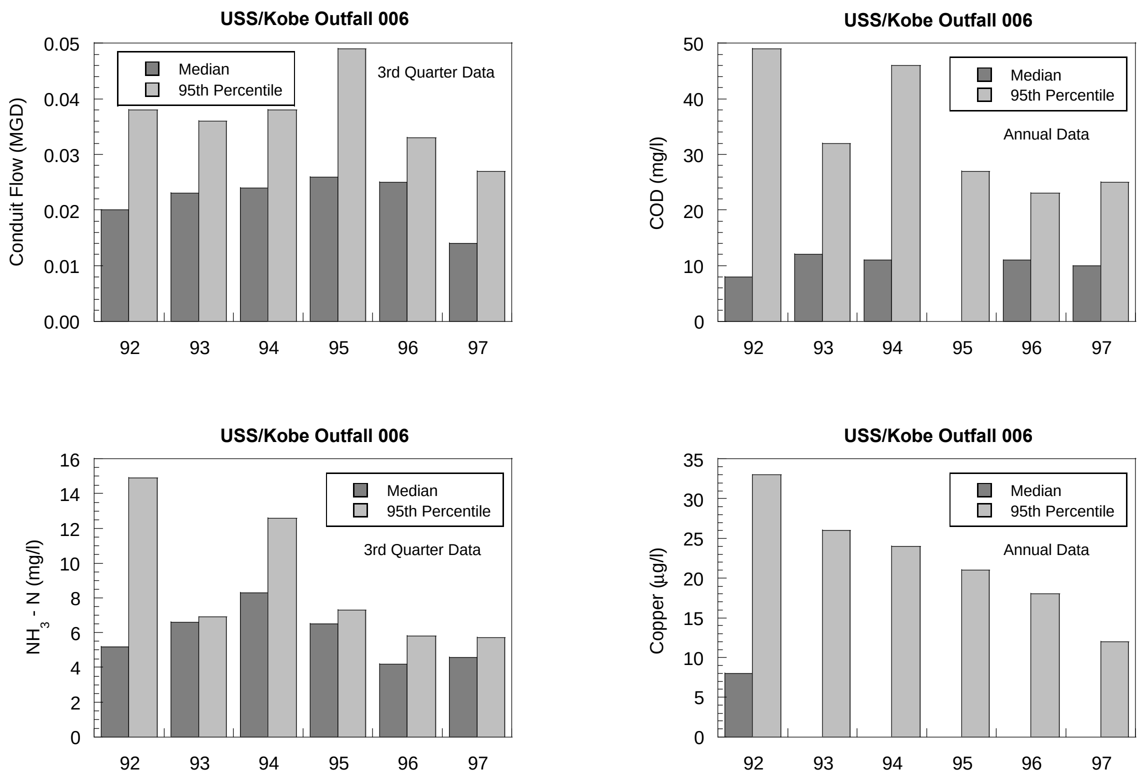


Figure 10. Median and 95th percentiles of annual conduit flows, 3rd quarter effluent concentrations of chemical oxygen demand and ammonia-nitrogen, and annual loadings of copper, 1992 - 1997, for the USS/Kobe Outfall 006.

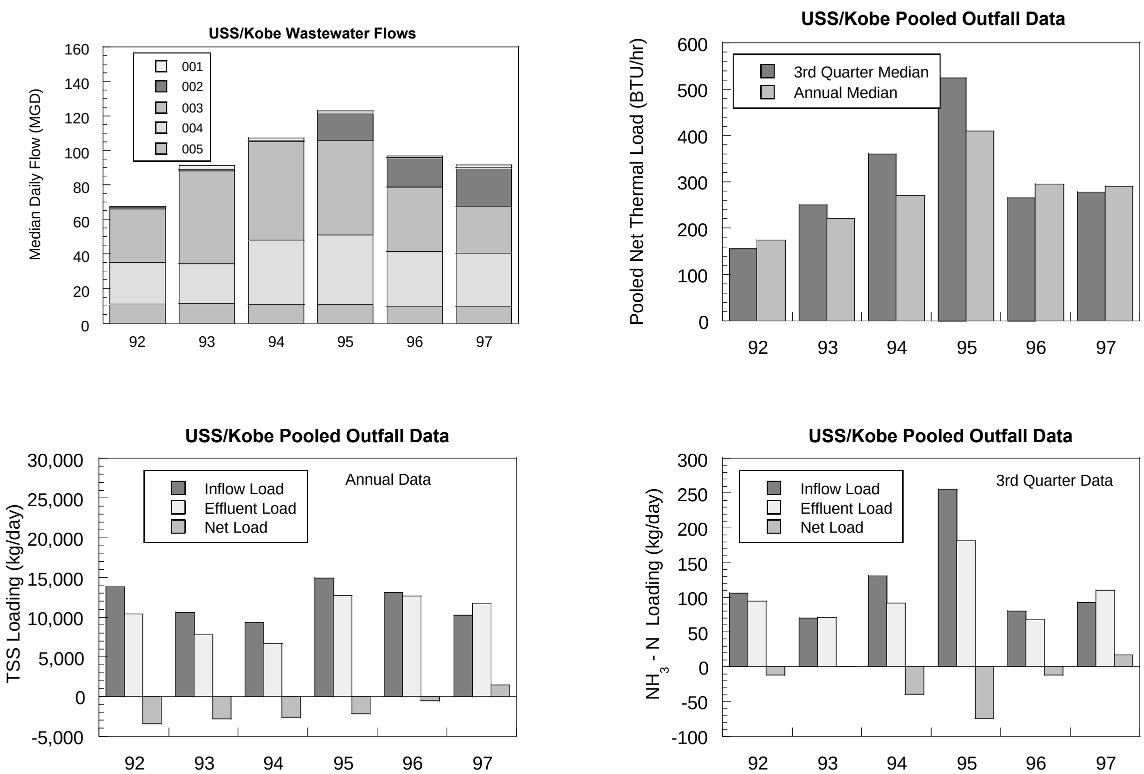


Figure 11. Pooled data for all USS/Kobe outfalls: median annual conduit flows, annual and 3rd quarter net thermal loadings, annual net loadings of total suspended solids, 3rd quarter loadings of ammonia-nitrogen, 1992 - 1997.

City of Lorain (Black River) WWTP (3PE00005):
The City of Lorain operates a secondary wastewater treatment plant located on the east side of the mouth of the Black River (outfall located at RM 0.08). The Lorain WWTP is permitted for an average flow of 15 MGD, with treatment consisting of pre-aeration, primary settling, aeration, final settling, disinfection using chlorine, and dechlorination using sulfur dioxide prior to discharge to the Black River. A portion of the flow from the plant was diverted to the Lorain West WWTP in 1988. Since then median flows have remained fairly constant over time (Figure 12), while peak flows, as represented by the 95th percentile, have been more variable. These differences in peak flows observed between years is likely the result of differences between precipitation patterns rather than operational practices, as evidenced by a similar pattern for 95th percentile effluent fecal coliform bacteria during the summer months (Figure 12). Concentrations of total suspended solids and phosphorus in the Lorain WWTP effluent have also remained relatively constant over time (Figure 12). However, median summertime effluent concentrations and loadings of $cBOD_5$ have been steadily increasing since 1992 (Figures 12). The WWTP has generally been able to meet the permitted effluent limits for this pollutant, and it is unclear what is causing this observed increase. In 1997, a partial upgrade of the WWTP was completed to include a belt filter press for sludges, which has reduced the volume of solids generated by the facility.

Effluent limits for the Lorain Black River WWTP are based upon a presumption that the plant discharges directly to Lake Erie. The justification for this assumption is the close proximity of the discharge to the mouth of the Black River. As a result, there is currently no effluent limit for NH_3-N in the NPDES permit for this facility. Consistently high concentrations of NH_3-N are discharged from the WWTP during the summertime period (Figure 12) with coincident high loading values. The combination of much higher relative toxicity of NH_3-N to aquatic organisms at higher temperatures and the frequent changes in flow regime at the mouth of the Black River in response to changes in lake level indicates that the appropriateness of the application of NH_3-N limits to this discharge should be evaluated. There exists a potential for adverse impacts on the biota of the lower river from this discharge under conditions of rising lake levels and high temperatures when the effluent water mass either is pushed upstream or if it becomes stagnated in the vicinity of the discharge. Further evaluation of this potential is warranted.

Compliance sampling was conducted at the Lorain WWTP by the Ohio EPA on April 21-22 and August 18-19, 1997. Analyses of treated effluent from the plant found no exceedances of permitted effluent limits. However, high concentrations of NH_3-N were detected during both sampling events. The effluent ammonia concentration was 17.7 mg/l during the April 21-22, 1997 sampling event and was 5.73 mg/l on August 18-19, 1997. Toxic volatile organic compounds were detected during both sampling events. Compounds detected included chloroform, bromochloromethane, 1,4 dichlorobenzene, methylene chloride, and toluene. None of these compounds were detected in concentrations greater than 5 μg/l. The source of these volatile organic compounds is unclear, although they could result from urban runoff, diffuse industrial sources, or carryover from compounds commonly formed when city water is disinfected by chlorination. Bioassay testing of the treated effluent found no acute toxicity associated with the discharge.

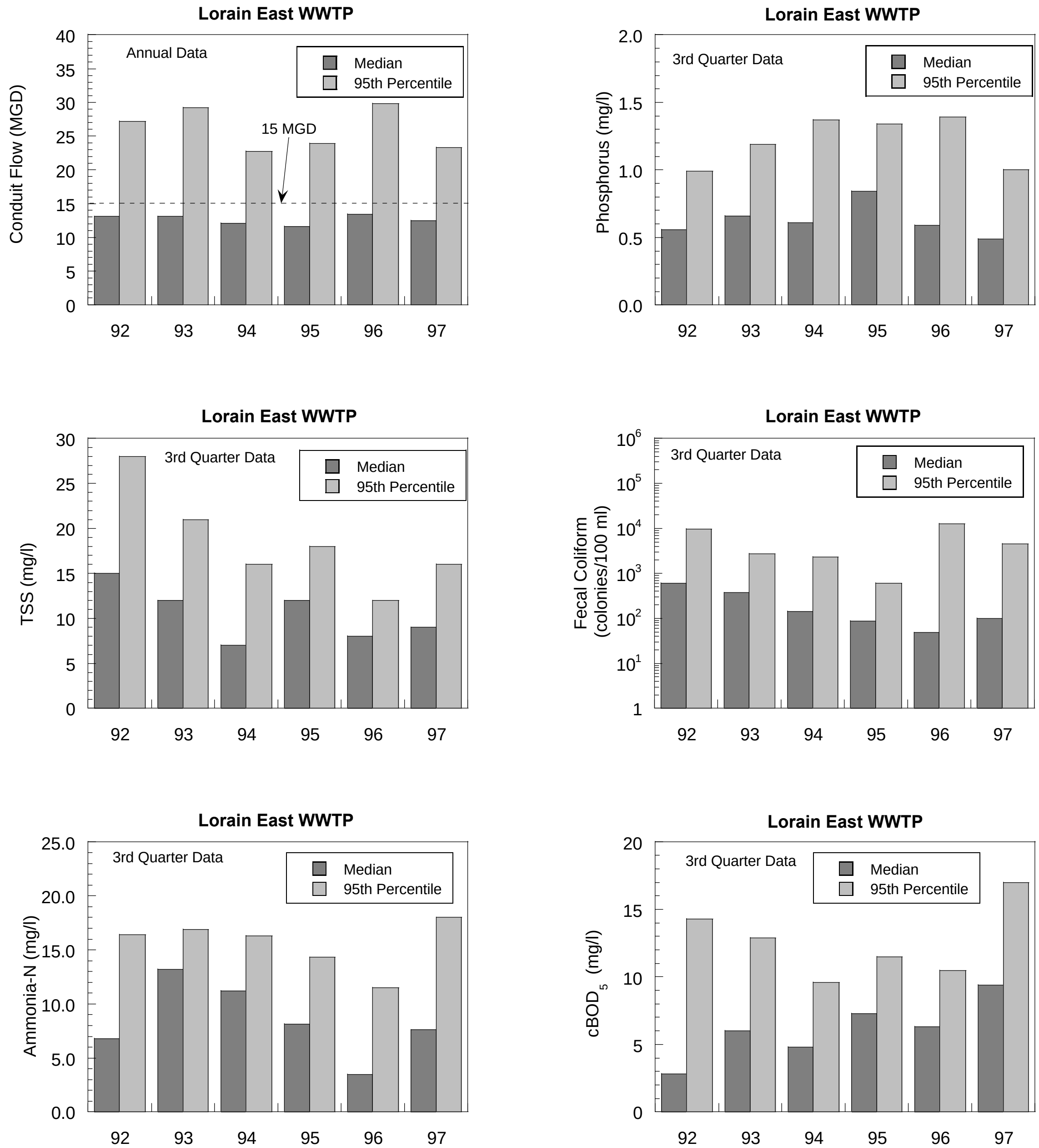


Figure 12. Median and 95th percentiles for conduit flow, and effluent concentrations of phosphorus, total suspended solids, fecal coliform colonies, ammonia-nitrogen and 5-day carbonaceous biological oxygen demand by the Lorain Black River (East) WWTP, 1992 - 1997.

There are currently 22 Separate Sewer Overflows (SSOs) associated with the sewage collection system for the City of Lorain WWTP. The city has provided a schedule and implemented a program to study and eliminate these SSOs by the year 2003. A permit to install to begin addressing the elimination of SSOs was issued by the Ohio EPA on October 1, 1998 when the Tacoma area retention basin and relief sewers project was approved. In addition, the City is conducting other activities to reduce inflow and infiltration to minimize the impacts of the SSOs on an ongoing basis. Examples include the installation of rain guards around sewer openings, sealing manholes, and the inspection and repair of broken sewer pipes, sewer connections and broken manhole castings. Monthly reports are provided to the Ohio EPA to summarize these activities and to provide data regarding overflow events. The SSO elimination schedule developed by the City of Lorain is provided in Appendix Table 3 to this report.

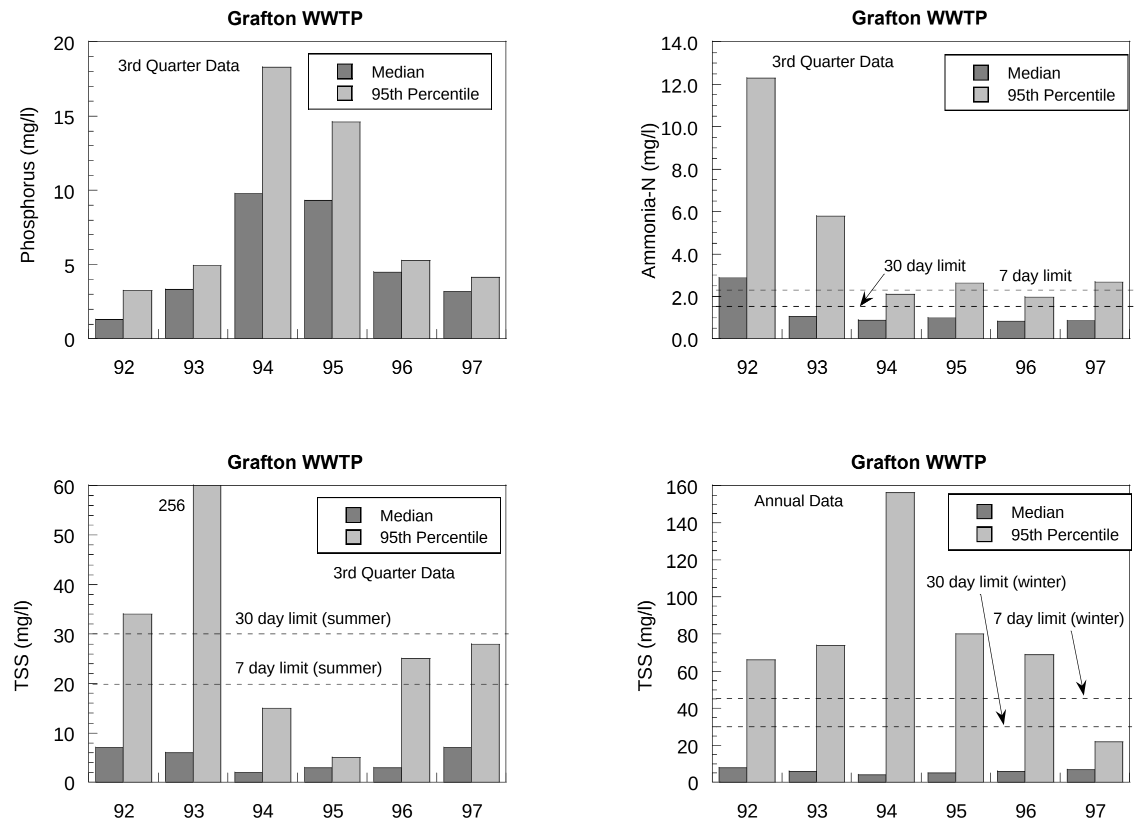
East Branch Black River

Village of Grafton WWTP (3PB00024):

The Village of Grafton WWTP utilizes sequencing batch reactors (SBRs) for treatment, and is designed for an average daily flow of 0.75 MGD. Peak hydraulic design flow for the WWTP is 4.5 MGD. The existing treatment scheme for the plant consists of the following processes: screening and pump station; grit removal tank; three sequencing batch reaction tanks; chlorine contact tank; and two aerated sludge holding tanks. Effluent from the WWTP is discharged to the East Branch of the Black River at RM 11.15 immediately upstream of the Lorain County Indian Hollow Metropark.

The Grafton WWTP completed an upgrade in 1988 to expand the facility. Since that time, a number of smaller package type wastewater facilities have been abandoned and tied into the Grafton WWTP sewer system. In addition, continuing expansion of the Ohio Department of Corrections prison facilities within the village has resulted in ever increasing flows to the WWTP. Infiltration and inflow has also been identified as a major contributor to chronic hydraulic overloading of the WWTP during precipitation events (Figure 13).

Monthly operating reports submitted by the Village of Grafton indicate that the current WWTP cannot consistently meet NPDES effluent limits. Violations have occurred frequently for NH_3-N and total suspended solids (Figure 13), with occasional violations for oil and grease and total residual chlorine. Excessive inflow and infiltration in the sewer system, operational and maintenance problems, unplanned variations in the flow and quality of sewage from the Department of Corrections facilities, and inadequate solids handling facilities have all contributed to the chronic inability of the WWTP to consistently meet NPDES permit limits. In addition, total phosphorus concentrations in the final effluent of the facility have been extremely high, with median concentrations up to 9.79 mg/l during the summer, and 95th percentile concentrations up to 18.3



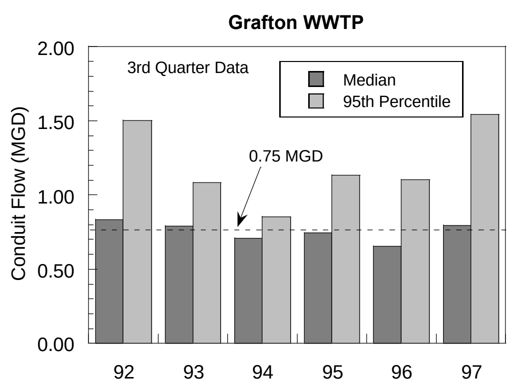


Figure 13. Third quarter median and 95th percentiles for effluent concentrations of phosphorus, ammonia-nitrogen, total suspended solids, annual total suspended solids, and third quarter conduit flows by the Grafton WWTP, 1992 - 1997.

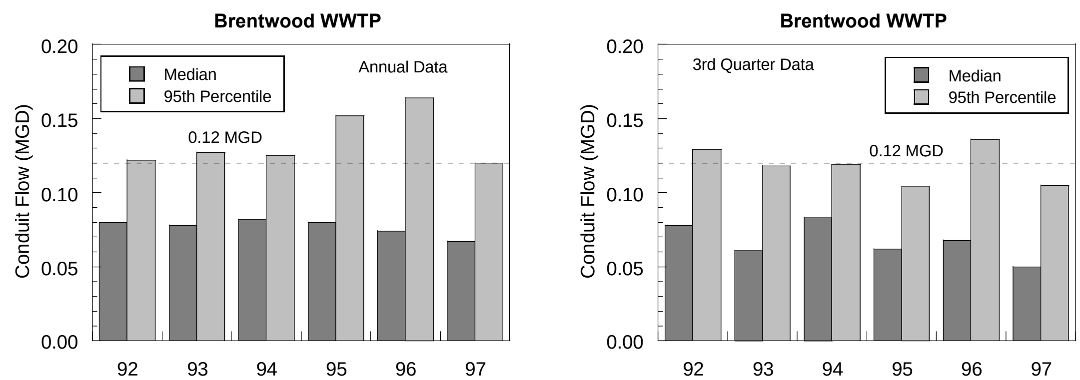
mg/l in 1994 (Figure 13). These extremely elevated concentrations have resulted in nuisance growths of algae downstream of the discharge, and are indicative of poor performance of the existing SBR system, caused by design and operational problems as well as hydraulic overloading.

Although the Village of Grafton constructed sludge handling facilities in 1996, it has yet to consistently meet NPDES permit limits for the quality of the sludge. As examples, inefficiency in solids removal has resulted in numerous violations of effluent quality for total suspended solids. In addition, the sludge accumulated at the facility contains excessive amounts of nickel. The WWTP has also experienced difficulties in complying with Section 503 land disposal regulations for sludge during the winter months. These problems are the result of inadequate volatile suspended solids reduction capability of the aerobic digester during wintertime operation.

The Department of Corrections is currently beginning construction of a new prison facility that will tie into the Village of Grafton WWTP. However, the Grafton WWTP is currently not adequately sized to handle the additional flows from the new prison facility. The Ohio EPA is negotiating a consent agreement with the Village through the Ohio Attorney General's Office that would result in the expansion of the WWTP to 1.5 MGD average flow and improvement in the WWTP design. The Village has proposed to upgrade the existing SBR tanks and to construct an additional SBR tank with Cass decanters (devices that improve the efficiency of the treatment process) and fine bubble aeration and selector zones (Poggemeyer Design Group, Inc., 1998). In addition, alum would be added to the treatment process to facilitate additional phosphorus removal. Tertiary filters are also planned to control solids discharges from the plant. The expansion of the WWTP and proposed permit limits will be subject to the anti-degradation review process as found in OAC 3745-1-05.

Brentwood Lake WWTP (operated by Lorain County) (3PH00024):

Lorain county operates the Brentwood Lakes WWTP which discharges to a tributary to the Black River, confluence at RM 5.89 (Brentwood trib). The Brentwood Lakes WWTP is permitted to discharge an average of 0.12 MGD. The treatment process consists of pretreatment using screens and comminutors, diffused air activated sludge aeration, secondary clarification and disinfection via chlorination. Over the years, there have been numerous violations for total suspended solids (Figure 14) and dissolved oxygen as well as periodic spikes in the concentration of ammonia nitrogen in the outfall. There have been no changes within the service area and median flows from the plant have not increased over time (Figure 14), indicating that operational problems are the primary cause of the observed violations and not hydraulic overloading.



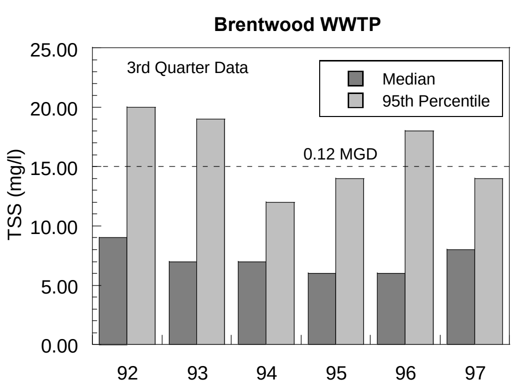


Figure 14 Annual and third quarter median and 95th percentile conduit flows, and third quarter effluent concentrations of total suspended solids by the Brentwood Lake WWTP, 1992 - 1997.

Willow Creek

Eaton Estates WWTP (operated by Lorain County) (3PH00023):

The Eaton Estates WWTP is operated by Lorain County and discharges to Willow Creek at approximately RM 6.0. The plant design consists of pretreatment via screens and comminutors, diffused air activated sludge aeration, secondary settling, chlorine disinfection, and dechlorination prior to discharge. The WWTP is designed for an average flow of 0.20 MGD. As with the Brentwood Lakes WWTP, the Eaton Estates WWTP has had little variation in flow or service area over the last five years, but has had a history of repeated violations for dissolved oxygen, ammonia-nitrogen and suspended solids (Figure 15). As with the Brentwood Lakes WWTP, problems associated with the operation of this facility appear to be attributable largely to problems associated with operation and maintenance.

Since 1993, the Lorain County Commissioners have been evaluating the possibilities of abandoning the Eaton Estates WWTP in favor of connection into a regional wastewater treatment facility[2]. This plan is part of a larger collaborative effort among twelve townships, three villages and the Lorain County Commissioners that resulted in the formation of the Lorain County Rural Wastewater District (LORCO) on February 4, 1997. The objectives of the district are to determine the needs for wastewater treatment in the rural areas of southern Lorain County and to facilitate implementation of needed wastewater improvements in the area. The current Phase I planning area of LORCO includes the northern part of Eaton Township and northeast Carlisle Township, including the service areas of the Brentwood Lakes WWTP and the Eaton Estates WWTP. The initial plans for this area include the abandonment of these two existing county operated plants in favor of connection to a regional wastewater treatment facility. Initial discussions with the City of North Ridgeville to provide treatment at the North Ridgeville WWTP were not fruitful. LORCO is now investigating the feasibility of connecting to the NEORSD southwest interceptor sewer. Under this scenario, treatment would be provided at the NEORSD Southerly WWTP in Cleveland[3].

---

[2]Correspondence from Commissioner Elizabeth C. Blair to the Ohio EPA dated July 23, 1998.

[3]Correspondence from Fred Alspach, LORCO Executive Director to Ohio EPA dated November 4, 1998.

East Fork East Branch Black River

Village of Lodi WWTP (3PB00027):

The Village of Lodi operates a tertiary treatment facility which is currently permitted to treat an average of 0.34 MGD. The plant design consists of preliminary treatment, extended aeration activated sludge secondary treatment, tertiary treatment using micro-screens. Disinfection is provided by chlorination followed by dechlorination using sulfur dioxide. Dechlorination equipment was installed at the plant in the spring of 1996. The last major upgrade of this plant was in 1988 when the aeration tanks were modified to operate as extended aeration tanks.

The Lodi WWTP has a history of bypasses resulting in violations of the effluent limits for ammonia-nitrogen and total suspended solids (Figure 15). These bypasses are the result of operational problems and excessive plant flows caused by inflow and infiltration and inadequate plant capacity. The Village has undergone a program to reduce the amount of inflow and infiltration in the last few years. However, this program has not resulted in significant reductions in the inflow rate during storm events (Engineering Associates, Inc., 1996). Peak inflow rates are estimated to be 2.1 MGD, with the inflow volume from a 5 year, two hour storm (1.65 inches) estimated to be 576,000 gallons. The majority of the inflow has been determined to originate from basement sumps in homes found on the west side of the village that are inappropriately tied to the sanitary sewers. Isolation of this inflow will not be possible until new storm sewers capable of preventing basement flooding can be installed in this portion of the village.

The Ohio EPA is currently negotiating a consent agreement with the Village through the Ohio Attorney General's Office to expand the WWTP to 0.8 MGD and improve the WWTP design. The upgraded facility will include the addition of a new influent channel and coarse bar screen and a new grit removal chamber prior to treatment. Wastewater will then be filtered through two new 24 inch diameter by 72 inch long rotary fine screens prior to aeration. Three new aeration tanks will be installed which will allow for 24 hour detention under average flow. In addition, flow equalization tanks will be installed in order to store flows in excess of peak design flow and eliminate bypasses of the plant. The two existing secondary treatment units will be converted into clarifiers where final solids settling will be accomplished. Tertiary treatment will be provided by the installation of two high rate traveling bridge sand filters. The existing micro-screen filter basins will be converted into chlorine contact tanks to increase contact time for disinfection by chlorine. Dechlorination will continue to be through the use of sulfur dioxide. In addition, the upgraded facility will also include the installation of phosphorus removal treatment equipment. The Village of Lodi has proposed to design the upgraded facility to discharge at the expanded flow with no increase in pollutant load. The alterations to the facility will be subject to the antidegradation review process as found in OAC 3745-1-05.

The addition of phosphorus control equipment at this facility should result in a significant improvement in downstream water quality and biological integrity. Phosphorus concentrations in the effluent have been extremely high (Figure 15), causing excessive nutrient enrichment of the East Fork of the East Branch of the Black River. The flow in the stream is effluent dominated during the summer months exacerbating the effects of loadings of nutrients from the WWTP. Median third quarter phosphorus concentrations in the WWTP effluent have ranged from 2.4 to 4.0 mg/l in the period of 1992-1997. Future monitoring of the biological communities downstream of the discharge should be designed to evaluate whether nutrient enrichment remains a problem following the completion of the facility upgrades currently contemplated.

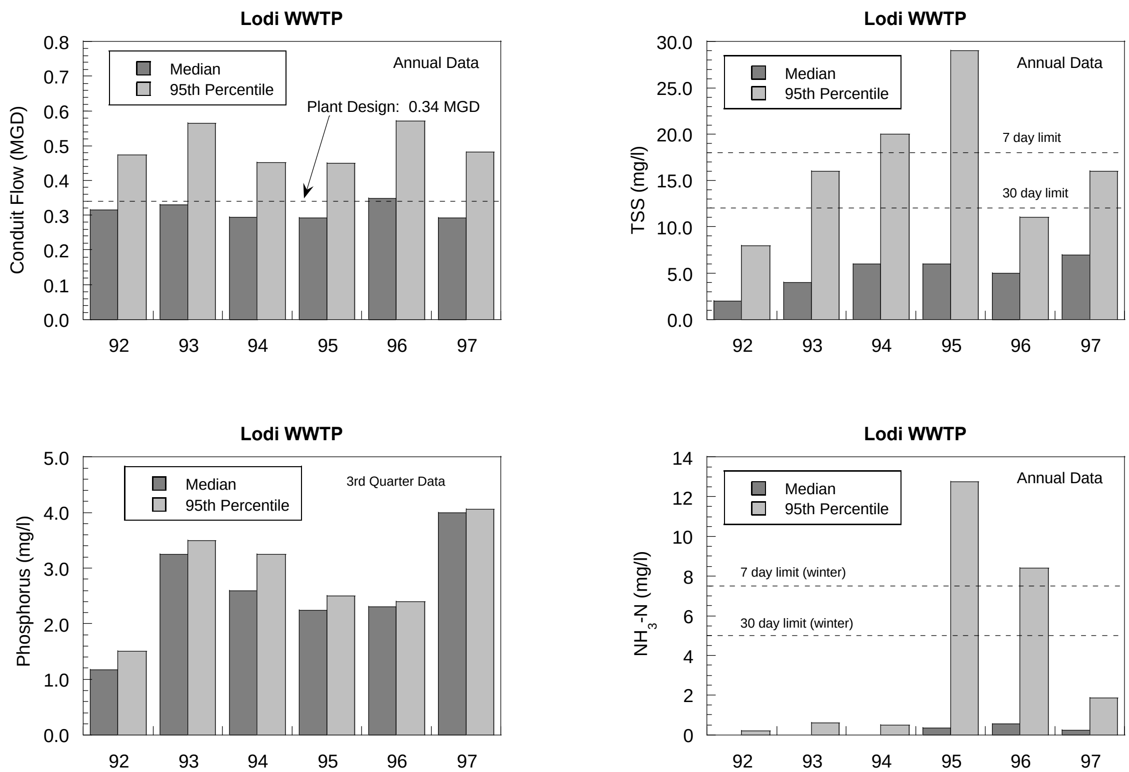


Figure 15. Median and 95th percentiles for annual conduit flow, effluent concentrations of total suspended solids, third quarter phosphorus concentrations, and annual ammonia-nitrogen by the Lodi WWTP.

French Creek
City of North Ridgeville WWTP (3PD00043):

The City of North Ridgeville operates a 7.5 MGD tertiary wastewater treatment facility discharging at RM 2.6 of French Creek. The treatment design consists of screening incoming effluent, complete mix activated sludge aeration, settling, and tertiary treatment using rapid sand filters. Disinfection is provided by chlorination using sodium hypochlorite followed by dechlorination with sodium bisulfate prior to discharge. Equalization of incoming flows is currently provided by four flow 280,000 gallon equalization tanks totaling 1.12 million gallons. However, due to an expanding service area and high rates of inflow and infiltration, the instances and severity of peak flow events have increased over time hydraulically overloading the plant (Figure 16). Performance of the North Ridgeville WWTP with respect to the discharge of ammonia-nitrogen, $cBOD_5$ and total suspended solids has consistently been within permitted effluent limits (Figure 16), but have been on a slight upward trend since 1986.

Compliance sampling was conducted at the North Ridgeville WWTP by the Ohio EPA on July 7-8 and September 29-30, 1997. Analyses of treated effluent from the plant found no exceedances of permitted effluent limits except that fecal coliform bacteria were detected at 5,100 colonies/100ml on September 30, 1997. Fecal coliform bacteria were detected at 1,300 colonies/100ml in a sample collected by the Ohio EPA on July 8, 1997. The cause for the elevated bacteria counts is unknown, since the plant appeared to be operating normally during both sampling events. Trace amounts ($< 5\ \mu g/l$) of toxic volatile organic compounds detected in the effluent during both sampling events included chloroform, bromodichloromethane and dibromochloromethane. The volatile organic compounds detected were likely trace laboratory contaminants or carryover from compounds formed when city water is disinfected by chlorination. Bioassay testing of the treated effluent and from samples collected from the Black River found no acute toxicity associated with the discharge.

Since 1993, the City of North Ridgeville has been addressing inflow and infiltration problems within the collection system by smoke testing to identify infiltration locations, sewer rehabilitation, and ditch cleaning efforts designed to eliminate flooding problems that cause major inflow problems. Other projects designed to alleviate the hydraulic overloading of the WWTP include the sealing of manhole covers through filling of holes or the installation of liners and the installation of stormwater retention structures with a 46 million gallon capacity in the French Creek watershed. The installation of stormwater retention results in the reduction of inflow problems through the alleviation of basement and sewer flooding.

The City of North Ridgeville has indicated that plans are underway to expand the design treatment capacity of the WWTP from 7.5 to 10.5 MGD. This expansion would facilitate the installation of a new westerly interceptor sewer serving new residential development and pick up some unsewered areas, and areas within the city currently serviced by the City of Elyria WWTP. Expansion of the plant to 10.5 MGD would be accomplished through the conversion of an existing tank now used for sludge digestion into an aeration tank accompanied by the installtion of a new 3.0 MGD aerobic digester for the treatment of sludges.

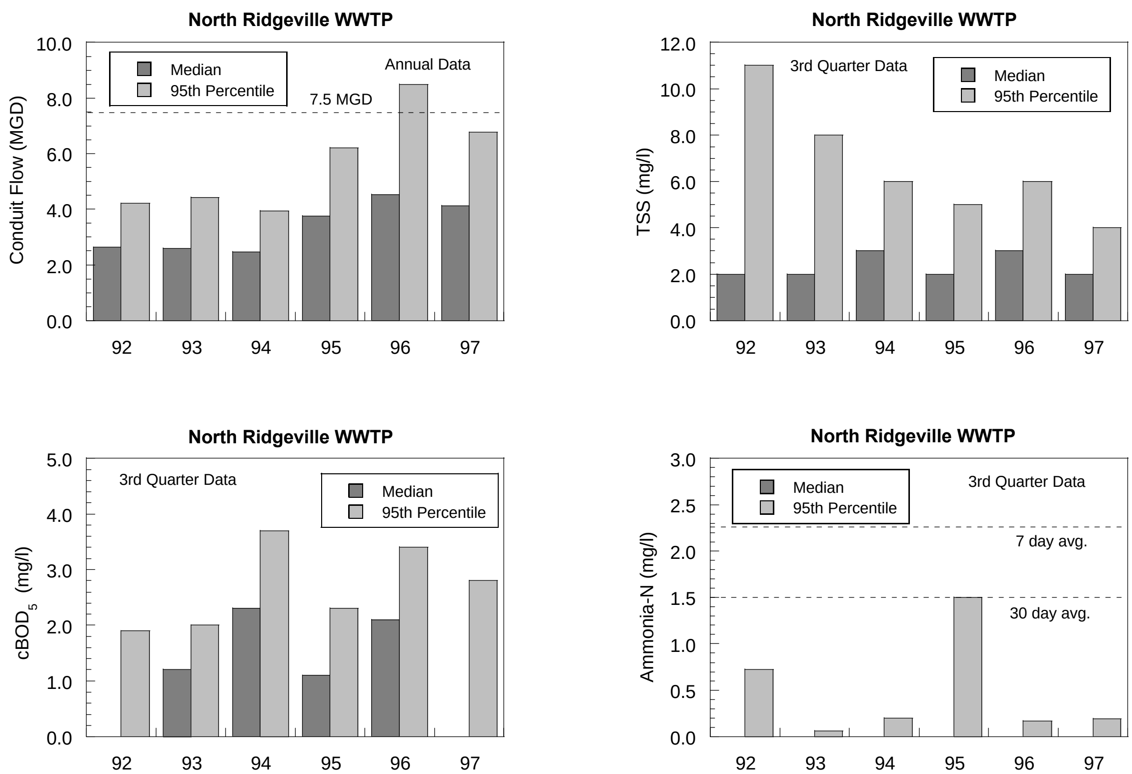


Figure 16. Median and 95th percentiles for annual conduit flow, and third quarter effluent concentrations of total suspended solids, 5-day carbonaceous biological oxygen demand, and ammonia-nitrogen by the North Ridgeville WWTP, 1992 - 1997.

Beaver Creek
City of Amherst WWTP, 3PD00001

The City of Amherst operates a 2.25 MGD secondary treatment plant that discharges directly to Beaver Creek at RM 3.85. The wastewater treatment at this facility includes an aerated grit removal chamber, primary settling, a two-stage trickling filter, and secondary clarification. Disinfection is accomplished by an ultraviolet disinfection unit installed in 1996. The plant is currently at its hydraulic capacity (Figure 17), which has resulted in wet weather overflows, and combined with operation and maintenance problems, has resulted in a history of violations of the permit effluent limits for ammonia nitrogen dating back to 1988 (Figure 17). In addition, concentrations of total suspended solids and $cBOD_5$ during the summer are frequently elevated (Figure 17).

Compliance sampling at the Amherst WWTP was conducted by the Ohio EPA in November of 1996 and in June of 1997. Bioassay testing of the effluent from both sampling events did not find any acute toxicity in the effluent for either fathead minnows (*Pimpheles promelas*) or daphnids (*Ceriodaphnia dubia*). However, the results of the sampling did indicate that, under low flow conditions in Beaver Creek, it is extremely likely that the effluent from the WWTP is a source of chronic toxicity to the stream. This has been confirmed through the review of monthly operating report data received from the entity and the results of ambient water quality monitoring conducted in Beaver Creek during 1997.

Based upon the current hydraulic loading conditions at the Amherst WWTP, the history of poor performance of the plant, especially during wet weather and the results of effluent and ambient stream monitoring by the Ohio EPA, it is evident that the plant is in need of a significant upgrade or abandonment. Because of the close proximity to the Lorain West WWTP, it appears that diversion of the flows from the Amherst WWTP and abandonment of the plant should be strongly considered and would have the greatest possibility for improving the water quality in Beaver Creek.

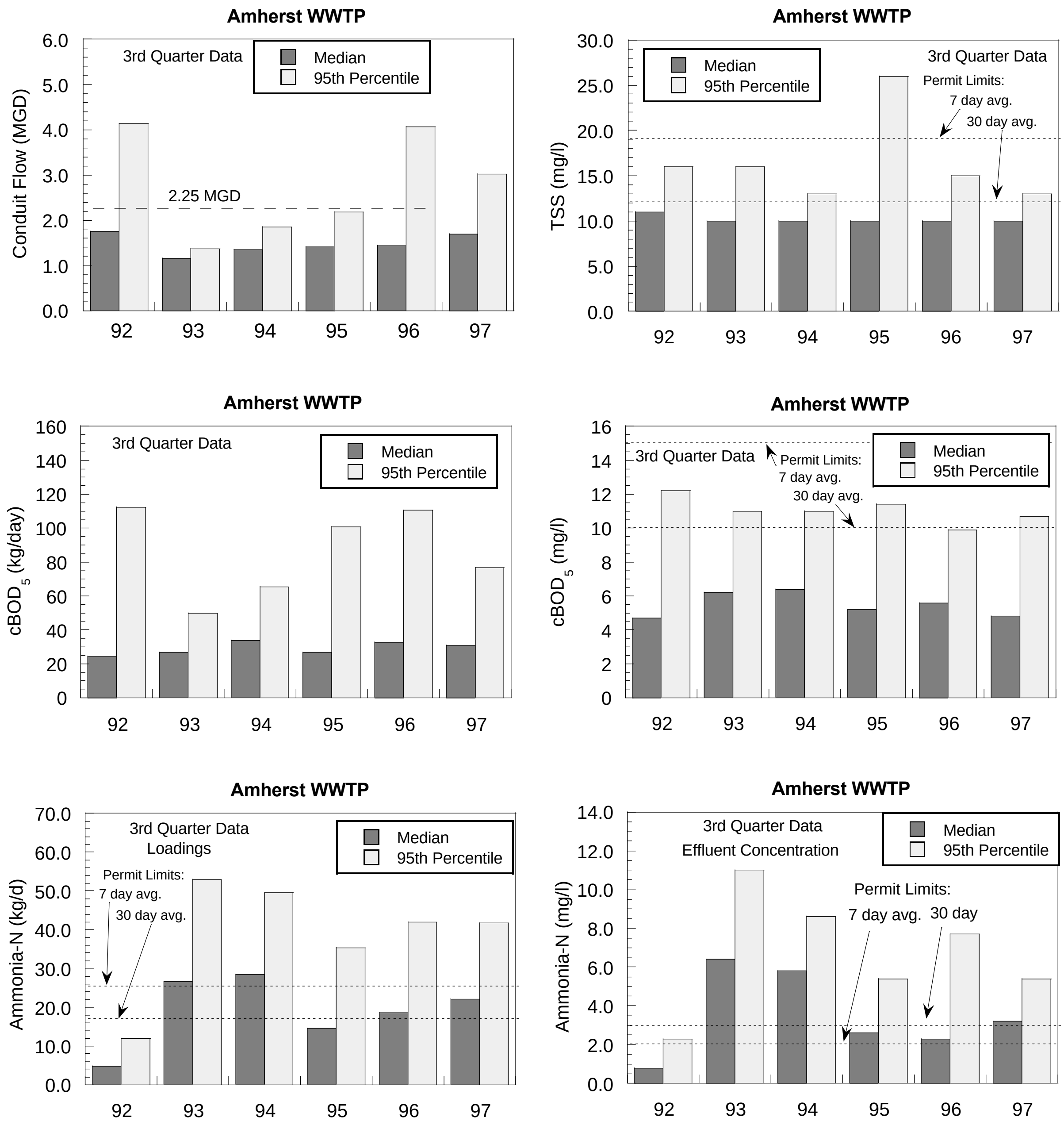


Figure 17. Third quarter median and 95th percentiles for (from left to right) conduit flow, effluent concentration of total suspended solids (TSS), CBOD5 daily loadings, CBOD5 effluent concentration, ammonia-nitrogen (NH3-N) daily loadings, and NH3-N effluent concentrations of the Amherst WWTP.

Spills, Overflows and Unauthorized Releases

A total of 27 spills were reported to the Ohio EPA Division of Emergency and Remedial Response within the Black River in 1997. None of the spills were reported to have resulted in fish kills. Of the reported spills, seven were uncontrolled releases of wastewater from the Oberlin WWTP to Plum Creek (a tributary to the West Branch of the Black River not included in the water chemistry portion of this study). Eleven of the spills reported occurred at the USS/Kobe Steel facility in Lorain. Ten of these spills involved the uncontrolled discharge of wastewater to the Black River and one report involved a spill of an indeterminate amount of fuel oil. Uncontrolled wastewater discharges from the USS/Kobe facility ranged from 100-7,000 gallons and resulted primarily from clogged or broken transfer lines which caused overflows in sumps used to collect wastewater prior to treatment.

The remainder of the spills reported from the Black River watershed in 1997 mainly involved releases of hydrocarbons to surface water. Notable releases include a 300 gallon crude oil spill to the East Fork of the East Branch of the Black River on May 1, 1997, and a release of approximately 2,000 gallons of a paraffin wax emulsion from the National Gypsum Company to the Black River on September 12, 1997.

Fish Kills

Three fish kills were reported for the Black River basin between 1992 and 1997. One involved an unpermitted dredge and fill operation to a tributary of the West Fork of the East Branch; another was due to the release of sewage by the Amherst WWTP; the third was observed in French Creek by Ohio EPA field personnel (Chuck McKnight) during the 1997 survey. The kill incidents on Beaver Creek and French Creek correspond with the biological impairment observed during the survey (see **Biological Communities - Macroinvertebrates and Biological Communities - Fish**, below).

Surface Water Quality

Water samples were collected from 28 sites throughout the study area during the period of June 30 to September 4, 1997 for the analysis of chemical water quality. A total of five samples were collected from each site during the study for chemical parameters and four samples were collected to test for fecal coliform bacteria. All stations were sampled on the same day for each of the sampling events. As much as possible, samples were collected under low flow conditions to document situations where the chronic (i.e. 30-day average) water quality criteria were possibly exceeded and to determine possible impacts from NPDES permitted wastewater treatment facilities.

Flow in the Black River is measured at a USGS gaging station located on the Black River in Cascade Park in Elyria at RM 14.94 (Station # 04200500). A flow hydrograph for the Black River gaging station over the study period is depicted in Figure 18. Water quality samples were collected at average daily stream flows in the Black River ranging from 11 to 173 ft^3/sec. However, on four of the five sampling dates, average daily flows were below 33 ft^3/sec. During the study period, the

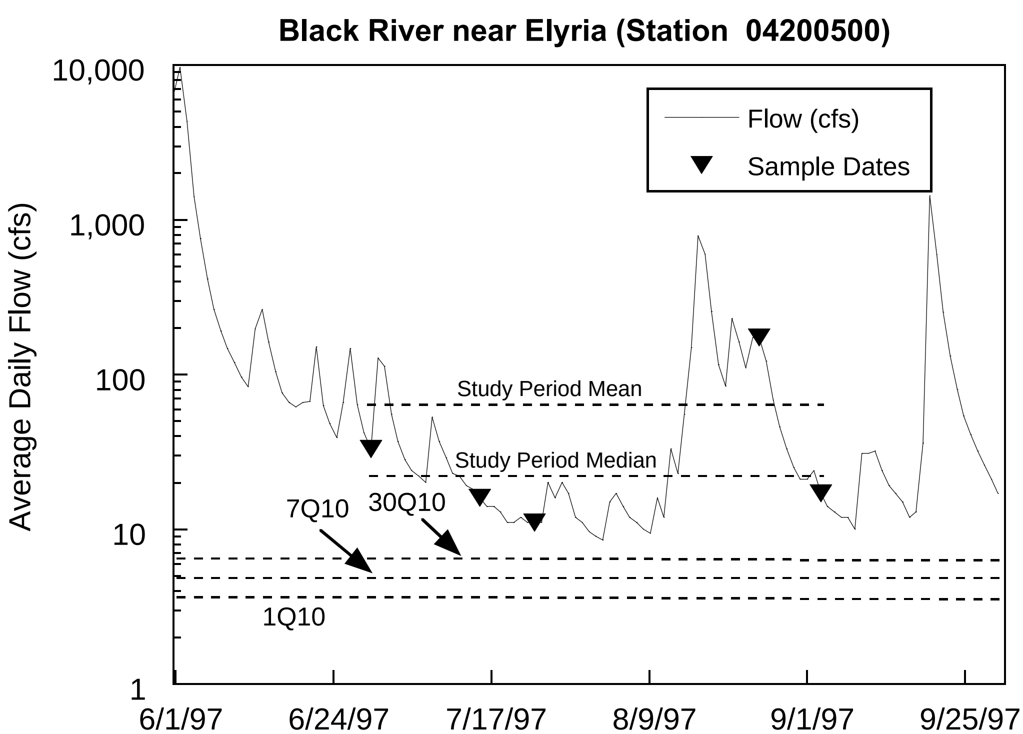


Figure 18. Flow hydrograph for the Black River, June through September, 1997.

minimum observed daily flow at the gaging station was 8.5 ft^3/sec and the maximum observed flow was 787 ft^3/sec. The median daily average flow during the study period was 21 ft^3/sec, and the mean was 64.9 ft^3/sec. The annual average daily flow for the Black River during water year 1997 (Sept. 1996 to Sept. 1997) was 526 ft^3/sec. Flows in the Black River during the summer of 1997 were elevated above the critical low flows used to model pollutant loadings for NPDES permitted discharges (1Q10 = 3.57 , 7Q10 = 4.93, 30Q10 = 6.48, for the period of 1961-1997), and therefore, extra dilution influences the water quality results from this study.

All analytical results for water samples collected during the survey are listed in tabular form in Appendix Table 4. Instances where analysis detected violations of Ohio Water Quality Standards are listed in Table 7.

East Fork East Branch Black River

Two sampling sites were located on the East Fork of the East Branch of the Black River (East Fork) to provide data upstream and downstream from the Village of Lodi WWTP discharge. The results indicate that the Lodi WWTP has minimal impacts on daytime dissolved oxygen concentrations in the East Fork. Dissolved oxygen (D.O.) concentrations ranged from 9.1 to 10.53 mg/l upstream from the plant and from 7.0 to 9.34 mg/l downstream. The median D.O. concentration decreased from 9.4 mg/l to 8.6 mg/l. Median concentrations of nitrogenous nutrients, total phosphorus (TP) and chemical oxygen demand (COD) all increased downstream from the WWTP. Observed increases in water column concentrations were as follows: ammonia-nitrogen (NH_3-N), from less than 0.05 mg/l to 0.16 mg/l; nitrate-nitrite nitrogen (NO_3-NO_2-N), from 0.10 mg/l to 2.04 mg/l; total Kjeldahl nitrogen (TKN), from less than 0.10 to 0.7 mg/l; and total phosphorus (TP) from 0.07 to 0.49 mg/l. Given the elevated concentrations of nutrients in the East Fork downstream from the WWTP, it is possible that D.O. depletion is occurring in the stream during the nighttime hours as the result of microbial respiration. Diurnal monitoring of the D.O. concentrations downstream from the Lodi WWTP should be conducted to determine if this is the case. The pending upgrade of the Lodi WWTP is to include treatment to remove phosphorus, which should reduce the impacts of the plant on downstream aquatic communities.

East Branch Black River

Water samples were collected at nine sites on the East Branch of the Black River (East Branch) between RM 0.3 and RM 41.5. Upstream from the Grafton WWTP discharge at RM 10.8, water quality in the East Branch is largely dependent upon non-point source contributions of sediment from the heavily cultivated watershed, as evidenced by high concentrations of total suspended solids (TSS) and associated increases in COD (Figure 19). The combination of sediment loads and flow characteristics of the stream resulted in declining D.O. concentrations, which reached their observed minimum at RM 18.9 (Figure 19). The median D.O. concentration at this site was 5.4 mg/l, and two of the five measurements taken there were below the 24 hour average water quality standard of 5.0 mg/l.

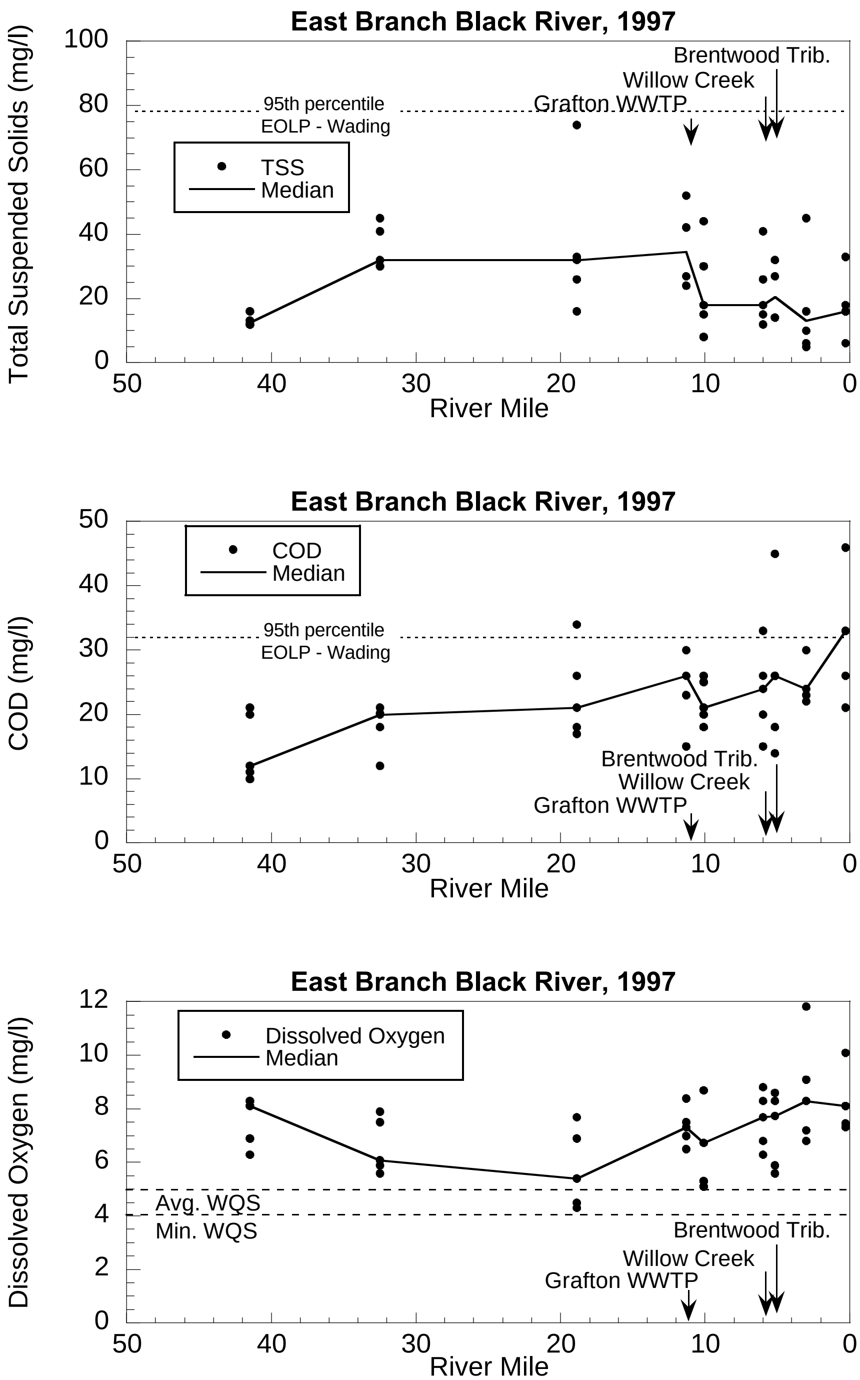


Figure 19. Concentrations of total suspended solids, chemical oxygen demand (COD) and dissolved oxygen in water quality samples collected from the East Branch Black River, 1997 in relation to the Grafton WWTP and selected tributaries.

The largest single impact on water quality in the East Branch is the discharge of treated wastewater from the Grafton WWTP at RM 10.8. The effluent discharge from the Grafton WWTP roughly doubled the flow in the East Branch downstream from the discharge, decreasing the median concentration of TSS by 48% (Figure 19). Although the median COD concentration also decreased immediately downstream from the Grafton WWTP, there was a coincident increase in the concentrations of TP and NO_3-NO_2-N (Figure 20) of 350% and 188%, respectively. These nutrient loads drastically changed the nutrient dynamics in the East Branch, resulting in a 25% increase in the median concentration of total nitrogen (concentrations of NO_3-NO_2-N + TKN) in the stream and decreasing the median ratio of nitrogen to phosphorus (N:P ratio) from 10.1 to 5.5 (Figure 20). Upstream from the discharge the median N:P ratio ranged from 10.1 to 11.5. Downstream from the Grafton WWTP discharge, the ratio ranged from 3.9 to 6.2. Assimilation of both TP and NO_3-NO_2-N was evident downstream from the Grafton WWTP. Nutrient uptake appeared to stimulate primary productivity in the stream, as evidenced by increasing concentrations of D.O. in the stream downstream from the wastewater discharge. Median daytime D.O. concentrations increased from 6.73 mg/l at RM 10.1 immediately downstream from the Grafton WWTP to 8.31 mg/l at RM 3.0.

In cases where in-stream habitat is available to support a well balanced fish community, it has been documented that excessive nutrient concentrations can significantly impact the biological community and result in impairment of the biological community within the stream as observed by decreases in biological indices used to assess attainment with the water quality criteria (Miltner and Rankin, 1998). Index of Biotic Integrity (IBI) scores for the fish communities downstream from the Grafton WWTP are significantly lower than those found upstream from the discharge (33 vs. 38 upstream) and are in non-attainment of the WWH aquatic life use designation found in OAC 3745-1-07. Analysis of data collected during the 1997 intensive survey leads to a conclusion that it is likely that elevated total phosphorus (TP) concentrations downstream from the Grafton WWTP may contribute significantly to the observed reduction in the IBI score downstream from the discharge.

The median summertime TP concentration in the effluent from the Grafton WWTP, based upon monthly operating report data for the period of 1993 though 1997, is 4.11 mg/l. Through application of the mass balance equation used by the Ohio EPA to calculate waste loads to streams, the load to the stream from the Grafton WWTP would result in an in-stream TP concentration of 1.31 mg/l downstream from the plant at summer 30Q10 flow (thirty day average low flow conditions observed once every ten years). This in-stream concentration is well above the 90th percentile concentration of 0.98 mg/l for wadeable streams in Ohio (Miltner and Rankin, 1998). Correlations drawn from 714 similar sites throughout Ohio indicate that significant impacts on IBI scores can be predicted when TP concentrations are elevated to this extent.

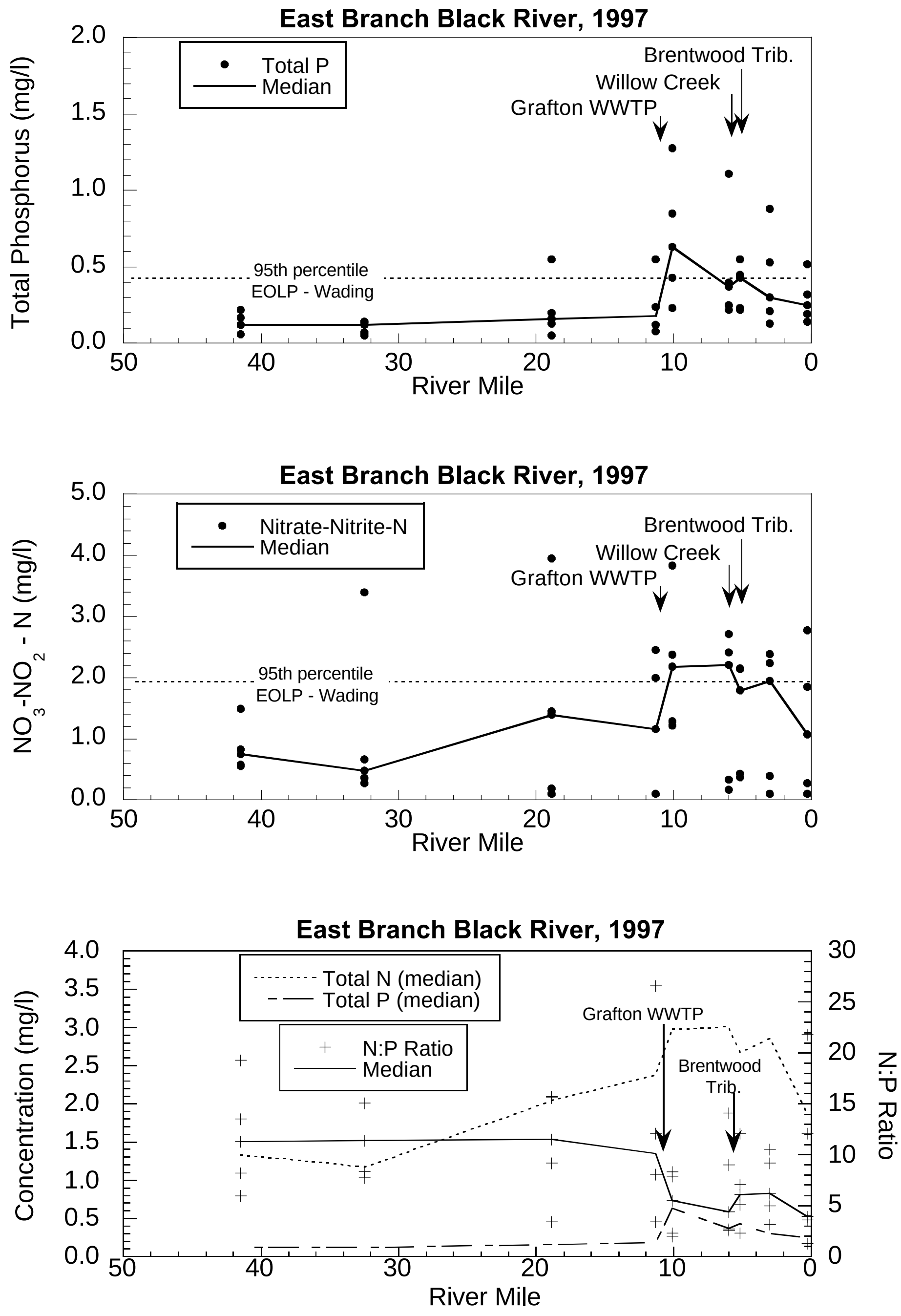


Figure 20. Concentrations of total phosphorus, nitrate-nitrite (NO_3-NO_2-N), and the ratio between the two in water quality samples collected from the East Branch Black River, 1997 in relation to the Grafton WWTP and selected tributaries.

Excessive concentrations of nutrients downstream from the Grafton WWTP are therefore the likely cause for the observed non-attainment of the aquatic life criteria downstream from the discharge.

The Village of Grafton is requesting to expand and upgrade the wastewater treatment facility. Under the proposal, the permitted average daily discharge from the plant would increase from 0.75 MGD to 1.5 MGD resulting in the Grafton WWTP being classified as a “major” discharger (a plant with an average daily discharge at or exceeding 1.0 MGD). Under the current Great Lakes Water Quality Agreement, major dischargers in the Lake Erie drainage basin are required to control phosphorus concentrations to 1.0 mg/l. In order to determine whether the imposition of a 1.0 mg/l limit for TP would result in improvement of the downstream biological community, a mass balance model of the in-stream TP concentration downstream at the expanded WWTP flow under summer 30Q10 flow conditions was constructed. Using the upstream median phosphorus concentration observed during the 1997 intensive survey as the background concentration, a mass balance equation yields a downstream TP concentration of 0.54 mg/l at the expanded flow with an effluent TP concentration of 1 mg/l. Although this concentration is lower than the in-stream water quality observed in 1997, this value exceeds the 75th percentile observed in wadeable streams in Ohio (Miltner and Rankin, 1998). Based upon data collected throughout the state, the correlations drawn from Miltner and Rankin (1998) predict an improvement in the biological community if TP concentrations are controlled to result in a downstream TP concentration of 0.32 mg/l or less (a reduction in TP to below the 75^{th} percentile found in wadeable streams). To achieve this downstream concentration, an effluent limit of 0.5 mg/l (30 day average) would need to be established for phosphorus discharged from the Grafton WWTP based upon a mass balance approach. The use of this limit should be strongly considered as a summertime limit in any permit issued for the expansion of the plant. In the winter, a limit of 1.0 mg/l would be protective of the aquatic life use because of higher upstream flows.

No significant impacts on chemical water quality were observed in the East Branch downstream from Willow Creek (confluence at RM 5.56 of the East Branch) or the unnamed tributary at RM 5.89 of the East Branch which receives effluent from the Lorain Co. Brentwood Lakes WWTP (Brentwood trib.). However, levels of fecal coliform bacteria increased in the East Branch downstream from these tributaries and within the City of Elyria (Figure 21). Median levels of fecal coliform were 1,200 and 1,100 colonies/100 ml at RM 3.00 and 0.30, respectively, and exceeded the primary contact recreational standard of 1,000 col./100ml in six of the eight samples collected at these locations. Potential sources of fecal coliform in the stream are failing on-site sewage systems located upstream from the City of Elyria, direct runoff from agricultural and urban areas, and bypasses and overflows within the City of Elyria sewer system.

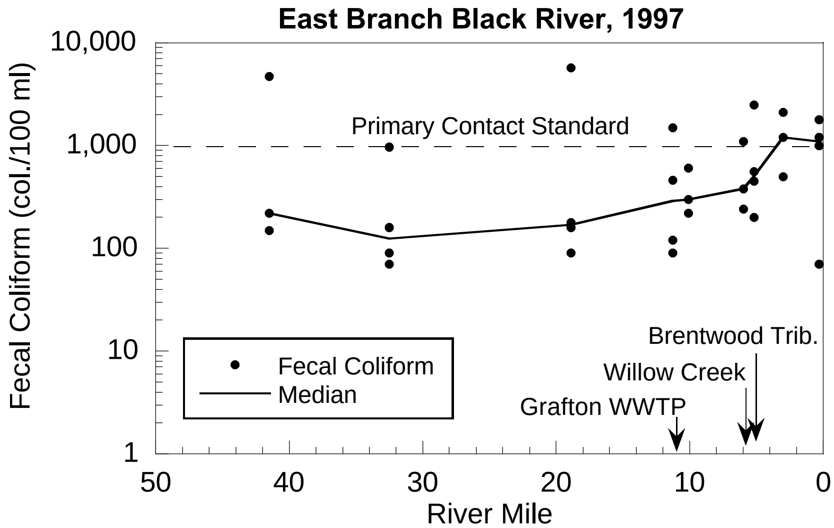


Figure 21. Counts of fecal coliform colonies per 100 ml in water quality samples collected from the East Branch Black River, 1997, in relation to the Grafton WWTP and selected tributaries.

Willow Creek

Willow Creek is currently not a listed tributary in the Ohio Water Quality Standards found in OAC 3745-1-07 and therefore does not have a designated aquatic life use. However, under the criteria for Lake Erie tributaries found in OAC 3745-1-07, Willow Creek is designated General High Quality Waters and the WWH chemical Water Quality Criteria do apply to the stream. Analysis of the water chemistry data for this stream is presented with this in mind.

Samples were collected from three sites in Willow Creek to assess the impacts of the Lorain County Eaton Estates WWTP on water quality. Samples collected upstream from the WWTP at RM 6.00 where the creek is a low gradient, channelized, vegetated ditch had elevated concentrations of NH_3-N and low D.O. concentrations (Figure 22) reflect the anaerobic condition of the ditch. Elevated numbers of fecal coliform bacteria (Figure 22) were also noted, possibly indicating the presence of failing on-site sewage systems or livestock. The flow in the creek at the RM 6.00 sampling site was low throughout the study period. Concentrations of all three of these parameters failed to meet the Water Quality Criteria for a WWH stream on several occasions (Table 7).

At RM 4.83, downstream from the Eaton Estates WWTP, dissolved oxygen concentrations recovered somewhat, although the WWH water quality criteria were not met on three of the five

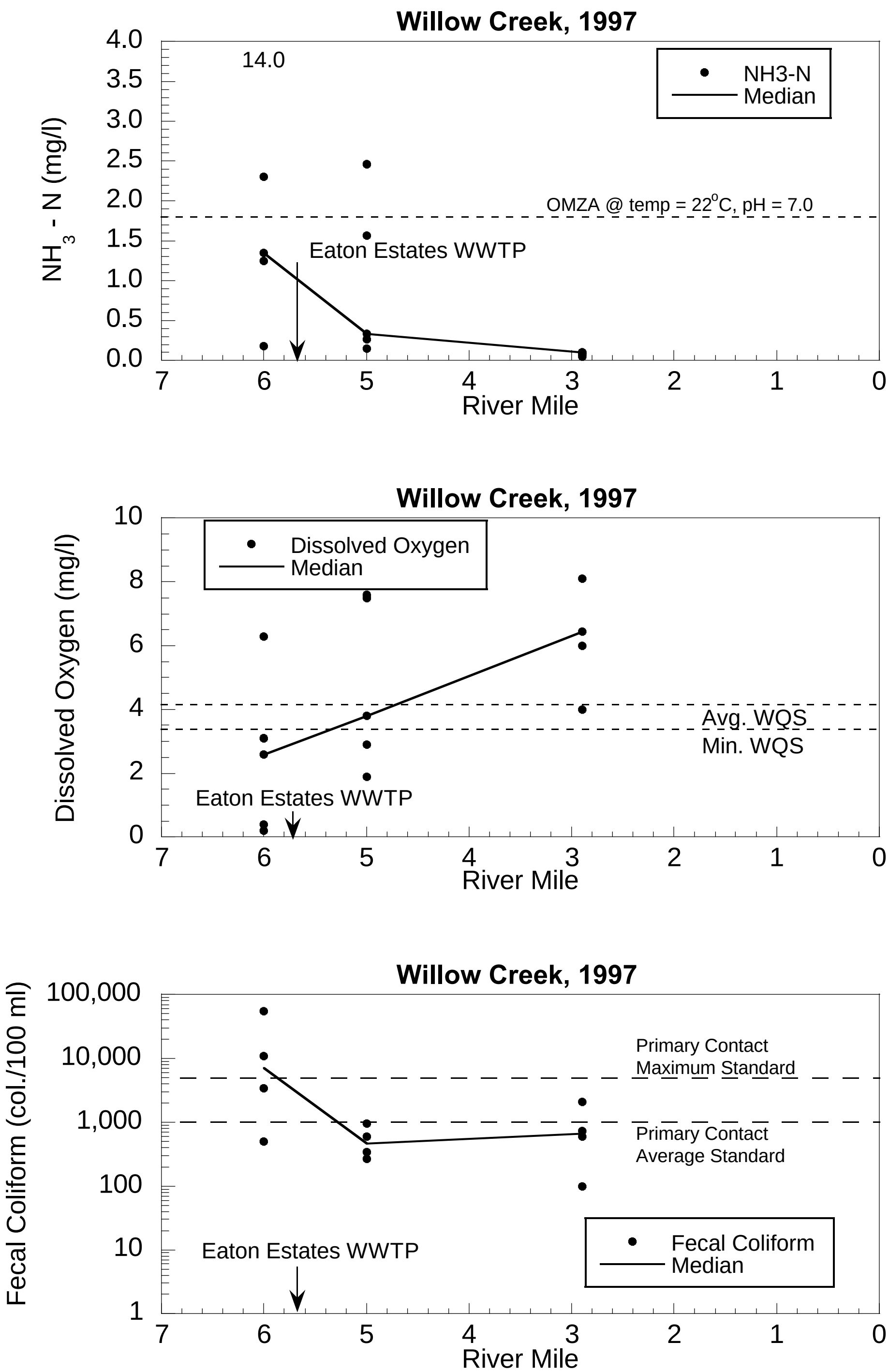


Figure 22. Concentrations of ammonia-nitrogen (NH_3-N), dissolved oxygen, and counts of fecal coliform colonies per 100 ml in water quality samples collected from Willow Creek, 1997 in relation to the Easton Estates WWTP.

sampling dates. Ammonia-nitrogen concentrations had declined to levels within the water quality criteria at this station, and numbers of fecal coliform bacteria had also declined, most likely due to the addition of chlorinated effluent from the Eaton Estates WWTP. Additional improvement in water quality was observed at RM 2.90. Assimilation of ammonia-nitrogen within the stream allowed D.O. concentrations to increase by this point, and chemical water quality criteria were met for all of the samples collected except for one date when fecal coliform bacteria exceeded the primary contact recreational standard.

The overall impact of the Eaton Estates WWTP is difficult to ascertain given the degraded water quality of the upstream location. However, under this situation, the discharge of additional pollutant loads to the stream is likely to exacerbate D.O. depletion and to delay recovery of the stream by adding additional pressures to the natural assimilative processes occurring in the stream.

West Branch Black River
Only one site was monitored in the West Branch of the Black River (West Branch) in the City of Elyria during the 1997 survey in order to provide a comparison with water quality in the East Branch. Dissolved oxygen,ammonia- nitrogen and TP concentrations were equivalent near the mouths of both the West and East Branches (Figure 23), while concentrations of COD and TSS were generally lower in the West Branch. The median COD in the West Branch was 20 mg/l, while that at RM 0.30 of the East Branch was 33 mg/l. Median TSS values in the West and East Branches were 6 and 16 mg/l, respectively. Fecal coliform bacteria levels were elevated at the mouths in both branches of the river throughout the study. All of the samples collected at the West Branch sampling site were above the primary contact recreation average criteria of 1,000 col./100 ml, as were three of the four samples collected at RM 0.30 of the East Branch. Unsewered areas upstream from the City of Elyria and combined sewer overflows within the city probably both contribute to this situation.

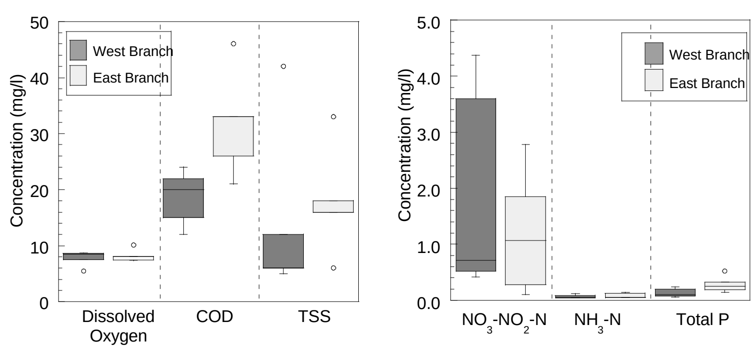


Figure 23. Concentrations of dissolved oxygen, chemical oxygen demand and total suspended solids (left) and nitrate-nitrite, ammonia-nitrogen and total phosphorus (right) in water quality samples collected near the mouths of the West Branch and East Branch Black River, 1997.

French Creek

Three sites were sampled along French Creek to determine water quality during the 1997 survey. Chemical water quality criteria were met at all of the stations throughout the study period. Dissolved oxygen concentrations (Figure 24) were not impacted by the North Ridgeville WWTP and met the water quality criteria at all of the sampling locations. Median NH_3-N concentrations were near the detection limit of 0.05 mg/l at all three sampling locations, and three of the five samples collected downstream from the North Ridgeville WWTP were less than the detection limit for this parameter. The main impacts of the WWTP were on TSS (Figure 24) and NO_3-NO_2-N (Figure 25). Median total suspended solids concentrations in French Creek decreased by 72% downstream from the WWTP discharge, reflective of the effluent dominated nature of the stream downstream from the WWTP. Nitrate-nitrite nitrogen increased dramatically downstream from the WWTP discharge. Median NO_3-NO_2-N concentrations increased from 2.01 mg/l at RM 3.2 upstream from the discharge to 6.09 mg/l at RM 0.40 downstream. The maximum NO_3-NO_2-N concentration observed at RM 0.40 was 16.70 mg/l on July 24, 1997.

The impacts of the loading of NO_3-NO_2-N to the biological communities in French Creek was likely minimal since the WWTP had little impact on in-stream total phosphorus concentrations. Total phosphorus concentrations upstream from the North Ridgeville WWTP ranged from less than detection (<0.05 mg/l) to 0.38 mg/l, while downstream from the plant they ranged from 0.08 to 0.32 mg/l.

The only exceedances of the Ohio WQS in French Creek were for fecal coliform bacteria, which were observed at all three sampling locations (Figure 16). Seven of the twelve samples collected from French Creek during the survey exceeded the primary contact recreation standard of 1,000 colonies/100 ml (Table 2). Currently, only the lower portion of French Creek (downstream from RM 0.40) is designated for primary contact recreation, while upstream portions of the stream are designated for secondary contact recreation. None of the samples collected exceeded the secondary contact recreation standard of 2,000 col./100 ml. It is recommended that the entire stream be re-designated to have the primary contact recreational use at this time. This recommendation is based upon the presence of the Lorain County French Creek Metropark which is located immediately upstream from RM 0.40 and because of data gathered during the intensive survey which indicates that deep pools are present all along the stream which would meet the criteria currently used to designate primary contact recreation streams.

Elevated fecal coliform levels in the upper reaches of French Creek are likely the result of runoff from agricultural and unsewered areas. However, the North Ridgeville WWTP is the likely source of the elevated levels observed at RM 0.40 (Figure 25). Analysis of monthly operating report data for the North Ridgeville WWTP indicates that 95th percentile fecal coliform levels during the summer month often exceeds 1,000 col./100ml and have been as high 7,500 col./100 ml. Methods to provide better disinfection of the discharge should be investigated in order to better protect the recreational uses of French Creek, especially since the discharge of treated effluent dominates the flow in the stream downstream from the WWTP under summertime low flow conditions.

Sampling to determine whether priority pollutant organic compounds were present in the water column was also conducted upstream (RM 3.2) and downstream (RM 0.4) of the North Ridgeville WWTP on July 16 and August 26, 1997. Analysis was performed for 53 semi-volatile and 59 volatile organic compounds on each sample. No organic compounds were detected in any of the samples collected from French Creek during the survey.

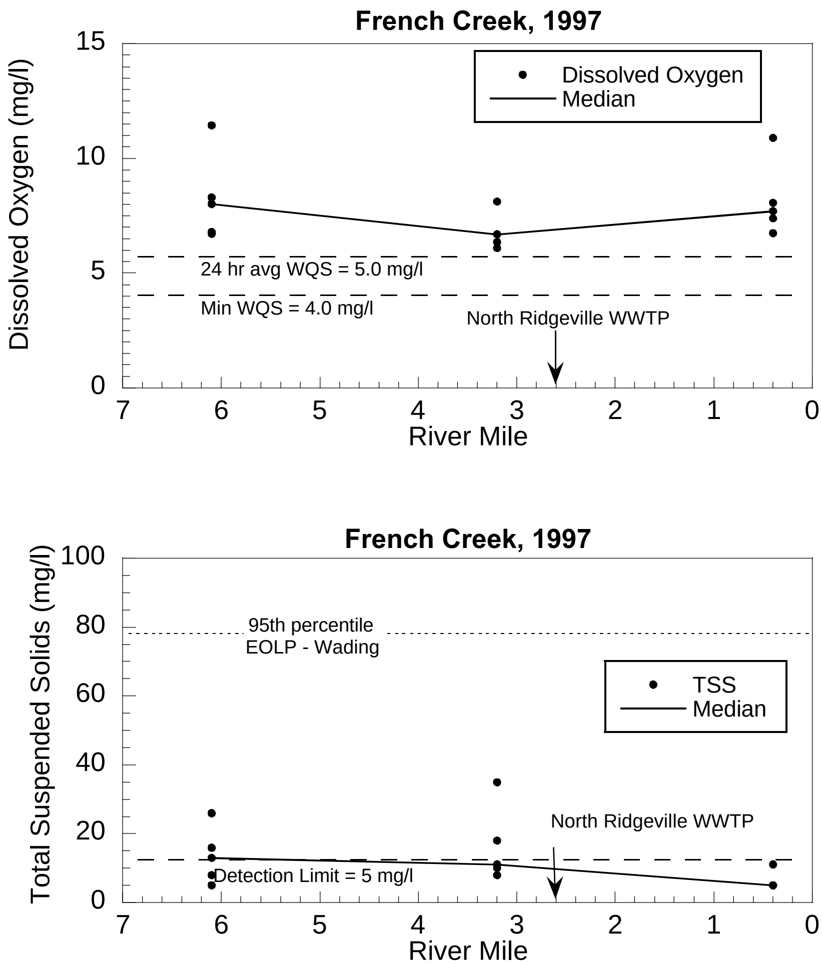


Figure 24. Concentrations of dissolved oxygen and total suspended solids in water quality samples collected from French Creek, 1997 in relation to the North Ridgeville WWTP.

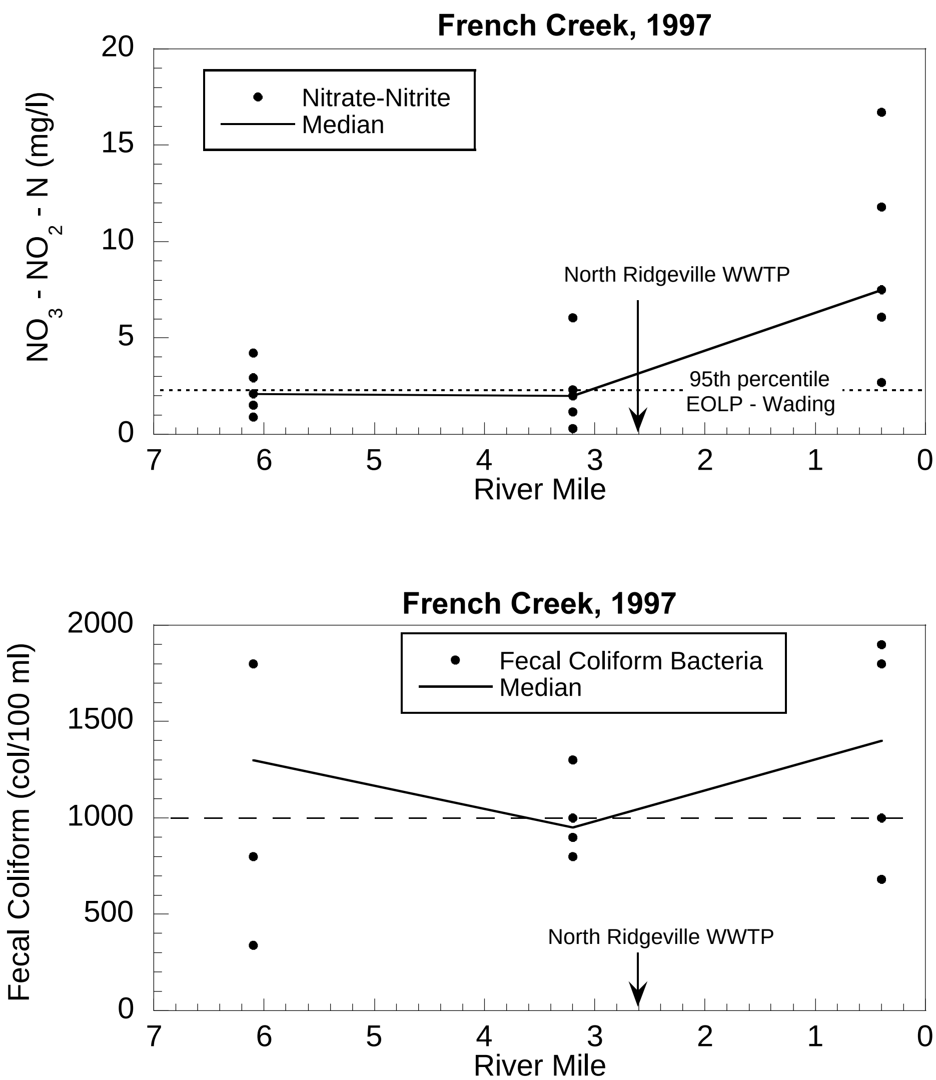


Figure 25. Nitrate-nitrite concentrations and counts of fecal coliform colonies in water quality samples collected from French Creek, 1997 in relation to the North Ridgeville WWTP.

Black River

Ten sites were sampled to evaluate the chemical water quality of the main stem of the Black River in 1997. Four sites were located in the free-flowing portion of the river, and six sites were located in the estuary of the river (from approximately RM 6.2 to the mouth), where flows are affected by changes in the elevation of water in Lake Erie. Of the six estuary sites, three were located upstream from the navigation channel maintained by the U.S. Army Corps of Engineers (upstream from RM 2.8), and three sites were located within the navigation channel. As a follow-up to the 1997 sampling, four surveys of the estuary portion of the river were conducted to measure field parameters (temperature, dissolved oxygen, pH, and conductivity) in 1998. Monitoring in 1998 was conducted at all of the sites utilized in the 1997 survey as well as at additional sites located at RM's 1.05, 1.83, 2.65, 3.75, and 4.15.

Each water chemistry site was also sampled twice during the survey to determine whether priority pollutant organic compounds were present in the water column July 16 and August 26, 1997. Analysis was performed for 53 semi-volatile and 59 volatile organic compounds on each sample. Analytical results listing organic compounds detected in the samples are listed in Table 6. All of the organic compounds detected at concentrations very near the detection limit, and none were present at levels violating any applicable water quality criteria.

Table 6. Concentrations of organic compounds detected in whole water samples collected from the Black River, 1997.

River Mile	Date	Compound/CAS Number	Concentration (μg/l)
9.80	7/16/97	Bromodichloromethane (75-27-4)	1.8
9.80	7/16/97	Chloroform (67-66-3)	4.3
9.80	7/16/97	Dibromochloromethane (124-48-1)	1.0
5.30	7/16/97	Chloroform (67-66-3)	1.2
5.30	8/26/97	Chloroform (67-66-3)	0.6
4.50	7/16/97	Chloroform (67-66-3)	0.7
2.24	8/26/97	Toluene (108-88-3)	0.6
0.42	8/26/97	Toluene (108-88-3)	0.6
0.10	8/26/97	Toluene (108-88-3)	0.8

Data regarding the concentrations of heavy metals in the Black River is presented in Figure 26. No detectable concentrations of chromium (Cr) or nickel (Ni) were noted during the study, although it is likely that the high detection limits (30μg/l for Cr and 40μg/l for Ni) of the analytical procedures utilized for the study prevented measurement of these elements. Mercury was detected at a concentration just at the detection limit of 0.2μg/l on one occasion at RM 9.80 just downstream from the City of Elyria WWTP discharge. This one occurrence was the only instance in which any of the applicable water quality criteria were exceeded for any of the metals during the study. Concentrations of copper and lead showed no distinguishable longitudinal pattern (Figure 26), while concentrations of arsenic appeared to be tied to loadings from the watershed, with the highest concentrations found downstream from the confluence of the East and West Branches. Arsenic concentrations decreased steadily downstream from the confluence, and did not increase downstream from the Elyria or North Ridgeville wastewater treatment plants, and became undetectable in the navigation channel (downstream from RM 3.0).

Although cadmium was detectable in almost all of the samples collected during the study, the concentration changed significantly as the result of point source discharges (Figure 26). Median concentrations of cadmium increased from 0.2μg/l at RM 15.00 to 0.9μg/l in the vicinity of French Creek at RM 5.3. The frequency of detection of zinc and the concentration of zinc (Figure 26) were both affected by point source discharges. Zinc concentrations increased from less than detection (10μg/l) to 18μg/l downstream from the Elyria and North Ridgeville wastewater treatment plants. Metals concentrations generally decreased markedly within the navigation channel, with a coincident marked decrease in the frequency of detection of these parameters within this stream segment. These changes within the navigation channel are indicative of sedimentation and incorporation of these elements into the river sediments.

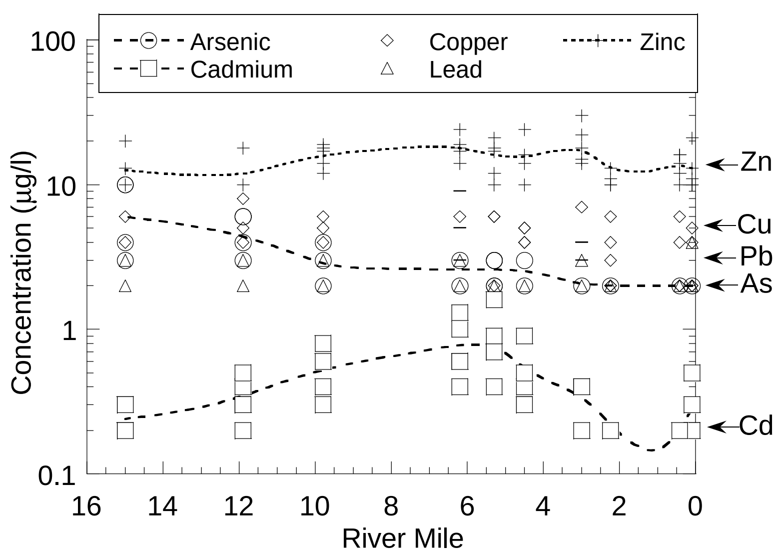


Figure 26. Concentrations of arsenic, cadmium, copper, lead and zinc in water quality samples collected from the Black River, 1997. Respective 75th percentile concentrations from reference sites in the EOLP ecoregion are shown on the right y-axis.

The principal problem regarding water quality in the Black River discovered during the 1997 survey was the reduction in dissolved oxygen concentrations in the portion of the river which is dredged for navigation (Figure 27). Surface D.O. concentrations at stations upstream from the navigation channel were generally well above the minimum water quality criteria on all sampling dates, with median concentrations ranging from 8.03 to 9.11 mg/l. Median surface D.O. concentrations declined to 5.12 mg/l at RM 2.42, and recovered near the mouth of the river (median = 6.67 mg/l at RM 0.42 and 6.80 mg/l at RM 0.10), probably because of the intrusion of Lake Erie water into the river. Monitoring conducted off the bottom of the river (0.5m above the sediment surface) found that D.O. concentrations were significantly reduced compared to the surface concentrations in July of 1997, and were below the minimum water quality criteria from RM 3.00 to RM 0.42 (Figure 28). Conditions with respect to D.O. had improved by September 4, 1997 (Figure 29), although D.O. concentrations were reduced in the navigation channel relative to conditions observed upstream, and D.O. concentrations near the bottom continued to be below the minimum water quality criteria at RM 2.45.

In order to better establish whether the conditions observed in 1997 with respect to dissolved oxygen in the navigation channel were characteristic of the long term condition of the river, additional sampling was conducted in 1998 on May 20, August 10, August 19 and September 23. Monitoring of D.O., temperature, pH and conductivity was conducted at 10 locations between RM 5.1 (just upstream from the confluence of the Black River with French Creek) to the mouth. Monitoring was conducted just below the surface and at 0.5 m above the river bottom at each location. Monitoring was also conducted at mid-depth in the water column for sites within the dredged navigation channel.

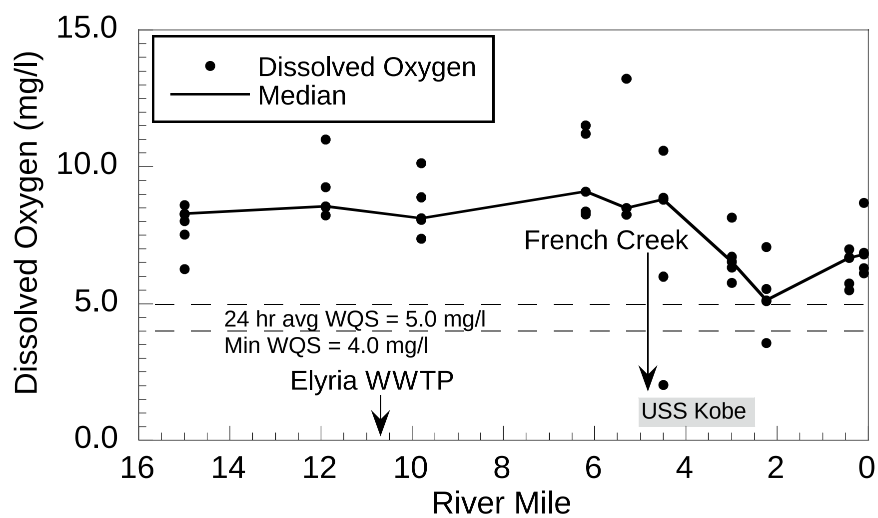


Figure 27. Surface instream dissolved oxygen concentrations in the Black River, 1997 in relation to the Elyria WWTP, French Creek, and the area of USS/Kobe discharges.

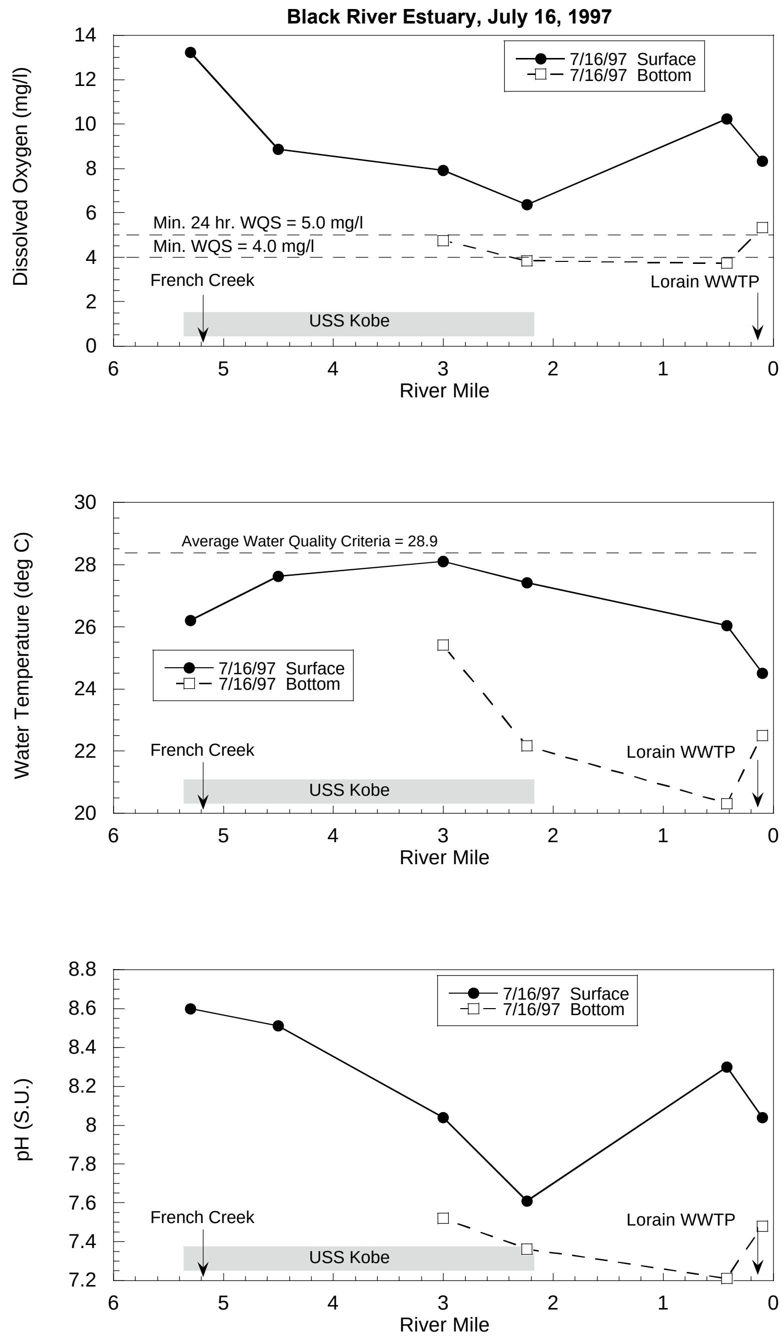


Figure 28. Plots comparing median surface and bottom (0.5 m off the bottom) concentrations of dissolved oxygen, temperature and pH in the lake influenced portion of the Black River 16 July 1997, in relation to French Creek, the area receiving discharge from USS/Kobe and the Lorain WWTP.

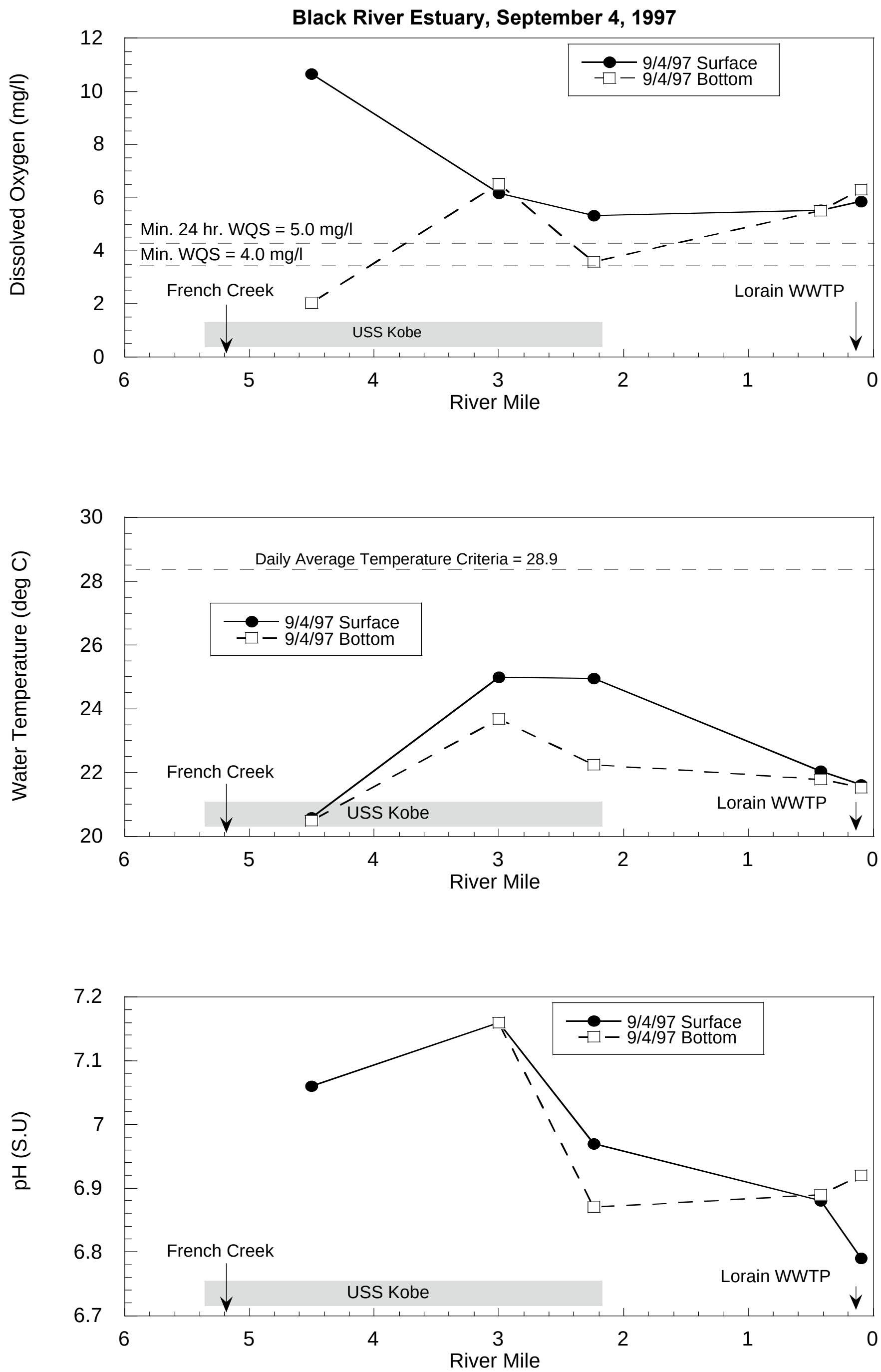


Figure 29. Plots comparing median surface and bottom (0.5 m off the bottom) concentrations of dissolved oxygen, temperature and pH in the lake influenced portion of the Black River 4 September 1997, in relation to French Creek, the area receiving discharge from USS/Kobe and the Lorain WWTP.

The 1998 monitoring revealed that the depletion of dissolved oxygen in the estuarine portion of the Black River was more severe in 1998 than in 1997. Thermal stratification was well established by May 20, 1998 (Figure 30) and dissolved oxygen concentrations at the bottom had declined to below the minimum water quality criteria in the navigation channel at RM 2.42 just downstream from the USS/Kobe turning basin (Figure 30). By August of 1998, dissolved oxygen concentrations within the navigation channel had declined throughout the water column so that minimum water quality criteria were not met at any depth within the navigation channel. Median surface D.O. concentrations ranged from 4.37 to 6.17 mg/l from RM 3.00 to the mouth on August 10 (Figure 31), from 3.96 to 4.85 mg/l on August 19 (Figure 32), and from 4.35 to 5.76 mg/l on September 23, 1998 (Figure 33). The navigation channel was strongly stratified thermally throughout this period (Figures 31 - 33), resulting in the depletion of D.O. in the bottom waters of the navigation channel. Minimum D.O. concentrations noted were 0.19 mg/l on August 10, 0.10 mg/l on August 19, and 0.15 mg/l on September 23, 1998.

It is not possible to identify one single underlying cause of the depletion of D.O. in the navigation channel of the Black River. Instead, it is likely that several factors combine to create a situation favorable to the observed conditions. These include the loadings of pollutants from both point and non-point sources, temperature regimes, and the physical and hydrologic characteristics of the river itself, especially since the estuary of the river is highly modified through dredging and shoreline modifications in order to accommodate navigation and industry.

Primary productivity can be a critical component in determining the dissolved oxygen concentration in the aquatic ecosystem (Wetzel, 1975) since oxygen is a byproduct of the process of photosynthesis. Data collected during the 1997 survey and the subsequent 1998 sampling of the Black River indicates that primary productivity in the Black River estuary is depressed. Depletion of dissolved oxygen during the daytime hours, decreasing pH (Figures 30-34), and decreasing COD concentrations (Figure 35) in the estuary are all indicative of a situation where bacterial respiration within the water column is occurring at a much greater rate than photosynthesis.

The likely cause for the depression of primary productivity in the Black River estuary is the consistently high concentration of suspended solids in the water column (Figure 35) which results in light limitation to algae and rooted aquatic plants. Median total suspended solids (TSS) concentrations at both sampling locations upstream from the Elyria WWTP were 16 mg/l during the 1997 study. The median TSS concentration increased to 28 mg/l in the vicinity of the mouth of French Creek, and ranged from 22 mg/l to 28 mg/l in the upper estuary of the river between RM 5.3 and RM 3.00. Concentrations of TSS decreased by roughly 40% in the navigation channel, where median concentrations ranged from 16 to 18 mg/l. The mouth of the river was the most variable with respect to TSS concentrations, with values ranging from less than the detection limit of 5 mg/l to 78 mg/l during the study. Water clarity, as measured by Secchi disk transparency, ranged from 0.2 to 0.5 m, indicating that algal productivity in the estuary may be limited by the lack of available

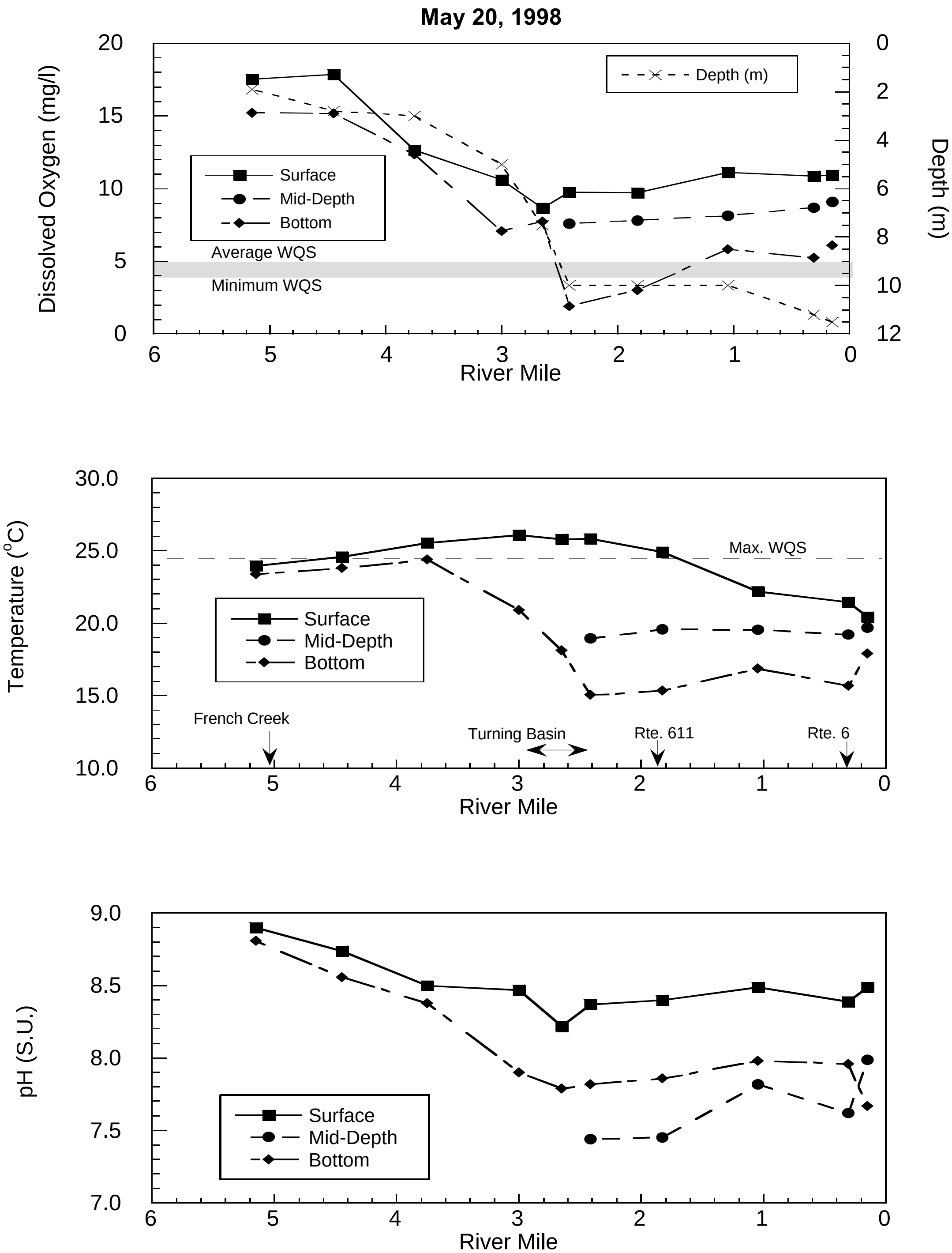


Figure 30. Plots comparing surface, mid-depth and bottom (0.5 m off the bottom) concentrations of dissolved oxygen, temperature and pH in the lake influenced portion of the Black River 20 May 1998, in relation to selected landmarks and depth

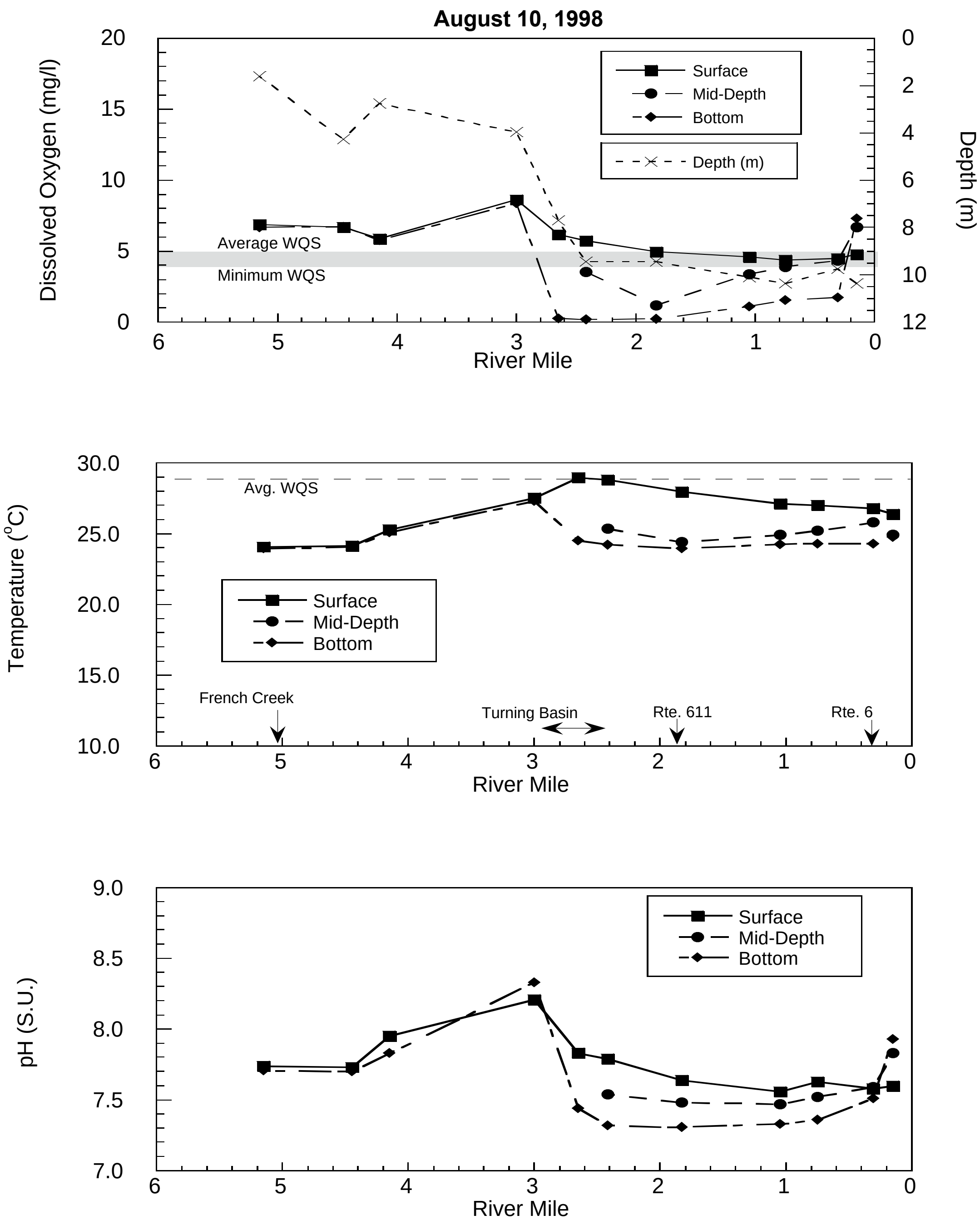


Figure 31. Plots comparing surface, mid-depth and bottom (0.5 m off the bottom) concentrations of dissolved oxygen, temperature and pH in the lake influenced portion of the Black River 10 August 1998, in relation to selected landmarks and depth.

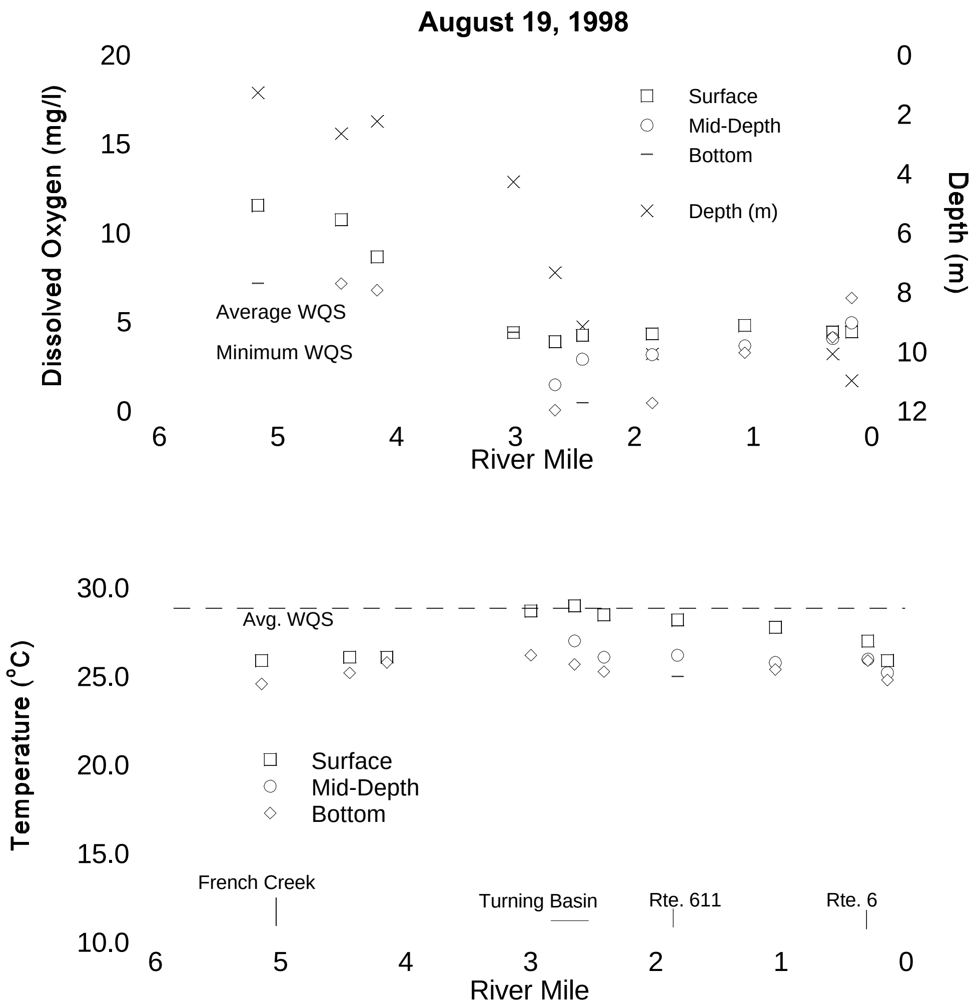


Figure 32. Plots comparing surface, mid-depth and bottom (0.5 m off the bottom) concentrations of dissolved oxygen, and temperature in the lake influenced portion of the Black River 19 August 1998, in relation to selected landmarks and depth.

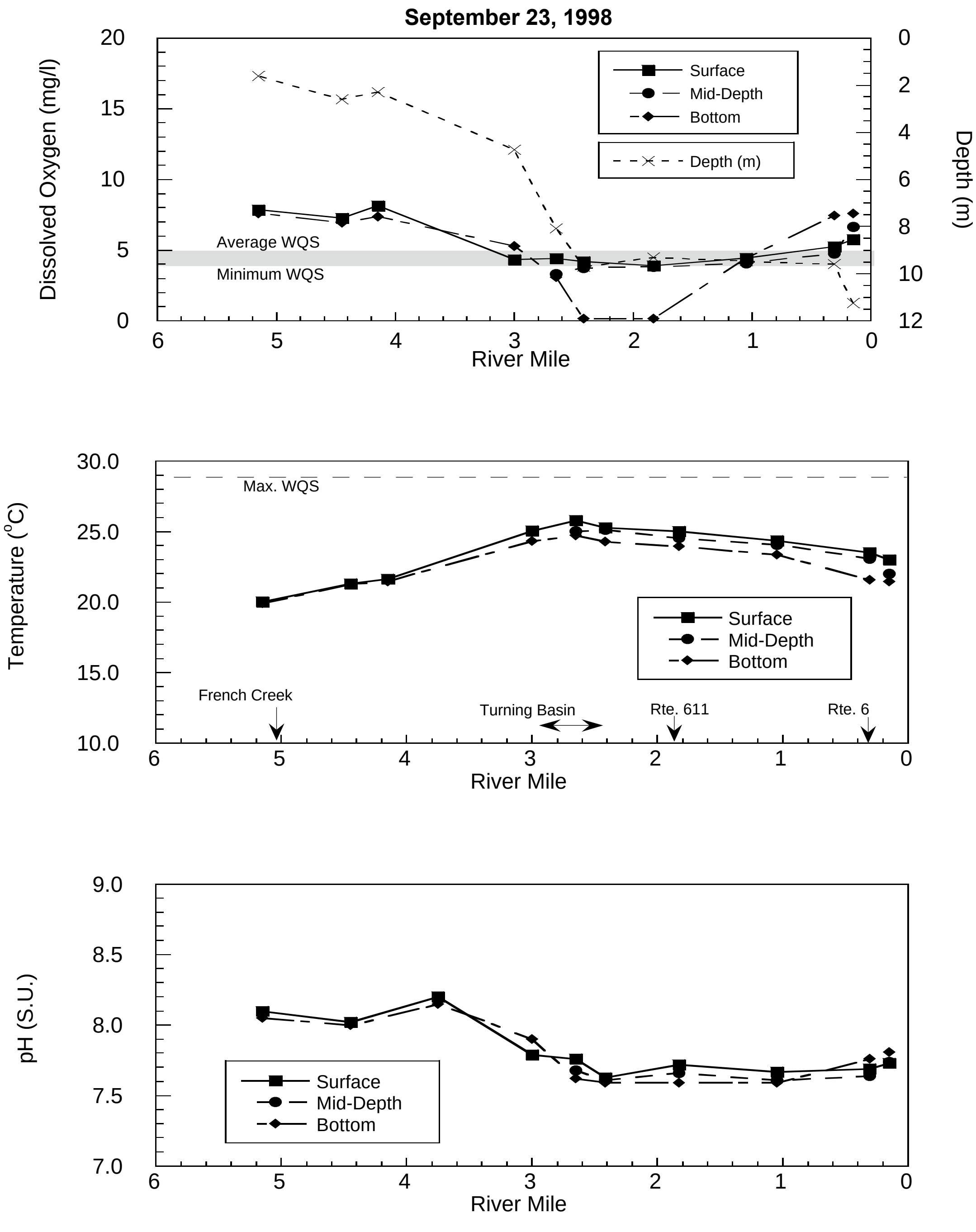


Figure 33. Plots comparing surface, mid-depth and bottom (0.5 m off the bottom) concentrations of dissolved oxygen, temperature and pH in the lake influenced portion of the Black River 23 September 1998, in relation to selected landmarks and depth.

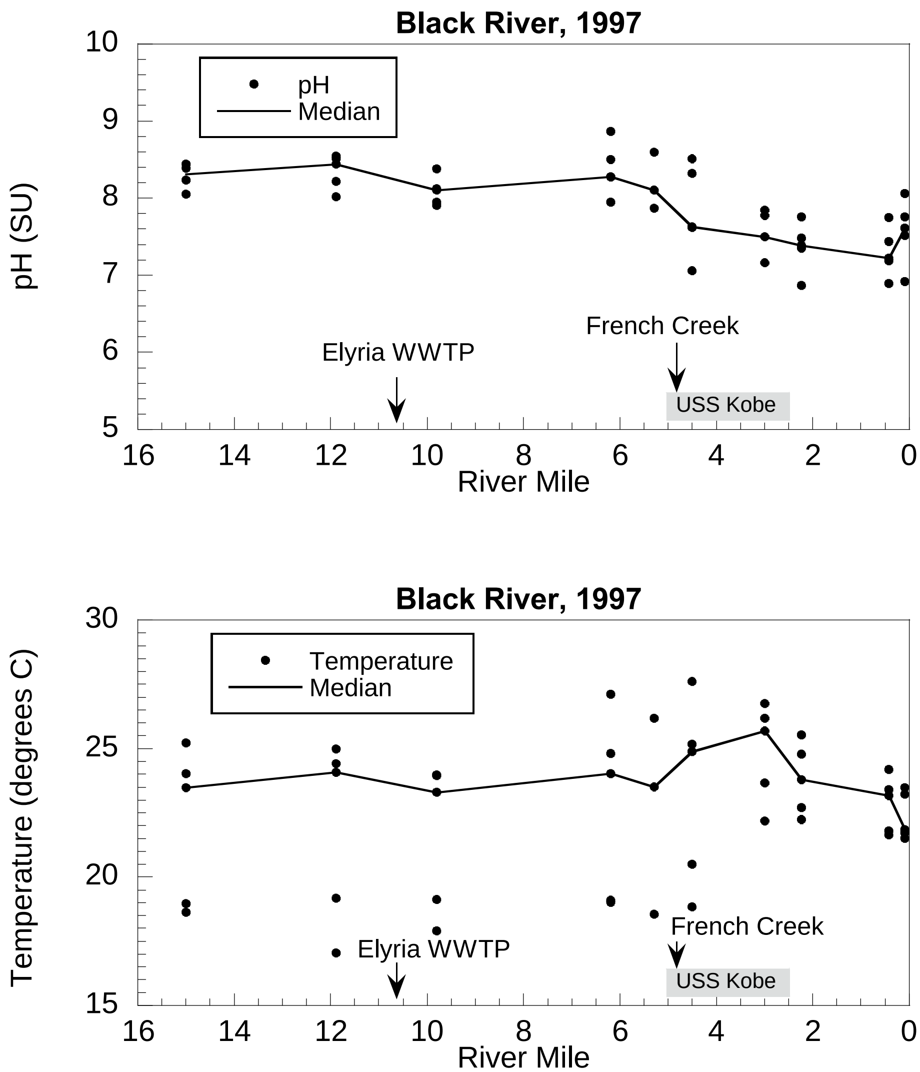


Figure 34. Instream pH and temperature measurements for the Black River, 1997 in relation to the Elyria WWTP, the area receiving discharge from USS/Kobe and French Creek.

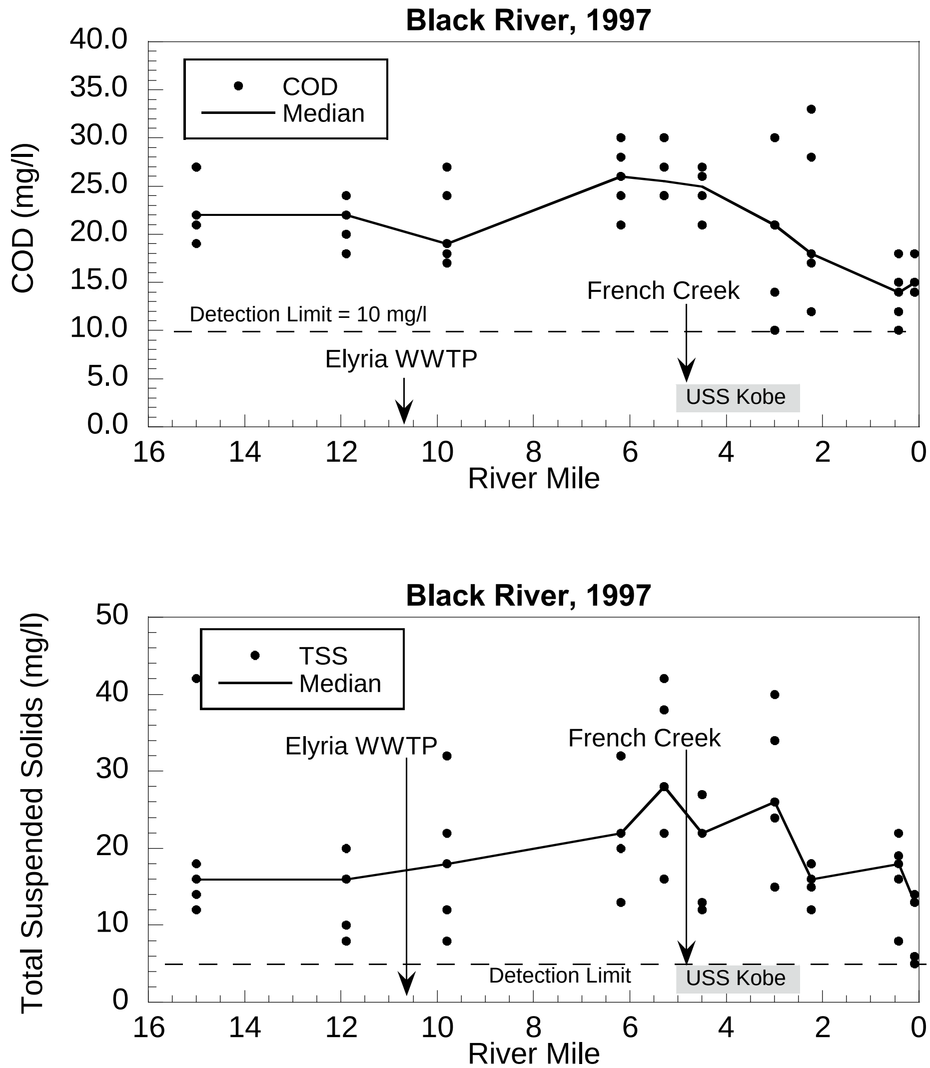


Figure 35. Concentrations of chemical oxygen demand (COD) and total suspended solids in water quality samples collected from the Black River, 1997 in relation to the Elyria WWTP, French Creek and the area of the river receiving discharge from USS/Kobe.

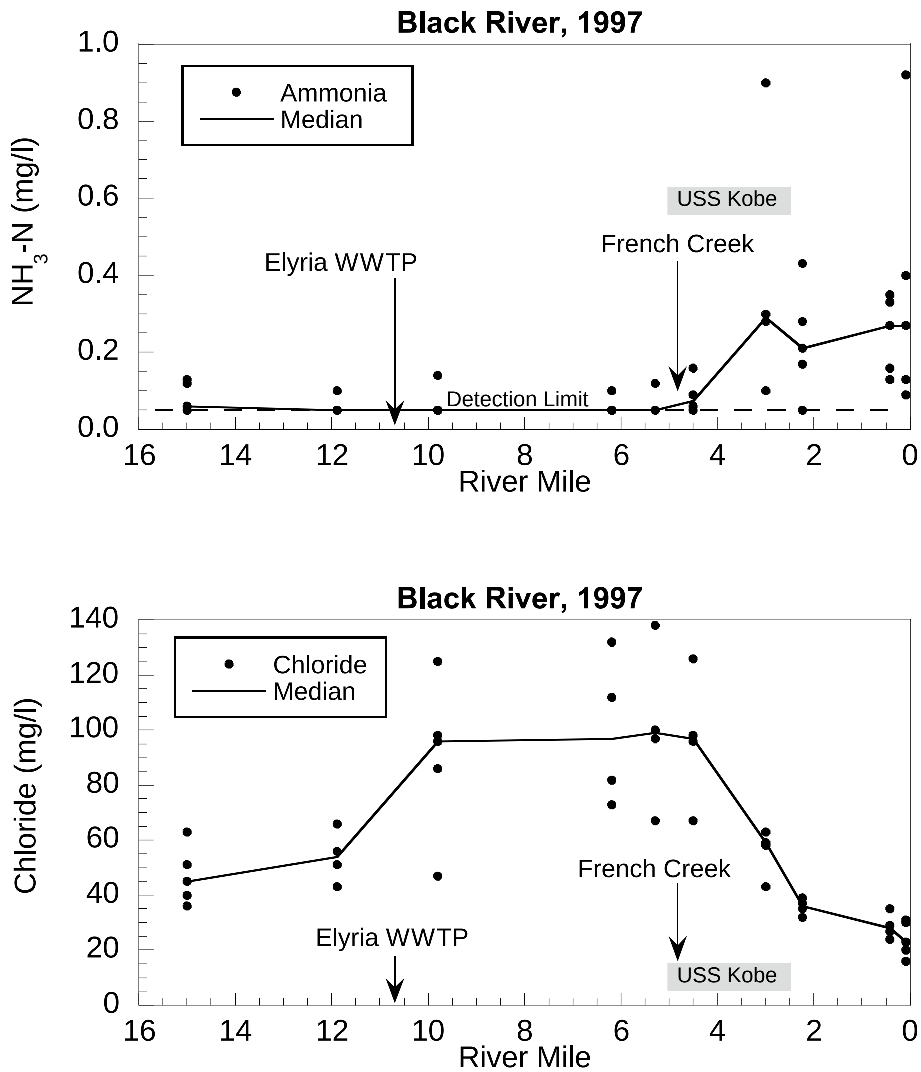


Figure 36. Concentrations of ammonia-nitrogen (NH_3-N) and chlorides in water quality samples collected from the Black River, 1997 in relation to the Elyria WWTP, French Creek and the area of the river receiving discharge from USS/Kobe.

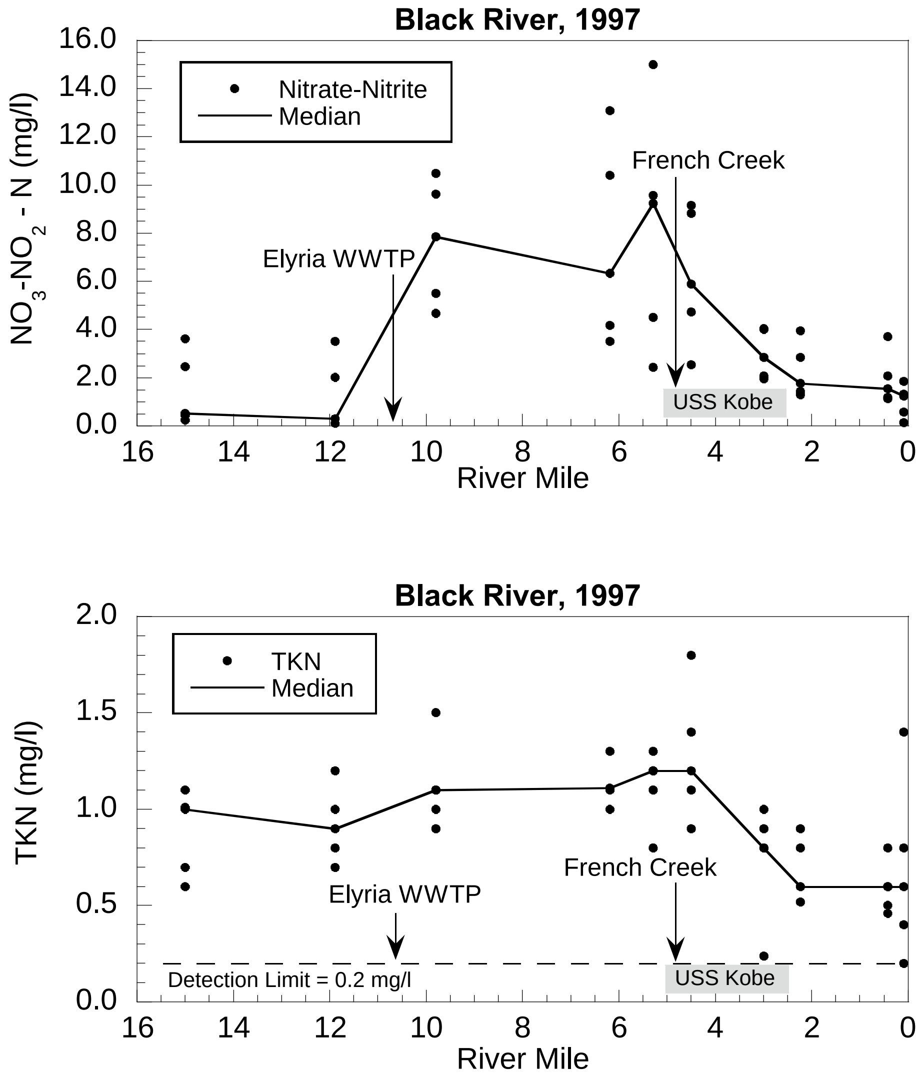


Figure 37. Concentrations of nitrate-nitrite ($N0_3$-NO_2-N) and total Kjeldahl nitrogen (TKN) in water quality samples collected from the Black River, 1997 in relation to the Elyria WWTP, French Creek and the area of the river receiving discharge from USS/Kobe.

light. In addition, in combination with the sedimentation rates implied loadings of solids to the Black River estuary, conditions are not favorable for the establishment of rooted aquatic plants. Sgro and Johansen (1995) found that the periphyton community of the Black River estuary indicated significant stress, being dominated by pollution tolerant species. Additional research into the causes of the observed inhibition of primary productivity is warranted for this stream segment.

The upstream loading of NH_3-N (Figure 36) from the free flowing section of the river (RM 15.56 to RM 6.2) was extremely low during the study period, with concentrations ranging from less than the detection limit of 0.05 mg/l to 0.06 mg/l. These concentrations are within the 25th percentile for unimpacted sites in the Black-Rocky watershed hydrologic unit (Brown, 1988), and are reflective of little or no impact from the Elyria WWTP or CSOs within the City of Elyria under low flow conditions with respect to in-stream NH_3-N concentrations. Concentrations of ammonia-nitrogen increased in the Black River estuary, with median concentrations increasing to 0.28 mg/l between RM 5.3 to the head of the navigation channel at RM 3.0. Median concentrations at the surface ranged from 0.21 to 0.28 mg/l within the navigation channel (from RM 2.8 to the mouth). Elevated concentrations nearing the WWH water quality criteria were observed in the lower river on two occasions during the survey. On June 30, 1997, the ammonia-nitrogen concentration at RM 0.10 was 0.92 mg/l and a concentration of 0.90 mg/l was observed at RM 3.00 on August 26, 1997

There are three potential mechanisms for the observed increase in ammonia- nitrogen concentrations within the navigation channel:

1. Flow reversals near the mouth of the river may result in a significant loading of ammonia-nitrogen to the lower navigation channel as the flow of effluent from the Lorain Black River WWTP is directed upstream. Concentrations of ammonia- nitrogen in the effluent of the WWTP are currently unregulated due to an assumption that the discharge is a direct discharge to Lake Erie. Observations of the river near the WWTP and data collected during the 1997 water quality survey document that flow reversal in the lower Black River is common when Lake Erie water levels rise. The dilution of chloride concentrations (Figure 31) within the navigation channel is also a good indication that flow reversals may impact the water chemistry in the lower river. This phenomenon cannot account for all of the observed concentration increases in the lower river, however, since it is highly unlikely that these pollutants are transported upstream as far as three miles.

2. Metabolism of NO_3-NO_2-N by microorganisms under conditions where dissolved oxygen concentrations are low may result in the generation of NH_3-N. Bacterial de-nitrification metabolism is favored under conditions where uptake of NO_3-N by algae (either planktonic or periphytic) is saturated or low and when dissolved oxygen is deficient (Keeney, 1973). Under these conditions, NO_3-N can be used by bacteria as an alternate electron acceptor (rather than oxygen) for the heterotrophic metabolism of organic compounds. The initial byproduct of this metabolism is NO_2-N, which can be further utilized as an electron acceptor under alternate metabolic pathways. One of these pathways completes the de-nitrification pathway, forming N_2

gas as a byproduct which is lost to the atmosphere. The second pathway results in the reduction of NO_2-N to NH_3-N.

Loadings of NO_3-NO_2-N to the Black River from the Elyria WWTP and the North Ridgeville WWTP via French Creek result in a drastic increase in NO_3-NO_2-N concentrations (Figure 32). Median NO_3-NO_2-N concentrations upstream from the Elyria WWTP ranged from 0.31 to 0.54 (mg/l). The median NO_3-NO_2-N concentration increased to 7.86 mg/l downstream from the Elyria WWTP (RM 9.80), declined slightly to 6.33 mg/l at RM 6.20, and then increased again to 9.24 in the proximity of French Creek (RM 5.2). Concentrations of NO_3-NO_2-N declined steadily within the estuary, with median concentrations being reduced to 1.76 mg/l and 1.55 mg/l at RM 2.42 and RM 0.42, respectively. The reduction in the concentration of NO_3-NO_2-N in the lower river is coincident with decreasing dissolved oxygen concentrations (Figures 20-26) and increasing NH_3-N concentrations (Figure 30), giving support that the metabolic pathways discussed above are important in controlling the relative concentrations of the forms of inorganic nitrogen in the lower Black River.

As was the case with the dissolved oxygen regime of the Black River estuary, it does not appear that algae or rooted aquatic plants play a significant role in controlling the relative concentrations of inorganic nitrogen compounds in the Black River estuary. These plants would tend to utilize NO_3-N and incorporate it into organic compounds as part of their biomass. In terms of this study, this would be observable as a conversion of NO_3-NO_2-N into TKN. However, no increase in TKN concentrations was observed (Figure 33). Rather a significant decrease in TKN concentrations was observed in the Black River estuary, which would again be consistent with the dominance of bacterial metabolic processes in this segment of the river.

3. It is also possible that the source of NH_3-N to the water column is the sediments which accumulate in the navigation channel. Sediments which contain nitrogen compounds may release NH_3-N to overlying waters under reducing conditions when dissolved oxygen is absent or deficient (Keeney, 1973; Wetzel, 1975). The relative importance of this pathway cannot be quantified based upon the data from this study. However, given the loadings of nitrogen compounds from upstream, it is possible that this pathway is insignificant compared to the metabolism of NO_3-NO_2-N through denitrification metabolism. Further water quality studies are necessary in order to determine the relative overall importance of metabolism within the water column and in the sediments to determine the mechanism through which the observed increase in water column NH_3-N is occurring.

Data collected in 1997 and 1998 also indicates that temperature effects within the Black River estuary may be important in controlling the degree of dissolved oxygen depletion since the rate of microbial metabolism is accelerated at higher temperatures. As discussed in the Pollutant Loadings section of this report, changes at the USS/Kobe Steel facility have resulted in increased discharge rates of cooling water at upstream locations (primarily outfall 002 at RM 3.50) within the facility while discharge rates at downstream locations have decreased. This has resulted in increased water temperatures within the estuary upstream from the navigation channel between RM 5.1 and RM 2.8 (Figures 30-34). On the average, in 1998, median surface water temperatures increased by 0.7°C downstream from USS/Kobe Outfall 001 (RM 5.05) and by 2.3°C downstream from Outfall 005 (RM 3.95). Monitoring conducted in 1998 found that at times temperatures within this segment of the estuary exceeded the water quality criteria for Lake Erie tributary estuaries. On May 20, 1998, surface water temperatures ranged from 24.58 °C to 26.09°C from RM 4.45 to RM 1.83, exceeding the maximum water quality criteria of 24.4°C. The surface temperature at RM 2.42 (28.97°C) on August 10, 1998 and at RM 2.65 on August 19, 1998 (29.00°C, Figure 34) also exceeded the average water quality criterion of 28.9°C, indicating the possibility that this criterion may be exceeded during the summertime.

A conceptual model of the multiple factors interacting to determine the water quality characteristics of the river is depicted in Figure 38. Further work is needed to determine the relative importance of each of the factors identified in this model in determining the timing and degree of depletion of dissolved oxygen in the navigation channel and the implications for the attainment of conformance for other water quality criteria including chemical and biological indicators. It is recommended that an integrated water quality model be developed for the entire Black River mainstem which can be utilized to predict the impacts of the various stressors on the Black River estuary (non-point pollution from the watershed, CSO/SSO contributions, point source impacts and lake water intrusion). This model could also be used to evaluate the feasibility of attainment of the water quality criteria in the estuary under various pollutant abatement scenarios to assess alternative strategies for meeting this goal. All of the stakeholders potentially affected by this effort should be included in the model development process from the outset in order to ensure that the final product is realistic for implementation. Until a model of this type is constructed, the Ohio EPA should not allow any increases in pollutant loads for point source dischargers that discharge to, or influence water quality in, the mainstem of the Black River. In addition, final approval of a long term control plan for combined sewer discharges within the City of Elyria cannot be granted until their overall contribution to the existing water quality problems in the Black River estuary are quantified.

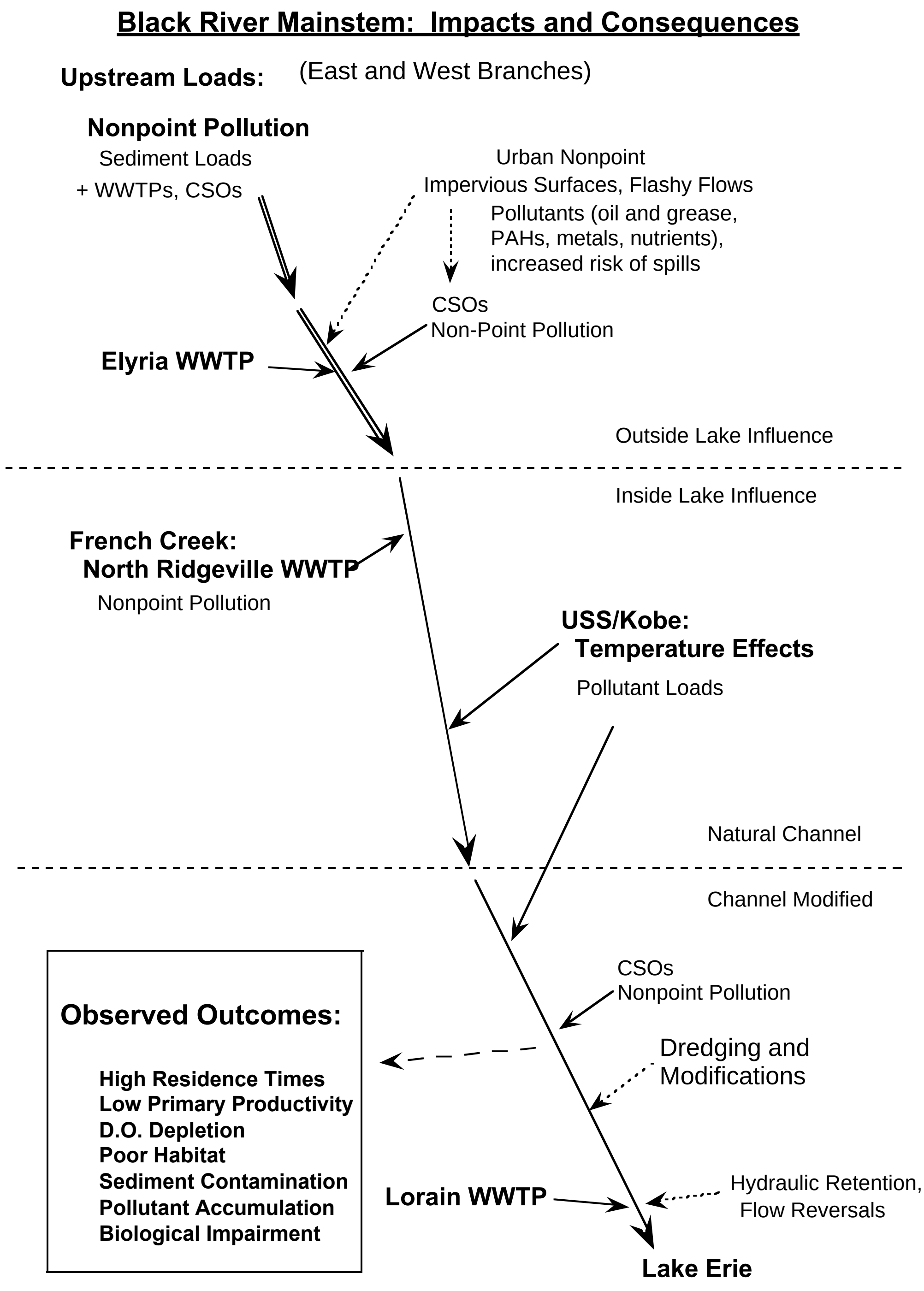


Figure 38. A conceptual model of the multiple factors interacting to determine the water quality characteristics of the Black River mainstem.

Table 7. Exceedances of Ohio EPA Water Quality Criteria (OAC Chapter 3745-1) for chemical parameters measured in the Black River study area, 1997. Units are colonies/100 ml for fecal coliform, mg/l for dissolved oxygen and μg/l for mercury.

Stream	River Mile	Exceedance: Parameter (value)
Black River	15.00	Fecal Coliform (2,200[#], 1,400[#])
	11.90	Fecal Coliform (1,600[#])
	9.80	Fecal Coliform (1,800[#]), Mercury (0.2[@])
	6.20	Fecal Coliform (1,300[#], 1,100[#])
	4.50	Dissolved Oxygen (bottom, 2.04**)
	2.24	Dissolved Oxygen (bottom, 3.57**)
East Fork E. Branch	2.70	Fecal Coliform (1,900[#])
	0.10	Fecal Coliform (2,500[#])
East Branch	41.50	Fecal Coliform (4,700[#])
	18.90	Dissolved Oxygen (4.5*, 4.3*); Fecal Coliform (2,500[#])
	11.30	Fecal Coliform (1,500[#])
	6.00	Fecal Coliform (1,100[#])
	5.20	Fecal Coliform (2,500[#])
	3.00	Fecal Coliform (1,000[#], 1,800[#], 1,200[#])
Willow Creek	6.00	Dissolved Oxygen (0.2**,0.4**, 3.1**, 2.6**) Ammonia-Nitrogen (2.31[†], 14.00[††]) Fecal Coliform (55,000[##], 11,000[##], 3,400[#])
	5.00	Dissolved Oxygen (1.9**, 2.9**, 3.8**)
	2.90	Dissolved Oxygen (4.0*) Fecal Coliform (2,100[#])
West Branch	1.20	Fecal Coliform (1,200[#], 1,700[#], 1,600[#], 1,400[#])

Table 7. Continued.

French Creek	6.10	Fecal Coliform (1,800#, 1,800#)
	3.20	Fecal Coliform (1,300#, 1,000#)
	0.40	Fecal Coliform (1,800#, 1,000#, 1,900#)

Exceedance of the Primary Contact Recreation average criterion for fecal coliform bacteria of 1,000 colonies/100 ml.

Exceedance of Primary Contact Recreation maximum criterion for fecal coliform bacteria of 5,000 colonies/100ml.

* Concentration below the Warmwater habitat Outside Mixing Zone minimum 24 hour average criterion of 5.0 mg/l.

** Concentration below the Warmwater Habitat Outside Mixing Zone Minimum dissolved oxygen criterion of 4.0 mg/l.

† Exceeds WWH Outside Mixing Zone Average criterion.

†† Exceeds WWH Outside Mixing Zone Maximum criterion.

@ Exceeds Lake Erie non-drinking water human health OMZA and Lake Erie wildlife OMZA (OAC 3745-1-33).

Beaver Creek

Exceedences of ambient water quality criteria for Beaver Creek were observed for NH_3-N and dissolved oxygen downstream of the Amherst WWTP (Table 8). Concentrations of NH_3-N were above the outside mixing zone average (OMZA) water quality criterion at the Cooper-Foster Rd. (RM 2.80) sampling site on each sampling date of the study (Figure 39). This site is located approximately one river mile below the Amherst WWTP outfall, indicating that a significant reach of the stream is impacted by chronic toxicity from this poorly controlled discharge. Assimilation of NH_3-N within the stream is evident downstream of Cooper-Foster Rd., where only one exceedance of the OMZA water quality criterion was noted at Longbrook Rd. (RM 1.6).

Table 8. Exceedances of Ohio EPA Water Quality Criteria (OAC Chapter 3745-1) for chemical parameters measured in the Beaver Creek study area, 1997. Units are colonies/100 ml for fecal coliform and mg/l for dissolved oxygen and ammonia nitrogen.

Stream	River Mile	Exceedance: Parameter (value)
Beaver Creek	4.65	Fecal Coliform (1,400$^{\#}$)
	2.80	Dissolved Oxygen (3.98*); Ammonia Nitrogen (2.53^{+}, 10.4^{+}, 2.4^{+}, 5.74^{+})
	1.60	Dissolved Oxygen (3.60*); Ammonia Nitrogen (6.62^{+})

Exceedance of the Primary Contact Recreation standard for fecal coliform bacteria of 1,000 colonies/100 ml.

* Concentration below the Warmwater Habitat average dissolved oxygen criterion (4.0 mg/l).

\+ Concentration exceeds the Outside Mixing Zone 30 day average Water Quality Criterion for Warmwater Habitat listed in OAC 3745-1-07, Table 7-7.

A distinct sag in dissolved oxygen concentrations in Beaver Creek was noted at both sampling sites downstream of the Amherst WWTP (Figure 39). Dissolved oxygen concentrations averaged 2.2 mg/l less at Cooper-Foster Rd. (RM 2.80 downstream of the Amherst WWTP) than those observed at Martin Rd. (RM 4.65, upstream of the Amherst WWTP). Concentrations of dissolved oxygen did not recover at the downstream sampling site at Longbrook Rd., indicating that dissolved oxygen deficiency may impact a significant portion of the downstream reach of the stream. The lower portion of the stream has very low gradient and the stream channel is characterized by deeper, slower moving water than is found upstream of the wastewater treatment plant. Therefore, problems associated with low concentrations of dissolved oxygen may persist to the mouth of the stream.

The primary cause for the decline in dissolved oxygen noted in Beaver Creek was the Amherst

WWTP discharge increasing in-stream oxygen demand (Figure 39) and enriching the stream with high concentrations of nitrogen nutrients (NH_3-N, nitrate-nitrite nitrogen, and total Kjeldahl nitrogen) and phosphorus (Figure 39). Nutrient enrichment of the stream was still evident at Longbrook Rd., although the concentrations of these nutrients declined somewhat through assimilative processes within the stream. The data from Longbrook Rd. indicate that Willow Creek does not contribute significantly to the water quality problems observed in the mainstem of Beaver Creek.

Analysis of Beaver Creek samples for toxic organics and heavy metals did not discover any in-stream water quality problems related to these compounds. Samples were collected twice during the survey for analysis for volatile and semi-volatile organic compounds. No toxic organic compounds were detected in the samples. Analyses of water collected from Beaver Creek for heavy metals found that all of these constituents were either undetectable or well below the water quality criteria for Lake Erie tributaries.

Modifications to the Amherst WWTP to significantly reduce the concentrations of NH_3-N, other nutrients, and oxygen demanding compounds are clearly needed if there is to be improvement in the water quality of Beaver Creek. As an alternative, the abandonment of the plant in favor of the use of the Lorain West WWTP as a regional wastewater treatment facility should be investigated. The aim of either approach should be to eliminate instances where chronic toxicity persists within the stream and to reduce the level of organic and nutrient enrichment to the stream to levels that can be assimilated without impairing the stream biota. Continued monitoring of the stream after implementation of corrective measures is necessary to evaluate their effectiveness in improving both chemical and biological water quality. If an upgrade of the existing WWTP is selected by the City of Amherst and the Ohio EPA as the corrective remedy for the current problem, it is likely that additional pollution controls to reduce nitrate-nitrite nitrogen and further reduce the ambient concentration of phosphorus will be necessary for the stream to reach its full potential for aquatic life use downstream from the WWTP discharge.

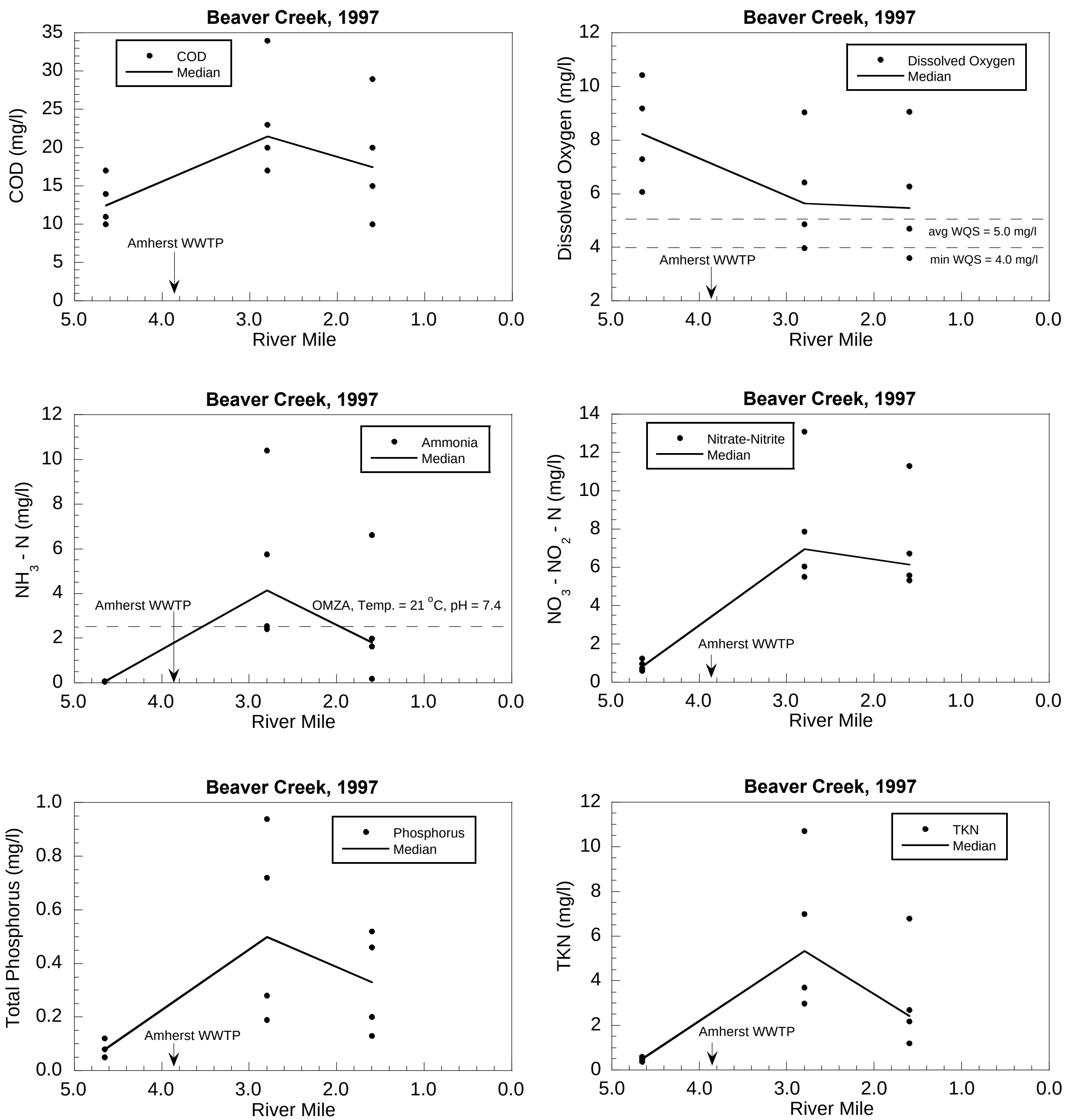


Figure 39. Concentrations of (from left to right) cheimical oxygen demand (COD), dissilved oxygen, ammonia-nitrogen (NH_3-N), nitrate-nitrite nitrogen (NO_3 NO_2 -N), total phosphorus, and total Kjeldahl nitrogen (TKN) in water quality grab samples collected from Beaver Creek in relation to the Amherst WWTP, 1997.

Sediment Quality

Surficial grab samples of stream sediment were collected from eight sites in the Black River, two sites in the East Branch and one site in Willow Creek in 1997 for the analysis of sediment quality (Table 9). Sediment samples were also collected by the Ohio EPA from two sites in the Black River, two sites in the East Branch, and two sites in French Creek in 1996 as part of the Lake Erie Basin Sediment Project funded by the U.S.EPA Great Lakes National Program Office (GLNPO). Additional sediment core sampling was also conducted in the Black River estuary by U.S.EPA GLNPO in support of a study conducted by Dr. Paul Baumann of the U.S. Geological Survey (USGS) with the assitance of the U.S.EPA coring boat, the *RV Mudpuppy*.

Grab samples were collected either using a stainless steel Eckman dredge or with a stainless steel scoop depending upon overlying water depth. Deep vibra-core samples were collected from five locations in the estuary at RM 0.27, RM 2.42, RM 2.51, RM 2.88, and RM 4.11 (see Appendix Table 5 for sample location information). Core samples were divided into discrete samples based upon the depth of the core for separate analysis. Core penetration varied from 21 inches to 54 inches for samples collected from the Black River. Samples were analyzed for particle size (Ohio EPA samples only), heavy metals, semi-volatile organic compounds, including polynuclear aromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), and toxic pesticide compounds (Ohio EPA samples only). Analytical results for sediment samples collected from the Black river watershed in 1996 and 1997 are listed in tabular form in Appendix Tables 6, 7, and 8 of this report.

East Branch Black River

Analysis of sediment samples collected from the East Branch of the Black River in 1996 and 1997 found no detectable PCBs, semi-volatile organic compounds, or toxic pesticides. In addition, heavy metals were found at concentrations considered non-elevated as compared to reference sites in the Erie Ontario Lake Plain ecoregion (EOLP). The exception to this was the sample collected at RM 11.40, where elevated concentrations of copper and slightly elevated concentrations of iron and zinc were detected. The concentration of iron found in this sample (46,666 mg/kg) exceeds that found to have a severe effect on aquatic life in studies conducted in Ontario, Canada (Persuad, et al., 1993). The source of heavy metals detected at this location is unclear, since this site is well downstream from point source discharges and is upstream from the Grafton WWTP, which discharges at RM 11.15. However, part of Grafton drains to the East Branch upstream from the sampling location, so the contamination may reflect urban and suburban runoff. The lack of significant concentrations of chemical pollutants in the East Branch sediments may be partially explained by the high percentage of sand in the stream sediments throughout the stream. Fine grained sediments tend to adsorb chemical contaminants, especially organic compounds much more readily than large grained, sandy sediments.

Willow Creek

As with the sediments in the East Branch, the sediments collected for analysis from Willow Creek in 1997 were largely composed of sand. These sediments did not contain detectable concentrations of toxic pesticides. No analysis was conducted for semi-volatile organic compounds or PCBs.

Heavy metal concentrations in the sediments collected from Willow Creek were at levels considered to be non-elevated except that barium and chromium were both considered to be slightly elevated in comparison to reference sites found in the EOLP.

French Creek

No semi-volatile organic compounds or PCB compounds were detected in the sediment samples collected from French Creek in 1996. However, low concentrations of toxic pesticide compounds (4-4'-DDD, 4,4'-DDE, and 4,4'-DDT) were detected in the two samples. Concentrations of these compounds were only slightly elevated above the analytical detection limit, ranging from 5.3 to 9.1 μg/kg. Concentrations of heavy metal constituents in the sediments collected from French Creek were at levels considered to be non-elevated except for copper and zinc. Copper concentrations were elevated relative to those found at unimpacted reference sites in the EOLP in samples collected both upstream (38.7 mg/kg, RM 6.10) and downstream (41.8 mg/kg, RM 3.20) from the North Ridgeville WWTP. Concentrations of zinc were non-elevated in sediments collected upstream from the North Ridgeville WWTP (78.9 mg/kg), but were highly elevated (221.0 mg/kg) at the downstream sampling location.

The presence of toxic pesticide compounds and elevated concentrations of copper in the French Creek sediment samples is likely the legacy of past agricultural practices in the French Creek watershed. These compounds were typically used in agriculture to control pest organisms, and may take some time to fully diminish in the ecosystem. However, the elevated zinc concentrations detected below the North Ridgeville WWTP can be attributed to the point source discharge with some certainty. Evaluation of the biological data collected both from French Creek immediately below the discharge and in the Black River estuary should be conducted to determine if additional limitations or controls are necessary for the discharge of zinc from this facility.

Black River

Analytical results for selected heavy metals in sediment grab samples collected from the Black River are depicted in Figure x. Comparison is made to concentrations found at Ohio EPA unimpacted reference sites located throughout the EOLP to indicate the degree of contamination identified during the survey. Concentrations of heavy metals are elevated all along the Black River, with the degree of contamination generally higher in the estuary of the river. The heavy metal present in greatest relative concentrations is cadmium (Figure 40), as it was found at concentrations considered extremely elevated for the EOLP ecoregion at all except one of the sampling sites, and therefore is potentially most problematic with respect to aquatic life impairment. Concentrations of cadmium in surficial grabs ranged from less than 2 mg/kg to 10.4 mg/kg. The maximum cadmium concentration in the core samples was 15 mg/kg. Several other heavy metals are present at concentrations likely to have severe effects on aquatic life (Persuad, et al., 1993), notably copper (two samples), iron (four samples) and nickel (one sample).

The relative degree of heavy metal contamination of the sediments within the Black River becomes evident when the data is compared with that from reference sites throughout the State of Ohio

(Figure 41). Analyses for heavy metals were pooled to determine the percentage of concentrations which fell into various percentile ranks generated from the reference site data. In comparison to the reference sites, the Black River sediments are extremely elevated with respect to heavy metals concentrations. Only 2.6 percent of the analyses of Black River sediments for heavy metals were less than the median concentrations found in reference site samples, and 40.8% of the analyses exceeded the 99^{th} percentile reference site concentrations.

Polychlorinated biphenyl cogeners (PCB-1242, PCB-1254, and PCB-1260) were detected in all of the Black River sediment samples (see Appendix Table 9). Total PCB concentrations in the grab samples ranged from 20.8μg/kg at RM 2.51 to 104.0μg/kg at RM 2.88. These concentrations are below those likely to have a severe effect on aquatic life (Persuad et al., 1993), and are well below regulatory thresholds set under the Toxic Substances Control Act. Concentrations of PCBs in deeper sediments were somewhat higher than those found in surficial grabs. For example, total PCB concentrations were 276μg/kg at the 4-24" sediment depth at RM 4.11 and 424μg/kg at the 4"-9" sediment depth at RM 2.51. These differences indicate that re-exposure of deeper sediments through dredging activities has some potential to increase the exposure rate of aquatic life in the Black River estuary to these compounds.

Concentrations of PAHs have been dramatically reduced in the sediments of the Black River since the cessation of coking operations at the USS/Kobe Steel facility in Lorain and the 1989-1990 remedial dredging of the Black River conducted by the USS Steel Co. under a consent agreement with the U.S.EPA (Table 9). Concentrations of PAHs have remained relatively constant during the five years since the previous Ohio EPA water quality survey in 1992 (Ohio EPA, 1994) (Figure 42). Total PAH concentrations in grab samples from the Black River estuary ranged from 6.85 mg/kg to 114.8 mg/kg in 1992, and from 6.0 mg/kg to 37.0 mg/kg in 1997. Concentrations of PAHs in core samples of the sediment collected in 1997 ranged from 0.8 mg/kg to 46.6 mg/kg. Concentrations of PAHs in sediments collected from the Black River upstream from the estuary ranged from 2.4 mg/kg to 3.0 mg/kg in 1997. As with PCBs, the presence of persistent contamination of the Black River sediments with PAHs continues to provide an exposure pathway for aquatic life in the estuary of the river.

Only one sample collected from the Black River mainstem had detectable concentrations of toxic pesticide compounds, and the concentrations detected were just above the analytical detection limit. It is unlikely that these compounds have any appreciable effect on the biological community of the lower Black River.

In 1997, a study of the Black River was also conducted by Wright State University to determine the toxicity of the sediments to aquatic organisms (Burton and Rowland, 1998). Toxicity testing was conducted *in situ* for a variety of aquatic organisms simultaneously with the collection of sediment samples for chemical analysis by the Ohio EPA and the USGS. In addition, laboratory toxicity studies were also conducted for both surficial and deep sediment collected during the 1997 survey. Water column *in situ* toxicity testing was also conducted in 1998 under high flow conditions to assess the relative impacts of high flow events on in-stream toxicity in the Black River estuary.

The results of the Wright State University laboratory toxicity studies indicate that the sediments of the Black River are potentially acutely toxic to aquatic organisms. However, there was no evident longitudnal pattern to the distribution of the toxic effects. The greatest degree of sediment toxicity was noted at RMs 15.0, 2.88, 2.51, 0.46 and 0.27. Little or no mortality was noted for sediment collected at RMs 11.60, 5.15, 4.11 and 2.42, nor from a sediment sample collected from the East Branch at RM 11.60. Sediment toxicity was generally greater in deeper sediments collected from core samples, indicating the potential for increased in-stream toxicity during events which disturb the distribution of sediments, such as storm events and dredging activities. Results from *in situ* toxicity testing resulted in greater survival of test organisms, both for test organisms exposed to sediments and water and for organism exposed only to water during high flows in the spring of 1998. The conclusion of Burton and Rowland (1998) was that even the low concentrations of PAHs found in the Black River estuary may result in photo-induced toxicity to aquatic organisms, especially when in-stream turbidity decreases under low flow conditions. In addition, toxic effects of elevated concentrations of heavy metals may also be important in determining the overall toxicity of sediments from the lower Black River.

Historical data is available regarding the impacts of PAH contamination of the sediments of the Black River associated with coking operations at the USS Steel facility in Lorain on tumor frequencies in fish inhabiting the river. Studies conducted by Baumann, et al. (1982), Baumann et al. (1987), and Baumann, et al. (1990) found extremely high tumor rates in brown bullheads (*Ictalurus nebulosus*) that were directly associated with the degree of PAH contamination. Following the closing of the coking facilities at the USS Steel facility in the mid-1980s, fish tumor frequencies declined dramatically. Remedial dredging activities conducted by USS Steel in 1989-90 resulted in resuspension of sediments in the river as well as exposure to deeper sediments with residual PAH contamination. Fish tumor frequencies increased following this activity. Studies conducted in 1997 in conjunction with the Wright State University and Ohio EPA studies found that tumor frequencies have declined significantly in the Black River estuary (Baumann, pers. comm.), indicating that the remedial dredging has been effective in reducing the long term impacts of the coking operations on the river. Continued assessment of the river over time is necessary to determine if fish tissue contaminant levels will decline to the point where fish advisories currently in place for the Black River can be lifted. In addition, it is important to thoroughly understand the long term impacts to aquatic life from the continued presence of elevated concentrations of heavy metals and residual PAH contaminants in the sediments to restore this important Lake Erie estuary to its full potential.

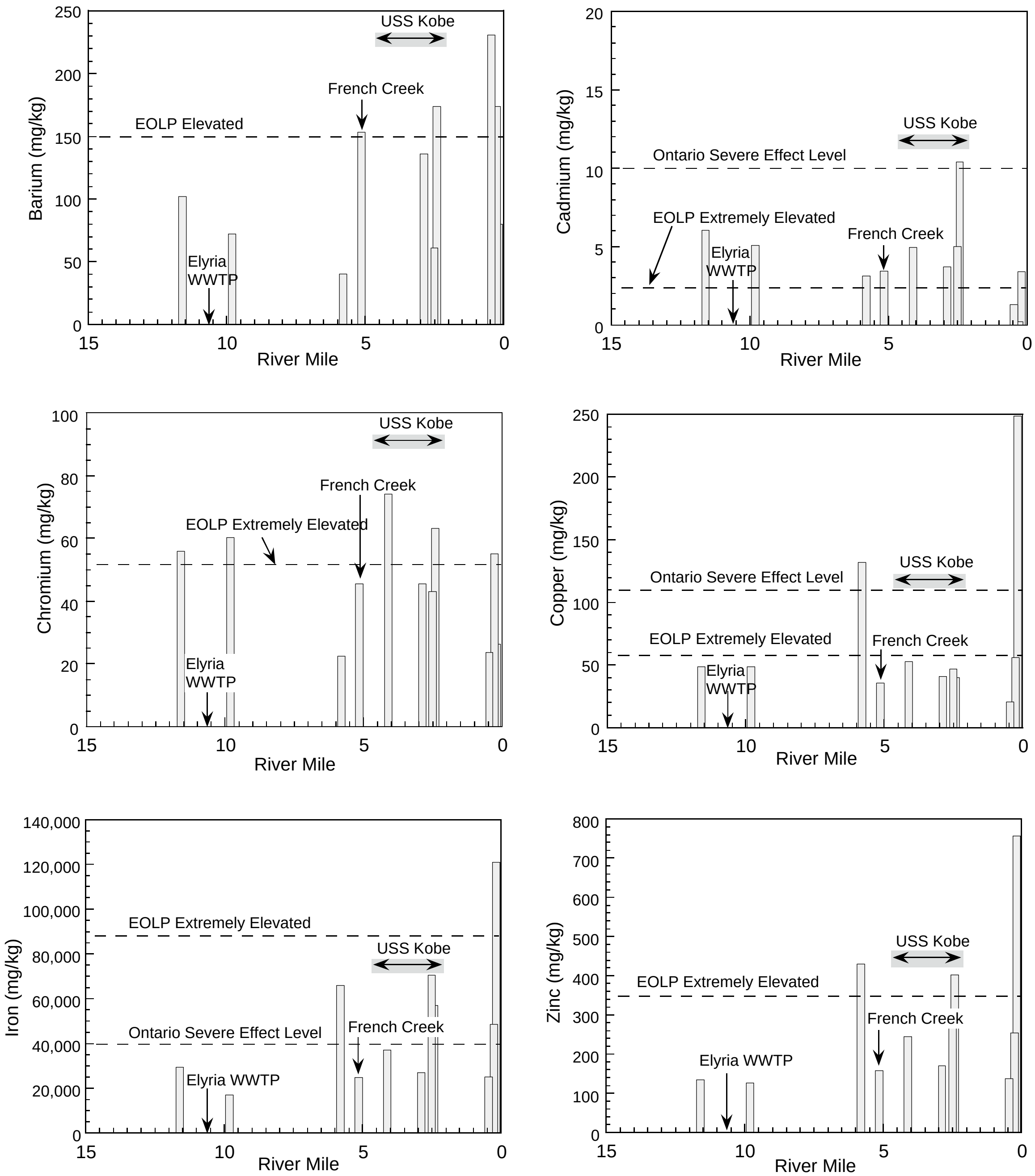


Figure 40. Concentrations of Ba, Cd, Cr, Cu, Fe and Zn in sediments collected from the Black River, 1997 in relation to the Elyria WWTP, the reach receiving discharge from USS/Kobe, French Creek. Reference ranges based on sediment metals concentrations at least impacted reference sites in the Erie-Ontario Lake Plain Ecoregion of Ohio, and Ontario Severe Effect Levels (Persaud et al. 1994) are presented as a frame of reference.

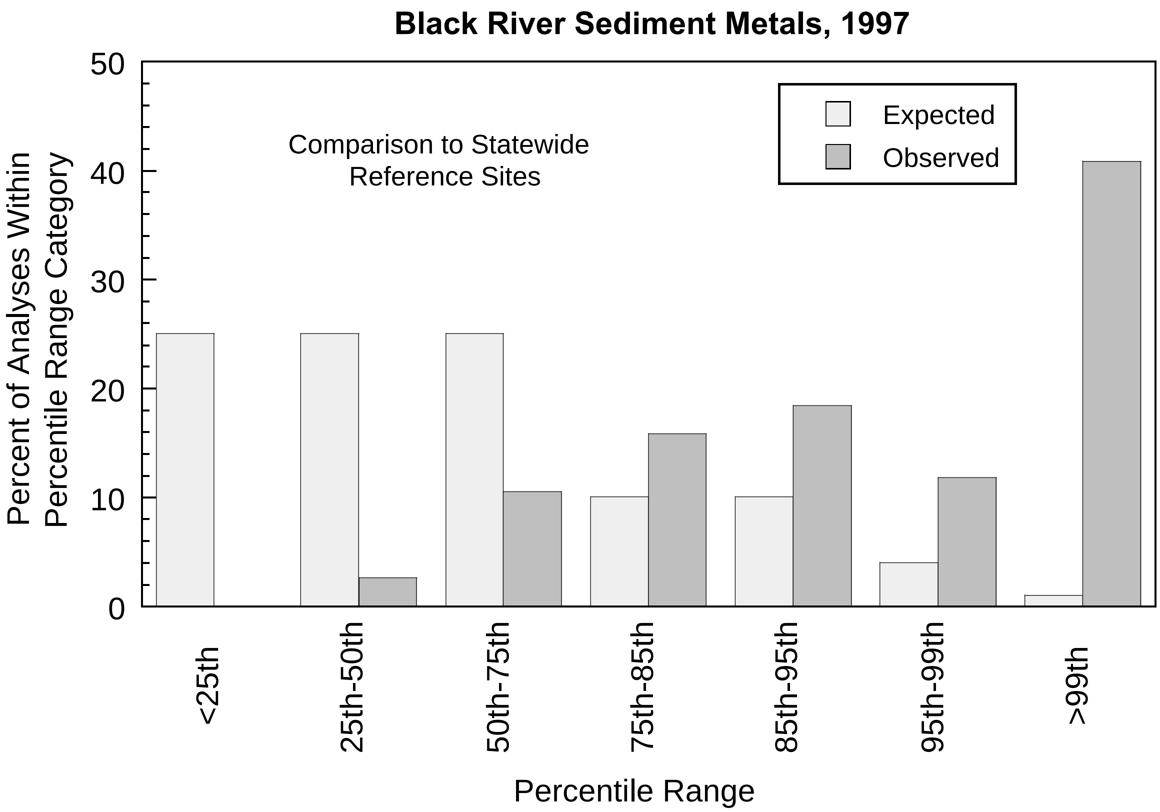


Figure 41. Distribution of sediment metals samples from the Black River with respect to the percentile distribution of metal concentrations from reference sites in the EOLP.

Table 9. Comparison of sediment concentrations of selected PAH compounds, 1988-1997.

Compound	**1988**[4]	**1992**[5]	**1997**
Phenanthrene	390	2.6	0.89
Fluoranthrene	220	3.7	1.86
Benzo (a) anthracene	51	1.6	1.02
Benzo (a) pyrene	43	1.7	0.88

[4]Source: Black River RAP Coordinating Committee, 1994

[5]Source: Ohio EPA, 1994

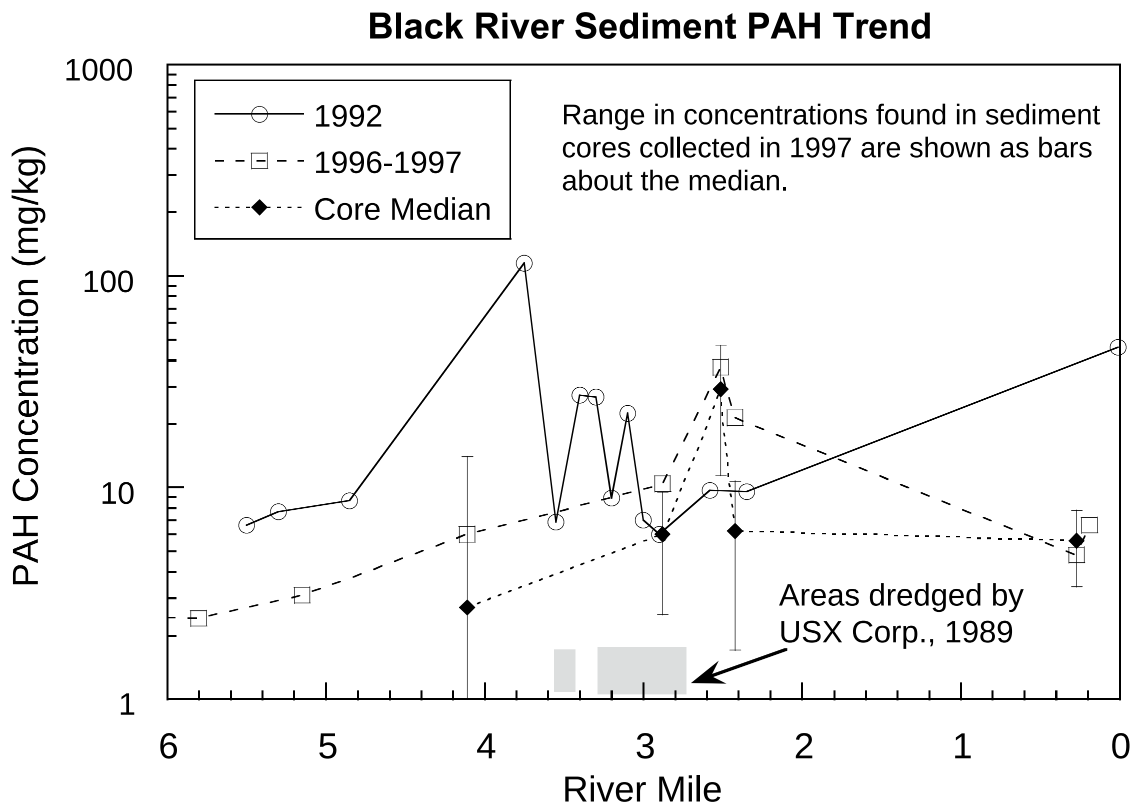


Figure 42. Total polynuclear aromatic hydrocarbon (PAH) concentrations in surficial sediments collected from the Black River, 1992 (open circles), 1996-1997 (open squares), and median concentrations plus ranges (shaded diamonds and bars) in cores from three depth levels.

Water Quality Trends

Previous assessments of the water quality within the Black River watershed have been conducted by the Ohio EPA in 1982 (Ohio EPA, 1987), 1992 (Ohio EPA, 1994), and 1992 and 1993 (Ohio EPA, 1996).

Black River flow data obtained from the U.S. Geological Survey for the period of 1992 through 1997 (Figure 43) indicates that the hydrologic regime of the river has not changed significantly during this period. Average daily flows vary widely depending upon precipitation and runoff characteristics within the watershed, ranging from a minimum of 3.2 cfs to 9,900 cfs during the 1992-1997 period. Extremely high flow events were rare, with the 95th percentile average daily flow equal to 2,000 cfs and the 90th percentile average daily flow equal to 993.6 cfs. Flows were less than the summertime 10 year 30 day average critical low flow (30Q10) value for the river of 6.1 cfs 5 percent of the time during the 1992-1997 time period.

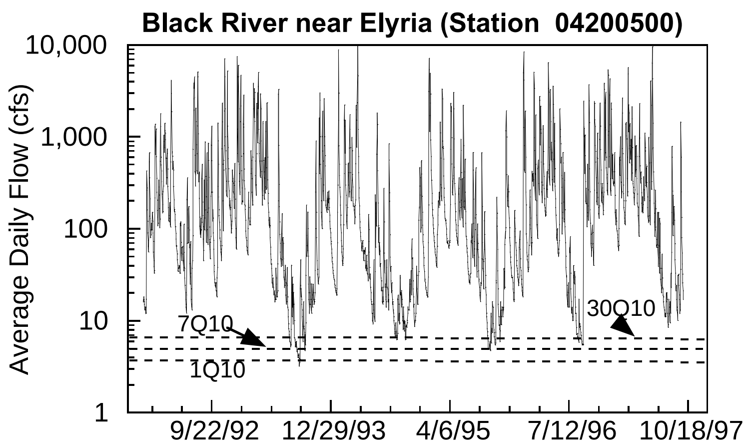


Figure 43. Average daily flows for the Black River, 1992 - 1997, recorded by the USGS gauging station located in Cascade Park approximately 0.8 miles downstream from the confluence of the East and West Branches.

East Fork East Branch Black River

The East Fork of the East Branch Black River has been surveyed by the Ohio EPA in 1992, 1993 and 1997 in the vicinity of the Village of Lodi WWTP. Chemical water quality upstream from the Lodi WWTP has consistently been very good, with concentrations for most parameters found at or below median concentrations at unimpacted reference sites throughout the ecoregion.

Impacts by the Lodi WWTP discharge are most obvious for nutrient parameters. Although NH_3-N concentrations are equivalent in upstream and downstream samples, concentrations of NO_3-NO_2-N and TP (Figure 44) increase dramatically downstream from the discharge. During the summer months, median in-stream NO_3-NO_2-N concentrations increased from 0.05-0.13 mg/l upstream from the WWTP to 2.04-7.72 mg/l downstream. Total phosphorus concentrations likewise increased from <0.05-0.07 mg/l upstream to 0.49-1.42 mg/l downstream from the discharge. The persistent nutrient enrichment of the East Fork by the Lodi WWTP discharge is likely a major cause of the impairment noted in the stream downstream from RM 1.6. The proposed upgrade of the WWTP, including phosphorus removal treatment should help the stream to recover from this nutrient-enriched condition.

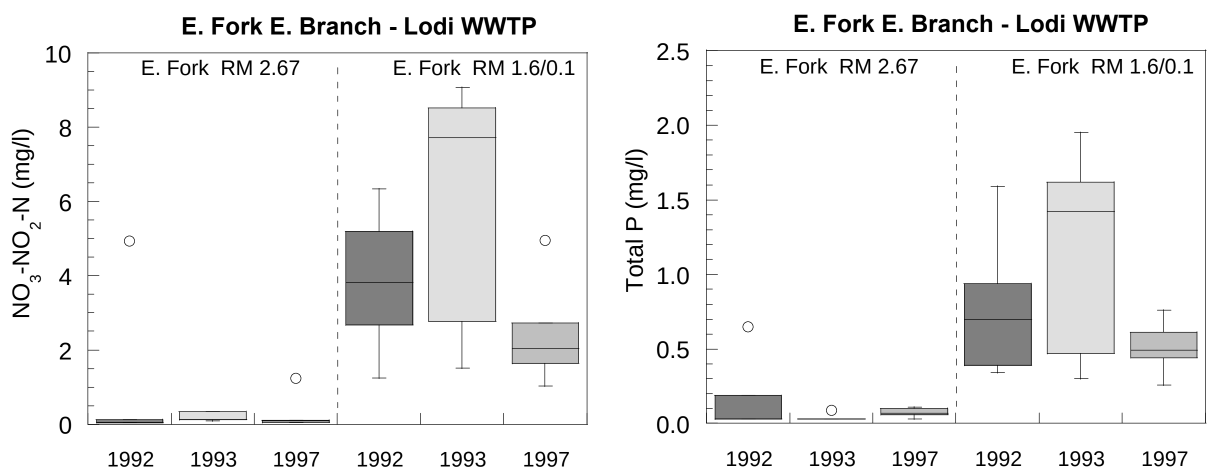
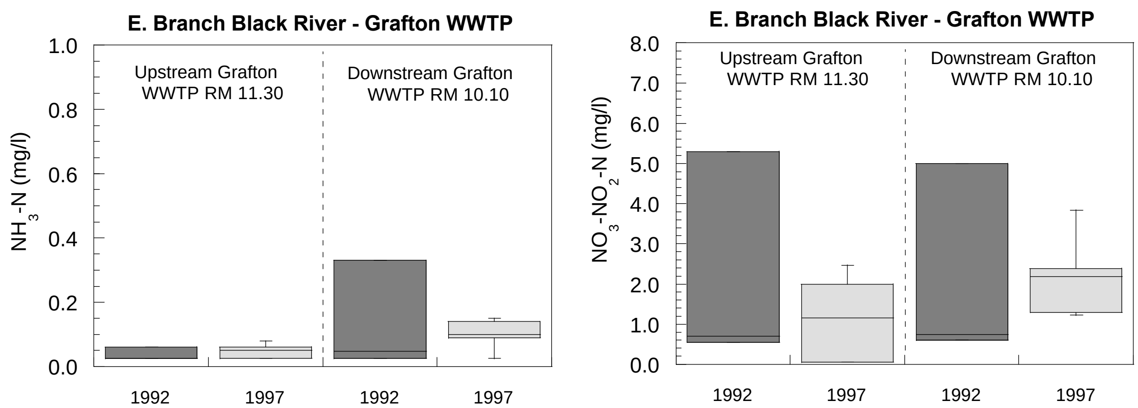


Figure 44. Concentrations of nitrate-nitrogen and total phosphorus in water quality grab samples collected from the East Fork of the East Branch, 1992, 1993 and 1997, upstream (RM 2.67) and downstream (RM 1.6 or 0.1) from the Lodi WWTP.

East Branch Black River

Few changes were noted in the chemical water quality of the East Branch of the Black River since the 1992 Ohio EPA survey. Impacts associated with the discharge from the Grafton WWTP continued to be the primary effect documented on chemical water quality in the stream. The data from 1997, however, was more clear-cut than the 1992 data, and indicate that the discharge has significant effects on the in-stream concentration of nutrient parameters. Both the 1992 and 1997 surveys found that in-stream NH_3-N concentrations were only slightly effected by the Grafton WWTP discharge at summertime low flow conditions (Figure 45). However, NO_3-NO_2-N concentrations downstream from the discharge were double those detected upstream in 1997, whereas in 1992, confounding effects from upstream appear to have masked any impacts on NO_3-NO_2-N concentrations downstream from the WWTP (Figure 45). Similarly, the impact of the Grafton WWTP on TP concentrations in the East Branch were more noticeable in 1997 than in 1992 (Figure 45). The median TP concentration increased from 0.18 mg/l upstream from the discharge to 0.63 mg/l downstream in 1997, as compared to an increase from 0.07 upstream to 0.13 mg/l downstream in 1992. As with the Lodi WWTP, reduction in the concentration of TP through the addition of phosphorus removal when the Grafton WWTP is upgraded should help to improve conditions for aquatic life downstream from the discharge.



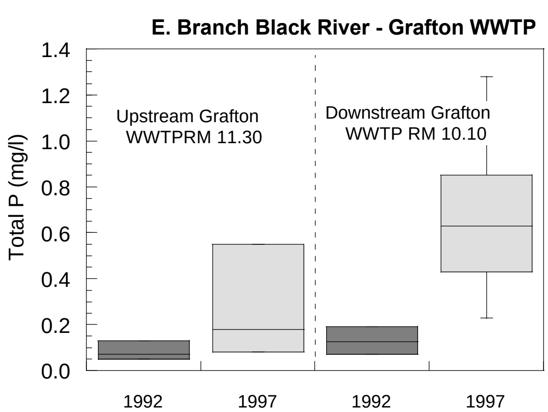
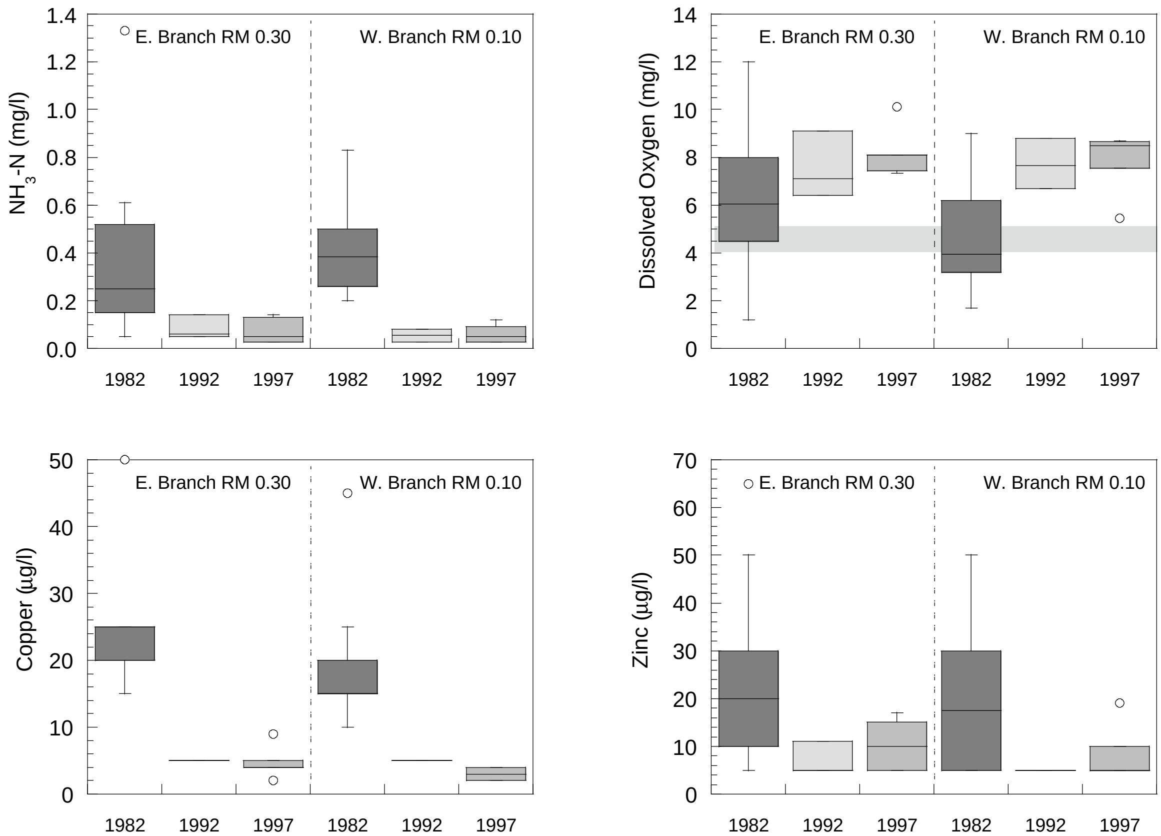


Figure 45. Concentrations of ammonia-nitrogen, nitrate-nitrogen and total phosphorus in water quality grab samples collected from the East Branch upstream (RM 11.3) and downstream (RM 10.1) from the Grafton WWTP, 1992 and 1997.

East Branch and West Branch Black River Compared

Chemical water quality in both branches of the Black River has improved dramatically when data from samples collected in 1982 is compared to data from the 1990s. Violations of water quality criteria for dissolved oxygen were common at the mouths of both branches of the river in 1982, and NH_3-N concentrations were elevated in both streams (Figure 46). In addition, concentrations of heavy metals were also elevated in both branches of the river in 1982. Since that time, dissolved oxygen concentrations have recovered to acceptable levels in both streams, and NH_3-N concentrations are routinely near or below the analytical detection limit. Concentrations of copper (Figure 46) have declined from a median of 25 μg/l in the East Branch and 15μg/l in the West Branch in 1982 to 4 and 3 μg/l, respectively in 1997. Similarly, zinc concentrations have declined from 1982 median values of 20 μg/l in the East Branch and 17.5 μg/l in the West Branch to 1997 median values of 10 μg/l and less than detection in the East and West Branches, respectively.

The water quality trend for TSS runs counter to the improvements documented above (Figure 46). Summertime concentrations of TSS in the 1990s are roughly double those found during 1982 in the East Branch, increasing from a median concentration of 9 mg/l in 1982 to 17 mg/l in 1992 and 16 mg/l in 1997. In the West Branch, the median concentration increased from 8.5 mg/l in 1982 to 17.5 mg/l in 1992. The median TSS concentration decreased to 6 mg/l in the West Branch in 1997, although the maximum concentration observed during the 1997 study (42 mg/l) was greater than that observed in either 1982 or 1992. Increases in TSS concentrations are probably reflective of increasing non-point source pollution pressures in the watershed resulting from riparian zone degradation and urbanization with coincident increases in erosion and sedimentation from runoff.



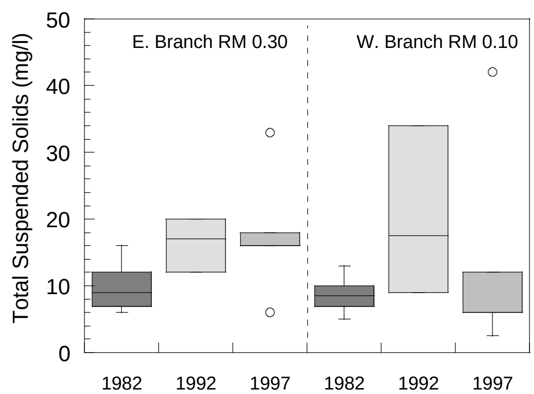


Figure 46. Concentrations of ammonia-nitrogen, dissolved oxygen, copper, zinc and total suspended solids in water quality samples collected from the East and West Branches near their confluence, 1982, 1992 and 1997.

Black River (*Upstream from the Estuary)*

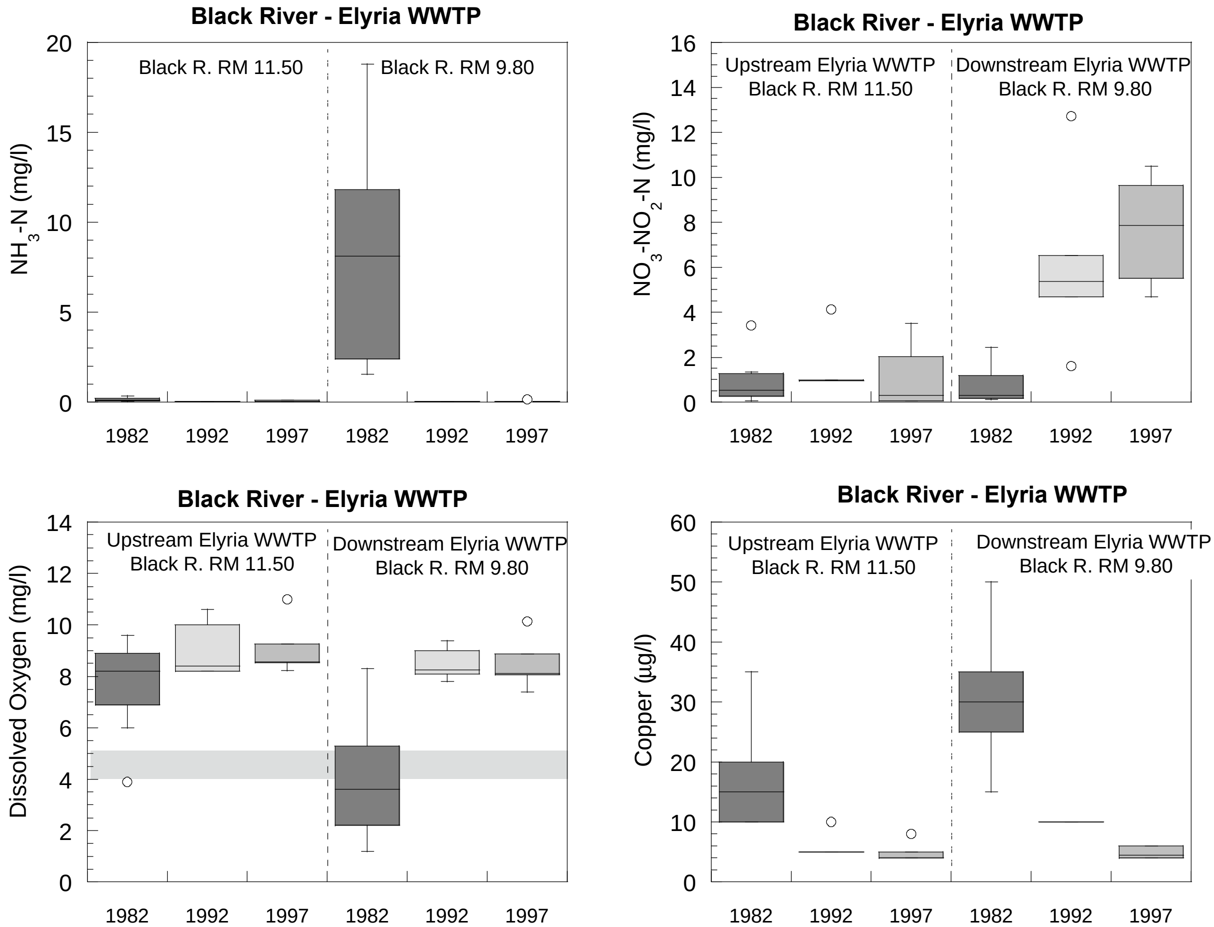
Significant improvement in the chemical water quality of the Black River has been documented downstream from the Elyria WWTP as the direct result of improvements made at the treatment facility in 1987-1989. Prior to this upgrade, the discharge of high concentrations of NH_3-N from the WWTP resulted in extremely high in-stream NH_3-N concentrations, that ranged from 1.57 mg/l to 18.8 mg/l in 1982 (Figure 47). The poor quality discharge caused depletions of D.O. downstream from the WWTP, resulting in numerous violations of the water quality criteria (Figure 47) and a median summertime D.O. concentration downstream from the Elyria WWTP in 1982 of 3.6 mg/l. Following the improvements made at the Elyria WWTP, D.O. concentrations have improved to be equivalent to those found upstream. In addition, median NH_3-N concentrations downstream from the WWTP are now near the analytical detection limit.

Heavy metals concentrations also decreased markedly following the upgrade of the Elyria WWTP. Concentrations of copper in samples collected at RM 9.8 have decreased from a median of 30 μg/l in 1982 to 4.5 μg/l in 1998 (Figure 47). Similarly, median zinc concentrations have decreased from 37.5 μg/l to 17 μg/l during the same time period. No changes have been observed for these constituents between 1992 and 1997.

Significant increases in NO_3-NO_2-N concentrations have occurred in the Black River downstream from the Elyria WWTP since the facility was improved (Figure 47). The upgrade in treatment has resulted in the conversion of NH_3-N to NO_3-NO_2-N prior to discharge of the effluent to the Black River. This has resulted in an increase in the in-stream NO_3-NO_2-N concentration downstream from the WWTP from a median of 0.3 mg/l in 1982 to 5.4 mg/l in 1992 and 7.9 mg/l in 1997. Although NO_3-NO_2-N is much less toxic to aquatic life than NH_3-N, it is an important nutrient in aquatic ecosystems which may affect the biological community. Further work is necessary to determine the effects of the Elyria WWTP discharge on the overall condition of the Black River estuary.

Black River Estuary

Reductions of concentrations of NH_3-N and heavy metals (Figure 48) in the Black River estuary reflect the water quality improvements observed in the Black River mainstem upstream from the estuary over time. Similarly, increasing trends in the concentrations of TSS and NO_3-NO_2-N (Figure 48) were also observed in the upper estuary. However, concentrations of these parameters in the portion of the estuary maintained for navigation (RM 2.8 to the mouth) were much less predictable. In 1982 there was a general reduction in the concentrations of conservative parameters such as TSS, copper and zinc, which were reduced by 50 to 75 percent in the dredged portion of the river. This sedimentation is to be expected in the deeper navigation channel due to it's longer hydrologic residence time. However, in 1992 and 1997, concentrations of TSS, copper, and zinc either remained the same or increased within the navigation channel as compared to the upper estuary.



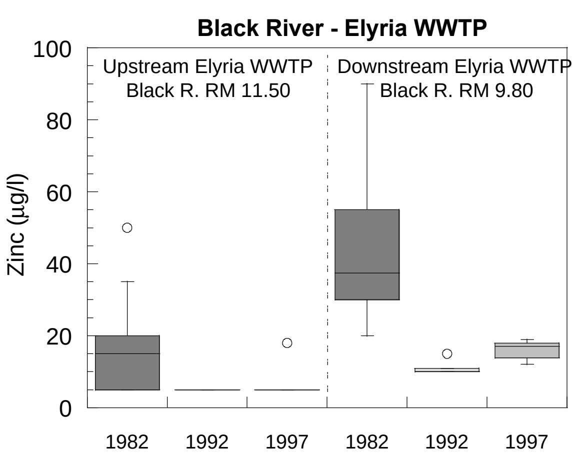
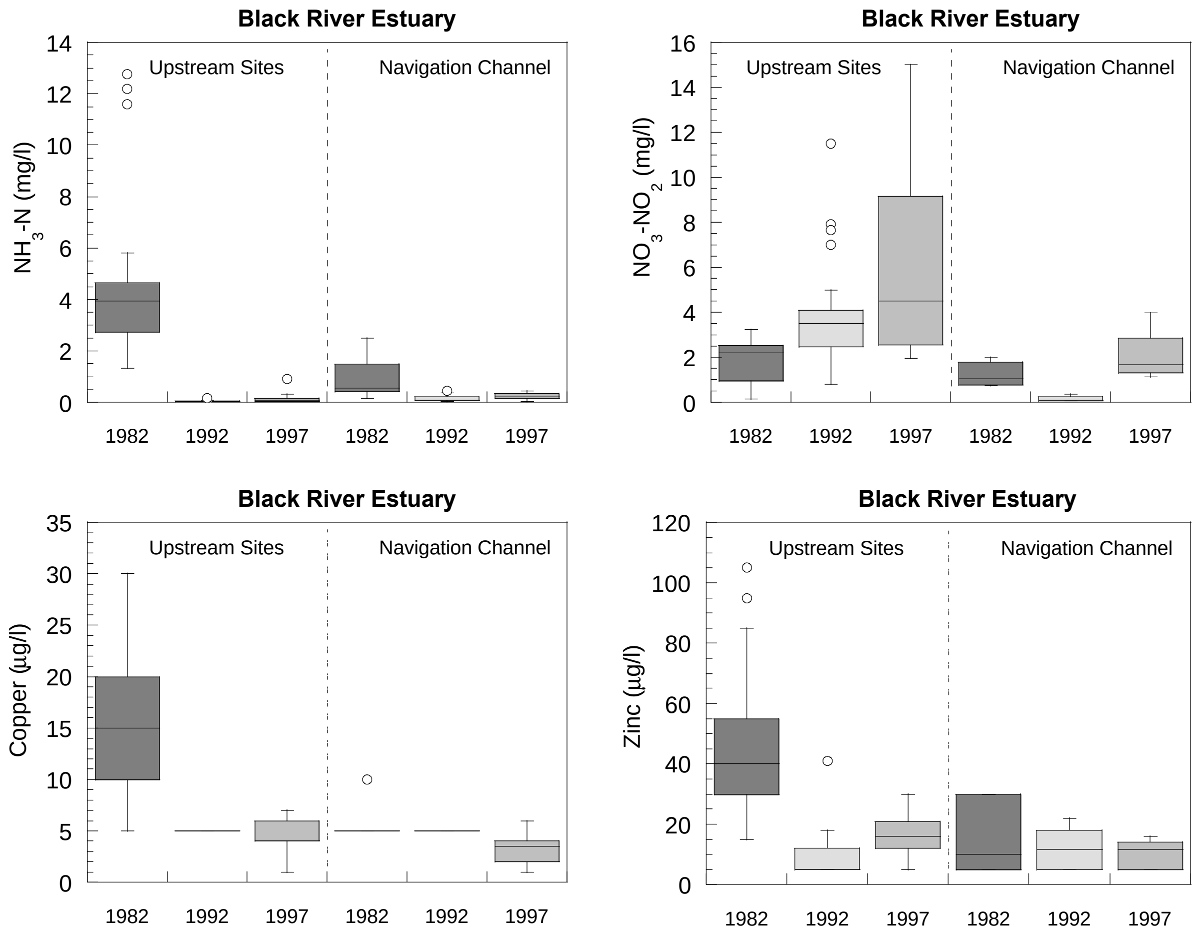


Figure 47. Concentrations of ammonia-nitrogen, nitrate-nitrogen, dissolved oxygen, copper, and zinc in water quality samples collected upstream and downstream from the Elyria WWTP, 1982, 1992 and 1997.



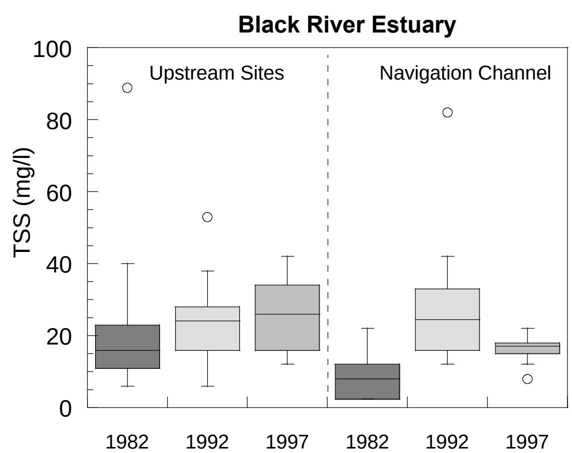


Figure 48. Concentrations of ammonia-nitrogen, nitrate-nitrogen, copper, zinc and total suspended solids in water quality samples collected from the lacustrine portion of the Black River at locations upstream from and within the navigation channel, 1982, 1992 and 1997.

Differences in the types of solids transported through the system may be responsible, although it is impossible to determine the specific cause of this phenomenon without additional study.

Assimilation of NH_3-N within the estuary is very evident from the results of sampling in 1982. Median NH_3-N concentrations were reduced from 3.94 mg/l in the upper estuary to 0.56 mg/l in the navigation channel in 1982. With the changes implemented at the Elyria WWTP and loadings from the North Ridgeville WWTP to the estuary via French Creek, concentrations of NO_3-NO_2-N in the upper estuary have increased from a median values of 2.19 mg/l in 1982 to 4.50 mg/l in 1997 (Figure 48). The maximum observed NO_3-NO_2-N concentration also increased from 3.24 mg/l in 1982 to 15.00 mg/l in 1997. Concentrations of NO_3-NO_2-N decline significantly in the navigation channel, with median concentrations equaling 0.11 mg/l in 1992 and 1.66 mg/l in 1997.

Improvements in chemical water quality upstream from the estuary portion of the Black River as well as changes in the discharge of wastewater at the USS/Kobe Steel facility have resulted in an improved dissolved oxygen regime in the portion of the estuary upstream from the maintained navigation channel (RM 2.8) (Figure 49). Surface D.O. concentrations within the upper estuary have increased from a median of 5.5 mg/l in 1982 to 7.85, 8.14, and 7.58 mg/l in 1992, 1997 and 1998, respectively. Dissolved oxygen concentrations at the stream bottom have also improved in this portion of the river over time. Median bottom D.O. in the upper estuary has increased from 3.6 mg/l in 1982 to 4.75 mg/l in 1997 and 6.90 mg/l in 1998. However, violations of the WWH water quality criteria have been observed recently at both the surface and the bottom in the upper estuary. Minimum D.O. concentrations at the surface were 2.04 mg/l in 1997 and 4.35 mg/l in 1998, while minima at the bottom were recorded at 2.04 mg/l in 1997 and 4.45 mg/l in 1998.

Dissolved oxygen data collected from the lower portion of the estuary which is maintained for navigation in 1992 and 1997 were almost identical to the results observed in 1982 (Figure 49). Median surface D.O. concentrations for these study years ranged from 5.22 mg/l in 1982 to 5.80 mg/l in 1997. Surface D.O. concentrations below the water quality criteria were noted in 1982, 1992, and 1997. However, the minimum D.O. concentration in 1982 of 1.0 mg/l was much lower than that observed in either 1992 (3.9 mg/l) or 1997 (3.57 mg/l). Dissolved oxygen concentrations at the bottom were significantly lower than surface D.O. concentrations in both 1982 and 1997, with median concentrations below the water quality criteria. Subsequent sampling conducted in 1998, revealed even worse D.O. concentrations than had been observed in the Black River through previous study with median D.O. concentrations below the water quality criteria at the surface (4.48 mg/l), mid-depth (3.72 mg/l) and bottom (0.82 mg/l). The continuing poor D.O. regime in the Black River estuary even under conditions where significant improvement in upstream water quality has been achieved indicates that the assimilative capacity of the estuary continues to be exceeded and that a comprehensive evaluation of the dynamics of this system must be investigated to determine if the Black River estuary is capable of meeting the applicable water quality criteria, and if so, what steps are necessary to achieve this goal.

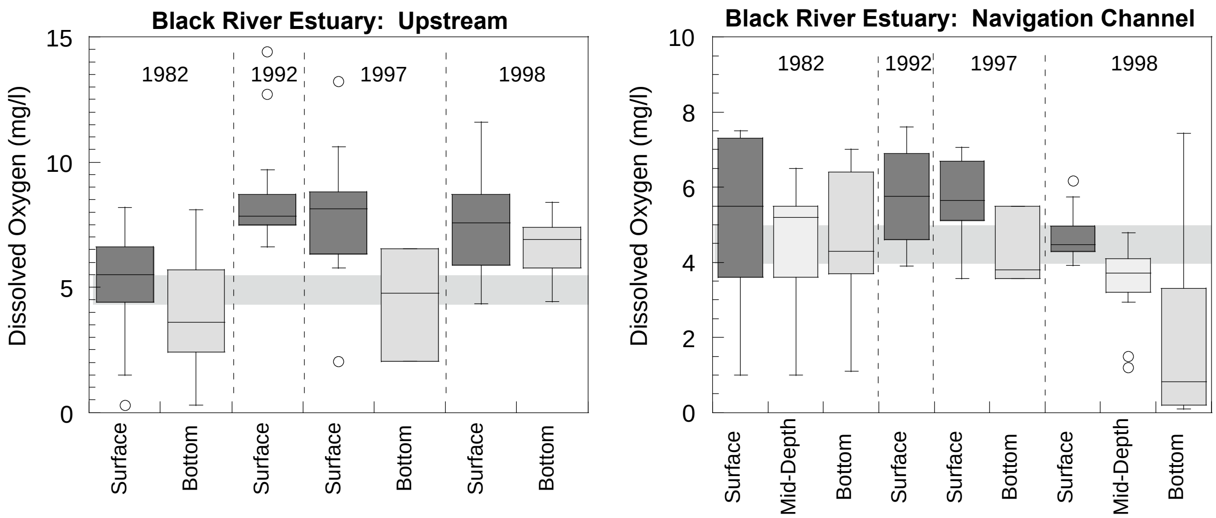


Figure 49. Dissolved oxygen concentrations measured at the surface, mid-depth and bottom in the Black River lacustuary upstream from and within the navigation channel, 1982, 1992 and 1997.

Black River Monthly Ambient Monitoring, 1992-1997

Samples are collected on a monthly basis from the Black River at Ford Rd. (RM 9.80) for the evaluation of water quality trends. Between 1992 and 1997, there has been little change in the chemical water quality found at this station. The 1987-1989 upgrade of the Elyria WWTP just upstream from the RM 9.80 monitoring station has reduced the in-stream NH_3-N concentration to the point where this compound is present at less than detection limit (0.05 mg/l) sixty percent of the time. The maximum concentration of NH_3-N observed at RM 9.80 during the period of 1992-1997 was 0.73 mg/l on February 19, 1997. This value is well below the water quality criteria for NH_3-N. Similarly, no violations of the dissolved oxygen water quality criteria have been observed at the RM 9.80 monitoring station during the period of 1992-1997.

Results for many of the water quality parameters at the RM 9.80 monitoring station are quite variable, reflecting the complex interaction of stream flow, precipitation events, performance of the Elyria WWTP, loadings from the watershed (including upstream CSO areas), and the timing of sampling with respect to various events affecting water quality. Examples of the water quality trends for total suspended solids, NO_3-NO_2-N, cadmium, and zinc (Figure 50) are provided to illustrate the variability in chemical water quality observed at this station over time.

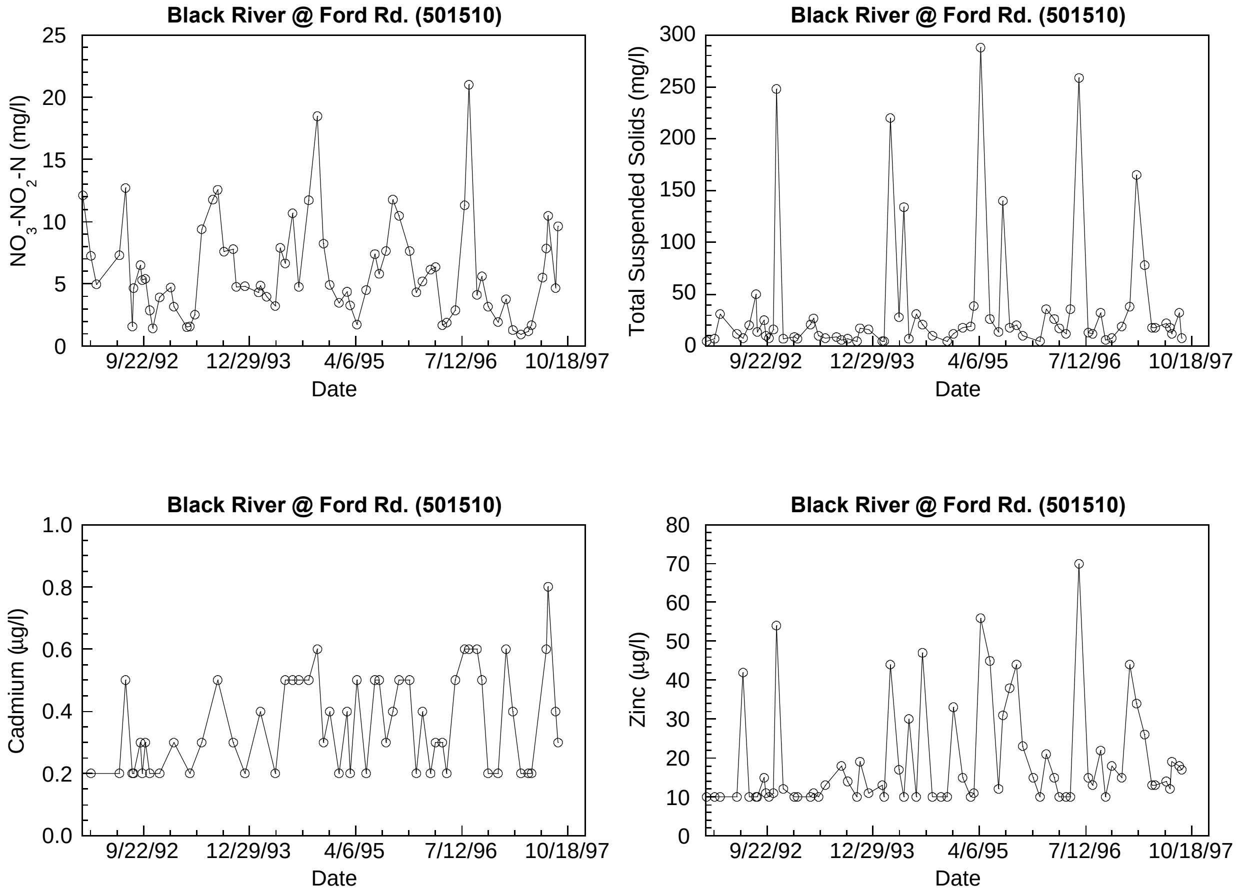


Figure 50. Concentrations of nitrate-nitrogen, total suspended solids, cadmium and zinc in monthly water quality samples collected from the Black River at Ford Road (RM 9.8 - downstream from the Elyria WWTP), 1992 - 1997.

Of all the parameters monitored at the RM 9.80 location, only two were found to correlate well with stream flow in the Black River. Total suspended solids concentrations in the river are positively correlated with stream flow, while NO_3-NO_2-N concentrations are negatively correlated (Figure 51). These results verify the results from the periodic water quality surveys of the Black River, and indicate that loadings of suspended solids from non-point sources is the primary cause of high turbidity in the lower Black River. Nutrients such as NO_3-NO_2-N, however, are primarily contributed to the river by point source discharges such as the Elyria WWTP. In-stream concentrations of these parameters decreases under high flow conditions due to the additional dilution of the discharge by higher upstream flows.

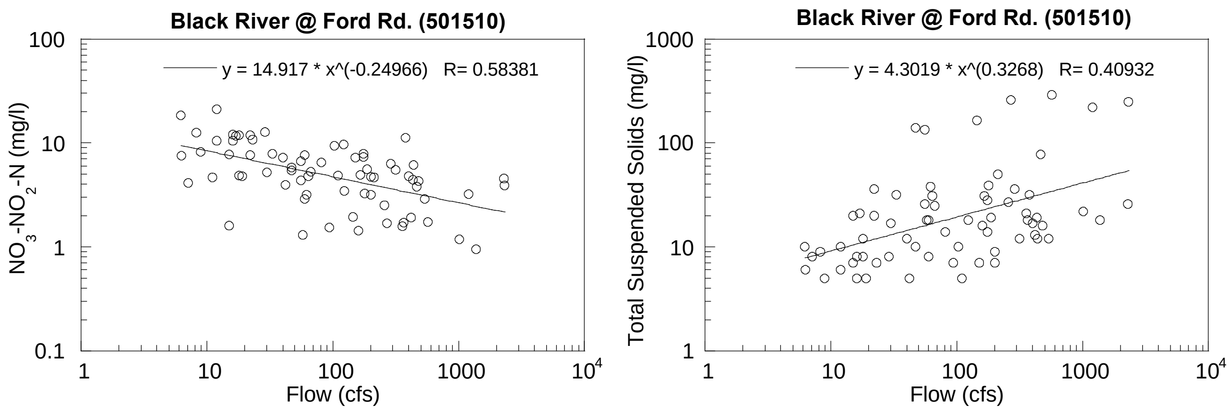


Figure 51. Concentrations of nitrate-nitrogen and total suspended solids in monthly monitoring samples from the Black River at Ford Road (RM 9.8) plotted against stream flow.

French Creek

No changes were observed in the water chemistry either upstream or downstream from the North Ridgeville WWTP. Concentrations of NH_3-N ranged from less than 0.05 mg/l to 0.33 mg/l during the 1982, 1992, and 1997 water quality studies. Concentrations of NO_3-NO_2-N in French Creek downstream from the North Ridgeville WWTP have also been very consistent over time, ranging from 0.6 to 5.0 mg/l (Figure 52).

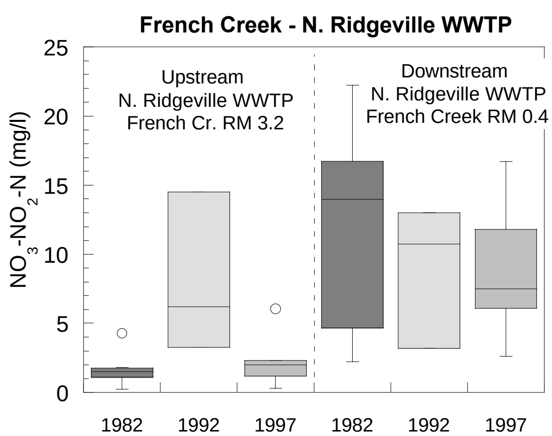


Figure 52. Nitrate-nitrogen concentrations in water quality samples collected from French Creek, 1982, 1992 and 1997, upstream and downstream from the French Creek WWTP.

Beaver Creek

Pollutant loadings from nonpoint sources upstream from the Amherst WWTP were higher in 1992 than 1997 as inferred from the higher concentrations of chemical oxygen demand, nitrate nitrogen and phosphorus (Figure 53). Downstream from the Amherst WWTP concentrations of ammonia nitrogen increased, both relative to upstream and compared to 1992, such that 3 of 4 samples at both sampling locations downstream from the WWTP had ammonia concentrations exceeding water quality standards. Dissolved oxygen concentrations correspondingly also decreased downstream from the WWTP. These results suggest that operation and efficiency problems at the Amherst WWTP have gotten progressively worse since 1992.

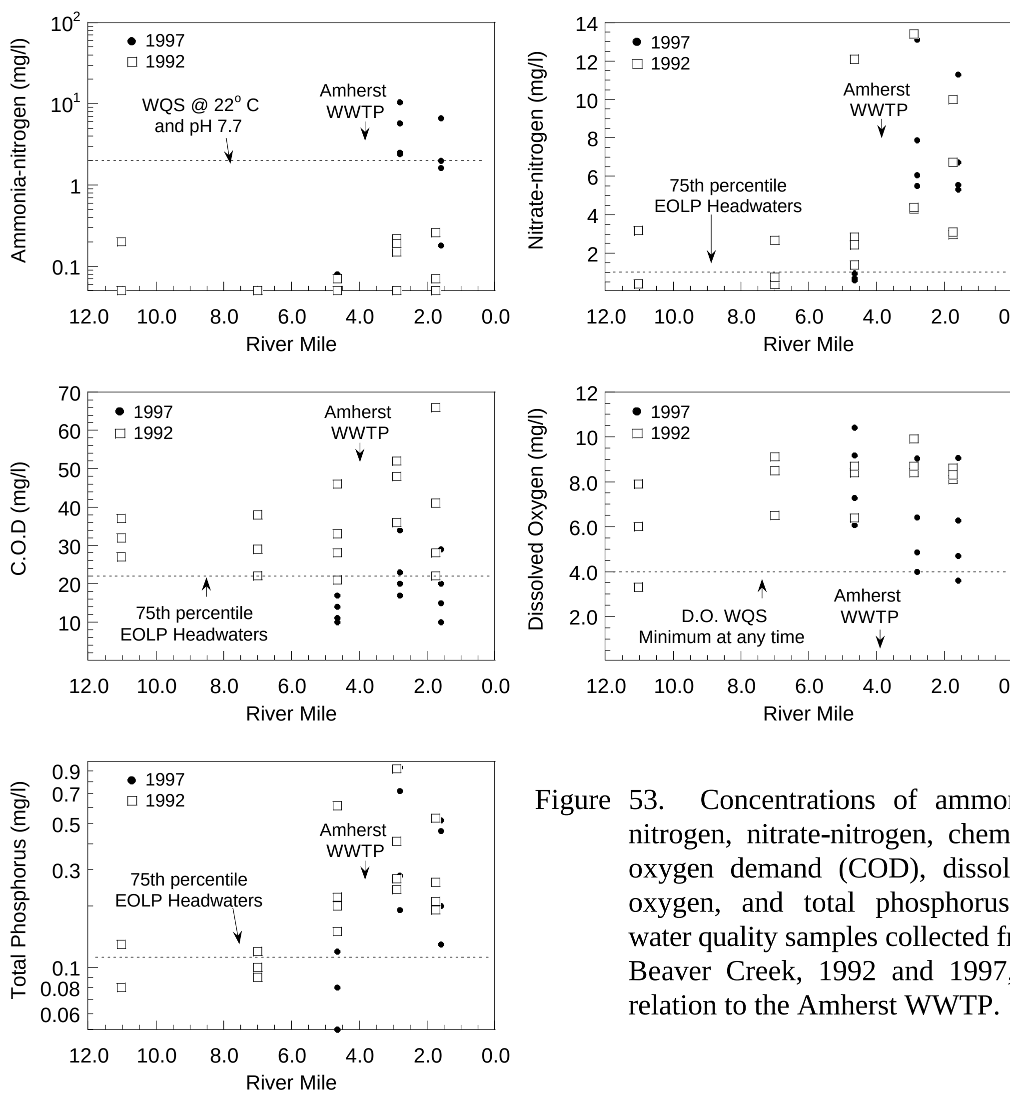


Figure 53. Concentrations of ammonia-nitrogen, nitrate-nitrogen, chemical oxygen demand (COD), dissolved oxygen, and total phosphorus in water quality samples collected from Beaver Creek, 1992 and 1997, in relation to the Amherst WWTP.

Physical Habitat for Aquatic Life

Black River

The free flowing reach of the Black River mainstem contains excellent habitat (Table 10). The sinuous free flowing nature river combined with glacial tills and woody debris provided for habitat complexity, heterogeneity of the substrates and good channel development. The excellent habitat owes much to the park lands in the river valley and wide riparian buffers that help attenuate some of the nonpoint sediment loadings from upstream. Silt deposits in pool and glide areas were mostly confined to depositional areas; however, the riffles were moderately to highly embedded with sand and silt.

East Branch Black River

Habitat impacts associated with agriculture and encroachment into riparian areas were more common in the East Branch than the mainstem; consequently, the ratio of modified to warmwater habitat attributes increased relative to the mainstem (Table 10). The channel in areas where the river flows over bedrock was wide in comparison to the amount of flow suggesting that historic loss and present lack of mature hardwoods along the banks allowed the river to widen. Wide shallow channels reduce current speed, and loss of woody debris reduces habitat complexity. Habitat impacts associated with agriculture were most severe in the upper reaches where the river flows through highly erodible lacustrine deposists. There, channel stability and development was low, and erosion increased the prevalance of small particle size substrates. Despite these modified habitat attributes, the habitat was amenable to supporting warmwater communities as judged by a mean QHEI of 65.6 ± 7.2 SD. Substrates were not unusually embedded with silt, however riffles were moderately embedded. Cobble, boulder and slab substrates from glacial till and fractured bedrock provided instream cover at most locations in the lower reach and woody debris provided cover in the upper reaches.

East Fork East Branch Black River

The East Fork is a headwater stream draining agricultural areas and the Village of Lodi. Modified habitat attributes were imparted by both the agricultural and suburban land uses within the catchment. The channel at each location was not well developed, instream cover was lacking and the stream banks and channels were unstable. At the upstream most site, lack of a riparian buffer was the single most significant factor affecting habitat. Immediately downstream from Lodi, stormwater runoff appeared to have exacerbated bank erosion along a bank missing woody riparian vegation. At the downstream most site, where the East Fork flows through highly erodible lacustrine deposits, the absence of woody riparian vegetation has destabilized the banks and stream channel. Sufficient warmwater habitat attributes do exists, however, to support a normal warmwater stream community. The channel has not been directly modified so that it is moderately sinuous and developed and cobble and gravel tills are present.

French Creek

Suburban landuse within the French Creek subbasin negatively affects habitat quality, primarily in that siltation from runoff results in embedded riffles. Also, stormwater runoff, development near the stream banks, and loss of riparian habitat facilitated bank erosion. Otherwise, the habitat was characterized primarily by warmwater attributes, yielding a mean QHEI score of 70.3 ± 3.5 SD (Table 10).

Willow Creek

Three locations were sampled on Willow Creek. The upstream and downstream most sites are channelized ditches wholly devoid of warmwater habitat characteristics and lacking riparian vegetation (Table 10). The middle site (RM 4.9) contains some warmwater habitat attributes, most notably a sinuous channel and instream cover provided by a mature riparian buffer. Collectively though, the severity of habitat degradation in Willow Creek is likely to preclude existence of a typical warmwater stream assemblage.

West Branch Black River

The channel substrate at the site sampled on the West Branch is almost entirely bedrock. Some grooves and broken slabs provide the only cover. Like the East Branch, the channel was unusually wide for the given stream flow, suggesting the stream had widened due to loss mature trees in the riparian buffer. Although the channel was natural it was not developed and no riffles were present. The resulting low QHEI score suggests that the habitat is locally limiting.

Plum Creek

Plum Creek contains good to excellent habitat owing to riparian buffers containing mature trees and lack of channelization. The woody riparian helps to minimize erosion and stabilize the channel, and woody debris adds cover and increases habitat complexity. Tills provide substrates with a variety of sizes. Siltation from suburban runoff resulting in embedded riffles was evident at all three sites. The channel at the site adjacent to the Oberlin WWTP had been straightened previously. Although the creek has recovered many warmwater attributes, cover remains sparse and sinuousity low.

Beaver Creek

As Beaver Creek flows through suburban Amherst the ratio of modified to warmwater habitat attributes increases. Most notably the degree of embeddedness increases and the amount of instream cover decreases. Some of the modified habitat attributes are a natural feature of the shale bedrock substrates; specifically the lack of cover. However, stormwater discharge paired with the loss of woody riparian buffers likely exacerbates the loss of cover from bedrock substrates. Positive habitat attributes include the presence of gravel and cobble substrates (from till deposits) and a natural free flowing channel. Overall, the habitat is only marginally suited to warmwater stream communities.

Table 10. QHEI matrix for sites sampled in the Black River basin, 1997.

WWH Attributes | MWH Attributes: High Influence | Moderate Influence

Key: QHEI Components

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 Embeddedness; Max. Depth > 40cm; Low/No Riffle Embeddedness

MWH Attributes, High Influence: Channelized or No Recovery; Silt/Muck Substrates; Low Sinuosity; Sparse/No Cover; Max. Depth < 40 cm (WD/HW)

MWH Attributes, Moderate Influence: Recovering Channel; Heavy/Moderate Silt Cover; Sand Substrates (Boat); Hardpan Substrate Origin; Fair/Poor Development; Low/No Sinuosity; Only 1-2 Cover Types; Intermittent & Poor Pools; No Fast Current; High/Mod. Embeddedness; High/Mod. Riffle Embeddedness; No Riffle

River Mile	QHEI	Gradient (ft/mile)	Total WWH Attributes	Total H.I. MWH Attributes	Total M.I. MWH Attributes	MWH H.I./WWH Ratio	MWH M.I./WWH Ratio
(20-001) Black River							
Year: 97							
15.0	70.5	3.70	9	0	0	0.10	0.10
11.9	75.0	5.62	8	0	1	0.11	0.22
10.3	73.5	5.62	8	0	1	0.11	0.22
8.5	78.0	4.00	8	0	1	0.11	0.22
5.0	56.0	0.10	5	0	3	0.17	0.67
5.6	42.5	0.10	2	1	8	0.67	3.33
5.2	46.5	0.10	4	1	5	0.40	1.40
4.0	54.0	0.10	5	0	4	0.17	0.83
3.1	53.5	0.10	4	0	5	0.20	1.20
2.2	45.0	0.10	4	1	5	0.40	1.40
0.9	34.5	0.10	2	2	7	1.00	3.33
0.1	29.0	0.10	1	2	7	1.50	5.00
(20-002) French Creek							
Year: 97							
6.1	77.5	17.24	7	0	2	0.13	0.38
3.2	71.0	6.05	7	0	4	0.13	0.63
1.0	66.5	5.21	7	0	4	0.13	0.63
(20-005) Beaver Creek							
Year: 97							
8.0	62.5	33.33	7	1	2	0.25	0.50
4.6	56.0	11.11	6	1	5	0.29	1.00
2.0	48.5	12.02	4	1	5	0.40	1.40
(20-010) East Branch Black River							
Year: 97							
40.5	62.5	0.47	6	0	4	0.14	0.71
32.5	57.5	1.55	4	0	4	0.20	1.00
18.9	63.5	2.90	7	0	4	0.13	0.63
11.3	74.0	12.02	8	0	1	0.11	0.22
10.9	73.5	11.63	9	0	1	0.10	0.20
2.0	50.0	0.33	4	2	3	0.60	1.20

Table 10. QHEI matrix for sites sampled in the Black River basin, 1997.

Key
QHEI
Components

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
			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 Embeddedness	Max. Depth > 40cm	Low/No Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max. Depth < 40 cm (WD/HW)	**Total H.I. MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Mod. Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total M.I. MWH Attributes**	**MWH H.I./WWH Ratio**	**MWH M.I. WWH Ratio**
(20-010) East Branch Black River																																		
Year: 97																																		
5.5	75.5	2.44	■	■		■	■	■		■	■	■	8						0									▲				1	0.11	0.22
9.0	62.0	13.51	■			■	■		■	■	■	■	7				●		1					▲								1	0.25	0.38
(20-014) East Fork East Branch Black River																																		
Year: 97																																		
2.7	57.0	30.30	■	■			■			■	■		5				●		1					▲		▲		▲			▲	4	0.33	1.00
2.1	76.5	29.41	■	■		■	■	■		■	■		8						0					▲				▲	▲	▲		4	0.11	0.56
0.1	45.0	4.69	■	■			■				■		4			●	●		2					▲	▲			▲	▲	▲		5	0.60	1.60
(20-018) Willow Creek																																		
Year: 97																																		
6.0	24.0	5.49											0	●	●	●	●	●	5		▲			▲	▲	▲		▲	▲		▲	7	6.00	*.**
4.9	52.0	6.26	■	■			■	■			■		5						0		▲			▲				▲	▲	▲		5	0.17	1.00
2.9	39.0	11.63		■									1	●		●	●	●	4		▲			▲	▲	▲		▲	▲		▲	7	2.50	6.00
(20-020) West Branch Black River																																		
Year: 97																																		
1.2	47.5	7.14	■				■			■			3				●	●	2					▲	▲			▲			▲	4	0.75	1.75
(20-021) Plum Creek																																		
Year: 97																																		
3.3	73.0	9.49	■	■		■	■	■		■	■		7						0									▲		▲	▲	3	0.13	0.50
2.9	63.0	10.42	■	■		■	■	■		■	■		7			●	●		2					▲	▲			▲		▲		4	0.38	0.88
1.6	86.5	7.14	■	■		■	■	■		■	■		8						0									▲		▲		2	0.11	0.33

Biological Assessment - Macroinvertebrates Communities

Black River 1977-1997
In 1997, the macroinvertebrate community was evaluated at 12 sites on the Black River from RM 15.1 to 0.1. Communities in the free flowing segment (RM 15.1 to 8.7) upstream from the Lake Erie lacustuary were evaluated as very good to exceptional, except for the site in the Elyria WWTP mixing zone (RM 10.6). Within the Elyria WWTP mixing zone, the community declined to the marginally good range during one qualitative sampling and good during the second qualitative sampling six weeks later. Acute toxicity in the mixing zone was not indicated by the results (Table 11).

Trend data shows that macroinvertebrate communities upstream from the Lake Erie lacustuary were in the poor and fair range in the 1970s and 1980s, but improved to the good to exceptional range in the 1990s (Figure 54; upper panel).

Black River Lacustuary
Macroinvertebrate communities in the Black River lacustuary (RM 5.6 to 0.1) have consistently scored below the proposed Lacustuarine criterion (LICI = 42) in 1992, 1994, and 1997 (Figure 54, lower panel). The exception were two sites in 1992 in the upper segment of the lacustuary. These scores may have been higher in 1992 due to higher flows in the Black River that year. Flows from July to September in 1992 were 7 to 10 times higher than in 1994 and 1997.

French Creek
Macroinvertebrates were evaluated at three locations in French Creek in 1997. The upper (RM 5.5) and lower (RM 0.4) sites were evaluated as fair. Only 4 and 5 EPT taxa were collected at these two sites, respectively, compared to 8 EPT taxa at the location sampled at RM 3.2 (evaluated as good). Additionally, on the September 3 sampling collection, the benthic field personnel observed dead fish at RMs 5.5 and 0.4, but not at RM 3.2.

Previous data in 1992 showed a fair community upstream (RM 3.2) from the French Creek WWTP and a good community downstream (RM 0.5), the reverse of the 1997 data. In 1982 both sites (RMs 3.2 and 0.5) were evaluated as good.

East Branch Black River
Macroinvertebrate communities were evaluated at nine locations on the East Branch Black River from RMs 40.4 to 0.1. The communities were very good to exceptional at all sites sampled (ICI scores ranged from 44 to 48). Total taxa ranged from 52 to 70, and total EPT taxa ranged from 14 to 23. These results were similar to the 1992 results (Table 11), except the 1992 results showed that the East Branch was adversely impacted downstream from the Grafton WWTP. Macroinvertebrate communities were very good or exceptional at all stations in 1992, except the two sites downstream from the Grafton WWTP (RM 11.2) which were evaluated as marginally good to good.

The communities in the lower reach of the East Branch were evaluated in 1982 as good at RM 3.1 and poor (ICI = 6) at RM 0.2. The 1992 data, and especially the 1997 data, documented significant water resource improvement at the lower site which was attributed to decreases in CSO discharges.

East Fork East Branch Black River

The macroinvertebrate community was evaluated upstream from Lodi (RM 2.7) and downstream from the Lodi WWTP (RM 1.7) at RM 0.1. The upstream station supported an exceptional community consisting of 14 EPT taxa and a QCTV score of 42.2. This was the only site in the 1997 survey where pollution sensitive stoneflies were collected. The community sampled downstream from the Lodi WWTP at RM 0.1 declined to the marginally good range. The downstream site had only 6 EPT taxa and lower QCTV score of 33.4. These results were similar to those from 1992.

Willow Creek

Macroinvertebrate communities qualitatively collected upstream (RM 6.1) and downstream (RM 4.9) from Eaton Estates WWTP were evaluated as poor. Both sites had less than 20 taxa with pollution tolerant aquatic worms common or prevalent. No mayflies or caddisflies were collected upstream at RM 6.1 and only 2 EPT taxa were collected downstream at RM 4.9. The macroinvertebrate community qualitatively collected at RM 2.8 was evaluated as marginally good. Thirty-eight taxa were collected including 7 mayfly and caddisfly (EPT) species; none of the taxa collected were particularly pollution sensitive. These results were similar to the 1992 data, where 40 total taxa including 7 EPT taxa were collected.

West Branch Black River

Macroinvertebrates were sampled near the mouth in 1997. The ICI score of 38 was evaluated as good, and is a substantial improvement compared to the ICI scores of 28 (fair) in 1992, and 2 (poor) in 1982.

Plum Creek

Macroinvertebrate communities evaluated in Plum Creek ranged from marginally good upstream (RM 3.3) from the Oberlin WWTP to very good (ICI = 44 at RM 0.8) 2.2 miles downstream from the Oberlin WWTP discharge at RM 3.0. The upstream site supported 27 taxa collected by qualitative methods including 6 taxa of mayflies and caddisflies; the QCTV score was 33.4. The WWTP discharge did not have an additional adverse impact on the macroinvertebrate community. The ICI was 34 (good) downstream from the discharge at RM 2.9. These results were similar to the 1992 results (Table 11).

Beaver Creek.

In 1997, macroinvertebrate communities collected upstream from the Amherst WWTP at RMs 4.9 and 7.1 scored ICI values in the very good and exceptional range, respectively. The downstream site at RM 2.8 scored an ICI value of 14 (fair), indicating the Amherst WWTP had an adverse impact on the macroinvertebrate community in Beaver Creek.

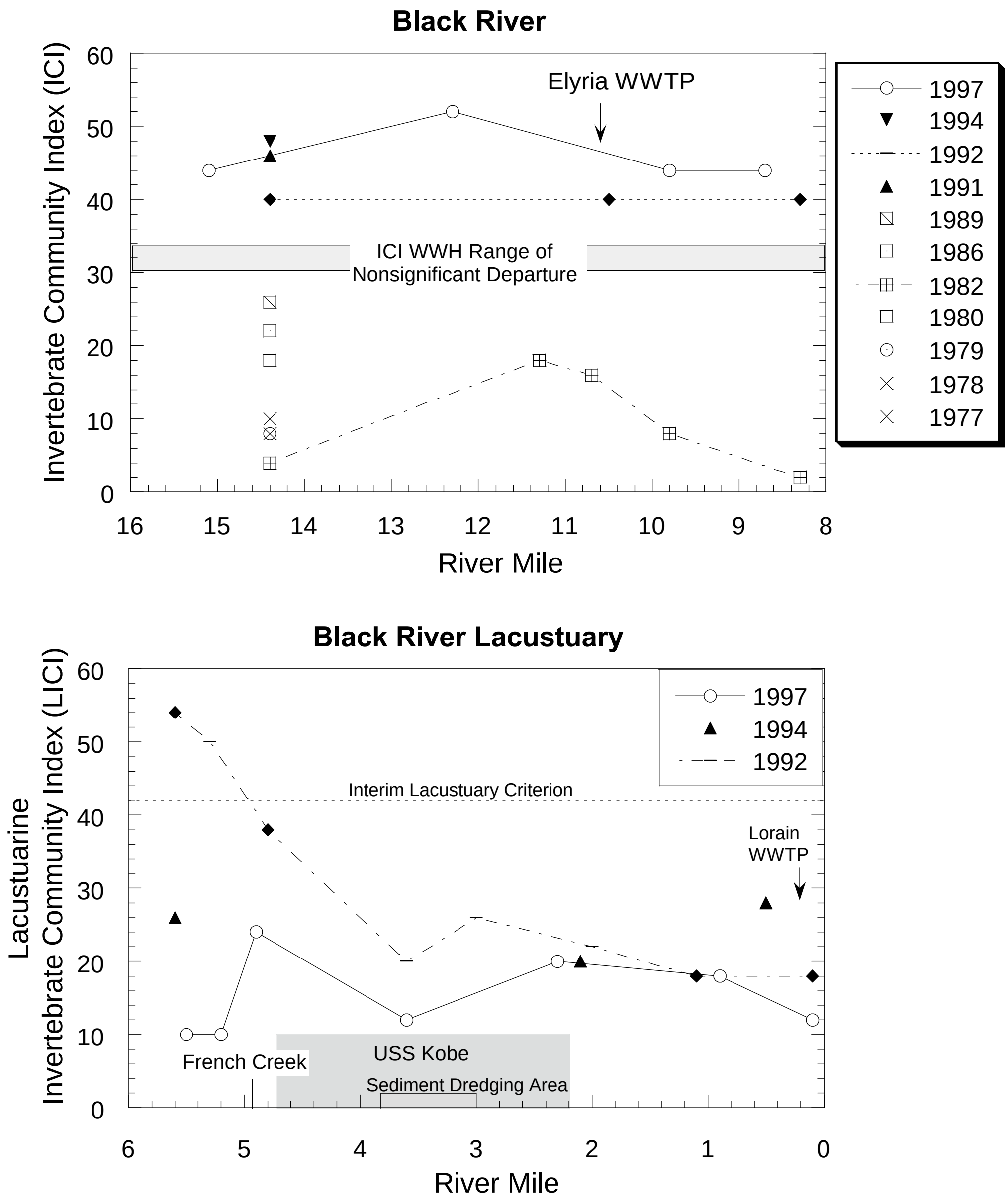


Figure 54. Invertebrate Community Index (ICI) scores plotted by river mile for the free-flowing Black River mainstem (upper panel) and the lake-influenced (lacustuary) portion of the mouth (lower pannel) in relation to the Elyria WWTP, French Creek, the reach receiving discharge from USS/Kobe, the area where contaminated sediments were dredged, and the Lorain WWTP.

Table 11. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and from natural substrates (qualitative sampling) in the Black River basin, 1997. Also included are historical collection summaries from 1977-97, where available.

Quantitative Evaluation

Stream/River Mile	Density (#/sq.ft.)	Quant Taxa	Qual Taxa	Qual EPT[a]	Total Taxa	QCTV Score[b]	ICI	Evaluation
Black River (1997) *Erie-Ontario Lake Plain Use Designation (Existing)*								
15.1	1375	38	36	13	52	40.7	44	Very Good
12.3	714	37	46	17	59	41.5	52	Exceptional
10.6	--	--	*31/38*	*7/10*	--	*34.9/38.7*	--	*Marg.G/Good*
8.7	1265	30	41	12	51	40.9	44	Very Good
Lake Erie Lacustuary, Interim Criteria Apply								
5.5W	6003	23	13	0	28	31.7	10*	Very Poor
5.2E	2382	23	12	1	27	30.4	10*	Very Poor
4.9W	813	24	20	2	35	30.2	24*	Poor
3.6W	2873	21	17	1	28	32.0	12*	Poor
2.3W	957	22	11	0	25	19.5	20*	Poor
0.9E	648	20	11	0	25	32.0	18*	Poor
0.1E	541	19	8	0	20	25.4	12*	Poor
Black River (1994) *Erie-Ontario Lake Plain Use Designation (Existing)*								
14.4	1464	32	46	17	56	39.5	48	Exceptional
Lake Erie Lacustuary, Interim Criteria Apply								
5.6	730	17	17	4	26	26.7	26*	Fair
2.1	1139	24	17	1	33	26.7	20*	Poor
0.5	1241	28	23	1	39	25.4	28*	Fair
Black River (1992) *Erie-Ontario Lake Plain Use Designation (Existing)*								
14.4	306	41	32	10	51	37.7	40	Good
11.2	-	-	32	9	-	38.6	-	Marg.Good
10.6	*490*	*40*	*33*	*9*	*50*	*33.4*	*28*	*Good*
10.5	470	39	39	10	58	38.6	40	Good
8.3	568	51	31	11	61	38.4	40	Good
Lake Erie Lacustuary, Interim Criteria Apply								
5.6E	617	46	18	2	56	32.4	54	Exceptional
5.3W	854	47	17	3	52	31.7	50	Good
5.0W	473	30	11	0	38	21.7	28*	Fair
4.8W	1067	42	18	1	47	33.1	38*	Fair

Table 11. (Continued)

Stream/River Mile	Density (#/sq.ft.)	Quant Taxa	Qual Taxa	Qual EPT[a]	Total Taxa	QCTV Score[b]	ICI	Evaluation
		Quantitative Evaluation						
Black River (1992)	*Lake Erie Lacustuary, Interim Criteria Apply*							
3.6W	2293	28	28	2	49	32.8	20*	Poor
3.0W	1708	33	24	3	44	34.3	26*	Fair
2.0W	1061	21	11	0	25	26.7	22*	Poor
1.1W	952	25	21	1	32	23.9	18*	Poor
0.1E	5238	27	10	1	30	23.1	18*	Poor
Black River (1991)	*Erie-Ontario Lake Plain WWH Use Designation (Existing)*							
14.4	1241	38	50	13	61	36.7	46	Exceptional
Black River (1989)								
14.4	1180	28	41	10	51	34.9	26*	Fair
Black River (1986)								
14.4	307	26	34	8	45	34.9	22*	Fair
Black River (1982)								
14.4	431	16	20	3	25	31.9	4*	Poor
11.3	683	27	30	5	46	32.8	18*	Fair
10.7	453	31	26	3	45	29.8	16*	Fair
9.8	613	13	11	0	19	29.8	8*	Poor
8.3	372	8	21	1	25	18.9	2*	Poor
6.7	--	--	23	4	--	29.8	--	Fair
Black River (1980)								
14.4	108	31	10	1	36	29.8	18*	Fair
Black River (1979)								
14.4	155	17	6	0	20	30.4	8*	Poor
Black River (1978)								
14.4	175	17	9	0	19	21.9	10*	Poor
Black River (1977)								
14.4	77	14	6	1	15	30.7	8*	Poor

Table 11. (Continued)

Stream/River Mile	Density (#/sq.ft.)	*Quantitative Evaluation* Quant Taxa	Qual Taxa	Qual EPT[a]	Total Taxa	QCTV Score[b]	ICI	Evaluation
French Creek (1997) *Erie-Ontario Lake Plain WWH Use Designation (Existing)*								
5.5	--	--	25	5	--	32.8	--	Fair
3.2	350	31	24	8	41	37.7	40	Good
0.4	--	--	18	4	--	38.4	--	Fair
French Creek (1992)								
3.2	426	43	32	1	55	31.9	22*	Fair
0.5	263	36	29	4	49	33.3	34	Good
French Creek (1982)								
3.2	174	33	27	6	44	32.6	40	Good
0.5	--	--	23	7	--	39.2	--	Good
Beaver Creek (1997) *Erie-Ontario Lake Plain WWH Use Designation (Existing)*								
7.1	288	34	26	7	43	40.9	48	Exceptional
4.8	131	30	31	10	44	39.5	44	Very Good
2.8	508	24	22	2	34	34.3	14*	Fair
East Branch Black River (1997) *Erie-Ontario Lake Plain WWH Use Designation (Existing)*								
40.4	823	46	35	9	58	39.5	48	Exceptional
32.4	547	38	37	6	60	38.7	44	Very Good
18.9	278	39	42	12	70	40.3	44	Very Good
11.3	2244	36	43	14	59	38.6	48	Exceptional
10.8	788	47	47	14	67	38.4	44	Very Good
6.0	2359	29	54	16	64	39.5	46	Exceptional
5.2	2859	46	45	18	64	40.9	48	Exceptional
3.0	2608	24	38	13	52	39.2	44	Very Good
0.1	756	38	37	12	53	38.6	46	Exceptional
East Branch Black River (1992)								
41.5	908	46	49	17	71	40.9	50	Exceptional
32.3	584	55	42	10	72	37.9	42	Very Good
18.9	510	48	32	11	64	39.8	46	Exceptional
11.3	941	47	47	14	70	40.9	46	Exceptional
10.8	1688	41	56	13	71	38.7	30[ns]	Marg. Good
6.0	1166	33	54	19	67	39.7	38	Good
5.4	880	50	50	20	74	41.0	48	Exceptional

Table 11. (Continued)

Stream/River Mile	Density (#/sq.ft.)	Quant Taxa	Qual Taxa	Qual EPT[a]	Total Taxa	QCTV Score[b]	ICI	Evaluation
			Quantitative Evaluation					
East Branch Black River (1992)								
3.0	1054	44	44	19	59	40.9	42	Very Good
0.1	581	46	33	13	58	39.2	42	Very Good
East Branch Black River (1982)								
3.1	--	--	41	11	--	38.6	--	Good
0.2	264	17	13	1	23	29.8	6*	Poor
East Fork East Branch Black River (1997) *EOLP WWH Use Designation (Existing)*								
2.7	--	--	37	14	--	42.2	--	Exceptional
0.1	--	--	36	6	--	33.4	--	Marg. Good
East Fork East Branch Black River (1992)								
2.9	256	46	42	15	67	39.8	46	Exceptional
1.5	526	46	44	10	63	37.7	40	Good
West Branch Black River (1997) *Erie-Ontario Lake Plain WWH Use Designation (Existing)*								
0.1	566	35	16	6	38	40.9	38	Good
West Branch Black River (1994)								
48.1A	--	--	36	4	--	29.4	--	Fair
48.1B	333	13	27	2	35	29.4	8*	Poor
44.0A	--	--	36	5	--	31.9	--	Fair
44.0B	127	22	34	2	45	32.8	14*	Fair
West Branch Black River (1992)								
41.7	297	51	50	15	74	40.9	54	Exceptional
25.3	447	40	41	9	65	38.4	38	Good
13.5	--	--	37	9	--	39.2	--	Marg. Good
4.2	487	33	34	5	52	34.3	22*	Fair
0.1	384	43	22	7	49	34.9	28*	Fair
West Branch Black River (1982)								
4.2	417	18	28	7	36	34.4	14*	Fair
0.1	858	12	14	2	18	32.4	2*	Poor

Table 11. (Continued)

		Quantitative Evaluation						
Stream/River Mile	Density (#/sq.ft.)	Quant Taxa	Qual Taxa	Qual EPT[a]	Total Taxa	QCTV Score[b]	ICI	Evaluation
Plum Creek (1997) *Erie-Ontario Lake Plain WWH Use Designation (Existing)*								
3.3	216	28	32	6	48	33.4	[24][c]	Marg. Good
2.9	232	34	14	4	37	38.7	34	Good
0.8	259	41	18	6	48	38.7	44	Very Good
Plum Creek (1994)								
6.0A	--	--	31	5	--	32.6	--	Fair
6.0B	134	19	30	4	39	32.6	<u>10</u>*	Poor
4.8A	--	--	31	4	--	32.6	--	Fair
4.8B	91	29	36	5	53	31.7	14*	Fair
3.3	64	22	42	7	53	33.3	20	Fair
2.8	225	34	24	3	44	32.8	30	Marg. Good
0.9	279	41	40	8	48	38.4	48	Exceptional
Plum Creek (1992)								
7.0	--	--	27	2	--	31.8	--	Fair
3.1	401	42	28	4	54	34.3	34	Good
2.9	230	39	23	3	50	32.8	36	Good
0.8	255	33	33	8	48	38.4	44	Very Good
Plum Creek (1987)								
7.0	--	--	42	3	--	32.8	--	Fair
3.1	--	--	56	9	--	33.4		Marg. Good
2.9	--	--	23	1	--	32.6	--	Poor
0.8	--	--	46	7	--	32.8	--	Fair

Table 11. (Continued)

			Qualitative Evaluation			
Stream/River Mile	Qual Taxa	QCTV Score[b]	Qual EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation
Black River (1997) *Erie-Ontario Lake Plain WWH Use Designation (Existing)*						
10.6A	31	34.9	7	Moderate	Hydropsychid caddisflies, Midges, Baetid mayflies	Marg. Good
10.6B	38	38.7	10	Mod-Low	Hydropsychid caddisflies, Midges, Baetid mayflies	Good
French Creek (1997) *Erie-Ontario Lake Plain WWH Use Designation (Existing)*						
5.5	25	32.8	5	Mod.-Low	Hydropsychid caddisflies flatworms	Fair
0.4	18	38.8	4	Mod.-Low	Hydropsychid caddisflies isopods	Fair
East Fork East Branch Black River (1997) *EOLP WWH Use Designation (Existing)*						
2.7	37	42.2	14	Low	Hydropsychid caddisflies, midges, mayflies	Exceptional
0.1	36	33.4	6	Low	nonred midges, scuds mayflies	Marg. Good
Willow Creek (1997) *Erie-Ontario Lake Plain WWH Use Designation (Existing)*						
6.1	16	18.9	0	Low	flatworms, aquatic worms	Poor
1.9	19	32.8	2	Mod.-Low	midges	Poor
2.9	38	35.9	7	Low	Hydropsychid caddisflies, midges, mayflies	Marg. Good
Plum Creek (1997) *Erie-Ontario Lake Plain WWH Use Designation (Existing)*						
3.3 32	33.4	6		Low	Hydropsychid caddisflies, mayflies, molluscs	Marg. Good

Table 11. (Continued)

Ecoregion Biological Criteria:

	WWH	EWH	Interim Lacustuary	MWH[d]
ICI	34	46	42	22

a EPT = total Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness.
b Qualitative Community Tolerance Value (QCTV) derived as the median of the tolerance values calculated for each qualitative taxon present (see discussion in text p.18).
c The quantitative sample was affected by slow current speed; evaluation was based primarily on the qualitative sample.
d Modified Warmwater Habitat for channelized/mine affected habitats.
ns Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
* Significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

Biological Assessment - Fish Communities

Black River

Fish communities in the free flowing portion of the Black River mainstem improved in 1996 relative to 1992, and improved considerably compared to 1982 and 1977 (Figure 55; Tables 12 and 13). Functional components of the fish community showing improvement included increased numbers or relative abundance of darter species, simple lithophils and insectivores, and decreased relative abundance of tolerant and omnivorous fishes. However, intolerant species remained virtually absent, only one river chub was collected at RM 15.0. Furthermore, the number of darter and sucker species, while improving slightly compared to previous surveys, remain below expectations. The absence of intolerant species, and the low numbers of darter and sucker species is a legacy of prior gross point source pollution, and an indication of continued watershed-scale habitat impairment. The decreased abundance of tolerant and omnivorous fishes coupled with increased abundance of insectivores signifies an improved trophic structure, likely due to lower levels of organic enrichment.

A localized impact associated with the combined sewer overflows (CSOs) and the Elyria WWTP was evident in the reach downstream from Elyria. The lowest IBI score in the mainstem was recorded downstream from the Elyria CSOs (RM 11.9) but upstream from the WWTP. The score there was driven by large numbers of bluntnose minnows on one pass. The MIwb score from the site downstream from the WWTP was lower relative to scores from samples collected upstream and further downstream from the plant (Figure 55). Mean IBI scores from the mixing zone and far-field sample did not differ, however, from the other sites. Response to a stressor in the MIwb but not the IBI may be symptomatic of intermittent or chronic toxicity where abundance is reduced, but overall community structure is maintained, or due to a very localized impact. The widely differing IBI scores between passes is further evidence for intermittent toxicity. The IBI scored 44 on the first pass compared to 28 on the second pass. The impact downstream from the Elyria WWTP was likely compounded by the CSOs upstream. Though the Elyria WWTP affected the fish community, substantial improvements in IBI scores downstream from the plant were realized in 1997, where the impact was minor and localized, compared to 1992 when the impact was more severe and recovery limited.

Very little change has occurred in the Black River lacustuary since 1992. All but one site (RM 0.9) remain in the poor to very poor range of IBI scores. Some slight improvement was observed in the stream segment associated with contaminated sediment removal but IBI scores are still poor. This area, as well as the rest of the lacustuary, remains strongly influenced by nutrient enrichment derived from point sources and nonpoint pollution. The small (but significant) decline observed below the USS/Kobe 001 outfall is a response to increased pollution loadings from that discharge. Considerable oil was observed to be coating the substrate downstream from the 001 outfall. The largest change in IBI from 1992 to 1997 was observed near the confluence with Lake Erie at RM 0.9. The influx of cleaner water low in nutrients from Lake Erie (during seiche activities) have created conditions more favorable to healthy fish communities. Largemouth bass and sunfish (*Lepomis* sp.) numbers have greatly increased in this area resulting in higher IBI values during 1997. Conditions at RM 0.9 confirm the observation that nutrient loads in the lacustuary are the principle cause of poor fish community attainment. At RM 0.9 water clarity was greater and aquatic vegetation was observed (a critical habitat component for lacustuarine fish communities). Nearer Lake Erie, at RM 0.1, fish communities remain poor in response to overwhelming habitat loss in the navigation channel. Vertical sheet piling and cement sea walls provide inhospitable habitat for fish colonization. The greatest environmental gains in the Black River lacustuary, both biological and chemical (*i.e.*, dissolved oxygen levels) would come with the reduction of nutrient loads from upstream sources.

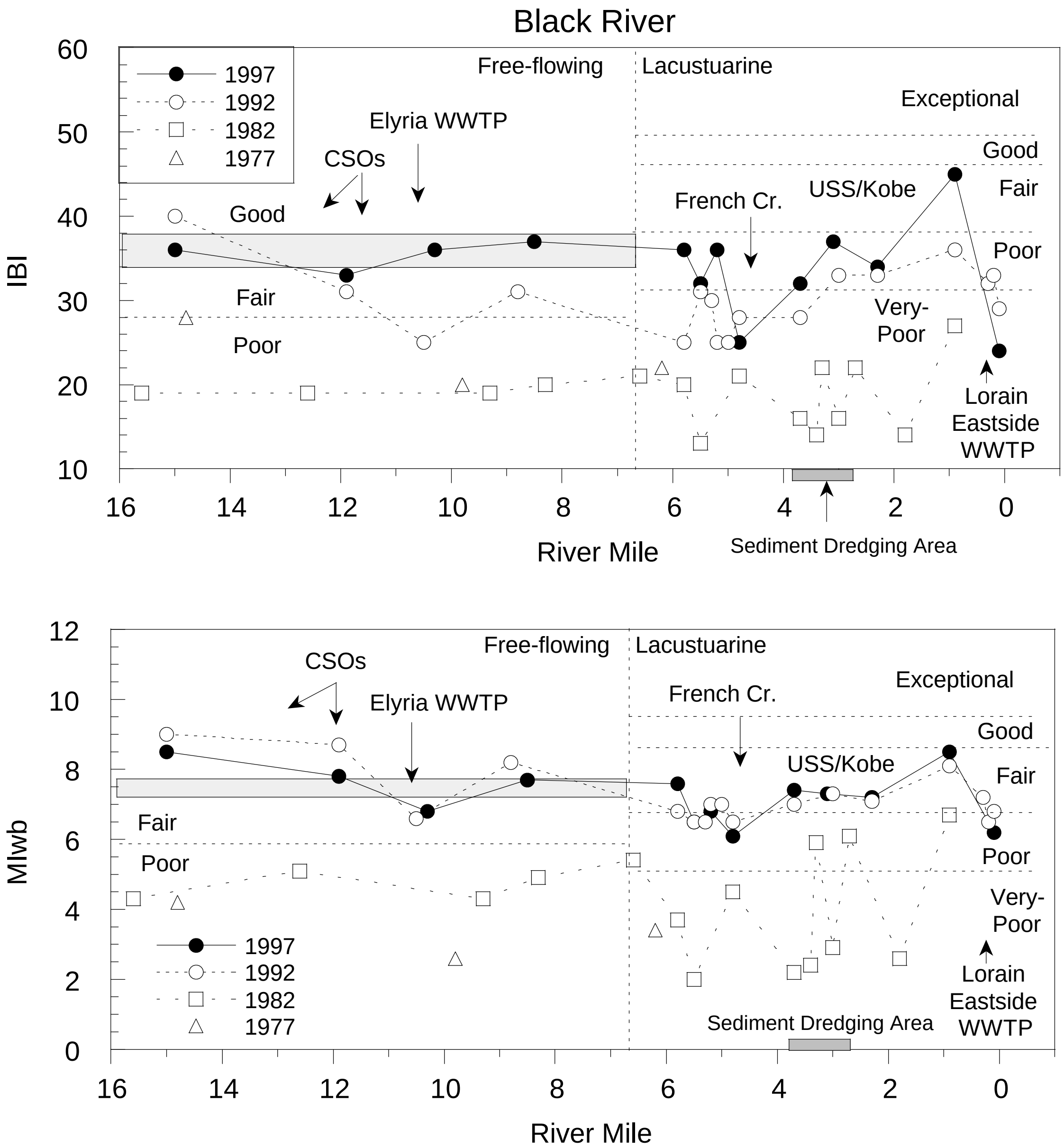


Figure 55. Plots of Index of Biotic Integrity (IBI, upper panel) and Modified Index of well-being (MIwb, lower panel) from the Black River, 1977 - 1997, in relation to the area receiving CSO discharges, the Elyria WWTP, the mouth of French Creek, the area of dredged sediments (which also corresponds to the area receiving discharge from USS/Kobe), and the Lorain Eastside WWTP.

Table 12. Fish community indices from samples collected in the Black River study area 1997, 1992, 1982 and 1977.

River Mile	Mean Number Species	Cumulative Species	Mean Rel. No (No./0.3 km)	Mean Rel. Wt. (wt./0.3 km)	QHEI	Mean Miwb[a]	Mean IBI	Narrative Evaluation
Black River (20-001) 1997 EOLP WWH Biological Criteria - Existing								
15.0	20.5	25	835	19.8	79.5	8.5	36[ns]	Good/M.Good
11.9	17.0	20	816	13.6	75.0	7.8[ns]	33[*]	M.Good/Fair
10.6	*11.0*	*15*	*384*	*14.4*	--	*7.1[ns]*	*35[ns]*	*M.Good*
10.3	15.5	19	236	10.7	79.5	6.8[*]	36[ns]	Fair/M.Good
8.5	14.5	18	408	12.5	78.0	7.7[ns]	37[ns]	M.Good
Lake Erie Lacustuary, Interim Criteria Apply								
5.8	20.0	28	286	103.8	58.0	7.6[*]	36[*]	Fair
5.5	18.0	23	267	106.4	42.5	6.5[*]	32[*]	Poor/Fair
5.2	16.0	22	293	78.6	48.5	6.8[*]	36[*]	Fair
4.8	16.0	24	168	82.9	55.0	6.1[*]	25[*]	Poor
3.7	*15.0*	*20*	*622*	*35.3*	--	*7.4[*]*	*32[*]*	*Fair*
3.1	20.0	26	485	103.9	53.5	7.3[*]	37[*]	Fair
2.3	20.0	24	737	332.8	45.0	7.2[*]	34[*]	Fair
0.9	20.0	23	842	114.5	34.5	8.5[*]	45	Fair/Good
0.1	5.5	7	841	17.6	27.0	6.2[*]	24[*]	Poor/Fair
Black River 1992 EOLP WWH Biological Criteria - Existing								
15.0	23.5	28	887	35.0	86.0	9.0	40	Very Good/Good
11.9	20.0	22	1182	27.8	87.5	8.7	31[*]	Good/Fair
10.6	14.0	16	789	51.1	0.0	6.4[*]	26[*]	Fair/Poor
10.5	19.0	24	895	41.6	87.0	6.6[*]	25[*]	Fair/Poor
8.8	20.5	25	591	14.2	77.0	8.2	31[*]	Good/Fair
Lake Erie Lacustuary, Interim Criteria Apply								
5.8	16.0	16	317	108.0	53.0	6.8[*]	25[*]	Fair/Poor
5.5	15.0	15	391	116.3	58.0	6.5[*]	31[*]	Poor/Fair
5.3	15.0	15	391	116.3	0.0	6.5[*]	30[*]	Poor
5.2	17.7	26	275	68.3	49.0	7.0[*]	25[*]	Fair/Poor
5.0	17.7	18	275	68.3	0.0	7.0[*]	25[*]	Fair/Poor
4.8	15.7	16	374	106.2	59.5	6.5[*]	28[*]	Poor
3.7	15.7	18	515	66.9	42.0	7.0[*]	28[*]	Fair/Poor
3.0	13.7	17	540	49.2	57.0	7.3[*]	33[*]	Fair
2.3	18.0	27	752	196.5	55.0	7.1[*]	33[*]	Fair
0.9	16.8	17	1002	67.4	52.0	8.1[*]	36[*]	Fair
0.3	15.5	25	783	220.9	59.5	7.2[*]	32[*]	Fair
0.2	11.0	18	335	75.8	54.5	6.5[*]	33[*]	Fair

Table 12. Continued.

River Mile	Mean Number Species	Cumulative Species	Mean Rel. No (No./0.3 km)	Mean Rel. Wt. (wt./0.3 km)	QHEI	Mean Miwb[a]	Mean IBI	Narrative Evaluation
Black River 1992		*Lake Erie Estuarine Biological Criteria Apply*						
0.1	12.3	18	780	127.3	40.0	6.8*	29*	Fair/Poor
Black River 1982 EOLP WWH Biological Criteria - Existing								
15.6	9.7	15	209	27.5	0.0	4.3*	19*	Very Poor/Poor
12.6	13.3	20	479	90.8	0.0	5.1*	19*	Poor
9.3	11.7	18	404	16.0	0.0	4.3*	19*	Very Poor/Poor
8.3	14.0	14	254	28.6	0.0	4.9*	20*	Poor
6.6	14.3	21	315	45.5	0.0	5.4*	21*	Poor
		Lake Erie Lacustuary, Interim Criteria Apply						
5.8	5.4	13	105	3.7	62.0	3.7*	20*	Very Poor/Fair
5.5	3.0	6	18	0.1	0.0	2.0*	13*	Very Poor
4.8	8.0	15	288	29.1	51.5	4.5*	21*	Poor/Fair
3.7	3.0	3	5	0.0	0.0	2.2*	16*	Very Poor
3.4	3.0	3	18	0.3	0.0	2.4*	14*	Very Poor
3.3	11.8	16	908	71.6	55.0	5.9*	22*	Fair
3.0	5.0	5	11	0.1	0.0	2.9*	16*	Very Poor
2.7	9.6	16	1784	35.9	39.5	6.1*	22*	Fair
1.8	5.0	8	29	1.1	0.0	2.6*	14*	Very Poor
0.9	10.5	20	1800	63.7	23.0	6.7*	27*	Fair
Black River 1977 EOLP WWH Biological Criteria - Existing								
14.8	19.0	19	71	0.0	0.0	4.2*	28*	Very Poor/Fair
9.8	8.0	8	3619	0.0	0.0	2.6*	20*	Very Poor/Poor
6.2	8.0	8	184	0.0	0.0	3.4*	22*	Very Poor/Poor
French Creek (20-002) 1997 EOLP WWH Biological Criteria - Existing								
6.1	8.0	10	211	2.7	73.5	3.9*	20*	Very Poor/Poor
3.2	12.0	15	474	5.8	71.0	5.8*	22*	Poor
1.0	16.0	22	356	6.7	66.5	7.6^{ns}	41	M.Good/Good
French Creek 1992 EOLP WWH Biological Criteria - Existing								
3.2	11.0	11	555	10.5	71.0	5.5*	18*	Poor
0.4	17.3	17	460	74.1	58.0	7.3*	30*	Fair
French Creek 1982 EOLP WWH Biological Criteria - Existing								
3.2	8.0	11	187	0.0	0.0	3.2*	19*	Very Poor/Poor
2.5	9.0	11	353	0.0	0.0	4.1*	23*	Very Poor/Poor
0.4	13.2	27	681	187.1	0.0	5.5*	26*	Poor
0.1	9.3	17	231	2.4	0.0	4.4*	20*	Very Poor/Poor

Table 12. Continued.

River Mile	Mean Number Species	Cumulative Species	Mean Rel. No (No./0.3km)	Mean Rel. Wt. (wt./0.3km)	QHEI	Mean Miwb[a]	Mean IBI	Narrative Evaluation
French Creek 1977 EOLP WWH Biological Criteria - Existing								
3.2	11.0	11	344	0.0	0.0	4.0[*]	26[*]	Very Poor/Poor
1.4	14.0	14	2068	0.0	0.0	5.4[*]	34[ns]	Poor/M.Good
East Branch Black River (20-010) 1997 EOLP WWH Biological Criteria - Existing								
40.5	21.5	25	632	18.7	63.5	7.8[ns]	44	M.Good/Good
32.5	16.0	16	282	4.0	58.5	6.8[*]	30[*]	Fair
18.9	16.5	20	218	4.8	63.5	7.7[ns]	42	M.Good/Good
11.3	16.5	20	748	7.0	74.0	8.0	38	Good
10.9	14.5	17	495	13.7	71.5	7.5[ns]	33[*]	M.Good/Fair
6.0	16.0	18	1472	6.1	56.0	7.6[ns]	34	M.Good
5.5	18.0	20	502	17.8	75.5	8.3	42[*]	Good
3.0	14.0	15	717	27.3	62.0	8.2	41[*]	Good
East Branch Black River 1992 EOLP WWH Biological Criteria - Existing								
41.5	21.0	24	863	8.3	54.5	7.9	33[*]	Good/Fair
36.8	19.0	20	692	8.5	75.0	8.0	32[*]	Good/Fair
32.5	20.0	22	491	17.8	60.0	8.1	26[*]	Good/Poor
24.6	10.0	12	653	65.1	57.0	7.3[*]	25[*]	Fair/Poor
18.9	18.5	21	284	8.0	73.0	7.4[ns]	37[ns]	M.Good
11.3	16.0	16	695	16.3	65.5	8.1	41	Good
10.1	17.0	18	717	8.1	90.0	8.2	42	Good
6.0	17.5	21	2022	7.8	53.5	7.4[ns]	27[*]	M.Good/Poor
5.2	18.3	22	871	161.1	84.0	8.7	31[*]	Good/Fair
3.0	16.0	18	524	36.2	63.5	8.3	37[ns]	Good/M.Good
0.3	11.7	13	456	51.8	57.0	6.5[*]	29[*]	Fair
East Branch Black River 1982 EOLP WWH Biological Criteria - Existing								
1.7	13.4	19	259	45.0	0.0	7.4[ns]	29[*]	M.Good/Fair
0.9	10.8	16	301	28.8	0.0	7.6[ns]	30[*]	M.Good/Fair
0.6	10.0	17	130	18.2	0.0	6.1[*]	25[*]	Fair/Poor
East Branch Black River 1977 EOLP WWH Biological Criteria - Existing								
45.0	16.0	16	537	--	--	--	44	Good
38.7	18.0	18	490	--	--	--	40	Good
32.4	18.0	18	314	--	--	--	28[*]	Fair
24.6	20.0	20	458	--	--	--	40	Good
17.4	23.0	23	902	--	--	--	36[ns]	M.Good
5.4	22.0	22	310	--	--	--	34[ns]	M.Good
3.0	21.0	21	580	--	--	--	40	Good

Table 12. Continued.

River Mile	Mean Number Species	Cumulative Species	Mean Rel. No (No./0.3km)	Mean Rel. Wt. (wt./0.3km)	QHEI	Mean Miwb[a]	Mean IBI	Narrative Evaluation
East Fork East Branch (20-014) 1997 EOLP WWH Biological Criteria - Existing								
2.7	12.5	14	936	--	52.0	NA	38[ns]	M.Good
2.1	18.0	18	2849	--	76.5	NA	48	Very Good
0.1	14.0	18	905	--	44.5	NA	39[ns]	M.Good
East Fork East Branch 1992 EOLP WWH Biological Criteria - Existing								
2.7	10.0	10	1745	--	71.5	NA	39[ns]	M.Good
1.6	17.5	20	1261	8.0	70.5	NA	39[ns]	M.Good
East Fork East Branch 1977 EOLP WWH Biological Criteria - Existing								
7.2	15.0	15	1563	--	--	NA	42	Good
5.8	14.0	14	603	--	--	NA	44	Good
3.8	10.0	10	1038	--	--	NA	42	Good
2.3	10.0	10	1760	--	--	NA	32	Fair
Willow Creek (20-018) 1997 EOLP WWH Biological Criteria - Existing								6.0
--	--	--	--	24.0	--	--	--	
4.9	7.0	9	345	--	55.0	NA	19*	Poor
2.9	10.0	13	632	--	39.0	NA	20*	Poor
Willow Creek 1992 EOLP WWH Biological Criteria - Existing								
2.9	11.0	12	1416	25.9	72.5	NA	18*	Poor
Willow Creek 1977 EOLP WWH Biological Criteria - Existing								
5.5	4.0	4	40	--	--	NA	16*	Poor
2.5	13.0	13	605	--	--	NA	20*	Poor
West Branch Black River (20-020) 1997 EOLP WWH Biological Criteria - Existing								
1.2	12.5	17	774	2.9	47.5	6.7*	30*	Fair
West Branch Black River 1992 EOLP WWH Biological Criteria - Existing								
1.2	15.5	19	448	20.7	69.5	6.7*	32*	Fair
West Branch Black River 1982 EOLP WWH Biological Criteria - Existing								
0.9	11.0	11	1056	83.6	--	4.7*	18*	Poor
West Branch Black River 1977 EOLP WWH Biological Criteria - Existing								
0.1	16.0	16	572	--	--	3.7*	22	Very Poor/Poor
Plum Creek (20-021) 1997 EOLP WWH Biological Criteria - Existing								
3.3	9.0	13	489	--	73.0	NA	27*	Poor
2.9	*6.0*	*8*	*253*	--	*63.0*	*NA*	*27**	*Poor*

Table 12. Continued.

River Mile	Mean Number Species	Cumulative Species	Mean Rel. No (No./0.3km)	Mean Rel. Wt. (wt./0.3km)	QHEI	Mean Miwb[a]	Mean IBI	Narrative Evaluation
Plum Creek 1997 - Continued.								
1.6	11.0	15	283	--	80.5	NA	31*	Fair
Plum Creek 1994 EOLP WWH Biological Criteria - Existing								
6.0	6.0	8	857	4.4	54.0	NA	<u>20</u>*	Poor
4.9	5.5	7	422	3.9	46.5	NA	<u>21</u>*	Poor
3.3	6.0	6	653	4.7	59.5	NA	<u>21</u>*	Poor
2.8	10.0	10	1417	6.3	51.5	NA	<u>27</u>*	Poor
0.9	16.0	16	989	15.0	76.5	NA	32*	Fair
Plum Creek 1992 EOLP WWH Biological Criteria - Existing								
7.0	5.5	6	189	--	70.0	NA	<u>23</u>*	Poor
3.3	7.5	8	713	5.3	69.5	NA	<u>21</u>*	Poor
2.9	6.5	7	597	5.9	57.0	NA	<u>24</u>*	Poor
2.8	6.0	7	512	5.6	--	NA	<u>21</u>*	Poor
0.9	16.0	16	846	9.0	87.5	NA	35*	Fair
Plum Creek 1987 EOLP WWH Biological Criteria - Existing								
7.0	6.0	6	233	1.0	--	NA	<u>22</u>*	Poor
3.3	8.0	8	599	4.4	--	NA	<u>22</u>*	Poor
2.9	4.0	4	54	0.2	--	NA	<u>20</u>*	Poor
0.9	9.0	9	227	3.1	--	NA	<u>22</u>*	Poor
Plum Creek 1977 EOLP WWH Biological Criteria - Existing								
3.2	9.0	9	151	--	--	NA	<u>24</u>*	Poor
0.8	6.0	6	1500	--	--	NA	<u>18</u>*	Poor
Beaver Creek (20-003) 1997 EOLP WWH Biological Criteria - Existing								
6.8	10.5	13	1311	3.0	60.5	6.4*	35*	Fair
4.6	12.0	15	1053	7.6	58.0	7.3*	37[ns]	Fair/M.Good
2.8	6.5	8	203	1.3	49.5	<u>4.2</u>*	<u>21</u>*	Very Poor/Poor
Beaver Creek 1992 EOLP WWH Biological Criteria - Existing								
11.0	5.0	5	120	--	61.0	NA	<u>24</u>*	Poor
7.0	9.0	9	440	--	71.5	<u>4.6</u>*	32*	Poor/Fair
4.7	14.0	14	623	6.2	70.5	7.5[ns]	34*	M.Good/Fair
3.0	12.0	12	1302	10.6	68.5	6.2*	<u>24</u>*	Fair/Poor
1.8	13.0	13	543	7.6	70.0	6.7*	<u>26</u>*	Fair/Poor

Table 12. Continued.

Ecoregion Biological Criteria: Erie-Ontario Lake Plain

SiteType	IBI WWH	IBI EWH	MIwb WWH	MIwb EWH
Headwaters	40	50	NA	NA
Wading	38	50	7.9	9.4
Boat	40	48	8.7	9.6
Estuarine	42	50	8.6	9.6

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

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

ns - Non significant departure from applicable biological criteria (4 IBI units or 0.5 MIwb units).

East Branch Black River

Longitudinal trends in IBI and MIwb scores for the East Branch were similar between sampling years, however IBI scores upstream from Grafton showed improvement. Most IBI and MIwb scores met or were within nonsignificant departure of the WWH biological criteria. Also, the impact associated with the Grafton WWTP was more immediate but less protracted in 1997 compared to 1992, and the Brentwood and Willow Creek tributaries did not retard recovery as they had appeared to do in 1992 (Figure 56). Higher proportions of simple lithophils and insectivores accounted for the improved IBI scores upstream from Grafton, and may signify a lessening of habitat impairment (*i.e.*, silt and sedimentation) from nonpoint impacts. Slight increases in the proportion of tolerant and omnivorous fishes were responsible for the lowered IBI score downstream from the Grafton WWTP. In the absence of changes to other functional components of the fish community, an increased abundance of tolerant and omnivorous fishes demonstrates organic or nutrient enrichment. Masses of filamentous algae covered the stream bed in the sampling reach downstream from the Grafton WWTP, directly implicating nutrient enrichment.

The comparatively low IBI and MIwb scores obtained from RM 32.5 were due mostly to locally limiting habitat; riffle and channel substrates were severely embedded with sand and gravel from bank erosion and agricultural runoff. However, tolerant fishes composed an unusually high proportion of the catch relative to the site upstream, despite similar levels of habitat impairment. The low gradient, deep pools and accumulation of detritus may contribute to nocturnal depletion of dissolved oxygen. Suburban development in the Spencer Lake area may also be contributing pollutant loads and should be monitored more closely in the next basin survey.

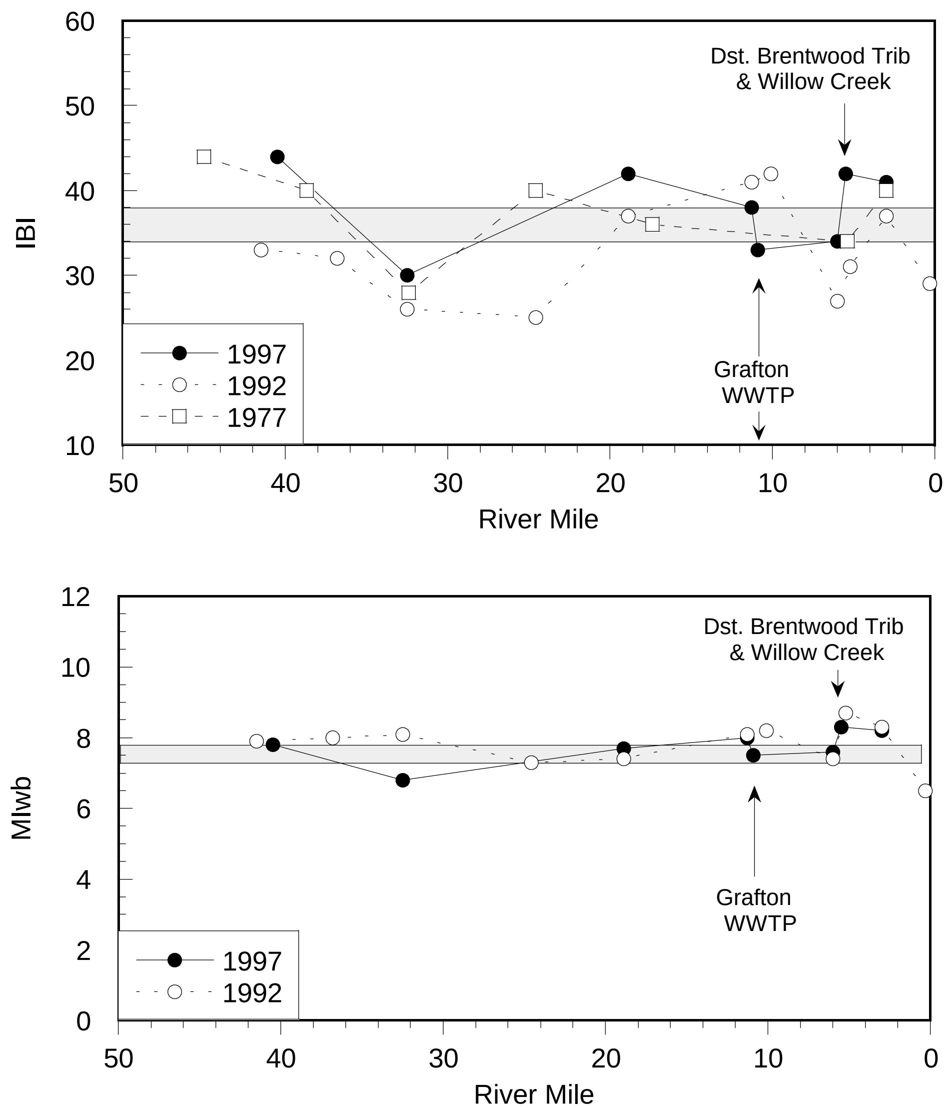


Figure 56. Plots of the Index of Biotic Integrity (IBI, upper panel) and Modified Index of well-being (MIwb, lower panel) scores from East Branch Black River, 1992 and 1997, in relation to the Grafton WWTP and the Brentwood and Willow Creek tributaries.

As with the Black River mainstem, the legacy of nonpoint pollution and habitat degradation was evident in the absence of intolerant species, and low numbers of darter and sucker species. However, the proportion of simple lithophilic and insectivorous fishes increased in 1997 relative to 1992, suggesting a lessening of nonpoint related impacts.

East Fork of the East Branch
The longitudinal pattern in IBI scores for the East Fork closely matched that for the QHEI (Table 57). Groundwater discharge may also have helped to augment the fish population at RM 2.1 given the presence of brook stickleback, central mudminnow and redside dace there, and not at the sites either upstream or downstream. IBI scores in the East Fork were similar between sampling years, however, redside dace were collected at RM 2.7 in 1992, but not in 1997. Gray-black deposits and a sulfide smell were noted in 1997 but absent (or not noticed) in 1992, possibly indicating a recent (since the last survey) failed septic system or other problem worthy of future attention.

French Creek
The fish community in French Creek at one site, RM 1.0, met applicable biological criteria. The site was located downstream from the French Creek WWTP. Despite having good habitat, the two sites sampled further upstream at RMs 3.2 and 6.1 had Poor to Very Poor IBI and MIwb scores (Table 12; Figure 57). A fly ash disposal area located upstream from RM 3.2 may have contributed to the observed impairment; however, the very poor biological performance upstream from the fly ash area suggests other or additional sources of impairment. Other sources were not identified, but the unusually elevated abundance of tolerant fishes coupled with an absence of sensitive species points to toxicity. Degraded fish communities were found at RM 3.2 in 1992, 1982 and 1977 implying that the sources of impairment have been persistent.

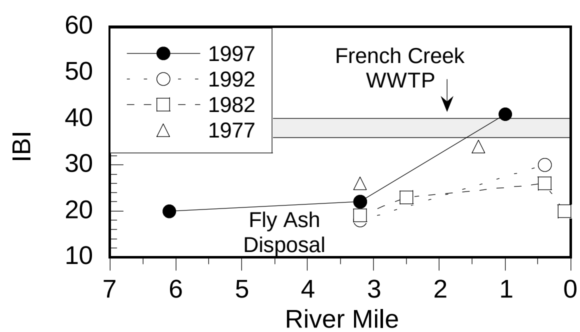


Figure 57. Index of Biotic Integrity (IBI) scores from French Creek, 1977 - 1997, in relation to the French Creek WWTP.

Willow Creek
Two of the three sites sampled were channelized, and consequently had degraded habitat. Channelization upstream from the site having a natural channel (RM 4.9) imparted modified attributes to it by embedding substrates with exported sediments. The grossly degraded habitats impaired the fish community at all sites in Willow Creek (Table 12); any impact associated with Ross Incinerator is either negligible or indistinguishable given the background nonpoint degradation.

West Branch Black River
The habitat at RM 1.2 in the West Branch was locally limiting. The substrate was almost entirely bedrock, the channel was very wide, and consequently the river was shallow with a maximum depth less than 40 cm. Accordingly, the fish community was suppressed. A septic discharge also impacted the fish community. Carp and goldfish were moderately abundant in response to the organic enrichment. The fish community performance at RM 1.2 was similar between 1997 and 1992 (Table 12) with one distinction, fewer tolerant and more lithophilic species were sampled in 1997, suggesting a lessening of nonpoint source related impacts.

Plum Creek
Plum Creek has been sampled four times over the last decade. Results over the last five years have been consistent, with the improvement over 1987 downstream from the Oberlin WWTP maintained (Figure 58). Mean IBI scores upstream and downstream from the Oberlin WWTP mix zone were both 27 (Poor). Only four species of fish, all tolerant, were collected downstream from the WWTP outfall on the first pass indicating an episodic event of toxicity or sewage bypass. Similar episodic events effect the fish community upstream from the plant given that as few as five species of tolerant fish have been sampled at RM 3.3 on a single pass. Consequently, the combination of nonpoint pollution, urban runoff from Oberlin, and possibly an additional unidentified source of pollution are the factors most limiting to the fish community.

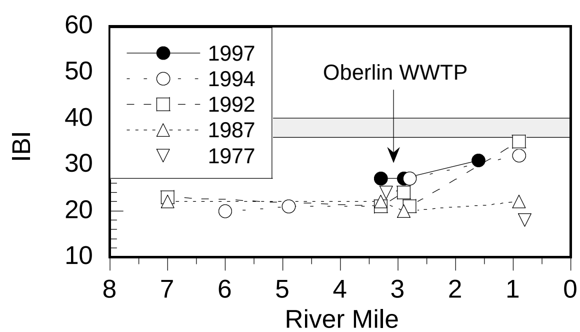


Figure 58. Index of Biotic Integrity (IBI) scores from Plum Creek, 1977 - 1997, in relation to the Oberlin WWTP.

Beaver Creek

The Amherst WWTP and nonpoint pollution significantly impact the fish community in Beaver Creek. Upstream from the WWTP, the fish community indices performed in the Fair to Marginally Good range, tolerant and omnivorous fishes were not unusually abundant, and rainbow darters, a sensitive species, were abundant. However, an elevated abundance of stonerollers, indicative of nutrient enrichment, suppressed the metric scores of insectivores, simple lithophils and top carnivores. Downstream from the WWTP, 4 to 5 species were eliminated, tolerant fishes composed the largest proportion of the community, and relative abundance was low. Results downstream from the plant differed substantially between passes where tolerant fishes comprised 89% of the community on the first pass and 30% on the second. The difference between passes suggest episodic toxicity or sewage bypasses. The performance between 1997 and 1992 was nearly identical (Figure 59).

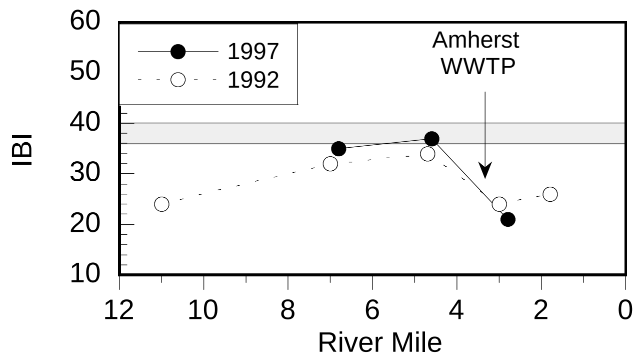


Figure 59. Index of Biotic Integrity (IBI) scores from Beaver Creek, 1992 and 1997, in relation to the Amherst WWTP.

Overall Trends

The magnitude of departure from the ecoregional biocriteria decreased for the IBI and MIwb, and increased in a positive direction for the ICI in the Black River mainstem (Table 13). The macroinvertebrate community improved from good at all sites in 1992 to exceptional at all sites in 1997. Because macroinvertebrates have short generation times, they respond to improvements in water quality faster than fish, and their recovery is not inhibited by watershed-scale habitat impairment to the degree suffered by the fish community. In the East Branch, the magnitude of departure for the IBI and MIwb collectively decreased by approximately 77%. Paralleling the Black River mainstem, the macroinvertebrate community improved to exceptional at all locations, and likewise, the disparity between the fish and macroinvertebrates was due to habitat impairment. In French Creek, the improvement downstream from French Creek WWTP seemed unrelated to plant performance as the plant performance has been relatively stable since 1992. Rather, the differences in IBI and ICI scores between 1992 and 1997 may be related to a combination of episodic toxic events originating upstream from the plant, and periodic upsets in plant performance. The slight improvement suggested by the ADVs for Beaver Creek was likely due to a lessening of impacts from nonpoint pollution, as the improvement was limited to upstream from the Amherst WWTP.

Table 13. Area of Degradation Values (ADV) comparing the longitudinal area of departure from established numeric criteria and attainment status for the Black River, East Branch Black River, French Creek and Beaver Creek, 1997 and 1992.

			Miles by Attainment Status				Miles by Narrative Status				
Index	ADV	**ADV/mi**	Full	Partial	**NON**	Poor/VP	Execpt.	Good	Fair	Poor	V. Poor
Black River											
1997											
IBI	8	**1.2**					0.0	6.5	0.1	0.0	0.0
MIwb	34	**5.2**	2.9	3.7	**0.0**	0.0	0.0	4.5	2.1	0.0	0.0
ICI	0	**0.0**					6.6	0.0	0.0	0.0	0.0
1992											
IBI	259	**39.2**					0.0	2.5	3.2	0.9	0.0
MIwb	94	**14.3**	2.2	3.5	**0.9**	0.9	0.9	3.4	2.3	0.0	0.0
ICI	0	**0.0**					0.0	6.6	0.0	0.0	0.0
East Branch Black River											
1997											
IBI	156	**4.1**					0.0	32.4	5.1	0.0	0.0
MIwb	221	**5.9**	19.2	18.3	**0.0**	0.0	0.0	24.1	13.4	0.0	0.0
ICI	0	**0.0**					37.5	0.0	0.0	0.0	0.0
1992											
IBI	1394	**37.1**					0.0	12.9	15.9	8.7	0.0
MIwb	233	**6.2**	10.6	18.2	**8.7**	8.7	0.0	30.4	7.1	0.0	0.0
ICI	0	**0.0**					31.9	5.6	0.0	0.0	0.0
French Creek											
1997											
IBI	467	**91.6**					0.0	0.9	0.7	3.5	0.0
MIwb	456	**89.5**	0.2	1.4	**3.5**	3.5	0.0	0.2	1.8	2.1	1.0
ICI	65	**12.7**					0.0	3.7	1.4	0.0	0.0
1992											
IBI	816	**160.0**					0.0	0.0	0.0	5.1	0.0
MIwb	494	**97.0**	0.0	0.0	**5.1**	5.1	0.0	0.0	0.0	5.1	0.0
ICI	408	**80.0**					0.0	0.0	5.1	0.0	0.0

Table 13. Continued.

			Miles by Attainment Status				Miles by Narrative Status				
Index	ADV	**ADV/mi**	Full	Partial	**NON**	Poor/VP	Execpt.	Good	Fair	Poor	V. Poor
Beaver Creek											
1997											
IBI	72	**16.8**					0.0	3.1	0.7	0.5	0.0
MIwb	292	**67.9**	0.0	2.3	**2.0**	1.9	0.0	0.0	2.4	1.8	0.1
ICI	77	**18.0**					2.5	0.8	1.0	0.0	0.0
1992											
IBI	126	**29.3**					0.0	1.3	2.3	0.7	0.0
MIwb	227	**52.8**	0.0	0.3	**4.0**	1.9	0.0	0.3	2.8	1.2	0.0
ICI	--	--					--	--	--	--	--

Public Lakes and Reservoirs

Monitoring and assessing the condition of natural lakes and reservoirs is one component of the Ohio EPA five year surface water quality monitoring strategy. Reservoirs act as watershed sinks for the upstream releases of nutrients, soil, pesticides, and toxic pollutants. The assessment of impounded stream reservoirs is one way to monitor the combined effects that both point sources and non-point source pollutant loadings have on surface water quality. Natural glacial lakes, many over 10,000 years old, are unique water resources and are commonly associated with rare and endangered plant and animal species. In Ohio, lakes and reservoirs are the primary recreational and public drinking water resource for millions of citizens.

Summary

Findley Lake, a shallow impoundment of Wellington Creek, was sampled in 1997 as part of the Ohio EPA 5-year Black River watershed assessment. The reservoir is located within Findley Lake State Park, which is managed by the Ohio Department of Natural Resources. Previous surveys of the lake had been conducted in 1977, 1980, and 1989.

The results of the 1997 survey indicated that the lake continues to show hypereutrophic conditions in the summer due to excessive amounts of phosphorus and blooms of algae. Diatoms, blue-green algae, and dinoflagellates attained bloom conditions at different times of the year. By late summer, large particle size colonial and filamentous forms of blue-green algae and dinoflagellates dominated the primary production of the aquatic food web. An analysis of nitrogen and phosphorus data indicates that the growth of algae is mostly stimulated by phosphorus. A significant source of phosphorus loading during the summer is the discharge from the campground WWTP.

Other than the effects of nutrient enrichment, the 1997 survey showed low dissolved oxygen during the summer at water depths below 10 feet, elevated levels of ammonia-N in bottom waters, shallow stream inlet from soil deposition, lack of surface water flushing for extended periods of time in the summer, and elevated copper in the lake sediment. A 1989 fishery survey by Ohio DNR showed reduced rate of growth of Largemouth Bass. The lake showed Partial attainment of its Recreational Designated Use, and Full Use-Threatened attainment for Aquatic Life and Public Water Supply.

Recommendations

Findley Lake scored a Lake Condition Index (LCI) value of 35.8, which indicates the lake should be given high priority for the development of a lake and watershed management plan. In general, lakes in Ohio with LCI values above 31.0 show signs of impairment for one of its four designated uses, whereas lakes with LCI values below 25.0 have essentially full attainment of all possible uses.

A variety of possible lake management options are recommended for consideration: (1) closing the upper boat ramp and allowing the inlet stream to become a wetland to filter and buffer the loading of nutrients and sediment from Wellington Creek, (2) placement of fish habitat structures in areas less than 10 feet in water depth, (3) controls on phosphorus loadings from cleaning compounds and the campground WWTP discharge, and (4) long term monitoring of nutrients and game fish populations, especially Bluegill, Largemouth Bass, and White Crappie.

Introduction

A water quality survey of Findley Lake was conducted by the Northeast District Office of Ohio EPA in 1997. This survey was conducted as part of the Ohio EPA Division of Surface Water assessment of significant public lakes in Ohio.

Findley Lake is a 84 acre impoundment of Wellington Creek, a tributary of the West Branch of Black River. The dam was completed in 1956. The upstream drainage area is about 6.5 square miles (4224 acres) and located in Lorain County. The 1995 water volume capacity has been estimated as being 810 acre-feet (1995 NRCS sedimentation report). The 1995 mean depth (V/A) was 9.6 feet. The lake has lost about 10.2 % of its original water volume, with a loss rate of about 0.26% per year. Land use is mostly agriculture (60%), with about 35% woodland and 5 % developed (Lorain County, SWCD, 1994). Findley Lake is part of the Ohio state park system, which is managed by the Ohio Department of Natural Resources, Division of Parks and Recreation. The lake fishery is managed by the Ohio DNR, Division of Wildlife. The park is used for camping, boating (electric motors only), fishing, and seasonal swimming at the lake beach. Hiking trails connect the scenic lake valley to the surrounding wooded areas.

Since the mid 1970s, a number of water quality surveys of Findley Lake have been conducted by the Ohio EPA (1977, 1980, and 1989 years sampled); Kent State University (Fulmer MS Thesis, 1993); and recently by Roger Nikiforow (1997), a student at Mount Union College. Surveys of the lake fishery, including fish tissue sampling in 1997, have been conducted by the Ohio DNR, Division of Wildlife. The Lorain County SWCD has studied land use and riparian zones in the Findley Lake watershed through the 1990s. The National Resources Conservation Service conducted a sedimentation survey of the lake in 1995.

A variety of lake management techniques have been used at Findley Lake in an attempt to control ongoing problems with sedimentation, nutrient enrichment, game fish populations, and excessive growths of aquatic plants. In the 1970's a small amount of sediment was removed from the Wellington Creek inflow channel near the south area boat ramp. Sediment traps were dug in 1992 on the inflow channel, but have mostly filled in. Aquatic plant harvesting was conducted prior to 1995 to control macrophytes. In 1993, and again in 1995, White Amur (Grass Carp) were added to the lake to help control macrophyte growth, at a rate of about 10 fish/acre. Chemicals (copper based) have been added routinely to the swimming beach area to control algae blooms. Underwater fish habitat structures have been added to improve fish spawning, the locations of which are shown on the attached contour map of the lake. There has been a slot limit on Largemouth Bass of 12-15" for many years, all fish within this size should be returned to lake.

The Findley Lake hydrology is significantly affected by the lack of water flushing out of the lake, over the lake dam, during summer and fall. This is due to the low baseflow conditions in Wellington

Creek. This characteristic of the lake hydrology would have the effect of concentrating nutrients in the upper photic zone of the lake (i.e. top 2-3 feet).

Findley Lake has two wastewater treatment plants (WWTPs) that discharge to the lake. The park campground WWTP (NPDES permit numbers 3PP00004, OH0037044) discharges for about six months of the year (May-October). In 1996 and 1997, the monthly flow from this WWTP averaged between 20,000 gpd to 44,000 gpd. Monitoring of total phosphorus is not a requirement of the current NPDES permit, however, the concentration of total phosphorus being discharged from the campground WWTP was 2.23 mg/l and 3.81 mg/l in two effluent samples collected in the summer of 1995. A much smaller loading of phosphorus enters the lake near the south boat ramp from the camp office WWTP (NPDES permit numbers 3PP00005, OH0037052), which has a monthly average discharge of less than 100 gpd.

1997 Ohio EPA Assessment Methods

Findley Lake was sampled six times in 1997. Samples were collected at two locations, site L-1, at the deep hole, near the lake dam; and at site L-2, mid-lake adjacent to the downstream state park boat dock. Chemical samples were collected six times in 1997: May 20, June 19, July 9, August 5, August 19, and September 24. Grab water samples were collected at 0.5 m from the lake surface and at 0.5 m above the lake bottom site L-1. Surface water samples (0.5 m) only were collected at site L-2. All chemical, physical, and laboratory methods and procedures follow those specified in the manual of Ohio EPA Surveillance Methods and Quality Assurance Practices.

Field measurements for pH, temperature, dissolved oxygen, and conductivity were collected through the water column at fixed intervals at site L-1. Field notes on condition of water and recreational uses were recorded at each visit to the lake. Secchi depth was measured with a black and white 20 cm disk. Water color was recorded using the Custer Color Scale (NEFCO) at one- half Secchi depth.

Low level total phosphorus (5.0 ug/l detection limit) was analyzed using Ohio EPA method 260.2, which includes digestion of unfiltered lake water with ammonia persulfate and sulfuric acid. Duplicate samples for chlorophyll-a analysis were collected at both Site L-1 and L-2 at 0.5 meters depth, and field filtered through Whatman GF/C 1.2 micron glass microfiber filters. Samples were frozen until analyzed within 30 days of collection. Chlorophyll-a concentration was determined using a Turner Model fluorometer modified for chlorophyll-a analysis with correction for phaeophytin.

Plankton samples were collected at Site L-I using a 11.5 cm diameter, 63 micron mesh, Wisconsin plankton tow. Duplicate samples were collected from vertical tows down to twice the measured Secchi disk depth. This depth is used to approximate the plankton community in the photic zone of the water column. Zooplankton samples were preserved in 75% ethyl alcohol for long term storage. Phytoplankton samples were preserved in a 1% Lugols iodine solution.

Carlson (1977) Trophic State Index values were calculated from TP, chlorophyll, and Secchi disk data using the following equations:

TP TSI = 14.42 [ln (TP ug/l) + 4.15]
CHL TSI = 9.81[ln (chl-a ug/l)+30.6]
SD TSI = 60- [14.41 ln (SD meters)]

The attainment or non attainment of Clean Water Act designated uses for Findley Lake was determined using the multi parameter Ohio Lake Condition Index (LCI) assessment protocol that was developed by the Ohio EPA (Davic and DeShon; 1989, Ohio EPA, 1996 update). The Ohio LCI uses fourteen metrics to determine the biological, chemical, physical, and aesthetic conditions of a lake or reservoir. Attainment of designated uses (e.g., aquatic life, recreation, public water supply, human fish consumption) is determined by the relative number of threatened and impaired sub-metric conditions for each designated use. The most recent update of the Ohio LCI is found in the 1996 Ohio EPA Water Resources Inventory Report, also called the "305(b) Report" (Ohio EPA, 1996). This document is also available from the Ohio EPA internet web page at: [http:www.epa.state.oh.us] under surface water programs.

Results and Discussion of Ohio EPA 1997 Survey data and Historical Information
Data for field parameters are found in Table 1. The results of trophic state measures collected are summarized in Table 2. A copy of chemical raw data for chemical samples in 1997 can be obtained by contacting the Ohio EPA, Northeast District Office. A summary of significant findings follows:

Dissolved Oxygen.
Very low levels of dissolved oxygen (less than 1.0 mg/l) were found at all depths below 3.0 meters (9.8 feet) from the July 9 sample until the August 19 sample. Oxygen levels recovered to 4.9 mg/l at the 3.0 meter depth by the September 24 sample. These data indicate that fish populations cannot survive at depths below 9.8 feet water depth in Findley Lake for the months of July and August. Identical results were found in the 1989 Ohio EPA survey (Ohio EPA, 1992), indicating that low dissolved oxygen below 3.0 m depth in summer months is a historical problem in this lake. A large percentage of the fish habitat structures currently in Findley Lake below the 10-foot control would not be functional in the summer due to lack of required dissolved oxygen.

Table 1. Results of chemical field parameters in Findley Lake, 1997. Ohio EPA data.

Date	depth (m)	temp ©	DO (mg/l)	pH (su)	cond (umho)
20-May-1997					
	0.5	16.6	11.5	7.8	288
	1.0	16.4	11.1	7.7	287
	1.5	16.4	10.9	7.7	286
	2.0	16.2	10.2	7.6	285
	2.5	16.1	10.6	7.6	284
	3.0	15.2	10.3	7.5	277
	3.5	14.2	9.7	7.5	269
	4.0	13.5	8.7	7.4	263
	4.5	13.0	7.2	7.3	259
	5.0	12.4	4.7	7.1	256
	5.5	12.1	3.4	7.1	255
19-Jun-1997					
	0.5	22.2	11.8	8.8	245
	1.0	21.9	11.4	8.8	244
	1.5	21.5	11.2	8.7	242
	2.0	20.4	5.3	7.8	237
	2.5	18.7	2.9	7.5	218
	3.0	15.9	2.2	7.3	188
	3.5	14.7	1.9	7.2	187
	4.0	14.1	1.7	7.2	199
	4.5	13.2	1.6	7.2	241
	5.0	12.7	1.4	7.2	256
9-Jul-1997					
	0.5	24.2	10.3	9.1	266
	1.0	24.2	10.4	9.0	266
	1.5				
	2.0	24.2	10.4	9.0	266
	2.5				
	3.0	19.4	0.6	7.2	228
	3.5				
	4.0	14.2	0.6	7.1	221
	4.5				
	5.0	12.4	0.6	7.1	247
	5.5	11.5	0.5	7.0	259

Table 1. continued.

Date	depth (m)	temp ©	DO (mg/l)	pH (su)	cond (umho)
5-Aug-1997					
	0.5	25.0	8.3	8.6	274
	1.0	24.8	8.1	8.6	274
	1.5				
	2.0	24.3	6.1	8.4	273
	2.5				
	3.0	21.0	0.6	7.5	262
	3.5				
	4.0	15.5	0.6	7.1	241
	4.5	13.7	0.5	6.9	250
19-Aug-1997					
	0.5	23.9	9.4	8.6	264
	1.0	23.4	9.3	8.6	260
	1.5				
	2.0	23.3	8.4	8.5	261
	2.5				
	3.0	22.5	0.6	7.6	268
	3.5				
	4.0	16.4	0.6	7.1	256
	4.5				
	5.0	12.4	0.5	6.8	281
	5.5	11.4	0.4	6.6	345
24-Sep-1997					
	0.5	19.3	8.2	9.5	234
	1.0	19.1	7.5	9.2	234
	1.5				
	2.0	18.9	5.1	8.7	234
	2.5				
	3.0	18.9	4.9	8.5	265
	3.5				
	4.0	18.2	1.8	8.0	251
	4.5				
	5.0	14.1	1.5	7.1	295
	5.5				
	6.0	13.8	1.5	7.0	299

The cause of the oxygen depletion in the bottom waters of a lake results from bacteria respiration over the summer as dead organic matter, mostly from algae and aquatic plant biomass, is decomposed when it falls to the lake bottom. This situation is very common in lakes that are nutrient enriched. Data from the Ohio EPA 1997 survey indicate that the oxygen depletion in Findley Lake was maintained throughout the summer by the formation of a thermocline, where the warm surface water separates from the colder bottom water (see depth profile temperature data in Table 1). This thermal energy barrier does not allow surface water oxygen to mix into the bottom waters of lake during the summer. A thermocline was present in 1997 between the 2.0 and 3.0 meter depth in July and August samples (Table 1). A similar condition was observed in the 1989 survey.

Recommendation. New fish habitat structures should be added within the littoral zone of the lake in areas that are less than 10 feet in depth. The cost and feasibility of adding oxygen into the bottom waters of the lake (hypolimnetic aeration) should be investigated, especially if the lake begins to experience winter fish kills in the future.

Nutrient Enrichment.
Findley Lake at site L-1 became progressively more eutrophic from spring to late summer (Table 2). Both total phosphorus and chlorophyll-a increased, while Secchi depth turbidity decreased. Findley Lake was hypereutrophic from mid July to mid October based on concentrations of chlorophyll-a. The lake became progressively more nitrogen limited (i.e., N/P ratios below 17:1) as the concentration of nitrate-N dropped over the summer, a condition that allows for blooms of blue-green algae. The spring and early summer ratios of N/P were well above 17:1, which indicates that phosphorus availability limits the growth of algae during this period.

All sample dates showed higher levels of total phosphorous at site L-2 (near the boat ramp) than at site L-1, near the lake dam. Site L-2 is closer to sources of phosphorus than site L-1 (such as discharges from WWTPs and the inlet stream). Wind direction in five of 6 samples was from the north and site L-2 was located south of where the campground WWTP discharge enters the lake. Thus, the potential exists for the campground WWTP discharge to affect the water quality at sample site L-2 when the wind causes surface currents to move toward the south.

Findley Lake has a history of problems with blue-green algae during late summer and early fall. A 1980 Ohio EPA phytoplankton survey showed that 99% of the algae were blue-greens (August 25, 1980 sample), with 61% from the genus *Oscillatoria*, a filamentous species. A sample collected at site L-1 by Ohio EPA on August 30, 1989 for chlorophyll-a gave a value of 267 ug/l, one of the highest chlorophyll-a values recorded in any public lake in Ohio (Ohio EPA, 1996). A more recent survey of phytoplankton (Nikiforow, 1997) showed that algae blooms continued to appear in 1997, a result confirmed by this 1997 Ohio EPA survey (Table 3).

Very green water was recorded in August of 1997 during the Ohio EPA survey. The phytoplankton samples collected by Ohio EPA in 1997 show that diatoms, blue-green algae, and dinoflagellates attained bloom conditions at different times during the summer of 1997. Of

Table 2. Results of trophic sate parameters collected from Findley Lake, 1997.

Lake Station/ Date Collected (m/day) Parameters	05/20	06/19	07/09	08/05	08/19	09/24
Station L1 (near dam)						
Chl-a (ug/l)	3.23	31.64	24.73	46.16	61.66	41.12
Secchi (meters)	1.87	0.91	0.96	0.79	0.87	0.62
NO2-NO3 (ug/l)	290	1240	380	<100	<100	<100
TKN (Kjeldahl-N) (ug/l)	300	800	800	940	1000	1100
Total Nitrogen (ug/l) (NO2-NO3+TKN)	590	2040	1180	990*	1050*	1150*
T Phosphorus (ug/l)	22	37	37	---	89	142
N/P Ratio	27:1	55:1	32:1	---	12:1	8:1
Station L2 (near second boat ramp)						
Chl-a (ug/l)	3.40	25.81	38.17	27.50	29.09	48.3
Secchi (meters)	1.13	0.78	0.69	0.45	0.63	0.48
NO2-NO3 (ug/l)	220	1130	340	<100	<100	<100
TKN (Kjeldahl-N) (ug/l)	400	900	1200	1600	1600	1100
Total Nitrogen (ug/l) (NO2-NO3+TKN)	620	2030	1540	1650*	1650*	1150*
T Phosphorus (ug/l)	95	66	75	---	213	144
N/P Ratio	7:1	31:1	21:1	---	8:1	8:1

* a value of ½ detection limit was used for NO2-NO3 in the determination to total N.

Table 3. Phytplankton species composition of net plankton samples from Findlay Lake, 1997. Findlay Lake, Lorain County. EOLP Ecoregion. Water Body ID: OH86 16-217

Total Phytoplankton Abundance Terminology for this Table:
The relative total phytoplankton abundance for the lake in question is characterized based upon field observations, comparison of measured chlorophyll a concentrations to lakes within the ecoregion, and microscopic analysis of the phytoplankton sample according to the following protocol:

Bloom: Algal abundance deemed to be extremely high due to highly nutrient enriched conditions, contributing to a significant impairment of lake uses. Chlorophyll a concentrations greater than the 90th percentile for the ecoregion. Phytoplankton community dominated by dense quantities of a small number (typically 2-3) species. Significant dilution of the phytoplankton sample necessary for proper evaluation of species composition.

Very High: Algal abundance typical of nutrient enriched conditions which would be perceived by the typical lake user, contributing to a impairment of some lake uses. Chlorophyll a concentrations greater than the 75th percentile for the ecoregion. Dilution of the phytoplankton sample likely for proper evaluation of species composition.

High: Algal abundance typical of nutrient enriched conditions which may or may not be perceived by the typical lake user, potentially contributing to some impairment of lake uses. Chlorophyll a concentrations falling between the 25th and 75th percentile for the ecoregion. Sample may or may not require dilution for proper evaluation of species composition.

Moderate: Algal abundance typical of balanced nutrient conditions, with waters that would be perceived as clean by the typical lake user. No impairments of lake uses caused by phytoplankton abundance of species composition. Chlorophyll a concentrations falling between the 10th and 25th percentile for the ecoregion.

Low: Algal abundance typical of nutrient poor conditions which would be perceived as extremely clear water by the typical lake user. Chlorophyll a concentrations less than the 10th percentile for the ecoregion.

Taxonomic Group Relative Abundance Terminology:
Characterization of relative abundance of algal groups (taxonomic Divisions or Classes) is accomplished using the following descriptions:

Dominant (Bloom): Species within the algal group constitute more than 80 percent of the total relative abundance when the total phytoplankton abundance is characterized as **Bloom**.
Dominant: Species within the algal group constitute more than 50 percent of the total relative abundance of the phytoplankton present.
Abundant: Species within the algal group constitute greater than 10 percent of the total relative abundance of the phytoplankton present.
Common: Species within the algal group constitute greater than 1 percent but less than 10 percent of the total relative abundance of the phytoplankton present.
Rare: Species within the algal group constitute less than 1 percent of the total relative abundance of the phytoplankton present.
Absent: No species from the algal group observed in the sample.

Parameter/Algal Division	20 May	19 June	9 July	5 August	19 August	24 September
Chlorophyll a (μg/l)	3.23	31.64	24.73	46.16	61.66	41.12
Total Phytoplankton Abundance	Low	High	High	High	Very High	High
Cyanobacteria (Blue-green Algae)	Rare	Common	Dominant	Dominant	Common	Common
Chlorophyta (Green Algae)	Absent	Rare	Rare	Rare	Common	Common
Chrysophyta (Yellow-brown Algae)						
Chrysophyceae	Absent	Absent	Absent	Absent	Rare	Absent
Bacillariophyceae (Diatoms)	Dominant	Dominant	Absent	Rare	Rare	Rare
Pyrrophyta (Dinoflagellates)	Common	Common	Common	Common	Dominant	Dominant
Euglenophya	Rare	Rare	Rare	Absent	Absent	Absent
Cryptophyta	Absent	Rare	Absent	Absent	Absent	Rare

Table 3. Findlay Lake Phytoplankton (cont.).

Division/ Species	20 May	19 June	9 July	5 August	19 August	24 September
Cyanobacteria (Blue-Green Algae)						
Anabaena flos-aquae		++	++	+	+	
Anabaena planktonica			++	+++	++	+
Anabaena spiroides			+			
Aphanizomenon flos-aquae		++	++++	++	++	+
Coelosphaerium Kuetzingianum		O	+	O		
Gleocystis sp.	+	O				
Lyngbia limnetica				O		++
Microcystis aeruginosa			+	++	+	O
Oscillatoria anghardii	O					
Oscillatoria rubescens					O	
Eudorina elegans					+	O
Oocystis sp.				O		
Pediastrum duplex		+	O	O	O	O
Sphaerocystis schroederti					O	
Schoederia setigera					O	O
Chrysophyta (Yellow-brown Algae)						
Chrysophyceae						
Chrysochromulina parva					O	
Bacillariophyceae (Diatoms)						
Asterionella formorsa	+++	O				
Aulacoseira (Melosira) granulata	O	++++		+	O	O

Key: +++++: Species present in bloom conditions (based upon total abundance estimate) at abundances >80% of total relative abundance in the sample; ++++: Species present at greater than 80% of total relative abundance in the sample in non-bloom conditions; +++: Species present at >20% but less than 80% of total relative abundance in the sample; ++: Species present at <20% but > 5% of total relative abundance in the sample; +: Species present at <5% but >1% of total relative abundance in the sample; O: Species observed in sample (<1% total relative abundance).

Table 3. Findlay Lake Phytoplankton (cont.).

Division/ Species	20 May	19 June	9 July	5 August	19 August	24 September
Bacillariophyceae (cont.)						
Fragillaria crotonensus	O					
Fragillaria capucina	++					
Melosira varians	++					
Nitzchia sp.	O					
Synedra spp.				+	O	+
Pyrrophyta (Dinoflagellates)						
Ceratium hirundinella	++	++	++	+++	+++	++
Peridinium sp.					+	+++
Eulenophyta (Euglenoids)						
Phacus sp.	++					
Trachelomonas sp.		O	O			
Cryptophyta (Cryptophytes)						
Cryptomonas ovata						+
Cryptomonas sp.		O				

Key: +++++: Species present in bloom conditions (based upon total abundance estimate) at abundances >80% of total relative abundance in the sample; ++++: Species present at greater than 80% of total relative abundance in the sample in non-bloom conditions; +++: Species present at >20% but less than 80% of total relative abundance in the sample; ++: Species present at <20% but > 5% of total relative abundance in the sample; +: Species present at <5% but >1% of total relative abundance in the sample; O: Species observed in sample (<1% total relative abundance).

interest is the fact that *Oscillatoria*, common in August of 1980, was replaced by three different blue-green taxa (*Anabaena*, *Aphanizomenon*, and *Microcystis*) in the 1997 Ohio EPA samples. The data in Table 3 also show significant seasonal changes in the phytoplankton from spring to early summer (May 20 to June 19). Phytoplankton abundance remained at bloom conditions through July 9 and at high levels until the final September 24 sample. Large particle size dinoflagellate algae of the genera *Ceratium* and *Peridinium* reached dominant to bloom abundances in late summer samples.

A likely mechanism that allows for the sequence of phytoplankton blooms from diatoms in spring to blue greens, to dinoflagellates by late summer in Findley Lake is as follows:

(1) The continuous loadings of phosphorus into the water column during the spring and early summer (May-July), results in high rates of algal growth and lakewide depletion of nitrate-N by early August (Table 2). Bacterial decomposition of dead organic matter results in depletion of dissolved oxygen in the bottom waters of the lake by the end of July. Anoxic sediment conditions (August and September) release phosphorus into the water column, which can be mixed into surface waters during high wind or storm runoff events. Evidence of release of phosphorus from anoxic sediments was found during the 1997 August 19 sample at site L-1, where TP in bottom waters was 438 ug/l, whereas surface total phosphorus was 89 ug/l.

(2) The combined effects of continuous WWTP discharge of phosphorus and internal loading results in excessive early summer growth rates of diatom and green algae. When nitrate becomes depleted these species are replaced by blue-greens. Blue-green algae can fix or use nitrogen from the atmosphere and are not affected by the lack of nitrate in the lake water.

(3) A combination of loss of edible diatoms and green algae, and increased rate of feeding on zooplankton by small filter feeding fish such as young-of-year Bluegill, results in a drastic decline in large filter feeding zooplankton such as Daphnia by mid summer, a phenomenon documented by Nikiforow (1997) in his seasonal survey of the zooplankton of Findley Lake. Loss of Daphnia has both a “top-down” and “bottom-up” effect on the food web of the lake. Fewer large zooplankton means less algae are being grazed and that less food is available for filter feeding fish that depend on zooplankton in their diet.

(4) Finally, by late summer, large particle size colonial and filamentous forms of blue-green algae and dinoflagellates dominate the primary production of the aquatic food web. Note that the above cascading mechanism to explain the algae blooms in Findley Lake has nutrient enrichment as its ultimate cause.

Evidence from Fulmer (1993) and Fulmer and Cooke (1990) shows that the sources of phosphorus found in Findley Lake are not primarily from the upstream Wellington Creek watershed. Using standard eutrophication phosphorus loading models they concluded that Findley Lake has higher levels of total phosphorus in the lake than would be predicted by background loading from the upstream watershed. They estimated that the "attainable" trophic state of Findley Lake based on background loading of phosphorus would result in a Carlson TSI of 55, which relates to a lake chlorophyll-a concentration of about 13 ug/l and total phosphorus (not dissolved phosphorus) of about 33 ug/l. The fact that Findley Lake has summer total phosphorus well above 33 ug/l and chlorophyll-a values that average in the 40-60 mg/l range shows that the lake is receiving phosphorus well in excess of background watershed loading. Fulmer (1993) also measured total phosphorus in the Findley Lake inlet stream twice in June and August of 1989 and found 74 ug/l and 47 ug/l TP, very similar to the ecoregion potential stream concentration of 50 ug/l. Thus Fulmers' analysis indicates that the concentration of total phosphorus that enters Findley Lake from the Wellington Creek watershed is not significantly elevated above background ecoregion concentrations. This implies that another source(s) of phosphorus loading affect the water quality of Findley Lake. These additional sources of phosphorus would include the two WWTP discharges and internal loading from the anoxic sediments in the summer.

In his 1997 phosphorus survey of Findley Lake, Nikiforow measured non filtered "dissolved phosphorus", what *Standard Methods for the Examination of Water and Wastewater*, 19th Edition, refers to as being "total reactive phosphorus". This type of phosphorus differs from the "total phosphorus" measured by the Ohio EPA in that "total reactive phosphorus" does not include a strong acid digestion to release phosphorus bound to organic matter and other complex molecules. Thus "total reactive phosphorus" is mostly a measure of the "dissolved phosphorus" phosphate ion concentration in the lake water. Hutchinson (1969) states that the turnover rate of ionic phosphate is a matter of minutes in a eutrophic lake due to high rate of algal uptake. Thus, one would expect to find decreasing levels of "total reactive phosphate" from spring to summer in a eutrophic lake unless there was a continuous source of new phosphate ion. Nikiforow (1997) found that "total reactive phosphate" levels did not change in Findley Lake after Memorial Day in a lake wide analysis of data. Because Nikiforow did not find declining levels of "dissolved phosphorus" over the summer, as would be expected if algae uptake depleted ionic phosphate, his data indicate that there was a constant loading of dissolved phosphate ions. This constant source of dissolved phosphorus observed by Nikiforow would explain the seasonal increase in chlorophyll-a and in total phosphorus found in the Ohio EPA 1997 survey. The only constant source of dissolved phosphate ion to Findley lake would be from the discharge of the two park WWTPs. Internal loading of phosphorus from anoxic sediment would only occur after wind mixing, and spring and fall turnover, and would not be a constant source of ionic phosphate.

Nikiforow (1997) also found that "nitrogen" levels declined in the summer and stayed low, which was identical with the "nitrate-nitrite" data in the Ohio EPA 1997 survey (see Table 2). Also the Secchi depth data and blue green algae bloom observations from Nikiforow (1997) are similar to those found in the Ohio EPA 1997 survey. Only the interpretation of the phosphorus data differed between the 1997 Ohio EPA and Nikiforow surveys, for the simple reason that two different types of phosphorus (total *vs* dissolved) were measured, thus leading to different conclusions.

In summary, the nutrient dynamics of Findley Lake are complex and appear to be related to a variety of factors including the loadings of phosphorus during spring and summer (WWTPs effluent, stochastic internal loading from anoxic sediment), algal uptake and depletion of available nitrogen, and lack of continuous flushing of nutrients out of the lake during the summer dry periods.

Recommendation: Efforts should be made to reduce as much as possible the discharge of phosphorus compounds to the lake. Cleaning agents that do not contain phosphorus should be used at all campground facilities. The costs and feasibility of alum addition to the campground WWTP effluent discharge, to reduce phosphorus concentrations, should be investigated. The current concentration of phosphorus being discharged is higher than the recommended 1.0 mg/l aesthetic condition criteria (OAC Section 3745-1-07) for discharge of total phosphorus to prevent nuisance growths of algae in lakes. Another option is to investigate the feasibility of diverting the campground WWTP discharge so that it bypasses the lake and is discharged below the lake dam. The feasibility of using wetland plants to remove phosphorus from Wellington Creek and the camp office WWTP before the stream flows into the lake should be investigated. Besides removing nutrients, wetland enhancement at the inlet stream could help to reduce loading of soil to the main body of the lake and provide fish habitat. The feasibility of adding alum directly to the lake bottom to stop internal loading of phosphorus from anoxic sediments should be investigated, but only if the continuous sources of phosphorus from the WWTP discharge is diverted Long term monitoring of trophic state using Secchi disk and chlorophyll-a should be conducted to decide trends in nutrient enrichment, especially during the summer months. These tests could also monitor the possible effects that the Grass Carp is having on the turbidity of the lake.

*Pesticides.*The pesticide Atrazine was found at low concentration (0.3 ug/l) in a sample collected at site L-1 on May 20, 1997. This concentration is well below the maximum contaminant level (MCL) standard for public water supplies of 3.0 ug/l.

Priority Pollutants (heavy metals and ammonia-N)

The concentrations of heavy metals in surface and bottom waters did not exceed Ohio water quality criteria for protection of aquatic life. An ammonia-N value of 2.34 mg/l was found in the bottom water sample on August 19th, which shows that the bottom waters of Findley Lake have potentially toxic levels of ammonia-N during the summer when the bottom waters are anoxic.

The source of the ammonia-N would be an oxidation-reduction chemical reaction that causes release of ammonia-N from the bottom sediments when no oxygen is present at the sediment-water interface. Aeration of the bottom waters of the lake would have the effect of stopping the release of ammonia from anoxic sediment.

Fecal Coliform Bacteria

Samples for fecal coliform bacteria at site L-1 and site L-2 showed very low values (9/100 ml and 1/100 ml respectively). These numbers are well below the bathing water standard of 200/100 ml.

Volume Loss Due to Sedimentation
In 1995 the NRSC conducted a survey of the extent that Findley Lake has filled with soil and decayed organic matter since it was formed in 1956. The results of the survey indicate that Findley Lake overall has lost 10.2 % of its water volume, with a loss rate of about 0.26 % volume loss per year. Loss rates less than 0.5 % per year are considered normal for impounded reservoirs in Ohio. While the overall loss rate may be normal, the inlet area where Wellington Creek flows into the lake has lost depth over time as the upstream soils have settled. This has resulted in problems with boat access, and excessive growths of aquatic weeds in the inlet area. It has also resulted in allocation of funds to dredge and remove the sediment, a management option that becomes increasing more costly over time.

Recommendation: The feasibility of closing the inlet stream boatramp should be investigated. The justification is as follows: If the inlet area of Findley Lake is not used as a direct boat launch access, then it could be allowed to revert to a natural wetland buffer. A wetland buffer at the inlet area would act to protect the rest of the lake from long term siltation and loss of water depth. Shallow wetland structure in the inlet stream area would also serve as important young-of-year habitat for game fish species, especially since the inlet area is entirely above the 10 foot contour depth that completely losses dissolved oxygen during the summer. Wetland plants can also be used to take-up nutrients that flow into Findley Lake from the park office WWTP and the Wellington Creek watershed. If required, the boat ramp near the State Route 58 park entrance could be modified to allow for increased access if the camping area ramp is closed. The benefits to the long term water quality of the lake from allowing the inlet area to revert to a natural wetland buffer would override the loss of use to boaters. Very few public lakes less than 100 acres in size have two boat access points.

Lake Fishery
A 1987 publication by Ohio DNR, Division of Wildlife, indicated that Findley Lake is noted for Largemouth Bass, Bluegills, White Crappies, Bullheads, Channel Catfish, and Northern Pike. The publication suggests that in July and August, after surface water temperature rises, fish can be taken in deeper water around fish shelters, however, the results of the 1989 and 1997 Ohio EPA dissolved oxygen surveys show that little oxygen is present in Findley Lake in July and August below the 10-foot depth.

In 1989, Ohio DNR conducted a creel survey for Findley Lake. The 1989 angler pressure was mostly Bluegill (8,826 kept), and Largemouth Bass (1,401 kept), with smaller numbers of Crappies (318 kept) and other sunfish (210 kept). No Bullheads or Channel Catfish were kept and no Northern Pike were found. An April 1996 night-electrofishing survey by Ohio DNR yielded a total of 588 Largemouth Bass in 185 minutes. The Proportional Stock Density (PSD; an index of adult fish quality size) was calculated to be 36.5 %. The recommended PSD objective range for a balanced bass-bluegill community is between 40-60% for Largemouth Bass. Growth rates of Largemouth Bass were slow in 1996, with fish achieving lengths of 12" at age 4. A satisfactory growth rate for Ohio Largemouth Bass is thought to be a length of 11-12" at age three. One possible cause of the low Bass growth rates is the loss of summer Daphnia documented by Nikiforow (1997). Fewer Daphnia means less food for small filter feeding fish that would serve as an important part of the Bass diet. As discussed in the nutrient enrichment section of this report, the loss of Daphnia is directly related to the increase of blue-greens, itself a consequence of phosphorus enrichment. Thus the possibility exists that control of phosphorus loading could have a positive effect on Largemouth Bass growth rates and proportional stock density.

In 1993 and 1995 Grass Carp were stocked in an attempt to control aquatic plant growth. The fish stocking rate was about 10/acre. Visual observations by Ohio EPA in 1997 indicate that fewer macrophytes were present in the inlet stream area than in 1989.

Recommendation: New fish habitat structures need to be added at depths above the 10 foot contour. The 1989 creel survey should be duplicated to see if there has been any significant change in the game fishery since the introduction of the Grass Carp in 1993 and 1995. The PSD for Bluegills should be calculated to allow for comparison of the Bass/Bluegill PSD ratio, a factor used for the management of optimal Bass/Bluegill lake fishery (Anderson, undated).

Lake Sediment
A core sample of the lake sediment was collected in 1995 by the NRCS. The sediment was analyzed for nutrients and heavy metals. The results suggested elevated levels of copper in the sediment, with a value reported of 634 mg/kg. The Ohio EPA LCI lake assessment protocol considers total copper levels above 150 mg/kg to be elevated. A likely source of the copper in the sediments is the use of copper based algicides to control blooms of algae. Elevated levels of metals in lake sediment can restrict options for disposing of dredged spoils.

Recommendation:
Additional sampling of sediment for copper should be conducted to confirm and delineate the extent of copper found during the NRCS 1995 sampling.

Public Perception of Water Quality
Since at least 1989, Findley Lake has experienced intermittent blooms of blue green algae. These blooms can impair aesthetic conditions, especially for swimming. The only way to reduce these blooms is to reduce the concentration of phosphorus ions. Another aesthetic concern is that after rain runoff the inlet area of Findley Lake has brown colored water. Other types of aesthetic problems such as fish kills, odors, oily films, were not reported in 1997.

Fish Tissue Contamination
In 1997 Ohio DNR collected fish tissue samples from game species, but the samples have not yet been analyzed by the Ohio EPA laboratory. In June 1997, the Ohio Department of Health issued a statewide fish tissue consumption advisory for children age 6 and under and for women of childbearing age. The advisory is due to low level statewide mercury contamination, with the likely source being atmospheric deposition. The advisory for children age 6 and under and women of

childbearing age is to "eat no more than one meal of fish (any species) per week from any Ohio body of water." No other consumption advisories are listed specifically for Findley Lake.

Ohio EPA Lake Condition Index (LCI) Assessment

The attainment or non attainment of designated uses for Findley Lake was determined using the Ohio EPA multi parameter Lake Condition Index (LCI) assessment technique (Davic and DeShon 1989; Ohio EPA 1996). Fourteen metrics are assessed to decide the biological, chemical, physical, and aesthetic conditions of a lake or reservoir. Attainment of designated uses (e.g., aquatic life, recreation, public water supply, human fish consumption) is detected by the relative number of threatened and impaired sub-metric conditions for each designated use. The LCI sub- metric continuum from full use (fu), to threatened (t), to impaired (I) can be viewed as being similar to a narrative grading system using the terms: good (fu), fair (t), and poor (I).

Criteria used to decide metric conditions include exceedences of Ohio water quality standards (3745-1 of OAC) and best professional judgement. The general ecosystem health of Ohio public lakes is evaluated using a final LCI value with a score of 10.0 representing a lake or reservoir ecosystem with all assessed parameters having full use condition. Based on analysis of data from about 117 lakes and reservoirs statewide, lakes with LCI scores less than 22.0 have exceptional overall ecosystem condition with no major impairments, whereas lakes with LCI of 31.0 or greater show varying degrees of impairment for certain designated uses (see Ohio EPA, 1996).

LCI metric scores for Findley Lake are summarized in Table 4. Either monitored or evaluated information was available to assess 12 of the 14 LCI metrics. Data are missing for organic chemicals in water-sediment and fish tissue. Of the 12 assessed metrics, 8 (67%) show less than full use condition (threatened), with no impaired sub-metric scores. Threatened conditions for Findley Lake include turbidity, fishery, macrophytes, low dissolved oxygen in bottom waters, nutrient enrichment, excessive growths of algae, and copper in sediment. Full use conditions were found for four LCI metrics and include heavy metals in water, volume loss, bacteria levels, and acid mine drainage potential. The final LCI score of 35.8 for Findley Lake ranks this lake with a group of significant public lakes in Ohio that should be given high priority for funding to develop a comprehensive lake management plan.

The U.S.EPA requires the Ohio EPA to determine the extent to which surface waters attain the goals of the Clean Water Act and to report the assessments under Section 305(b) of the CWA. The Ohio EPA publishes its 305(b) report under the heading *Ohio Water Resources Inventory*, which was most recently updated in 1996 (Ohio EPA, 1996), and is available on the Ohio EPA internet web page at: [http:www.epa.state.oh.us]. The Ohio EPA uses the LCI assessment process to determine if lakes are attaining their designated uses. US EPA requires that each potential lake use be assessed as either attaining full use, full use-threatened, partial use-impaired, or impaired use-impaired. Using the LCI data in Table 4 above, and the LCI assessment protocol in the Ohio EPA 1996 305(b) report, the attainment of CWA designated uses for Findley Lake are given as shown in Table 5 below. Of the four designated uses, only the Recreational Use has been found to be meeting less than full attainment. The threatened conditions for public drinking water and aquatic life uses indicate that the lake could have future problems and should be monitored closely to determine long term trends.

Table 4. Summary of Ohio LCI metric assessments for Findley Lake, Lorain County, 1997.

Lake	SD	IBI	NM	A	NP	PPO	PPM	P	N	F	V	S	B	M
Findley Lake	t(m)	t(bpj)	t(bpj)	t(m)	t(m)	ne	fu(m)	t-h(m)	t-e(m)	ne	fu(m)	t(m)	fu(m)	fu(m)
Final Lake Condition Index (LCI) = 35.8														

SD=Secchi depth, IBI=fish Index of Biotic Integrity, NM=nuisance macrophytes, A=aesthetics, NP=nonpriority pollutants, PPO=priority organics, PPM=priority metals, P=algal production(chlorophyll-a), N=nutrients (total phosphorus), F=fish tissue contamination, V=volume loss due to sedimentation, S=sediment contamination, B=bacteria contamination (fecal coliform), M=mine drainage. Metric Conditions: fu=full use, t=threatened, I=impaired, m= monitored, bpj=best professional judgement, e=eutrophic, h=hypereutrophic, ne=not evaluated.

Table 5. Summary of attainment of CWA goals for Findley Lake, 1997

Uses	Recreation	Public Water Supply	Aquatic Life	Fish Consumption*
Attainment	**PARTIAL**	**FULL-Threatened**	**FULL-Threatened**	**UNKNOWN**

***** See discussion for statewide mercury consumption advisory for children six years and under and women of childbearing age.

References

Anonymous. 1992. Wastewater treatment/disposal for small communities, manual, EPA/625/R-92/005

Baumann, P. C., W. D. Smith, and M. Ribick (1982). Hepatic tumor rates and polynuclear aromatic hydrocarbon levels in two populations of brown bullheads (*Ictalurus nebulosus*). In: M. W. Cooke, A. J. Dennis and G. L. Fisher (eds.), *Polynuclear Aromatic Hydrocarbons: sixth International Symposium on Physical and Biological Chemistry,* pp. 93-102. Battelle Press, Columbus, Ohio.

Baumann, P. C., W. D. Smith and W. K. Parland (1987). Tumor frequencies and contaminant concentrations in brown bullheads from an industrialized river and a recreational lake. Trans. Amer. Fish. Soc. 116:79-86.

Baumann, P. C., J. C. Harshbarger and K. J. Hartman (1990). Relationship between liver tumors and age in brown bullhead populations from two Lake Erie tributaries. Sci. Total Environ. 94:71-87.

Brown, P. S. (1988). Analysis of unimpacted stream data for the State of Ohio. Ohio EPA division of Water Quality Monitoring and Assessment. 75 pp.

Burton, G. A., and C. Rowland (1998). Assessment of sediment quality in the Black River. Final Report to the U.S. EPA, GLNPO, Grant No. GL985554. 97 pp.

Fausch, D.O., J.R. Karr 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. 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.

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.

Gordon, N.D., T.A. McMahon, B.L. Finlayson. 1992. Stream Hydrology: An introduction for ecologists. John Wiley & Sons, Ltd. Chicheler, West Susex, England. 526 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. 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.

Keeney, D. R. (1973). The nitrogen cycle in sediment-water systems. J. Environ. Quality, 2:15-29.

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

Leonard , P.M. and D.J. Orth. 1986. Application and testing of an Index of Biotic Integrity in small, cool water streams. Trans. Am. Fish. Soc. 115: 401-414.

Long, E.R. and L.G. Morgan. 1991. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. Technical Memorandum NOSOMA 52. National Oceanic and Atmospheric Administration, Seattle, Washington.

Miltner, R. J. and E. T. Rankin (1998). Primary nutrients and the biotic integrity of rivers and streams. Freshwater Biology 40: 145-158.

Ohio Department of Natural Resources. 1960. Gazetteer of Ohio Streams, Report No. 12, Ohio Water Plan Inventory . Columbus, Ohio.

Ohio EPA (1996). Interim report on the Black River TMDL Project. Ohio EPA, Division of Surface Water. Columbus, Ohio. 46 pp.

Ohio EPA (1994). Biological and water quality study of the Black river (with selected tributaries) and Beaver Creek. OEPA Technical Report EAS/1993-12-8. Ohio EPA Division of Surface Water. 128 pp.

Ohio EPA (1987). Comprehensive water Quality report for the Black River: Amendments to the Ohio Water Quality Management Plan. Ohio EPA, Division of Water Quality Planning and Assessment. 160 pp.

___ 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.

___ 1988a. Ohio nonpoint source assessment. Division of Water Quality Monitoring and Assessment, Nonpoint Source Management Section Columbus, Ohio.

___ 1988b. Biological and Water Quality Study of the Little Scioto River Watershed - Marion County , Ohio. Division of Water Quality Monitoring and Assessment, 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 manual of surveillance methods and quality assurance practices, updated edition. Division of Environmental Services, Columbus, Ohio.

___ 1990a. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

___ 1990b. Compendium of biological results from Ohio rivers, streams and lakes: 1989 edition. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

____ 1990c. State of Ohio Nonpoint Source Assessment. Volume 5. Lake Erie West Region. Division of Surface Water, Nonpoint Source Program Management Section, Columbus, Ohio.

____ 1993. State of Ohio Water Quality Standards. Chapter 3745-1 of the Ohio Administrative Code.

____ 1994. Biological, Sediment and Water Quality Study of the Little Scioto River, Marion, Ohio. Division of Surface Water, Columbus, Ohio.

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

Persaud, D., J. Jaagumayi, and A. Hayton. 1994. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ministry of the Environment, Public Information Centre, Toronto, Ontario.

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

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

Reash R.J. and T.M. Berra. 1989. Incidence of fin erosion and anomalous fishes in a polluted stream and a nearby clean stream. Water, Air, Soil Pollution. 47: 47-63.

Reash R.J. and T.M. Berra. 1987. Comparison of fish communities in a clean-water stream and an adjacent polluted stream. Am. Midl. Nat. 118: 301-322.

Reash R.J. and T.M. Berra. 1986. Fecundity and trace-metal content of creek chubs from a metal contaminated stream. Trans. Am. Fish. Soc. 115: 346-351.

Schuler, T. R. 1994. The importance of imperviousness. Watershed Protection Techniques 1:100-111.

Sgro, G. V. and J. R. Johansen (1995). Ecology and assessment of the algae of four Lake Erie estuaries. Final Report for the Lake Erie Protection Fund. Dept. of Biology, John Carroll University. 273 pp.

Simpson, K.W. and R.W. Bode. 1980. Common larvae of Chironomidae (Diptera) from New York State streams and rivers. Bull. No. 439, New York State Education Dept., Albany. 105 p.

Steedman, R.J. 1988. Modification of an index of biotic integrity to quantify stream quality in southern Ontario. Canadian Journal of Aquatic Science. 45: 492-501.

Thurston, R. V., R. C. Russo, and K. Emerson. 1979. Aqueous ammonia equilibrium - Tabulation of percent un-ionized ammonia. U.S. EPA Environmental Research Laboratory, Duluth, MN. EPA-600/3-79-091.

U.S. Environmental Protection Agency. 1976. Quality Criteria for Water. Washington, D.C.

Warren, C. E. 1971. Biology and Water Pollution Control. W. B. Saunders Co., Philadelphia, Pa. 434 pp.

Wetzel, R. G. (1975). Limnology. W. B. Saunders Co., Philadelphia. 743 pp.

Yoder, C. O. and E. T. Rankin. 1996. Assessing the condition and status of aquatic life designated uses in urban and suburban watersheds. Pages 201-227 *in* Effects of Watershed Development and Management on Aquatic Ecosystems, L. A Rosner, editor. American Society of Civil Engineers, New York, NY.

Nonpoint Section References

Lorain County Health Department-Discussion with James J. Boddy, Director of Health, on March 12, 1999, in Elyria, Ohio.

Lorain Soil and Water Conservation District-Discussion with Karl Schneider (NRCS) on March 11, 1999, in Elyria, Ohio.

"Black River Watershed Nonpoint Source Pollution Management Plan"-March 1995, prepared by Lorain Soil and Water Conservation District and Natural Resources Conservation Service-USDA.

"Upper Black River Watershed 319 Project", 1998 grant application submitted by Seventh Generation, Elyria, Ohio.

Medina Farm Service Agency-Information from Carroll Weineroer on March 11, 1999, in Medina, Ohio.

Medina Soil and Water Conservation District-Discussion with Kelly Standridge, (Urban Stream Specialist) on March 11, 1999, in Medina, Ohio.

"Ohio EPA-Division of Solid & Infectious Waste Management Northeast District Office-Archive File Listing (pre 1988)". Revised October 1997. Prepared by John Schmidt, P.E. (Environmental Engineer) Ohio EPA in Twinsburg, Ohio.

Ohio EPA (Northeast District Office)-Discussion with Charles Allen (Environmental Engineer) on March 12, 1999, in Twinsburg Ohio.

Public Lakes and Reservoirs References

Anderson, R.O. Undated. Managing ponds for good fishing. Agricultural guide. Missouri Cooperative Fishery Research Unit. University of Missouri-Columbia Extension Division. Columbia, Missouri.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.

Carlson, R.E. 1991. Expanding the trophic state concept to identify non-nutrient limitedlakes and reservoirs. *In*: North American Lake Management Society. Enhancing the states' lake management programs, 1991: 59-71.

Davic, R.D. and J.E.DeShon. 1989. The Ohio lake condition index: a new multiparameter approach to lake classification. Lake and Reservoir management 5:1-8.

Fulmer, D.G. 1993. Master Thesis. Kent State University. A study of regional patterns in the trophic state, restoration potential, and zooplankton distribution of selected Ohio reservoirs.

Fulmer, D.G., and G.D.Cooke. 1990. Evaluating the restoration potential of 19 Ohioreservoirs. Lake and Reservoir Management. 6(2):197-206.

Hutchinson, G.E. 1969. Eutrophication, past and present. *In* Eutrophication: causes, consequences, correctives. Washington, D.C., National Academy of Sciences, pp 17-26.

Nikiforow, R. 1997. The effects of human usage on Findley State Park lake's water quality. Report of Mount Union College, Department of Biology. Alliance, Ohio.

Ohio EPA. 1996. Ohio Water Resources Inventory Report. Vol. III. Ohio's public lakes,ponds, and reservoirs. *By:* R.D. Davic, D. Eicher, J.E. DeShon. Division of Surface Water. Ecological Assessment Unit. Columbus, Ohio.

Ohio EPA. 1992. Ohio Water Resources Inventory Report. Vol. III. Ohio's public lakes, ponds, and reservoirs. *By:* R.D. Davic, and J.E, DeShon. Division of Water Quality Planning and Assessment. Columbus, Ohio.

Youger, J. 1982. Ohio's Lakes: 1982 305(b) report. Ohio EPA. Division of Wastewater Pollution Control. Section of Surveillance and Standards. Columbus, Ohio.